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Mariotte, E

The Motion of WATER, *and other* FLUIDS.

BEING A

TREATISE OF HYDROSTATICKS.

Written originally in *French*, by the late Monsieur MARRIOTTE, Member of the *Royal Academy of Sciences* at *Paris.*

Divided into FIVE PARTS, and Translated into ENGLISH.

Together with

A Little TREATISE of the same Author, giving PRACTICAL RULES for Fountains, or *Jets d' Eau.*

By J. T. DESAGULIERS, M. A. F. R. S.
Chaplain to the Right Honourable JAMES Earl of CAERNARVON.

By whom are added,
Several ANNOTATIONS for Explaining the doubtful Places.

LONDON: Printed for J. SENEX at the *Globe* in *Salisbury-Court, Fleetstreet*, and W. TAYLOR at the *Ship* in *Pa er-Noster-Row.* MDCCXVIII.

To the

RIGHT HONOURABLE

JAMES

Earl of CAERNARVON,

Viscount WILLTON, and
Baron of CHANDOIS, &c.

MY LORD,

AS it is to *Your Lordship*'s Favours alone that I owe the Leisure which I have been able to allow my self in Translating this Book; so no one has a better Claim to it than You; and I might justly have been thought ungrateful if I had not dedicated it to *Your Lordship*. It is to You, therefore, my *Lord*, that the Reader is beholden, for this excellent Treatiſe of *Water-Works*; which muſt be the more acceptable, becauſe nothing has yet appear'd in *Engliſh* upon this Subject, but what has been altogether trifling and imperfect. Among the Arts and Sciences, which *Your Lordſhip* has always cheriſh'd and countenanc'd, *Experimental Philoſophy* (to which I have more particularly apply'd my ſelf,) has met with ſo much Encouragement, that I think it is not ſufficient to acknowledge my Obligations to my Patron in a publick Manner, unleſs I daily endeavour to produce ſomething worthy his Acceptance.

So when *Virgil*'s Shepherd had been reſtor'd to his Flocks by the Favour of *Auguſtus*, he does not think it enough to ſay,

- - - - - *Deus nobis hæc otia fecit:*

But adds, - - - - - - - *Illius Aram*
Sæpe tener noſtris ab ovilibus imbuet agnus.

I ſhould

I ſhould be tempted to apply the Poet's Character of that Emperor to *Your Lordſhip*, were I not aſſur'd that no one who has heard of Your Name, can be a Stranger to Your excellent Qualities; and that You hate Praiſe as much as You deſerve it.

I am,

MY LORD,

Your Lordſhip's

Moſt oblig'd,

Moſt humble, and

Moſt obedient Servant,

J. T. DESAGULIERS.

Channel-Row, Weſtminſter, June 24. 1718.

Monsieur De la HIRE's

PREFACE.

SUCH *as have hitherto treated of* Hydraulics, *have given us very curious Observations concerning the* Gravity, Velocity, *and several other Properties of Water. Monsieur* Paschal's *Treatise of the* Equilibrium of Liquors, *is one of the most considerable, as well on account of his fine Discoveries, as of his clear and convincing Manner of demonstrating every Property; which makes us not doubt but that so great a Genius would have certainly exhausted this Subject, if he had examin'd all the Parts of which it is made up.*

Monsieur Marriotte *had been for many Years applying himself with more than ordinary Care in making the Experiments which are in Monsieur* Paschal's *Treatise, to see whether he might not have neglected some particular Circumstances, which it might be worth his while to examine* *anew. And indeed in making the Experiments, he has made ſeveral Obſervations which are not to be met with in Monſieur* Paſchal's *little Book, nor in any other written before: This inſenſibly engag'd our Author in that Part of this Work which is the moſt uſeful, as the* Meaſure, *and what is call'd the* Expence *of Water, according to the different Heights of Reſervoirs, and different Ajutages. Then he ſhews what Caution is requir'd in the conducting of Water; and after having treated very amply of the Reſiſtance of Solids, he ſpeaks of the Strength requir'd for Pipes which are to ſuſtain different Weights of Water. He had an Opportunity of making ſeveral Experiments of that kind at* Chantilly, *before his Royal Highneſs the Prince, where the great Quantity of Water, and the Height of the Reſervoirs, ſupply'd him with all the Means neceſſary. He likewiſe made ſeveral at the Obſervatory before the Members of the* Royal Academy. *All thoſe Experiments examin'd, and reduc'd to Method, are the Materials of this Work.*

When he firſt fell ſick of the Diſeaſe of which he died, he deſir'd me to take Care of the Printing of this Book, leaving me the Liberty of changing, or leaving out what I ſhould think fit; but I thought it better to communicate it to the Publick ſuch as he wrote it, than to add any thing of my own. Nevertheleſs, if I had undertaken to have alter'd any thing, it ſhould

have

have been with the Advice of the whole Academy, which he himself would have consulted upon any Difficulty.

Half this Work was written fair enough for the Press; but I had no small Trouble in putting in Order such Memoirs as were given me after his Death.

I have, as far as in me lay, endeavour'd to have nothing obscure or confus'd in the last Parts, and precisely to follow the Order that he propos'd; nevertheless, I have not dar'd to explain all the difficult Places, lest I should wander from his Notions, or, perhaps, become darker my self.

I had also resolv'd to have added at the End of the Book some Remarks that I had made upon some Places, which might have explain'd or confirm'd what the Author advances; and among others, from Archimedes's *Principles, to have given the Demonstration of the Mechanical Problem, where the common Proportion is inverted; with some Observations that I have made upon the Origin of Fountains, and the Rise of Vapours; but I have judg'd it most fit to give them separately, with some other Essays of Physicks, than to swell this Book with my own particular Thoughts.*

I had not so long deferr'd the Printing of this Book, if I had not been hinder'd by Things of great Consequence, which Monsieur de Louvois *did me the Honour to set me about. He had*

had himſelf conſider'd, that the River Eure, *from its Head, to the Place where it falls into the* Seine, *near the Bridge call'd the* Pont d' Arche, *up to which the Tide reaches, only goes thro'* 45 *Leagues ; and that from the Springs of that Head ſome Brooks ran with great Swiftneſs to meet the* Huine, *and ſo in the* Loire *quite to the Sea, at about* 20 *Leagues Diſtance from the common Source ; that the Stream is very rapid, appears alſo from ſeveral Mills that it turns : He judg'd therefore that the* Eure *muſt have a very conſiderable Declivity. And a little after Monſieur* Marriotte's *Death, he order'd me to take the Level of that River, in reſpect of the Caſtle of* Verſailles. *Tho' the Diſtance between that Caſtle and the Place where the Height of the River might be conveniently taken, was above* 20 *Leagues, yet my Levels taken thro' different Roads, and often repeated, have perfectly agreed, and ſhewn me that this River may be eaſily conducted to the Height of the Caſtle of* Verſailles ; *and that at* Ponjoin, 7 *Leagues above* Chartres, *it is* 110 *Foot higher than the higheſt Ground above the Caſtle.*

Running Water conducted in an Aqueduct, is certainly to be preferr'd to Water rais'd by Engines, becauſe Repairs, which hinder the coming in of the Water, are not ſo often needed, and the Water may come eaſily, and in great Plenty ; but as in ſome Caſes Engines are very uſeful, and altogether neceſſary for raiſing Water, it *were to be wiſh'd that Monſieur* Marriotte *had left us in Writing his Opinion concerning the different Pumps and other Engines which are in uſe, or which have only been propos'd for that Purpoſe; with an Examination of them, and a Calculation of what Quantity of Water each kind will raiſe, and how they are made uſe of according to different Circumſtances. He often aſſur'd me, that he intended that Subject for one Part of this Treatiſe; but I found nothing of it in his Minutes fit to be publiſh'd. He had often chang'd the Order of the Parts of this Work; but at laſt, a few Days before his Death, he gave me the following Diviſion, which has been of great uſe to me, eſpecially in making up the laſt Parts.*

This Book, containing a great Number of Experiments, and ſeveral Rules which are deduc'd from them, with Obſervations upon the ſaid Rules; I thought proper to ſubjoin a very ample Table, that the Places which treat of any thing we have occaſion for, may be eaſily found.

This whole Treatiſe is divided into Five Parts.

The Firſt Part contains Three Diſcourſes.

The Firſt Diſcourſe treats of ſeveral Properties of Fluids.

The Second, of the Origin of Fountains or Springs.

The Third, Of the Cauſes of Winds.

The

The Second Part contains Three Discourses.

The First, concerning the Equilibrium of Fluids by their Weight.

The Second, concerning the Equilibrium of Fluids by their Spring.

The Third, concerning the Equilibrium of Fluids by their Impulse.

The Third Part contains Four Discourses.

The First, of the Inches and Lines which are the Measures of running and spouting Water.

The Second, of the Measure of Spouting Water, according to the different Heights of the Reservoirs.

The Third, of the Measure of Spouting Water thro' Ajutages of different Bores.

The Fourth, of the Measure of running Water.

The Fourth Part contains Two Discourses.

The First, of the Height of perpendicular Jets.

The Second, of the Height of oblique Jets.

The Fifth Part contains Three Discourses.

The First, of Pipes of Conduct.

The Second, of the Resistance of Solids, of the Strength of Solids, and of the Strength of Pipes to conduct Water.

The Third, of the Distribution of Water.

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TABLE

Of the chief MATTERS contain'd in this TREATISE.

PART I.

Concerning ſeveral Properties of Fluid Bodies, the Origin of Fountains, and the Cauſes of Winds.

DISCOURSE I.

Of ſeveral Properties of Fluid Bodies. *Page* 1

Obſer-

DISCOURSE II.

DISCOURSE III.

PART

PART. II.
Of the *Equilibrium* of Fluids.

DISCOURSE I.
Of the *Equilibrium* of Fluids by their Gravity.

DISCOURSE II.
Of the *Equilibrium* of Fluids by their Spring.

Rules

DISCOURSE III.

PART III.

Concerning Running and Spouting Waters.

DISCOURSE I.

DISCOURSE II.

Of the Measure of Spouting Waters, according to the different Heights of the Reservoirs.

DISCOURSE III.

Of the Measure of Spouting Water thro' Ajutages of different Bores.

DISCOURSE IV.

PART IV.

Concerning the Height of Jets.

DISCOURSE I.

DISCOURSE II.

PART V.

Of the Conduct of Water, and the Resistance of Pipes.

DISCOURSE I.

DISCOURSE II.

DISCOURSE III.

Of the Distribution of Water.

Advertisement to the Reader.

THose that would reduce the Proportions in the following Treatise to the *English* Measures and Weights, are to observe, That the *Paris* Foot is to the *English* Foot as 16 to 15; and therefore their Cubic Foot is to our Cubic Foot as 4096 the Cube of 16, to 3525 the Cube of 15. Their Pint is nearly equal to our Quart; and their Pound is to our Pound *Averdupois* as 93 to 100.

ERRATA.

PAge 2. Line *ult.* dele *more.* p. 3. l. 27. r. *has been.* p. 8. l. *penult.* r. *or Pewter.* p. 10. l. 12. r. *is in such.* p. 27. l. 29. r. *take up more Room.* p. 48. l. 33. r. *touches.* p. 51. l. 29. r. *the Isles.* p. 86. l. 4. r. *more press'd.* p. 89. from lin. 5. to lin. 8. r. *will weigh but 64 Pounds instead of 70 that a Cubic Foot of Water weighs: Now the Product of 6 (the Difference between 64 and 70) multiplied by 400, &c.* p. 90. l. 9. r. *the Hole.* p. 93. l. 9. r. *void Space.* p. 114. l. 15. r. 12000 *Pounds.* p. 118. l. *ult.* r. *Treatise of* Percussion, *or of the.* p. 120. l. 24. r. *Ruler* Q R *ibid.* r. *Ruler serving.* p. 121. l. 26. r. *Impulse.* l. 29. r. *Ruler.* p. 127. l. 15, 20, 21, 26, 29. r. *Ruler.* p. 128. l. 23. r. *each other.* p. 156. l. 10. dele *not.* l. 25. r. *pass thro'.* p. 157. l. 5. r. *comes not from.* l. 18. dele *not.* p. 168. l. 19. dele *these.* p. 182 l. 21. r. *spouts fast.* l. 22. r. *spouts slow.* p. 184. l. *ult.* r. *of 4 Lines.* p. 185. l. *ult.* r. *subduplicate.* p. 196. l. 5. r. *give a Second.* p. 199. l. 20. r. *Conduct-Pipe.* l. 23. r. *Conduct.* p. 207. l. 33. r. A B E F. p. 228. l. 24. r. *what has.* l. 33. r. *rise higher.* p. 232. l. 32. dele *that.* p. 235. l. 13. r. *of the Strength.* p. 236. l. 26. r. Galileo *wrote.* p. 251. l. 17. r. *wide sustain'd.* l. 22. r. *have sustain'd.* l. 23. r. *if it had been.* l. 31. r. *5 Inches in the clear.* p. 252. l. 12. r. *Inches in the clear.* p. 255. l. 15. r. *and filed.* l. 18. r. *the filed Part.* p. 256. l. 6. r. *pretty strong.* p. 259. l. 31. r. *Height of the Jet.* p. 271. l. *penult.* r. *Fig.* 114.

A TREATISE OF HYDROSTATICKS.

Wherein the Motion of WATER and other FLUIDS, is consider'd.

PART I.

Concerning several Properties of Fluid Bodies, the Origin of Fountains, and the Causes of Winds.

DISCOURSE I.

Concerning the several Properties of Fluid Bodies.

AIR and *Flame* are Fluid Bodies; Water, Oil, *Mercury*, and other Liquors, are Bodies both Fluid and Liquid; for every *Liquid* is a Fluid, but every *Fluid* is not a Liquid. By a Liquid I mean such a Fluid as being in a more sufficient Quantity, will flow and extend it ſelf under the Air, till its upper Surface be level; and becauſe Air and Flame want that Property, I ſhall not call them Liquids, but only Fluids. Hardneſs and Firmneſs is oppos'd to Fluidity; a hard and firm Body, as Iron, Stone, *&c.* is divided or paſs'd through by other Bodies with Difficulty; and when it has been paſs'd through, its ſeparated Parts do not join again. On the contrary, Fluids are eaſily paſs'd through, but their ſeparated Parts immediately reunite; and in this Fluidity conſiſts. For this Reaſon fine Sand may be call'd a Fluid, but not a Liquid; becauſe it does not run or flow upon a Plain ſomewhat inclin'd, and when a Veſſel is fill'd with it, the upper Parts do not of themſelves run to a Level.

Water is moreover call'd *Moiſt* or *Humid* by ſome Philoſophers, but improperly; becauſe it is only that which is moiſten'd or wet by Water, which may properly be call'd Humid; and in that Senſe the Air is Humid, when fill'd with aqueous Vapours. Dryneſs is contrary to Humidity; and a Cloath which is ſaid to be Humid when it is wet, is ſaid to be Dry, when the Water wherewith it was wet is evaporated.

Water is Hard and Liquid ſucceſſively. Its natural State is to be an Ice; that is, when no External Cauſe acts upon it, it remains Firm, and not Liquid.

It becomes Flowing and Liquid by a moderate Heat, and at the ſame time ſome of its Parts riſe up in Vapours; that is, in ſeveral little Drops which are ſeparate from one another; and ſo ſmall, that the Eye cannot perceive them ſingly. Experience proves this; for if you throw a burning Coal into Water, at firſt you'll ſee a thick Smoak ariſe;

arife; but when it is fo far fpread in rifing, that the little Particles of Water are feparate from one another, you cannot perceive any of 'em.

Thick Vapours are fometimes vifible, and fometimes invifible, according as their fmall Particles are greater or lefs, more or lefs agitated. When they are Vifible, and near the Earth, they are call'd Mifts; and Clouds when they are higher. More Vapours rife in a great, than in a moderate Heat; tho' they will rife in a fmall Heat; nay, even when the Water is frozen. I have obferv'd, that Two Pounds of Ice, in extreme cold Weather, loft about Two Drams a Day of their Weight: Whence we may infer, that when the Water begins to freeze, it ftill retains fome fmall Degree of Heat; as Lead retains pretty much of its Heat, when it begins to harden after it has been melted.

There are in Water fome ftrange and heterogeneous Parts, which are chang'd into Air by a great Heat; as when you fet a Veffel of Water upon the Fire, you may fee feveral fmall Bubbles of Air form themfelves at the bottom of the Veffel, and afterwards rife up to the top of the Water. It is not to be fuppos'd that they fhou'd proceed from the Flame which might pafs through the Veffel, becaufe fuch Bubbles do not rife in Oil, when it has heen left a little while upon the Fire, to evaporate its moft aqueous Parts, not even though the Fire be afterwards increas'd.

Such kind of Bubbles are alfo form'd in the Water when it freezes; and becaufe this Heterogeneous Matter, which I call Aerial Matter, takes up moft Space when it is reduc'd into Bubbles of Air, it endeavours to extend it felf; and finding no Paffage through the Ice, it caufes it to break, as alfo the Veſſels which contain it, if they be narrower at the Top than towards the Middle.

To underſtand why this Aerial Matter contain'd in the Water, takes up more Space where it becomes Bubbles of Air; you may ſuppoſe Air to conſiſt of a great Number of ſmall Threads, mix'd and interwoven into one another, as the Threads in a Piece of Wool or Cotton. For if you immerge a Piece of Cotton in a Glaſs half full of Water, it will at firſt take up a Space according to its Bulk, and cauſe the Water to riſe conſiderably towards the top of the Glaſs; but by ſeparating the little Threads by Degrees, you open the Cotton ſo, as to let the Water into all its Intervals; then will the upper Surface of the Water deſcend almoſt to the Place where it was in the Glaſs before the Cotton was put into the Water.

This Experiment ſhews that the Air may, by little and little, inſinuate it ſelf into the Water, and take up much leſs Room than when it is in Bubbles; and that after it has been mix'd, and as it were abſorb'd in the Water, if by the Motion which Heat, or any other Cauſe may give it, it reſtores it ſelf to ſmall Bubbles, it will take up much more Room than it did before.

You may by the following Experiment, know that Air will inſinuate it ſelf into Water. Boil Water for Three or Four Hours, and when it is cold again, fill a ſmall Glaſs Viol full of that Water, then putting your Finger on the Viol, invert it in a Glaſs of Water, in ſuch manner that there be a Bubble of Air at the top of the Water in the inverted Viol, about as big as a Hazle-Nut; then you will find that in Twenty Four Hours this Air will diſappear. Put in another Bubble of Air almoſt as big, and it will alſo inſinuate it ſelf into the Water by Degrees,

 but

but more Time will be requir'd to abſorb it wholly. You may, after the ſame manner, make the Water ſuck in ſeveral ſuch Bubbles one after another: But at laſt, when the Water is ſufficiently impregnated with 'em, the Water will ſuck in no more of 'em; and a ſmall Bubble of Air of about Two Lines in Diameter, will lie above Fifteen Days upon the Water, without getting into it. This is more eaſily obſervable in Spirit of Wine; for if you take a Glaſs half full of it, and put it into the Receiver of the Air pump, a great Quantity of this Aerial Matter will come out of it in large Bubbles, as ſoon as you have pump'd a pretty deal of the Air outof the Receiver; but after a while no more Bubbles will ariſe. Make the ſame Experiment with this Spirit, as you did before with the boil'd Water, only letting the Bubble of Air be as big as the top of your Thumb; this Air will inſinuate it ſelf into the Spirit of Wine in leſs than Two Hours: And if you let in Bubbles of the ſame Bigneſs, Two or Three times one after another, they will mix themſelves with the Water, as before; but if this Viol be put into the Air-Pump, that which was, as it were, diſſolv'd and inviſible in the Spirit of Wine, will come out of it in large Bubbles, as ſoon as you begin to pump the Air out of the Receiver: Which ſhews that it is real Air which comes out of Water, or other Liquors, when they freeze or boil, or have the Weight of the Air incumbent upon them diminiſh'd by means of the Air-Pump; which I have explain'd more at large in my Treatiſe concerning the Nature of the Air.

What happens to Water in its Freezing, I have diſcover'd by the following Experiments.

Having fill'd a Cylindrick Veſſel of about Seven or Eight Inches high, and Six Inches Diameter, within Two Inches of the Top with cold Water, I expos'd it to the open Air in a great Froſt, and obſerved exactly the whole Progreſs of the freezing of the Water.

The firſt Congelation was in the upper Surface of the Water, in little long Shoots or Laminæ, which were jagged like a Saw, the Water between them remaining ſtill unfrozen, which froze by Degrees, all but a little Place in the Middle, which remain'd unfrozen, though the reſt of the Surface was already frozen to the Thickneſs of more than two Lines. I obſerv'd that ſeveral Bubbles of Air were form'd in the Ice, that begun to fix on the Bottom and Sides of the Veſſel; ſome would riſe up, and others remain'd entangled in the Ice; which made me imagine that theſe Bubbles taking up more Space in the Water than when their Matter was, as it were diſſolv'd in it, they puſh'd up a little Water through the Hole at Top, after the ſame manner that new Wine works out at the Bung-hole of a Veſſel, when it begins to heat: And the little Water which ooz'd out at this little Hole in the Ice, ſpreading it ſelf upon the upper Surface of the Water, which was already frozen, became Ice alſo, and there began to form a Hill of Ice; and that Hole continuing open, by reaſon of the Water which paſs'd ſucceſſively through it, being puſh'd up by the new Bubbles, which form'd themſelves in the Ice, which continued to encreaſe about the Sides and Bottom of the Veſſel; I obſerv'd that the upper Surface of the Water was frozen above an Inch think towards the Edges of the Veſſel, and above an Inch and an half round about the little Hole; before the Water that was contain'd in it, as as in a Pipe, became frozen; but at laſt it was frozen; then the Middle of the Water remaining unfrozen, and the Water which was compreſs'd by the new Bubbles, which form'd themſelves for two or three Hours, having no Iſſue out at the little Hole, the Ice broke at once towards the Top by the Spring of this included Air. I tried the Experiment a Second Time, and when the Ice was about two Inches thick, I warm'd the Sides of the Veſſel, to melt the out-ſide of the Ice, and by that means drew it whole out of the Veſſel, without ſpilling the Water, which was contain'd in the Middle of the Ice: Then expoſing this Ice to the open Air, that the reſt of the Water might freeze, it broke three or four Hours after; and I found a Cell in the Middle of about $1\frac{1}{2}$ Inch Diameter, containing the Water that remain'd ſtill unfrozen, which ran out upon the breaking of the Ice. I made the Experiment a Third Time, and having taken out the Ice as before, with a large Pin I made a Hole in the Ice, over the little Channel or Pipe abovementioned, (where the Ice was an Inch higher than any where elſe, by reaſon of the Water which had ooz'd out at the little Hole, and was there frozen) and as ſoon as I drew out the Pin, ſome Water ſpouted out at the Hole, and then the Hole was frozen up again. Still as the Hole was frozen up, I prick'd the Ice till all the Water was frozen; then I expos'd that Lump of Ice to the Weather, for a whole Night, without its breaking; which plainly ſhew'd, that in the foregoing Experiments the Spring of the Air-Bubbles, was the only Reaſon of the breaking of the Ice. The Middle of this frozen Lump had about as much Air in it as Ice; but there were but few Bubbles towards the out ſide in Proportion to the Ice. If by boiling the

Water you drive the Aerial Matter out of it, before you set it out to freeze, you will have Ice two or three Inches thick, without any visible Bubbles, and so transparent as to be as fit to burn by the Sun's Rays as Convex Glasses do: And you may make this Ice convex in the following Manner. Take a Vessel made hollow in the Form of an Hemisphere of about Six Inches Diameter, and having put a Piece of this transparent Ice into it, set it upon the Fire to melt the out side of it, and pour out the Water as the Ice melts; then turn it on the other Side, and melt some of it after the same manner, till it becomes Convex on both Sides, and very smooth; and being thus prepar'd, it will collect the Sun's Rays so, as to set Paper or Gunpowder on fire. Some People have believed that boil'd Water would freeze sooner than other Water; but I never could find that the one froze sooner than the other, tho' I expos'd 'em both to the Air, having first made 'em equally cold.

In such Places and Creeks where Water does not run in Rivers, a great deal of Mud is gather'd together, out of which a great deal of Air rises when you walk upon it, or when you thrust a Stick into it; whether it be, that this Air is form'd there, by Degrees, out of the Aerial Matter contain'd in the Water of the River, or that the Water sinking through small Channels, below the Bed of the River, drives up the Air that happens to be there, which is stopp'd by the Mud that it meets with in its Rise. Besides the Aerial Matter which is contain'd in Water; it has also a *Fulminating Matter*, as we may call it, which I have discovered by several Experiments like the following: Take a little Vessel of Brass and Pewter, and having put a large Drop of Water into it, pour on Oil to the Height of about one Inch; then holding the Veſſel over a Candle, ſo that the Flame may be juſt under the Drop of Water, ſmall Bubbles of Air will go out of it for ſome Time, and after a while ſcarce any; but when the Oil comes to be heated, there will be Fulminations in the Drop of Water, which will make the Oil leap up and break the Drop of Water into three or four Parts.

This may be occaſion'd by Particles of Salts, or other unknown Matter, diſſolv'd in the Water, which being heated to a certain Degree, dilate themſelves at once like *Aurum fulminans*.

There is this Analogy between Oil and Water; *viz.* That Oil is harden'd and frozen by a great Degree of Cold, but not ſo much as Water; That it flows with a moderate Heat; That a great Heat makes it riſe up in Smoak and Exhalations, much of the ſame Conſiſtence with the Vapours that come out of Water; And laſtly, Theſe Fumes, at leaſt their moſt ſubtile Parts are chang'd into Flame by a very great Heat.

Air, *Mercury*, and Water which has a great deal of common Salt diſſolv'd in it, do not freeze or harden by cold, any more than Spirit of Salt-Peter, Spirit of Vitriol and other ſpirituous Liquors, which always remain liquid and flowing, and are made to riſe in Vapours by Heat.

Mercury, Water, Oil, Wine, Spirit of Wine, and other Liquors, are dilated by a moderate Heat, and condens'd by a moderate Cold, without ſhewing that any Air is contain'd in 'em, no Bubbles coming out of 'em. Put ſome Oil into a Bottle, that has a long narrow Neck, and having warm'd it moderately, you will ſee it riſe in the Neck, and as it cools come down to the Ball or Body of the Bottle, without perceiving that any Air gets into or

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comes out of it; nay, if having fill'd the Bottle with warm Oil, having ſtopp'd it with your Finger, you invert it in cold Water, ſo that it be up to half the Neck in it; when you have taken away your Finger, as the Oil cools, it will leave the Neck to riſe all up into the Ball, and the Water will ſucceed in the Neck; but if you warm the Bottle in this Poſition, the Oil will go down again and drive out the Water, no Bubbles of Air forming themſelves either in its riſing or falling. This Effect is very ſenſible in the Spirit of Wine, that is, ſuch Glaſs-Thermometers as are Hermetically ſeal'd: For in very cold Weather the Spirit of Wine deſcends as far as the Ball; and when the Weather is very hot, it riſes up to the Top of the Tube, though it be above Two Foot long. I have ſeen Thermometers fill'd with *Mercury* inſtead of Spirit of Wine, whoſe Effect was the ſame.

Mercury does not riſe in Vapours, without a very great Heat. I kept two Pounds of *Mercury* in an open Bottle in a Cloſet, where the Sun ſhone all Summer; and I found its Weight after ſo long a Time to be ſenſibly the ſame that it was at firſt: But if you ſet it on a great Fire, it will riſe into inviſible Vapours, which being receiv'd in an Alembick, will again become running and liquid *Mercury*, as before their Evaporation.

There is in Water a kind of Viſcouſneſs, which makes it Parts ſtick to one another, and to other Bodies, as to Wood and clean Glaſs, in ſuch manner, that a large Drop of Water will hang upon Wood or Glaſs without falling: And if you pour Water into a clean Glaſs, without filling it, that Part of the Water which is next to the Glaſs will riſe above a Line and half higher than the Level of the reſt. And though we cannot tell wherein this Viſcoufnefs confifts, yet its Effects are always fenfible. After this manner two diftinct Drops of Water will unite into one, as foon as they touch one another ever fo little. The fame Thing will happen to two Drops of *Mercury*, or to two Drops of Oil laid foftly upon Water, if you bring 'em to touch one another: The fame will alfo happen to thofe Bubbles of Air, which are at the Bottom of a Difh full of Water, when it has ftood a while upon the Fire; for if you pufh 'em towards each other, with a Pin, or any Thing elfe, they will, after the fame manner, run into one another. I once faw about as much *Mercury* as the Bignefs of a large Hazel-Nut run along a fmooth Stone Table; and as it found a little Hole in the Table, I obferv'd that fome went into the faid Hole, and the reft continuing to flow, was ready to feparate from the fmall Quantity that was in the Hole, that Part which join'd them not being above two Lines broad; but the Vifcoufnefs which joins the Parts of the *Mercury* hinder'd it, and all the reft of the *Mercury* came back to what was in the Hole, and fo fettled upon and round about it. To explain the Reafon of this Vifcoufnefs as well as we can, we might fay, That each of thefe Subftances having their Particles in conftant Motion, the Particles of each Kind have a Figure proper to hook and unite themfelves to thofe of the fame Kind, and that they faften to each other as foon as by their Motion they come to touch. There is another Conjecture, *viz.* That the Air having a ftrong Spring, endeavours to reduce thofe Fluid Bodies to the leaft Space which they can take up, which is a Spherical Figure: But if this was true, then a Drop of *Mercury* and a Drop of Water wou'd be reduc'd into a Globe: Befides, we find that in the exhaufted Receiver, Drops of Water or

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Mercury keep their globular Figures, and unite into one in that rarified Air as they do in common Air. In the midſt of theſe Doubts let us be ſatisfied with the following Principle; namely, That Fluids of the ſame Nature are diſpos'd to unite as ſoon as they touch; and if you will, you may call this the *Motion of Union*.

There are alſo Bodies which Water either will not ſtick to, or not without Difficulty; as Tallow, Colewort-Leaves before they are handled, Swan or Duck-Feathers; if it lies upon thoſe Subſtances, it is in round Drops, or if it be in a pretty large Quantity its outſide is round, and the reſt is a level Surface. *Mercury* does not adhere or ſtick to Glaſs, Wood, or Stone; for which Reaſon it has been call'd Quick-ſilver; becauſe when it is in a ſmall Quantity, its Gravity makes it roll upon thoſe Subſtances, till it meets with Holes or Crevices that ſtop it; but it ſticks eaſily to Tin, Gold, and ſome other Metals, into which it will ſink ſo far as to diſſolve the Continuity of their Parts, and together with them make that Body which Chymiſts call an *Amalgama*.

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DISCOURSE II.

Of the Origin of Springs, or Fountains.

THE Aqueous Vapours which ariſe from the Seas, Rivers, and Marſhy Grounds, being got to the Middle Region of the Air, form Clouds there and grow cold: They cannot mount higher, becauſe they come up to an Air in thoſe Regions which being leſs condens'd than that which is near the Earth, is of a leſs Specifick Gravity, and ſo not able to ſuſtain them. Theſe Vapours being toſs'd about by the Wind, are driven againſt one another, and ſtick together, ſo that by the Union of ſeveral unperceivable Drops, pretty large ones are form'd, which becoming heavier than the Air beneath them, as they deſcend, meet with other ſmall ones, and ſo are ſucceſſively increaſed till they become Drops of Rain: Such Drops as come down from the higheſt Clouds are the biggeſt, becauſe they have more Space to increaſe their Bulk. And *Ariſtotle* was miſtaken when he affirm'd the contrary: The Reaſon that he gives, is, That if a Pail of Water be thrown down from a very high Window, it will be divided into leſs Drops than if it had not been thrown down from ſuch an Height. But this is a fallacious Compariſon; for certainly a Drop of Water as big as one's Thumb-End, falling through the Air faſter than a very ſmall one, is eaſily broken into two or three Pieces by the Shock of the Air; eſpecially when the Wind blows hard; and for that Reaſon the

the biggeſt Drops are ſeldom more than three or four Lines in Diameter; and when two or three of theſe Drops join together, they immediately part again: But it is only by the uniting of a great many Drops that one of three Lines in Diameter can be form'd: And when Fogs grow thick, very ſmall Drops of Rain fall, which cannot well be perceiv'd, unleſs ſome black Object be behind.

Since then Rain in its beginning be very ſmall, it is plain that it muſt fall from a great Height in order to become large; and this is the Reaſon why the Drops of Rain in Winter are commonly very ſmall; becauſe then the Clouds riſe but to a ſmall Height. I have obſerv'd, that when the Air was cover'd with thick Clouds, and the Rain fell in large Drops at the Foot of a very high Mountain, the Drops were leſs as I went up the Mountain; and when I was almoſt at the Top, the Rain was very ſmall, and I was then in a Miſt, which ſeen from the Bottom of the Mountain appear'd to be a Cloud.

One Cloud driven by ſtormy Winds may ſucceſſively rain upon a Space of Fifty Leagues, which has often been obſerv'd by the Damage which is done by the Hail of one ſingle Cloud.

The Rain Water being fallen, penetrates into the Earth, through ſmall Canals or Paſſages in the Ground; ſo that when the Earth is digg'd pretty deep, ſuch Canals are commonly found, whoſe Water meeting at the Bottom of the Hole digg'd, ſupply ſuch a Well with Water; but the Rain-Water which falls upon the Hills and Mountains, having penetrated the Surface of the Earth (eſpecially when it is light and mix'd with Pebbles and Roots of Trees) often meet with Clay or Wax (as the Workmen call it) or continuous Rocks, along which it runs without being able to penetrate them, till being got to the Bottom of the Mountain, or to a confiderable Diftance from the Top, it breaks out of the Ground and makes Springs. This Work of Nature is eafy to prove: For, Firft, The Rain-Water falls every Year in a fufficient Quantity to fupply all the Springs and Rivers; as will be hereafter fhewn by Calculation. Secondly, It is daily obferv'd, that Springs increafe or decreafe in Proportion as it does or does not rain; and if during two whole Months it does not rain much, moft of them lofe half their Water; and if the Drought continues two or three Months longer, they are for the moft Part dried up; and fuch as are not, will be diminifh'd by two Thirds, or three Fourths; whence it may be concluded, that if the Rain was to ceafe for one whole Year, either very few Springs wou'd be left, and thofe almoft dry, or elfe they wou'd be all dried up.

Great Rivers, like the *Seine*, often diminifh at the End of the Summer, above ⅚ of the Bulk which they have after great Rains, although the Drought does not laft above Three Months together: And if there be fome Fountains which diminifh only the Half, or the Third Part of their Bulk; the Reafon of it is, becaufe they have great Refervatories which they have digg'd in the Rocks, by carrying away the Earth, and by having made themfelves but fmall Paffages; which is the Reafon alfo why they don't increafe fo much as others, by continual Rains. Some Philofophers give another Caufe for the Origin of Springs; which is, that there arife Vapours from the inward Parts of the Earth, which meeting Rocks in the tops of Mountains, that are in the form of Vaults, do there become Water, as in the top of a Still; and that Water afterwards runs out at the Foot, or at the

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Declivity of the Mountains; but that Suppoſition can hardly be maintain'd. For if A B C, (*Figure* 1.) is a Vault in the Mountain D E F; it is evident, that if the Vapours ſhou'd become Water in the Concave of the Surface A B C, that Water would fall Perpendicularly towards H G I, and not towards L, or M, and conſequently would never make a Spring: Beſides, it is deny'd that there are many ſuch hollow Places in Mountains, and it can't be made appear that there are ſuch. If we ſay there is Earth on the Side of, and beneath A B C, it will be anſwered, that the Vapours will guſh out at the Sides towards A, and C, and that very little will become Water; and becauſe it appears that there is almoſt always Clay where there are Springs, it is very likely that thoſe ſuppoſed Diſtilled Waters can't paſs thorough, and conſequently that Springs can't be produc'd by that Means.

Some Authors tell us, that Springs have ceas'd running, for having given Vent to great Subterraneous Cavities, from whence there proceeded great Quantities of Vapours, which became Water in thoſe Caves. It may be anſwered to that, That thoſe Stories are ſuſpected; but it is not denied but that there may be ſuch Diſpoſitions in the tops of Mountains, and chiefly of ſuch as are cover'd with Snow, that the Vapours which would condenſe by meeting with a great Body of Stone, as in a Still, might form a little Stream of Water, which would come out at the Sides; but we very rarely meet with them, and there can be no Conſeqnence drawn from this, as to the other Springs. It is again objected, that the Summer Rains, although very plentiful, don't penetrate the Earth above half a Foot, which may be obſerved in Gardens, and tilled Grounds. I grant the Experiment; but I main-

maintain, that in uncultivated Land, and in Woods, there are ſeveral little Canals, which are very near the Surface of the Earth, into which the Rain Water enters; and that thoſe Canals are continued to a great Depth, as it appears in Wells that are very deep; and that when it rains, Ten or Twelve Days following, at laſt the Surface of Till'd Ground is entirely moiſten'd, and the reſt of the Water paſſes into the ſmall Canals which are under, and which have not been broken by Tillage.

You may ſee in the Cellars that belong to the *Royal Obſervatory* of *Paris*, ſeveral Drops of Water which fall from the top of the natural Arched Roofs of Stone which are there; but it is eaſy to obſerve, that they don't proceed from Vapours, for they are always ſeen to run through ſome Chinks, or through ſome little Holes of the Rocks, the other Places of the Rock remaining dry, or very little moiſt, and that happens after great Rains. There is even a Place where the greateſt Vault is, from whence there continually diſtill ſeveral Drops of Water, but they proceed from an Accumulation of Water directly above.

There are Quarries in ſeveral Places, where Roofs are in the Form of Vaults, which have not above 20 or 30 Feet of Earth above; where it may be obſerved, that the little Drops of Water which are there formed, paſs through little Chinks between the Beds of Stone; and that they proceed from Rains, becauſe they are never ſeen but after great Rains, and continue but a Fortnight or Three Weeks after it hath done raining: It may alſo be eaſily conjectured, that the other Flowings of Springs are after the ſame manner.

The Summer of the Year 1681, was very dry in *France*, which cauſed moſt of the Wells and Springs to be dry'd up in ſeveral Places ; and though it was pretty cold towards the End of *October* and the Beginning of *November*, the Waters continued to diminiſh ; which they would never have done, if Water had been formed by Vapours ariſen from ſubterraneous Places, and condenſed by the Coldneſs of the Surface of the Earth. There is a Cavity in the Cellars of the Obſervatory, wherein there was always Water from the Year 1668 to 1681. but the Drought of that Year dry'd it entirely, that there was not one Drop left in *February* 1682. altho' it rained very hard for ſeveral Days in the Beginning of that Month : And the Summer following having been very Rainy, the Water notwithſtanding did not return in the Month of *September*, nor even during the two Years following.

If upon a firm hard Piece of Ground into which the Water can't eaſily penetrate, you throw a great Quantity of Stones, Sand, and Rubbiſh mixed with Earth, to the Height of about 10 or 12 Feet, there will be formed a little Spring in the loweſt Place, which will continually run, if that Piece of Ground contains an Acre or two.

I ſaw this Experiment in a Place where Rubbiſh had been heap'd up to the Height of about three Foot, which Place contain'd about 500 Fathom, where it happen'd that the Rain-Waters which fell upon that Place, and upon the Tops of the neighbouring Houſes, being detained by the Plaiſter and Rubbiſh, paſſed through by Degrees, and not being able to penetrate the Pavement, and the hard Ground which was at the Bottom, ran together to the loweſt Place, where there was formed a continual little Stream

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of Water. Sometimes the Earth of Mountains is dispoſed after ſuch a manner, that the Waters that penetrate may go out again, and run between Two *Strata* or Earths, or between the Earth and the Rocks; and then they can't be diſcovered but by making pretty deep Trenches upon a riſing Ground; and it often happens that Waters are gather'd in great Quantities by thoſe means, as it has been often practis'd in ſeveral Places.

There are ſome Springs which proceed from the Middle of Mountains, and are formed when the Rain-Waters having found a Paſſage through this Sandy Ground, and the Clefts of Rocks, as far as two Thirds or three Quarters of the inward Part of the Mountain, meet with a continued Bottom of hard Clay, or Beds of continued Stone where the Water ſtops, and is heap'd up to a conſiderable Height, which preſſing on all Sides by it Weight, at length forces open ſome Paſſages thro' the Clefts of the Rocks, towards the Bottom of the Mountain. Theſe Sorts of Springs laſt longer than others during great Droughts; and may be impregnated with divers Salts, and other Matters which are there diſſolved.

There are ſometimes found very high Springs in the Top of Mountains; and ſome affirm that they are in the very Top: I obſerved one of thoſe Springs in a Mountain two Leagues off of *Dijon*, which gives a great Quantity of Water; and when you come very near it, you can't ſee above 40 Feet in Height of Ground above it where the Declivity is very ſteep; but if you look at this upper Mountain from a far off, you ſee it extend it ſelf with a gentle Shelving for above 500 Fathom in Length, and 200 in Breadth. Now, in that Space there falls Rain enough to feed that Spring, as ſhall be hereafter proved.

There are Lakes upon the Tops of ſome Mountains which produce little Rivulets: that may happen, becauſe there is Ground round about the Lake higher than the Level of the Water, and of a great Extent. M. *Caſſini* ſays, he ſaw in *Italy* a pretty large Lake upon the Top of a high Mountain, where there were here and there Elevations of more than half a League long, which were often covered with Snow, the melting of which, together with the flowing in of Rain-Waters, might eaſily feed the Lakes, which ought to have a hard Earth or continued Rocks at the Bottom: It is commonly very cold there, which is the Reaſon that that Water is not conſiderably exhaled.

There is a Spring in *Mount-Valerien*, two Leagues from *Paris*, much of the ſame Nature: The Earth which produces it, is about 100 Fathom long, and 50 broad: It is near a Houſe, which ſtands about the third of the Mountain's Height. There are ſeveral other Places on the ſame Side, in which Water is found, and little running Springs made there, by digging the Ground Seven or Eight Foot deep; for if after having found Water, the Trench is continued Horizontally, inclining towards the Bottom, until you come to the outward Earth, you will have a Fountain that will ſeldom be dry'd up. There is on the other Side of the ſame Mountain, almoſt at the Bottom, a pretty large Spring which never dries up. There are alſo three or four upon M. *Martre*; the higheſt of them is about 50 Foot from the Top of the Mountain; the Ground which produces the largeſt is but about 300 Fathoms long, and 100 broad. It gives therefore but little Water, even after great Rains: The two others don't give each of them a quarter ſo much as the great one; and never run but after exceſſive Rains.

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The City of *Langres* is ſituated at the Extremity of a very high Eminence, which continues of the ſame Height for a League in length, and of moderate breadth. There is another Mountain oppoſite near the ſame Height and Length, and more than a quarter of a League wide; between thoſe two Mountains is a great Valley, through which runs a large Brook or little River, which proceeds from ſeveral Springs, which are not very far from the Top of thoſe Mountains; and it is eaſy to believe that they are produced by the Rain-Waters, which fall upon the Plains that are above, and that have a ſpacious Platform; moſt Water comes from that that has the greateſt Breadth.

All other Springs are almoſt like this, and ought to have conſiderable Heights above their Heads. There is a Plain ſix Leagues from *Paris*, between the Valley of *Palaizeau*, and that of *Marcouſſi*, which is above Two Leagues long and one wide, where there are ſeen Pools in ſome Places, that are over-topp'd by the higheſt Places but by 5 or 6 Foot, but the Ground is very hard at about 2 or 3 Foot deep, chiefly near the Caſtle of *Beauregard*, where there are three or four of theſe Pools; and that Ground is ſo impenetrable to Water, that to make a Conduit of Water, it was thought ſufficient to dig a little Ditch two or three Foot deep, and to fill it with Stones, without putting any Cement at Bottom.

It may be objected, that there does not fall in a whole Year Rain enough to ſupply the great Rivers, that diſcharge themſelves in the Sea.

To ſolve this Objection, I make uſe of an Experiment which was made at my Requeſt Seven or Eight Years ago at *Dijon*, by a very skilful Man, and very exact in his Experiments. He placed near the Top of his House a Square Vessel, of about two Foot Diameter, at the Bottom of which there was a Pipe which conveyed the Rain that fell into it, into a Cylindric Vessel, where it was easy to measure it as often it rained; for when the Water was in the Cylindric Vessel, there was very little exhaled during five or six Days. The Vessel of two Foot Diameter was sustained by a Bar of Iron, which advanced above six Foot beyond the Window, whereon it was placed and fixed; that it might receive only Rain-Water, which fell immediately upon the Breadth of its Opening, and that there might not enter any but what was to fall according to the Proportion of the upper Surface. The Result of these Experiments, was, That in a Year there might commonly fall in Rain-Water to the Height of 17 Inches. The Author of a *French* Book, entitul'd, *De l' Origine des Fontaines*, affirms, that he made the like Experiment for three Years; and that one Year with another, there fell Rain to the Height of 19 Inches 2 Lines $\frac{1}{3}$.

I'll say less than these Observations, and suppose that in a Year there falls Rain only to the Height of 15 Inches; upon this Supposition, there would fall upon a Fathom in a Year 45 Cubic Feet of Water: And supposing that a League contains 2300 Fathoms in Length, a Square League contains 5.290,000 superficial Fathoms; which being multiplied by 45 will give us 238.050,000 Cubic Feet.

The most remote Heads of the *Seine* are near 60 Leagues from *Paris*; to wit, those of the River *Armanson*, and of the other Rivers which fall into the *Yonne*, and the *Seine*; if you trace them from the Springs that are nearest the *Loire*, near the *Charity*; and those which fall into the *Marne*, from the Springs which are nearest the *Meuse* beyond *Bar-le-Duc*.

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The Diſtance of theſe moſt remote Heads from one another, is about 60 Leagues. If the *Seine* is cut by a perpendicular Line, which paſſes five or ſix Leagues from *Paris*, on the Side of *Corbeil*, there are found Springs towards the Extremities of that Line, which are diſtant from one another about 45 Leagues. I ſuppoſe then that the Contents of that whole Extent of Land is 60 Leagues in Length, and 50 in Breadth, which makes 3000 ſquare Leagues; the Product of which being multiplied by 238.050,000 amounts to 714,150.000,000; whence it appears, that the Lands which furniſh the Waters of the *Seine* at *Paris*, receives from the Rain 714,150.000,000 Cubic Feet of Water in a Year.

The *Seine* above *Pont-Royal* when it touches the two Keys, covering but very little of the Extremity of Land on both Sides, for about the Breadth of 400 Foot, and 5 Foot in mean Depth, is then in its mean Bulk, and its Velocity at the Surface is ſuch, that it goes 150 Foot in a Minute, but it goes 250 when the Waters are at their greateſt Height: For a Stick which is carried in the Middle of the Stream, goes as ſwiftly as a Man who walks very faſt, which may be 15000 Foot in an Hour, and conſequently 250 in a Minute, which is 4 Foot in a Second: But becauſe the Bottom of the Water does not go ſo ſwift as the middle, nor the middle ſo faſt as the upper Surface, (as ſhall be hereafter proved) let us ſay for a mean Velocity 100 Foot in a Minute.

The Product of 400, Foot which is the Breadth, multiplied by 5 the middle or mean Depth, gives 2000; for it is 8 or 10 Foot deep in ſome Places, in others 6, 3 or 2; and the Product of 2000 by 100 Foot makes 200,000 Cubic Feet, and conſequently there paſſes through a Section of the Bed of the River *Seine* above *Port-Royal*, 200 Thouſand Cubic Feet in a Minute; 12.000,000 in an Hour; 288.000,000 in 24 Hours; and 105,120,000,000 in a Year; which is not the ſixth Part of the Water that falls by Rains and Snow, which is 714,150.000,000. It is plain then, that if the third Part of the Rain-Water was to be exhaled up in Vapours immediately after it fell, and if half of the reſt was to remain ſome upon the Surface of the Earth to keep it wet, as it ordinarily happens, and ſome in the ſubterraneous Places under great Plains; and if only the Remainder ſoak'd in thro' little Conducts to make Springs underneath, or upon the Declivity of a Hill, there would ſtill be enough to produce thoſe Springs and Rivers as they now appear. If you take 18 Inches inſtead of 15 in the above-mentioned Calculation, you will have inſtead of 714,150.000,000; 856,980,000,000 Cubic Feet; which will give eight times as much Water as the *Seine*.

To calculate the Quantity of Water in the greateſt Spring of *Mont-Martre*, multiply 300 Fathoms in Length by 100 in Breadth, the Product is 30000 Fathom, which will give at 54 Foot for every Fathom, 1.620,000 Cubit Feet nearly in a Year. Moreover the Soil of that Mountain is Sandy for the Depth of 2 or 3 Foot, and the Bottom is Clay; one Part of the Water of great Rains runs immediately to the Bottom of the Mountain, one Part of the Remainder remains in the Land near the Top, the reſt runs between the Sand and the Clay; and if it be ſuppoſed to be but the fourth Part of the whole, which is 56.700,000 Pints in a Year, or 155,341 in a Day, which makes 6,472 in an Hour, and 107 in a Minute, that Quarter will be about 26 Points in a Minute, which is the Quantity that the Spring ought to give, and what it really does give, when it is a little higher than ordinary.

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DISCOURSE III.

Of the Original Causes of Winds.

THE Original of Winds is much harder to difcover than that of Springs, becaufe each Spring having the beginning of its Production, and the Iffue of its Head in one Mountain, one Man may obferve all the moft confiderable Circnmftances; but one Wind extending it felf very often for the Space of a Hundred Leagues, there muft of Neceffity be feveral Obfervations at the fame Time, to know where it begins, and where it ends, and what Space it takes up in Breadth.

I have feveral times undertaken to have a Correfpondence for thefe Obfervations in the Extent of Seven or Eight Hundred Leagues in feveral Places of *Europe* at the fame Time; as for Example, from *Paris* to *Warfaw*, and towards the Extremities of *Italy*, and *Spain*; from *London* to *Conftantinople*, and fo for every Hundred Leagues; and though feveral curious Perfons, to whom I had fpoken of it, or writ to, had promis'd me to obferve; and on my Side, I made my Obfervations very exactly at *Paris*, and at other Places, I could notwithftanding have but very few Correfpondent Obfervations, which I fhall fpeak of hereafter.

Ariftotle, and fome other Philofophers, have thought that Winds proceed from the Exhalations or Fumes rifen from the Earth, when they are reflected, after their rifing perpendicularly as high

high as the middle Region of Air. This Opinion has very little Reſemblance of Truth; for the Exhalations ariſe very ſlowly, and conſequently their Reflexion can give but a very feeble Trembling to the Air, and produce but a very little Wind, which would blow commonly only in the middle Region of Air, and would never come down to the Surface of the Earth. It is true, that if there ariſes in ſome Places a vaſt Quantity of Exhalation and Vapours, they might take up room enough in the Air, to repell a part of it in Circumference; but that Motion of Air alone would not be ſufficient to produce a conſiderable Wind, which ſhould have a Velocity equal to that of moſt Winds. It would alſo follow, if that Opinion be true, that there would come no Winds from the Ocean, towards the Coaſts of *France* and *Spain*, ſince there ariſe little or no Exhalations from the Waters of the Sea, but only Aqueous Vapours; and nevertheleſs there you have often very violent *Weſtern* Winds.

Monſieur *Deſcartes*, who was willing to give Reaſons for all Things, thought that the Clouds, which were upon the Point of diſſolving into Water, might produce Winds, by falling downwards one upon another; but he never conſider'd that there is no Cloud ſo thick, but what has a great deal of Air in the Intervals of the Vapours of which it is formed, and that by that Reaſon the Air which is between Two Clouds, may eaſily paſs thorough as they approach one another, or fall from on high towards the Earth: Beſides, the upper Clouds deſcend ſo ſlowly upon the under, that it is impoſſible they ſhould give a great Velocity to the Air which is between; and there can never follow a Motion of the Air on one Side, which can be carried on to any conſiderable Diſtance. The

Reaſon

Reaſon that Author gives to prove that high Clouds produce Tempeſts; which is, that the greater the Height is from which heavy Bodies fall, the more violent is the Fall, is a meer Cavil: For that never happens, but only to very heavy Bodies, as Stones, and Metals; as to the Clouds which begin to deſcend when they are juſt ready to diſſolve into little Drops of Rain, the greateſt Velocity they can acquire in deſcending, is to fall Five or Six Foot in a Second, and theſe little Drops may acquire the ſame Velocity in falling only from the Height of Fifty Foot. That ſame Author hath again endeavoured to explain the Phenomenon of the Winds, by the unequal Dilatations of Vapours; and hath maintained, that the Vapours by dilating a Thouſand times more in Proportion than in the Air, ought to be the Cauſe of Winds; bringing for Example the Wind in the *Æolipile*; but all theſe Arguments are founded upon falſe Suppoſitions. For it is not true, that Water being mightily heated, produces only Vapours: for it produces alſo a great deal of Air, and other Matters more rarified, as has been before proved; and theſe together produce the Wind in the *Æolipiles*, and not the aqueous Vapours that the rarefied Matter forces out with it. For the Vapours, which are nothing elſe but little Particles of Water which the Heat ſeparates from the reſt of the Water, don't become Air, nor take up more Air for their being more rarified, ſince that Dilataɹion is, ſpeaking properly, only a Separation of thoſe little Particles; as if when you throw up into the Air a Handful of Aſhes, or Duſt in a Room, the little Particles of the Aſhes being ſpread, don't take up any more Room in the Chamber than when they were in the Hand, and don't thruſt out the Air to make them-

ſelves

ſelves room: And if it was true, that the Vapours which compoſe a Cloud, were the Cauſe of Winds, the Cloud would remain immoveable, and would drive the Winds on all Sides round about it, which is contrary to Obſervation; for it is found by Experience, that the Winds puſh and drive the Clouds on one Side, and that they are much broader than the largeſt Clouds. I obſerved one Day, whilſt I was upon the top of the Platform of the Obſervatory, that there came a large Cloud from the *Weſt*, from which there fell a very heavy Rain; that Rain fell within Three Hundred Foot of the Obſervatory, whilſt yet there was then no conſiderable Wind upon the Platform: I went down with thoſe who were with me to avoid the Storm, which laſted Seven or Eight Minutes; when it was over, I ſaw the Cloud which was gone by, and was at a conſiderable Diſtance; but then there was no longer any ſenſible Wind upon the Platform; which made me know for certain, that it was the Wind that cauſed the Rain, and that the Cloud from which the Rain fell, did not produce the Wind that puſhed the Rain; which I explain in the following manner.

When for any Cauſe ſoever, there ariſes a conſiderable Wind in any part of the Air near the Earth, it drives before it the Vapours that it meets, and heaps them up one upon another in a little Time; for if it blows with a Velocity able to go Twenty, or Twenty Five Foot in a Second, it may go Six or Seven Leagues in an Hour, and form a Cloud of above a League in Breadth, and a League in Length, as was that of which I juſt now ſpoke: And laſtly, when the little Particles of Water, of which the Vapours are form'd, are mightily preſſed by the Wind, Drops of Water are formed of them, as has been formerly explain'd;

plain'd; from whence it follows, that it is the Wind that produces the Clouds and the Rains, and that the Clouds don't cauſe the Wind.

Here follow ſome Conjectures that appear very likely, upon the true Cauſes of Winds; which I have grounded upon ſeveral Obſervations which I have made, or caus'd to be made; or that I have deduced from ſeveral Relations of Sea Voyages.

I ſuppoſe that what Swiftneſs ſoever can be given to a Space of Air of the Bigneſs of a Cloud, it cannot continue a ſenſible Motion through the reſt of the immoveable Air, but for about a quarter of a League at moſt; which is eaſy to prove by Experiment, by puſhing the Wind of a pair of Bellows from one end of a Room to the other.

I ſuppoſe beſides, that more Vapours riſe from the Waters of the Sea than from the Land, and more Nitrous and Sulphureous Exhalations from ſuch Parts of the Earth which are not cover'd, than from thoſe which lie under Water.

This being ſuppos'd, I ſay there are Three Principal Cauſes of Winds, and ſome other particular and leſs important ones. The Three Principal and uſual Cauſes are, Firſt, The Motion of the Earth from *Weſt* to *Eaſt*; or, if that Hypotheſis be not allowed of, that of the Heavens from *Eaſt* to *Weſt*.

Secondly, The Viciſſitude of the Rarefactions of the Air by the Heat of the Sun, and of its Condenſation when the Sun ceaſes to warm it.

Thirdly, The Variation of the Riſe of the Moon towards its *Apogæon*, and of its Deſcent towards its *Perigæon*.

The

The moſt conſiderable of theſe particular Cauſes are, Firſt, Some extraordinary Exhalations and Vapours which riſe from the Earth in certain Places.

Secondly, The Fall of great Rains or Hail.

Thirdly, The Eruption of Sulphureous and nitrous Exhalations in Earthquakes.

Fourthly, The ſudden Melting of the Snow on the High Mountains.

Now theſe particular Cauſes ſtrengthen the Principal ones, or leſſen and prevent their Efforts, according to the Diverſity of Places and Times, by ſeveral Combinations. The Eruption of Exhalations may be very irregular in the Periods of Time, and in their Quantity and Force; for we ſee Irregularities in the Periods of Earthquakes, and in the Variation of the Magnetick Needle; and we may impute the one and the other to ſome great Changes which happen from Time to Time in the inner Part of the Earth. We alſo ſee, that *Volcano*'s do not vomit up their Sulphureous Matter in Limited and Periodical Intervals of Time.

By theſe general and particular Cauſes, it will be an eaſy Matter to explain all the Winds in the following manner.

It is manifeſt, if the Earth moves about its Centre from *Weſt* to *Eaſt*, that the Surface goes much faſter under the Equinoctial Line, than at Thirty or Forty Degrees of Latitude on either Side of it; and that this Surface draws with it the Air that is near, but with leſs Swiftneſs; and that Motion of the Air ought to appear from *Eaſt* to *Weſt*, to thoſe who are under the Equator, and quite to a Latitude of more than Twenty Degrees on each Side; for this Motion being ſwifter than that

that of the Air, they must consequently be sensible of the Shock of the Air which they meet successively; and from thence proceed those Winds call'd *Trade-Winds*, which usually blow between the Two Tropicks; but with this Difference, that when the Sun is at the Tropick of *Cancer*, it commonly proves an *East-North-East*, or *North-East* Wind; and when it is near the Tropick of *Capricorn*, this Wind is generally *South-East*, which we may easily explain from the Second Cause; *viz.* the Rarefaction of the Air, excited by the Heat of the Sun: For when it is in the Signs of *Capricorn* and *Sagitarius*, it warms the Air very much: From whence it happens, that this Air being extreamly dilated, and that which is under the opposite Signs being condens'd at the same Time by the Coldness of the Winter which then reigns there; it must necessarily cause a Motion of the Air from the *South* to the *North*; which joining with the Motion which goes from *East* to *West*, it ought to make a Wind compounded of Two, *viz. South-East*, or *East-South-East*: But on the contrary, when the Sun is in the Tropick of *Cancer*, it ought to cause a Motion of the Air, from *North* to the other Pole; which joining with the same Motion from *East* to *West*, makes the Wind *North-East*, or *East-North-East*.

Some Pilots affirm, that *Westerly* Winds generally blow in the Ocean, from the Twenty Seventh Degree to the Fortieth. I shall explain these Winds in the manner following, taking the Thirty Third Degree of Latitude for an Example.

The Air that is between the Two Tropicks, goes somewhat less swift towards the *East*, than the Earth which is under it; for we perceive there

but

but a gentle Wind, which does not go above Five or Ten Foot in a Second; whereas the Surface of the Earth which is under the Equator, goes about 1423 Foot in the ſame Time: But the Surface of the Earth at the Thirty Third Degree of Latitude, does not go more than 1195 Foot; and conſequently if the Air which is in this Parallel, went as faſt as that which is under the Equator, it would go faſter than the Surface of the Earth about 228 Foot in a Second. Now if the Air of the Twenty Third Degree had no Motion but that of the Earth, which being under it, carries it along, we ſhould there feel an *Eaſterly* Wind, whoſe Velocity would be about Eight or Ten Foot in a Second; but becauſe the Air from the Equator to the Tenth Degree, draws along that which is on the Side, always diminiſhing to the Thirty Third Degree, it may happen that this Diminution will be reduced to Twenty Foot in a Second; ſo that being join'd to the Diminution of Ten Foot in a Second in a different Direction, which muſt happen if there was no other Cauſe, the Air will be there caus'd to go Ten Foot in a Second more than the Sutface of the Earth towards the *Eaſt*; and we ſhall there feel a *Weſterly* Wind as great as the Trade-Winds which are between the Two Tropicks. To this we may add, that the Trade-Winds meeting with the Coaſts of *America*, that are ſhap'd like a half Moon, from *Cayenne* to the Gulph of *Mexico*, may be reflected againſt their high Mountains, and aided to produce theſe *Weſterly* Winds, and encreaſe their Velocity.

And theſe Winds would always blow thus, if it was not for one, or ſeveral of the Cauſes before-mention'd.

There

There are a great many Places between the Two Tropicks, which produce extraordinary Winds that come from the Lands towards the Sea upon the Approach of Night, and from the Sea against the Coasts, from the Sun's Rising till Noon; we shall explain these Winds in the following manner.

Suppose there was a great Island at the Fifteenth or Twentieth Degrees of Latitude, where the Trade Winds may blow but feebly; the Sun warming the Land of this Island from Noon, to Four or Five a Clock at Night, and at the same Time the Sea which is near causes no sensible Motion of Air; but immediately after Sun-set, the Air of the Sea condenses very much in cooling, and the Earth of the Island preserving its Heat for a long Time, the Air which is above condenses but by little and little, and much less at first than that of the Sea; from whence there ought to proceed a Wind by the Motion of the Air of the Island, which runs to fill the Place of that which is so much condens'd above the Neighbouring Sea. But as soon as ever the Sun is risen, the Island being made cold by the Length of the Night, and the Air being there pretty much condens'd, there ought to be a Reflux of Air, which had mov'd towards the Sea in such Proportion, as to cause a small Wind from the Sea against the Coasts.

The Vicissitudes of Winds, or their Flux and Reflux, are further observed, according to some Relations along the *Mediterranean* Sea, in certain Seasons of the Year; for it is affirm'd, that there is an *Easterly* Wind there in the Morning, and a *Westerly* at Night. The First may proceed from the Dilatation of Air which is made towards the Countries *Eastward* of this Sea, *viz. Natolia, Arabia*, &c. where the Sun is already risen very high; and when it rises, with respect to the Middle of the *Mediterranean*, this Dilatation may cause an *Easterly* Winds near the Islands of *Malta* and *Sicily*; but a *Westerly* Wind ought to blow there from Two or Three in the Afternoon, till late in the Night, by Reason of the Dilatation of the Air by the Heat of the Sun, which then warms very much the Land which is beyond this Sea in *Spain* and *Africa*, and ceases to warm that which is near the *East*; from whence a Reflux of Air must necessarily proceed from *West* to *East* in the Middle of the *Mediterranean*.

In the Beginning of *November*, in the Isle of *France*, in *Burgundy* and *Champagne*, there are generally *South* Winds which bring great Rains, because then that Part of the Earth near the *North Pole*, not seeing the Sun any more, the Air through excessive Cold, is there very much condens'd, whereby the Land of *Africa* being mightily warm'd, drives its Air thither for many Days together, so as to heap it up beyond an *Æquilibrium*; whence flowing back, it causes a *North-East* Wind, which is mild enough, by Reason of the *South* Wind, which has there brought a warm Air, which coming to make a Reflux, causes fine Weather, without cold, for Three or Four Days together; and this is what the *French* call the *Summer of St.* Dennis, *or St.* Martin.

It is easy to conceive, that when the Sun shines Perpendicularly upon a great Part of the Earth, the Air above it is pretty warm, and extends it self every way in Circumference; and that when the Air is there made cold by the Absence of the Sun, there ought to be a Reflux of Air. This Flux and

and Reflux of Air is often ſeen in little: Mr. *Huygens* told me, that one Day he had obſerv'd when his Chamber was very cloſe ſhut, that the *Mercury* in his *Barometer*, which was one of thoſe wherein the Liquor ſinks by the Increas'd Gravity of the Air, and whoſe Variations are very ſenſible, had fallen and riſen ſeveral times alternately in a Quarter of an Hour. I attributed the Cauſe to ſome Wind that was beaten down in the Chimney of his Chamber, which having there preſs'd the Air, had given it a greater Spring, which had made the Liquor ſink in the Barometer. And this denſe Air, having the Liberty to extend it ſelf afterwards by the Ceſſation of the Cauſe, repaſs'd through the Chimney, and its Spring being diminiſh'd, the Liquor of the Barometer roſe. And becauſe the Motion acquir'd by the Air which went back again up the Chimney, made much more go out than was agreeable to the Proportion of an *Equilibrium*, it made another Deſcent of Air through the ſame Funnel, which put in Confuſion the Condenſation of the Air of the Chamber beyond an *Equilibrium*, and caus'd the Liquor to fall in the Barometer; and ſo on diminiſhing by little and little, till the *Equilibrium* return'd.

I have ſeen the like Effect in a Lime-kiln; it was like a little Arch'd Chamber with a Window in the Middle of about a Foot and a half Square, through which was thrown the Wood to feed the Fire. It happen'd that the Fire being very great, the Air that was ſhut up, dilated extreamly, and Part went out of the Window with a great deal of Velocity, and the Fire being then diminiſh'd by the Defect of Air, the Heat of the Air being ſhut up, diminiſh'd, and conſequently becoming leſs rarified, the external Air neceſſarily re-enter'd at the Window, in Form of a Wind that blew and lighted the Fire again, which made the Air dilate again by an Increaſe of Heat, and made it go out again at the Window.

This Variation made a kind of Reſpiration like that of Animals. Thoſe who have been uſed to this Work aſſur'd me, that the ſame Thing is univerſally done in all their Lime-kilns: I further obſerv'd, that Butterflies, and other Inſects that fly about the Candle in the Night, being about a Foot or Two from the Window, were drawn into the Kiln by the Air which enter'd with a great Velocity, after it had been driven out of it. The Times of each Reſpiration was Three or Four times longer than that of Animals.

I have found by ſeveral Obſervations, that at *Paris*, and in the Neighbourhood, the Winds in Fifteen Days almoſt make an entire Revolution, blowing ſucceſſively from all the Points of the Horizon, and that at Full and New Moons, the Wind is moſt commonly *North*, and *North-Eaſt*. That is to ſay, if there be a *North* Wind at New Moon, it paſſes to *Eaſt* in Three or Four Days, and then to *South*; and then *Weſt*, and returns to *North* near the Full Moon; from whence it repaſſes ſucceſſively to *Eaſt*, *South*, and *Weſt*, and returns to *North*, or *North-Eaſt*, at Full Moon. Some of theſe Winds turn ſometimes a little backward, as from *Weſt* to *South Weſt*, and from *North-Eaſt* to *North*, and then theſe Winds laſt for Seven or Eight Days; but they very ſeldom go quite round. It happens alſo ſome times, that the Wind paſſes from *Weſt* to *North-Eaſt*, and from *Eaſt* to *South-Weſt*, without ſtopping at any intermediate Points.

Theſe Revolutions of Winds, may be explain'd by the Third and Principal Cauſe, in the following Manner.

It

It is very probable, that the Moon riſing up to its *Apogæon*, muſt carry a great deal of Air with it, if we ſuppoſe it to ſwim in the Air, and that its Diameter is about Five or Six Hundred Leagues, as the Aſtronomers affirm; for in going from the Earth, it ought to carry along with it the Air which is next to it; and that, the Air which is below, even to the Land that is under the *Torrid-Zone*; and for this Reaſon the Air which is near the Poles on each Side, muſt flow thither to preſerve the Equilibrium of its Spring, which produces a *North* Wind towards the Middle of the temperate *North-Zone*; which joining with an *Eaſterly* Wind that is produc'd by the ſaid Firſt Cauſe, *viz.* (by the Motion of the Earth) makes up the *North Eaſt* Wind which commonly blows at *Paris* at the new Moons.

There ought likewiſe to be a ſmall *Northerly* Wind by the great Motion of the Air carried by the Earth, from the Equinoctial Line, to the Fiftieth or Sixtieth Degree. I made an Experiment with a Ball of Lead of about Two Inches Diameter, which I turn'd round very faſt near a Pail of Water, and it drew up the Sediment which was at the bottom of the Pail; and then having ſuſpended a Ball of about Eight Inches Diameter, and turning it round pretty faſt, it made a great Motion of Air Sideways, and another very ſmall one upwards towards the Pole of the Ball; which I farther confirm'd, by placing ſome Down Feathers upon the top of a Perpendicular Stick, diſtant about Two or Three Inches from the Ball, which endeavour'd to mount up towards it; but this Wind was very weak. From whence we may judge, that the Air towards the Poles moves againſt the Earth, and

the River, whilſt the Flux or Flood ſtill continues towards the moſt diſtant Places; ſo the *North* or *North-Eaſt* Wind does not blow at *Paris*, whilſt the Moon is in its *Apogæon*, till after it is got much nearer to the Earth.

It is alſo an eaſy matter to conceive that when the Moon is near the Tropick of *Capricorn* in its greateſt *Southern* Latitude, the Air which it raiſes or repels then, takes up more Time to make its Motion ſenſible towards the *Northern* Countries, than when it is at its greateſt Proximity to the *Northern* Pole; and even that the Motion may be too feeble to extend it ſelf towards the Fiftieth Degree of *Northern* Latitude. I have obſerv'd ſeveral Times at *Paris*, that the Wind having been *North Eaſt* for Seven or Eight Days together, and where the *South* Winds ought to have blown in their Turn, the *North Eaſt* blew ſtill below; but there were ſome very high Clouds, that were carried at the ſame Time by the *South* Wind, though very ſlowly; which made me imagine, that towards the Fortieth Degree of Latitude the *South* and the *South Weſt* Wind might be powerful enough to blow there alone. It muſt needs happen alſo, that the unequal Elevations of the Moon will make conſiderable Differences with reſpect to theſe Winds, as well with reſpect to their Force, as to the Days when they ought to blow. It is likewiſe neceſſary that there ſhould be many Irregularities in theſe Winds, by the Mixture of particular Cauſes, of which we ſpoke before: But theſe Winds are generally more regular in Places where there are the feweſt Mountains, as in the *Iſle of* France and *Champaign*, than in very mountainous Places.

The Motion of Winds is not uniform any more than the Current of Rivers; and as in these so in those are Waves and Turnings, which we call Whirlwinds, that have different Velocities. We may observe in great Storms, that within the Compass of a quarter of a League, where the greatest Part of the Trees have been blown down, there are yet some Places where there are some left standing, by Reason the Wind has not there been so violent. We may also remark, that all Winds blow by Fits and sudden Blasts; which we cannot but be sensible of by the Sound of Bells which diminishes and increases in small Intervals of Time; of which these are the Causes. Suppose there was a mighty Wind, and of great Extent, that should meet with Houses towards G, (*Fig.* 2.) and small Eminences, which should make it reflect in some Places, and make Waves not parallel, as A, B, C, D. It is evident, that the Spring which they will make by their Congress at B, will make the Wave B D, go much faster; and that that which is in the Direction G B will then strike the Ear more feebly at B. The same Thing consequently happens in all the other Places of the Wind.

It happens sometimes that when a great Wind meets Sideways with another more weak, whether it be oppos'd to it or not, it carries away the Air which is nearest to it, and turns it round with a great Velocity; and this turning round of the Air, which we call a Whirlwind, goes on with the strongest Wind, and carries away whatever it heaps together, which is not very heavy; as Dust, dried Leaves, and even whole Cocks of Hay, which will sometimes fall above a Quarter of a League distant from the Place where they were taken up. These Whirlwinds sometimes raise up likewise a great tity of the Sea Water, which appears to thoſe who ſee it at a Diſtance to be a great Column of Water.

We ſee an Example of theſe Winds that ſtrike one another Sideways, but in a contrary Senſe, in ſome Chimneys when we have made a great Fire in them, the Chamber continuing ſhut: For the rarified Air and the Flame which riſes, makes ſome Part of the Air of the Chamber to follow; and that which remains being by this Means too much dilated, ſome muſt neceſſarily come down the Chimney, which brings back ſome Smoak with it, and diſperſes it throughout the Chamber, and commonly the Smoak and rarified Air mount up on one Side, and the condens'd Air deſcends on the other, with a conſiderable Quantity of Smoak; but to avoid this, we leave a Window or Door half open: For the Air which comes in follows the Motion of the Smoak up the Chimney, and ſufficiently fills the Chamber; and if there was only an Hole of an Inch Diameter in the Window or Door, for to let in the Air, there wou'd enter a Wind great enough to put out a Candle that ſhou'd be expos'd to it.

When the Wind meets with an Obſtacle, as a great Wall, it changes its Direction, and is beaten down beyond this Obſtacle, as you ſee in *Fig.* 3. in which A B repreſents the Wall, and the Lines C A, G H, I L, F B, the Direction of the Wind being free. Now it is evident, that the Air is put to its Spring between A and B, and that not having Power to extend it ſelf downwards, it extends it ſelf on the Side C A, even to D E, and the Air which is towards R, having but a little Motion, that which is at D E M, is puſh'd thither by that which is above it from M to N, as we we see it happens in Water, beyond the Piles of Bridges, where it is very rapid.

From whence it follows, that if on that Side from which the Wind comes, there be a Wall higher than a Chimney, the Smoak can hardly come out, because the Wind beats down in a Whirlwind, after having pass'd the Wall, and forcibly enters the Funnel of the Chimney; and though even the Wall shou'd be level with the Chimney, and a little distant from it, yet it would have almost the same Effect: As we may judge by *Fig.* 4. in which A B shews the Direction of the Wind, B C is the Wall opposite to this Direction, D E are two Funnels of Chimnneys level with the Wall. The Wind that meets with the Wall is repell'd as to F G, and enters not into the Chimney D; on the contrary, it carries away the Smoak that comes out of it with great Violence; but the superior Wind A B that continues violent, meeting with it at G, turns it into a kind of Whirlwind, and gives it the circular Motion G H E, and consequently it is beaten down the Chimney E, which hinders the Smoak from going out. But if the Wind strikes the Wall that is before the Chimney obliquely, the Smoak will go out free enough, for Part of the Wind A B will be reflected by the Side, and will rise but a very little; and consequently make no considerable Whirlwind to beat down the Smoak.

The Variety of Winds that blow at the same Time in different Places proceeds from several Causes.

The first is, That the Winds always blow in a great Circle, from whence it is easy to judge, that if one continued *Westerly* or *South-westerly* Wind shou'd go round the Earth, it wou'd seem very dif-

different in Places at a great Diſtance one from the other.

The Second Cauſe is, That a great Wind blowing in any Place, carries the Air with it on both Sides, and puſhes it a little to the Sides; as we ſee in Rivers, where the Middle going very faſt, puſhes the Waves a little obliquely towards the Shore.

The Third is, when in two Places of the Earth, about a Hundred Leagues diſtant from one another, there ariſe great Quantities of Exhalations and Vapours, which drive the Air in a Circumference, whether at the ſame Time, or in the Space of ſome Hours, there neceſſarily will ariſe two contrary Winds, from one of theſe Places towards the other, which meeting, go back with oppoſite Direction.

The Fourth and laſt Cauſe is, the Oppoſition of high Mountains, which reflect the Winds, and make them follow their Directions. We ſee an Example of this in the Lake of *Geneva* which ſpreads it ſelf between two Ranges of high Mountains, for the Space of full Twelve Leagues from *Geneva* to *Lauzane*; where there are ſeldom or never known but two Winds to blow, which ſucceed one another and follow the Direction of the Lake; which might alſo oppoſe one another towards the Middle of the Lake, if there ſhould blow a Wind at *Geneva* a little obliquely to the Direction of the Mountains, and another at *Lauzane* obliquely in a different Direction; as if E F and I H were the Winds, A B C D the Mountains; for E F being reflected to F G, and from I H to H L cauſe theſe two contrary Winds to meet towards M N, as in *Fig.* 5.

The ſame Thing happens at the Port of *Ambleteuſe* near *Calais*; where the *Weſt South Weſt* blows about Three Quarters of the Year, by Reaſon that the *Engliſh* Coaſts and thoſe of *France*, which are oppoſite to them in this Place, have this Direction; and Ten Leagues from thence there may be a *South Eaſt* or *North* Wind. I caus'd ſome Obſervations to be made near *Cherbourg* Glaſs-Houſe, which do fully convince me, that only Two oppoſite Winds blow there, which ſucceed one another alternately, *viz.* the N E and S W, which happens from the ſame Cauſe of the Directions of ſome Mountains.

Mr. *Varin*, who has made Obſervations in the Iſle of *Gorea* near *Cape Verd*, aſſur'd me, that a *North Weſt* Wind blows there often inſtead of an *Eaſterly*; which proceeds from the high Mountains about a League diſtant from this Iſland, on the *North Weſt* Side, which reflect the Trade Winds *Eaſt* or *South Eaſt* towards it, and cauſe a *North Weſt* Wind, when theſe ſame Trade Winds are perceiv'd at the ſame Time Ten Leagues beyond this Iſland at high Water. I have been credibly inform'd, that when Ships ſail along the Coaſts of *Genoa*, where there are very high Mountains, between ſome of which there are long Valleys that have their Direction towards the Sea, there is felt a conſiderable Wind blowing from the Shore, when the Veſſels are directly oppoſite to one of theſe Valleys.

I have known great Variety of Winds at the ſame Time, by the Obſervations made at *Warſaw* in *Poland*, by Mr. *Deſnoyers*, and at *Aberdeen* in *Scotland* by Mr. *Gregory*; by comparing them with thoſe that I made at *Paris* at the ſame Time; for the Winds often differ there from thoſe of *Paris*

near

near the Eighth Part of the Compaſs; as when the Wind is *South Weſt* at *Paris* it ſhall be *Weſt* at *Aberdeen.* The Winds at *Paris* are ſometimes quite oppoſite to thoſe of *Warſaw*: The Wind being the ſame Day *South Weſt* at *Paris*, and *North Eaſt* at *Warſaw*: Theſe Cities are ſituated very near *Weſt-South Weſt*, and *Eaſt-North Eaſt*, with reſpect to each other; from whence it muſt neceſſarily follow, that theſe Winds muſt blow almoſt directly againſt each other, in ſome Part of *Germany* near *Poland* or *France.* I my ſelf obſerv'd this Oppoſition of the Wind in one and the ſame Place, as I travell'd, by means of a pretty deal of Snow that fell over Night: I could perceive that it had been driven for the Space of a League, by a *South-Eaſt* Wind, and that in the following League, there had been a Calm, and that in the Three or Four following Leagues the Snow had been driven by a *North-Weſt* Wind; which I was further confirm'd in from the Tops of Houſes and Branches of Trees that had no Snow on that Side againſt which the Wind did not blow.

I perceiv'd the like Effect by Obſervations made at the ſame Time at *Paris*, *Loches*, and at *Mount de Marſan* in *Guyenne*; for a *South-South-Weſt* having blown three Days ſucceſſively in theſe three Places, which are almoſt in the Direction from *South-South-Weſt* to *North North-Eaſt* there was a *North-North-Eaſt* at *Paris*, the *South-South-Weſt* ſtill blowing at *Loches* and *Mount de Marſan*: The next Day the *North-North Eaſt* blew at *Loches* and at *Paris*, and *South South-Weſt* at *Mount de Marſan*; and the Third Day the *North-North-Eaſt* blew in theſe three Cities: Whereby it manifeſtly appear'd, that Winds repel one another ſometimes, and that the ſtrongeſt carries away with it that

which

which is opposite to it. In the same correspondent Observations, I took Notice that a violent *Westerly* Wind having blown at *Loches*, there was at *Paris* at the same Time, a *West-South-West*, and a *West-North-East* at *Mount de Marsan*; which may be deduc'd from the Second Cause of the Diversity of Winds.

I have often known a great Variety of Winds at the same Time, and in the same Place, when there were Two or Three different Heights of Clouds. Which may be explain'd, by supposing that the highest Clouds are generally driven by the *South* Winds, and the lowest by the *North:* And when this happens at the same Time, the Clouds of the First and Second Height ought to move in a contrary Direction; and that does not hinder the Clouds that are very high from being driven by an *Easterly* Wind, which always blows when it is not hinder'd by other Causes, or by a *Westerly* Wind produc'd by the Third Principal Cause, or by some other particular one.

To make a just Observation of the different Motions of the Clouds, you must observe the top of a Steeple, or some other high and fix'd Object, in order to compare the different Motions of the Superior and Inferior Clouds; for otherwise one may be apt to believe, that Two Clouds not equally distant from the Earth, should move in opposite Directions, although they were carried on the same way, because the Superior seem to go slower than those that are lower, although they go equally fast; and this Appearance of a slower Motion, may make one imagine that they move in an opposite Direction. It may be suppos'd, that an *Easterly* Wind is properly but an Appearance of Wind, since the

Motion

Motion of the Air goes the ſame way as the Surface of the Earth.

This Contrariety of Winds in the ſame Place in different Elevations of Air, may happen when a greater Wind, that being carried along a Valley, and which of Conſequence has but little Extention and Elevation, meets with another that takes up a much greater Space in the Air; and then the inferior Wind may force away a part of the other; *viz.* that which is near the Earth, leaving it a free Courſe in the upper Part of the Air, where the high Clouds are.

But when Two contrary Winds meet, which are of equal Strength, Extent and Height, they ſtop one another, and cauſe a Calm in the Place of their Meeting; and having there heap'd up a great deal of Air, they preſs it, and increaſe its Spring, whereby it happens that this Air, to regain its Liberty, flows back both ways, and makes Two other contrary Winds, which blow both from this Place.

If there happens to blow a *South* Wind in Winter that comes from afar, it may drive along the higheſt Clouds; for blowing along a Tangent, it removes more and more from the Earth as it advances; and having at laſt very much condens'd the ſuperior Air, the Spring of this Air may cauſe a *Northerly* Wind near the Earth, that will force down the Rain or Snow; which I have ſeen happen ſeveral times. All the Winds that blow throughout the Earth, may be explain'd after the ſame Manner, from theſe different, general, and particular Cauſes.

With reſpect to Storms, and great Tempeſts, it is difficult to explain them from common Cauſes. We may obſerve in *Summer*, that it generally rains pretty thick, and in great Drops, which are al-

ways

ways accompany'd with a violent Wind that precedes them ſome Seconds, and that its Violence ceaſes as ſoon as the Cloud has paſs'd by. I ſhall in the following Manner explain theſe Storms, ſome of which are ſtrong enough to blow down Trees and the Roofs of Houſes.

When Two great Winds (inclin'd to one another in an Angle of Fifteen or Sixteen Degrees, come from afar, and having collected and driven before 'em all the Vapours they met with, and form'd each a thick Cloud of them,) begin to meet; they condenſe the Air in the Place of their Meeting, putting it to a great Spring; and according to the Rules of Percuſſion, make it go almoſt a Third Part faſter than each of them did ſeparately. Suppoſing then that theſe Winds ſhould go with the Velocity of Twenty Four Feet in a Second, which is the uſual Velocity of offenſive Wind, againſt which it is often troubleſome for us to Walk; the Wind compos'd of theſe Two, goes with the Velocity of Thirty Two Feet in a Second, and the thick Cloud which they drive before 'em, being riſen half, or a quarter of a League high, the Drops of Rain which are form'd there, are about Three Lines in Diameter, and acquire their compleat Velocity of falling Thirty Two Feet in a Second, after they have fallen One Hundred Foot, as has been explain'd at the End of the Treatiſe of Percuſſion: Each Drop in falling from the Height of the Cloud, draws along with it Two or Three Times as much Air as its own Bigneſs, which is prov'd by an Experiment of a Ball of Lead, let fall into a Pail of Water; for as ſoon as it touch'd the Bottom, there will riſe up Two or Three Bubbles of Air, each as big as the Lead, which muſt proceed from the Air's following it to the bottom of the Pail. Now we we know that in many Places they make uſe of a kind of Bellows to melt Iron in Furnaces, only by the Fall of Water, which is thus perform'd.

They have a Pipe of Wood, or Tin, about Fifteen or Sixteen Foot High, and a Foot Diameter, which is cloſely fix'd to an indifferent large Tub inverted, the bottom of which is plac'd upon the Ground; ſo that when a little Water falls there, it ſhuts the Openings, and prevents the Air from paſſing through any more. They always leave an Opening at the top of the Pipe, of about Three or Four Inches Diameter, in which they put a Funnel, whoſe Neck fits the ſaid Hole; then from an Height of Fifteen, Twenty, or Thirty Foot, they let fall Water from ſome Spring or Pond, the Largeneſs of which in falling, is almoſt equal to the opening of the Funnel, ſo that the Water can't riſe there above Five or Six Inches high. This Water in falling, draws with it a great Quantity of Air, which follows it to the lower Part of the Funnel, and even to the bottom of the Tub, and cannot go out again through the Funnel, by Reaſon of the Weight of the Water which continues to fall, and the Velocity of its Motion; there is alſo a Pipe at the Side of the Tub, which is narrower and narrower, till it comes to the Hole of the bottom of the Furnace, where the Charcoal is to be blown, and the Air that is preſs'd and ſhut up in the Tub not being able to get out at Top, by Reaſon of the impetuous Fall of Water, which keeps the Neck of the Funnel continually full; nor at bottom, by Reaſon of the great Quantity of Water there, and which riſes a Foot or Two above it;

It is therefore constrain'd to issue out with great Violence at the End of the Pipe, so as to have the same Effect in blowing the Charcoal, as great Leathern Bellows, which we make Use of upon other Occasions. It must then consequently happen, that the Water which falls from the Clouds in great Drops, and in great Abundance, draws a great deal of Air with it, as has been before prov'd; which cannot rise again when it is near the Earth, by reason of the impetuous Falling of the other Drops; it cannot also extend it self towards the back part of the Cloud, because it is sustained by the great Wind that drives it; and even very inconsiderably towards the Sides, because the same Wind also presses the Cloud on each Side.

It remains therefore, that all its Effort must be made towards the Forepart of the Rain, and that this Effort being joined with that of the Wind which carries the Cloud along, must have about twice the Velocity of the Wind that pushes it; and that this Wind thus increased, must go above Sixty Foot in a Second, which may then be strong enough to blow down Trees, as I shall further prove. It cannot precede the Rain above Three or Four Hundred Paces, generally speaking, for the Reason already given, that a Space of Air driven along with a certain Velocity, cannot continue its Motion very far in a strait Line, if the Cause of the Impulsion ceases. I was confirm'd in my Opinion of this Hypothesis, in seeing Rain fall from a Cloud at a Leagues Distance; for from that Side from whence the Wind came, the Drops fell almost Perpendicular: But in the Middle, and as far as the first Drops, they made an Angle of above Forty Five Degrees, as in *Fig.* 6. in which A B, is the Cloud; B D, B D, the Side from whence the Wind comes; and G H, the moſt advanc'd Drops. The ſame Thing neceſſarily happens in Hail, and eſpecially if it be very thick, and the Hail-Stones pretty large, for then it will draw down more Air from above, and make a Storm yet more violent, whoſe Velocity may be Seventy Five Foot in a Second. The great Winds that happen without Rain, muſt proceed from the Combination of Three or Four Cauſes, and they come commonly from the *South* and *South-Eaſt*; there may then happen to riſe a great Quantity of Vapours and Exhalations at the ſame Time in *Africa*; and there may be exceſſive Heat for Three or Four Days together; the *Northern* Countries may grow more Cold, and the Moon deſcending towards its *Perigæon* from its higheſt *Apogæon*, makes a Reflux of the Air, which was carried thither by a *North-Eaſt* Wind: Theſe Four Cauſes together make a very great Wind, which will blow ſucceſſively from *Africa* to *England*.

I obſerved one Day at *Paris*, a great Storm coming from the *South*; and I was then credibly inform'd, that Two or Three Days before, there had been a furious Storm upon the Coaſt of *Algier*. Now this City is very near in the ſame *Meridian* with *Paris*; and if this Wind went Thirty Feet in a Second, it might arrive in Two Days at *Paris* from *Algier*. To explain theſe Hurricanes, which rage almoſt every Year in ſome of theſe Iſles, call'd the *Antillæ*, we muſt have Recourſe to ſome other Cauſes. Firſt, Becauſe theſe Tempeſts are much more violent, and go above One Hundred Feet in a Second. Secondly, That they laſt but for Seven or Eight Hours. Thirdly, That they ſeldom are known to be any where but in thoſe Iſlands. And Fourthly, That they generally begin with a *North-Weſt* Wind, which changes successively into other Winds, *viz.* *West*, *South-West*, *South*, *South-East*, *North East*, and *North.* Fifthly, That there are found in the Neighbouring Seas, great Quantities of dead Fish, and that Earthquakes are felt there: From all which Circumstances we may conjecture, that the Earth which is under these Seas, throws up Nitrous and Sulphureous Exhalations in several Places successively, which cannot be taken Notice of, because the Vessels that come into these Places must be sunk; and it may happen, that the First Eruptions being made near the Continent of *America*, the *North-West* Winds which they raise, may be reflected against the Coasts of *Cayenne*, and the Neighbouring Coasts; and there being made at the same Time new Eruptions, the first having ceas'd, the Wind must increase, and come from the *West*, as those assure me that have perceiv'd their Effects; and these Eruptions of Fire, and Nitrous and Sulphureous Exhalations, must destroy great Quantities of Fish in the Places where they rise up. Those who have been acquainted with these Hurricanes, and have observ'd many other Circumstances, may explain them with more Certainty.

PART

PART. II.

Of the Equilibrium of Fluids.

DISCOURSE I.

Of the Equilibrium of Fluids by their Gravity.

FOR the better Explanation of the Equilibrium of Fluids, with reſpect to each other, or to other Bodies, we may make Uſe of the following Rules.

RULE I.

A Body reſiſts a Force that endeavours to raiſe it, only according as that Force makes it move from the Center of the Earth; and a very heavy Body may be mov'd with a very ſmall Force, if you don't make it change its Diſtance, with reſpect to that Center.

The Experiment is thus made; Put a great Ciſtern full of Water in a cloſe Place, where there is no Wind ſtirring; (*Fig.* 7.) let G, a great heavy Veſſel, Swim upon the Surface of the Water; tie a fine Silken Thread to it, as H I, and draw it along in ſuch manner that it may not break, *i. e.* with a very ſmall Force; the Veſſel G will follow the Thread; and although little Waves will ariſe in the Water, and ſome Force be requiſite to divide it, yet that won't hinder the Veſſel from going pretty faſt when it gets near the Point D, if its Motion be accelerated by little and little. Indeed if you would immediately give a conſiderable Swiftneſs to the Veſſel G; you wou'd break the Thread, and even a pretty ſtrong Cord, almoſt as ſoon as if it were tied to an immoveable Body, becauſe a very heavy Body cannot receive a very great Motion all at once, but by a very great Force.

This Truth is ſtill further confirmed, by hanging a very great Weight by a long Cord in an open Place; for the leaſt Wind will give it Motion, though it can't move without receding a little farther from the Center of the Earth, than it was when at Reſt: Hence you ſee the Reaſon why it is eaſy to ſuſtain a very heavy Bowl, as D, (*Fig.* 8.) upon a Plain very much inclined, as A B, for the Bowl being drawn or puſh'd from A, to B, it riſes no higher with reſpect to the Center of the Earth, than the length of the Line B C, which is ſuppos'd Perpendicular to the Horizontal Line A C; whereas if it had been raiſed Perpendicularly in the ſame Time, to an Height equal to A B, it had acted with all its Gravity, and a much greater Force would have been neceſſary to have rais'd it.

RULE

RULE II.

If Two Bodies without Elaſticity, and of the ſame Kind, meeting each other horizontally and directly, have equal Quantities of Motion; that is, if their Velocities be reciprocally as their Bulks, at their Congreſs they will make an Equilibrium. (Bodies of the ſame Kind being ſuppoſed to have their Weights proportioned to their Quantities of Matter:)

According to this Rule, if a Weight of Two Pounds moving with Four Degrees of Velocity, meets directly and horizontally another of Four Pounds, which has Two Degrees of Velocity, they will ſtop each other, and make an Equilibrium. But if the firſt of Two Pounds moves Six times faſter than another of Ten Pounds, it will carry it along with it; for the Product of Two, Multiplied by Six, being Twelve, is greater than the Product of Ten, Multiplied by an Unit: Theſe Weights are ſuppoſed to ſtick together at their Congreſs. Hence the Truth of that Mechanical Principle is eaſily demonſtrated, which has been ill proved by *Archimedes*, *Galileo*, and many others: Namely, "that in a Balance, when Weights are to "each other reciprocally as their Diſtances from the "Center of the Balance (*Fig.* 9.) they make an "Equilibrium;--- for let B A C be the Balance, A the Center of Motion, A C four times the Length of A B, the Weight B four times greater than the Weight C; I ſay that one of the Weights will not overbalance the other; for ſuppoſe (if it be poſſible) that the Weight B ſhou'd preponderate; it can't move with any Velocity whatſoever, deſcending in the Arc B D, but it muſt make the Weight C move four times faſter in the Arc C E, ſince the

Semidiameter A C is four times as long as the Semidiameter A B, and then the Quantities of Motion of theſe Two Bodies would be equal; and one Quantity of Motion would be ſuppoſed to overpower another, which ſhould be equal to it, which is impoſſible; ſince they ought to make an Equilibrium by the Second Rule. For the ſame Reaſon the Weight C cannot deſcend; but if you put it a little further from the Point A, it will deſcend, for then it can give the other Weight a leſs Quantity of Motion than it will take it ſelf, and conſequently it will overpower it; and 'tis pretty ſtrange that the Weight B being Thirty Pounds, and the Arm A B a Foot long, if a Man can't ſuſtain this Weigh, by putting his Hand under it, yet a Weight of One Pound may by the ſame Man be eaſily ſuſtained by his Hand under it, at Thirty One Foot Diſtance from the Point A, if the Weight B be taken away; for it will only have One Pound Weight, though it were placed at One Hundred Foot Diſtance from the Point A; and yet at the ſame Time, if you place the little Weight at Thirty One Foot Diſtance from the Point A, and the great one at one Foot, the little one will preponderate; which cou'd not happen were it not diſpoſed in its Deſcent, to give a leſs Quantity of Motion to the Weight B, than it takes it ſelf, and did they not both act with all the Force of their Gravity by the firſt Rule; becauſe they have the ſame Direction towards the Center of the Earth.

RULE III.

When Two Weights not having the ſame Direction towards the Center of the Earth, are ſo diſpoſed, that one can't move without making the other

other move as faſt; the Force of each of them is not to be eſtimated by its abſolute Quantity of Motion, but by a relative one, which is found by multiplying each Weight into its Velocity, with reſpect to its approaching to or receding from the Center of the Earth.

The EXPLANATION. *Fig.* 10.

A is a Weight hung upon the Pully B, by the Cord E B A, which likewiſe ſuſtains the Bolt C D, by means of two little Cords tied to the Axis of the Bowl, and to the Point E of the Cord A B E. H G is a Horizontal Line, H F is a perpendicular one; E B is a Parallel to the inclin'd Plain G F, repreſented by the Line G F. It clearly appears, that the Bowl is diſpoſed to move as faſt as the Weight A, whether the Weight A deſcends, or the Bowl in deſcending makes it riſe; but when the Bowl in deſcending obliquely has paſs'd through the Space F G, it will have got no nearer the Center of the Earth than the Diſtance F H; all the Points of the Line H G of two or three Foot in Length, are to be look'd upon as equally diſtant from the Center of the Earth, becauſe the Difference is inſenſible. To know then the Forces of theſe Weights or their reſpective Quantities of Motion, you muſt multiply the Weight of the Bowl C D, by the Length of the Line F H, and that of the Bowl A by a Length equal to F G, becauſe this latter Bowl goes as far whether in aſcending or deſcending, as the Bowl C D, and moves directly towards the Center of the Earth: Now if F G be thrice as long as F H, and the Weight C D be thrice as heavy as the Weight A, you will ſee that there will be an *Equilibrium* betwixt the

two

two Weights, which proceeds from the Reaſons before explained in the two firſt Rules. But if you add ſome Weight either to the Weight A, or to the Weight B, that to which you add the Weight will deſcend, and make the other riſe, abſtracting from the Friction of the Pully and the Axis. You may explain in like manner the *Equilibriums* that ought to happen when the Plain F G is more or leſs inclin'd, by Application of the ſame Rules, which may be called Experimental Principles, or Laws of Nature.

If two Weights as A and B in the 11th Figure, be upon Plains differently inclin'd as C D, C F, the Line D F being ſuppoſed Horizontal, and the Line C G perpendicular to D F; to make an *Equilibrium* the Weight B muſt be to the Weight A as the Line C F is to the Line C D; and the Proof may be deduced from the ſame Rules: For if F H be taken equal to C D, and H I be drawn parallel to C G, 'tis plain, that whilſt the Weight B wou'd go from F to H, the Weight A would go from C to D, then C G would be the Meaſure of the Velocity of the Weight A, with reſpect to the Center of the Earth; and H I that of the Weight B, going from F to H in the ſame Time: But as F C is to F H, ſo is C G to H I; and by the third Rule, the Weight B ought to be to the Weight A, as C G is to H I; that is, as F C to C D, in order to make an *Equilibrium*. And conſequently theſe Weights thus diſpoſed will ſtop each other.

The ſame Thing will happen to Weights faſtened to the Extremities of the Spokes of a Wheel; that is, that the Weight A (*Fig.* 12.) placed at the End of the Spoke K A, may make an *Equilibrium* with the Weight B, the Line A K being Horizontal; and the Line B K being rais'd ſixty Degrees above

A K F, the Weight B muſt be double the Weight of A; for the Line B F being drawn perpendicular to the Spoke K B till it meets with the Line A K G F, the Plain B F will be rais'd 30 Degrees, and the Perpendicular B G will be but half the Length of B F, then the Motion of the Weight B towards F, being made at the Beginning along the Tangent B F, will get no nearer the Center of the Earth than in Proportion to the Space B G, the half of B F; whereas the Weight A will have its Direction along the Tangent M A H, perpendicular to A K F, which moves directly from the ſaid Center; and conſequently it will be diſpos'd to go twice as faſt as the Weight B, with reſpect to that Center: But as F B is to B G, ſo is the Spoke K B or A K to K G; then the Weight B will have the ſame Effect with reſpect to the Weight A, as if it were at G; that is, if A K be the Meaſure of the Velocity of the Weight, A K G will be the Meaſure of the Velocity of the Weight B; but A K is double the Length of K G, as F B is of B G; then the Weight A will be reciprocally to the Weight B as K G to K A. And by the Second and Third Rule, theſe Weights thus diſpoſed will make an *Equilibrium*, and the one will not over-power the other.

The ſame Thing will happen to Powers, which being faſtened to the Extremities of equal Spokes draw obliquely and directly: For at the Point L, in the Line B G, continued directly to L, let a Power draw by the Rope L B tied to B, according to the Direction B L; and let another Power at M draw along the Tangent A M, by the Cord A M, faſtened to the Point A: If theſe Powers be equal, they will not make an *Equilibrium*; but the Power at M will over-balance the other; and to make an *Equilibrium*, the Power at L, ought to be to the

Power

Power at M, as the Line A K to the Line K G; because the Power at L does not draw the Point B directly to it; but it goes along the Tangent B F at the Beginning of its Motion, and at the same Time the Power at M goes directly along the Tangent H A M. Now if you suppose B N indefinitely short in the Tangent B F, and N Q perpendicular to B L, 'tis evident that the Point B being at N, the Point L will be got to P, if N P be parallel and equal to B L; and L R and Q N being parallel to A F, R P will be equal to B Q, and L P to B N: Now the Power fix'd at the Point M will be got forwards the Length of a Line equal to B N or L P, according to the Direction A M, in which it endeavours to move; and the Power at L will be got no farther in the same Time according to its Direction B L or N P, than the Length of the Line R P, which is but the half of B N or L P, as B G is but the half of B F: So that to make an *Equilibrium* betwixt the two Powers, that which is at the Point L ought to be double that at the Point A, this latter drawing along the Tangent H A M, and the other according to the Direction B L, which makes an Angle of 30 Degrees with the Spoke K B. So that the Weight B must be twice as heavy as that at A to make an *Equilibrium.*

From these Three Experimental Principles, one general Rule for all moving Forces may be deduced: Which Rule or Universal Principle is this,

The General Mechanical Principle.

WHEN two Weights, or other Powers, are so disposed, that the one can't move without moving the other, if the Space which one of the Weights ought

ought to move through, according to its proper and natural Direction, be to the Space through which the other ought to move in the ſame Time, according to its proper and natural Direction, reciprocally as this laſt Weight is to the firſt; there will be an *Equilibrium* betwixt the two Weights: But if the Proportion of one of the Weights be greater than that of the other, the Weight which has the greateſt Proportion will over-balance.

From this Principle a ſurprizing Effect may be demonſtrated, which can't eaſily be proved by other *Hypotheſes*; namely, That if two *Brachia* or Arms of equal Length, be fix'd to the ſame Axis A, as A B, A C, *Fig.* 13. and a Weight E be put upon the Arm A B, and another Weight *b* upon the Arm A C, at the Point F; ſo that the Diſtances A E, A F be equal; the Weight at F being round and not faſtened to the Point F, in ſuch Manner that it might roll from F to C, were it not hindered by the perpendicular Glaſs Plane, which is very well poliſh'd as G C *g*: To make an *Equilibrium*, the Weight E muſt be much greater than the Weight *b*, *viz.* in the Proportion of A E to A H, if the Line H F be perpendicular to B A G K; the contrary of which happens when the Weight at F is faſtened to the inclined Plain A F C; for then to make an *Equilibrium*, the Weight at F muſt be greater than the Weight E in the ſame Proportion, as the Line E A is to A H, as was explained in the foregoing Figure.

For Proof this Paradox, draw the Horizontal Line *f b e* paſſing through the Center of the Bowl *b*; 'tis evident, that the Point *e* is higher than the *Fulcrum* or fix'd Point F; and that the Line *b e* is a little longer than Semidiameter *b f*. But to demonſtrate this, you muſt ſuppoſe the Triangle F *b d* very

very ſmall, and the Point F join'd to the Point *e*, and the Perpendicular F *b* to paſs through this Point: Now the Bowl *b* in its Deſcent will make the Point C turn in the Arc C *d*; and if *d g* be equal to the Diameter of the Bowl, the ſame Arm will be in the Situation A *b d*, when the Diameter of this Bowl will be got to *d g*, and the fix'd Point F will have deſcrib'd the Arc F *b* in the ſame Time that the Center of the Bowl has deſcended by a Space equal to *e d*. But if by Reaſon of the Smallneſs of the Arc you take the Arc F *b* for its Tangent, you will have the Triangle F *b d* ſimilar to the Triangle A H F, and *d* F will be to F *b*, as F A or *e* A to A H; and becauſe the Weight E riſes only in Proportion to the Line F *b*, the Space paſs'd through by the Bowl in deſcending directly from the Point F to *d*, will be to the Space paſs'd through in the ſame Time by the Weight E in aſcending again directly, as A E is to A H; then by the general Principle, the Weight E ought to be to the Weight *b*, as E A is to A H in order to make an *Equilibrium*; and becauſe the Bowl falls from a Point a little higher than the Point F; namely, from *e*, it follows, that the Weights being according to this Proportion, the Weight *b* will deſcend and make the Weight E riſe, which I have found true by Experiment; for having diſpoſed the Arm A C in ſuch Manner as to make an Angle of 60 Degrees with the Horizontal Arm A H K, I obſerved that the Weight *b* being double the Weight E, it made an *Equilibrium* with it, when I had ſtopp'd it to hinder it from rowling; but having left it free, only placing a Piece of Looking-Glaſs, repreſented by C G, to hinder it from rowling on one Side, I was obliged to put the double Weight at E, and the ſingle one at *b*, to make the *Equilibrium*, and even to add a little to the Weight at E. The ſame Reaſons will likewiſe prove, that if the Angle KAC were of 45 Degrees, the Weight E muſt be the greateſt, in Proportion as the Diagonal of a Square is to its Side in order to make an *Equilibrium.* That the Center of the Bowl F is a little on one Side of the fix'd Point, is not here conſidered.

Theſe Things being preſuppoſed, the *Equilibriums* of Fluids may be explained well enough.

The lighteſt, that is to ſay, the *leaſt heavy* Fluid is Flame, but becauſe it riſes in the Air, and does not lye extended upon other Bodies, it can't make an *Equilibrium* by its Weight, but only by its Impulſe and by its Spring.

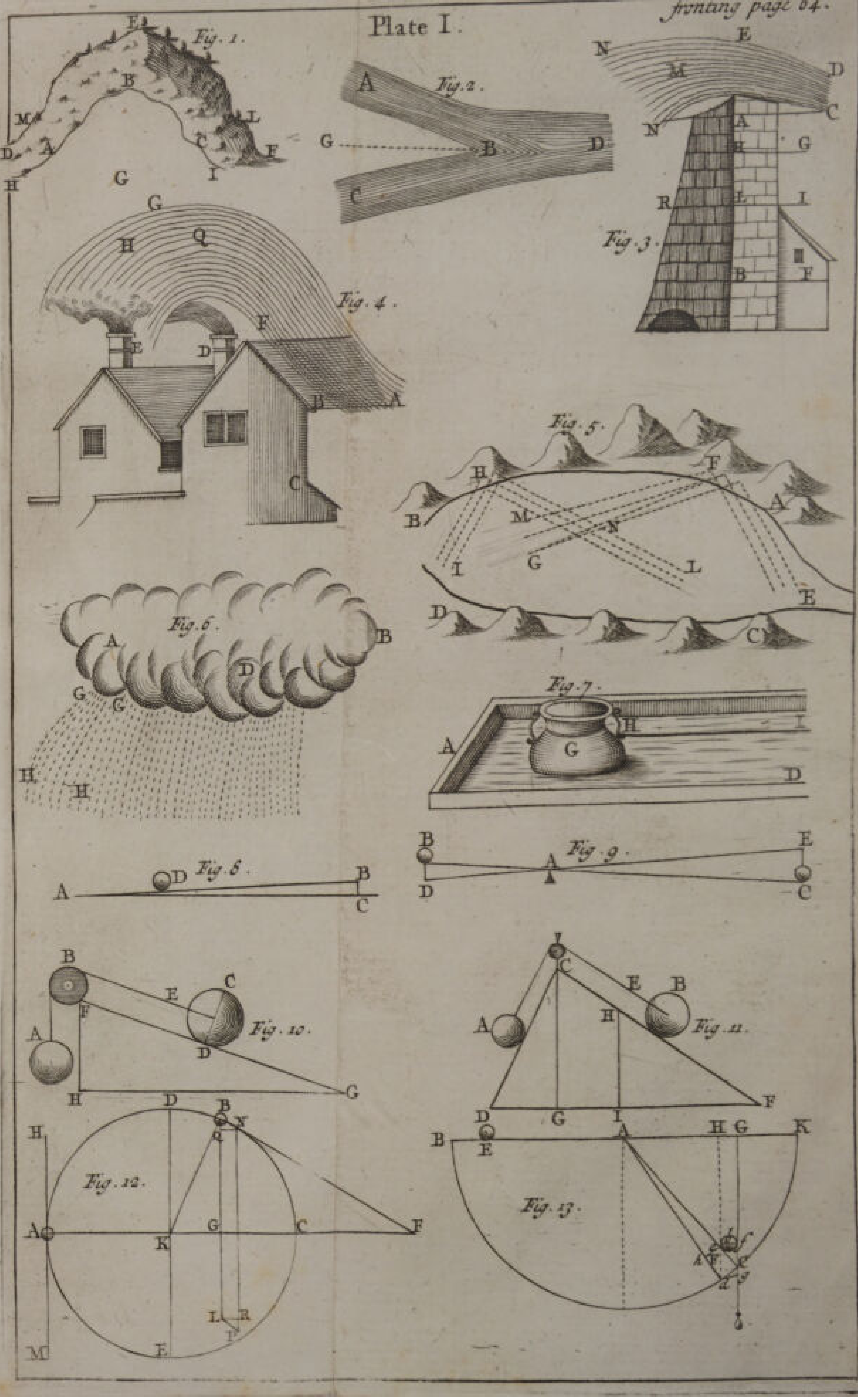
Air, which is extended above the Earth and Water, can make an *Equilibrium* with other Fluids more groſs than it ſelf, and even with hard and ſolid Bodies, by its Weight, by its Impulſe, and by its Elaſticity. The Weight of the Air is prov'd from the Effects of the Barometer, which is a ſtrait Glaſs Tube two Foot and an half or three Foot long, hermetically ſeal'd at one End. You fill it with *Mercury*, no Air being left within it, and ſtop the other End with your Finger; and after having turned the ſeal'd End uppermoſt, you dip the Finger in ſome other *Mercury* put into a Veſſel, then take away the Finger that ſuſtain'd the *Mercury* in the Tube, and ſome part of it will fall into the Veſſel, and after ſome Vibrations it will reſt in the Tube 27 or 28 Inches high (*Paris*-Meaſure;) for according to the Changes of the Winds and Air, it riſes ſometimes to 28 Inches and an half, and at other Times only to 26 and an half, and commonly at *Paris* it riſes to 27 Inches and an half or thereabouts.

Now this rising of the *Mercury* can't well be explain'd, unless you suppose that a Column of Air of the same Breadth with the internal Diameter of the Tube weighs as much as the 27 or 28 Inches of *Mercury* which rose in the Tube, taking this Column from the Surface of the *Mercury* in the Vessel, to the utmost Limits of the highest Region of the Air; for if you carry the Barometer up to the Top of a Mountain, or of a very high Tower, you will see the *Mercury* fall by little and little, till it be reduced to the Height of 24 or 25 Inches, as being then press'd by a shorter Column, and therefore a less Quantity of Air; and if you go down with it into a very deep Cave or Mine it rises by little and little, according as you descend, as being successively press'd by a greater Quantity of Air.

The Weight of the Air and the *Equilibrium* which it makes with Water, may still further be known from the same Rules, by supposing that an Inch of *Mercury* weighs almost as much as 14 Inches of Water, as I have found it does by the Experiments which I have made; for 28 Inches of *Mercury* will weigh about as much as 383 Inches of Water, which are something short of 32 Foot; from whence it follows, that when the Weight of the Air makes the *Mercury* rise to 28 Inches and some few Lines, it will make Water rise 32 Foot in a Tube of 35 or 40 Foot long, and that when it rises but 27 Inches and an half, Water ought not to rise quite so high as 31 Foot, which is found to agree well enough with some Experiments which I made at the Observatory in the following Manner; I caus'd Mr. *Hubin* an Enameller to make a Glass Tube 40 Foot long, which he secur'd in the Groove of a Beam of Wood from being broken in the managing; it consisted of five or six Pieces, which

fronting page 64.

Plate I.



he ſolder'd together by melting the Glaſs, in the great Hall of the Obſervatory; we rais'd one End of it to the Top of the Platform, through a Hole which is there, that anſwers perpendicularly to the Hollow or Newel in the Cellar Stairs; then we let it fall by Degrees till it came to this Hollow, and fix'd it by tying it in ſeveral Places to the Iron Rails or Range; afterwards we ſtopp'd the lower End, and fill'd it with Water, and then apply'd a Glaſs Stopple to the Hole at Top, that fitted it exactly, and in order to ſeal it down yet more cloſely, we covered it with a Piece of Bladder; we likewiſe fill'd another Veſſel with Water, that was plac'd below the other End of the Tube, till that End dipp'd in the Water, and after we had unſtopp'd it, the Water in the Tube fell about 12 Foot; but ſo many Bubbles of Air came out of it, that we cou'd not mark exactly how high it roſe again; at laſt it reſted at 29 Feet, by Reaſon of the Spring of the Air in the Bubbles, which came out of the Water, and roſe to the Top of the Tube. Two Days after, we again put Water into it, that had been boil'd a little before, to expel the Aerial Matter out of it; we renew'd the Experiment, and the Water, after ſome Vibrations, ſtopp'd at 29 Feet 4 Inches, or thereabouts; but we ſaw it riſe higher by little and little, till it reſted at 30 Feet 2 Inches, the other Barometers in the mean Time never changing. I attributed the Cauſe to this Water's having a little Dirt mix'd with it, and conſequently it weigh'd more than clear Water; but the Dirt deſcended by little and little to the Bottom of the Veſſel; and by this Means the Water becoming lighter by Degrees, it roſe higher by little and little. Two Days after, I obſerved that the common Barometers being at 27 Inches 9 Lines, the Water in the long Tube was risen to 30 Feet 8 Inches; it wou'd have risen a little higher if some Bubbles of Air had not got to the Top, and hinder'd its Rise: The common Barometer being at 28 Inches it rose still higher, and fell afterwards when the common Barometer was below 28 Inches, whence I knew that the Water Barometers have their Variations proportion'd to those of *Mercury*, and that 32 Feet of Water, or thereabouts, may be taken for the greatest Height of these Barometers, when the Water with which they are fill'd, is of the lightest Kind, and the Aerial Matter is extracted from it. For the more easy Calculation, we will here suppose that the Weight of the Atmosphere makes an *Equilibrium* with 32 Feet of fresh Water precisely, and that *Mercury* weighs precisely 14 Times more.

The Weight of the Air is still farther prov'd, by an Experiment curious enough: Take a Glass Bottle A B (*Fig.* 14.) in which there is an Hole made of 2 or 3 Lines, as at C; put a Glass Tube as D E about Two Lines Diameter into the Neck of the Bottle, as at G, and cement them together with a Mixture of Wax and Turpentine, or with Pitch, so that the Air can't get between them; then laying the Bottle along, through the Aperture C, you fill it with Water, and fill likewise at the same Time the Tube E D, keeping the End D close stopp'd; and when you place the Bottle in its perpendicular Situation, the Water in the Tube will descend to E, and as much will go out through the Hole C, if the Extremity E of the Tube answers in Height to the Middle of the Hole C; but if the Tube reaches down below the Hole as far as I, the Water will cease running, when the Tube is empty as far as E, and the Bottle will remain full of Water up to the cemented Neck towards G; but if the End of the Tube

Tube be a little higher than the Top of the Hole C, as at L, and it be two or three Lines broad, then you will ſee the Air go out through this open End, and riſe again to the Top of the Bottle, and at the ſame Time the Water will go out through the Hole C, till there be none left above the Point C.

These Effects are explained in the following Manner.

The External Air preſſing towards the Hole C by its Weight, endeavours to puſh up the Water, which endeavours by its Weight to get out, and the Air which is above the Tube E D preſſes likewiſe, and acts by its Gravity upon the Water contain'd in the Tube, which being join'd to the Weight of that Water, muſt overpoiſe the Weight of the Air which acts at C, which cauſes the Water in that Tube to deſcend to E, and then the Air preſſing on one Side at E, and at the other at C, jointly ſuſtain the Water in the Bottle from E and C up to A and H, and it wou'd even ſuſtain it though the Height C H were of 30 Feet, provided the End of the Tube were below the Bottom of the Hole C; but when the Tube deſcends no lower than L, then the Water from L to E, join'd to the Weight of the Air which preſſes upon L, will over-poiſe the Air at C, and the Water will go out through the Hole C, whilſt the Air deſcending from D to L, and entring Drop by Drop into the Water through the open End L, riſes above the Surface of the Water which is below the Neck of the Bottle; but if you incline the Bottle in ſuch Manner that the Point L and the Middle of the Aperture C may be in the ſame horizontal Line, you will ſee half a Drop of Air get below the Point L, but not ſeparate from the reſt, unleſs you raiſe the End L a little higher, When you have let ſome Air into the Bottle, ſo that the Surface of the Water is at N O, and dilate that Air by heating it with your Hand, you will force out ſome Drops of Water at C, though the End of the Tube be below this Hole, and the Water will deſcend as to *p q*, but if you let the Air grow cold again, you will ſee for ſome Time Bubbles of Air enter in at C; becauſe the Air which had deſcended as far as P Q, contracting it ſelf within the Space which it took up at firſt from N O to A H, and there being no Water to fill up the Space N O P Q, the Air muſt come in from without through the Hole C.

Water has no ſenſible Elaſticity, and makes an *Equilibrium* with other Bodies only by its Weight or its Impulſe: The firſt *Equilibrium* that is remarkable in Water with reſpect to Air, is, that being reduc'd to very ſmall Particles, it becomes lighter than Air, and riſes in a Vapour, as was before obſerved. We can't tell how ſmall ſuch a Particle of Water muſt be to make an *Equilibrium* with the Air near the Earth, becauſe thoſe Particles, which are a little lighter or a little heavier than Air, are inviſible when they are ſeparate from each other. 'Tis very difficult likewiſe to find out the Reaſon of their Riſe, for it can't be that they are mix'd with Air, becauſe they wou'd ſtill weigh more than pure Air; 'tis not by Reaſon of Heat, becauſe we ſee Vapours ariſe from very cold Water: 'tis probable then that in the Air there are very fine Pores, void of all heavy Matter, into which theſe fine Particles of Water may inſinuate themſelves and riſe therein, and into which the groſſer Particles can't enter.

Theſe ſmall Particles make an *Equilibrium* with the Air at about a League or two Leagues diſtance from the Earth, where they remain a long Time

ſuſpended,

ſuſpended, till many of them being join'd together they become heavier; and when the Air is very much rarified, they fall to the Earth.

This is further illuſtrated by an Experiment in the Air Pump; for when you have pump'd out ſome Part of the Air, you ſee the Recipient grow dull by the Fall of the Vapours, which the Air by Reaſon of its too great Rarefaction being no longer able to ſuſtain, they fall in fine little Drops upon the Glaſs which contains them.

In Places where there are great Water-Falls, you ſee Vapours perpetually ariſe, which are nothing but Particles of Water broken by their Impulſe: And when a Soap Bubble comes to break, one Part of the Water of which it conſiſts falls, and the reſt being reduc'd to very fine Particles aſcends in a Vapour.

RULE I.

For the Equilibrium *of Water by its Weight.*

Water being in one or ſeveral Veſſels, that communicate with each other, has its upper Parts always upon an equal Level; that is, at equal Diſtances from the Center of the Earth.

The EXPLANATION. *Fig. 15.*

Let ABC be a recurve Tube, whoſe Diameter is equal in all its Parts; pour ſome Water into it at the End A, and it will riſe to the ſame Height in the other Leg of the Tube; that is, if D E be an Horizontal Line, and the Water in the Leg AG, riſes as far as D, it will riſe in the other

other as far as E, and there continue when you have ceas'd pouring, and the Water is at rest.

For, First, if the Legs be of equal Breadth, and equally inclin'd to the Horizon, there being an Equality in every Respect on both Sides, the Water can't remain at the unequal Heights A and F, because the Weight of the Water A G will be greater than that of the Water H F; and consequently in descending it can take it self a greater Quantity of Motion, than it will give to the other in ascending, since they will have equal Velocities and the same Directions.

Therefore by the universal Principle, the Water can't be at Rest, unless it be at the same Height in the Two Legs. But if you stop the End C with your Finger, before you pour in the Water at A, and fill the Leg A G with Water up to A, the other will be empty, and no Water, or very little at most will rise into it; because the Air takes up the Place, if the Leg A G be not above two or three Feet in Height; then if you take off your Finger, the Water in the Leg A G will descend, and Part of it will go into the other Leg, and rise as high as E, whilst the other falls as low as N, and afterwards it will rise to D, and fall again as low as M; till at length after several Vibrations, it will be at Rest on both Sides at an equal Height as I F.

When in this Experiment the Water begins to descend from the Leg A to go into the other, it accelerates its Motion till it be at an Equal Height in the two Legs, as at I F, where the *Equilibrium* ought to be; and afterwards its Velocity gradually diminishes till it be got to the Points N and E; it descends again after the same Manner, accelerating its Motion from the Height E, till it be past the aforesaid Level I F, and diminishing it till one of the

Heights

Heights be at D, and the other at M; and theſe Vibrations will continue till the Water be at reſt at I F, juſt as a Pendulum accelerates its Motion, till it comes to the Point of Reſt, which it diminiſhes in reaſcending from that Point; and at length, after ſeveral Vibrations, ſtands ſtill.

The ſame Thing will happen in a Veſſel, as A B C D (*Fig.* 16.) fill'd with Water up to E F; for if by pouring in Water at F you raiſe it as high as G, it will not remain in that Situation, after you have left off pouring in other Water: For the Weight of the Water G K H C, being greater than that of the Water K I L H, (L H and H C being ſuppos'd equal,) it will for the ſame Reaſons over-power it, and raiſe Water towards I K, and at the ſame Time the upper Surface G K being inclin'd, the Water will move from G towards I; and for the ſame Reaſons, the Water E B L I will riſe likewiſe: And at laſt, after ſeveral Vibrations, the upper Surface of the Water will be upon a Level. Hence what happens, when a Stone is thrown into a ſtanding Water, as at N, (*Fig.* 17.) may be explained; for the Stone raiſing the Water round it in a Circular Wave, whoſe Elevation is repreſented by O and P, it can't remain in that Poſition; but the Part O will move towards L, and in its Motion will impel and raiſe the Water next to it as R, which will likewiſe impel and raiſe that which follows it in ſuch manner, that the Water rais'd at O will ſeem to move as far as L.

The ſame Thing will happen to that Part of the Water raiſed at P, and by this means a Circular Wave will ariſe, which receding from the Point N, will grow larger and larger, till it reach the Banks L and M, if they be not too far diſtant; and in its Reflection from thence, a new Circular

Wave will be form'd, which will advance on both Sides towards N, continually enlarging its Circumference, and leſſening its Height, till the whole Surface of the Water be got to a Level.

Let us ſuppoſe now the two Legs (*Fig.* 18.) of unequal Diameters as A B C D, the Water will be at the Height E F, which is the ſame in both Legs, and the Column A B will not over-poiſe the Column C F; for let the Baſe B G which is ſuppoſed Square, be Sixteen Times greater than the Baſe C, and if it be poſſible let the Water deſcend from E to I, and aſcend on the other Side to D; that which is ſuppos'd to deſcend from E to I, will be equal to the Water contain'd betwixt F and D, and the two little Cylinders F D, E I, will have their Heights reciprocally as their Baſes: Then as 16 is to 1, ſo is the Height F D to E I: Now the Cylinder E B being Sixteen Times greater than the Cylinder C F will weigh Sixteen Times as much: But the Space paſs'd through in the ſame Time by the little Cylinder, will be likewiſe Sixteen Times greater than the Space paſs'd through by the great Cylinder, and their Directions are the ſame, both being perpendicular: Then their Velocities muſt have been reciprocally as their Weights, and they muſt have had an equal Quantity of Motion, which is impoſſible; for by the univerſal Principle, theſe Cylinders ought to make an *Equilibrium*; and one can't make the other move, becauſe they are diſpos'd to take an equal Quantity of Motion, according to the ſame Direction.

If you pour Water into the narrow Tube till it be as high as D, it can't remain there in a State of Reſt till the other Leg be fill'd up to A: For let the Height F D be an Inch, and its Baſe an Inch, and F G 10 Inches, then the whole Column of Water

Water C D will be 11 Cubic Inches, and the Water B E, 160 Cubic Inches. If then the whole Column C D falls an Inch, the Water E B will riſe $\frac{1}{16}$ of an Inch; *viz.* the Height E L, and the Space E L will be the Meaſure of the Velocity of the Water B E, as D F is that of the Water C D: Now 160 multiply'd by $\frac{1}{16}$ gives 10 for the Quantity of Motion, and 11 multiply'd by 1 gives 11; then the Quantity of Motion of the Water D C will be greater than that of the Water B E, or which is the ſame Thing, the Velocity of the Water in the ſmall Tube will be greater in Proportion to the Velocity of the Water in the great Tube, than the Weight of this latter is to the Weight of the former; and by the univerſal Principle, the Water in the ſmall Tube muſt deſcend. The ſame Conſequences may be drawn with reſpect to other unequal Heights, till the two Surfaces of the Water in each Leg be upon a Level, nor will the Water be at Reſt, till it be at the ſame Height in both.

The Water A G may be ſtill further conſidered, as divided according to its Length, into Sixteen little ſquare Columns, each of which may be ſuppoſed equal to the ſmall ſquare Column C D; and becauſe none of theſe ſmall Columns can riſe higher or fall lower than the others, the ſame may be concluded of the little Column C D, though it be not contiguous to them.

Hence it follows, that if you put a floating Body upon the Water in the Leg A B, and the Weight of this Body be equal to that of the Water contain'd in the Height A E, when that Water is pour'd off, the Water in the little Leg will ſtill remain at the Height C D, and there will be an *Equilibrium* betwixt the Column C D, and the Water

ter B E, joined to the Weight of the Floating Body, for the Reasons above-mentioned.

When the narrow Leg is very small, as about half or one third of a Line in Diameter, the Water will rise an Inch or two higher in that than in the other Leg; which likewise happens when you dip a Glass Tube, whose Diameter is less than one Quarter of a Line, into Water, for it will rise therein to the same Height of an Inch or two above the other Parts of the Water's Surface, and the whole Quantity of Water that rises above the Level, in Tubes that are very small, or in such as are only moderately so, as about a *Line*, or half a Line in Diameter, is sensibly equal to a great Drop of Water, that being fix'd to some Body hangs at it without falling.

The same Effect may be seen in the Experiment of the Bottle before-mention'd(*Fig.*14.); for if the Tube be very small, as about half a Line in Diameter, the Water will fall in it no lower than L, about an Inch above E, and then this particular Cause of Adhesion resists the Effort of the Air, which is above the Water in the Tube; and the narrower the Tube is, the higher the Point L will be.

Some attribute the Cause of this Effect to the Weight of the Air, which acts with its full Force upon the Water in the large Tube, and can't act so well upon that in the small one; but this can't be the Reason: For if you dip such a Tube in *Mercury*, it will not rise so high in it as the Level of the rest of the *Mercury*; and yet in this Case the Weight of the Air ought to have the same Effect upon the *Mercury* that it has upon the Water: whereas if one of these narrow Tubes, that is not above half an Inch high, be dipp'd in Water, the Water will rise in it to the Top, altho' the Air has

then

then no Difficulty to insinuate it self. And for a further Proof, if the Sides of the Tube be thick, or if it has been some time without Wetting, it contracts a certain greasy Substance, which the Water can't fix upon; and then the Water will not rise above the Level, though the suppos'd Defect of the Weight of the Air continues the same without Alteration.

This Effect then is to be explain'd by the same Reasons, that make Water in a Vessel of Wood rise above a Line and an half towards the Sides with a little Concavity, which causes Two Drops of Water to join together, when they touch each other, of which Reasons I have spoken at large in the first Discourse.

A surprizing Effect of the *Equilibrium* of Water may seen in the following Experiment; take a Vessel or Butt of Water, about two or three Foot broad, as A B C D, (*Fig.* 19.) make an Hole at the Top, as at E, and fix a Tube therein, of an Inch Bore, so closely join'd with Hurds and Pitch, or other glutinous Matter, that no Air can get into it, and let this narrow Tube, *viz.* E F be 12 or 15 Inches high; fill the Vessel with Water by some Holes made in the Top and afterwards stopp'd up, and put thereon Seven or Eight Hundred Pounds Weight, which will sink that Top to a Concavity, as A M D; if you put a white Mark on the outside of the Tube, as at the Point H, and at the Side a little higher a Ruler or Index as I L plac'd in a neighbouring Wall; and fix'd in such Manner, that it may remain immoveable; as you pour Water by little and little into the narrow Tube E F, you will see when it comes to be full, that the Top A M D, together with the 800 Pound Weight that it bears, will be rais'd not only to its first Situation

A E D,

AED, but that it will take even a Convex Figure, and be rais'd in the Middle as much above the Point E, as the Point M was below it before; which you will ſee by obſerving the white Mark H riſe by Degrees above the Ruler I L, with which you may meaſure the Difference. And if the Tube be longer, the Elevation of the Weight will ſtill be greater: Whence you may conclude, that the ſmall Quantity of Water in the Tube has as much Force to raiſe this great Weight, and puſh up the Top of the Veſſel to a Convexity, as if the Tube were of the ſame Bore or Breadth as the Veſſel. This Effect is prov'd by the ſame Reaſons before-mentioned, concerning the Water in the ſmall Tube CD, which will raiſe the Water in the Tube B A (*Fig.* 18.) when 'tis no higher than E, tho' it ſhou'd weigh 1000 Times as much: For the Velocity which the Water in the ſmall Tube F E (*Fig.* 19.) will take in its Deſcent, will be to the Top of the Veſſel in aſcending, as the Surface of this Top is to the Surface of the Water in the Tube; that is to ſay, if the Tube be an Inch in Diameter, and the Top of the Veſſel 30 Inches, the Surface of this Top will be 900 Times greater than the upper Surface of the Water in the Tube: Then if the Water in the Tube deſcends an Inch, that which touches the Top of the Veſſel will riſe but $\frac{1}{900}$ Part of an Inch. And conſequently if the Water in the Tube weighs a Pound, it will make an *Equilibrium* with 900 Pounds, then it will raiſe the 800 Pounds that are on the Top of the Veſſel, with the little Quantity of Water that is above AED; but for the greater Exactneſs of the Calculation, and of the manner of Reaſoning, you muſt ſuppoſe that the whole Top of the Veſſel riſes all at once.

When one of the Legs of a Syphon is inclin'd, and the other Perpendicular, both being pretty near of the ſame Diameter, Water in that Syphon will likewiſe be upon a Level; (ſee the 20th *Figure*) for let the Syphon A B C be plac'd in ſuch manner, that the Leg A B may be Perpendicular, and C B in an inclin'd to the Horizon, it is manifeſt that the Weight of the Water in D B will be to the Weight of the Water in E B, as the Bulk D B is to the Bulk E B; but if E D be an Horizontal Line, the Sum of the Force, which the Water E B has to deſcend, will be to that which it wou'd have if it fell perpendicularly, as the Length E B is to the Length D B: Therefore it will make an *Equilibrium* with the Water D B, whoſe Direction is Perpendicular according to the univerſal Principle; for the Spaces paſs'd through in the ſame Time by both Quantities of Water in each of theſe Tubes, according to their natural Direction towards the Center of the Earth, will be in a Reciprocal Proportion of their Weights, that is, as the Weight of E B is to that of D B, and conſequently the Water E B will not over-poiſe the Water B D; the greater Friction in the long Tube may cauſe ſome Difference, and a little retard the Motion of the Water along the inclin'd Plane E B; but altho' either of theſe Tubes ſhou'd be larger than the other, that wou'd not hinder the *Equilibrium* for the Reaſons above-mention'd.

When a Syphon has one of its Legs much larger than the other, as in the 21ſt *Figure*, ſtop the Mouth of the little Leg with your Finger, and afterwards fill the great one with Water, then take off your Finger all at once, and you will find that the firſt Motion of the whole Column of Water A B is retarded, by Reaſon of the Difficulty which it meets

meets with in its Paſſage at G; but the Motion through F C is much faſter in its Beginning, than when the Two Legs are of equal Bore; whence it happens, that if you pour a little Water into the Leg F C, till the Tube of Conjunction B C be full, and after you have ſtopp'd the Mouth F with your Thumb, you fill A B, the other Part of the Syphon, up to the Horizontal Line E D, and then take off your Thumb all at once, the Water will riſe higher than D, even up to F, becauſe the Water in the great Leg, though it deſcends ſlowly, yet it makes that in the little one riſe very faſt, and all the Water being in Motion, in order to come to an *Equilibrium*, it ſtill moves (after it has got thither) by its acquir'd Velocity, as appear'd in the uniform Syphon; which cauſes the Water in the great Leg to deſcend ſtill, and make the other riſe Three or Four Inches above D, from whence it deſcends again, and after ſome Vibrations ſtands at laſt at the ſame Height, in both Legs below E F; and though the Tube A B ſhou'd be full before you take off your Thumb, the Water wou'd ſtill ſpout up Three or Four Inches higher than F, provided the Leg A B be much larger than C D; for then the falling and riſing in this large Leg will be very ſmall and almoſt inſenſible. Theſe are the Experiments that have been made concerning it.

I took a Veſſel made of Tin as A B C D, (*Fig*. 22.) of Four Inches Diameter, which had a Tube E F, to which I join'd a bended Glaſs Tube, as F G H; I fill'd the Veſſel and the Tube E F, after I had ſtopp'd the Mouth at H with my Thumb, to hinder the Air from getting out; and when I had taken off my Thumb, the Water ſpouted up to I, Three Inches higher than the Surface of the Water D A; but when the Glaſs Tube reach'd Five or Six Inches higher

higher than A D, the Water roſe in it Four Inches higher than H, from whence it fell again, and at length came to an *Equilibrium*. The ſame Experiment was made in a Tube L E F, whoſe Diameter was equal throughout, G H being ſtill narrower than L E F, and the Water ſpouted up above the Point H, juſt as it did when the Veſſel A D was above E F: Now in theſe Caſes the Water begins to riſe pretty faſt at G, and afterwards riſes a little faſter when the Water L E has acquired ſome Motion. But this Velocity in the Paſſage from G to H begins to diminiſh, when the Water in each Tube or Leg is come to an *Equilibrium*, that is, to the Height at which it ought to ſtand in both the Tubes, as to the Horizontal Line K M. But if you put different Liquors in the two Tubes, the lighteſt will be higher than the other, in a reciprocal Proportion of their Weights. The Rules of which are as follow.

A Rule for the Equilibrium *of different Liquors by their Weight.*

THERE are two Sorts of Gravity in Bodies here to be conſidered; one proceeding from the Maſs or Bulk of the Body, as a Cubic Foot of Wood weighs more than a Cubic Inch of the ſame kind of Wood, the other proceeding from the Denſity of Bodies, or from ſome other Reaſon by which one Body weighs more than another of equal Bulk, as a Cubic Inch of Gold weighs more than a Cubic Inch of Iron; this latter we ſhall call *Specific Gravity*; thus the Specific Gravity of Water is greater than that of Oil; the Gravity of the Air, in which the Body is weigh'd, is not here conſider'd, though in ſtrictneſs it ought to be.

Let

Let there be an *Equilibrium* of Water at the Height DE, in the Syphon ABC (*Fig.* 23.); pour ſome Oil gently into the Tube CD, to the Height C, then you will ſee the Water deſcend below E, and riſe about D in the other Tube; let EF be the Meaſure of the Deſcent, and DG of the Elevation, and draw the Horizontal Line FH; then the Oil FC will be to the Water HG reciprocally, as the Specific Gravity of the Water is to that of the Oil; for the Water FB will make an *Equilibrium* with the Water BH, then the Oil FC will make an *Equilibrium* with the Water HG; now that the whole ſhou'd remain in this Situation, 'tis neceſſary that the Parts H and F ſhou'd be equally preſs'd, from the above-mention'd Principle: Then the Quantity of Oil FC will weigh as much upon F, as the Water HG upon H. The ſame Effect will appear in *Mercury* and Water; for if you put *Mercury* into the Syphon ABC to the Height DE, and then pour in Water gently at C, inclining the Syphon a little at firſt to hinder the Water's mixing with the *Mercury*, and let the Water riſe up to C, and the *Mercury* to I, the Water will then fall to the Horizontal Line KL; and the Water KC, together with the *Mercury* KB, will make an *Equilibrium* with the *Mercury* BI; and as the Specific Gravity of *Mercury* is to that of Water, ſo reciprocally will the Height KC be to the Height LI, and by this means it will be eaſy to determine the Specific Gravity of Liquors with reſpect to each other; for if *Mercury* weighs fourteen Times more than Water, KC will be fourteen Times longer than LI.

Having treated of the *Equilibrium* of different Liquors, with reſpect to one another, that of Solid Bodies ſwimming in Water, as Wood, Wax, *&c.*

comes next to be consider'd; concerning which you may observe the following Rules.

Rules for the Equilibrium of solid Bodies, whose specifick Gravity is less than that of Water.

RULE I.

Every solid Body heavier than Air, and lighter than Water, being put into Water, will sink in it a little, and the Part so immers'd will be to the rest of the Body, as the specific Gravity of that Body is to that of Water.

PUT some Water into a Vessel, as B C D E (*Fig.* 24.) whose upper Surface is B C; and let A F G H be a solid Body, specifically lighter than Water, and heavier than Air; I say that it will not remain upon the Surface of the Water; for the square Column of Water K R L I would be more press'd than B E I K, a Column equal to it, since it would have an Addition of the Weight of the Body A H; then the Weight will descend, and dip in the Water, but not sink so as to be entirely cover'd with it, because then the Column K R I L, made up of this Body and Water, would be lighter than an equal Column of Water as B E I K. Let us suppose then that the Body immerges as far as K R, and that the Water about it rises to B C, which is higher than it was before, because the immers'd Part of the Body as K G H R takes up the Place of a Part of the Water that is oblig'd to rise: I say then that the Water contain'd within the Space K G H R, whose Place the Body takes up, is equal in Weight to the Weight of the whole Body; that is, if a Quantity of Water equal in Bulk to K G H R, weighs as much in the open Air, as the entire Body A F G H, then it will remain in this Situation; and K R G H the immers'd Part will be to the whole, as the ſpecific Gravity of that whole Body is to that of Water.

So if the ſpecific Gravity of the Body A F G H be to that of the Water, as 3 to 4, the Part of A F K R, which will appear above the Water, will be one Fourth of its whole Height; for if the Body weigh'd 12 Pounds in the Air, an equal Bulk of Water would weigh 16 Pounds; and conſequently if the Part K R G H were Water, it would weigh 12 Pounds, but as it is Wood, therefore it will weigh but 9 Pounds, and A F K R the Part above the Water will be 3 Pounds, and the whole will weigh 12 Pounds, as that Bulk of Water whoſe Space is taken up by that Part of the Weight which immerges in it would weigh 12 Pounds, according to the Proportion of 3 to 4; and by the firſt Rule the Wood will remain in this Situation in the Water.

And becauſe Cork is 4 times lighter than Water, if you put a Cylinder of Cork as A F G H, into the Water B C E D, it will ſink a little; and if the Superficies of the Water be double to that of the Baſe of the Cylinder, the Water will riſe but the eighth Part of the Cylinder's Height, and only one fourth Part of the Cylinder will ſink into the Water; ſo that the Part which will remain out of the Water, will be three Fourths of the whole Cylinder.

Water ſticks ſometimes to light Bodies, and riſes in a ſmall Concave againſt the Part above K, and ſometimes makes a little ſinking under it, as was before explain'd; which might create ſome Difficulty; but the Difference which this ſmall Quantity of Water makes by riſing above the reſt of the Surface of the Water, is ſo little, that it is not here conſider'd.

This Property of Water's ſticking or not ſticking to certain Bodies, ſometimes produces ſurprizing Effects, as appears by the following Examples.

A B C is a Glaſs half full of Water, whoſe upper Surface is D E; if a little frothy Bubble full of Air as F (*Fig.* 25) or a little hollow Ball of Glaſs, full of Air, and lighter than Water, or any other Body of that kind ſwims at Top, it will move towards the Sides E or D, and ſtick there as if it were glew'd; but on the contrary, if the Glaſs be quite full of Water, as to A C, then the little Ball K cannot get near the Side, and if you puſh it thither, it will return towards the Middle at K. But there are other very ſmall light Bodies, which produce quite contrary Effects. Take a ſmall Ball of Wax not wet, and place it gently upon the Water at F; when the Glaſs is not full, it will fly from the Sides; but if you put it towards the Middle at K, when the Glaſs is full, it will go with Precipitation towards G, till it touches the Sides of the Glaſs.

Theſe Effects may be explain'd after the following manner.

A B (*Fig.* 26) is the Surface of the Water when the Glaſs is not full; C D is the Side of the Glaſs where the Water makes a little Riſing as *e f g*; E is the Ball of Wax, which being fat, and plac'd gently upon the Water, makes a little Hollow therein, becauſe the Water does not ſtick to it, and the Ball ſinks beneath the Surface of the Water A H K B, till that Part beneath the Surface, together with the Air compriz'd below the pricked horizontal Line, weighs as much as the Water that was contain'd within the Space contain'd by that printed Line H K, and the Curve H I K; now if you puſh the Ball forwards as far as *g*, when the Point K, which is the Extremity of the Concavity H I K endeavours to approach nearer the Side of the Glaſs than the Point *g*, then the Water at *e f* being no longer ſuſtained by that at the Point *g*, deſcends, and repells the Bowl till the Point K be join'd to the Point *g*, the Curve *e f g* remaining in its firſt Situation.

But if the Glaſs be quite full, and the Water riſes above the Brims, without running over, as it may eaſily do, and as you ſee it does in *Fig.* 27, where the Water makes a Convexity from L to the Side of the Glaſs B; then, when the Ball E is got forwards till the Section H I K meets the Convexity L B, as it does at P, this Point P will be lower than the Point H on the other Side of the Ball; and by this means the Ball will bear on a Declivity, which will ſtill encreaſe, as that ſame Section draws nearer to B, and this Inclination will become yet more ſteep till the Ball touches the Glaſs at the Point B, as you ſee in the ſame Figure, at the other Side of the Glaſs.

For the ſame Reaſons, when two of theſe Balls are put pretty near one another, they will join each other: (*Fig.* 28.) for let the Line A C D E F B be the Level of the Surface of the Water; C *a e* E, D *e b* F the two Hollows made by the Balls, and the Point *e* the Interſection of thoſe Hollows; 'tis plain that the Point *e* will be lower than the Level of the Water A C F B, and conſequently that there will be an Inclination on both Sides; which will cauſe the Balls to move forwards till they meet each other, as you ſee in this ſame Figure. But if one of the

Balls

Balls be wet, ſo that the Water may ſtick to it, they will repell one another, which is prov'd after the ſame manner; (*Fig.* 29.) the wet Ball B will cauſe a Riſing of the Water as C B and B D, and the other Ball E a Hollow as F G H; if you puſh them one againſt the other, the Water will riſe more towards C betwixt the two Balls, and in a greater Quantity, which will repell them from each other.

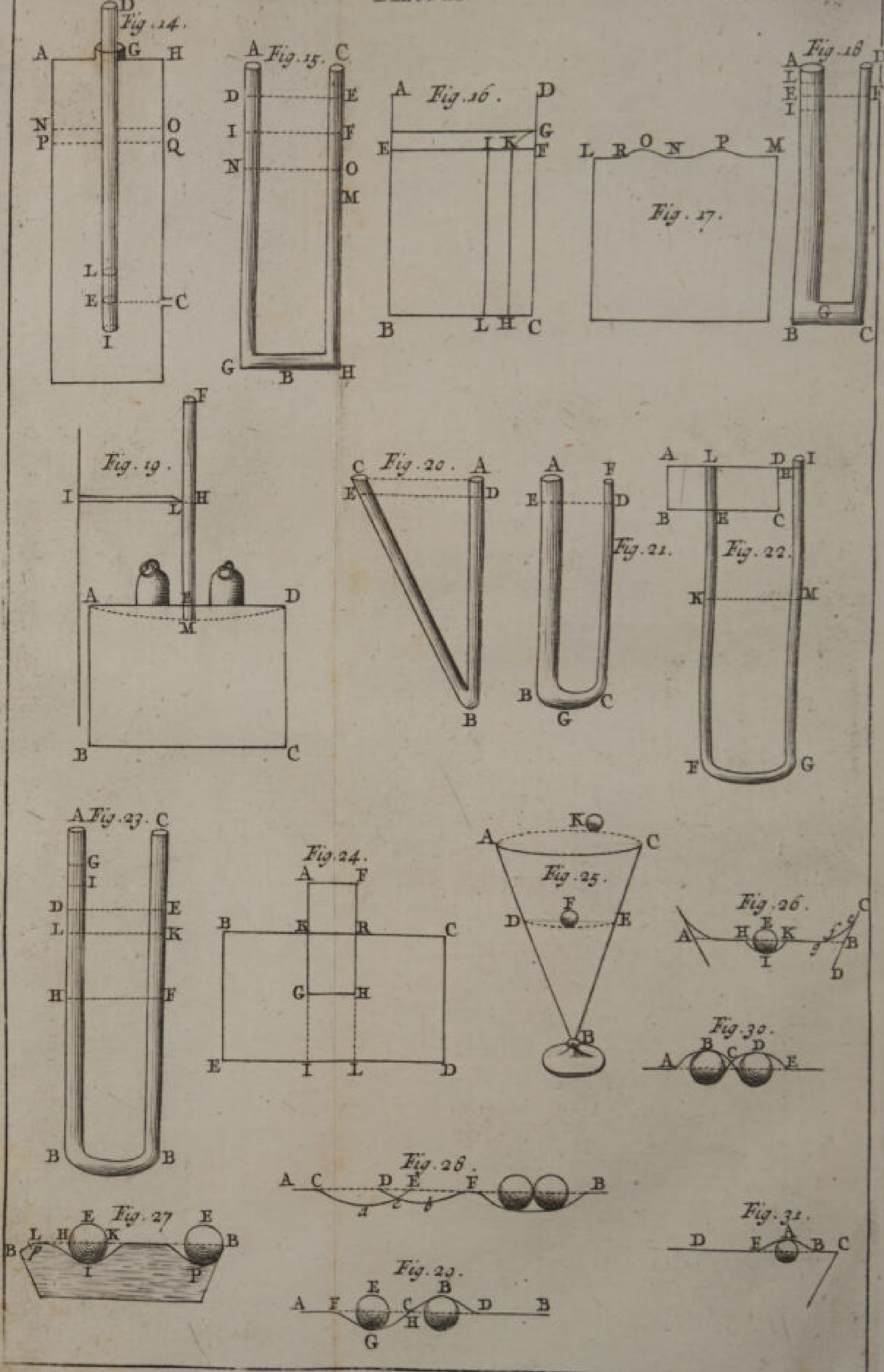
But if both the Balls in the foregoing Figure be wet, they will approach each other by reaſon of the Concavity betwixt them, and they will join for the ſame Reaſon that two Drops of Water unite and make but one. For the two Riſings of the Water B C, C D (*Fig.* 30.) are as two half Drops, which muſt join if they touch ever ſo little.

The ſame Reaſon makes two wet Balls join and go on together towards the Sides of the Glaſs when it is not full; for there is then the ſame Elevation of the Water, and when it is full, and the Water riſes above the Brims, the wet Ball is puſh'd from them after the ſame manner in which it is repell'd by a Ball that is not wet; for as it goes forwards towards the Side of the Glaſs C (*Fig.* 31.) the little Elevation of the Water A B raiſes that betwixt B and C ſomething higher, and then the whole Elevation has greater Force than the ſingle Elevation D F, which is but a Concave; and conſequently the Ball will be repell'd on the Side towards D, as appears by Experiment.

The Difficulty with which Water ſticks to Wax, is the Reaſon that ſometimes Bodies heavier than Water do not ſink to the Bottom; as if the little Cylinder E K be of *Lignum Vitæ*, or any other Wood heavier than Water, and be rubb'd over with Tallow, or cover'd with ſome Varniſh, to hinder the Water from ſticking to it, it will remain ſuſpended, and make a Dent in the Water as F G H K I L M; (*Fig.* 32.) For the Space of Air G F L M, which is below the Level A F M B having no Weight, the Base O P will be no more charg'd than C O which is equal to it, and you may even push the small Cylinder downwards a little way with your Finger, without its going to the Bottom, provided the Curves F G, M L be less in Depth than a Line and a half, for they may be two Lines long, and yet the Water not flow upon G L; but then there will be more Air at Top, and as soon as you take off your Finger, the Cylinder will rise up again, not because the Air draws it to it, but because the Columns of Water of each side, whose Bases are equal to P O, weigh more, and therefore make the Cylinder G L to rise. For the same Reason you may put a small Needle upon still Water, without its sinking it, if it be a little greasy or dry; but as soon as it is wet, the Water will stick to it, and no Dent being made to receive the Air, it will go to the Bottom.

It may be wonder'd why Ice goes to the Top of the Water; for one would imagine that being colder than flowing Water, it ought to be more condens'd, and consequently heavier; but you are to consider that there are always some Bubbles of Air interspers'd in Ice, as was explain'd in the first Part, and 'tis this Mixture of Air that makes it lighter: And tho' in some Parts of the Ice this Mixture is not visible, by reason of the Smallness of the Bubbles of Air, yet 'tis probable that there is always some little in it, and that this little join'd to the Ice, whose Condensation with respect to Water is not very considerable, may make a Compound heavier than Water.

Plate II. *fronting page 86.*



The ſame thing happens to Lead, Tallow, Wax, and ſome other Bodies of that kind; for when theſe Bodies are melted, they ſuſtain thoſe Parts that are not melted, which muſt proceed from there being ſeveral void Spaces always interſpers'd in thoſe Bodies as they begin to grow hard. If you cut a Bullet in the middle, you will find a conſiderable Void towards the Center. Tallow, when it congeals, becomes opaque from the little void Intervals that are in it, which hinder the Light from going on in a direct Line on account of the ſeveral Reflections and Refractions which it undergoes.

The Application of this Rule.

Take an empty Veſſel as A B C D (*Fig.* 33.) and put it into Water as F E I L contain'd in ſome other Veſſel, repreſented by G L I H keeping the empty Veſſel in ſuch an upright Poſition, that it may not overturn; as much Force is requiſite to hold part of it at a certain Depth below the Surface of the Water E F, as would be to ſuſtain in the Air the Weight M, which being put in the Bottom of the Veſſel A B C D would keep it in that Situation; the Sum of which Weight, together with that of the empty Veſſel, ought to be equal to the Weight of the Water whoſe Space is taken up by the immers'd Part of the Veſſel N O D C, as was before explain'd.

This Experiment may be applied to Ice which forms it ſelf in Rivers round Piles that ſuſtain Bridges, to judge whether if the River happens to ſwell by extraordinary Floods, the Ice which ſticks to the Piles can raiſe them up, and overthrow the Bridge. For, ſuppoſe the Ice to be a Foot thick, and that together with the Air with which it is fill'd, it weighs $\frac{1}{12}$ leſs than Water, a Calculation may eaſily be made to know what Weight will hinder it from riſing to the Top of the Water; for if its Surface be 400 Foot, it will then conſiſt of 400 Cubic Feet, every one of which will weigh 64 Pounds; whereas a Cubic Foot of Water will weigh 70, and the Product 6; the Difference betwixt 64 and 70 being multiplied by 400, gives 2400 Pounds: Now if the Weight of the Piles that ſupport the Bridge be above 2400, the Ice will not pluck up the Piles; for beſides their Weight, you muſt conſider, that the Reſiſtance of the Piles by their Friction againſt the ſolid Foundation in which they are fix'd, will likewiſe prevent them from being forc'd up.

If the Ice were only ſticking to the Piles at Top, and extremely long as A B, it might ſerve for a Leaver, (*Fig.* 34. having its fix'd Point upon the laſt Pile C D) to pluck up the Piles E F and G H; but the Portion of its Force is to be eſtimated only from half the Diſtance A B, becauſe every Part of the Ice acts only according to its own Diſtance from the fix'd Point D; but if there be Ice likewiſe on the other Side, and of the ſame Length, it will then act with all its Force: But as Bridges are commonly very heavy, they are rather born down by the continual Shock which they receive from great Flakes of Ice, which ſhake them by degrees, and by frequently daſhing againſt them at the Top of the Water, root them up; than by the Riſing of the Ice underneath which can't produce ſo great an Effect.

If a very light Body be put into Liquors of different ſpecific Gravity, its Part immers'd in the one, will be to its Part immers'd in the other, as the ſpeci-

ſpecific Gravity of one Liquor is to the ſpecific Gravity of the other.

For the ſame Reaſon Ships or Boats laden with Goods ought to ſink in Water, till a Bulk of Water equal to the immers'd Part, weighs as much as the whole Veſſel with its Burden; whence it has ſometimes happen'd, that a Ship coming out of the Sea into Rivers, has ſunk to the Bottom; becauſe the freſh Water being lighter than the Sea Water, the Weight of the Veſſel was greater than that of an equal Bulk of freſh Water equal to it; and in the Sea the Weight of the Veſſel was leſs than that of an equal Bulk of Water.

RULE 2.

Bodies lighter than Water being kept by Force at the Bottom of the Water, and afterwards let go, riſe to the Top of the Water in the following manner:

(*Fig.* 35.) A B C D is the Water contain'd in the Veſſel; E F G H is the Body whoſe Specifick Gravity is leſs than that of Water; now the Column K I G H weighs leſs than a Column of Water of equal Bulk as I H B D, and conſequently the Water near the Point H, betwixt H and D, is more preſs'd than that betwixt G and H, and will therefore inſinuate it ſelf, and get under the Body G H, and will puſh it upwards. The other Parts of the Water at the Bottom of the Veſſel which are at the ſame Depth as the loweſt Part of the Body, will have the ſame Effect to puſh it upwards; and as it gets higher, meeting with the ſame Diſpoſitions, it will continue to riſe till part of it be got above the Surface of the Water; and becauſe it will riſe with ſome Swiftneſs, it will paſs a little beyond the

the Place at which it ought to reſt; but then it will fall again a little below that Place, and at laſt after ſome Vibrations, will ſtand at the Place of its *Equilibrium*, according to the foregoing Rules.

But if there had been a Hole at the Bottom of the Veſſel as L, thro' which the Water ſhould run out, the Body F H would not riſe at all; for the Water which ought to puſh up the Body, deſcends thro' the whole, and by its viſcous Quality draws the Body to it; and being preſs'd above by the Column of Water K E I F, it will always remain at the Bottom of the Water till all be run out.

'Tis evident from what has been ſaid, that if A B C D (*Fig.* 36.) be a Veſſel full of Water, having an Hole at E, the Water which is on one Side, as at F, being preſs'd by all the Water above it, will be preſs'd by a greater Force towards the Hole, than that at the Point I, which is perpendicularly above the ſaid Hole. If the Point G be farther diſtant from the Point E than the Point F, you will ſee an Experiment of it, by letting fall into the Water a little piece of wet twiſted Paper, or ſome other little Body a little heavier than Water; for as ſoon as you have taken off your Finger which ſuſtain'd the Water at E, the Water running out will be followed by the Paper that was at F, which ſhews that the Parts of the Water next this little Body are puſh'd that way, as well as the other Parts neareſt the Hole, which are compriz'd within the Hemiſphere Q H I L N; thoſe that are neareſt of all, as at M or F, ſucceed thoſe that run out faſter than the more diſtant Parts, as H and L, and a great deal faſter than thoſe that are at G, or higher at O. The Experiment may be made by letting fall ſeveral little Bodies into the Water before you take off your Finger; for you will ſee that thoſe at H or L, (which

(which fell thither perpendicularly) will divert from their Courſe, and go along the Radii of the Hemiſphere H E and L E with a greater Velocity than the little Bodies of the ſame kind which are at O or G. The ſame Thing will happen if the Hole be made at P inſtead of E; for the little Bodies within the Hemiſphere K R S, will run out there as ſoon as you have taken off your Finger; for this Reaſon if you pierce an Hogſhead of Wine, an Inch above the Lees, and the Hole be pretty large, the neareſt Parts of the Lees will riſe, and running off with the reſt of the Wine make it thick and foul. When the Holes E or P are very ſmall, the Hemiſphere does not extend ſo far as when they are large.

RULE III.

Bodies whoſe Specific Gravity is greater than that of Water will ſink to the Bottom.

The EXPLANATION.

Let A be a Body heavier than Water, (*Fig.* 37.) it will fall after the ſame manner in Water as it would in Air, only not ſo faſt, the Water B immediately below the Body will be puſh'd downwards by it; which Water impelling that next below it, will puſh it on each ſide in a Circumference towards C and D, and all the Water in the Veſſel will be put in Motion, and when the Body is fallen as far as B, it will cauſe other *Vortices* to fill the Place, which it leaves till it touches the Bottom.

RULE IV.

Bodies whoſe Specific Gravity is greater than that of Water, loſe as much of their Weight in Water, as the Water gains whoſe Place they take up.

Suſpend

Suſpend the Body A B, in Water by the Cord C D, (*Fig.* 38.) and ſuppoſe that the Part E be taken out of the Inſide, ſo that the Remainder may weigh as much as the Water which would fill the Space A B, if the Body were remov'd; 'tis evident that it will then make an *Equilibrium* with an equal Bulk of Water on each Side; and conſequently that it will weigh nothing upon the Cord C D, no more than if you dipp'd it into the Water without the Body: Then if you imagine that the Part E, is replac'd in the Body A B, the whole will weigh upon C D, no more than the Weight of the Part E; from whence the Truth of the above-mention'd Propoſition is fairly deduc'd. Hence may be found a Method of knowing the Specific Gravity of all Bodies heavier than Water, as well with reſpect to Water, as other Bodies; for Example, let the Body A B be Gold, you muſt weigh it in Water with a Balance, fixing it to one of the Scales by a little a String, and putting an equal Weight in the other Scale, and then letting it wholly immerge in Water; now if to continue the *Equilibrium* in the Water, you are obliged to take away $\frac{1}{18}$ of that Weight that made an *Equilibrium* with it in the Air, you will know that the Specific Gravity of Gold is to that of Water as 18 to 1; and if the Body be of Lead, and you are to take away $\frac{1}{11}$ of the Weight which made an *Equilibrium* with it in Air, you will know that the Specific Gravity of Water with reſpect to Lead is as 1 to 11; and likewiſe that that of Gold to Lead is as 18 to 11; thence you may diſtinguiſh, whether a Piece of Gold be good or bad, without making any Alteration in it; for if by an Experiment of this kind, you find that it loſes one 12th or 14th of its Weight in Water, you may conclude that there's a pretty large Quantity of of other Metals mix'd with it, as a Third, or perhaps One half of the whole, and therefore that 'tis bad; but if it loſes but one 17th, you may take it for good, becauſe there will be very little Mixture in it. If you hang a great Cylinder of Glaſs or Metal by a Cord in a Bucket, in ſuch manner that it may almoſt fill the Bucket without touching either the Sides or the Bottom, and afterwards pour in Water, to fill the void Spaces up to the Heighth of the Cylinder; then he that eaſily ſupported the Bucket before the Water was pour'd into it, will ſcarce be able to bear it; for it will weigh as much as if the Cylinder were taken away, and it were full of Water as high as the Cylinder; and he that held the Cord will be eas'd of as much Weight, as that of the Water would be whoſe Space is taken up by the Cylinder: The Reaſon is, becauſe it is then ſubject to the ſame Rules as Bodies ſuſtain'd in Water, which loſe as much of their Weight as the Weight of a Bulk of Water equal to the Space which they take up; and conſequently he that held the Cord muſt perceive himſelf eas'd of a Weight equal to that of a Quantity of Water of the ſame Bulk as the Cylinder, and he that held his Hand under the Bucket muſt bear as much Weight, as the other was eas'd of, beſides the little Addition of the Water that was pour'd in.

Sometimes Bodies lighter than Water ſink to the Bottom, for a Reaſon very eaſily explain'd; of which you have the following Experiment. Take a Cylindrical Glaſs 7 or 8 Inches in Height, and 3 or 4 in Breadth, as A BCD (*Fig.* 39.) which in the Middle of the Baſe has an Hole, as E, about 3 Lines in Diameter; ſtop the Hole with your Finger, and then having fill'd the Glaſs with Water, put a Ball of Wax as F on the Top of it, ſmall enough to paſs thro' the Hole at E, and when the Water is ſtill and at reſt, take off your Finger, and let the Water run out; the Wax will deſcend as the Surface of the Water does, and go out at E with the laſt Water. But if you give the Water a great Circular Motion, either by ſhaking it againſt the Sides of the Glaſs, or otherwiſe, when you take off your Finger from the Hole, you will ſee the Ball immediately deſcend as ſoon as the Water begins to run out, and there will be a void Space in the Middle of the Water, into which the Air will inſinuate it ſelf, as from H to E; which Void will not be fill'd up till all the Water be run off, and you will ſee all the Time as it were a twiſted Column of Air from the Top of the Water down to the Aperture at E.

This Effect is thus explain'd. The Water in the Hemiſphere CILMD is puſh'd towards E, when the Water is ſtill, without any conſiderable Motion, as was before prov'd, and it ſucceeds the Water that runs out, before that towards H can fall ſo low; but when the Water has a great Circular Motion, the lateral Parts towards M and I, or *r* and *ſ* can't get to E till after 4 or 5 Spiral Turns, and are even carried towards the Sides of the Glaſs, becauſe they are puſhed along the Tangents of the Circles which they deſcribe; whence it happens that the entire Column FE falls down to the Hole immediately, and paſſes thro' it, together with the little Ball of Wax at the Top of it; and becauſe the Water on each Side of this Column that ran out can't fill up its Place faſt enough, by reaſon of its Circular Motion, whoſe Direction is not that Way, the external Air muſt neceſſarily inſinuate it ſelf by its Weight and Spring, and remain there till all the Water be run out.

It ſometimes happens that the Ball of Wax does not lye directly upon the Column, and then it is carried a little on one Side within the Water; nay, if it returns towards the Middle, the Air by its Spring repells it towards the Sides of the Glaſs; but at laſt it gets into the empty Column, and turning round with great Swiftneſs, paſſes on thro' the Hole before half the Water be run out.

For the ſame Reaſons, if there be a large Hole or Paſſage under the Bottom of any deep Water, whether in a River or the Sea, thro' which the Water may flow down to ſome lower and more diſtant Receptacle, as, they ſay, the *Caſpian Sea* empties it ſelf into the *Euxine*, the Water will draw in the Ships that paſs over this Whirl-Pool; for the Water falling there in an inclin'd Direction, takes a Circular Motion, and has the ſame Effect with reſpect to the Ships that paſs over it, as the Water that turns round in the Glaſs A B C D has with reſpect to the Ball of Wax. 'Tis reported likewiſe, that in ſome Sea near *Sweden*, there is ſuch a Whirl-Pool as I have deſcrib'd, and that the broken Remains of Ships have been ſeen in a Sea not far diſtant, which is lower. 'Tis eaſy to conceive that the Water will be a longer Time in running off thro' the Hole E, when it turns round, than when it does not, becauſe in the firſt Caſe the Air takes up ſome Part of the Hole.

DISCOURSE II.

Of the Equilibrium *of Fluids by their* Spring.

AIR and Flame acting by their Spring make an *Equilibrium* with other Bodies. The Spring of the Air is evident from ſeveral Experiments, both in Barometers where it is very much dilated, and in Wind-Guns where it is extremely condenſed; but theſe Dilatations and Condenſations are not eaſily explain'd. To give you ſome Idea of them, you muſt conſider the whole Extent of the Air from Top to Bottom as a great Heap of Spunges or Balls of Cotton, the higheſt of which have their natural Extent; but the lower being preſs'd by the Weight of thoſe above them, will be reduc'd to a very ſmall Compaſs; and when diſcharg'd of that Preſſure, will return to their former Dilatation.

According to this Hypotheſis, you may ſay, that the Air here below makes an *Equilibrium* by its Spring, with the Weight of all the reſt of the Air by which it is preſs'd; ſo that if this upper Air ſhould become heavier, or there ſhould happen to be more of it, the lower Air would be a little more condens'd than it is; and if the upper Air ſhould become leſs heavy, or there ſhould be leſs of it, the lower would be more dilated. The Spring of the Air may likewiſe be compared to a Steel Spring, which

which is more preſs'd down and contracted when a greater Weight is laid upon it, and again opens and extends it ſelf, when ſome Part of the Weight is taken off; and as it may be ſaid, that a Steel Spring being preſs'd and reduc'd to a certain Figure by a Weight lying upon it, in this Situation makes an *Equilibrium* with that Weight; ſo in like manner one may ſay, that the Air in its condens'd State here below, makes an *Equilibrium* by its Spring with the whole Weight of the Atmoſphere.

Many Experiments ſhew, that Air is condens'd in Proportion to the Weight by which it is compreſs'd: The following one is very eaſy. Take a bended Tube of Glaſs as A B C (*Fig.* 40.) clos'd at the End C, and open at the other; pour in a little *Mercury* up to the Horizontal Height D E, that the Air enclos'd within the Space C E may expand it ſelf neither leſs nor more than the Air in the other Leg of the Tube; for if the Quickſilver were a little higher in one Leg than in the other, the Air would be leſs preſs'd in one than in the other. The Height E C muſt be moderate, not above 12 Inches, as is ſuppoſed in this Figure; and the other D A, as long as you can well have it. The *Mercury* then being on both Sides of an equal Height towards D and E; and there being no farther Communication in the Air in E C, with that in D A, pour in ſome more *Mercury* thro' a little Funnel at the End A, but take care that no more Air gets into the Space E C; you will perceive that the *Mercury* will riſe by degrees towards C, and will condenſe the Air that was in C E; and if E F be ſix Inches high, and F G an horizontal Line, the *Mercury* will have riſen in the other Leg as high as H, if this Point be 28 Inches diſtant from the Point G, and he *Mercury* in common Barometers be then at the

Height of 28 Inches in the Place where you make your Obſervation; for if it be but at 27 and a half, the Space G H will be no more than 27 Inches and a half: Now in this State the Air in F C is preſs'd by the Weight of the Atmoſphere, ſuppoſed to be equal to the Weight of 28 Inches of *Mercury*, beſides the 28 Inches in the Space G H; and conſequently it is preſs'd by a Weight double to that by which the Air is preſs'd that is in the Place where the Experiment is made, and which is of the ſame Tenour that the Air in E C was, before it was condens'd by the Weight of the *Mercury* G H. You ſee then plainly by this Experiment, that the Air in E C is condens'd in Proportion to the Weight by which it was preſs'd; you will find the ſame Proportion in the other Experiments, by making the Calculation after this manner: For your Firſt Term, you muſt take the Sum of the Weight of the Atmoſphere, and of the *Mercury* that roſe above the loweſt Level of the Air in the Leg D A: For the Second Term, the Weight of the Atmoſphere, that is to ſay, 28 Inches of *Mercury*: For the Third, the Diſtance E C; and the Fourth Proportional, will be the Space or Height to which the Air encloſ'd in the Tube E C, will be reduc'd. As if the Air were reduc'd only to the Space I C of 8 Inches, the *Mercury* in the other Tube would be only 14 Inches higher than the Horizontal Line I L. Now theſe 14 Inches added to 28, the Weight of the Atmoſphere, make 42; you muſt ſay then according to this Rule, As 42 Inches to 28: So is the Extent of the Air E C to the Space I C. And if you would reduce this ſame Air to M C, a Space of 3 Inches, which is $\frac{1}{4}$ of E C, you muſt put 84 Inches of *Mercury* into the Tube D A above the Horizontal Line M N; and this Proportion may be found

found by the following Calculation: As M C, or 3 Inches is to M E, or 9 Inches; so is 28 the Weight of the Atmosphere to 84; for if you convert the Terms, 84 will be to 28, as 9 to 3, and by Composition 84 + 28, that is to say, 112 will be to 28, as 9 + 3, that is to say, as E C or 12 is to 3; and if you would know what Height the Tube must be of to reduce the Air to O C, or the Space of one Inch, you must say, As O C 1 Inch, is to O E 11 Inches; so is 28 the Weight of the Atmosphere to 308; and 308 will be the vertical Height which must be given to the *Mercury* above the Height O or P; whence you may conclude, that to make this Experiment, the Tube D A must be above 308 Inches high, that is to say, it must about 320, that there may remain a little Space above the *Mercury*, to hinder it from running over.

The same thing will happen, whether the Leg E C be much wider or much narrower than the Leg D A; for if you pour in *Mercury* till it rises in C E up to the Height G F, G H the Height of the *Mercury* in the other Leg must be 28 Inches (*Fig.* 41.); for as the *Mercury* D G makes an *Equilibrium* with the *Mercury* E F, tho' there be a much greater Quantity of it, as has been already prov'd with respect to Water; so the Spring of the Air F C will make an *Equilibrium* with the *Mercury* G H, because it would sustain it, if G H were of the same Bore as F C; and consequently it has the same Effect as if the Leg E C were as long as the other, and the *Mercury* contain'd in it were as high as H. I made the following Experiments concerning it. Having pour'd *Mercury* into the Tube till it arose up to L, which was one Third of the Space E C, I found it to rise 13 Inches $\frac{3}{4}$ above I L in the other Leg; and when I had fill'd till the *Mercury* came up to E F, half the Space of E C, I found it to be 27 Inches and $\frac{1}{2}$ above G F, and having fill'd it to 44 Inches and $\frac{1}{2}$ above N M, M C was found to consist of 3 Parts $\frac{4}{5}$ and a little more of the whole Space E C, divided into 10 of those Parts, which still makes the same Proportion; for the Barometers were then at 27 Inches $\frac{1}{2}$: For the same Reasons, if the Leg E C were much narrower than the other, the Air enclos'd in it would by its Spring make the same *Equilibriums* with the *Mercury* in the other Leg. You will see the same Proportions when the Air is more rarified than that in the Place where the Experiment is made; which may be demonstrated after this manner.

Take a Barometer, as A B, (*Fig* 42.) of what Length you please; for Example, 38 Inches long; make a Mark in it at a certain Point, as Z, an Inch above the open End B; that this End being dipp'd in the *Mercury* of the little Vessel C D E up to the Mark, there may remain 37 Inches above it. Fill the Tube with *Mercury*, and leave in it 9 Inches of Air, that when the Tube is inverted, as you see in the Figure, and sustain'd with your Finger, there may be 9 Inches of Air at the Top of the Tube; then if you dip your Finger, together with the End of the Tube, into the little Vessel of *Mercury*, and afterwards take off your Finger, the *Mercury* will descend, and after some Vibrations, rest when the Air is extended to 21 Inches; which it must do, to preserve the Proportion betwixt the Weights and the Condensations, before explain'd: Which may be thus prov'd.

The DEMONSTRATION.

Let the Tube A B (*Fig*. 42) be 38 Inches, and Z B 1 Inch; A H, the Air enclos'd above the *Mercury* H B, (sustain'd by the Finger at B) of what Extent you please. I say, first, if you take away

your

your Finger, the *Mercury* will deſcend; foraſmuch as the Air A H is condens'd equally with that in the Place where the Experiment is made, it ought by its Spring to make an *Equilibrium* with the Weight of the whole Atmoſphere, as has been already prov'd; and being added to the Weight of the *Mercury* in the Space Z H, theſe two Powers together will overbalance the Weight of the Atmoſphere, and the Air A H muſt neceſſarily expand it ſelf, and part of the *Mercury* fall down, but it will not fall entirely; for if it did, the Air A H would be too much dilated, and in that State could no longer make an *Equilibrium* with the Weight of the Atmoſphere; whence it follows, that ſome Part of the *Mercury* muſt remain in the Tube. I ſay, Secondly, That if A H be 9 Inches, it will expand it ſelf, and puſh back the *Mercury*; ſo that it will remain at the Height of 16 Inches above the upper Surface of the *Mercury* F Z G; let Z L be the Meaſure of this Elevation. Now then there will be an *Equilibrium* betwixt the Weight of the whole Column of the Air of the Atmoſphere, and the Spring of the expanded Air A L, join'd to the Weight of the 16 Inches of *Mercury* Z L; and becauſe the Complement of 16 to 28, is 12, the expanded Air A L by its Spring will make an *Equilibrium* with the Weight of 12 Inches of *Mercury*; which added to 16 Inches, are equal to the Weight of the Atmoſphere. But as 28 is to 12, ſo is A L or 21 Inches to 9; whence it follows, that the *Mercury* ought to reſt 16 Inches above the Mark Z, when 9 Inches of Air are left in the Tube above the *Mercury*; becauſe the Air is condens'd in Proportion to the Weight by which it is preſs'd. But if the *Mercury* in another Experiment ſhould be at the Height of 21 Inches, you may judge according to the ſame Rule, that ſince these 21 Inches of *Mercury* make an *Equilibrium* with ¾ of the Weight of the Atmosphere, the remaining fourth Part equivalent to 7 Inches, will be sustain'd by the Spring of the rarified Air enclos'd in the Tube, according to the Distinction of the *Equilibrium* of Springs. Now 28 Inches of *Mercury*, the entire Weight of the Atmosphere, is to 7 Inches, as 16 Inches of expanded Air is to 4 Inches of common Air; whence you conclude, that 4 Inches of Air must be left in the Tube above the *Mercury*, that the *Mercury* may be at the Height of 21 Inches, and the Air expand it self to 16. But if you would reduce the *Mercury* in the same Tube to 14 Inches, (which is half the Weight of the Atmosphere) above the Mark Z, you must consider that there will remain 23 Inches up to A, and that the Air expanded to the Space of 25 Inches ought by its Spring to make an *Equilibrium*, with the remaining Half of the Weight of the Atmosphere. You must say then, That as 28 is to 14, the Complement of 14 to 28, so is 23 the expanded Air that fill'd the Tube above the 14 Inches to 11 ½, which shews that 11 Inches and a half of Air must be left above the *Mercury* in a Tube of 38 Inches for the Experiment; and it plainly appears, that the Spring of the enclos'd Air then making an *Equilibrium* only with half the Weight of the Atmosphere, since the 14 Inches of *Mercury* make an *Equilibrium* with the other half, the Air is rarified in a double Proportion; and by all these Experiments, you may judge (making use of the Rule before explain'd) what Quantity of Air must be left in a Tube, great or small, to make the *Mercury* rest at such a Height as you please. For tho' the Tube were only 6 Inches above the Mark Z, you will find the same Proportions, by calculating after the same manner. As for Example;

If

If 2 Inches be the given Height of the *Mercury*, and you have found that as 28 is to 26, the Complement of 2 to 28, ſo is 4 the Space of the expanded Air above the two Inches of *Mercury* to 3 $\frac{5}{7}$; 3 Inches $\frac{5}{7}$ will be the Quantity of Air that muſt be left in the Tube, that the *Mercury* may reſt at two Inches Height, in a Tube of 7 Inches immers'd an Inch in a Veſſel of *Mercury*.

If the Quantity of the encloſ'd Air in the Tube be given, and you would know at what Height the *Mercury* will remain after the Experiment, you muſt make uſe of an Algebraic Calculation, applying thereto the ſame Rules, as I have taught in my Eſſay upon Logick, and my Treatiſe upon the Nature of Air.

You will find the ſame *Equilibrium* from the Spring of the Air in Tubes full of Water and Air, ſuppoſing that the greateſt Weight of the Atmoſphere is equal to 31 Foot of Water, which is found true by Experience; for the common Barometer being at 27 Inches 8 Lines, the Water-Barometer was at 31 Foot 1 Inch; and when the former was at 28 Inches, this latter was at 31 Foot 4 Inches; and if the other had been at 28 Inches 7 Lines, as it is ſometimes, the Water would have been at 32 Foot. If the Tube be 40 Foot long, and you would reduce the Water to 16 Foot, you muſt put 12 Foot of Air above the Water; for the Air expanding it ſelf to twice the Space, and taking up 24 Foot, it will make an *Equilibrium* by its Spring with half the Weight of the Atmoſphere; and the 16 Foot of Water that remain, will make an *Equilibrium* with the other half. We ſuppoſe that a ſmall Part of the Tube being immers'd in the Water, to make the Experiment the ſame as that of the *Mercury*, there will remain 40 Foot above the immers'd Part.

Hence you see plainly, that if you immerge an inverted Bottle full of Air, into a very deep Water, hanging a Weight about its Neck sufficient to sink it to the Bottom, whilst it gradually descends, the Water will get into it, and rise by degrees into the Neck; and when it is sunk to a Depth of 32 Foot, the Water that is got into it will reduce the Air to half the Extent that it had in the Bottle before its Immersion; which I have explain'd more at large in my Essay upon the Nature of Air.

You see farther the Error of those that imagine, that Water may be made to rise 32 Foot in a Pump, by drawing it with a Piston above it, since according to the Stroke of the Piston, you can only raise it to a certain determinate Height. For Example; Let there be a smooth Pump-Barrel of 20 Foot, having above the 20 Foot a Piston of the same bigness, which can neither rise nor fall above the Space of a Foot; I say, that if there be a Valve or Clack at the Bottom of the Pump, and you play the Piston, the Water can't rise 12 Foot. For let it rise 11 Foot, if it be possible, or pour Water upon the Clack to the Height of 11 Foot, and refit the Piston, there will remain 9 Foot of Air up to the Piston; and this Air, which will be rarified by raising the Piston a Foot, can only be rarified according to the Proportion of 9 to 10; and because 21, the Complement of 11 Foot to 32, which is the Weight of the Atmosphere, is to 32 as 9 to $13\frac{5}{7}$, to sustain the Water at 11 Foot, the Piston must be raised 4 Foot $\frac{5}{7}$ to make the *Equilibrium* betwixt the Weight of the Atmosphere, and the diminish'd Spring of the Air enclos'd, join'd to the Weight of 11 Foot of Water, as was before explain'd; whence it follows, that if the Piſton be raiſed only a Foot, the Clack will not open at all, nor the Water riſe above 11 Foot.

To give Rules for the riſing of Water in Pumps, make uſe of an Algebraic Calculation in this Manner. We will call A the Height to which the Water ought to riſe in the Barrel of the Pump from the Stroke of the Piſton, abſtracting from the Weight of the Clack. Let the Barrel be 12 Foot above the Surface of the Water that you would raiſe; and ſuppoſe that you have a Mind to raiſe it to this Height of 12 Foot by one Stroke of the Piſton, you muſt make this Analogy: As 20, the Complement of 12 Foot to 32, is to 32; ſo is 12 Foot of common Air to a 4th Proportional; this 4th Proportional will be 19 $\frac{1}{5}$, which ſhews that the Barrel of the Pump muſt be pretty long to raiſe the Piſton 19 Foot $\frac{1}{5}$ above the 12 Foot, in order to raiſe the Water 12 Foot by only one Stroke of the Piſton; but if the Play or Stroke of the Piſton were limited to 2 Foot, you muſt ſay; As 32 — A is to 32, ſo is 12 — A to 14 — A. The firſt Term is the Complement of the unknown Height to which the Water will riſe, to 32 Foot of Water; which is the Weight of the Atmoſphere: The third Term is the 12 Foot *minus* that Height, and the fourth is the 2 Foot that the Piſton riſes, join'd to 12 Foot *minus* the ſame Height. Now the Product of 14 — A, by 32 — A, is 448 — 46 A + A A, and the Product of the two middle Terms is 384 — 32 A; the Equation being reduc'd, there will be an Equality betwixt A A and 14 A — 64; and becauſe 64 cannot be taken from 49 the Square of 7, which is half the Roots, 'tis a ſign that in continuing to pump, at ſeveral times you may raiſe the Water up to the Piſton; and to know how far it will riſe the firſt Stroke,

you

you muſt ſuppoſe, that the Piſton is riſen 2 Foot; there will then be an uniform Barrel of 14 Foot; and according to the Rules laid down in my Eſſay upon Logick, and my Treatiſe of the Nature of Air, make this Calculation. The encloſ'd Air was 12 Foot; 12 Foot + A is to A, as 32 to 2 + A; the Equation being reduc'd, you will find that A A will be equal to 24 + 42 A; and, at laſt, that the Value of the Root will be a little leſs than $\frac{4}{7}$; which being taken from 2, there will remain 1 $\frac{3}{7}$ and a little more; and conſequently the Water will by the firſt Stroke of the Piſton riſe but one Foot $\frac{3}{7}$ and a little more.

If you had ſuppoſ'd the Play of the Piſton to be one Foot, you might know by the ſame Calculation how high the Water would riſe by the firſt Stroke of the Piſton; and if you would know to what Height it may riſe after ſeveral Strokes, you muſt ſay, As 32 + A is to 32, ſo 12 + A is to 13 + A; the Equation being reduc'd, you will find 13 A — 32 equal to A A. The Square of 6 $\frac{1}{2}$ the Half of the Roots is 42 $\frac{1}{4}$; from which ſubſtracting 32, there remains 10 $\frac{1}{4}$, the Root of which is 3 $\frac{5}{24}$ a little leſs: Take that from 6 $\frac{1}{2}$, and there remains 3 and $\frac{7}{24}$; add that to 6 $\frac{1}{2}$, and it will make 9 $\frac{19}{24}$; and theſe Numbers 3 $\frac{7}{24}$ and $\frac{19}{24}$ will be the two Roots; which ſhews that the Water can never riſe when the Barrel is empty, above 3 Foot $\frac{7}{24}$ and a little more, tho' you play the Piſton as long as you pleaſe; but if you had fill'd the Barrel 9 Foot $\frac{18}{24}$, you might make the Water riſe 12 Foot compleat by ſeveral Strokes of the Piſton.

Let us ſuppoſe now that the Barrel is 14 Foot up to the Piſton, and that the Stroke of the Piſton is 2 Foot; 32 — A will be to 32, as 14 + A to 16 — A. To find the Equation eaſily, you muſt

muſt multiply 32 by 2, the Difference of 14 and 16: The Product is 64 for the abſolute Number, and that of 16 A will be the Number of the Roots, and A A will be equal to 16 A — 64; the Square of half the Roots is 64, from whence ſubſtracting 64, there remains 0, whoſe Root is 0, which being taken from and added to 8, ſtill makes 8; which ſhews that there is but one Root, and that the Water can't riſe above 8 Foot; but if you make the Piſton play ever ſo little higher than two Foot, the Water will riſe 14 Foot. The Analogy is eaſy; for the Piſton being rais'd 2 Foot, the Barrel will be 16 Foot, and that Water being at 8 Foot, there will remain 6 Foot of Air; but 32 is to 24 the Complement of 8 Foot to 32, as 8 Foot of rarified Air to 6 Foot of common Air; then the Water will riſe no higher than 8 Foot, if the Piſton plays but 2 Foot.

Thence you ſee, that to draw up Water to a conſiderable Height, as 20 Foot, the Breadth of the Pump-Barrel muſt be diminiſh'd, and a ſufficient Space muſt be allow'd for the Stroke of the Piſton; for, ſuppoſing that the Surface of the Piſton be 4 times broader than the Baſe of the Barrel, the riſing of the Piſton 1 Foot will have the ſame Effect as if it roſe 4, if the Diameter of the Piſton were only equal to that of the Barrel; if then the Stroke be a Foot and a half, it will be the ſame as if it roſe 6 Foot, and were of the ſame Breadth: Now the 4 Terms of Equation being 32 — A; 32, 20 — A, 26 — A, there will be 6 times 32, *viz.* 192 for one Term of the Equation, and 26 A for the other, according to what has been ſaid; there will be then A A equal to 26 A — 192; the Square of half the Roots is 169 leſs than 192; and

and consequently if you pump a long Time, you may raise the Water 20 Foot.

If in the Example above-mention'd, you take 8 Foot for the highest Term of the Water, when the Barrel is 14 Foot, and the Stroke of the Piston 2 Foot, 'tis easy to prove, that if you suppose 9 Foot of Water upon the Clack, it will continue to rise by the playing of the Piston 2 Foot; for there will remain 5 Foot of Air. Now there is a less Proportion betwixt 5 and 7, than there is betwixt 27, the Complement of 5 to 32, and 32, and consequently the Water will rise higher than 9 Foot. The Proportion will still be more unequal, if you take 10 or 11 Foot; and if you take 7 instead of 8 Foot, the Water will still rise, for there will remain 7 Foot of Air; now 25, the Complement of 7 to 32, is to 32 as 7 to 8 $\frac{24}{25}$; then if the Piston goes 2 Foot, it will raise the Water higher than 7 Foot; it will rise still more easily, if you pour in only 6 Foot of Water; for there will be 8 Foot of Air. Now the Complement 26 is to 32 as 8 to 9 $\frac{22}{26}$; then if instead of 9 $\frac{22}{26}$ which makes the *Equilibrium*, the Piston goes 10 Foot, it will make the Water rise still better than when it was at 7 Foot; and better still when it is at 5 Foot, *&c.* If you would know what Play the Piston must have to raise the Water 20 Foot, you must take a Number a little greater than the half of 30, as 16, at which Point pretty near the Water will rise with the greatest Difficulty; the Complement is 16, the Remainder of Air is 14; as 16 is to 32, so is 14 to 28. The Piston then must rise 14 Foot; or if the Barrel be 2 Inches Diameter, the Piston must be 7 Inches $\frac{1}{2}$; for the Square of 7 $\frac{1}{2}$ is 56 $\frac{1}{4}$, which is a little more than 14 times 4 the Square of 2 Inches; and then it will be sufficient that the Stroke of the Piston be

one

one Foot; but as it is ſtill more difficult at an Elevation of 18 Foot, the Piſton muſt be 8 Inches Diameter to raiſe the Water above 18 Foot, when its Stroke is but one Foot. By the ſame Force of the Air's Spring may be eaſily explain'd the following Experiment, which is pretty curious.

Take a Tube about 12 or 15 Lines in Diameter, clos'd at the Bottom as A G (*vid. Fig.* 43.) but ſomething narrower towards A, that you may ſtop it exactly with your Thumb; fill it with Water, and put therein a ſmall Figure of Glaſs or hollow Copper, that has a ſmall Pin-hole in it, as at D, ſo that Air and Water may get into it; and let its Gravity with reſpect to Water be ſo well proportion'd, that if you add a little Weight to it, it will ſink to the Bottom, and if you take it away, it will ſwim in the Tube like Wax. Apply your Thumb to the open End A, and preſs it ſtrongly, the little Figure will deſcend as far as B, or lower; nay, even to the Bottom; take away your Thumb, and it will riſe again; and if, after it has riſen as far as E or C, you put your Thumb on again, it will again begin to deſcend. The Cauſe of theſe Effects is this; When you preſs the Water with your Thumb, you preſs likewiſe the Air that is in the Figure, and condenſe it, tho' you do not condenſe the Water; and conſequently you force ſome Water into the Figure at the little Hole at D, which makes its Specific Gravity then greater than that of the Water, and therefore it deſcends; but when you take off your Thumb, the enclos'd Air puſhes out the Water thro' this ſame Hole by virtue of its Spring that is ſet at Liberty; and being expanded as before, (the Figure with the Water and the enclos'd Air regaining their former Diſpoſition) it reaſcends. But if you take off your Thumb ſuddenly, a little Air will ruſh out with the Water, and both of them by their

Impulſe

Impulſe againſt the Water in the Tube, will make the Figure whirl about. It ſometimes happens, that too much Air gets out of the Figure, and when it is got to the Bottom, it can't riſe again, tho' you do take off your Thumb; in this Caſe you muſt ſink your Thumb pretty far in the Tube, and draw it back, ſo that it may fill the Mouth of the Tube exactly, that the external Air may not get in in the Place of your Thumb; the Air in the Figure being then leſs preſs'd, will expand it ſelf more than it commonly does, and force out more of the Water that was in the little Figure; which will make it lighter and raiſe it up, provided you keep your Thumb ſtill in the Tube, and do not withdraw it entirely. Sometimes the Weight of the Figure and of the Air encloſ'd in it, is ſo well proportion'd to the Specific Gravity of the Water, that by putting your Thumb upon A, the Figure will deſcend as to F, and taking away your Thumb again, the Figure will reaſcend; but if you let it ſink as far as B, and then take away your Thumb, it will continue to ſink, becauſe the Weight of the Water A C does not preſs enough upon the Air in the little Image, to force into it a Quantity of Water ſufficient to make it of a Specific Gravity equal to that of Water; and the Preſſure of the Water A B upon the Air is ſufficient for this Effect; which cauſes it to ſink to the Bottom, where the Weight of the Water being ſtill greater, the Air in the little Figure is more condens'd, and more Water is forc'd into it; whence proceeds its riſing again with greater Difficulty. Hence you ſee the Error of thoſe who imagine that Water and Air don't weigh upon Bodies below them; and they judge ſo, becauſe we are not ſenſible of the Weight of the Air. But it ought to be conſider'd, that our Bodies are natu-

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rally diſpoſed to bear this Preſſure of the Air, ſuch as it is here below; wherefore we ſuffer no Inconvenience from it. But if we were carried up to an Air twice as much rarified, the Aerial Matter in our Blood and other Parts of the Body that are very hot, would turn to Air, and make ſuch Bubblings as would inflate and ſwell up our Bodies, and prove very inconvenient. You ſee an Experiment of it, by putting a Bird in an Air-Pump; for when the Air is reduc'd to a Rarefaction twice or thrice greater than that which it commonly has near the Earth, the Bird dies in a ſhort Time, becauſe its Blood being hot, and no longer preſs'd by the common Spring of the Air, it throws out a great many Bubbles, juſt as hot Water does, which is for ſome time enclos'd in the Air-Pump. But on the contrary, if we were in an Air doubly condens'd, we ſhould ſuffer very much from it, tho' we ſhould ſcarce be ſenſible of its Preſſure; becauſe if on one Side it preſs'd upon the Breaſt to hinder Reſpiration, on the other Side the Spring of the Air, that would get into it by Reſpiration, would prevent the Action of the external Air; whence it follows, that thoſe that go 7 or 8 Foot under Water, can't feel any ſenſible Weight, becauſe it preſſes upon them equally on all Sides, and the Weight of the Atmoſphere being equal to 32 Foot of Water, the Addition of theſe 8 Feet augments the Preſſure but about $\frac{1}{5}$, which can't be very ſenſible. Some object againſt theſe Arguments and Effects of the Spring of the Air, that when a Tube open at both Ends is made uſe of in the Experiment of the Air enclos'd above the *Mercury*, and any one ſtops the upper End of the Tube with his Finger, to prevent the Communication of the outward Air with that enclos'd, when the Experiment is made, it ſeems to him that ſtops the

the upper End, that his Finger is ſuck'd or drawn in by the deſcending *Mercury*, and he even feels ſome Pain as if he were pinch'd; whence they conclude, that the expanded Air in the Tube does not act by its Spring to ſuſtain a Part of the Atmoſphere, becauſe it would preſs againſt the Finger, and repell it rather than attract it. To clear this Difficulty, you muſt conſider, that when a wither'd Apple, or ſome ſuch Body, is put into an Air-Pump, after you have pump'd out a great Part of the Air, the Body ſwells and expands it ſelf; and if your Finger were enclos'd therein by means of a Bladder cut at both Ends, or any other way, that Part of your Finger would ſwell extremely, and you would feel a great deal of Pain; whence it follows, that that Part of the Finger which ſtops the upper End of the Barometer-Tube, being contiguous to Air that's very much rarify'd, and the reſt being preſs'd by the whole Weight of the Atmoſphere, this ſmall Part muſt ſwell, and make a great Convexity towards the Inſide of the Tube, which it can't do without Pain; and the more the Air is rarify'd in the Tube, the more this Swelling and Pain are ſenſible, and the weak Endeavour of this rarify'd Air to repell the Finger, will not be ſdfficient to hinder it from ſwelling, ſince that Part of it that's expos'd to the open Air will be much more preſs'd.

It may ſtill be objected, that when there are 28 Inches of *Mercury* ſuſpended in the Tube, if you raiſe it with your Hand, without taking it out of the ſtagnant *Mercury*, the Veſſel is charg'd with a Weight equal to that of the enclos'd *Mercury*, which it ought not to be, if it made an *Equilibrium* with the Weight of the Atmoſphere. This Difficulty is anſwered, by ſaying, that the ſuperior Air which is above the Tube has then no other Air to

make

make an *Equilibrium* with it; for that which ought to ſuſtain it below the Tube, ſuſtains the *Mercury* which is in the Tube; then you muſt ſuſtain all the Weight of the ſuperior Air that weighs 28 Inches of *Mercury*; and if the Tube were only 14 Inches long, and the *Mercury* were up to the Top of it, then you would only feel the Weight of 14 Inches of *Mercury*, becauſe the Air that preſſes upon the ſtagnant *Mercury* in the Veſſel, would ſuſtain theſe 14 Inches, and ſtill have a Force towards the Top of the Tube internally equal to 14 Inches more; ſo it would make an *Equilibrium* with half the Weight of the ſuperior Air, and the Hand would ſuſtain the reſt.

Flame can likewiſe by its Spring make an *Equilibrium* with other Bodies; but as there is no other Flame beſides that of Gunpowder that can bear to be compreſs'd without being extinguiſh'd, and ſince this Flame continues but a ſhort Time, it's very difficult to make Experiments of its *Equilibrium*; and the Force of its Spring is ſo great, that no Weight has hitherto been found great enough to overcome it, it being able to overturn not only entire Baſtions, but even Mountains.

To underſtand how it acts with ſo great a Force, you may ſuppoſe that a certain Quantity of Powder is ſet on Fire, that fills a pretty large Tube plac'd perpendicularly; and that a great Weight, whoſe Breadth exactly fills the Mouth of the Tube, preſſing upon the Flame of the Powder, contracts it; ſo that being reduc'd to a very ſmall Space, and not extinguiſh'd, it makes an *Equilibrium* with the Weight; which it may be conceiv'd to do during the Space of a Second, and in this State 'tis the Spring of the Flame that makes the *Equilibrium* with the Weight; ſo that the Weight being increas'd, this Flame would be reduc'd to a narrower Compaſs, ſuppoſing it unextinguiſh'd, and its Spring being then ſtronger, would ſtill make an *Equilibrium* with this greater Weight. Now if you imagine that at the ſame Moment an Addition of Powder is ſet on Fire, the Spring of the Flame will be increas'd, and the Weight being no longer able to make an *Equilibrium* with it, will be puſh'd up; and being once ſet in Motion, the Continuation of the Extenſion of the Flame's Spring, which will extricate and extend it ſelf further, will accelerate its Motion more and more, and at laſt force up the Weight very high into the Air.

This being ſuppos'd, it is eaſy to conceive, that if you put 10 or 12000 Weight of Powder in a Mine; and that when all the Powder is ſet on Fire, it will take up the Space of 200 Foot in Height, and 100 in Breadth, it will happen that only a ſmall Quantity of it will be lighted at firſt, which will not be ſufficient to raiſe up the whole Baſtion; but becauſe this Flame has the Property not to be ſmother'd or extinguiſh'd by being preſs'd, 30 or 40 times more will be ſet on Fire than the Chamber of the Mine could contain if it were laid open; and then if its Spring be ſtrong enough, it will begin to raiſe the Earth above it; which being once ſet in Motion, and the reſt of the Powder continuing to take Fire, and filling the Space which the Earth had quitted when it began to riſe; ſo that its Spring is ſtill ſtronger than the Weight of the Earth which is already in Motion; it will accelerate its Velocity more and more, and at laſt blow up the Baſtion at the Top and Sides; or at leaſt ſome Part of it, till all the Flame has acquired its natural Extent in the open Air.

A little Powder has the ſame Effect in Canons; for it takes Fire ſucceſſively, tho' in a very ſhort Time, without driving the Bullet forwards, till the Spring of the Flame compreſs'd overcomes the Reſiſtance of the Bullet, and when it has begun to move, the reſt of the Powder that ſuddenly takes Fire, increaſes its Spring, and accelerates the Velocity of the Bullet, ſo as to drive it out 15 or 1600 Yards.

Whence you ſee that a Canon of 20 Foot muſt carry a Bullet further than one of 10 Foot, becauſe the Powder has more Time to take Fire and increaſe its Spring whilſt the Bullet paſſes thro' thoſe Spaces.

You ſee likewiſe, that if one Drachm of Powder when it has taken Fire, has Force enough to ſtir a Bullet that is not cloſely fix'd to the Canon, it will not be driven ſo far as if it were well ramm'd and preſs'd down with Cork, or ſome other Materials that may hinder it from being put in Motion till 2 or 3 Ounces of Powder have taken Fire; for in this latter Caſe, its Motion at the Beginning will be faſter and its Acceleration greater.

For the ſame Reaſon, if the Powder be very fine, and eaſily takes Fire, it will drive the Bullet farther than if it were courſe and large, becauſe more of it will be fir'd whilſt the Bullet is in the Cannon.

DISCOURSE III.

Of the Equilibrium *of Fluids by their Impulse.*

FLAME can make an *Equilibrium* with Weights by its Impulse; you may measure its Force, if you let it out at at a pretty large Tube, and make it strike against the Floats of a Wheel horizontally situated, provided the Floats are in an oblique Position, just as the Sails of a Windmill are. The Flame that goes up Chimneys is made use of in several Places to turn some small Engines near the Fire, and the greater the Fire is, the swifter is the Motion of the Flame; but this Motion cannot be much increas'd by Art, and its Impulse has no great Force. A Rocket rises by the Impulse of the Flame against the Air, but if it be too heavy it can't rise; thus its *Equilibrium* may be measured. The Flame of Thunder, that moves with great Velocity, has a very considerable Force; for it overturns Towers and Rocks; the Velocity of the Flame likewise increases its Force in burning, as may be observ'd in great Fires when the Wind is very high. You may see likewise very sensible Effects of it, when the Enamellers blow the Fire of their Lamps against Glass or Metals, in order to melt them; but because Flame is not easily govern'd, or made to continue of the same Velocity or Bulk, and it would

would coſt too much to maintain it ſo as to produce any extraordinary Effects, it is very rarely made uſe of to work Engines; wherefore it is not neceſſary here to examine its Force, or compare it with that of other Fluids.

Air and Water are employ'd to move Engines by their Impulſe. Their *Equilibrium* with each other, and with ſolid Bodies that they ſtrike againſt, may be found by the following Rules.

RULE I.

Jet-d'eau's, *or Spouts of Fountains, do not impell with the united Force of all their Parts, as ſolid Bodies do.*

The EXPLANATION.

(*Vid. Fig.* 44.) A B is a *Jet-d'eau* iſſuing from the Cylinder C D, and E F is a Cylinder of Wood; whoſe Parts being join'd and united together, 'tis evident that when the Extremity F of this Cylinder ſtrikes againſt a Body, it impells it with the united Force of all its Parts: But a *Jet-d'eau*, as A B, being carried according to the Direction A *d* B, can only act by thoſe Parts that go firſt; for Water being a Fluid, and compoſed, as it were, of an infinite Number of Corpuſcula, or little Bodies, that ſlide one upon another, as ſmall Grains of Sand would do; only the firſt towards B, can make the firſt Effort upon Bodies that they meet, and they either reflect, or fall off before the other Parts at *d* can impell in their Turn. For the better underſtanding of this, you muſt conſider, that the Velocity of Water going out at a ſmall Hole, made at the Bottom of a very large Tube, is very different from the Velocity of that that issues out from a Tube whose Diameter is equal throughout; for in this latter Case, it begins to go out very slowly, just as a Cylinder of Ice would, that you should let fall. Let A B, (*Fig.* 45.) a Tube of equal Breadth throughout, be fill'd with Water, and sustain'd with the Finger at B; 'tis evident that the Velocity of the Water when it goes out at B, is equal to that at A, and that the whole Cylinder of Water falls all at once, as if it were solid; and consequently it is subject to the same Rules in falling, that a Cylinder of Ice of the same Bulk would be; namely, that beginning by a very small Degree of Velocity, it increases it in its Descent, according to the uneven Numbers 1, 3, 5, 7, *&c.* that is to say, if in one Quarter of a Second it falls a Foot, the Second Quarter it will fall 3 Foot, in the Third 5, *&c.* whence it follows, that the Water which was at A, being got to B, will go out much faster than that which goes out first.

Galileo has spoken pretty largely of the Acceleration of the Velocity of Bodies that fall freely in the open Air; which I conceive to be thus: If a very light Body strikes against another 100 times heavier than it self, it will give it the hundredth Part of its Velocity, and striking it a Second Time, it will give it another hundredth Part; so that if the impelling Body has 101 Degrees of Velocity, the impell'd Body will take one Degree at the first Impulse, and its Quantity of Motion will be 100; and being impelled a Second Time by the light Body with the same Velocity of 101 Degrees, it will receive from it a new Degree of Velocity; which, joined to the First, will make two Degrees: The Third Impulse will still add a Degree, and so on, as was prov'd in the Treatise of the Impulse of Bodies.

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The ſame thing will happen, if a weak Power draws a very heavy Body to it, by acting upon it ſucceſſively. Now whether a Body be attracted or impell'd by a very light Fluid, if at the firſt Moment of its Effort, it moves a Line by an uniform Velocity; at the ſecond Impulſe and the ſecond Moment it ought to move two, and at the third Moment three, *&c.*

Now if you take ſeveral Numbers one after another, beginning with a Unit, as 1, 2, 3, 4, *&c.* to 20, and count 20 Moments, the Sum of this Progreſſion will be 210; and if you count 40 Moments, according to the ſame Progreſſion to 40, the Sum of theſe latter Numbers will be 820, which is near the Quadruple of 210, the Sum of the 20 firſt Numbers; but if you proceed thus in *Infinitum*, this laſt Sum will be the Quadruple of the firſt preciſely, becauſe the Proportion of the Defect continually decreaſes; which *Galileo* has alſo prov'd in his Treatiſe of the Acceleration of the Motion of falling Bodies. But if the Motion be made thro' a very heavy Fluid, the Acceleration will ſoon be ſtopp'd, and the falling Body reduc'd to an uniform Velocity; as likewiſe a very light Body that falls in the open Air, as has been prov'd in the Treatiſe of Percuſſion. One may judge further of the ſlow Motion of the firſt Drops of Water iſſuing from a Tube of an uniform Breadth, by the following Experiment. Take a bended Tube 2 or 3 Foot long, of equal Breadth throughout, as C D G (*vid. Fig.* 46.) pour in Water at C till it runs out at G, then ſtop the End G, and pour on till you fill the Tube up to C; after this, ſtop the End C with another Finger, and open the End G, if the Tube be only 3 or 4 Lines in Diameter, the Water will not run out at all; take off the Finger that ſtopp'd the End C, and put it on again very ſuddenly, the Water will ſpout out at G only 4 or 5 Lines high; whereas if the Tube C D be much wider than the Hole G; for Example, if it be 9 Lines in Diameter, and the End only 2 or 3 Lines, and you open and ſhut the ſmall Aperture at G with the ſame Haſte, the Drops of Water that go out at G will ſpout up almoſt as high as C. You may ſtill further perceive the Slowneſs of the Water's Motion at its firſt going out of the Tube, as A B in *Figure* 45, and its Acceleration, if you fill this Tube with Water, and ſuſtain it with your Finger, ſuſtaining likewiſe a little Stone with another Finger of the ſame Hand; for, taking away your Hand ſuddenly, you will ſee the Stone and the loweſt Part of the Water deſcend with the ſame Velocity for 12 or 15 Foot.

Another very curious Experiment for the Proof of this Rule, is made after the following Manner.

Take a Tube 8 or 10 Foot long, as M N, repreſented by *Figure* 49, as ſmooth and even within as it can be made; fill it with Water, which you muſt ſuſtain with your Finger, and then of a ſudden let it run out upon the End of the Rule Q R, near the Point R; which Rule ſerving for a Balance, ought to be Horizontal, and ſupported at the other End by a Prop, as O U; and the Point R ought to be only 5 or 6 Lines diſtant from the Baſe of the Tube thro' which the Water paſſes, that is to ſay, a Line more than the Thickneſs of the Finger that ſuſtains the Water; then if at the other End Q, you fix a Weight Q $\frac{1}{4}$ or $\frac{1}{5}$ leſs than the whole Weight of the Water in the Cylinder, this Weight will not riſe at the Beginning of the Water's Fall, tho' the whole Body of Water ſeems to weigh upon R, but only when the Tube is almoſt empty; which ſhews, that only the firſt Parts

of

of the Water make the Impreſſion, and that when they go out very ſlowly, as they do at the Beginning of their Fall, they can only raiſe a Weight much leſs than the Weight of the whole Cylinder; but that when they have acquired a great Velocity in falling from the Height M, the remaining Parts, by their great Impulſe, raiſe what the firſt could not raiſe by their weak Impulſe at the Beginning of their Fall. And if you raiſe the ſame Tube 2 or 3 Foot above R, and leave only an Inch of Water at the Bottom of it (if the Tube be 7 or 8 Lines in Diameter) it will have leſs Force in falling upon R, to raiſe a Weight at Q, than a little Ball of Wax, or Wood lighter by half than the Water, falling from the ſame Height; which ſhews, that the Ball makes its Impreſſion by all its Parts, and the Inch of Water only by thoſe that are neareſt to the firſt Surface that impells the Balance, and which are help'd a little by the more diſtant Parts that fall on each Side. For tho' Water does not impell by all its Parts, and it be difficult to determine the preciſe Height of the Water from which the Parts immediately impelling ought to be eſtimated; yet 'tis very probable that the Parts that fall firſt act the moſt, and that thoſe that are a little higher, as 2 or 3 Lines, act a little leſs; and that ſome ſmall Impuſe may reach even 5 or 6 Lines; as would happen if 5 or 6 little Grains of Sand were contiguous to one another (*vid. Fig.* 47.) as A E F D B falling upon the Rule G H, from a determinate Height, not being all in the ſame perpendicular Line, the two Grains D and B would ſtill contribute a little to the Impulſe of the firſt, tho' they would not act with their whole Weight, and all their Velocity, not being in the ſame Line of Direction; the higheſt Grains A E F contribute likewiſe a little, and cauſe the Rule to be impell'd

more

more ſtrongly, than if only the Grains B and D were there.

Now Water being compos'd of an infinite Number of *Corpuſcula*, or little Bodies, contiguous to one another, much leſs than the ſmalleſt Grains of Sand, that eaſily roll and ſlide one againſt another, a little Cylinder of Water, as G H, will have an Impulſe ſomething ſtronger than a leſſer one, as L H, becauſe there are more of theſe *Corpuſcula* in a direct Situation one upon another in the Height of G H, than in the leſſer L H.

RULE II.

Water that ſpouts out at a round Hole from the Bottom of a Reſervatory, makes an Equilibrium *by its Impulſe with a Weight equal to the Weight of a Cylinder of Water, whoſe Baſe is that Hole, and whoſe Height is from the Center of the Hole to the upper Surface of the Water.*

This Propoſition, together with the Force of the Air's Impulſe, is thus demonſtrated. A B C D is a hollow Cylinder, whoſe two Baſes A D, B C, are of Wood, and the reſt of Leather (*vid. Fig.* 48.) ſuſtain'd and extended by ſeveral Hoops of Wood or Wire, as F E, H I, L M, in ſuch manner that the Baſe A D may be brought down very near the Baſe B C, which is ſuppoſed immoveable. N is an Aperture or Hole made in the Baſe B C, thro' which the Air enclos'd in the Cylinder may go out: This Cylinder is loaded with a Weight P, plac'd on the Surface A D; and to the Bottom of the Cylinder, you apply a Balance like that in the 49th Figure; ſo that the Rule Q R being in an Horizontal Poſition, the Point R near its End, muſt be very near the Aperture N, and directly under the Center of it.

The

The *Apparatus* being thus fix'd; I ſay, that if you put a Weight, as Q, upon the other End of the Balance, whoſe Axis is ſuppoſed to turn eaſily upon the Points C D; and that the Air which the Weight P in its Deſcent forces out thro' the Aperture N, impelling the Extremity of the Balance towards R, makes an *Equilibrium* with the Weight Q, ſuppoſed to be equally diſtant from the Axis C D; this Weight will be to the Weight P, in the ſame Proportion as the Surface of the Aperture N, is to the entire Surface of the Baſe B C: For if by means of a Pair of Bellows, whoſe Pipe has a Bore equal to the Aperture N, you blow Air againſt this Aperture with a Force equal to that of the Air which the Weight P drives out, there will be an *Equilibrium* betwixt theſe two Powers, and the Weight P will not deſcend, becauſe no Air will go out at the Aperture; and then the Air impell'd by the Bellows, filling this Aperture, will ſuſtain its Part of the Weight P, as the other Parts of the Baſe B C ſuſtain the reſt of this Weight; and that Part which the impell'd Air ſuſtains, will be to the whole Weight P, in the ſame Proportion as the Aperture N is to the entire Breadth of the Baſe C D; then reciprocally, the Air iſſuing out at this Aperture after the Bellows are remov'd, will make an *Equilibrium* by its Impulſe with a Weight which is to the Weight P, as the Aperture N is to the Baſe B C. And if you ſtop up the Aperture at N, and open another of the ſame Breadth, very near the Baſe A D, as at the Point K, the Air will go out at it with the ſame Velocity as thro' the Aperture N, if the Baſe A D be preſs'd with the ſame Weight P, and will make an *Equilibrium* by its Impulſe, with the Weight to which it was an equal Counterpoiſe before.

And if the Cylinder be preſs'd ſucceſſively by different Weights to make the Surface A D deſcend faſter or ſlower, the Air that goes out thro' the Aperture N, will make an *Equilibrium* by its Impulſe with Weights that are in the ſame Proportion one to another, as the Weights that ſucceſſively preſs the Baſe A D; becauſe the Proportion of the great Weight P, to the little one that makes the *Equilibrium*, is always the ſame as that of the Baſe B C, to the Aperture N; whence it follows, that the little Weights muſt be to each other in the ſame Proportion, as the great Weights that are put ſucceſſively upon the Surface A D. And if the ſame Cylinder be fill'd with Water, the Water ejected thro' the Aperture K, by the Force of the Weight P, will produce the ſame Effect as the Air; that is to ſay, it will make an *Equilibrium* by its Impulſe, with a Weight which will be to the Weight P, as the Aperture K to the whole Baſe B C; becauſe then the Weight of the enclos'd Water will contribute nothing ſenſibly to the Force of the Ejection, becauſe 'tis almoſt all below it; and if a *Jet-d'eau* of the ſame Breadth, and the ſame Velocity, ſtrikes directly againſt the Water that ſpouts out at the Aperture K, it would ſtop it, and make an *Equilibrium* with it, and ſuſtain a Part of the Weight P, according to the Proportion of the Aperture K, to the Surface B C; whence a Paradox follows ſurprizing enough, namely, that Air and Water ſucceſſively iſſuing out at the ſame Aperture K, what Weight ſoever you put upon the Baſe A D, raiſe the ſame Weight by their Impulſe, tho' Water be of a much denſer and heavier Matter than Air: But to make amends, the Air goes out with a greater Velocity than Water; for it has been found by ſeveral Experiments, that when the Cylinder is full of Air,

it

of equal Diameter; it has been ſhewn before, that Water ſpouting out at the E, will make an *Equilibrium* with a Weight, equal to the Weight of the Cylinder of Water E G; and that the Jet ſpouting out at F, will make an *Equilibrium* with a Weight equal to the Weight of the Cylinder of Water F H. Now theſe little Cylinders having by the Hypotheſis equal Baſes, will have their Weights in the ſame *Ratio* as their Heights; whence it follows, that the Weights with which theſe Jets will make an *Equilibrium*, will be to each other as the Heights A B, C D; conſequently it is evident, that the firſt Velocity of a Jet at its going out ought to be ſuch, that the firſt Drop of Water that ſpouts out ſhould be diſpos'd to riſe as high as the upper Surface of the Water: For ſuppoſe Water in the large Cylinder A B C D, (*Fig.* 50.) to the Height A D, and a Cylinder of Ice, of the Breadth of the Aperture, reaching only from F to G, and ſuſpended from this Point directly over the Aperture F, and about half a Line diſtant from it; if you let the Water paſs at once, it will raiſe up the Cylinder F G by its Impulſe, becauſe it can make an *Equilibrium* with a Cylinder of the ſame Breadth, and the Height of F E. Therefore if the Water ſhould ſpout no higher than G from the Point F, it could not remain at that Elevation, becauſe the Force of the Water that follow'd, would puſh it higher, if it were ſolid as a Cylinder of Ice; whence one may conclude, that the firſt Drop would riſe as high as A E, were it not for the Reſiſtance of the Air, and ſome other Impediments; beſides, the Water that goes out at F being carried upwards, to make an *Equilibrium* with the Water A D, the firſt Drop that riſes ought to have Force enough to go as high as the upper Surface of the Water in the Reſervatory,

abſtract-

abstracting from the Resistance of the Air, as was explain'd in the first Discourse; where I shew'd, that in rising to make the *Equilibrium*, it spouted even higher than the upper Surface of the Water, by the Velocity acquired by the great Motion given to the Jet, in order to raise it to the Height of the upper Surface of the Water.

Having fill'd the Reservatory A B C D with Water 16 Inches high above the Aperture of the Jet at F, and about a Line above the Brims of the Vessels; (for, as I said before, Water will not run over till it be about a Line and a half or two Lines above the Brims of the Vessel that contains it, especially if they be rubbed over with a little Tallow) I put a Rule upon it, as O L, in an Horizontal Position, which was consequently about a Line lower than the upper Surface of the Water. I observ'd, that upon letting the Water spout out a little obliquely thro' the Aperture F, and keeping the Vessel A B C D all the Time full, a Line above the Base of the Rule; the Jet went as high as the Rule, which I found by a little Water sticking to it, which perhaps might have had Force enough to have risen a quarter of a Line higher; but when the Water was only even with the Top of the Reservatory, and did not rise above the Brims, no Water stuck to the Rule, by reason of the Air's resisting the Force of the Jet.

But if the Vessel was two Foot high, the Jet did not go so high as the Rule by almost two Lines; but when the Reservatory was lower, as 7 or 8 Inches high, and the Apertures 3 or 4 Lines in Diameter, the Jets rose sensibly as high as the Surface of the Water, because the small Space of Air which they had to pass thro' could not sensibly diminish their Force.

Now

Now according to *Galileo*'s Doctrine, a Drop of Water risen to a Height of 2 or 3 Foot, when in its Fall it is got to the same Point from which it began to rise, ought at that Point to recover the same Velocity with which it rose; whence it follows, that we may take it for a Rule or Law of Nature, that Water spouting from the Bottom of a Reservatory, thro' a little Aperture, has the same Velocity that a great Drop of Water acquires in falling from the upper Surface of the Water in that Reservatory to the Aperture of the *Ajutage*, abstracting from the Resistance of the Air.

The CONSEQUENCE.

Hence it follows, that the Velocities of Water issuing from the Bottom of Reservatories of unequal Heights, are to each other in a subduplicate Proportion of their Heights; for since the Velocity of each Jet ought to make them rise to the Height of their Reservatory; and since *Galileo* has demonstrated that Bodies moving with different Velocities rise to Heights which are to each other in a duplicate Proportion of those Velocities, it follows that the Velocities are to each in a subduplicate Proportion of the Heights.

RULE IV.

Jet-d'eau's *of equal Breadth, and unequal Velocities, sustain by their Impulse Weights that are to each other in a duplicate Proportion of those Velocities.*

The EXPLANATION.

Since Water may be considered as made up of an infinite Number of small imperceptible Particles, it it muſt happen, that when theſe Particles move twice as faſt as they did, twice as many of them impell at the ſame Time; and for this Reaſon, the Jet that moves twice as faſt as another, has twice as great an Effort, by the ſole Quantity of the impelling Particles; and becauſe it moves twice as faſt, it ſtill has twice as great an Effort by its Motion, and conſequently the two Efforts together ought to produce a Quadruple Effect, and ſo with reſpect to other Proportions.

(*Vid.* Fig 45.) This Rule is further prov'd after this manner: A B is a Cylinder four times higher than the Cylinder C D; the Hole E is equal to the Hole F, and the two Cylinders full of Water: Now ſince the Jet at E ought to ſuſtain a Weight equal to the Weight of the ſmall Cylinder of Water G E, and the Jet at F ought to ſuſtain a Weight equal to the Weight of the ſmall Cylinder H F; it follows, that the Weights rais'd will be as 4 to 1; but by the Conſequence of the preceding Rule, the Velocity of the Jet at F, is to that of the Jet at E in a ſubduplicate Proportion of the Height F H, to the Height E G, and conſequently it will be as 1 to 2. Then a double Velocity of a Jet of the ſame Breadth will ſuſtain a Weight four times as great, and ſo with reſpect to other Proportions; whence it follows, that a Jet of Air moving 24 times as faſt as another, will ſuſtain a Weight 576 times greater; 576 being the Square of 24; and becauſe a *Jet-d'eau* moving 24 times ſlower, ſuſtains the ſame Weight, we may conclude that Air is 576 times rarer than Water, ſince the *Jet-d'eau* moving with the ſame Velocity, ſuſtains a Weight 576 times greater.

The Force of the Air's Impulſe may be known by an Experiment made by a Machine deſcrib'd *Fig.* 51.

as well as by that of *Fig.* 48. relating to the Second Rule. (*Vid. Fig.* 51.) A B C D is a Cylindrical Veſſel of Tin well ſolder'd, open at C D, and turn'd Bottom upwards into another Cylinder, as E F G H; in the Baſe of which there is fix'd a little Tube, well ſolder'd, as L I, that goes into the inverted Cylinder, paſſing a little above the Water N K, that is in the Cylinder E H. The upper Baſe A B is preſs'd by ſeveral different Weights ſucceſſively, to make the Cylinder deſcend, and at the ſame time to drive out the Air with Violence thro' the Tube I L; to the Bottom of which a Balance is apply'd, like that deſcrib'd *Fig.* 49. and upon one of the Ends of it different Weights are laid, to try the Force of this Air's Impulſe. The Experiments will appear to agree with the Demonſtration above-mention'd; for Example, if with a Pair of Bellows you blow Air enough into the Tube L I, to hinder the Weight M and the Cylinder A D from deſcending; then the Air ſo blown in, will have the ſame Effect, as if you ſtopt the Point L with your Thumb, to hinder the Air from going out; and as in this Caſe, your Thumb would bear its Part of the Weight M, join'd to the Cylinder A D, and the reſt would be ſuſtain'd by the reſt of the Baſe G H; and this Part would be to the whole Weight ſuſtain'd in the Proportion of the Baſe G H, and the Height of C D to the Aperture L; ſo that if the whole Weight were a hundred Pound, and the Baſe G H 100 times greater than the Aperture L, the Air blown into the Tube would ſuſtain the hundredth Part of the whole Weight; then reciprocally if you ceaſe blowing, the Air that goes out with the ſame Velocity that the Air from the Bellows had, which before hinder'd it from going out, will make an *Equilibrium* with a Weight equal to that hundredth Part.

Hence

Hence it follows, that if two Cylinders full of Air of the ſame Height, having unequal Baſes, are preſs'd by equal Weights, diſpos'd as the Cylinder A B C D; and having equal Holes or Apertures thro' which the Air is to paſs, the Weights which the Air ruſhing out will raiſe, will be to each other in a reciprocal Proportion of their Baſes; for let each of the two Cylinders A B C D, *a b c d*, be put into another Cylinder full of Water, as was explain'd in the foregoing Figure; and let the two Weights M and *m*, plac'd upon theſe unequal Cylinders, be equal, and the Weights rais'd be P and *p*, namely, P by M, and *p* by *m*; foraſmuch as the Baſe G H is to the Aperture L, as the Weight M to the Weight P, rais'd by the Air going out at L; and as the Aperture *l*, equal to L, is to the Baſe *h g*, as the Weight *p*, rais'd by the Air going out at *l*, to the Weight M or *m*; the Proportion being found to be equal, the Baſe G H will be to the Baſe *hg*, as the Weight *p* to the Weight P. But if the Weights preſſing upon the Cylinders be proportionable to their Baſes, they will raiſe equal Weights by the Impulſe of the Air, which they will force out at equal Apertures; as if the Baſe G H be 24, and the Baſe *g h* 12, and the Weight M be 12 Pound, and the Weight *m* 6; the Aperture L being 4, and *l* the ſame, the Weights P and *p* will be each 2 Pound, which may very eaſily be prov'd.

The Conſequence of the Firſt DEMONSTRATION.

It follows, that the Time of the Air's going out of the great Cylinder, will be to the Time of the Air's going out of the little Cylinder, when they are preſs'd by equal Weights in a Compound Ratio of that of the Baſe G H, to that of the Baſe *g h*, and of the Subduplicate of the same Base G H, to the same Base *g h*; for if the Velocities were equal, the Times would be as the Bases: But the Weights rais'd, being in a reciprocal Proportion of the Bases and the Velocities, by the Third Rule, being in a subduplicate Proportion of the Weights rais'd, the Velocities will be reciprocally in a subduplicate Proportion of the Bases; that is to say, that the Velocity thro' *l*, will be to the Velocity thro' L, in a subduplicate Proportion of the Base G H, to the Base *g h*; and consequently the Time of the Air's going out of the great Cylinder, will be to the Time of the Air's going out of the little Cylinder, in the *Compound Ratio* of that of the Base G H, to the Base *g h*, and of the subduplicate of the same Bases one to the other; which is found true by Experiment: For a Cylinder whose Base is 8 Inches 7 Lines in Diameter, and another whose Base is 5 Inches 6 Lines, being each press'd by a Weight of 44 Ounces, the great one will be emptied in 47 half Seconds, and the little one in 12. Now the Bases G H and *g h* are to each other, as the Squares of their Diameters G H and *g h*; and 74 Inches, which is pretty near the Square of G H, whose Diameter is as 8 Inches 7 Lines is to 30, (which is pretty near the Square of *g h*, whose Diameter is 5 Inches 6 Lines,) as 47 to 19 pretty near; and as 74 is to 47 the Mean Proportional betwixt 74 and 30, so is 19 to 12; whence it appears, that 47 is to 12 in the *Compound Ratio* of that of the Base G H, to that of the Base *g h*, and of the subduplicate Proportion of the said Base G H, to the said Base *g h*

RULE V.

Jet-d'eau's *of the same Velocity, and different Holes,*

Holes, ſuſtain by their Impulſe Weights that are to each other in a duplicate Ratio *of the Diameters of their Holes.*

Let two Surfaces A B, and C D, have two Holes at E and F (*Fig.* 52) and let the two *Jet-d'eau's* E N, F M, paſs thro' theſe Holes; it is evident, that the Surface of the Hole E is to the Surface of the Hole F, in a duplicate Proportion of the Diameter G H, to the Diameter K L; and the Velocities being ſuppos'd equal, if the Diameter G H be twice as great as the Diameter K L, there will be four times as many ſmall Particles of Water to impell in the Baſe G H, as in the Baſe K L; they will produce then a quadruple Effect, and if the Surfaces of the Jets are reciprocal to the Heights of the Reſervatories, they will make an *Equilibrium* with equal Weights.

To eſtimate the Force of running Water ſtriking againſt the Paddles or Floats of a Water-Mill, or any other Machine, you muſt know its Velocity, and compare it with that of Water ſpouting from the Bottom of a Reſervatory. It is neceſſary likewiſe to know the Specific Gravity of Water, with reſpect to other Bodies; concerning which I made the following Obſervations.

I caus'd a Cubic Veſſel of Copper to be made, one of whoſe Sides was 6 Inches, and conſequently its Contents the 8th Part of a Cubic Foot. I put it into one of the Scales of a Balance, and a Weight equal to it in the other; afterwards I fill'd it very carefully with Water, thro' a little Hole made towards an Angle in the upper Plate. I found by ſeveral Trials, that this Water weigh'd 8 Pounds $\frac{3}{4}$, and conſequently that a Cubic Foot of Water ought to weigh 70 Pounds. The *Paris Muid* or Barrel, contains

8 Cubic Feet, and every Cubic Foot 36 Pints; when the Meaſure is ſo exact, that the Water does not riſe above the Brims; but when it riſes as much above the Brims as it may without running over, it contains only 35 Pints; every one of theſe laſt mention'd Pints weighs 2 Pounds, and the other 2 Pounds wanting 7 Drams. The *Paris* Barrel contains 288 of thoſe latter Pints, and 280 of the other; thence you know that a Cylinder of Water a Foot in Height, and whoſe Baſe is a Foot in Diameter, weighs only 55 Pounds, becauſe the Proportion of a Circle to the Square that circumſcribes it, is, pretty near, as 11 to 14. Now as 14 is to 11, ſo are 70 Pounds to 55; whence you know that a Cylinder a Foot in Height, and an Inch in Baſe, weighs 6 Ounces and a Dram very near; for the 144th Part of 55 Pounds, is 6 Ounces and $\frac{1}{9}$, and a Dram is $\frac{1}{8}$; whereupon I made the following Experiments.

Having faſten'd a little Boat to another very great one, that was unmoveable in the midſt of the Stream of a River where it was very rapid, we meaſur'd a Diſtance of 15 Foot lengthwiſe on the little Boat; we afterwards threw out a little Piece of Wood, or a Blade of Graſs 2 or 3 Foot from this little Boat, over-againſt the Place where the firſt Mark of the 15 Foot was; and by the Vibrations of a half Second Pendulum, we counted how many half Seconds it was in paſſing from one Mark to the other; if it paſs'd in 10 half Seconds, we concluded that in this Place the River went with the Velocity of 3 Foot in a Second. Afterwards we made uſe of an Axis with two Rulers acroſs it, in ſuch a manner that the Planes in which they were cut each other at right Angles. At the End of one of theſe Rulers we fix'd a little thin ſquare Board, 6 Inches broad, that dipp'd

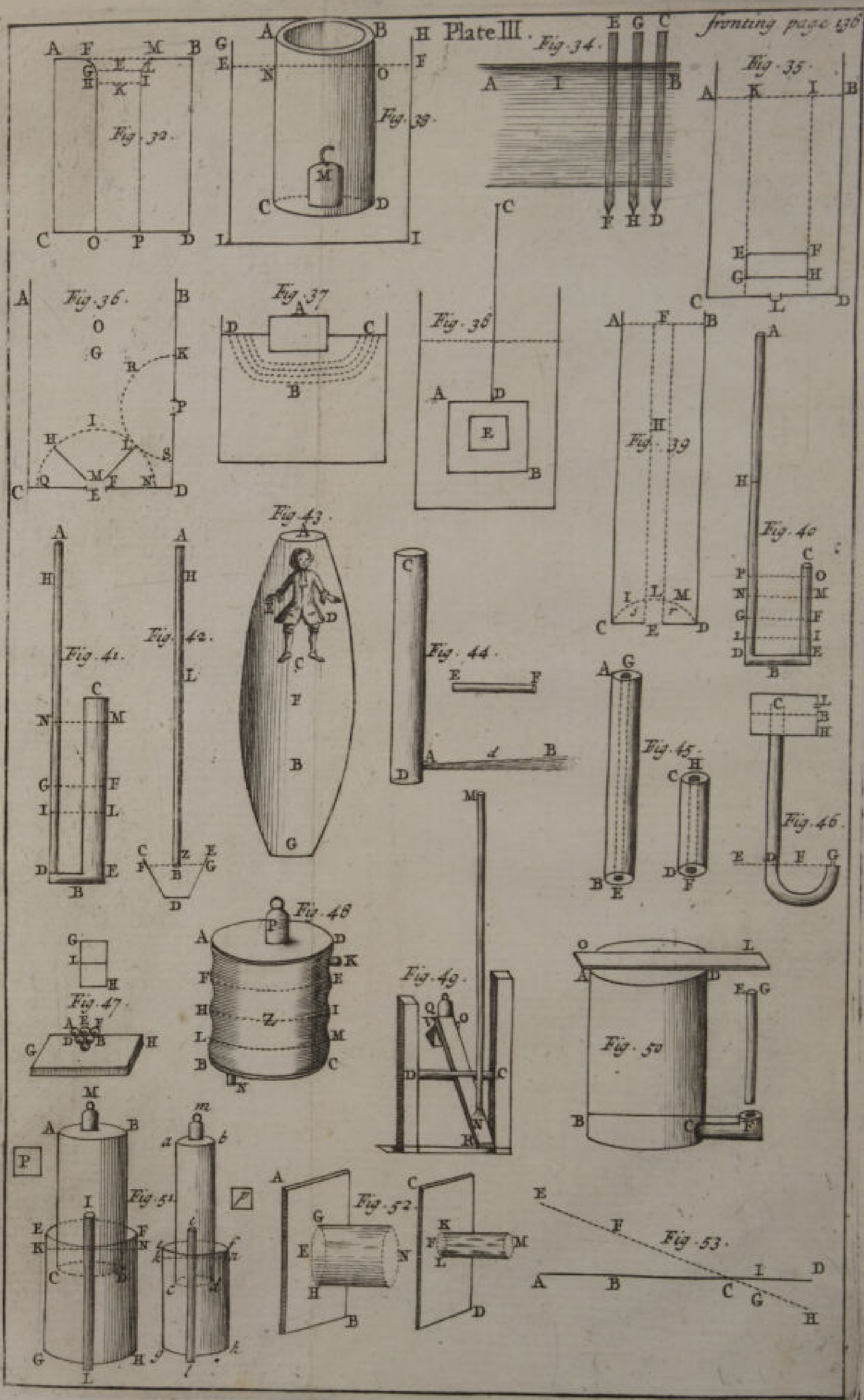
Plate III.
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Fig. 32.
Fig. 33.
Fig. 34.
Fig. 35.
Fig. 36.
Fig. 37
Fig. 38
Fig. 39
Fig. 40
Fig. 41.
Fig. 42.
Fig. 43.
Fig. 44.
Fig. 45.
Fig. 46.
Fig. 47.
Fig. 48
Fig. 49.
Fig. 50
Fig. 51.
Fig. 52.
Fig. 53.

dipp'd perpendicularly in the Stream, till the Water roſe 2 or 3 Inches above it; and at the ſame Time, at the End of the other Rule that was in an horizontal Poſition, we put a Weight at the ſame Diſtance from the Axis as the middle of the Board, and increas'd or diminiſh'd it till it made an *Equilibrium* with the Impulſe of the Water againſt the *Pallet*, or little Board. We made ſeveral of theſe Experiments in that Part of the River where the Stream was moſt rapid, and in other Places where the Water did not go ſo faſt; and we always found pretty near the ſame Proportions correſpondent to the Force of Water iſſuing from the Bottom of a Tube 12 Foot high: This is the way to make the Calculation.

Having found that the moſt rapid Water went 3 Foot $\frac{1}{4}$ in a Second, and that it then ſuſtain'd by its Impulſe againſt the Palet 3 Pounds $\frac{1}{4}$, we concluded that the Jet from the Bottom of a Reſervatory 12 Foot in Height, goes out with the Velocity of 24 Foot in a Second, according to *Galileo*'s Doctrine, before explain'd. This Velocity is then about 7 times $\frac{1}{2}$ greater than that of the River. The Square of 7 $\frac{1}{2}$ is 56 $\frac{1}{4}$, and conſequently if this Jet be of the ſame Breadth as the Pallet, it ought to ſuſtain a Weight about 56 times greater. Now 12 Cubic Feet of Water weigh 840 Pounds, the Quarter of which is 210 Pounds; which we take, becauſe the *Pallet* is but half a Foot; and a Column of Water whoſe Baſe is but half a Foot ſquare, and 12 Foot high, weighs 210 Pounds; and if you divide 210 by 56, the Quotient will be about 3 Pounds $\frac{3}{4}$, the Weight found by the Experiment.

I found in like manner the Force of running Water in ſeveral other Places of the River, and even in the Aqueduct of *Arcüeil*. I made an Experiment at the Side of the River where the Water moved a Foot and a quarter in a Second, and it made an *Equilibrium* with a Weight of 9 Ounces; to compare it with the Velocity of 3 Foot $\frac{1}{4}$, you must take the Square of 1 $\frac{1}{4}$, which is $\frac{25}{16}$, contain'd about 6 times $\frac{3}{4}$ in the Square of 3 $\frac{1}{4}$, which is 10 $\frac{9}{16}$; for the Product of 6 $\frac{3}{4}$ by $\frac{25}{16}$ is 9 and $\frac{90}{94}$, which is a little more than 60 Ounces, which make 3 Pounds $\frac{3}{4}$.

The Wheels of the Mills that are upon *Seine* at *Paris*, betwixt *Pont-Neuf*, and *Pont-au-Change*, have at their Circumference but half the Velocity of the running Water that strikes against them; which comes to the same thing, as when a Weight in Motion meets with another equal to it self, that is at rest and sticks to it; for being join'd together immediately after their Congress, they go forwards with only half the Velocity of the impelling Weight; and so you may suppose, that the Resistance from the Friction of the Axis of the Wheel, and that of the Mill, and the Grain that it grinds, join'd to the Weight of the Mill and its Floats, is pretty near as great as the Resistance of a Weight equal to that of the impelling Water; and consequently they ought to retard pretty near one half of the Velocity of the Water that strikes against them: The same Proportion is observ'd in the Wheel of the Pump of the *Samaritain*.

You must consider, that the Water of a River does not go equally fast at its Surface, and in its other Parts; for the Water near the Bottom is very much retarded by meeting with Stones, Weeds, and other Inequalities.

I made the following Experiments of these different Velocities.

I put two Balls of Wax, fasten'd to a Thread of a Foot long, into a little River whose Motion was uniform; the one was loaded with little Stones

within,

within, to make its Specifick Gravity a little greater than that of Water; ſo that when the two Balls were in the Water, the heavieſt ſtretch'd the Thread, and made the lighteſt ſink lower than it would have done, had it been alone; and by this means its upper Part was almoſt upon a Level with the Surface of the Water, ſo that the Wind could have no Power over it. I always obſerv'd, that the loweſt Ball ſtay'd behind, eſpecially in the Places where there were ſome Weeds at the Bottom of the Water near which the lower Ball paſs'd; for this River was but about 3 Foot deep: But when theſe ſame Balls were put in a Place where the Water meeting with ſome Obſtacle, roſe a little, and afterwards took a more rapid Courſe, as is obſervable under Bridges, the lower Ball outwent the upper; which ſhew'd, that the Water in the middle then went faſter than that of the Surface; which proceeds from this Cauſe, the Water riſing a little higher by reaſon of the Obſtacle, acquires a greater Velocity, by running down a ſteeper Declivity; and this violent Motion cauſes it to plunge, and go below that of the Surface; as if A B C D be the Courſe of the upper Water, and by an Obſtacle towards B, (*Fig.* 53.) it riſes to the pricked Line E F, it will run faſter along the ſteep Declivity E F C; and by the Velocity which it will have acquir'd at C, it will continue its Direction below C D, as to G H; and conſequently it will go ſwifter at G and H, than at I and D; and thence it happens, that in moderate Rivers there are always great Cavities a little below Bridges. You ſee a Proof of it in all the Bridges of the Cauſeway of *Nogent* upon the *Seine*; for the Water which riſes, by meeting the Piles of a Bridge, acquires a greater Velocity, and paſſes on with Violence below that above it, to the Bot-

Bottom, where it carries away the Sand, and draws it along to a Place a little below the Bridge, and collects it together in an Heap; but when the Water is in its Bed, and its ordinary and moderate Courſe, the upper Part of it ought to go ſwifter than that which is a Foot below it: For let A B (*Fig.* 54.) be an horizontal Line, and C B the Declivity of the Bottom of the River, D E the Water half a Foot Diſtance from the upper Part F G, both parallel to C B. Now becauſe Water is viſcous, and its contiguous Parts are a little faſten'd together, the Water D E will carry along that which is immediately above, with almoſt the ſame Velocity which it has it ſelf; and afterwards that which is at F G, which moving likewiſe of it ſelf, by reaſon of its Inclination, goes a little faſter than the Water D E; which may be better comprehended, if you ſuppoſe F L to be a Board ſwimming upon the Water, whoſe upper Part is in an Inclination parallel to C B, having a very round Ball upon it; for this Board being carried along by the Water, would carry the Ball along with it, which would of it ſelf roll the Length of the Board to G, and conſequently its Velocity would be greater than that of the Board.

I have farther often obſerv'd Weeds carried along by the Water; and I plainly ſaw, that thoſe within the Water, neareſt the Bottom, being advanc'd farther than thoſe near the Surface, were ſoon overtaken, and left behind by the upper ones; and if I caſt into the ſame Stream a Handful of great Sawings of heavy Wood, that went ſome ſooner than others to the Bottom, I always found that thoſe nearer to the Top, went before the others in a proportional Order, as they were more or leſs diſtant from the Bottom. From which Experiments it appears, that in Rivers that run freely, the upper Part of the Water goes faſter

faster than that in the Middle, and the Middle faster than that towards the Bottom; and in those that are constrain'd to pass in a narrow Channel, being kept in on both Sides, the Middle goes swifter than the Surface, if there be but 2 or 3 Foot depth of Water.

Here follows is the manner of calculating the Force of the Mill-Wheels upon the *Seine*.

I suppose that there are two Wheels to one Axis; that they are 5 Foot in Semi-diameter; and that the Boards call'd *Ladles*, *Floats*, or *Pallets*, are 2 Foot high in the Water, and 5 Foot long: I suppose likewise that the Velocity of the Water that strikes against the Floats, is 4 Foot in a Second, which is common enough; for it rises a little upon meeting with the Boat that carries the Mill, and consequently over-against the Middle of the Boat it goes faster than if it had not been stopt. Now a Jet half a Foot square, spouting from a Reservatory, wherein the Water continues 12 Foot higher than the said Jet, can sustain 210 Pounds; its Velocity, which is 24 Foot in a Second, is 6 times greater than that which impells the Wheels of a Mill; then this Water that strikes against a Float of half a Foot, ought to sustain but the 36th Part of 210 Pounds, according to the first Rule; it will sustain then 5 Pounds and $\frac{5}{6}$. The square Foot will sustain the 4th Part, namely, 23 Pound $\frac{1}{3}$; and because the Floats of a Wheel have 10 Foot in Superficies. they will support 233 Pounds $\frac{1}{3}$, the other Wheel will have the same Force; then the Two will sustain 466 Pounds $\frac{2}{3}$, plac'd on an Horizontal Ruler at the same Distance from the Axis as the Middle of the *Pallettes*, namely, at 4 Foot Distance.

The Force of the Wind's Impulse against the Sails of a Windmill, may be found after the following manner.

Take a cylindrick Machine with Rulers, like that mention'd in the foregoing Experiments; A B (*Fig.* 55.) represents its Axis; G H is an horizontal Ruler that goes thro' the Axis of the Cylinder at right Angles; I L is another Ruler plac'd perpendicularly upon G H; again, M N O P is a perpendicular Ruler, plac'd obliquely in an Angle of 45 Degrees in respect of the Ruler G R: Now if you suppose a Jet of Water to strike directly upon the Ruler I L, at the Point Q, so as to turn the Cylinder according to the Order of the Letters *a b c d*, it will act with all its Force to sustain the Weight R; but if another Jet equal to it strikes the Ruler M O directly at the Point S, which you suppose as far distant from the Axis as the Point Q, it cannot sustain the Weight R, because its Direction will not be parallel to the Direction of the Extremity of the Ruler I L, and it can only sustain a Weight that will be to the Weight R, as the Side of a Square to its Diagonal; and if the same Jet be parallel to the Axis A B, and strikes at the same Point S, you must still diminish the Weight R in the same Proportion to make the *Equilibrium*, because this Jet will strike this Ruler obliquely in an Angle of 45 Degrees, and then R will have but half its Weight; for if A B C D (*Fig.* 56.) be a Square, the first *Ratio* will be as that of A C to A B; and the second as that of A B to A E, the half of A C, as has been further explain'd in the Treatise of Percussion, at the End of the 13th Proposition of the Second Part. Now the Wind that impells the Sails of a Windmill, strikes against them obliquely; and if it met every Sail in an Angle of 45 Degrees, no more of its Force would remain than in the Proportion of a Diagonal of a Square to its Side for that only Reaſon; but if that Sail which is oblique to the Axis, were ſo in the ſame Angle, this ſecond Cauſe would ſtill diminiſh the Force of the Wind in the ſame Proportion, as was ſaid before of the *Jet-d'eau*; and the total Diminution from theſe two Cauſes, would be of half the Force of this Wind, when it ſtrikes againſt this Ruler, as I L, diſpos'd to move at the beginning according to its Direction; ſo that if its total Force was ſo, it would be reduc'd to 40 by theſe two Cauſes. But becauſe the Sail, whoſe Obliquity is 45 Degrees, receives a leſs Breadth of the Wind, than when it is directly oppos'd to it, it ſtill receives a Third Diminution in the ſame *Ratio* of A C to A B; and the total Diminution will be as A C to E F, or meerly as 80 to 28 $\frac{1}{4}$. But if the Obliquity of the Sail be N O, and the Angle made by A B and N O be of 60 Degrees, (*Fig.* 55.) then the firſt Cauſe alone will diminiſh half the Force of the Wind, and reduce it from 80 to 40, and the two others together, will reduce it from 40 to 31, pretty near; whence you may judge, that it is better that the Sails of a Windmill ſhould have this Obliquity, than that of 45.

To know the Force of Wind that ſhould blow directly againſt the Sails of a Ship, you muſt know the Velocity of the Wind. You may find it by letting a very light Down Feather be carried by the Wind from ſome fix'd Place, and obſerving the Time that it takes up in running thro' a certain Space, as of 30 or 40 Foot. Now, ſuppoſing the Wind to go 24 Foot in a Second, as it does in an ordinary high Wind that's much leſs violent than great Tempeſts and Hurricanes, it will go as faſt as a Jet that ſpouts from a Hole 12 Foot below the Surface of its Reſer-

vatory;

vatory; and becauſe the Wind ought to go 24 times faſter than the Water, to produce the ſame Effect, it will perform no more than Water of an equal Breadth, that goes but one Foot in a Second, or than the Jet that goes 24, if the Breadth of the Wind be 24 times greater in Diameter, or 576 times in Surface. Now a Jet half a Foot ſquare coming from a Reſervatory 12 Foot high, can ſuſtain, as was ſaid before, a Weight equal to the Weight of a ſquare Column of Water, whoſe Baſe is half a Foot ſquare, and its Height 12 Foot; and ſince a 6 Inch Cube of Water weighs 8 Pounds $\frac{3}{4}$, if you double this Height, it will be 17 Pounds $\frac{1}{2}$ for a ſquare Column a Foot long, and half a Foot broad; and if it be 11 Foot long, 210 Pounds will be ſuſtain'd by a Jet half a Foot ſquare: That the Wind then moving with this Velocity, may ſuſtain the ſame Weight of 210 Pounds, the Sail that it impells muſt be 24 times broader and longer than half a Foot; that is to ſay, it muſt be 12 Foot broad as well as long, or 6 Foot broad, and 24 Foot long; and then the Wind that goes 24 Foot in a Second, will ſuſtain 210 Pounds, plac'd upon an horizontal Ruler, faſten'd to the ſame Axis as the ſquare Sail of 12 Foot, at the ſame Diſtance from the Axis as the Middle of the Length of the Sail, which ought to be in a perpendicular Situation; but if the Wind goes but 12 Foot in a Second, it will ſupport but 52 Pounds $\frac{1}{2}$, the Quarter of 210 Pounds.

If you would make the Experiment in ſmall, you muſt make uſe of the Axis deſcrib'd, (*Fig.* 55.) and take a Sail a Foot broad, and a Foot long, whoſe Surface being a Foot, will ſupport but the 114th Part of 52 Pounds $\frac{1}{2}$, namely, 5 Ounces $\frac{5}{8}$, if this Weight be at the ſame Diſtance from the Axis

as

as the Middle of this little Sail; but you muſt chuſe a Wind that goes 12 Foot in a Second.

This Way you may eaſily calculate the different Forces of Water and Wind by their Impulſe.

To compare the Force of Windmills with that of the Mills upon the *Seine* above-mention'd, I ſuppoſe that each of the 4 Sails is 30 Foot long, and 6 Foot broad, which produce 180 Feet; if the Wind goes but 12 Foot in a Second, it ſuſtains 5 Ounces $\frac{8}{9}$, when it impells a Sail of a Foot Surface; if it impells one 180 Foot in Surface, it will ſuſtain almoſt 66 Pounds; but you muſt take away $\frac{5}{8}$, by reaſon of the triple Obliquity of the Impulſe, as was before prov'd; if the Obliquity be of 30 Degrees, there will remain 29 Pounds, and the four Sails will ſuſtain 100 Pounds; but the Diſtance of the Axis from the Middle of the Wheel is 20 Foot, and that from the Middle of the Floats to their Axis is but 4 Foot: Then by this Cauſe the Windmills will augment their Force in a Quintuple Proportion; and if the Cog-Wheel of each be 2 Foot in Diameter, the Force of the Windmill will be 10 times 100, and that of the Watermills twice 466 Pounds, when the Wind goes 12 Foot in a Second, and the Stream of the Water 4 Foot: You may make the like Calculations for greater or leſs Velocities of Waters and Winds, and for greater or leſs Sails.

Some have undertaken to make horizontal Mills, to turn with every Wind, of which I have ſeen Three Kinds.

Thoſe of the firſt Kind, had their Sails concave and convex in an Angle of 45 Degrees, as you ſee in (*Fig.* 57.) A B is the Top of the Concave, and C D the Top of the Convex, the Wind blowing againſt both, will not act after the ſame manner; for

it

it will ſlide on both Sides from the Ridge, or Rib C D along the Planes C L and C N, and will act only in the *Ratio* of 8 to 5 $\frac{2}{3}$; whereas when it meets the Concave, and cannot ſlide off, it will act with all its Force, as if there was a Cloth ſtretch'd upon E Q H F, and ſo it will act with all the Force of its Impulſe, which is 8; and there being Six ſuch Sails, Three of them will always receive a little leſs than a Third more of the Impulſe than the Three others; which muſt neceſſarily make the Wheels turn but with very little Force, ſo as to turn only when the Mill is empty; or they muſt be immenſely great, and then they would not be able to ſuſtain their own Weight, and would be in danger of being carried away by an impetuous Wind: To bring them to Perfection, the Angle E A Q muſt be of 30 Degrees, and then the Proportion of the Force of the Wind in the Concave, in reſpect of the Convex, will be as 4 to 1, as was explain'd in the Rules of the Fall of Bodies, at the End of the Treatiſe of *Percuſſion*, the Third Edition. Moreover the Faces C N, C L, and B E, B Q, may be made moveable, that they may fold in a little in the Sail C D, and open in the other, which would ſtill increaſe the Proportion; each Pair of theſe 6 Sails muſt likewiſe be put one over another, that they may receive the Wind the better, and theſe Mills may produce the ſame Effect pretty near as thoſe before-mention'd.

The ſecond Kind had the Breadth of their Sails in a vertical Situation; but the Cloth that cover'd them was in moveable Frames, and on one ſide lean'd entirely upon the Ends of Beams of Wood that incompaſs'd them when the Wind blew againſt them, and thus they receiv'd all the Force of it; but on the other ſide, turning upon an Axis, and having no Stop, they gave way to the Wind; and by this Means, ſome part of the Wind paſt thro' the Openings that were made, which occaſion'd much leſs Force on that Side than the other, and the Wheel neceſſarily turn'd; but it turn'd very weakly, even when the Mill was empty. When the common Windmills turn'd with a moderate Wind, this did not turn at all, or very ſlowly, becauſe there was not a quarter more Force remaining on that Side where the entire Force of the Wind was apply'd, than on the other; which happen'd for this Reaſon, That the Frames receiv'd as much of the Wind on one Side as on the other; and the Side-frames that open'd, fell a little by their Weight, and ſo met the Wind that ſuſtain'd them, never riſing up to the horizontal Height; but it open'd only half more or leſs; they were therefore uſeleſs for the moſt Part, and could only grind in violent Winds.

The Third Way was to cover half the Number of the Sails by half a Cylindrical Circumference of Tin, or other light Subſtance, which was directed towards the Wind by a large Vane, at a great Diſtance from the Center of the Machine; and by this Means, only three on one Side receiv'd the Impulſe of the Wind, without Obſtruction from the three on the other Side; but this Machine could not be made in great, by reaſon of the prodigious Bigneſs that muſt have been given to the Semi-Cylindrical Circumference, which would have indanger'd its being carried away by a Wind of ordinary Violence.

I have ſeen likewiſe a Model of horizontal Windmills, made uſe of (as they ſay) in *China*; they are made like a Lantern, with ſeveral Sails that turn upon Axes towards the Center of the Machine, and the opposite Point towards the Top: These Sails meet with Pegs in certain Situations, that stop them, so that they receive the Wind the most directly that can be; and when they have made half a Turn by the Revolution of the Machine, they turn and lye before the Wind like Weathercocks, and are acted upon but very little, so as not to obstruct those on the other Side, which the Wind impells almost directly: In a word, there are none on the other Side but what receive the Wind very obliquely; and by this Means, the Wind always acts almost twice as much on one Side, as on the other; which produces a sufficient Effect in the whole Machine, whose Axis is placed in the Middle of the Mill-stone that is beneath; wherefore it is not necessary to apply Cogs and Rounds to this Kind of Mills as it is to others, by the Friction of which the Force is diminish'd.

By the same Method above-mention'd, you may calculate the Velocity of Wind necessary to overthrow Trees, or Pillars set up on End, without sustaining any thing: These are Examples of it.

Let A B C D (*Fig.* 58.) be a Square of Wood, as those of a Paper-Frame, a Foot in Breadth; let the Weight, together with the Paper pasted to it, be a Pound and a Quarter, or 20 Ounces, and the four little Pieces of Wood that make up the Square, be an Inch broad. Place it perpendicularly upon an horizontal Plane, and expose it directly to the Wind; then a Wind that goes 12 Foot in a Second, impelling it, will sustain near 6 Ounces, as was before prov'd; and because it is but 12 Lines thick, half its Thickness where its Center of Gravity is, will be but 6 Lines; for the Weight of the Paper is not here consider'd; and because the Distance from its Center of Gravity, to its Fulcrum, or Center of

Motion, is 6 Inches, the Wind will act like a Lever; as 6 Inches to 6 Lines, or as 12 to 1; and E F being the Axis of Motion, the Proportion of the Wind's Force againſt the Weight of the Square of 20 Ounces, will be as 72 Ounces, the Product of 6 by 12, to 20 Ounces, therefore a leſs Force of Wind than this will make an *Equilibrium*; and if you take 6 Foot in a Second, you will have only a Quarter of 72 Ounces, namely, 18 Ounces; and if 36, the Square of 6, gives 18, 40 will give 20 Ounces. The ſquare Root of 40 is a little more than $6\frac{1}{3}$; a Wind then that goes 6 Foot $\frac{1}{3}$ in a Second, is requiſite to overturn this ſquare Frame; I have made the Experiment at the Top of the Obſervatory, and in *The Samaritaine*.

You may calculate in like manner, the Force that's neceſſary to break a Branch of a Tree half a Foot thick, 15 Foot the Length of the Body, and 30 Foot in Boughs and Leaves, which make 900 ſuperficial Feet for the Wind to impell. The abſolute Reſiſtance of the Bottom of the Branch to be broken, taking it from Top to Bottom, will be 207360; for the abſolute Reſiſtance of a Stick of 3 Lines, has been found to be 360 Pounds. A B (*Fig.* 59.) is the Body of the Branch, D F E B the Compaſs of its Boughs and Leaves, and C the Center; the Diſtance A C is 30 Foot, the Proportion of 30 Foot to the Third of the Thickneſs towards A, which is but 2 Inches, is as 180 to 1; dividing 207360 by 180, the Quotient will be 1152: The Force then of 1152 Pounds is neceſſary to break the Branch at A; there are 900 ſuperficial Feet in the Boughs and Leaves of the Tree; and becauſe 2 ſuperficial Feet, impell'd by a Wind that goes 12 Foot in a Second, ſuſtain $\frac{3}{4}$ of a Pound, they will ſuſtain 450 times $\frac{3}{4}$; that is to ſay, 337 Pounds, pretty near, which is a much less Number than 1152: Therefore as 337 is to 1152, so 144, the Square of 12, is to 492 $\frac{84}{337}$, whose square Root is 22 $\frac{1}{4}$, pretty near; the Wind then must go 22 $\frac{1}{4}$ in a Second, to break such a Branch of a Tree.

The Impulse of the Wind against the Sails of a Ship to incline or overset it, follows the same Rules, and those of the *Equilibrium*; for if to the Ship A B C (*Fig.* 60.) whose Center of Gravity is in the Line D B, you fix a Weight at the Point C, it will incline, and the common Center of Gravity will be in the Line *b* D; that which is in the Water will make an *Equilibrium* with it self, and the Weight C, with the rest of the Ship on the other Side, above the Water: Now the Sail D being impell'd, produces the same Effect as a great Weight, and their Efforts may be compared, as before, according to the Force of the Wind, and the Elevation of the Sail above the Ship; and if you make use of the Method before explain'd, you may know what Velocity the Wind must have to overset a Ship, if you know the Weight of the Ship, and all that's in it, the Breadth of the Sails, and the Obliquity or Direction of the Impulse, in comparing its Force with that of a Weight, as C; but you must consider, that a Ship does not turn by the Wind, as if there were an Axis at the Point B, that turn'd upon two unmoveable Pivots or Centers, and that it is not overset so easily as it would then be; but likewise, that in rolling it can take a Continuation of Motion; which, join'd to a great Impulse by a sudden Blast of Wind, may carry it much beyond the *Equilibrium*, and overset it.

When you can only employ a certain Quantity of Water to some Impulse, you may augment its Force in causing it to spout from a greater Height.

AB (*Fig.* 61.) is the Top of a River kept in on both Sides; CD is an Opening of a Foot ſquare, thro' which the Water ought to iſſue forth, let E be the Middle of the Opening, and the Height B E, 3 Foot.

It has already been demonſtrated, that the Impulſe of the Water will ſuſtain the Weight of a Bulk of Water whoſe Baſe is the Square of C D, and the Height E B of 3 Foot; this Weight then will be thrice 70 Pounds, or 210 Pounds. Let the Water then be ſo reſtrain'd, that its Height may be 12 Foot to F, which is the Middle of the ſquare Opening G H, the Jet thro' F will go twice as faſt as thro' E. If then it be contriv'd, that as the Diagonal of a Square is to its Side, ſo C D may be to G H; the Surface of this Opening will be half that of C D, and the ſame Quantity of Water will paſs thro' in the ſame Time, becauſe it will go twice as faſt; and the Weight which it will ſuſtain by its Impulſe, will be equal to the Weight of the Bulk of Water whoſe Baſe will be the Square G H, and its Height that of F B: But this latter Bulk of Water having four times the Height of the former, and its Baſe only leſs by half, it will weigh twice as much; and the Jet thro' G H will ſuſtain a Weight double to that ſuſtain'd by the Jet CD; whence you ſee, that to turn a Mill that wants Water, and has but half the common Quantity, by giving it a Depth four times greater, the ſame Water will turn it, and produce as great an Effect, as if there had been twice as much Water.

PART. III.

Concerning running and spouting Waters.

DISCOURSE I.

Of the Inches *and* Lines *of Water by which the Measure of running and spouting Waters is express'd.*

THE Fountain or Conduit-Makers, measure the Quantity of Water that Springs give, by the Circular *Inches* and *Lines* which are contained superficially in the Area of the Holes which the Water fills in running gently thro' them; but they have not determined what Quantity of Water those Circular Inches and Lines give in a certain Time, nor what ought to be the Elevation of Water above those Holes, to supply their running with a full Bore; which yet is necessary, to know what an Inch of Water is; for if the Water stood at 6 Lines above a Circular Hole of an Inch, it would give a great deal more Water, than if it was but 1 Line above it: For as it has been demonstrated before in the Second Part, a greater Height of Water makes the

the Water-ſpouts go quicker, and the Expence of Water thro' the ſame Paſſage is according to the Proportion of the Velocity it has in flowing out; which is prov'd in the following manner.

A B (*Fig.* 62.) is a Veſſel full of Water, C E D B is one of the Sides of the Veſſel wherein there is an Opening at I; G H is a Cylinder of Wood, or Ice, which paſſes thro' that Hole with an uniform Swiftneſs.

But if it be ſuppoſed, that in a Second it advances the Space G H, it is evident, that in the ſame time it will paſs entirely and exactly thro' the Opening I; if it begins to enter at the End H, and that if it goes twice as ſlow, it muſt take up two Seconds to paſs thorough entirely; and conſequently there will paſs but half in a Second, and the ſame as to any other Proportions.

The ſame Conſequence may be deduced as to Water-ſpouts, *viz.* That there will paſs twice as much Water in the ſame Time thro' the Opening I, when it runs twice as faſt; and that if in a Minute it gives 10 Pints in paſſing thro' that Opening with a certain Swiftneſs, it will give 30 in the ſame Time, if it goes thrice as faſt.

This being ſuppoſed, it is evident, that if there be two Openings round and equal in a Reſervatory; one a Foot below the upper Surface of the Water, and the other 4 Foot, there will iſſue out of the latter twice as much Water in the ſame Time, ſince it hath been proved, that Water will iſſue out of the latter twice as faſt as the former.

From this it appears, that to determine the Quantity of Water which muſt paſs thro' an Opening of an Inch, ſituated perpendicularly, it muſt neceſſarily be determined how much higher the Surface of the

Water that ſupplies the running muſt be above the circular Inch.

Here follow ſome Experiments that have been made to determine that Height, and the Quantity of Water that iſſues out in a certain Time.

FIRST EXPERIMENT.

We made uſe of a Veſſel of Tin M B, (*Fig.* 63.) of 2 Foot long, and 10 Inches wide, with a ſquare Hole at C, about 16 Lines broad, whereto was applied a little Copper Plate, bored very exactly with a circular Hole of about an Inch Diameter; the Veſſel being ſituated ſo, that the Inch Hole was vertical, it was filled with Water above the Opening, ſhutting it with the Hand, and letting Water run from a Barrel F G, which was very near it, in ſuch Quantity, that paſſing thro' the circular Opening C, the upper Surface of the Water in the Veſſel remained always about a Line above the Opening.

To make this Experiment very exactly, there was made a Hole or Paſſage in one Side of the Veſſel, as at L, a little higher than the circular Opening C, to ſerve for a Diſcharge of the ſuperfluous Water, whoſe Height was diminiſh'd at Pleaſure, by means of a little Plate of Tin, which was apply'd with a very ſticking Cement of Wax and Turpentine. There was alſo applied another thin Plate of Tin, at one or two Inches Diſtance on one Side the Opening C, and one Line wanting $\frac{1}{4}$ above it: It was parallel to the Water in the Veſſel; ſo that when the Water extended it ſelf a little above it, as the Thickneſs of a quarter of a Line, we were certain that the upper Surface was near a Line higher than the Top of the Opening C, and without that Contrivance, it would prove very hard to be aſſured of it; becauſe Water commonly makes a little concave Elevation of about two Lines high along the Bodies it touches, when they are moiſten'd by it; which hinders one from obſerving exactly the Height of the Surface of the Water, in reſpect of the Opening C. There was alſo in the Veſſel a croſs Piece of Plate to receive the Shock of the Water which fell from the Barrel into the Veſſel, that it might not cauſe Waves; and that croſs Piece reach'd down till within 3 Inches from the Bottom of the Veſſel, and was pierced in ſeveral Places, that the Water might paſs thro' freely. This being well diſpos'd, the Opening was ſhut with the Hand, or otherwiſe; and the Veſſel fill'd ſo high, that the Water was 3 or 4 Lines above the little Plate M, and afterwards the Water was ſuffered to run at the ſame Time from the Barrel or Reſervatory, and thro' the Opening; and if the Water of the Veſſel remained at the Height of 3 or 4 Lines, or if it mounted ſtill higher, the Diſcharger L was lower'd a little, till there was but very little Water upon the little Plate M, as the Thickneſs of a quarter of a Line; and that it remain'd ſenſibly in that Poſition for ſome time. Then there was placed on a ſudden the Veſſel N, to receive the Water which iſſued out at the Opening C; and after having left it there preciſely 30 Seconds, it was taken away ſuddenly, and the Quantity of Water that was in it meaſured.

To mark the Time of the flowing out, we made uſe of a Pendulum of very fine Thread, at the End of which hung a Leaden Ball of 8 Lines Diameter: The Length of the Thread from the Point of Suſpenſion to the Center of the Ball, was 3 Foot 8 Lines. This Pendulum ſwung Seconds, which was confirmed, by comparing it with a very exact Clock which mark'd the Seconds. This Experiment

periment was repeated feveral Times, and it was found that there ran in 60 Seconds thro' the Opening of an Inch, when the upper Surface of the Water in the Veffel was 7 Lines higher than the Center of the Opening, about 13 Pints $\frac{3}{8}$ (*Paris* Meafure) each Pint weighing 2 Pound wanting 7 Drachms.

In the Countries near the Equator, the Pendulum fhould be fhorter, becaufe the Motion of the Surface of the Earth is greater there than in *France*. Mr. *Richer* and Mr. *Varin* have made Obfervations upon this; the firft at *Cayenne*, where he found it fhorter by 1 Line $\frac{1}{4}$; and the other in the Ifle of *Gorey*, near Cape *Verd*, where it muft be only 3 Foot 6 Lines $\frac{1}{2}$: This Effect is demonftrated in the following manner. A B C D (*Fig.* 64.) reprefents a Meridian paffing thro' the Poles B C, and A E F is the Equinoctial Line; G H M N is the Parallel of *Paris*: If you fuppofe the Motion of the Earth from *Weft* to *Eaft*, a Stone laid at the Point A, would fly off from the Earth in a Tangent; and becaufe the Point A would go as faft, if the Attraction towards the Center K did not furmount that Motion, it would fly off from the Earth in the Line A I; but the Attraction or Tendency towards the Center being ftrongeft, the Stone does not rife; but notwithftanding it lofes fome of its Tendency to move towards K. The fame thing will happen to a Stone at the Point G; but its Tendency to move along the Tangent will be much weaker, becaufe the Point A moves much fafter than the Point I: Therefore it will lefs retard a Stone falling from G to K, the Center of the Earth; and even the oblique Situation of the little Circle G M, as to the Line G K, may alfo a little diminifh the Hindrance towards the Center; for G L, an oblique Line to K G, being equal to G O, the Point L will be nearer K, than the Point O. By

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theſe two Cauſes the Stone being looſed at I, will deſcend more ſlowly towards A, than the Stone A L towards G: Therefore the Vibrations of the Pendulum will be more ſlow at A than G; and conſequently to make them Iſochronal, the String of the Pendulum muſt be ſhorter at A than G.

It is evident, that the ſame Quantity of Water cannot be found in all the Experiments; and that there will be always ſome little Difference, for ſeveral Cauſes, *viz.* That it is hard to begin to count the Seconds at the ſame Inſtant that the Water begins to run; that the Veſſel cannot be ſnatch'd away preciſely at the End of the 30th Second; that the Hole out of which the Water iſſues is not perfectly perpendicular, or that it is not exactly an Inch, or that the String of the Pendulum may be lengthned or contracted while the Experiment is making; or, finally, becauſe the Height of the Water may be a little more or leſs in Height than a Line at the little Plate M; all which Things hinder a preciſe Exactneſs; but between the greateſt and the leaſt Quantity, the Meaſure was found to be 13 Pints ⅛. If you have a Mind to know what Quantity of Water leſſer circular Openings give, as of 4 or 6 Lines Diameter; you muſt place them ſo, that their Centers be 7 Lines under the Surface of the Water in the Veſſel; for if the Top of each Opening was placed at a Line Diſtance from the Surface, they would give much leſs Water than according to the Proportion of their Bigneſs; but if they are placed ſo, that the Center of their Holes be at the ſame Diſtance from the Surface of the Water, they will give Water very near according to the Proportion. Here follow ſome Experiments that have been made.

EXPE-

EXPERIMENT II.

The Water was made to run ſeveral times from the ſame Veſſel thro' an Opening of 6 Lines, whoſe Center was always at the Diſtance of 7 Lines from the Surface of the Water during the running out ; and there was found between the greateſt and the leaſt 15 *Demi-ſeptiers*, (*Quarterns*) or Quarters of a Pint, in a Minute, altho' the Surface of that Opening be not a quarter of a circular Inch ; and that according to that Proportion, there ought not to run out in a Minute but the quarter of 13 Pints ⅜, according to the Fourth Rule of the *Equilibrium*, by the Shock. This Difference is owing to ſeveral Cauſes.
1. That altho' the Water in the Veſſel ſtands at the Height of a Line above the Inch Hole, it does not remain near the Opening, but about the Third Part of a Line whilſt it is running out ; which is eaſily known by the particular Reflexion of Light which is made in that Place where the Water is lower than in the reſt of the Veſſel ; and its being lower happens, becauſe the Water which ſupplies the Place of that which runs out, muſt come from the neighbouring Parts, as it has been already explain'd ; and as there is not enough of it at Top near the Hole, it muſt needs almoſt all ſink down to paſs, which diminiſhes ſome of the Force of the Preſſion of the Water, and retards the Swiftneſs of the flowing out.

2. That ſince there comes but a little Water from the Top, there muſt in lieu of it come ſome from very far, to ſupply the Place of that which runs out, which alſo retards the Swiftneſs ; but the ſame thing does not happen to the Hole of 6 Lines, becauſe ſince that is to give but the Quarter of what the

the Inch Hole gives, and its Opening has the Height of 4 Lines of Water above it, there is no ſenſible ſinking; and conſequently the Water is preſſed by theſe 4 Lines wholly; beſides the Water which is to ſupply the Place of that which runs out, comes not ſo far, as when the Opening is of an Inch; and that the Top of the Water which is directly over the Inch Hole, may be 7 Lines higher than its Center, it muſt be near 8 Lines high in the other Parts of the Veſſel.

There is alſo another Cauſe, which is, That the Swiftneſs of the flowing out being in a ſubduplicate *Ratio* of the Heights of the Water, as it has been already ſaid; if there be a Veſſel A B, (*Fig.* 65.) with an horizontal Hole made in it at the Bottom, as *a b c d*, and another vertical one, as *e f g h*, equal to one another; and if the Water in the Veſſel be rais'd preciſely to the Height *e f*, there ought not to run out at the vertical Hole but the $\frac{2}{3}$ of the Water which runs out at that at the Bottom of the Veſſel in the ſame Time, if the Water is kept conſtantly at the Height *E f*, which is thus proved.

The Water which runs out at the Bottom of the vertical Hole *e h*, has its Swiftneſs to that which runs out at L I, in a ſubduplicate *Ratio* of the Height *e g*, to the Height *e* L, and the ſame as to all the horizontal Diviſions that may be made in the Square *e f g h*, at unequal Diſtances; from whence it follows, that if the Velocity of the Water of the firſt Diviſion towards the Top be 1, or R 1. the ſecond will be R 2, the third R 3, &c. which is in the ſame Proportion as the Ordinates of a Parabola. Let A C D then be a Parabola, whoſe Baſe C D is alſo the Baſe of the Rectangle C D Q P, and let the Axis A B be divided into ſeveral unequal Parts by the Lines E F, G H, I L, M N, &c. parallel

to

to B D, these Lines shall be the *Ordinates*. But by the Property of this Figure, the Squares of the *Ordinates* are to one another, as the *Abscissæ*, or Segments of the Axis that answer to them, A E, A G, A I, A M, *&c.* and those *Abscissæ* are to one another, as the following Series, 1, 2, 3, 4, *&c.* Therefore these Squares will be also to one another, as 1, 2, 3, 4, *&c.* and consequently O E F, R G H, S I L, T M N, will be to one another, as R. 1, R. 2, R. 3, R. 4, *&c.* But if you take all the *Ordinates* that may be drawn parallel to B D, (infinite in Number) for the Parabola, they will be to the infinite Lines that make up the Rectangle, as the Parabola is to the Rectangle; but the Triangle C A D, which is half the Rectangle P Q C D, is the $\frac{3}{4}$ of the Parabola, as it hath been prov'd by *Archimedes*; if the Triangle be 3, the Rectangle will be 6, and the Parabola 4, which therefore is the $\frac{2}{3}$ of the Rectangle.

Those that are not acquainted with the Properties of the Parabola, may, by Calculation, come very near this Truth, by taking the Series of these *Ordinates* in Numbers, and extracting their square Roots by Decimals; as in the following Table, where the first Row marks the whole Numbers, the second the Tenths, the third the Hundredths, *&c.*

	Units	*Tenth-Parts*	*Hundredths*	*Thousandths*
R. 1. is	1.			
R. 2.	1.	4.	1.	4.
R. 3.	1.	7.	3.	2.
R. 4.	2.			
R. 5.	2.	2.	3.	6.
R. 6.	2.	4.	4.	9.
R. 7.	2.	6.	4.	5.
R. 8.	2.	8.	2.	8.

R. 9.

R. 9. is	3.			
R. 10.	3.	1.	6.	2.
R. 11.	3.	3.	1.	6.
R. 12.	3.	4.	6.	2.
R. 13.	3.	6.	0.	5.
R. 14.	3.	7.	4.	3.
R. 15.	3.	8.	7.	2.
R. 16.	4.			
R. 17.	4.	1.	2.	3.
R. 18.	4.	2.	4.	2.
R. 19.	4.	3.	5.	8.
R. 20.	4.	4.	7.	2.
R. 21.	4.	5.	8.	2.
R. 22.	4.	6.	9.	1.
R. 23.	4.	7.	9.	2.
R. 24.	4.	8.	9.	9.

But if you take the Sum but from the 12 firſt Numbers, 'tis a little greater than 29; and 12 times the 12th Number, *viz.* 3, $\frac{4}{10}$, $\frac{6}{100}$, $\frac{2}{1000}$, gives a Product a little greater than 41 $\frac{1}{2}$, and conſequently that Sum, which is the Parabola, is greater than the $\frac{2}{3}$ of that Product, which is the Rectangle; but if you take that of the 24 Numbers, you will find a little more than 79 for the Parabola; and the Product of the laſt 4, $\frac{8}{10}$, $\frac{9}{100}$, $\frac{9}{1000}$, by 24, is a little more than 117, of which $\frac{2}{3}$ are 78. And thus the Sum of theſe 24 Numbers differs from the $\frac{2}{3}$ of this Product but about an Unit; and you come nearer to it, than when you take but the 12 firſt Numbers; and if you continue to increaſe the Table by a greater Number of Diviſions, the Difference of that Sum and the Product will continually diminiſh, and you may eaſily judge that it will at laſt come preciſely to the $\frac{2}{3}$.

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It appears also, that if you take the 6 middle Numbers of the 12, they will exceed the Sum of the 3 first and the 3 last; and that the Sum of the 6 first and the 6 last of the 24, will be less than the Sum of the 12 middle ones, which ought necessarily to happen; and it is thus proved.

The Sum of the Extremes of the Squares of the Numbers which are in arithmetical Progression, is greater than the Sum of the Squares of the middle Numbers. As the Sum of Squares of 2 and of 8, which makes 68, is greater than 52, the Sum of the Squares of 4 and of 6; and the Overplus, is 16, produced by the Square of the Difference, multiplied into the Number of the Terms of the Progression. Since then the Squares of the *Ordinates* of the Parabola are in an arithmetical Progression, and that the Sum of the Extremes are equal to the Sum of the middle Numbers, it follows that their Roots are not in an arithmetrical Progression; and that the first and the last added together, give a Sum less than the Addition of the middle Numbers; for if they were equal, the Sum of the Squares of the Extremes would be greatest; and because the Expence of running Water follows the Velocities, it follows, that if there be 8 Divisions in the Square A B C D, (*Fig.* 76) the 4 middle ones, which make the Rectangle E F G H, will give more Water than the 4 Extremes which are the 2 Rectangles A H, F D; and L M N O, which is half that Rectangle, and a quarter of the great Square, will give more than the quarter of all the Water that is given by the great Square.

It happens then for this Reason, and on account of the Difficulty of the running, that a Hole of 6 Lines square, having Water 4 Lines above it, gives more than the quarter of the Water which is given by a square Inch, which has but the Weight of one

Line

Line of Water above it near the Hole. It is true that there is a little leſs Friction in Proportion, againſt the Sides of the great Hole, than againſt the Sides of the little one, which gives a little Advantage to the great one; but the other Cauſes being more conſiderable, there always runs out more Water in Proportion thro' the leſſer Holes, till you come to two Lines in Diameter, than thro' the greateſt; which I found agreeable to Experiments.

The ſame thing ought nearly to happen, and for the ſame Reaſons to circular Holes; that is to ſay, if in the great Circle A B C D (*Fig.* 68.) you take the little inward concentrick one E F, whoſe Diameter E F is equal to half of A C, and conſequently the Surface equal to a quarter of the Surface of the great Circle, there will run thro' that Opening a little more than a quarter of that which will run thro' the whole Opening A B C D; which was found to be agreeable to all Experiments in little Elevations of Water above the Hole, the great Circle having nearly always given 13 Pints in a Minute, and the little one always 15 Quarterns, as it has been already ſaid.

If it happens again, that if the little Opening thro' which the Water runs, is placed horizontally at the Bottom of the Veſſel, ſo that the Water runs perpendicularly from the Top to the Bottom, there will run out more in the ſame Time, than if in another Veſſel the Hole was vertical, and the Jet or Water-ſpout horizontal; although the Surface of the Water was as much above the Center of this laſt, as the Center of the other; which proceeds from this, That the Water coming down from Top to the Bottom, accelerates its Velocity, and upon the account of its Viſcouſneſs, it draws along with it the Parts that are contiguous to it faſter, and even those which are near the Opening within the Reservatory; and there will still issue out less from a like Hole, if it be placed so as to make the Water spout up perpendicularly from the Bottom to the Top, as thro' the Opening C, because the Water goes faster at D than at E, so that the lowest Water is always a little retarded.

It has been found by several Experiments, that if there ran out 15 Pints in a certain Time by a Water-spout, whose Hole was of 4 Lines in Diameter, which ran downwards, there issued out but about 14, when it was made to spout upwards perpendicularly, tho' each Hole had the same Height of Water above it; and this happens particularly in the moderate Heights of Reservatories; for if they are of 20 or 30 Foot high, the Difference is much less sensible, because the Water runs out so fast from Top to Bottom in the Beginning, that it does not make any considerable Acceleration in the Water of the Jet, which is beneath the Hole; because a Drop of Water in falling acquires very little more Velocity, than that of the Water which runs out thro' a Hole, when the Surface of the Water of the Reservatory is 30 Foot above, as has been explain'd at the End of the Third Edition of the Treatise concerning the Shock of Bodies, or *Percussion*.

By all these Reasons and Experiments it appears, that it is hard to determine what is an Inch of Water; and because the Expences of Jets are commonly made by great Heights of Reservatories, and by moderate Holes for Ajutage, we ought therefore rather to make an Estimate by Experiments of moderate Holes, as those of 6 or 4 Lines, than by those of an whole Inch. I have taken a Medium between these Different Experiments, as well for the Facility of calculating, as to have a certain Meaſure, and remove all Difficulties.

I here call an Inch of Water, the Water which running for the Space of a Minute, gives 14 Pints *Paris* Meaſure, of thoſe which are a little above the Brim, and which weigh 2 Pounds each. An Inch Hole will give this Quantity, if the Water is a Line above the Hole; but it muſt be 2 Lines higher in the reſt of the Veſſel, that it may be preciſely a Line higher above the Hole. As for the Holes of 6 Lines and under, it will ſuffice that Water in the Veſſel be 7 Lines above their Centers.

This Meaſure, thus determin'd, is very uſeful for Calculation, becauſe in the Space of an Hour, an Inch will give 3 *Paris Muids*, or Barrels, and in 24 Hours, 72 Barrels. Thoſe that are not acquainted with the *Paris* Meaſures, and who know what a Pound is, may eaſily make their Calculations; whereas if they took for the Inch 13 Pints and $\frac{5}{8}$ of thoſe which weigh 2 Pound wanting 7 Drams, it would give but 66 Barrels and $\frac{61}{72}$ in 24 Hours; and theſe Fractions would give a great deal of Trouble, when we would deſire to know the different Expences of Water by different Ajutages, fix'd to the Bottom of different Heights of Reſervatories. To confirm this Rule, the following Experiment hath been made.

EXPERIMENT III.

We took a Veſſel containing a Cubic Foot, divided in Inches; only the Top of it was two Lines above the laſt Diviſion. Water was made to run into it by the Means of a Veſſel in which was a circular Hole of an Inch, as has been before deſcrib'd in *Fig.* 63. The little Plate M was 2 Lines $\frac{1}{4}$ higher than the Top of the Hole, so that close to the Top of the Hole, the Surface of the Water remained higher by a Line, when it was two Lines higher in the rest of the Vessel. This Cubic Foot was fill'd to the Top of the 12th Inch with Water, which ran into it in the Space of two Minutes and a half; from whence it follows, that the circular Holes so disposed, gave 14 Pints, or 28 Pound of Water in a Minute, since it gave 35 Pints in two Minutes and a half.

It may by these Means be easily known how many Inches of Water a moderate Spring, or a running Rivulet gives; for you need only receive the Water in any Vessel that may be measur'd, and that contains Water, by counting what Number of Minutes or Seconds you please: For Example, if you have received in a Vessel 7 Pints in 30 Seconds, you may call that *an Inch* of Water; or say, that such a Spring or Reservatory *gives an Inch of Water*: If it gives 21 Pints in the same Time, you may say that it gives 3 Inches, and so in other Proportions.

DIS-

DISCOURSE II.

Of the Measure of spouting Waters, according to the different Heights of the Reservatories.

IT hath been proved, that the Quantities of Water which issue out at equal Holes made below the Surface of the Water in Reservatories of different Heights, are to one another in a subduplicate *Ratio* of the Heights; but to confirm this Rule by Experiments, I have made several with great Exactness; of which here follow the chief.

EXPERIMENT I.

A Hole of 6 Lines, whose Center was 39 Lines below the Surface of the Water in the Vessel, gave in a Minute 8 Pints $\frac{6}{7}$ of such Pints as weigh but 2 Pound wanting 7 Drams: The Water ran horizontally, as in the above-mention'd Experiment, where the same Hole had its Center 7 Lines below the Water in the Vessel, and gave 15 Quarterns in a Minute. To compare these two Experiments according to the Rule, you must take a Number which is a Mean Proportional between 7 and 39, which is nearly 16 $\frac{1}{2}$, and to the three Numbers 7, 16 $\frac{1}{2}$, and 15, find the 4th

Proportional, which is nearly 35 $\frac{3}{7}$; 35 Quarterns $\frac{3}{7}$ make 8 Pints $\frac{6}{7}$, and conſequently theſe Expences of Water have been in a ſubduplicate *Ratio* of the Heights of the Reſervatories.

EXPERIMENT II.

A Pipe having its Height of 16 Inches, gave thro' a Hole of ſomething leſs than three Lines, made at the Bottom, thro' which the Water ran perpendicularly, two Pints and a half and about two Spoonfuls in 30 Seconds, always keeping the Water the Height of 16 Inches. We put alſo at the Bottom of another Pipe the ſame Plate, in which was the Hole of 3 Lines: This ſecond Pipe had its Height of Water at 64 Inches, which is 4 times as high as the firſt of 16 Inches, and conſequently it ought to give the double of 2 Pints $\frac{1}{2}$ and 2 Spoonfuls, always keeping the Water at the Height of 64 Inches, which hath been proved by Experiments; for there ran out of the Pipe 5 Pints and about 4 or 5 Spoonfuls of Water in the ſame Time, *viz.* 30 Seconds. This Experiment was made with great Exactneſs, and repeated 3 times. We alſo made ſome for Waters that ſpout up to the Height of 5 or 6 Feet, and we always found the ſame ſubduplicate Ratio of the Heights of the Reſervatories. You may then take the following Rule for a Truth.

A RULE *for Meaſuring ſpouting Waters.*

The Expences of Jets of Water which ſpout out at equal Holes, under different Elevations of Reſervatories, are to one another in a ſubduplicate Ratio of the Heights of the Surfaces of Water in the Reſervatories. To find eaſily by Calculation all the Quan-

the 60th Second. I made this Experiment after another Manner, to avoid the Doubt of the Inequality of Water that was pour'd in; we put 7 Pints in the Reſervatory from one Mark, as H, ſo as to fill it up to B; then 7 more from B to another, as L, at equal Diſtances from the Point B; we kept the Hole ſhut till we began to count the Seconds; and we obſerved, that the Surface of the Water was at L.

It is eaſy to judge, that during this running out, there was ſpent ſenſibly as much Water, as if it had always remained at the middle Height of B, of 13 Foot; becauſe that if it went faſter at L, it went alſo ſlower at H, in the ſame Proportion.

The Experiments which I made at great Heights, as 35 Foot, gave about a 17th or an 18th leſs than according to the ſubduplicate *Ratio* of 13 Foot to theſe theſe Heights, and thoſe that I made at the Heights of 6 or 7 Feet, gave a little more; which proceeds from the Friction more or leſs againſt the Edge of the Hole of 3 Lines, and from the greater or leſſer Reſiſtance of the Air; but as theſe Differences are very inconſiderable, Calculations may be preciſely made according to the Rule of the ſubduplicate *Ratio*. Here follows a Table of the Quantities of Water given by Reſervatories of different Heights as far as 52 Foot, thro' an Ajutage of 3 Lines in Diameter.

TABLE

TABLE of the Expences of Water at different Heights of Reservatories, thro' an Ajutage of three Lines in Diameter, in a Minute.

Heights of Reservatories.	*Expences of Water.*
6 Feet	9 Pints $\frac{1}{2}$
9 Feet	11 Pints $\frac{2}{3}$
13 Feet	14 Pints
18 Feet	16 Pints $\frac{1}{2}$
25 Feet	19 Pints $\frac{1}{3}$
30 Feet	21 Pints $\frac{1}{3}$
40 Feet	24 Pints $\frac{1}{2}$
52 Feet	28 Pints

We make our Calculations in the following Manner. Let 2 Feet be the Height of the Reservatory; the Product of 2 by 13, is 26, whose square Root is nearly 5 $\frac{1}{10}$; as 13 is to 5 $\frac{1}{10}$, so is 14 Pints to 5 $\frac{1}{2}$, within a very little; from whence we conclude, that a Reservatory of 2 Foot high, thro' an Hole of 3 Lines, will give 5 Pints and $\frac{1}{2}$ in a Minute.

If the Height was 45 Foot, we might take the square Root of 585, the Product of 13 by 45. This Root is nearly 24 $\frac{3}{16}$; therefore as 13 is to 24 $\frac{3}{16}$, so is 14 to 26; by which we know that a Reservatory of 45 Feet, thro' an Opening of 3 Lines, would give 26 Pints in a Minute.

If you apply a narrow perpendicular Pipe to a large Reservatory, it will give more Water than if the Pipe was away, and there was only at the Bottom of the Reservatory a Hole equal to the Opening of the Pipe. Here follow some Experiments that I have made relating to it.

AB

ABCD (*Fig.* 70.) was a Reſervatory of a Foot broad, and a Foot high; we fix'd at the Hole E a Glaſs Pipe of 3 Foot, of 3 Lines Bore towards the Top, and 3 Lines $\frac{1}{2}$ towards the Bottom F. If there had been nothing but a Hole of 3 Lines at E, without a Pipe, it would have given in 60 Seconds a little leſs than 4 Pints, according to the abovesaid Rules; and if it had been equally broad all over, as A B, the Height GE being of 4 Foot, and the Hole E being of 3 Lines, it would have given about 8 Pints $\frac{1}{2}$ by the ſame Rules; but the Pipe being on, it gave only according to the mean Proportion between 4 Pints and 8 Pints $\frac{1}{3}$. The Reaſon why it gives more than by a Hole of 3 Lines at F, proceeds from the Acceleration which is made of the Water running thro' the Pipe, which would increaſe according to the odd Numbers, if there was only the Pipe; but the Water is retained by that which is in the Reſervatory, which diminiſhes that Acceleration, becauſe it can't be ſeparated from it; but alſo, that which is in the Pipe makes that which is in the Reſervatory follow farther than it would if the Pipe was not added; and by theſe Means, there is made a middle Swiftneſs of running out, which alters according to the Length and Breadth of the little Pipes.

I obſerved in theſe Experiments, that the Pipe being unequally wide at the two Ends, as in this, which was 3 Lines wide at one End, and 3 $\frac{1}{2}$ at the other; it gave always the ſame Quantity, put which End you would into the Hole E; the Reaſon of which was, that all the Water emptied it ſelf always in the ſame Time, the Pipe being full from one End to the other.

I made juſt ſuch another Experiment, having ſolder'd a Pipe of 6 Foot long, and an Inch Bore at the Hole

Hole E of a Veſſel which was a Cubic Foot; which being fill'd with Water when the Pipe was on, emptied it ſelf in 37 Seconds; the Pipe being cut off at the Middle H, emptied it ſelf in 45; and being cut off at the Top E, it was 95 Seconds in running out; from which it appears, that the Length of the Pipe gives more Acceleration.

Another Veſſel in which the Water was 4 Inches above the Hole E, which was 4 Lines over, and where the Pipe E F ran in when it was two Foot high, gave 12 Meaſures and a half of thoſe of which it would have given but 8 and a half, at the Height of 4 Inches; and if the Veſſel had been down to F, it would have given 18 and a half; ſo it is a mean Proportion; which proceeds from the Acceleration of Water which always fills the Pipe, and makes the Water deſcend faſter at E, but not ſo faſt as if the Veſſel was 28 Inches high. We found theſe 8 and a half, when the Pipe was but an Inch high, becauſe then there was but very little Acceleration. Another Pipe of 4 Foot had almoſt the ſame Effect; it was of 4 Lines at one End, and 4 and a half at the other. It was fix'd to the Hole E, according to the two Poſitions, and gave the ſame Quantity of Water; only it ſeemed, that when that End which was of 4 Lines was at E, and that of 4 and a half at F, there ran out 3 or 4 Spoonfuls more.

But having applied a narrow Pipe of 2 Foot and a half long, and $\frac{3}{4}$ of a Line in Bore, there did not go $\frac{1}{8}$ more when the Pipe was of its full Length, than when it was only of an Inch long; which proceeds from the Friction of the long narrow Pipe, which hinders the Water from accelerating its Velocity in falling.

DIS-

DISCOURSE III.

Of the Measure of ſpouting Water thro' Ajutages of different Bores.

WE have ſhewn in the Third Diſcourſe of the Second Part, that Waters which ſpouted with equal Velocities thro' different Holes, balanced by their Shock, Weights which were to one another in a duplicate *Ratio* of the Diameters of the Holes. We may ſay the ſame thing in reſpect to the Expence of the Water iſſuing thro' different Ajutages, below Reſervatories of equal Heights; namely, that the Expence of the Water is according to the duplicate *Ratio* of the Diameters of the Holes: The Demonſtration is made in this manner.

DEMONSTRATION.

A B (*Fig.* 71.) is a Plane with a round Hole bor'd in it at *e f*; C D is another Plane, bor'd with another Hole, tho' leſs, at *g h*; I L is a Cylinder paſſing entirely thro' the Hole *e f* in a certain Time, as in 2 Seconds, according to an uniform Velocity; M N is another Cylinder of the ſame Length, but the Baſe much leſs, which alſo paſſes entirely thro' the Hole *g h* in two Seconds: It is manifeſt, that if the

Plate IIII

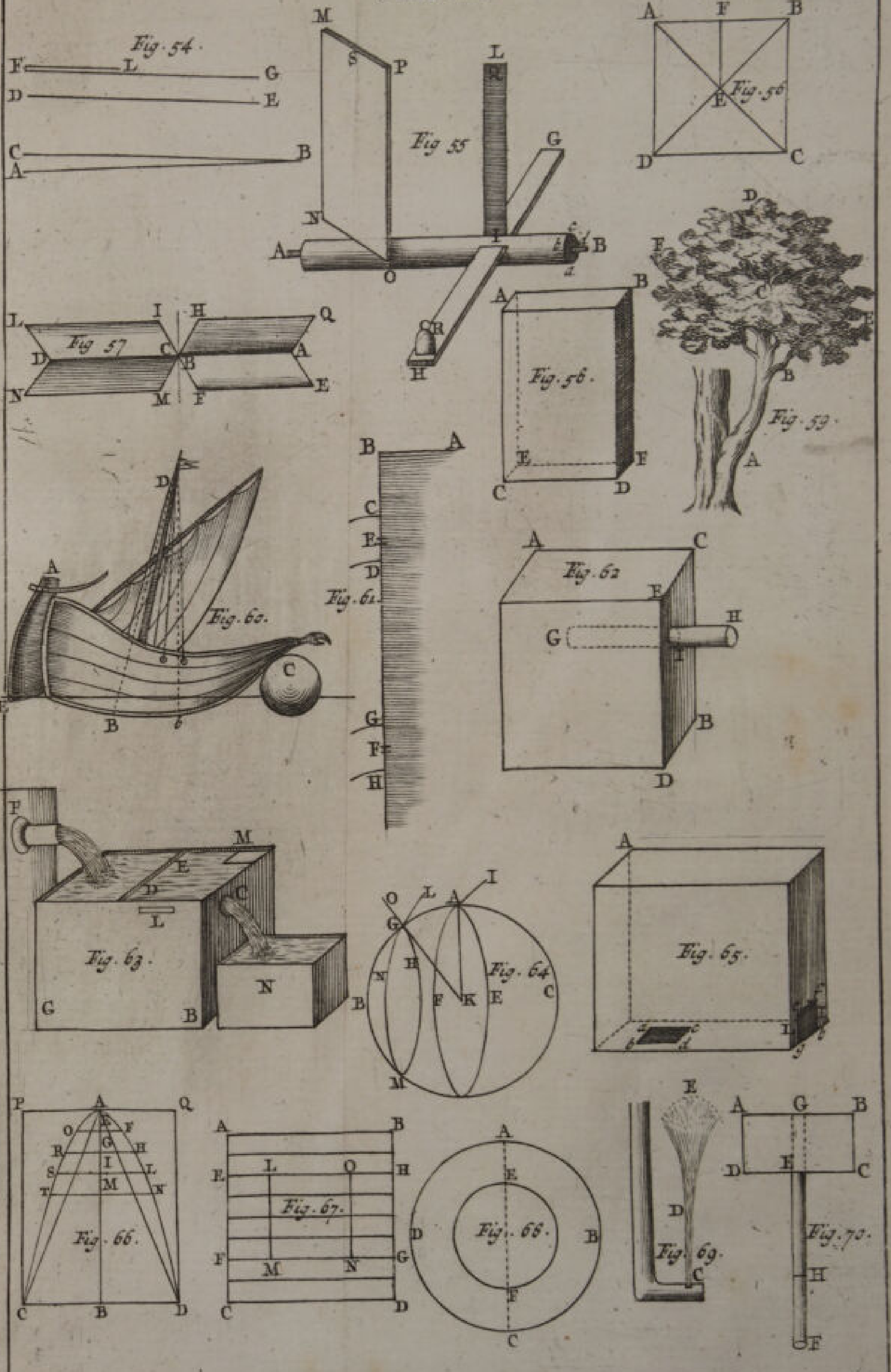


Fig. 54
Fig 55
Fig. 56
Fig 57
Fig. 58
Fig. 59
Fig. 60
Fig. 61
Fig. 62
Fig. 63
Fig. 64
Fig. 65
Fig. 66
Fig. 67
Fig. 68
Fig. 69
Fig. 70

the Diameter E F, of the Cylinder I L, which is equal to that of the Hole, be double the Diameter of *g h*, the great Cylinder will be four times as big as the other, ſince they are to one another as their Baſes, each of which is ſuppoſed to be equal to the Hole thro' which they paſs: Now ſince they have the ſame Velocity, when the Half of the great Cylinder is paſs'd through, the Half of the little one will be alſo gone thro'; and that which has paſs'd of the one and the other will always be in the ſame Proportion of 4 to 1: Then if we ſuppoſe theſe Cylinders to be Water-ſpouts that have the ſame Velocity, there will always ſpout 4 times as much Water from the great Hole, as from the little one, which is in a duplicate Proportion of the Diameters of the Holes; and juſt ſo with reſpect of other Proportions: To confirm this Maxim, we have made the following Experiments.

EXPERIMENT. I.

A Reſervatory or Ciſtern 12 Foot 4 Inches deep, yielded thro' an Hole of exactly 3 Lines Diameter, 14 Pints in 61 Seconds $\frac{1}{2}$, if continually full; and thro' an Hole of exactly 6 Lines, it will yield the ſame Quantity in 15 Seconds $\frac{1}{2}$, which is almoſt according to the duplicate Proportion of the Diameter; for it would have yielded 56 Pints $\frac{1}{2}$ in about the Time of 62 Seconds.

EXPERIMENT II.

A Reſervatory of 24 Foot 5 Inches deep, yielded thro' the ſame Hole of 3 Lines, 14 Pints in 44 Seconds $\frac{1}{2}$, and another time in 45; and the Hole of 6 Lines yielded the ſame Quantity in 11 and almoſt

a $\frac{1}{4}$;

a $\frac{1}{4}$; and having repeated the Experiment, it yielded it in 11 Seconds precisely. From these two Experiments, and from several others, not unlike the former, which I made in different Reservatories; as from 5 Foot high to 27, I found that the different Holes always yielded Water sensibly, and very near according to the Proportion of their Surfaces.

RULE for the Expence of spouting Waters.

Water-spouts thro' different Holes, fix'd at the Bottom of Reservatories of equal Heights, yield Water according to the Proportion of the Holes, or in a Duplicate *Ratio* of the Diameters of the Holes.

A TABLE of the Expence of Water in a Minute, by different round Ajutages, the Water of the Reservatory being 13 Foot high above the Ajutage, or spouting Pipe.

Diameter.	*Expence.*
By an Ajutage of 1 Line	1 Pint and $\frac{10}{18}$
By 2 Lines	6 Pints $\frac{2}{3}$
By 3 Lines	14 Pints
By 4 Lines	25 Pints very near
By 5 Lines	39 Pints
By 6 Lines	56 Pints
By 7 Lines	76 $\frac{1}{4}$
By 8 Lines	110 $\frac{2}{3}$
By 9 Lines	126
By 12 Lines	224 Pints

If

If any one calculates the Inches, he will find that an Hole of 3 Lines will give an Inch, 6 Lines 4 Inches, and 12 Lines 16 Inches.

There are ſome Cauſes that prove a Hindrance to the Exactneſs of theſe Rules; for, very often, the great Holes give a little more in Proportion than the ſmaller ones, and ſometimes leſs; ſometimes the greateſt Heights give a little more than in a duplicate Proportion, and ſometimes a little leſs: For Confirmation of which, I have made the following Experiments.

EXPERIMENT III.

I took a Pipe of half a Foot Diameter, and about 6 Foot high, having a Reſervatory at the Top, which contain'd about 12 Pints; I put the ſame Plate at the Bottom that had ſerv'd in the firſt Experiments, with a Hole bor'd in it of 12 Lines, and another of 4 in the ſame Bottom. The Hole of 12 Lines was about an Inch diſtant from the Side of the Baſe, and that of 4 Inches the ſame Diſtance; I put a great Veſſel below, where there was a Separation that divided it unequally; (This Veſſel muſt be ſo contriv'd, that the Water which runs thro' the Hole of 4 Lines, may enter into the little Separation, and that which runs thro' the Inch Hole, runs into the other:) One may let the two Holes ſpout at once, provided the Pipe be full, and that the Veſſel which was put there to receive it, be taken away ſuddenly; ſo that both Holes may ceaſe to run into it in the ſame Inſtant of Time. We ſhall always find that the great Hole, which, according to the Second Rule, ought to give 9 times as much as the little one, will give but 8 times as much, and with ſomething more Diſadvantage in other Experiments. The Cauſe of this Effect, is the ſame with that which I have mention'd before, *viz.* That Water

ter does not spout from the great Hole with such Facility as it does from the little one; for since the great one ought to yield 9 times as much Water, the Water which succeeds that that runs out, must come from the Circumference of about a Foot; and the Distance of one Side of the Pipe was but an Inch, and the farthest only from 4 Inches; which retarded the running, the superior Water not being able to flow with that Velocity that was necessary; whereas for the little Hole, the Distance of an Inch on all Sides was sufficient to furnish the Expence of Water fast enough; and this Difference made this 9th of Difference in the Quantity of the expended Water, as in the Experiment of the Inch, the Center of which was lower than the Surface of the Water of 7 Lines, which gave but 13 Pints $\frac{3}{8}$; whereas the Hole of 6 Lines gave one fourth Part of 15 Pints, its Center being at the same Distance of 7 Lines from the superior Surface of the Water.

EXPERIMENT IV.

To remove this Difficulty of running, we made several Experiments in a Vessel whose Bottom was large enough to make a Hole of an Inch, at a Foot from the nearest Side, and we made a little Hole about a Foot distant from the great one. The Experiment being made with the same Vessel, where there was a Separation, we always found that the great Hole gave 9 times more than the little one; for it wanted sometimes $\frac{1}{18}$ of it, and sometimes $\frac{1}{30}$, that is to say, if the little one gave a Pint, the great one gave 8 Pints and a half, or 8 Pints $\frac{3}{5}$; we measured the two Holes very exactly again, and found that that of an Inch was something more in Diameter proportionably than that of 4 Lines, at least we

were

were assured, that it was not less than barely an Inch, and consequently that the Defect of the Quantity of Water that it ought to give, did not proceed from this Cause. In the Experiments that we made separately with different Holes, the great ones gave commonly more in Proportion than the little ones: There are Three Causes that may contribute to this Effect.

The first is, That there is more Friction in Proportion in the little Holes, than in the great ones; for the Circumference of the different Holes are to one another but in the Proportion of their Diameters; whereas the Water that they yield are in a duplicate Proportion of the said Diameters. Now if we suppose that the Water, by reason of its Viscousness or Tenacity, sticks a little to the Sides of the Holes, we must for that Reason reckon that we lessen, in some measure, the Largeness of the Diameters: For Example, in a Hole of 3 Lines, we may reckon it lessen'd $\frac{1}{10}$ of a Line; therefore in a Hole of half an Inch, altho' the Square of 6 be four times the Square of 3, and that the round Holes are to one another as the Squares, the Sides of which are equal to the Diameters of the Circles, nevertheless the Circumference of the Hole that has 6 Lines for its Diameter, will be only the double of that which has 3 Lines; wherefore such a Hole can be suppos'd to be lessen'd but a 5th, or $\frac{2}{10}$ for this Impediment; from whence we perceive that Jets with large Holes are not so easily stopp'd or retarded as those with small ones, and give more Water in Proportion to their Diameters.

The Second Cause is, that a little Thread of Water finds more Resistance in the Air at its coming out, than a great Jet; as it happens in little Bullets that do not go ſo far as the great ones, altho' they go at the ſame Time out of the ſame Muſket.

The Third Cauſe is the greater Impulſe of Water that is pour'd in to ſupply the ſpouting of the great Holes. For to keep a Reſervatory full where the Water runs thro' a Hole but of 4 Lines, it is ſufficient to pour in Water very ſoftly, and with a little Veſſel; but when the Jet is of an Inch Bore, you muſt pour in Pails full at a time, and very faſt; which gives an Impulſe to the Water, and makes it go faſter than if it had only the Weight of the Water to preſs upon it. The Experiment was made by placing horizontally an Hole one Inch in Height, and four in Length; for in 36 Seconds and $\frac{1}{2}$, it gave a Quantity of Water which it ought to have given only in a quarter of 154 Seconds; namely, in 38 $\frac{1}{2}$, which proceeded from the Water's being pour'd in with great Force, to ſupply that which went out; and even when the Reſervatories are not kept full, the Water deſcends much faſter thro' a Pipe of 3 or 4 Inches Diameter, when the Jet is large, than when it is ſmall; which neceſſarily increaſes the Velocity of the Water at its going out.

Theſe three Cauſes together are ſometimes a little more powerful than the bare Difficulty of the Water's Paſſage; and ſometimes they only equal it, when the Experiments are made ſeparately thro' different Holes.

I made theſe following Experiments concerning it, with an Hole of 3 Lines, and one of 6 Lines.

EXPERIMENT I.

The Hole of 3 Lines having its Reſervatory 5 Foot and a half high, gave 14 Pints, of 2 Pound

Weight each, in 93 Seconds; and the Hole of 6 Lines gave them in 23 Seconds, instead of 23 $\frac{1}{4}$.

EXPERIMENT II.

A Reservatory a little more than 24 Foot high, thro' a Hole of 3 Lines, gave 14 Pints in 44 Seconds and a half; and thro' 6 Lines, gave the same Quantity in 11 Seconds, the Water in the Reservatory being continued at its first Height.

EXPERIMENT III.

From a Height of 12 Foot $\frac{1}{3}$, the Hole of 3 Lines gave 14 moderate Pints in 61 Seconds $\frac{1}{2}$, keeping the Reservatory still full, and thro' the Hole of 6 Lines, it gave the same Quantity in 15 $\frac{1}{2}$.

EXPERIMENT IV.

I plac'd a Mark in the Cistern or Reservatory that was at the Top of the Pipe, higher than that which mark'd the 12 Foot 4 Inches; and another lower, at an equal Distance from it, that letting the Water run from the upper Mark to the lower, it might produce the same Effect as if it had been kept full to 12 Foot 4 Inches: There entred 13 Pints and $\frac{1}{2}$ in the Reservatory, from the lower Mark to the higher; they pass'd off thro' 3 Lines in 58 Seconds; and thro' 6 Lines in 15, instead of 14 $\frac{1}{2}$.

EXPERIMENT V.

The Reservatory being 24 Foot 3 Inches high, and at the middle Mark, thro' the 3 Lines, gave 14 Pints in 44 Seconds $\frac{1}{2}$; and thro' the 6 Lines, gave the ſame Quantity in 12 ½, pretty near; and in letting the 13 Pints ½ paſs from the higher Mark, that Quantity went out thro' the 3 Lines in 42 Seconds, and in 10 ½ thro' the 6 Lines: This laſt Experiment makes the Proportions equal, as well as the Second.

I found pretty near the ſame Effect from a Reſervatory of 35 Foot.

By theſe different Experiments, you ſee that the Second Rule may be follow'd, without Fear of any conſiderable Error; and that contrary Cauſes always make a pretty juſt Compenſation when the Experiments are made.

With reſpect to the ſubduplicate *Ratio* of the Heights of the Reſervatories, there are two Cauſes that diminiſh it, and two that increaſe it.

Thoſe that diminiſh it are, That the Air reſiſts more in Proportion to a great Velocity, than a ſmall one; and that the Friction is greater againſt the Sides of the Ajutage.

Thoſe that increaſe it, are the ſame that ſometimes cauſe great Holes to give more Water in Proportion than little ones; namely, becauſe you muſt pour Water with greater Force to keep Reſervatories full at a great Height than at a little one, and the Water deſcends faſter when you let it run out.

Theſe Cauſes compenſate one another pretty exactly; but it moſt commonly happens, that there is a little leſs than a ſubduplicate *Ratio* in the great Heights; but when the Experiments are made at the ſame time, from the ſame Reſervatory, great Holes always give leſs in Proportion than little ones.

Toricelli, in his little Treatiſe of the Motion of Water, has demonſtrated, that if the Reſervatory A B C D has a little Hole of 4 or 5 Lines at the Bottom at E (*Fig.* 72); and the Water being at the Height

Height of the Line A B, may run out in 10 Minutes, without pouring in any more, in its Deſcent it will paſs thro' unequal Spaces in equal Times; ſo that if you divide the Line B C into 100 equal Parts, during the firſt of theſe Minutes, it will deſcend 19 of theſe Parts, during the ſecond 17, during the third 15, *&c.* and ſo according to a Series of odd Numbers down to an Unit; ſo that the laſt Part will go out in the laſt of the 10 Minutes. The Reaſon of this Effect is founded upon the firſt Reaſon, before explain'd, that the Velocities of running Water are in a ſubduplicate *Ratio* of their Heights, and conſequently that they are to each other as the Ordinates of a Parabola A B C, beginning at the greateſt A B, and ending at the Point C; which cauſes the Spaces, paſs'd thro' in the ſame time by the Surface of the Water A B, to be as the Series of odd Numbers, beginning at the greateſt.

Thence you may draw this Conſequence, That if you meaſure the Quantity of Water contain'd in the Reſervatory to the Line A B, and it runs out in 10 Minutes, twice as much will run out in the ſame time, if you keep the Reſervatory always full, to the Height A B; which proceeds from this, That if a Drop of Water fell in a certain Time from B to C, and continued its Velocity acquired at the Point C, without increaſing or diminiſhing it, it would in the ſame Time paſs thro' a Space double to B C: Now the Water that goes out at firſt thro' the Hole E, has a Velocity equal to that which the falling Drop would have acquir'd at the Point C; and all the Water that goes out, has always the ſame Velocity, if the Reſervatory continues full; wherefore twice as much will go out in the 10 Minutes, as would go out were it ſuffer'd to run of it ſelf, without any Addition to it; and in 5 Minutes, as much as the Contents of the Reſervatory.

But the ſame thing does not happen, when this Pipe is but half a Foot wide, and 2 or 3 Foot high, as the Pipe A B C D (*Fig.* 73.) having the Hole K of 6 Lines; for the Velocity of the deſcending Water gives an Impulſe to that that goes out; which, join'd to the Weight of the Water, makes it go faſter than it does when it deſcends very ſlowly, this Pipe being very wide.

I found ſeveral times, that if the Water of it ſelf ran entirely out of ſuch a Reſervatory in 4 Minutes, leſs Water by $\frac{1}{6}$ would go out in two Minutes when the Reſervatory was kept full; and if this Pipe contain'd 24 Pints, and they ran out in 4 Minutes, when it was kept full, there went out but 20 Pints during the Space of 2 Minutes; and to give 24 Pints, 2 Minutes and 24 Seconds were required: This Defect is occaſion'd likewiſe by the Jet's being more retarded by the Friction, and by the Reſiſtance of the Air in Proportion, when it is faſt, than when it is ſlow, as was before explain'd; and thus it is always equally retarded by theſe two Cauſes, when the Pipe is kept full; but it is much leſs ſo when the Water is no higher than L M, and ſtill leſs when it is fallen as low as F G.

It is true, if there be a Turning in the Water, as there often happens, then the Courſe of the Water will be retarded, and may compenſate the Effect of the Acceleration: This Turning happens when the Hole is not in the ſame Plane, and the Water runs out a little ſideways in one Place.

In the laſt Experiment that I made upon this Subject, the Water was 10 Inches high above a Hole of 4 Lines, which was made within the Bottom of the Pail: On one ſide of the Hole, at the ſame Height,

I plac'd

I plac'd a Stick on which were mark'd 10 Inches divided into 36 Parts, and the whole into 6 Divisions, of which the first near the Hole had one of these Parts; the Second 3, the Third 5, the Fourth 7, the Fifth 9, and the Sixth 11; the First Division at the Top ran out in 39 Seconds, the Two following the same; the Fourth in about 36 Seconds, and each of the other Two still in less, tho' the Water then had a Turning, which proceeded from the Acceleration of the Water when it was come out of the Hole. The same Proportion is less observ'd when the Hole is very great in Proportion to the Height, as when its Diameter is equal to the fourth or fifth Part of that of the Base of the Cylinder A B C D (*Fig.* 73.) for the Water will run out in great Abundance, and consequently will very much accelerate its Velocity in falling, and impell that that goes out so strongly, that altho' its Weight be then less than when it was at the Height A B, the Impulse will overcome this Defect, and more Water will go out tho' the Hole K, when the upper Surface is got to H I or L M, than there did when it was at A B. This Truth will easily appear, if you consider that when the Pipe is all open, the upper Surface of the Water descends in equal Times, according to the Series of the odd Numbers 11, 9, 7, 5, 3, 1, &c. And when the Pipe is very wide and the Hole very small, it descends according to the Numbers 7, 9, 7, 5, 3; and it necessarily follows that the Heights, the Diameters, and Holes of the Pipes may be so proportion'd that you may give what Modification of Velocity you please to the Water that goes out, that is to say, you may make the Two Halves pass out in Two equal Times, and the Third Part towards the Bottom run out in a Time Thrice less than the rest, and so of the other Parts; but when the Water is fallen pretty low as to F G, it will no longer accelerate, but always diminish its Velocity, for then the Compression will be diminish'd more than half, and the Acceleration will necessarily cease, and it will continue diminishing to the End. I found by an Experiment made with a Glass Tube 5 Foot high, and 10 Lines in Diameter, that had a Hole of 2 Lines, and was divided into 5 Parts, that the First ran out in 7 Spaces of Time, the Second in 6, the Third in 6, the Fourth in 7 pretty near, and the rest still diminishing: Whence it follows that in such a Tube, there are Two different Places, one towards the Top, and the other toward the Middle of the Tube, where the Water descends with the same Velocity; whence you see, that 'tis impossible that the Water shou'd descend uniformly, the whole Length of the Cylindric Vessels, what Heights, Diameters, and Holes or Ajutages soever they have; for if the Weight which it has at H I, joined to the Impulse of its Velocity, makes it go out with a determinate Velocity thro' K; the Impulse of the same Velocity, if it be continued, joined to the Weight which it has at L M, which will be less, will make it go out less fast, and consequently the upper Surface of the Water will not descend so fast at L M as at I K; whence it follows, that if the upper Surface of the Water diminishes its Velocity from the Beginning, it will always diminish it to the End.

Thence you may judge in what Time a Barrel, or other Vessel, will empty it self, letting it run thro' a Hole of a determinate Bore: For let A B C D (*Fig.* 74.) be a *Paris Muid* or Barrel plac'd on one End, having a Hole at 4 Lines at

E, the common Height of the Wine betwixt the Bottoms, which is 30 Inches or 2 Foot and a half multiplied by 13 Foot, makes $32\frac{1}{2}$ whoſe Root is 5 and $\frac{12}{17}$ nearly; and as 13 is to $5\frac{12}{17}$, ſo is 14 to $6\frac{1}{6}$ pretty near: Therefore if the Hole E were 3 Lines in Diameter, 6 Pints $\frac{1}{6}$ would go out in a Minute, the Barrel being kept full; but being of 4 Lines, the Surfaces of theſe Holes are as 9 to 16; then as 9 is to 16, ſo is $6\frac{1}{6}$ to $10\frac{25}{27}$, that is, almoſt to 11; and if 11 Pints are given me in a Minute, in what Time ſhall I have 280; you will find in about 25 Minutes and a half, keeping the Veſſel ſtill full. Therefore by what has been ſaid before, the double of this Time will be requir'd, namely 51 Minutes for it to run quite out: Since the Hole will be very ſmall in proportion to the Largeneſs of the Veſſel, the Swellings A G D, and B F C, will make no conſiderable Difference in the Calculation.

It is proper enough in this Place to reſolve a pretty curious Problem which *Toricelly* has not undertaken to reſolve, tho' he propos'd it; this Problem is to find a Veſſel of ſuch a Figure that being pierc'd at the Bottom with a ſmall Hole the Water ſhould go out, its upper Surface deſcending from equal Heights in equal Times. If in the Conoidal Figure (*Fig.* 75.) B L is to B N, as the Square ſquared of L M is to the Square ſquared of N O; and B N to B H, as the Square ſquar'd of N O, to the Square ſquar'd of H K, and ſo on; the Water will deſcend from A D C uniformly, till it comes to the Hole at B; for let B P be the mean Proportional betwixt B D and B H; ſince the Square ſquared of K H and of D C, are to each other as the Heights B H, B D; the Squares of H K, D C, will bein a ſuoduplicate *Ratio* of B H to B D, or as the Heights

Heights B P, B D; but the Velocity of the Water that goes out at B by reaſon of the Preſſure of the Height B D, is to the Velocity of that that goes out by reaſon of the Preſſure of the Height B H, in a Subduplicate *Ratio* of B D to B H, that is to ſay as B P to B D, therefore the Velocity of the Water deſcending from H is to the Velocity of the Water deſcending from D, as the Square of H K to the Square of D C; but the Circular Surface of the Water at H is to the circular Surface of the Water at D, as the Square of H K to the Square of D C, therefore they will deſcend and run out one as faſt as the other; and if the Surface A D C, runs out in a Second, the Surface G H K will run out likewiſe in a Second, ſince the Quantities are as the Velocities. The ſame Thing will happen to the other Surfaces at E and F, &c. But the Hole at B muſt be very ſmall, that no conſiderable Acceleration may be made, and that the Water may not go out thro' the Hole ſenſibly, but in proportion to its Weight. Such a Veſſel may ſerve for a *Clepſydra* or Water-Clock.

The Explanation of it in Numbers.

Let D B be 16, and B I 1; the Square ſquar'd of I R will be one, if the Square ſquared of D C be 16, and conſequently D C will be 2 if I R be one. Let B H be a mean Proportional betwixt B I, and B D, which conſequently will be 4. The Velocity by reaſon of the Weight I B will be 4, if the Velocity by reaſon of the Weight D B be 16; but the Circle or Surface I R will be 1, and the Circle D C be 4; therefore theſe Quantities will be as their Velocities, and conſequently the Circles or Surfaces D C, and I R will run out in the ſame Time; and if the Surface I R requires a Second

Second of Time to run out; Four times as much will run out in the ſame Time, by a Quadruple Velocity, namely, the Surface DC, ſince that is the Quadruple of the other. The ſame Proportion will be found in all the other Surfaces that compoſe the whole of the Water, or in the Solids, whoſe Thickneſs is indefinitely little. You ſuppoſe in all theſe Experiments, that there is no Turning, or Circular Motion in the Water; nor any little Pit, as there is in Funnels, when they empty themſelves.

RULE.

If there be 2 Tubes, AB, CD, of equal Height and unequal Bores, (*Fig.* 76.) (whatever that Inequality be,) and the Water goes out at the Bottom of them thro' equal Holes; there will go out no more Water from the narrow Tube than from the large one, if you keep them full; provided that the Tube with the leaſt Bore hath its Diameter about 4 times as large as the Hole which the Water goes out at, and that the Water hath no Circular Motion in the Tubes: For the Water going out thro' equal Holes, will raiſe equal Weights by that which hath been ſaid above; it will go then as faſt thro' the one as the other, and conſequently there will go out as much Water from it in the ſame time.

If there be then a Reſervatory of an 100 Foot Diameter, and one of 1 Foot, and that they be of equal Height, and bor'd at the Bottom, or at the Side, with equal Holes at the ſame Height under the Surface of the Water; there will go out as much from the one as from the other, in the ſame time.

A Queſtion may be aſk'd here; *viz.* If one has 2 Tubes of an Inch Bore, and unequal in Height, (for Example, one of 5 Foot, and another

of

of 10) and that they be both fill'd with Water; whether one will give as much Water as the other at the ſame Time? The Anſwer is, That they will ſenſibly give as much one as the other at the ſame Time; becauſe the Water in both falls equally faſt, as 2 unequal Cylinders of the ſame Matter in the Beginning of their Fall: Becauſe the Air does but little reſiſt either of them; and that they accelerate ſenſibly after the ſame manner, according to the odd Numbers. If then there goes out 6 Foot of Water at a certain Time from the one, there will go out as much from the other. But if the Hole of the great Tube be leſſen'd to 4 Lines to its Bore, it will give more Water in the firſt Quarter of a Second, than if it was all open. This is the Calculation of it:

The Product of 13 by 52 is 676, whoſe Root is 26; as 13 is to 26, ſo 14 Pints are to 28. This Hole then will give 28 Pints, or 56 Pounds in one Minute: And thro' a Hole of 4 Lines, 99 Pounds and a half; and in one Second, about 26 Ounces and a half; and in one Quarter of a Second, 6 Ounces and a half: But in one Quarter of a Second, the Cylinder of Water deſcends but 3 Quarters of a Foot; which when an Inch in Diameter, contains little more than 4 Ounces. Therefore in a Quarter of a Second, there goes out of the great Cylinder 2 Ounces and a half more Water by the Hole of the 4 Lines, than there runs out of the little Cylinder quite open.

DISCOURSE IV.

Of the Measure of Water running in an Aquæduct, or in a River.

TO measure Water running in the Chanel of an Aquæduct, or that of a River, which cannot be receiv'd into a Vessel, we must make use of the following Method.

We must place upon Water a Ball of Wax, loaded within with something more heavy, insomuch that but very little of the Wax lies above the Surface of the Water, for fear of the Wind; and after having measur'd a Length of 15 or 20 Feet in the Aquæduct, we shall know by a Half-Second Pendulum in how much Time the Ball of Wax, carried by the Current of the Water, will run that Distance: Afterwards we must multiply the Breadth of the Aquæduct by the Height of the Water, and the Product by the Space which the Wax shall have run thro': The last Product which is solid, will give all the Water which shall have pass'd during the Time of Observation, thro' one Section of the Aquæduct. To make this Operation with Exactness, it is necessary that the Bed of the Aquæduct should have the same Inclination as the Superficies of the Water that passes in it: And moreover we suppose, that the Water runs equal-

ly

ly faſt, in the Bottom, on the Top, and on the Sides.

EXAMPLE.

We ſuppoſe that in an Aquæduct which has a Breadth of Two Feet, and the Water in it One Foot high, the Wax has run 30 Feet in 20 Seconds, which will be one Foot and a half in a Second: But becauſe the Water goes ſlower at Bottom than at Top, we muſt take but 20 Feet; and then we ſhall have 1 Foot in a Second: The Product of one Foot in Height by 2 Feet Breadth, is 2; which multiplied by 20 of Length, gives 40 Cubic Feet, or 40 times 35 Pints of Water, which make 1400 Pints in 20 Seconds: And if 20 Seconds give 1400, 60 Seconds will give 3 times as many, *viz.* 4200 Pints: And dividing 4200 by 14, which is the Number of the Pints which an Inch of Water gives in one Minute, or in 60 Seconds, we ſhall find the Quotient 300, which will be the Number of Inches which the Water of the Aquæduct will give.

This way we ſhall eaſily calculate the Number of Inches which the River *Seine* gives: For ſince there paſſes under the Red Bridge in one Minute 200,000 Cubic Feet of Water; if we multiply 35, which is the Number of the Pints which a Cube of one Foot contains, by 200,000, we ſhall have 7.000,000 Pints; which being divided by 14, give 500,000, which is the Number of Inches which the River *Seine* gives, when it is at a moderate Height.

If we have a mind to calculate what Quantity of Water goes thro' large Paſſages, as thro' a Square Fathom, it is neceſſary to conſider the Height

Height of the Surface of the Water, above the Middle of the upper Part of this Square Hole, thro' which the Water is ſuppos'd to run. Let it be, for Example, 5 Feet; there will be then 8 Feet from the Top of the Water to the Middle of the Square Fathom. The Product of 8 by 13 is 104, whoſe Square Root is very near 10 and $\frac{1}{5}$; as 13 is to 10$\frac{1}{5}$, ſo is 14 to 11 nearly: And becauſe a round Inch is 16 times greater than a round Hole of 3 Lines, an Inch with 8 Foot of Water above it, will give 16 times 11 Pints, or 176 Pints; which being divided by 14, give 12 Inches $\frac{4}{7}$ for an Inch Diameter of the Hole. A round Hole of one Foot Diameter, gives an 144 times more; the Product of 12$\frac{4}{7}$ by 144, is 1810; the round or Cylindric Foot then will give 1810 Inches. The round Toiſe contains 36 times a Cylinder of one Foot: The Product of 36 by 1810, is 65160; as 11 is to 14, ſo is 65160 to 82930. Then a Paſſage of a Square Fathom having 5 Feet of Water above it, will give 82930 Inches.

From thence we ſhall find, that if the River *Seine* were ſtopt, when it is ſwell'd a little above its uſual Greatneſs, and was rais'd 8 Feet above a Square Hole, 10 Foot high, and 18 Foot wide, it would go all out thro' ſuch a Hole: For there would be a Diſtance of 13 Feet from the Surface of the Water which was ſtopt, to the Center of the Circle, which would have 10 Feet Diameter; and it would give thro' an Hole of 3 Lines Diameter an Inch of Water: Thro' one of an Inch Diameter, it would give 16 Inches; thro' one of a Foot, 144 times 16 Inches, which makes 2304 Inches: And multiplying this Number by 100, the Square of 10 Feet, which is the Breadth of the Hole, we ſhould have 230400; and according to the Proportion of the Circle

Circle to the circumscrib'd Square, which is of 11 to 14, we should find very near 293236 Square Inches; and adding to it 8 Feet in Length, we should have more than 500,000 Inches; which is what the River *Seine* gives at a moderate Height, as has been said before; and consequently it would all go out thro' a Square Hole, which should have 18 Feet in Length, and 10 Feet in Height.

If Water runs thro' an Aquæduct, or thro' the Channel of a River, in a gentle uniform Declivity, it will acquire in a moderate Space a Velocity, which will increase no more: For the Friction of the Banks, and the Bottom of the Channel, and the Parts of the Water being turn'd over one another, and the Resistance of the Air to the little Waves which are in the Surface, cause it to lose a Part of its Velocity; and consequently it cannot accelerate its Motion, but to a certain Velocity which it acquires in a little Time. From whence it follows, that if a River has run thro' a pretty long Space in a certain Inclination, and that it runs afterwards in a less steep Inclination, that is to say, along a Plane less inclin'd, it will diminish its Velocity: For since it will have acquir'd in the first Inclination all the Velocity which it can have by it, and could not have been able to acquire by a less; it follows, that its Velocity will lessen by degrees in that Inclination which is less, till it be reduc'd to that Velocity only, which it can acquire by this gentler Declivity.

PART

PART. IV.

Concerning the Height of Jets.

DISCOURSE I.

Of the Height of perpendicular Jets.

WE have ſhewn already, that Jets ought to riſe to the Height of the Reſervatories; but that the Friction of the Sides of the Ajutages, and the Reſiſtance of the Air occaſion'd, that in Jets which have very high Reſervatories, the Height of the Jets does not come up to that of the Reſervatory by a great deal.

In order to explain the Rules which we muſt follow to calculate the Height of Jets, according to the Height of the Water of the Reſervatories, we muſt conſider the following Rules.

RULE I.

When the Pipes that furniſh the Water are large enough, the larger the Ajutage is, the higher or farther it carries its Jet.

An Experiment of it is easily made; if we take a Barrel of Water, set up on End, and pierce it on the Side near the lower End at the same horizontal Height, with five or six Holes of different Bore; as for Example, of 2, 4, 6, 10 and 12 Lines Bore, &c. for we shall see that the largest Bores will always carry the Water farthest, provided that the Bores be the same Distance from the Superficies of the Water. The same thing will happen in Pipes whose Bore is 3 or 4 Inches, provided that the Bore of the Ajutage does not exceed one Inch Diameter.

It is pretty easy to explain the Cause of this Effect, if we consider what must happen to Balls of Wood of different Diameters; for since they are one to the other in a triplicate Ratio of their Diameters, their Weights will be likewise in the same Ratio, as also will be their Force to overcome the Resistance of the Air; and consequently if we throw with the same Velocity one Ball of two Lines Diameter, and another of 4, the last will go farther. We see a Proof of this, when we charge a Gun with Lead-Dust, Shot, and Balls, at the same time; for tho' they go out with the same Velocity, the Shot go farther than the Powder of Lead, and the Balls go farther than the Shot; and for the same Reason, a Cannon Bullet will go farther than a little Ball of the same Metal, setting out with the same Force. It is true, that if the Reservatory be but 2 or 3 Feet, a Jet of 8 Lines will not be sensibly different from a Jet of 10 or 12 Lines; and one of 4 Lines will be sensibly as high as one of 6 Lines; but the Difference will be very considerable in Jets of 30, 50, and 60 Feet in Height, and more.

RULE

RULE II.

The Jets fall short of the Height of the Reservatory, according to the Duplicate Ratio of the Heights to which they rise.

Let A B C be a Reservatory (*Fig.* 77.) or a large Tube spouting thro' the Ajutage D; and let the Height of the Water in the Tube be successively A and E: I say, that if the Line E H be the Deficiency of the little Jet, whereby it spouts short of E, and G A the Deficiency of the great Jet, whereby it spouts short of A, A G will be to E H in a duplicate Ratio of D H to D G.

For let it be suppos'd that the Weight of the Air is to the Weight of the Water as 1 to 600; or, for the more easy Calculation, as 1 to 60; and that one only Drop or Particle of Air be met with very near the going out of the Ajutage, by the first Drop of Water of the Jet, and that afterwards it rises freely, as in a Vacuum: It is evident by what has been shewn in the Rules of *Percussion*, or of the Motion of Bodies which strike one against the other, that the Drop of Water will lose $\frac{1}{61}$ of its Velocity, if that Velocity be express'd by 61. Suppose then D E be 61, and D H 60, and that the Drop be retarded of $\frac{1}{61}$, namely E H. Now let the Height be D A, the Velocity of the Drop will be to its first Velocity in a subduplicate Ratio of D E to D A; and that Drop, by meeting still with a little Particle of Air, will lose still the 61st Part of its Velocity, and will lose a Part proportionable to H E, according to the Ratio of D E to D A; suppose A L be that Diminution, D E will be to D H, as D A to D L. But as we have suppos'd a Particle of Air for the

Space D E, there will be as many Particles of Air thro' the Space D A, in proportion as D A, or D G, is greater than D E or D H; and every Particle diminiſhing ſenſibly the Height of the Drop of Water in the ſame Proportion, this will be ſecond Ratio equal to the firſt, and conſequently A L being to A G, as D E to D A, or H E to A L, A G will be the Deficiency of the Height of the Elevation of the Drop of Water; but becauſe there are ſeveral Particles of Air between D and E, each of which retards the Motion of the Drop in the ſame Proportion, the Motion of the Drop in the Space D E will be much more retarded than by the meeting with one only Particle, as we have ſuppos'd. But we may conſider all theſe Spaces of Air, as if it were but one only Particle, and the Space of the Air D A is alſo in the ſame Proportion as D A to D E, and conſequently we muſt add a ſecond Ratio equal to the firſt; from whence it follows, that if A L be to A G in a duplicate Ratio of D E to D A; G A will be the Deficiency of the Jet below the Height of the Water of the Reſervatory D A, if E H be that of the Height D E; *which was the thing to be proved.*

EXAMPLE.

Let D A be quadruple of D E, the Velocity of the Jet of Water preſs'd by D A will be double that of the Jet of Water preſs'd by D E; if we take then as above the Height D E for 61, the Height D H will be 60; and as the Velocity of the great Jet is double, and as it ought to riſe to a quadruple Height, it will loſe by meeting with as much Air as there is in D E, 4 times as much Height as H E; namely, whereas the Jet ought to riſe to D A 244, it will riſe but to D L 240; but the

Inches; and so in order, according to the Series of Squares. We do not make the Calculation in diminishing the Height of the Reservatories; for if we had taken a Reservatory of 100 Feet, it would be necessary to diminish 400 Inches of the Height, that is to say, 33 Feet $\frac{1}{3}$. One of 200 Feet would have of Diminution about 133 Feet; and one of 400 Feet, the Quadruple of 133 Feet, namely, 532; and consequently it would not spout at all; which is impossible; for the Jets ought always to increase to that Height: But we must observe that the Jet of 200 Feet of Height, has its Reservatory at 333 Feet; and a Jet of 400 Feet, at 932 Feet.

For all the different Heights, we shall make use of the followig Table.

The Height of the Jet.	*The Height of the Reservatory.*		
5 Feet	5 Eeet	1 Inch	
10	10	4	
15	15	9	
20	20	16	
25	25	25	
30	30	36	or 33 Feet
35	35	49	
40	40	64	
45	45	81	
50	50	100	
55	55	121	
60	60	144	or 72 Feet
65	65	169	
70	70	196	
75	75	225	
80	80	256	
85	85	289	
90	90	324	or 117 Feet.
95	95	361	
100	100	400	

So

So the Jet of 30 Feet will have 33 Feet for the Height of its Reſervatory; that of 60 Feet, 72 Feet; that of 90 Feet, 117 Feet; that of 100 Feet, 133 Feet $\frac{1}{3}$; that of 120 Feet, 168 Feet: There is no need of a longer Table, for it is not uſual to make a Height of Reſervatory of 168 Feet; and a Jet of 120 Foot would be diſſipated by its Violence into ſmall imperceptible Drops, as thoſe of a Miſt; the Pipes might burſt; and when the Pipes are narrow, or the Hole of the Cock which one turns to let the Water out, is much narrower than the reſt of the Tube, the little Jets fail much more than according to theſe Meaſures; and then there goes out much leſs Water than in Proportion to the Height of the Reſervatories.

We ſhall then calculate the Expence of Water according to the Height of the Reſervatories, to which the Heights of the Jets agree; as if a Reſervatory of of 30 Feet gives a Jet but of 20 Feet thro' the Defect of the Hindrance of its Conduit or other Things, then it will be neceſſary to calculate the Expence of the Water, as if the Reſervatory was 21 Foot 4 Inches high, with a Bore ſufficient for the Conduit.

To know the Diminutions of the Heights, which are more than according to the Rule when the Holes are ſmall, I have made the following Experiments.

A Jet thro' a Line to a Tube of 4 Feet and a half wanted near 6 Inches.

To a Tube of 14 Feet it wanted 3 Feet.

To one of 27 it wanted about 8 Feet; which ſhews that the narrow Jets do not ſpout to their true Height.

To know the Heights of the Jets, without calculating them, even before one has made any Experiment of them, we muſt have a Ball of Lead, and one of Wood, each to be 5 Lines Diameter, and throw them up on high with the ſame Force; if that of Lead riſes to 27 Feet, and that of Wood to 24 Feet $\frac{1}{2}$, it will be a Sign, that a Reſervatory of 27 Feet will make its Jet but 24 Feet, thro' a Hole of 5 Lines: For though the Ball of Wood be lighter than the Water, the Lead is alſo a little retarded by the Air; and if we caſt the ſame Lead with a little Ball of Wood of one Line, and the Lead goes 14 Foot, and the little Ball 11, it will be a Sign, that a Jet through one Line to a Reſervatory of 14 Foot, will mount but to 11 Foot.

To confirm this Rule, we have made the other following Experiments.

We took a Pipe whoſe Bore was 3 Inches, on the Top of which we ſolder'd a Barrel of one Foot Diameter. The Figure of the Tube was as in the Figure A B C D, (*Fig.* 78.) the lower Part was a Curve. We plac'd the Reſervatory A B at different Heights in order to make different Experiments.

The Water of the Reſervatory being at 24 Foot 5 Inches higher than the Hole D, the Jet aroſe to 22 Foot 10 Inches; the Hole of the Ajutage was of 6 Lines; the Square of 22 $\frac{5}{6}$ is 521 $\frac{13}{36}$: wherefore we ſay, as 25 ſquare of 5 is to 521 $\frac{13}{36}$, ſo one Inch of Height of Reſervatory above 5 Foot, is to a little leſs than 21 Inches; which are to be added to 22 Foot 10 Inches, to have the Height of the Reſervatory, according to the Meaſures of the foregoing Table; which makes 24 Foot and near upon 7 Inches, which agrees pretty well with the Experiment.

The Jet of 4 Lines at the ſame Height of Reſervatory aroſe only to 22 Foot, 8 Inches $\frac{1}{2}$, and ſpouted only one Inch, or an Inch and a half lower than that whoſe Adjutage was 6 Lines; but that of 3

Lines

Lines was lower than that of 6 Lines near 8 Inches, and was but 22 Foot 2 Inches.

A Reſervatory of 12 Foot $\frac{1}{3}$ has made the Foot ſpout through a 6 Line Bore to 12 Jet: That is a little higher than according to the Rule.

Another Reſervatory of 5 Feet $\frac{1}{2}$ in Height, with a Conduct-Pipe, which was very large, the Ajutages being of 3, 4, and 6, Lines, the Jets have ſpouted very near 15 Lines below the Surface of the Water of the Reſervatory, and there was not more than near the difference of one Line between that of 3 and that of 6 Lines. By the Calculation, the Square of 5 $\frac{1}{2}$ is 30 $\frac{1}{4}$; and by the Rule 25 Foot is to 1 Inch, as 30 $\frac{1}{4}$ to $\frac{1}{5}$ a little more, which would give the Height of the Reſervatory leſs only by half a Line than it was found to be by the Experiment, which it is not poſſible to obſerve.

Little Jets in ſmall Heights loſe very little by their ſtriking the Air, and are not much leſs high than thoſe of 6 Lines, provided that the Pipes be large enough; the Surplus of the Length does not increaſe the Height of the Jet, nor the Quantity of the running out, or of the Expence of the Water when you keep the Pipes full.

The Reſervatory being of 26 Foot 1 Inch, the Hole of 6 Lines has ſpouted to 24 Foot, and 2 or 3 Inches; and by the Rule the Square of 24 $\frac{1}{4}$, being 588 $\frac{1}{16}$, as 25 is to 588 $\frac{1}{8}$, ſo is 1 Inch to 23 Inches and a half very near; which ought to be added to 24 Feet 2 Inches, to make the Height of the Reſervatory, which will be then of 26 Foot 1 Inch $\frac{1}{2}$, as is ſeen by the Experiment.

The ſame Height of the Reſervatory, with an Ajutage of 10 Lines, has made the Jet ſpout to 23 Foot 9 Inches; and through an Ajutage of 3 Lines it has ſpouted 22 Foot. In the firſt of theſe

Expe-

Experiments, the deficiency of the Height proceeds from the Ajutage being too large for a Conduit of 3 Inches, and from the Waters having very much Friction by reason of its going too fast in it; and in the second it was the Smallness of the Jet, which having very much Air to pass through was considerably retarded, and its Height diminish'd, as has been explain'd in the first and second Considerations.

The Water of the Reservatory being at 35 Feet of Height, wanting half an Inch, through an Ajutage of 6 Lines, the Jet went up to 31 Feet, 8 or 9 Inches; and by the Rule, the Square of 31 Feet ½ being 1000 very near; and 25 is to 1000 as 1 to 40 Inches very near, that is to say 3 Feet 4 Inches; which being added to 31 Feet 8 Inches, make 35 Feet; so this Experiment is agreeable to the Rule.

For the same Reservatory the Ajutage of 3 Lines has spouted up to 28 Feet; that of 4 Lines 30 Feet; and one of 15 Lines to 27 Feet only, for the same Reasons which have been given; *viz* that in this last Experiment the Pipe of Conduct was not large enough for the Bigness of the Jet and for the Expence of the Water; and in the 2 first, that the Height being great, the Air too much resisted the little Jet of 3 or 4 Lines.

Moreover, I made Experiments with a Reservatory 50 Foot high, and the Jets followed the same Rules, the Ajutage of 6 or 7 Lines made the Jets the highest.

When there is a large Reservatory, as a Barrel of one Foot fix'd to the Top of a Tube of 50 or 60 Feet high, and of 3 Inches Bore; it happens, that when you let go a Jet of 9 or 10 Lines, it does not mount so high as it ought to do according to this

this Height of the Reſervatory; for the Water of the Reſervatory cannot come faſt enough from the Sides, which are diſtant from the Hole, to enter into the Pipe; and there is uſually made a ſort of Funnel, by the turning of the Water, upon the account of the too great Expence of the Water, which is made through the Ajutage join'd to the Friction in the Pipe, as has been explain'd before. From thence there happens an Effect pretty ſurprizing, which is, that when the Jet is gone at firſt to a Height as of 45 Feet, it diminiſhes and goes but to 44 Feet; and afterwards it mounts up again to 46, or to 47, which happens as ſoon as the Air can enter thro' the Hole or Bottom of the Barrel; for then, beſides the Acceleration of the Water which goes faſter, the Height of the Jet is made according to the Height of the Water from the Bottom of the Barrel; and it is no longer kept back by the ſuperior Water: This Reaſon is confirm'd by the following Experiment.

We made a Reſervatory 6 Foot high as ABCD, (*Fig.* 79.) and at a Foot below the higheſt part of it we ſolder'd a Plate within, repreſented by EF, bor'd with a Hole of 8 Lines Diameter in G. We pour'd Water in it till it begun to run thro' the Ajutage D, and we ſtopp'd this Hole filling up the Reſervatory. To do it ſooner, we muſt make a little Hole below F as in K, that the Water entring into the Reſervatory thro' the Hole G, the Air may go eaſily out of it, and ſhut it afterwards, when the Pipe ſhall be full to EF, to be able to fill the Reſervatory even to AB. This Reſervatory being full, we let the Water run thro' the Hole D, and the Jet roſe at firſt up to I, and diminiſh'd by degrees till the Water was below the Plate; and then the Water roſe to K.

The

The Cauſe of this Effect is the ſame as that of the greateſt running of the Water, when one puts a narrow Tube in the Hole of a large Reſervatory: For then the Water runs thro' the Cylinder of Water G L M D, the ſame as if it were a Pipe, the reſt of the Water not having a conſiderable Motion by reaſon of the Plate: But when the Water is below G, and that the Air begins to paſs in it, all the Water E F M is free to act upon D, and it ought to ſpout near to F. The Effect will be ſtill more wonderful, if the Hole D be of 6 or 7 Lines, and the Hole G of 3 or 4; for the Jet will not go higher at firſt than to N, and will decreaſe as far as O, and when the Water above is come down to G, it will riſe up again as far as near to F.

In like manner if there be a Syphon as A B D C, (*Fig.* 80.) which makes the Water of a Bucket E F run (whoſe Surface is I K) thro' B H D C, it will ſpout thro' a little Hole as far as H; and if the Tube were not ſo long, the Jet would not be rais'd ſo high from its Hole at C. But when there is no more Water in the Bucket above A, the Pipe will be empty from A as far as B, and when the Height of the Water ſhall be at B, it will ſpout as far as I, if the Syphon be of 5 or 6 Lines Diameter, and the Bore C be as ſmall as Two Lines, becauſe then the Velocity is given by the Height C B; and at firſt it was given only by the Height C K, and diminiſh'd always, till the Water of the Bucket was below A.

It ſeems it is the Weight of the Water, which occaſions the Jet to riſe that it may be reduced to the *Æquilibrium*; and if one preſs'd the Water which is near the Ajutage by a Weight equal to that of the Water of the Pipe, the Jet would go as high.

Here

Here follows an Experiment which I have made to prove it.

A B C (*Fig.* 8 1.) is a Glaſs Tube of an Inch and a half Diameter, and its Height D A is one Foot, the Ajutage or Bore C is 2 Lines $\frac{1}{2}$; we pour'd Mercury thro' A till the Bottom E F was fill'd with it: Afterwards we put Water gently into the Space C F, after that we ſtopp'd the Hole C with the Thumb, and fill'd the Tube with Mercury as far as A. When we raiſ'd the Thumb from the Hole C, the Water C F aroſe to 12 or 13 Feet very near. The Cauſe of its riſing ſo high is the ſpecifick Gravity of the Mercury, which is to that of the Water as 14 to 1. Conſequently one Foot of Mercury in D A will weigh as much as 14 Foot of Water, which would be a greater Tube, and will make the ſame Effort to make the Water ſpout thro' C. And becauſe a Reſervatory 14 Foot high makes the Water ſpout to the Height of about 13 Foot, one Foot of Mercury ought to produce the ſame Effect.

The like Effects will follow from Weights put upon a Syringe, inſtead of the Weight of the Water or Quickſilver.

Let, for Example, A B C D (*Fig.* 82) be a Syringe of 3 Inches Diameter, having at its Paſſage a Bore of 4 Lines at E, the Piſton is F G, which has a Plate H I below its Handle, to which it is fix'd that the Syringe may be kept upright, the Piſton being juſt within; there is Water poured in to fill from the Height of the Piſton L as far as E. M N, O P, are two Sticks fix'd to the Body of the Syringe, on which we hang Two equal Weights Q and R with Two Cords on each Side of the Syringe. I ſay, that if theſe Two Weights weigh 20 Pounds, the Jet will ſpout thro' E as high, as if a Reſervatory, which

which ſhould have Communication with the Bore E, and whoſe Pipe which contain'd the Water, ſhould be equal in Diameter to the Body of the Syringe A B C D, was high enough to contain the Water weighing 20 Pounds. Now the Pipe being 3 Inches Diameter, it will have 9 Inches Surface, each of which weighs 6 Ounces and $\frac{1}{8}$; there is then 55 Ounces, or 3 Pounds 7 Ounces for every Foot of Height; and if the Reſervatory was 6 Feet, it would be 20 Pounds 10 Ounces; then the Jet would go to about 6 Feet, ſuppoſing that the Friction of the Piſton was but of 10 Ounces: So that if the 2 Weights were 40 Pounds, they would make the Water ſpout to very near 12 Feet; and if they were 100 Pounds, it would ſpout as if the Pipe was 30 Feet in Height.

But if we make a Barrel of Copper G K P H, *(Fig.* 83.) whoſe upper Plate is very thick to ſuſtain a great Force, and that we fix into it a hollow Cylinder I L; the Barrel being filled with Water as far as M N, let there be a Hole O to inject Air into it by means of a Syringe there applied, and a Valve within; And having ſtopp'd the Hole Z, when the Air ſhall be condens'd ſo as to be 4 Times denſer, its Effort will be equal to 4 Times 32 Feet of Water; and if the Barrel was one Foot Diameter, every Foot of Water in Height would weigh 55 Pounds; it would be then 128 Times 55 Pounds or 7040 Pounds. There would be required then the Force of 7040 Pounds to condenſe the Air 4 Times: But the Bore O was a Quarter of an Inch, and the Baſe H P one Foot, the Proportion would be as 1 to 2304, and the Force of 4 Pounds would be ſufficient to make the Air enter till it was of a Strength proportionable to 4 Times this Number, that is to ſay, even to carry the Weight of 9216 Pounds; it would

I carry

carry then as much Weight as that of 128 Feet of Water, and consequently when one should open the Bore Z, the Jet would go near 100 Feet.

And if the Barrel was larger, the Air which would be between M N and K G, would not be more difficult to condense thro' the Bore O, as it has been prov'd in the Treatise of *Percussion*, and it would also make the same Effort to spout to 128 Feet in height, as well a Pipe of the whole Height full of Water.

I made moreover the following Experiment. I took Two unequal Syringes, the one was Two Inches $\frac{1}{4}$ Diameter, and the other $3\frac{1}{4}$; in that of 2 Inches $\frac{1}{4}$ a Five Pound Weight made the Piston descend when it was empty; and having fill'd all the Syringe, and pushing the Piston with a Force which was very near equal to 12 Pounds, I made the Water rise thro' a Hole of 8 Lines to 4 Feet very near. Now one Foot in Height of the Pipe of the Syringe is very near equal to 32 Ounces or 2 Pounds, and 4 Feet are equal to about 8 Pounds. If then the Effort was 13 Pounds, taking away 5 Pounds for the Friction of the Piston, there remain'd 8 Pounds for the equivalent Weight of the Water of a Reservatory of a little more than 4 Feet high, and of 2 Inches and $\frac{1}{4}$ Diameter. The other Syringe did the same in Proportion.

If we push'd the Piston A B K I (*Fig.* 84.) into the Barrel of the Pump C D F E, which is narrower towards the Top, and as we see in the Figure at I H, the great Friction of the Water along the narrow Pipe G I H, stops considerably the Force of the Impulse to make the Water contain'd in A B E T pass out, and it would pass better if that Conduct went only to I, and much better if the Conduct was larger than the Barrel of the Pump where the

Piston

Piston plays as L M N O, which it will be necessary to consider when one raises Water by Pumps to great Heights.

In short, we may carry a Jet very high according to the following Method. Have a Cylindrick Vessel of Copper A B C *(Fig.* 85.) round at the Top about Two Foot in Height and 8 Inches Diameter, and fix'd firmly and close upon a Plane of Wood or Iron, &c. Have on the Side a Syringe or Barrel of a Pump D E F with its Piston Q N, and a Sucker or Valve at the Bottom, as one usually makes in Pumps, and let the Piston in going down with the Force of one or Two Men, make the Water by its Pressure to enter into the Vessel thro' the Pipe G H furnish'd with a Sucker at H, as has been taught in the Beginning of this Treatise: Fix to the Side of the hollow Cylinder or Vessel another Pipe I L, curve towards the Top, where there is an Ajutage of 12 Lines at its Extremity L; if we fit afterwards to the Two sides of the Vessel two other Pumps like this, we shall be able to make a great Quantity of Water go in this Vessel. The Pistons may be fix'd to Ends of Levers as N to have more Force, being fix'd to the *Fulcrum* or Center of Motion at O. When you make the Pistons play by means of the Levers, the Water will go into the Vessel A B C, and pass at first into the Tube I L with a moderate Force; but in continuing to work, we shall force in so much Water, that it will not be able to go out all thro' the Ajutage L; then it will rise as far as P, and condense the Air inclos'd in the Top of the Vessel; and if we still send up the Water with more Force, it will rise up higher, as to R, condensing the Air more and more: And when it shall be condensed 8 Times more than usual, it will press the Water R S H I to make it go out thro' K, as if there was

7 Times

7 Times 32 Feet of Water above H I, that is to say 224 Feet, which would make a Jet of Water thro' the Ajutage L of more than 120 Feet in Height. But it is necessary that the Three Pumps should furnish Water enough; for the Ajutage L of 12 Lines will waste more than 64 Inches of Water.

The Air being condens'd in proportion to the Weights with which it is press'd, if we make a Machine A B (*Fig.* 86.) compounded of a Trunk E F G H, full of Water as far as the Line I L, a little below E F; and a Pipe M N, which is well solder'd at M and O to the 2 Plates E F, G H, which make the Top and Bottom of the Trunk, to hinder the Air from going into it; the Trunk E G will serve for a Reservatory.

It is necessary, however, that there should be another Trunk equal to the first, as C D T K, full of Air, to which the Pipe M N may be solder'd. When we pour the Water thro' M, it will go down thro' N, as far as to K T; and being risen up as far as P Q, the Air contain'd in the Space Q P C D, and in the Pipe X Y, open at X, and well solder'd to the Two Trunks, will not be able to go out thro' A; and will be condens'd by degrees, till there be made an *Æquilibrium* between the Weight of the Water in M N, and the Spring of the included Air.

For Example: If the Water be rais'd to R S, the Air contain'd in the Space C D S R, in the Pipe X Y, and in the Space E I F L, will be condens'd by the Weight of the Water M S, and will press the Water I H G L: Then if we open the Ajutage A, whose Pipe descends near to H G towards V, the Water will spout to the Height A Z, equal to very near the Height M S; because the Air press'd by the Height of the Water M S, makes the same Effort upon the Water I G, as if the Pipe M S, full of Water, was above the Water I L: And the Water which ſhall fall from the Jet paſſing thro' M, will re-enter into the lower Trunk; and by this means the Jet will laſt till all the Water, which reach'd from the Extremity V of the Pipe A V, to the Extremity Y of the Pipe X Y, be gone out in ſpouting.

This Machine is call'd *Fons Heronis*, or *Hero*'s *Fountain*; which he deſcrib'd in his Treatiſe entitled *De Spiritalibus*, according to the Tranſlation of *Commandinus*.

We may make this Water ſpout much higher, by increaſing the Height of the Pipe M N.

The Beauty of Jets of Water conſiſts in their Uniformity and Tranſparency, at the going out of the Ajutage, without ſpreading but very little, and that to the higheſt Part of the Jet. We have try'd ſeveral ways of making the Ajutages; of which there are ſome which ought to be preferr'd to others, for ſeveral Reaſons. The worſt Sort are thoſe which are Cylindrical; for they retard very much the Height of the Jets: The Conic retard it leſs. But the beſt way is, to bore the Horizontal Plane, which ſhuts the Extremity of the Pipe of Conduct, with a ſmooth and poliſh'd Hole; taking care that the Plate be perfectly plane, poliſh'd and uniform.

Here follow ſome Experiments, that I have made relating to this.

Having a Pipe of Tin, A B C, of 15 Feet in Height; and having bor'd it in D with a Hole of 3 Lines, the Jet was perfectly fine, and went 14 Feet: But the Pipe having been made higher, even to 27 Feet, and having made in it a Hole of 6 Lines, the Jet went but 12 Feet, ſpreading very

very much, and dividing it ſelf into ſeveral Drops; becauſe the Water which ſupply'd the Jet was thrown acroſs with Force, as we ſee in the Second Scheme of the Figure, which repreſents the Part B C of the aforeſaid Pipe. For the Water E D and F D, which comes thro' the Sides, hath a great Velocity croſs-ways, which carries it to D L and D M; and G D is carry'd to D N, and H D to D O, which makes the Jet ſpread: Becauſe the little Water which comes directly from P to D, is not ſufficient to make the Jet upright again.

To remedy this Inconveniency, I caus'd an Ajutage of an Inch long, and one Inch Bore, to be fix'd to D, as we ſee in the 88th *Figure*; where BCD repreſents the Part BCD of *Fig.* 86: We bor'd the little Pipe with a Hole of 6 Lines, making DQ riſe to Q; then the Jet was finer, and roſe 3 or 4 Feet higher.

Afterwards I caus'd the End of the Conduct Pipe to be made, according to the Curve Figure ILMNOP, in the 89th Fig. the 1ſt Scheme; and in the Plate QP, I caus'd an Ajutage to be made like the 2d Scheme: It was a little Conick. But there was an inward Plate, repreſented by E Q, which left a Hole of one Inch in the Middle; and the upper Plate AIB was bor'd in I, in the Middle, with a Hole of 6 Lines; which was made, that there might be no Friction but in the Plate E Q within; for there could be but very little in E A and BQ. But that ſucceeds very ill: For the Jet went not ſo high, and ſpread more than it had done thro' a plain Conic Ajutage, which might proceed from the different Motions of the Water; which having paſs'd thro' Q E, ſtruck the Plate A B with Violence on the Side of its Hole, and being reflected, hinder'd the Remainder of the Water

 from

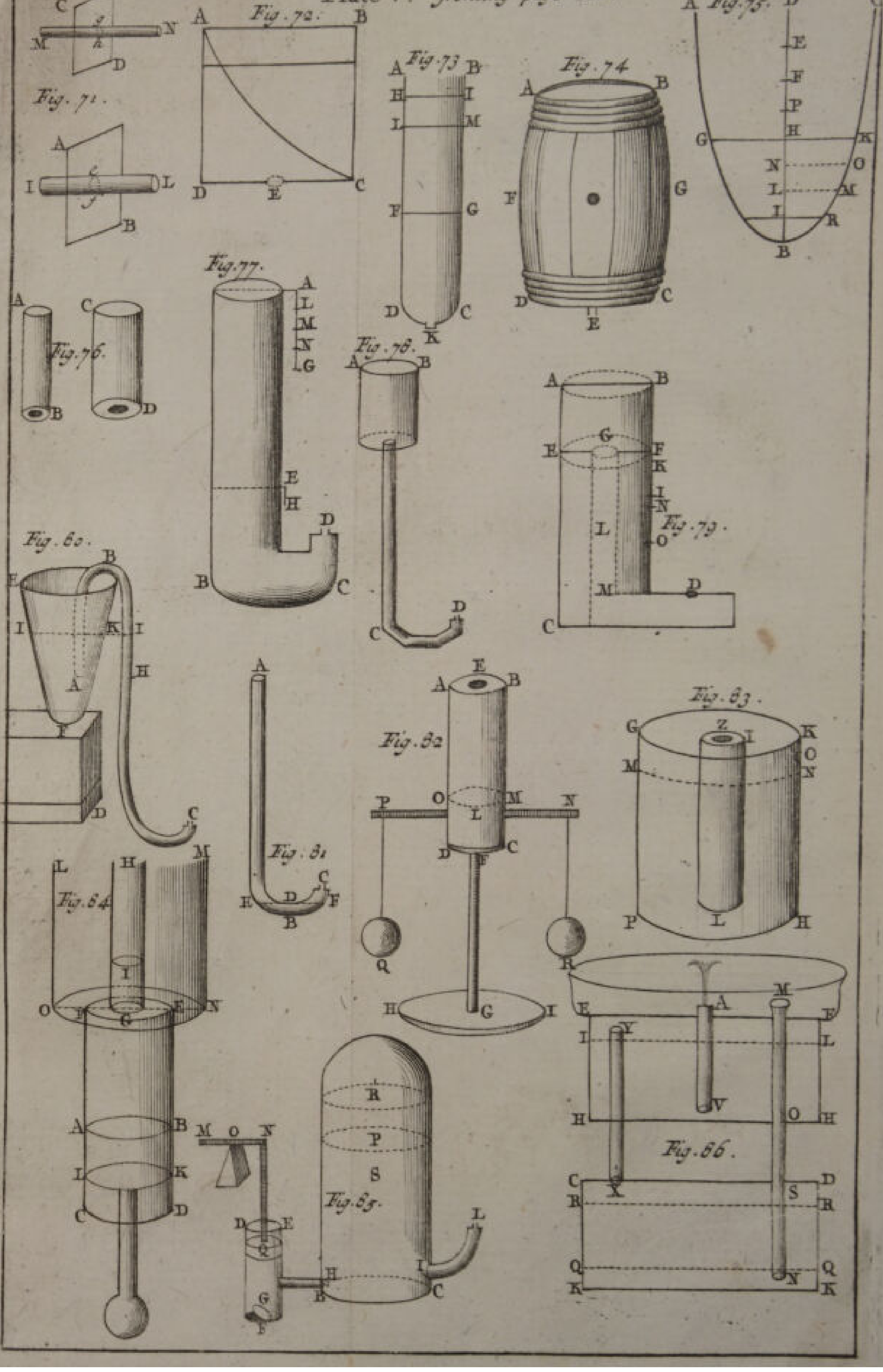
from going out ſtreight. At laſt I caus'd a Plate to be made well poliſh'd in P Q, bor'd with a Hole of 6 Lines very round, and poliſh'd: Then the Jet was very fine, and roſe 32 Feet; the Reſervatory being 35 Feet 5 Inches, whereas the other Jets roſe but to 27 or 28 Feet: Which happens, becauſe the Water takes the Direction of its Motion from R, and that there comes very little of it laterally from the Sides Y and Z, which however contributes to the Direction of the Jet; the Plate being well poliſh'd, and the whole being equal on the one Side and the other, and ſtopping equally the lateral Motion one of the other. Now the Jet roſe thro' this Ajutage 22 Feet without being ſeparated, unleſs in falling down again; and was ſtopp'd very little at the Top, when it went 32 Feet, and much leſs than thro' the other Ajutages.

I have ſeen a Plate bor'd with a Hole of 4 Lines, and 6 or 7 little ones about, which made a kind of Wheat-Sheaf; all the Jets of which were very fine and tranſparent, and that of the Middle roſe 18 Feet.

The Jets widen neceſſarily in Proportion as they riſe; the Reaſon of which is, that they loſe their Velocity by degrees: And becauſe it is the ſame Water, which by reaſon of its Viſcouſneſs keeps united without ſeparating; it muſt needs take up more Room in the Place where it goes leſs ſwift, according to the Proportion of the Velocity in one Place, to the Velocity in another.

For the ſame Reaſon, the Water which runs thro' a Hole of 5 or 6 Lines, when it is in the Reſervatory only at the Height of 3 or 4 Inches, goes always narrowing, till it is reduc'd into Drops, when the Thread of Water is become too ſmall. For there ought to be only the ſame Quantity

Plate V. *fronting page 212.*



tity of Water in all the Spaces that it runs thro' in falling; which in equal Times are to each other, as the odd Numbers in their Series; from whence we ſee, that the Thread of the Water would become at laſt finer than a Hair. But before it comes to this, it is ſeparated and divided into Drops, which always accelerate their Motion, till they have acquir'd their greateſt Velocity.

We muſt not regulate the Expence of the Water by the Height of the Jets, but by the Velocity of its going thro' the Ajutage. Now in the Ajutages of one Line, or of two Lines, the Jets do not go ſo high at the ſame Height of the Reſervatory, as thoſe of 5 or 6 Lines; and nevertheleſs they ſenſibly give Water in Proportion to their Bores, as we have ſeen.

To know the Cauſes of theſe different Effects, we muſt conſider, that the little Globules are to the great ones in a Triplicate *Ratio* of their Diameters: But they are retarded in their Motion by the Air, according to the Surfaces of their great Circles; and they force that Reſiſtance of the Air, according to the Differences of their Weights, as has been explain'd before. From whence it happens, that if we ſhoot a Muſket charg'd with Balls, and with ſmall Shot; the Balls will go farther than the ſmall Shot, tho' they go out of the Muſket with the ſame Velocity, as we have explain'd.

The ſame Thing ought to be underſtood of the ſmall and great Ajutages, which have the ſame Height of Reſervatory: For tho' at the going out of the Ajutages, they go within a little near as faſt one as the other; when they paſs thro' very much Air, the ſmall Jets are retarded from their going out to their greateſt Height, much more in

Proportion than the great Jets; and consequently the great ones will go much higher than the little ones; but they will not give more Water in Proportion, or at least much more; since it ought to be esteem'd only by the Velocity which the Jets have at their first going out of the Ajutage, which is within a little nearly equal in the little and great Ajutages.

When we have a Jet of Water supply'd by a sufficient Quantity of Water, and that we bore the Pipe of Conduct with a Hole equal to that of the Ajutage, to make use of the Water which goes out from it; we shall find the Diminution of the first Jet after this manner.

Let ABCD (*Fig.* 90.) be a Reservatory 13 Foot high above the Ajutage H of 6 Lines Bore; the Jet ought to rise about 12 Feet and a half, if the Conduct be 3 Inches Diameter. We make a Hole in I of 6 Lines, from whence the Water IE goes out: The Jet HM spends 4 Inches of Water, by the Rules which have been given. And because there ought to go out near as much thro' the Hole I, the Conduct is too narrow to give the same Height to two Jets equal to HM: Wherefore as soon as we let the Water IL run out, the Jet HM will diminish a little; And because the two Holes H and I give very near 8 Inches, and that the Water NO, which supplies the Water in the Reservatory, is but 4 Inches by Supposition, the Reservatory will be empty'd by degrees, if it be very spacious; and very quickly, if it contains but Half a Barrel, or 100 Pints. The Water then must needs descend in the Pipe, till the Jet HM gives but 2 Inches: For then the Hole I giving also 2 Inches, all the Water NO will be employ'd. Now 13 Feet is to its Half $6\frac{1}{2}$, as $6\frac{1}{2}$ to $3\frac{1}{4}$; there-

therefore the Height of the Water being P Q of 3 Feet $\frac{1}{4}$ above H, the Jet will only riſe to 3 Feet, 2 Inches, and ſome Lines, according to the Rules beforemention'd: And conſequently, we ſhall ſee the Jet H M decreaſe, till it riſes no higher than 3 Feet, 2 Inches, and ſome Lines; and the Water N O will keep up the Height of the Water, to the Height Q P.

And if we ſtop the Hole I, the Jet thro' H will begin to increaſe, till it comes to H M; and at the ſame time the Water of the Conduct will riſe above B, till it is in the Reſervatory A H, at its firſt Height. We ſhall obſerve the ſame Rules in other Caſes of the like Nature.

If the Heights of the Reſervatories were very great, the Jets would be diſſipated by their violent Impulſe againſt the Air; and inſtead of ſpouting higher than the Jets of ſome Reſervatories not ſo high, they would very much fall ſhort of them.

I made the following Experiments for that Purpoſe.

EXPERIMENT I.

I charg'd a Croſs-Bow with a ſmall Pipe of an Inch Diameter, and 6 Inches long, held faſt in the Notch of the String; and having bent it, we rais'd it perpendicularly, and fill'd the little Pipe with Water; the Water being impell'd by the Force of the Bow, went out, and meeting with the great Reſiſtance of the Air, was very much diſpers'd. Thoſe that ſtood by did not ſee the Jet mount; but ſaw a great many ſmall Drops fall down, ſpreading to the Circumference, of above 20 Foot round him that held the Croſs-Bow; who affirm'd, that he ſaw the Water mount to about 30 Foot. Now this Velocity agrees with a Reſervatory of more than 600 Foot, whoſe Jet ought to be 300, according to the Rules.

EXPERIMENT II.

I caus'd a Piſtol to be charg'd ſeveral Times with 4 Inches of Water, inſtead of Bullets; which Water being ſhot againſt a Door at 20 Foot Diſtance, elevating the Piſtol to an Angle of about 45 Degrees, to prevent the Water's falling; there did not ſo much as one Drop reach the Door. I caus'd it to be ſhot a ſecond Time, at 10 Foot Diſtance; but 'twas ſtill the ſame: And when the Perſon that ſhot advanc'd, and look'd directly up, he felt little Drops of Water fall upon his Face. Then again we ſhot it againſt a Piece of Paper, plac'd at the Top of the Door, at 7 Foot Diſtance; and the Paper was all wet: Therefore we found, that the Water diſpers'd it ſelf to 2 Foot Diameter: For having ſhot another Time at 8 Foot Diſtance, the Paper was not wet. Now if we calculate this Water as a Cylinder of 5 Lines Diameter, and 4 Inches long, and divide the Product by a Surface of 2 Feet Diameter; we ſhall find, that its Thickneſs will not be above $\frac{1}{70}$ of a Line. For the Solid of the Square of 5 by 48, is 1200; and the Solid of the Square of 188 Lines by $\frac{1}{70}$, is a little leſs than 1200 Cubic Lines; and the exact Cylinder is 943 Cubic Lines, and that which has 2 Feet Diameter for its Baſe, is 931. It happens then that the Water being reduc'd again to a much leſs Thickneſs, as when it was ſhot from a 10 Foot Diſtance, it ſeparated into little Drops; ſome of which roſe up in Vapours, and the reſt fell down again; but they are imperceptible.

We

We ſee the ſame Effect in the breaking of a Bubble of Soap'd Water: For thoſe Particles of Water that are too ſmall, riſe up in viſible Vapours, and the others fall down.

A Thread of Water coming out of a Hole of Half a Line, by a Preſſure of Water from 100 Feet high, meeting with the Hand in ſpouting aſlope, was alſo turn'd into Vapours.

It may be objected, perhaps, that if Water was ſhot out of a Cannon of a Foot Bore, the Water would go much farther than 10 Feet; I grant it. But it will not go 100 Feet; as may be prov'd, and experimented.

Now this Velocity is ſo great, that no acceſſible Reſervatory can produce the like. For ſince the firſt Velocity of the Water that ſhould go out of it, will go 1000 Feet in a Second, as Sound does; let us ſuppoſe the Reſervatory to be 10000 Foot high; and that the Velocity of a Globe of Water of a Foot, ſhould be ſuch as to make it fall 13 Feet in a Second; it would go 26 Feet horizontally: The Product 13 multiply'd by 10000, is 130,000; the Square Root of which is about 360: As 13 is to 360, ſo is one Second to 28, or very near.

If we ſuppoſe then that a Globe of Water of a Foot, accelerates according to the Series of the odd Numbers, which it only does for a ſmall Diſtance; it will fall 10000 Feet in 28 Seconds, and go 20000 Feet horizontally, with an uniform Velocity, equal to the Velocity acquir'd in 28 Seconds; and in one Second about 714 Feet, which is a Velocity leſs than that produc'd by the Powder in the Cannon. But as there is no acceſſible Place of 10000 Feet high, ſo we cannot ſee the Effect of ſuch Water Jets. Beſides, this Height of 10000 Feet

Feet ſhould give from a Hole of 1 Foot almoſt 4512 Inches, which would make too conſiderable a River to be at ſo great a Height.

We muſt then conſequently believe, that the greateſt Jets will not go 300 Foot; for the Reſervatory being about 600 Foot high, the Jet ought to be about 6 Inches Diameter, and the Conduct ought to be 20 Inches Diameter, and it ſhould give 16128 Inches, which is yet too great a Quantity of Water; and therefore it ought to be reduc'd to 100 Foot high, and about 12 or 15 Lines Ajutage; for tho' it ſhould riſe quite 150 Foot, it would ſcarcely then appear higher to the Sight at 20 Foot Diſtance.

DISCOURSE II.

Of the Height of oblique Jets, and of their Amplitudes.

THE Jets that ſpout horizontally, or obliquely, as in the 91ſt Figure, deſcribe a Curve Line, which is a Parabola, or a Semi-parabola, of which *Toricelli* has given us the Demonſtration after *Galilæo*; but we muſt abſtract the Reſiſtance of the Air; yet if the Jets are feeble, the Curve Line will always be ſenſibly a Parabola, by reaſon that the Air reſiſts to a ſmall Velocity, and that the Acceleration of the Velocity of the Drop that falls, or the Diminution of that which ſpouts, is made ſenſibly according to the odd Numbers. And likewiſe in the midling

ling Velocities of Jets, their Curvity comes very near to a Parabola; because if on one Side, the horizontal Direction be retarded by little and little, and does not go with an uniform Motion, the Acceleration also will not go according to the odd Numbers at the End of the Fall, but will be retarded by the Resistance of the Air, as I have explain'd before: And thus one of the Defects recompences the other, as we see in Fig. 91, where the true Parabola is A B C, if in 3 small Intervals of equal Time the moving Body runs horizontally over the 3 equal Spaces A E, E G, G D, and that it runs over A I in descending the first Time; I M, which contains 3 times A I in the second Time; and in the Third M N, which contains 5 Times A I. But if the Resistance of the Air, instead of its going to D, should make it go no farther than H, then in these 3 Times also the Resistance of the Air will hinder it from descending in the same Time to N; therefore it will go no further than K, and by drawing the Parallel K L, which will cross H F at L, a little within the Curve A B C: The Curve Line A O L, which will be describ'd by this Motion lessen'd in Proportion (which is not true, however strictly speaking) will be another Parabola within the first A B C. From this Property of Bodies that move in the Air, we did deduce the following Problems.

PROBLEM.

The mean Height of a Reservatory being given, and the Jet being oblique, to find where it will fall upon an horizontal Plane.

Let A B (*Fig.* 92.) be the Pipe of the Reservatory, C the Ajutage, C D a Line Parallel to A B,

DEC

DEC a Semi-circle, of which H is the Center. *Galilæo* and *Torricelli* have demonſtrated, that if the Direction of the Jet coming out of the Ajutage, is in the Line C E, which ſhould make the Angle D E C, with the perpendicular D C, of 45 Degrees; having continued H E, perpendicular to D C, to F, ſo that E F be equal to H E half the Diameter of the Circle, the Point F will be the Vertex of the Parabola E F G, deſcrib'd by the Jet; as is ſeen in the Figure; C E will be the Tangent of that Parabola at the Point C, and C G the Amplitude of the Parabola, and the Double of H F or C D.

If another Direction is given to the Jet, as C L, you muſt let fall the perpendicular L M, upon C D; and M L N being the double of M L, the Point N will be the Vertex of the Parabola, which will be deſcrib'd by the Jet, of which C R will be the Amplitude equal to twice M N, and the ſame in reſpect to the other Directions. From whence it follows, that if the Angle L C E is equal to the Angle E C O, the Jet, with the Direction C O, will go as far as with the Direction C L; and Q O P being equal and parallel to M L N, P will be the Vertex of the Parabola of that Jet, and they will meet in the horizontal Line C G, at the Point R, becauſe their Amplitude, the Quadruple of M L, or the Double of M N, will be common to both.

The Jets of Bombs full of Powder follow the ſame Rule; from whence it follows, that if it has been found by Experiment, that a Bomb, whoſe Elevation is about 45 Degrees, goes about 500 Fathom in Length or Diſtance, it will go perpendicularly 250; for if C G be 500 Fathom, and the Bomb has deſcribed the Parabola C F G, it will riſe but to the Height C D, which is the Diameter of the Semi-circle, which conſequently will be 250 Fathom,

Fathom, which is half the Amplitude C G, of the Parabola L F G; but you muſt conſider, that the Reſiſtance of the Air alters theſe Meaſures a little: For there is more to be gone thro' by C F G, than C D; ſo that the Bomb will go a little nearer in Proportion to the Point D, than to the Point G. And for the ſame Reaſon, if the Direction of the Bomb was C L, and it fell at the Point R, it would go a little farther in the Direction C O, becauſe there is more Air to beat thro' in the Parabola E N R, than in that of C P R. Here follow the Experiments that I have made with Water, which muſt be more retarded by the Air than a Ball of Iron, or a Bomb.

In the foregoing Figure, ſuppoſe A B C to be a Pipe of 6 Foot high from the Surface of the Water at the Height D in the Reſervatory, to the Ajutage C, the Direction of the Jet C F G was of 45 Degrees above the Horizon; and by what has been already ſaid, C G, which was the Amplitude of the Parabola, ought to be of 10 Foot; but the Jet erred towards the End, and that which came the neareſt to 10 Foot, reach'd to 9 Foot 10 Inches, and conſequently the Jet wanted but $\frac{1}{60}$, that is, 2 in 120. But having made the Experiment upon greater Heights of Water, the Jet diminiſh'd more of its Amplitude in Proportion, by reaſon of the great Reſiſtance of the Air; and that Diminution ought to be in Proportion to that of different Heights of the Jets, and ſo we muſt take the Double of the perpendicular Height of the Jets, to know the Amplitude of the Parabolical Jet at the Elevation of 45 Degrees.

Jets of Quickſilver have the ſame Effect, but their Ends ſcatter more than the Jets of Water; the Reaſon of which is, that the upper *Mercury* B F (*Fig.* 93.) ſlides upon the under C E D, by its rubbing

bing againſt it; and on the contrary, the *Mercury* which is at E, deſcends by its own Weight, and by the Shock of that which is uppermoſt, which is the Reaſon that the Drops of *Mercury* are much ſeparated from one another between D and F, and from the Top to the Bottom; but they don't widen in Breadth. And if you place your Eye in the Plane of the Direction of the Jet, it will appear like a Stream all of the ſame Bigneſs which it had when it went out at the Ajutage; becauſe, not opening when it goes out, the Drops which are neareſt the Eye, cover all thoſe that are under in the whole Extent of the Jet.

To prove by Experiment that the moſt heavy Bodies make their Parabola's greater, I ſuſpended a Ball of Steel to a Thread of 42 Inches, or 3 Foot ½ long; and having raiſed it by an Arc of 50 Degrees, I let it go; it returned, after having riſen on the other ſide to 49 Degrees 45 Minutes; the Arc of the 25 Minutes which were wanting, was 6 Lines broad, and conſequently it loſt but nearly a Line and a half in falling to the Point of Reſt. I us'd afterwards a Ball of Wax of the ſame Bigneſs, with a little Weight within; ſo that its ſpecifick Gravity was as that of Water; and having raiſed it to 40 Degrees, it returned, wanting 4 Inches at the Second Vibration: It loſt then 8 times as much by the Reſiſtance of the Air, as the Steel Ball, which is nearly in Proportion to the ſpecifick Gravity of Water to Steel.

When in a Pipe the Holes are higher one than another, and the Jets horizontal, one may know the Length of the Jets by the ſame Rules in the following manner.

Let A B C D (*Fig.* 94.) be a Cylindric Veſſel, or of another Form, having Holes made at F and at G, the

the Water being always kept at the Height A B; H I is an horizontal Plane, and you have a Mind to know where the Jets F and G will fall upon the Plane H I. We ſuppoſe that the Side of the Pipe B F G H, in which the Holes F and G are made, is perpendicular; upon the Line B H for a Diameter, having deſcribed the Semi-circle B L K H, let there be drawn F L and G K, Perpendiculars to the Line B H, as far as the Semi-circle at L and K; and having made H I double of G K, and H M double of F L, the Jets will deſcribe the half Parabola's G I and F M, as has been already ſaid; from whence it follows, that if N be the Center of the Semi-circle, the Jet that ſpouts out at N will go the fartheſt of all, becauſe the Line N O, which is half the Diameter, is the greateſt of all the Ordinates, as I K, F L: And if you take equal Heights above and below N, the Jet will fall at the ſame Point upon the horizontal Line H I.

If you have a mind to know what Height the Water ſtands at in a Veſſel or Reſervatory A B C D, you muſt make a Hole ſomewhere or other, as at G; and having marked ſome Point I, thro' which the Jet paſſes, let the Line H I be drawn Level thro' the Point I, and thro' the Point G, the Line G H, perpendicular to I H. Having cut off H I in two equal Parts, of which one half is G K, let there be found the Line G B, the third Proportional (in continued Proportion) to G H and G K; the Line G B is the Height of the Water in the Reſervatory above the Opening G, which is but the Converſe of the foregoing Proportion; as it is eaſily ſeen, if you ſuppoſe that the Height of the Reſervatory above the horizontal Plane H I, be H B, and the Hole of the Jet be at G; for according to the Elements of Geome-

Geometry, because of the Semi-circle, the three Lines G H, G K, and G B, are in continued Proportion; which agrees with what *Galilæo* hath demonstrated in his 3d Proposition of the Motion of Projectiles; where he says, that half the Amplitudes of the Parabola's of the Jets are mean Proportionals between the Height of the half Parabola, and the Height of the Liquor above the Opening of the Jet.

PART

the great Hole M roſe to the leaſt Height, that at N a little higher, and the little one K the higheſt of the Three. 'Twill not be difficult to know the Reaſon of theſe Effects if you conſider that a great deal of Water goes out at the Holes L and M, and that to ſupply it the Water muſt go faſter thro' the narrow Tube than thro' the wide one, which cauſes a conſiderable Friction that retards the Velocity of the Water, and hinders it from running faſt enough to ſupply the Ajutage. But in the Holes H and K, as the Velocity thro' the Pipes is 16 Times leſs than when the Water goes thro' L and M, the Friction in the narrower Pipe is inconſiderable, and does not ſenſibly retard the Jet K more than the Jet H, and they both riſe pretty near to the ſame Height: It follows likewiſe, that if you diminiſh the 2 Holes I and N, for Example each of them a Line, then the Jet thro' I will not riſe ſo high as it did, and that thro' N higher; becauſe there will be leſs Friction in the Pipe F G, that overcomes the Defect from the Air's Reſiſtance; and in the Pipe C E this Diminution of Friction will not be conſiderable, but the Reſiſtance of the Air will be a little greater than in that of 4 Lines; this it is that has deceived ſeveral Perſons that have made their Experiments in narrow Pipes as F G; and they with the greateſt Part of the Fountain-Makers have concluded that Water roſe higher thro' narrow Ajutages than thro' wide ones; which is contrary to Reaſon and Experiment if the Pipe of Conduct be not too narrow.

The ſame Thing happens when the Ajutages are 6 or 7 Inches long, or even 2 or 3 Foot, the Jet will be higher thro' a plain Hole in a Plate not above a Line or a Line and a half thick. The Experiment will be eaſily made, if you have a Pipe of 6 or 7 Inches Diameter, as A B C D (*Fig. 96.*) and

and in the Pipe E F of a ſufficient Bore, 2 equal Holes be made at G and at H; the firſt having the Ajutage G I, and the other only the Thickneſs of the Metal: For you will ſee that the Jet thro' H will go much higher than thro' G I, and the more you diminiſh the Height of I G, the nearer will its Jet riſe to that of H: Whence it follows that the long Ajutages that are commonly put to the Mouths of Dolphins in Fountains are very defective; and tho' the Ajutage ſhould be a little conical, the Jet will ſtill be retarded; of which take the following Experiment; A Glaſs Pipe a Foot in Height and an Inch Diameter, having a Hole of Two Lines and a half, ſpouted only 10 Inches $\frac{1}{2}$ high, when there was a little Cone in it; but when it was made without a Cone it ſpouted 11 Inches and $\frac{1}{2}$.

To regulate the Diameters of Pipes of Conduct according to the Height of the Reſervatories and the Bigneſs of the Ajutages, I made the following Obſervations.

At *Chantilly* there is a Conduct Pipe made of Pieces of bored Oaks; the Bore is 5 Inches Diameter. The Height of the Reſervatory is 18 Foot, and the Slope of that Pipe to the Horizontal Canal is near 104 Fathom. Having cauſed the Water to be taken out of the Canal, I pierced one of the Pieces of Oak at Top, and put an Ajutage of 10 Lines in it, the Water being kept in at the Bottom, the Jet roſe 15 Foot, ſo that the Length of the Pipe and the Ajutage was ſome little Obſtruction to it, for according to the Rules it ought to ſpout near 17 Foot. I put another Ajutage 80 Fathom lower in the ſame Pipe which I made to ſpout alone, and it did not riſe quite 14 Foot; which may be attributed to a Defect in the Ajutage, which was not made ſo well as the other. I afterwards let the Two Ajutages ſpout together, and the Jet neareſt the Top went but 12 Foot, and the other but 11; which ſhewed that a Pipe of Conduct 5 Inches Diameter is not ſufficient for an Ajutage of 14 or 15 Lines at this Height of the Reſervatory, or for Two of 10 Lines each.

I ſtopp'd the Holes and let the common Jet ſpout which is on the ſide of the Canal, and rais'd 2 or 3 Foot higher, at the ſame Diſtance from the Reſervatory as the laſt Hole; the Reſervatory was not quite 16 Foot high above the Ajutage which was conical, and 12 Lines in Diameter; it ſpouted about 14 Foot; whereas according to the Rules it ought to have ſpouted a little higher than 15 Foot; which proceeded without doubt from the Ajutage being made Conical, as has been demonſtrated.

I made other Experiments with the Pipe of 50 Foot beforemention'd, with a Ciſtern at the Top a Foot high: I fix'd at the Bottom of it an horizontal Conduct Pipe, of the ſame Breadth of 3 Inches, and 40 Foot long; at the End of which I put an Ajutage of 6 Lines, and the Jet roſe as high as when it was but a Foot from the deſcending Pipe; the Jet likewiſe produced the ſame Effects, namely, after having ſpouted at firſt to a certain Height, it dimiſhed it by little and little about a Foot; and the Water being got to the Bottom of the Ciſtern, the Jet roſe again and went a little higher than at the Beginning, and thus an horizontal Pipe 40 Foot long and 3 Inches Diameter, did not diminiſh a Jet whoſe Ajutage was 6 Lines.

It has been found alſo by Experiment, that an Ajutage of 7 Lines did not ſpout leſs high, than that of 6 Lines, at 35 Foot from the Reſervatory, with a Pipe of Conduct 3 Inches Diameter, and ſo that a

Pipe of 3 Inches might have 52 Foot in Height for an Ajutage of 6 Lines: It may then be taken for a fundamental Rule, that a Reſervatory of 52 Foot ought to have a Conduct Pipe of 3 Inches Diameter, when the Ajutage is 6 Lines; and that the Jet will riſe to the greateſt Height that it ought to have.

To compare the Breadth of this Conduct Pipe, with that which Reſervatories ought to have, and the Breadth of the Ajutages, make uſe of this Rule for Proportion.

As the Number of Inches which one Jet gives, is to the Number of Inches which another Jet gives; ſo is the Square of the Diameter of the Conduct Pipe of the Firſt, to the Square of the Diameter of the Conduct Pipe of the other.

This Rule is founded upon this, That the Velocity of the running Water be equal in both Pipes, that there be no more Friction in one than the other. But if the Number of Inches be Quadruple, the Section of the Bore of the Conduct muſt be four Times greater, that the Velocity in the Pipes may be equal.

According to this Rule, if you would know what Diameter you muſt give your Conduct Pipe, to have a Jet of 100 Foot thro' an Ajutage of 12 Lines you muſt take a Height of 52 Foot, which thro' an Ajutage of 6 Lines, having the Pipe 3 Inches Diameter, gives 8 Inches; and that becauſe of the Table of the Heights of Jets, the Reſervatory of a Jet of 100 Foot, ought to be 133 Foot $\frac{1}{3}$, you ſay that as 52 is to 133, ſo 64 the Square of 8 is to 170; and the Square Root of 170 being 31 pretty near, you ſee that a Reſervatory of 133 Foot thro' 6 Lines will give 13 Inches, and thro' 12 Lines of Ajutage 52 Inches of Water. Then as 8 is to 52, ſo 9 the Square of 3, which is the Diameter of the Pipe, ought to be to 58 $\frac{1}{2}$ whose Square Root is 7 $\frac{2}{3}$ pretty near; which will be the Diameter of the Pipe that was sought, but for greater Security you may give it 8 Inches.

When the Ajutages are unequal, and the Heights of the Reservatories equal, you have no more to do than to make the Diameters of the Pipes in the same Proportion to one another, as the Diameters of the Ajutages; for then the Frictions will be equal, and the Water will go faster into one of the Pipes than in the other, of which you have this Example.

A Pipe 13 Foot high gives one Inch thro' 3 Lines; then thro' 6 Lines it will give 4 Inches; and consequently if the Pipe continued of the same Bore the Water wou'd go 4 Times faster and wou'd have 4 Times as much Friction; to make it go as fast as then, the Square of the Diameter of the Conduct Pipe must be 4 Times greater, and then the Root of this Square will be to the Root of the other as 6 to 3.

There happens an Effect surprizing enough in the Conduct of some Pipes at *Chantilly*.

These Pipes that are of Wood thrust one into another pass thro' a little Pond, and afterwards thro' a long Canal; whence it happens that if you shut the Entrance of the Reservatory all at once, and the Water no longer runs in the Pipe of Conduct, this Jet of 14 Foot does not quite cease, but still continues to spout above 2 Foot; supposing the Entrance of the Reservatory to be close shut, this Effect might be attributed to this, that the Water running off with great Velocity, the Weight of that of the Pond, and the Canal, makes the Pipes that go one into another open a little, and there is a little Aſpiration or ſucking in of the Water; as there is a ſenſible Expiration of Air, when this Pipe of Conduct being empty, you let the Water from the Reſervatory into it all at once; for then the Air being preſs'd, forces the Pipes, and makes a ſmall Paſſage between thoſe that are thruſt one into another. But the Aſpiration or ſucking in of a little Water from the Pond and the Canal, is great enough to ſupply this Jet of 2 Foot.

There is likewiſe another extraordinary Effect obſervable in the ſame Jet, which is this, if you put your Hand upon the Ajutage and hold it there 10 or 12 Seconds, the Water does not ſpout immediately after you take away your Hand, but begins by little and little to riſe to 3 Inches, then to a Foot, and afterwards to 2 ſucceſſively for a conſiderable Time, I ſaw the ſame Effect in Water that ran horizontally thro' a Copper Pipe: For having ſtopp'd it with my Hand, imagining that the Water being kept in a little Time would have a greater Effort and ſpout further, I was ſurpriz'd to ſee ſcarce any Water run at firſt, but afterwards it recover'd its ordinary Force by Degrees: This Effect may be thus explain'd.

In the Canal of *Chantilly* that inclines a little till it comes within 80 Fathom of the Jet, the Water wou'd run very ſlowly if it were not puſh'd forward by the ſuperior Water, whoſe deſcent is more ſteep.

If you ſuppoſe now that A B C D is the ſteep Deſcent *(Fig. 197.)* and that the Canal is but half full, as from C D to F G, the Water will run there faſt enough, and with the ſame Impreſſion will puſh that forwards which is at G H D E, and by the Motion that it will have acquired by the Way, it will be carried along pretty fast to the Entrance of the Ajutage, which it fills entirely; and being impell'd by the succeeding Water, it will rise 2 Foot; but when you keep it in, you stop its Motion, and it even flows back towards B G D, rising towards the Top of the Pipe near C; which is the Cause, that this Water being in its Motion, and its least Height at B being less than the Height from the Point L, it can make no Effort to run or spout, till after the Motion begins from the first flowing of the Water, which is very slow.

You must take care that your Pipes of Conduct be not made with Elbows at Right Angles; for the Water in its Motion striking against that Part of the Tube that is opposite to it, endangers its bursting, and is considerably retarded by the Shock.

If you wou'd have spouting Water preserve its Force for several Years, you must have your Pipes of Conduct a little wider than according to the Calculation that has been made; for they will gather Dirt and Filth that will a little retard the Motion of the Water, nay some Waters carry along with them stony Particles, that joining to one another form Stones that stop the Pipe.

I made the Observation in the Aquæduct of *Arceuil*; you see here in the Observatory in the great Receptacle where the Waters are separated, a great Jet in the middle half a Foot high; the Circumference of this Basin is of Copper, wherein were made several circular Holes of an Inch Diameter, to shew the Quantity of Water that there is in the Aquæduct; but by Degrees a stoney Matter was collected in these 3 Holes, that at length entirely stopp'd them up, not permitting the Water any longer to pass thro' them; which is surprizing

enough;

enough; for one would think that the running Water ſhould carry off the Filth that might gather there.

This is done after the ſame manner that Snow is collected on the Sides, or upon the Boughs of Trees in miſty and very cold Weather; for the Wind carrying along ſmall Particles or Atoms of frozen Vapours, drives them into ſome Pores of theſe Boughs; and the firſt retain and hold faſt thoſe that follow, and at laſt there is a Collection of them 2 or 3 Inches high.

In like manner the Water carrying along with it ſome ſtony Particles with which it is impregnated in paſſing thro' the Earth, fixes ſome of them in the Pores of the Metal; and ſome of thoſe that follow, agreeing in Diſpoſition and Figure with thoſe that ſtuck firſt, join themſelves to them. A great many paſs thro' that do not fix: But in ſome Years, ſo many of them get together as are ſufficient to ſtop up the Holes entirely, as if it were only one pretty hard Stone; ſo that every 50 Years, or thereabouts, you are oblig'd to take up your Pipes, and make them new.

When the Conduct of Water in a large Pipe is ſubdivided into ſeveral Pipes, to make ſeveral Jets, you muſt conſider all the Inches of Water which all the Jets together ought to give, to determine the Diameter of the great Pipe of Conduct, and you muſt afterwards reduce them by Calculation to one Jet only.

EXAMPLE.

The principal Pipe of Conduct is divided into ſix Pipes, two of which have each of them an Ajutage of 3 Lines Diameter, two others that have each

each of them 5, one that has 6, and another 8; the Height of the Reſervatory is ſuppos'd to be 52 Foot; then if the Pipe be ſufficiently wide, and there be Water enough in the Reſervatory to ſupply the whole Expence, the Ajutages of 3 Lines will each of them give 2 Inches, according to the Rules and Tables above-mention'd; thoſe of 5 Lines will each of them give 5 Inches $\frac{4}{7}$, and that of 6 Lines will give 8 Inches, and that of 8 Lines will give 14 Inches and $\frac{3}{9}$: The Sum then of the Expence of Water of all theſe Jets will be 37 Inches $\frac{2}{9}$; wherefore, according to the foregoing Rule, for a Reſervatory 52 Foot in Height, the Diameter of the Ajutage ought to be to the Diameter of the Pipe of Conduct, as 6 Lines to 3 Inches, or as 1 to 6, which is in the ſame Ratio.

But as in this Example we have only the Expence of the Water, which is 37 Inches $\frac{2}{9}$ when the Reſervatory is 52 Foot high; you muſt enquire what the Diameter of the Ajutage ſhould be that would ſupply this Quantity of Water; which is found by the Rule of the Meaſure of ſpouting Waters in the Second Part to be very near 13 Lines; you ſay then as 1 is to 6, ſo is 13 to 78 Lines the Diameter of the Pipe of Conduct of all the Water, or 6 Inches $\frac{1}{2}$; and each of the Pipes will be an Inch $\frac{1}{2}$ wide for an Ajutage 3 Lines in Diameter; for by the foregoing Rule, the Diameters of the Pipes of Conduct are to each other in the ſame Ratio as the Diameters of the Ajutages, the Height of the Reſervatory being the ſame; each of thoſe that have Ajutages of 5 Lines, will have 2 Inches $\frac{1}{2}$; that with an Ajutage of 6 Lines, will have 3 Inches Diameter; and that of 8 Lines, will have 4 Inches. And if the Water in the Reſervatory can give or ſupply 37 Inches, theſe Jets will ſpout continually. You will obſerve,

that

that the Jet of 8 Lines Ajutage will go the higheſt of all. To know its Height, you will find in the Table of the Second Rule, Diſcourſe the Firſt, Part the Fourth, That a Jet of 50 Foot ought to have a Reſervatory 58 Foot 4 Inches high; wherefore the Jet is betwixt 45 and 50 Foot, and very near 45; and if you make the Calculation by the Rule for the Jet of 46 Foot high, you will find 52 Foot ½ for the Height of the Reſervatory; whence you may conclude, that the Jet will not ſpout quite 46 Foot, tho' the Reſervatory be 52 Foot high.

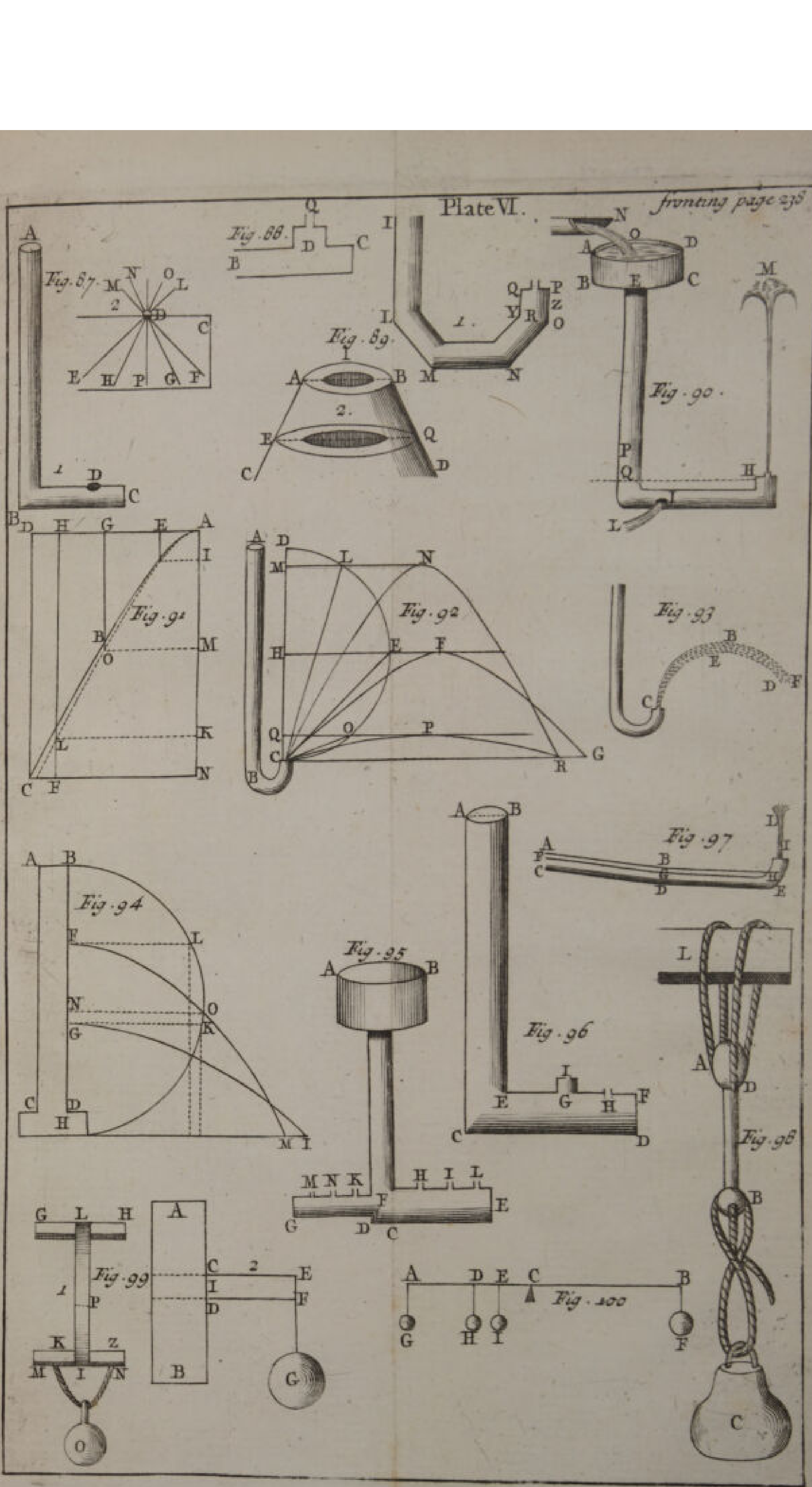
DISCOURSE II.

Of the Force of Pipes of Conduct, and the Thickneſs which they ought to have, according to their Matter, and the Height of the Reſervatories.

WHEN Reſervatories are very high, or Water is carried from a very high Place, the Pipes of Conduct are often in danger of breaking, eſpecially if the Conduct be thro' deep Vallies; and it would give a Man a good deal of Uneaſineſs, after he had been at a great Expence, if ſome Pipes ſhould happen to burſt, whether thro' the Defect of the Solder, or Weakneſs of the Pipes. You muſt take care likewiſe not to uſe too much Lead or Copper to make your Pipes very thick, for a moderate Thickneſs is ſufficient. The following Obſervations will be of uſe in this Matter.

Solid

Plate VI. *fronting page 238*



Pounds, the Weight G need only be 2 Pounds, if the Length F D be 5 times greater than D C; but if you consider another Part, as I, equally distant from C and D, you need but one Pound at G, because the *Brachium* F D would then be 10 times longer than the other *Brachium* D I; and because he supposes that the breaking happens at once in all the Parts of C D, some of which are betwixt D and I, and the others betwixt I and C, he lays it down, that the Augmentation of the Force of the Weight ought to be in the Ratio of F D, to the mean Distance D I; which, however, disagrees with several Experiments that I have made with Solids of Wood and Glass; whereby I found that F D was to be compar'd with a Length or Line less than D I; as with a Quarter of D C, or a Third, *&c.* and not that F D was to be compar'd to the Half of D C. To find this Proportion, and shew that *Galileo*'s is false, I take the following Method.

First, I suppose that Wood, Iron, and other Solid Bodies, have Fibres and Ramous Particles interwoven one in another, and that cannot be separated but by a certain Force; and that all together they make up that Firmness and Resistance of Bodies to a Power that endeavours to break them, drawing them perpendicularly downwards according to their Length.

Secondly, That these Parts may be extended more or less by different Weights: And, *Lastly*, That there is a Degree of Extension which they can't bear without breaking: So that if a Solid of Wood must be extended 2 Lines, in order to be broken; and a Weight of 500 Pounds will cause this Extension, a Weight of 125 Pounds will extend it but half a Line, one of 250 Pounds but one Line, *&c.* and so every Extension will make an *Equilibrium* with a certain Weight.

This

This being suppos'd, let us consider the Balance A C B, turning upon the *Fulcrum* C, (*Fig.* 100.) laden at the End B with the Weight F, that makes an *Equilibrium* with the 3 equal Weights G H I; the Distance B C is to C E, as 12 to 1; C D is twice the Distance of C E, and C A twice that of C D. Now if the Weight G be 12 Pounds, you must have a Weight at F of 4 Pounds to sustain it, because the Distance B C is thrice that of C A; there needs no more than 2 Pounds to sustain the Weight H, and a Pound only to sustain the Weight I; and thus a Weight of 7 Pounds at F will make an *Equilibrium* with these 3 Weights each of 12 Pounds at G, H, and I; if then you add a little Weight at F, the 3 Weights will be overpois'd; and tho' they will rise unequally, each will act with a Weight of 12 Pounds, according to its Distance from the Weight C. But the same Proportions do not hold good with respect to the Parts of a Solid that breaks transversly. And to shew it,

Let us suppose F C (*Fig.* 101.) to be 12 Foot long, C A 4, C E 2, and C B one Foot; and the Solid A D C N, join'd to the immoveable Solid A C B E, by three Strings equal, and equally strong, as D I, G L, H M, stretch'd a little, and passing thro' little Holes in the Solid A C P E, and tied above the other, as you see in the Figure; let us suppose then that every String must be extended two Lines more than it is, to be ready to break; and that a Weight R of 4 Pounds, suspended at F, is strong enough to reduce the String I D to this Extension; and that if you add very little more Weight to it, it must break; it is evident, that you must have a Weight of 2 Pounds at R, to stretch the String L G, (when alone) 2 Lines, and a Pound only to stretch the String H M so far, if the Center of Motion be at C; but becauſe when the String D I is extended two Lines, the String G L is extended but one, and the String H M but half a Line when they are drawn all together, it follows by the Second Suppoſition, that about a Pound Weight will then make an *Equilibrium* with the Tenſion of the String G L, which is but one Line, and that you will want but 4 Ounces to make an *Equilibrium* with the Tenſion of the String H M, tho' its whole Reſiſtance be a Pound; and conſequently to reduce the Three Strings to this State, it will be ſufficient that the Weight R be 5 Pounds $\frac{1}{4}$; and that if you add a very ſmall Weight, the String D I will break, and almoſt in the ſame Moment of Time as the two others, becauſe they reſiſt much leſs than the three together.

Let us now apply theſe Reaſonings to the Solid A B C D, fix'd perpendicularly in the Wall E A D O, (*Fig.* 102.) and let us ſuppoſe, that if it were drawn perpendicularly downwards, 600 Pounds would be requiſite to break it; I ſay, that if A D be divided into 3 equal Parts thro' the Points G H, and C D, be to D H, as 60 to 1, if the Weight L be of 10 Pounds, it will be ſufficient to break the Solid; whereas, according to *Galileo*, it ought to be 15 Pounds; ſince C D is to D I the half of D A, as 60 to one and a half, or 40 to 1; and 600 is the Product of 15 by 40.

To prove this Proportion, let us ſuppoſe, as was before explain'd, that the Fibre towards A muſt be extended to 16 very ſmall Parts, before it can be broken, and that an equal Extenſion is requiſite to break the Fibres towards G I and H; it's evident, that theſe laſt will not reſiſt with all their Force, to hinder the breaking of the Fibre towards A; and that if they reſiſt in Proportion to their Diſtance from

from the Point D, and if 16 Pounds at L be necessary to break the Fibre at A, 12 only would be sufficient to break the Fibre at G, 8 to break the Fibre at I, and 4 to break that at H; but because when the Fibre at I breaks, the Fibre at G will be extended in but 12 of its Parts, that at I in but 8, and that at H but 4. And thus instead of 12 Pounds to break the Fibre towards G, you need only 9 Pounds, namely, the $\frac{3}{4}$ of 12, and 4 Pounds to break the Fibre towards H. Now 12 is a Proportional Mean betwixt 16 and 9, and 4 betwixt 16 and 1, and consequently these Numbers 1, 4, 9, 16, being square, if you conceive the Length A D to be divided in *Infinitum*, the Resistance of all the Fibres will be in the Proportion of a Series of Squares, beginning at 1. But take what Number or Series of Squares you please, beginning at One, thrice their Sum *Minus* the triangular Number that corresponds with the last Term of the Progression, will be equal to the Product of the greatest Square, by the Number of the Progression beginning at 0; and this triangular Number exceeding will be to this last Product, according to the Progression in *Infinitum* $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{16}$, &c. the Excess of which in *Infinitum* will be as nothing, and consequently all the Squares in *Infinitum* taken together will make but the Third of so many Squares as are equal to the greatest, adding thereto one for the first Term of the Progression; so that if you take a Progression following in a regular Series, 0, 1, 2, 3, 4, 5, 6, &c. the Sum of all these Numbers is the half of the Product of the greatest, multiply'd into the Number of the Progression.

To prove by Induction this Property of a Series of Squares, let us take 1, which is the first Square. The Triple of 1 is 3; 1 multiplied by the Numbers

of

of the Terms of the Progreſſion 0 1 is 2, which is leſs than 3 by the firſt triangular Number 1, which is half the Number 2: 1 and 4 make 5; 3 times 5 is 15; the Product by the Progreſſion 0, 1, 2, is 12, leſs than 15 by 3, which is the ſecond triangular Number, and which is $\frac{1}{4}$ of 12; 55 is the Sum of the five firſt Squares; 3 times 55 is 165, the greateſt Square 25 multiplied by the 6 Terms of the Progreſſion, 0, 1, 2, 3, 4, 5, 150 leſs than 165 by 15, which is $\frac{1}{10}$ of 150.

To know whether Experiment would agree with this Reaſoning, I cauſ'd two Pieces of very dry Wood to be turn'd; one of them repreſented by A B, (*Fig.* 103.) had two little Balls or Knobs at each End, the remaining Part C D was uniformly 3 Lines thick; the other E F was 3 Lines thick throughout: I put the End of this laſt as far as the Point G, in a little Hole made in a Beam, and it fill'd it exactly; and at the other End F, I fix'd a Weight of 6 Pounds; the Diſtance G F was 4 Inches, or 48 Lines, and conſequently it was 48 times greater than the Third of the Thickneſs of the Cylindrick Stick G F, becauſe this Third was only a Line; and according to *Galileo*, the Proportion of the Weight was increas'd 32 times, but the Stick bent a little, and the Diſtance was no more than as 30 to 1, pretty near: The Weight I of 6 Pounds, ſuſpended at the Point F, broke the Stick at the Point G. Now if the Force of this Weight had been increas'd but 30 times, its Effort ought to have been no greater than that of 180 Pounds, which is the Product of 30 multiplied by 6. I afterwards ſuſpended the Stick A B by 4 little Strings faſten'd to a little Cord that went twice round the Neck D, and was kept on by the Knob B D. And in the ſame manner I fitted four other Strings to the Knob

 C A,

C A, to hang a Weight of 180 Pounds, which ought to break the Stick A B, drawing it perpendicularly downwards, if *Galileo*'s Rule had been true; but it did not break it. The Experiment was made before Meſſieurs *Carcavy*, *Roberval*, and *Hugens*. I added Weights of 10 or 12 Pounds one after another; and at laſt, when there was about 330 Pounds, it broke at the Point H.

Now if you take the Proportion of 47 to 1, (which is the Third of the Thickneſs) becauſe the Stick bent a little before it broke, the Product of 47 by 6 is 282, inſtead of 330; but 'tis probable that if we had only put 300 Pounds, and left them there ſome time, as the 6 Pounds were left at I, it would have broke in the ſame manner; but at laſt the Proportion was much greater than that of 30 to 1, and there only wanted $\frac{1}{7}$ to make it as 47 to 1; which might happen, becauſe the Stick G F was perhaps weaker towards the Point G, or a little thicker. We renew'd the Experiment, leaving a great Thickneſs at each End of the Stick E F, and only two Inches from G towards F, that that Part might bend a very little. I afterwards made uſe of ſome Canes of ſolid Glaſs $\frac{4}{3}$ of a Line in Thickneſs, and I always found that pretty near the Proportion of the Length of the Cylinder of Glaſs to a Third of its Thickneſs was to be taken; and in an Experiment, wherein, according to *Galileo*, only 30 Pounds were ſufficient to break a ſmall Rod of Glaſs in a perpendicular Situation downwards, we were obliged to hang 50: The Sieur *Hubin* fitted little Balls of Glaſs to the Ends of the Cylinder to ſuſpend it.

It may be objected, that in Wood, Glaſs, or Metals, nothing is extended without breaking; I agree that the Extenſion of Glaſs is not ſenſible, but that of Metals is eaſily known, becauſe the

Strings

Strings of an Harpſichord, of what Metal ſoever they be, are ſenſibly extended; whence it follows, that a Cylinder an Inch thick, ought likewiſe to extend it ſelf, but you muſt have above 2000 Pound Weight to extend it ſenſibly; for ſince a Ball of Glaſs or of Steel is dented in by a Blow, and afterwards reſtores it ſelf to its former Figure, it may likewiſe be extended. If you let a Cylinder of dry Wood an Inch thick fall upon a flat Stone, it rebounds, and conſequently has a Spring, and its Parts ſuffer Extenſion and Compreſſion. And becauſe Experience ſhews, that a little Stick, when you bend it in order to break it, contracting it ſelf towards the Concavity where it is bent, neceſſarily extends its ſelf towards the Convexity, before it breaks: Thence you may conclude, that it muſt have an Effort to make the Compreſſion towards the Concavity.

That being ſuppos'd, if A B C D (*Fig.* 102) be a ſquare Piece of Wood fix'd in a Wall, you may conceive that from D to I, which is half the Thickneſs A D, the Parts are preſs'd together by the Weight L; thoſe that are near D, more than thoſe towards I; and that they are extended from I to A, as has been before explain'd; and the ſame Reaſoning about the little Cords may be applied to the Part I A; whence it will follow, that as the Length I F is to the Third of the Thickneſs I A, ſo will the Force of the Weight L be increas'd, in order to break the Solid; and as there is more Force requir'd to preſs the Parts towards D, than towards H, if you ſuppoſe that this Force is diminiſh'd according to the Series of Numbers to an Unit, the ſame Proportion of the Length I F, to the Third of the Breadth D I, will be ſtill requiſite to make this Compreſſion; and as it is very probable that theſe Compreſſions reſiſt as much as the Extenſions, and that as great a Weight is neceſſary to make them, theſe Extenſions and theſe Compreſſions will divide the Force of the Weight L, adding the Third of the Thickneſs I A, to the Third of the Thickneſs I D, the whole will be equal to the Third of the Thickneſs A D; whence will follow the ſame thing as if all the Parts were extended: Therefore to reduce the Parts towards the Point A to ſo great an Extenſion, as that the Solid A B C may be broken, the Weight L muſt be a little more than 10 Pounds, if the Length C D be to the Third of the Thickneſs A D, as 1 to 30, and more than 300 Pounds will be requir'd to break it when it is drawn perpendicularly downwards; for the ſame thing muſt happen with reſpect to the Effort of the Weight, as if the Parts betwixt I and D were extended, as well as thoſe above them.

By an Experiment made before Sieur *Hubin*, I found that a Cane of Glaſs a quarter of a Line thick, and four Foot long, ſtretch'd $\frac{4}{5}$ of a Line, without breaking; and taking off the Weight, it return'd of it ſelf to its firſt Extenſion. I caus'd three of equal Thickneſs to be thus extended, which broke when they were ſtretch'd a Line and a half. To find this Extenſion, I caus'd a Ball of Glaſs 2 or 3 Lines in Diameter to be fix'd at each End of every one of theſe Canes; one of theſe Balls was held faſt betwixt two Tenter-Hooks, which were driven in half their Length towards the End of a Table; ſo that in puſhing them with great Force, you could not ſenſibly move them, and conſequently the great End of the Glaſs Cane being held ſtrongly by the Nails, could not come near the other End of the Table. There were three little Pin-holes to diſtinguiſh the Lengthning by; the Cane bore upon the Table lengthways; but when it was moderately drawn, it did not lean any longer upon it. The great End by which we drew, touch'd the Table; and I obſerv'd that the End of it touch'd the firſt Pin-hole, when it was drawn moderately with the Hand, and when it was drawn more ſtrongly, it advanc'd to the ſecond Hole; and drawing it ſtill with greater Force, it reach'd the Third; and relaxing it a little, it return'd to the ſecond or firſt Hole. To have made the Experiment as it ought to have been, one of the Ends ſhould have been drawn by an Iron Pin, in a Hole, and the other ſhould have been faſten'd to 2 or 3 little Strings; which being join'd together, would have made but one, and ought to have been wound about one of the Pegs of a Lute, or other Muſical Inſtrument; ſo that turning the Peg by little and little, the Cane might be ſtretch'd: There might have been Marks made to diſcern the Extenſion, and the Glaſs Cane might have been made to ſound like the String of a Harpſichord.

This being ſuppos'd, the Experiments that I made relating to the Reſiſtance of Solids, are as follows. Theſe Rules may be of great Uſe to Architects for Beams, for Jettings out in Buildings, &c.

A Glaſs Cane $\frac{5}{3}$ of a Line, broke by its own Weight jetting out 6 Foot.

A Cylinder of black Marble, 5 Lines in Diameter, ſuſtain'd horizontally 190 Pounds, that is to ſay, 10 $\frac{1}{2}$, at 48 Lines Diſtance. The Square of $\frac{5}{3}$ is $\frac{25}{9}$; its Product by a Foot Length, or 144 Lines is $\frac{3606}{9}$, or 400 Lines, 6 Foot of which will weigh 2400 Cubic Lines. As 14 to 11, ſo is 2400 to 1886 Lines; and becauſe a Cubic Inch, or 1728 Lines weigh two Ounces 1 Dram, 1886 Lines will weigh about 2 Ounces 3 Drams.

A Sword-Blade, one End of which was fix'd in a Hole, and obliquely aſcending from it, ſupported 68 Pounds, and a little Plate of Tin ſupported 80.

It is evident, that if a Solid A B is broken by a Weight L, (*Fig.* 104.) ſuſpended at its Middle E, being ſupported at each End by the two Rulers G and F; it muſt likewiſe break, if the fix'd Point be at E, and the two Powers at A and B be equal to each other, and both together equal to the Force of the Weight L, ſince there is ſtill the ſame Force acting at E.

Galileo has demonſtrated, that the ſame Weight that breaks at E, will break a Solid of the ſame Thickneſs fix'd in a Wall as far as the Point A, if its Length be equal to A E; whence follows what I have found true by Experience, namely, that a flat Glaſs A B, 12 Inches long, reſting upon each End, and having 9 Inches unſupported, being broken by the Weight of a Pound, 10 Ounces and 5 Drams, was broken by 3 Pounds 5 Ounces and 4 Drams, when its Extremities were cloſely tied with little Cords betwixt the Supporters and two flat Pieces of Wood; becauſe then they muſt break at A B, cloſe to the Supporters, and becauſe the two Diſtances by both their Extremities reſiſted twice as much as E A alone at its Extremity A, it requir'd twice the Weight at L.

The ſame Author has further demonſtrated, that if the Supports are at a double Diſtance, half the Weight that was at E will be ſufficient to break the Solid; the Reaſon is, becauſe the Lever becomes twice as long, and the Weight conſequently has twice the Force, the Counter-Lever not changing at all; but if the Solid be twice as thick, it muſt have 4 times the Weight, becauſe on one hand there is twice the Number of Parts to divide; and likewiſe the Force of the Lever is diminiſh'd by one half, which is the Reaſon that the Weight ought to be quadruple; and, generally, the Weights muſt be in a duplicate Ratio of the Thickneſs.

Thence may be reſolv'd a very ſurprizing Theorem, namely, that if a flat Square of Wood, Glaſs, or other brittle Subſtance, plac'd upon a Frame, in ſuch manner that the Extremities are ſtrongly inclos'd by the Frame, juſt as Panes of Glaſs are fix'd in their Frames; the ſame Weight, which being diſtributed throughout the whole Extent of the Square, would be ſufficient to break it, will break any other Square of the ſame Thickneſs, let its Breadth be what it will.

The DEMONSTRATION.

A B C D (*Fig.* 105.) is the Frame that incloſes the Square of Glaſs; E F is another leſs Frame, incloſing another Square of Glaſs of the ſame Thickneſs; I ſay, that will ſuſtain as great a Weight, equally diſtributed, as the other; for let a little Liſt, as Q H, be plac'd upon the little Square; and to make the Demonſtration more eaſy, let the Liſt I L, in the other Frame, be double the Length Q H, and of the ſame Breadth and Thickneſs: 'Tis evident by what *Galileo* has demonſtrated, that if you put a Weight on the Middle of Q H, preciſely ſufficient to break it, half this Weight plac'd in the Middle of I L will break it; but if you double the Breadth of I L, and the Liſt be M N K S, the entire Weight will be requiſite to break it; for the Lever will continue the ſame, but there will be twice as many Parts to divide; and if you diſtribute the firſt Weight the Length of Q H, you muſt double the Weight to break the Liſt Q H, as was
prov'd

prov'd by the ſame Author. You muſt therefore double the Weight to break M S, which is twice the Breadth of I L; but if you add another Liſt, as O P, croſswiſe to the little Frame, you muſt double the Weight, which I have found true by Experience; for a ſingle Liſt being broken by a little leſs than two Pounds and a half; when it was croſs'd, requir'd 4 Pounds 11 Ounces and a little more, which is a little leſs than twice the Weight; which might proceed from the Middle Square's not being doubled. If then you put another Liſt acroſs, as G R, of the ſame Breadth as I N, it will bear the ſame Weight as the Croſs P O Q H; and if you continue to enlarge theſe Croſſes according to the ſame Proportions, the great one will always ſuſtain an equal Weight, diſtributed as before. In ſhort, this Experiment may be continued till only 4 ſmall Squares remain at the Corners of every Frame; whence you may conclude, that if theſe two Squares were finiſh'd or fill'd up, the ſame Effect would always follow, and even in all other Proportions; for if the middle Square of the little one is the Cauſe that the Croſs does not bear a Weight double to that which the Liſt will bear, the great Square will alſo produce the ſame Effect.

Theſe Rules are of uſe for brittle Solids, as dry Wood, Glaſs, Marble, Steel, *&c.*

But for ſupple and pliable Subſtances, that are broken by Traction alone; as Paper, Tin, Ropes, *&c.* other Rules are neceſſary, of which theſe following are the chief.

RULES for pliant and ductile Solids.

Liſts of Paper, Tin, and ſuch kinds of Bodies, break equally, whether they be long or ſhort.

The

The EXPLANATION.

B C (*Fig.* 106.) is a Liſt of Paper paſted, or of Tin nail'd upon the two Supporters E G, F H, the Length C B being unſupported; a little Stick, as I L, is laid at the Middle upon the Liſt; and to each End of the Stick that comes out a little beyond the Sides of the Paper, are little Cords fix'd to ſuſtain the Weight P; for if a Cord were put upon the Liſt of Paper, it would plait it or cut it. The Liſt being of Paper 6 Lines wide, broke by a Weight of 4 Pounds.

Another ſuch Liſt broke in like manner, when the Supporters were at half the Diſtance; and when being twiſted at both Ends, round the two little Cylinders G H, M N, a Weight was faſten'd to the Cylinder below, by means of two little Cords, (as you ſee *Fig.* 99.) the Liſt broke likewiſe by a Weight of 4 Pounds.

Some object, that the Cords K Z ſuſtain a Part of the Weight, and that that Weight does not contribute to break the Liſt I L; but 'tis evident, that the Liſt carries all that is below it, whether the Cords ſtretch or not; and to prove it, I made the following Experiment.

A Braſs Wire turn'd into a Worm or Screw, and ſuſtain'd by the Hand at A (*Fig.* 107.) having the Weight C ſuſpended at the End B, was extended in ſome meaſure by this Weight, more or leſs, according as it was more or leſs heavy, but all the Diſtances of the Spires were perfectly equal; and when the Hand was held at D, the Diſtances remain'd ſtill the ſame, without any Alteration; which ſhew'd plainly, that the Extenſion of the ſuperior Spires, when the Suſpenſion was at A, did no way leſſen the

the Force of the Weight, with reſpect to the inferior Spires. The ſame thing happens to a long Rope that ſuſtains a Weight; for all the Parts ſuffer the ſame Extenſion, the upper Parts not diminiſhing the Extenſion of the lower; and a long Rope and a ſhort one always ſupport the ſame Weight, unleſs that in a long Rope there may happen to be ſome faulty Place, in which it will break ſooner than in a ſhorter.

The ſame thing will happen in ſmall Slips of Tin; for in a long one there may be perhaps ſome Defect that may not be in a ſhort one; and if you ſhould take that Part of it which did not break, it would ſuſtain a greater Weight, becauſe the Defect would be remov'd: I have made ſeveral Experiments of it.

A ſmall Slip of Tin 3 Lines $\frac{1}{4}$ wide ſupported 100 Pounds, without being broken, and broke by 130, and 128; and being drawn perpendicularly downwards, it did not break with 120; but it broke with 123 in a Place where there was ſome Flaw; you muſt judge that it would have ſupported more, had it been drawn directly, and there had been no Defect in it.

A Slip of Tin 4 Lines $\frac{1}{3}$ wide, having 5 Inches unſupported in the little Frame, did not break by 180 Pounds; nay, it was not broken by adding more Weight.

A Liſt or Slip of Paper 6 Lines wide being paſted at both Ends, upon the two oppoſite Sides of a ſquare Frame, 5 Inches within the Work, was broken with 4 Pounds 3 Quarters; and you muſt have added 4 Ounces to break ſuch a one, drawing it perpendicularly downwards. Two others likewiſe of 16 Lines were broken by 4 Pounds, holding them

them $\frac{3}{4}$ of a Minute with the Weight upon them, as well in the great Frame, as in the ſmall one.

Another Slip of Paper of the ſame Strength, 6 Lines and $\frac{1}{3}$ wide, was broken by 4 Pounds; it was laid upon the ſame Frame as well in the one as the other: There were three Strings that bore a little Bucket, and another String below it, that was ſuſtain'd above by a little Stick. In this Bucket we put Weights by little and little, till the Paper broke.

I paſted ſome Paper in the great Square of 9 Inches within the Work; and in the little one of 5 Inches in the clear, as Window-Frames are made; on the Middle of the great Paper I laid a round Piece of Leather of 3 Inches 4 Lines; and upon this Leather a Lead Weight of 4 Pounds, whoſe Baſe that reſted upon the Leather, was but 2 Inches and a half in Diameter; I heap'd ſeveral Weights upon the Firſt, and the Paper did not break till 42 Pounds were laid on.

The other Paper upon the little Frame broke with 32 Pounds, but the little Piece of Leather was only an Inch $\frac{3}{4}$ wide, on which the firſt Weight was laid.

To compare theſe Experiments with each other, and with the Slips of Paper, the Breadth of the Leather that lay in the great Frame, being 3 Inches, and the Baſe of the Weight two Inches and a half, the Leather therefore did not lie very cloſe towards the Edges; and you may ſuppoſe that the Breadth of the Slip which the Diameter took up, was 5 times greater than that of the Liſt of 6 Lines, which had ſupported 4 Pounds; and taking another croſs Liſt C D, of the ſame Breadth (*Fig.* 109.) if the firſt A B ſuſtain'd 20 Pounds, the Quintuple of 4 Pounds, both ſuſtain'd 40; the 2 Pounds more were

were ſuſtain'd by the 4 Diagonal Liſts, E G R F, which ſuffer very little, for the Reaſons above-mention'd, with reſpect to the little Cords, becauſe they are longer than the other, and do not ſtretch as far as is neceſſary to break them. In the little Frame, the Liſt A B was but 3 times and a half broader than the Liſt of 6 Lines; it ought then to ſuſtain 14 Pounds, and the 2 croſs Liſts 28 Pounds: The 6 Pounds remaining, were for the 4 Diagonal Liſts; and tho' this be more in Proportion than in the great one, that proceeds from the Inequality of the Matter, whoſe abſolute Reſiſtance is leſs in one Place than another. If both the Weights had been equal in both Squares of Paper, they ought to have born the ſame Weight, and both ſhould have broken betwixt the Weight and the Frame of Wood.

After having made many ſuch Experiments as theſe, I made ſeveral of them upon Pipes full of Water; I caus'd a Pipe to be made of 50 Foot, ſuch as was before mention'd; and having ſolder'd it in a Cylindric Barrel of a Foot, ſhut cloſe on all ſides, I laid the Barrel upon 3 Props.

The Baſes were of Copper Plates, a Line thick, and the Circumference was of Tin: The aſcending Pipe, 5 Inches wide, was ſolder'd in a Hole made in the Middle of the upper Plate; and the Cylindric Surface of the Tin was ſolder'd with the Plates, after this manner. A B (*Fig.* 109.) repreſents the Diameter of the upper Plate; the little Squares C and D the Thickneſs of a Wire that went all round the Tin that made the Caſe joining the Plate, and ſerv'd to ſolder it the better to it; E F is the Tin Pipe 50 Foot long, the lower Plate was ſolder'd with the Tin Caſe as well as the upper: I fill'd both the Barrel and the Pipe with Water; when it was full up to the Top, the Plates bent to a Convexity, by the Weight of the Water; and as it acted as a Lever, the End of which was G, and the other *Brachium* the Breadth of the Solder, upon the End of the Tin, and on the Breadth of the Wire, the Solder undid by this Effort, the Parts nearest to G separating the first: The Space unsolder'd was 4 Inches, thro' which all the Water ran out; we solder'd it again, and the lower Plate unsolder'd in the Experiment. I caus'd another Barrel to be made, in which the Tin being laid upon the Plates, enclos'd them within, and was well solder'd to 'em; we afterwards increas'd the Height of the ascending Tube to 100 Foot, and it continued full of Water a pretty long time before it broke; but at last one of the Solderings of the Case open'd at the Bottom, as from S to R, and tore slantwise from R to T; the Plates were bent above an Inch, but their Solder, with the Tin, did not break; because acting like a Lever, as in the first Experiment, and even more strongly, by reason of the greater Effort of the Water, the solder'd Part of the Tin rose along with it, and so could not unsolder. We kept Water in this Pipe a long time 80 or 90 Foot high, but nothing broke; and because the Water 100 Foot high acted upon this Case of Tin as if the Pipe had been a Foot wide, quite up to that Height, as was prov'd in the Discourse of the *Equilibrium*, you may be certain that a Tin Pipe 80 Foot long, and a Foot wide, will not break, being full of Water.

I afterwards made use of a Barrel of Lead, instead of one of Tin; it was two Lines and a half thick, a Foot broad, and 18 Inches long; but it was swell'd out like a Hogshead, till it met with flat Plates of Lead about 8 Inches wide, and of the same Thickness of two Lines and a half: The Solderings lay over the Plates half an Inch, and likewise

wiſe one that was laid on and join'd the Plates, ſo that they were above an Inch broad, and they were above 8 Lines high; we fill'd the Pipe of 100 Foot with Water, and the two Plates bent round more than an Inch, but nothing broke; for the ſoldering roſe with the reſt, and the Thickneſs of the Lead was too great. There is a kind of Porous Lead that would have let ſome ſmall Threads of Water paſs thro', which I once ſaw an Experiment of in a Barrel of a Foot and a half, and two Lines thick, tho' the aſcending Pipe was but 15 Foot. Laſtly, To finiſh the Experiment, I caus'd the Barrel to be ſcrap'd, and fill'd in the Middle to the Height of about 6 Inches, and the Breadth of 4; and when its Thickneſs was reduc'd to a little leſs than a Line in the Middle of the fill'd Part, then the Lead ſwell'd in this Place, and a Slit was made 3 Inches long, thro' which all the Water ran out. You may then ſecurely make uſe of a Pipe of 100 Foot, 12 Inches wide, and of the Thickneſs of two Lines, or even of a Line and a half, if the Lead be good. The Reſiſtance of the Tin Barrel may be thus explain'd: You muſt conſider it as a Liſt of Tin a Foot broad, that muſt be broken by being torn. Now this Liſt is 24 times broader than that of 3 Lines, that ſupported 120 Pound, it ought then to ſupport 445 times more, pretty near; and becauſe the Water in the Pipe then weigh'd 5500 Pounds; for you muſt conſider it as if it were of the Breadth of a Foot, to the Height of 100 Foot; and a Cylindric Foot of Water weighs 55 Pounds, which being multiply'd by 100, give 5500; 45 times 120 make 5400, and conſequently the Proportion is pretty juſt; and if the Solder had been good throughout, the Barrel would ſtill have born 100 Pounds, or the Height of two Foot more

Water.

Water. You muſt conſider, that you are to have no Regard to the Weight's being diſtributed thro' the whole, tho' it be to tear it. If you would know the Proportion of the Reſiſtance of other Pipes, obſerve the following Rules: The Plates are ſuppos'd to be pretty ſtong.

RULE I.

If the Height of the Reſervatory be double, you will have double the Weight of Water, and conſequently the Metal of your Pipe muſt be twice as thick, that it may have twice as many Parts to ſeparate. If the Diameter of the Pipe be twice as great, you muſt have twice the Thickneſs; for the ſame Parts of the Tin will be no more chang'd, and they are only double.

RULE II.

If the Plates be the weakeſt Part, and the Breach is to be made in them, ſuppoſing them of caſt Iron, or ſome other ſoure and brittle Matter, when the Pipes are 4 times the Height, you muſt only double the Thickneſs of the Metal, as was before prov'd; for then the Plate breaks as a Lever, and the Counter-Lever, or other *Brachium*, becomes twice as great, and there are twice as many Parts to ſeparate. The ſame thing will happen, if the Diameter be double; for it will have 4 times as much Weight. You muſt then only double the Thickneſs; beſides theſe different Plates are able to ſupport the ſame Weight, but the Weight being quadruple, you muſt double the Thickneſs; and if the Height and Breadth of the Pipe together be greater, you muſt firſt calculate the Height, and then the Breadth, as in in the Example above. You muſt double the Thickneſs by reaſon of the quadruple Height, and double that again on account of the quadruple Surface of the Baſe, therefore you are to quadruple the Thickneſs of the Plate; but when it is of Tin, or very yielding Copper, if the Reſervatory be 4 times higher, there will be 4 times more Weight, there muſt be therefore 4 times more Thickneſs; and if the Diameter be double, there will be ſtill 4 times more Weight, and you muſt again quadruple the Thickneſs, which will make 16 Thickneſſes. Thus if the Thickneſs of half a Line of Copper can ſupport Water in a Tube 60 Foot high, and 4 Inches Diameter; if the Height be increas'd to 240 Foot, and the Diameter 8 Inches, you muſt have 8 Lines Thickneſs of Copper.

It is always better to make the Pipes a little thicker, than according to the Calculation; for it often happens, that the Matter of which the Pipes are made is faulty. I have ſeen Pipes of Conduct made of caſt Iron, 4 Inches Diameter, and 3 Lines thick, which were made up of ſeveral Pipes join'd together for the Pipe of Conduct, which broke, becauſe in the caſting there were Hollows, or Honey-Combs made in them, and the Metal was faulty in thoſe Places: I have likewiſe ſeen the Water ouſe thro' their Pores at the Beginning; but afterwards the Pores clos'd by the foul Particles that the Water carries along with it, and they were ſerviceable for the future.

DISCOURSE III.

Of the Distribution of Water.

TO divide Water into several Jets, and to know how much it will give to each, which may likewise serve for the Distribution of the Water of a Spring to several Persons, you must have a Gauge, whose Holes must be square, and not round.

As A B (*Fig.* 110.) is the Height of the Vessel that serves for the Gauge, and C D the Height of the Water, you must place the square Holes about 2 Lines below the Surface C D, in an horizontal right Line E N. Now if this Gauge be divided into several Squares of an Inch every way, as E F P H, *&c.* they will give more than an Inch; for if the circular Holes give 14 Pints in a Minute, the square ones will give a Quantity that will be to 14, as 14 to 11; which Proportion of 14 to 11, is pretty near that of a Square to a Circle of the same Diameter: If then a round Inch gives 14 Pints in a Minute, a square Inch will give almost 18 Pints; for 11 is to 14, as 14 to 17 $\frac{9}{11}$; therefore you must divide E F into 14 equal Parts; and if E R contain 11 of those Parts, the long Square E R S H will be very near equal to a circular Inch, and it will give an Inch, that is to say, 14 Pints in a Minute, if the Water in the Gauge Vessel continues at the Height C D. You may make several Holes

Holes regularly following each other, equal to E R S H, under the ſame Line E N, as R L T S, L M U T, *&c.* and if you would give half an Inch, you muſt divide one of theſe long Squares, as O Q I G, by a middle Line X Y, and each half will give half an Inch; that is to ſay, 7 Pints in a Minute; and all the other Diviſions the ſame, if you take the Third, as I K Z Q, or the Fourth, *&c.* There will be this further Advantage, that if the Water that ſupplies the Pipes diminiſhes, and paſſing thro' them, fills only a Third, or the Half, or two Thirds of the Height of the Holes in the Gauge, every Perſon will loſe in Proportion, which cannot be when the Holes are round; and if there be a little more Friction in the little Holes than in the great ones, the Water ſupplying the Expence through a narrow Paſſage better than a wide one, will compenſate that Defect. If you would give 3 or 4 Inches, you muſt take 3 or 4 entire Holes, each equal to E R S H, as L T U M; but you muſt make a little Separation, and have ſome Diſtance betwixt the Holes, when you give but an Inch to each Perſon; for their Waters would be confounded together, if there were but 2 or 3 Lines betwixt them; the Entrance into each Pipe muſt be wide enough to receive the Water of each Diviſion.

You may diſtribute a Spring to ſeveral Perſons in a Town, in this manner.

I ſuppoſe that the Spring gives 40 Inches of Water in the Summer, and 50 Inches in the Winter, and 55 at other times. You muſt make ſeveral Reſervatories, as F G H I (*Fig.* 111.) where the Water may diſcharge it ſelf.

In the firſt, which ſhall be the greateſt, you muſt let the Water riſe to a determinate Height, as A B, where there muſt be a Paſſage for the Water to run further on, and Holes for the firſt Diſtribution, as at C D E, a Foot below A B: Theſe Holes may be wide enough, taken together, to let 20 Inches paſs thro', and the 25 remaining Inches will paſs above A B. It is evident, that when the Water is ſtrongeſt, the Elevation of the running Water will be greater above A B, and when the Water is weaker, that Elevation will be leſs; but not above an Inch at moſt: So that when the Water that goes into the Reſervatory is 50 Inches, 20 and a half of them will go thro' the 3 Holes; and only about 19 and a half will paſs thro' them when the Water gives but 40 Inches. We will do the ſame in reſpect of the Water that paſſes above A B, and that that paſſes thro' the Holes; and make little Reſervatories in other Parts of the Town, where we will diſtribute to particular Perſons the 25 Inches, and the 20 Inches; always obſerving to make the Holes 12 Inches, or at leaſt 10 Inches below A B. At laſt it will happen, that during the great Plenty of Water, there will remain 5 or 6 Inches of Water, which may be given to the Publick, in ſome unfrequented Place, for particular Uſes; and this Water will remain only during the great Plenty of Water; which may be obſerv'd alſo in the other Conduits, as C D E: For there will be always ſome Remainder for the Service of the Town; either for Fiſh-Ponds, or other Receptacles for Water, that are kept a long time without any Addition of freſh Water, and which may be ſupply'd from time to time; the reſt will be equally diſtributed at the Rate of 45 Inches, only they will have ſometimes a little leſs, ſometimes a little more.

Frontinus, a *Roman* Author, has diſcours'd of theſe Conducts of Water after another manner. What we call an Inch, he calls *Quinaria*; but his *Quinaria* was a little leſs: His manner of applying

what

were leſs; and every 10 Years Care muſt be taken that the Gauge Holes do not fill with a ſtony Subſtance, which fixes to the Edges of the Holes; which, in ſuch Caſe, muſt be made a-new.

When the Conduct Pipes are not large enough, a fine Mud ſettles in the loweſt Part of them, which will ſubſide even from the cleareſt Water; and at laſt, as it hardens, it will wholly fill up the Pipe: Therefore it will be neceſſary now and then to open them at the loweſt Places, ſo as to make the Water run out with Violence, and it will bring out this Mud along with it, provided it be not yet petrify'd.

If a Conduct-Pipe is to be carried over ſome riſing Ground, there muſt be a ſmall Pipe ſolder'd to it in the higheſt Place with a Cock to it, that is to be open'd now and then to let out the Air; which being drawn down with the Water, gathers in the upper Part of the Pipe, and being condens'd by the Water that compreſſes it, comes out in Bubbles, and ſtrikes ſometimes with ſuch Violence againſt the Conduct-Pipe, as to to crack it, if it be not ſtrong enough to reſiſt; or breaks pieces out, if it be made of any brittle Subſtance.

ADVERTISEMENT 2.

THE following Rules *(not Printed with the* French *Treatiſe) were drawn up by Monſieur* Mariotte, *for the uſe of Monſieur* de Louvois; *and tho' a great Part of them is taken out of the foregoing Book, I thought they would not be unacceptable to the Reader; becauſe this* Appendix *does not only give a Summary of the Book at one View, but ſupplies us with what was wanting in order to Practice, and could not be had without comparing ſeveral Experiments, and making ſome troubleſome Calculations.*

PRACTI-

PRACTICAL RULES *for* JETS d'EAU.

Of the Expence of Water thro' different Ajutages, *or Spouting Pipes, according to the different Heights of the* Reservoirs, *or Cisterns.*

A Cubic Foot of Water weighs 70 Pounds, and contains 36 Pints (*Paris* Measure) when they are just fill'd; but if the Water rises above the Brims, as it may do without spilling, then a Pint will weigh two Pounds, and 35 only will be contain'd in a Cubic Foot. The *Paris Muid*, or Hogshead, contains 280 of these Pints, and 288 of the others.

An Inch of Water is the Quantity of Water which runs thro' a circular Hole of an Inch Diameter, vertically made in one of the Sides of a Vessel, when the Surface of the Water which supplies the running out, always remains at the Height of one Line above the Hole, that is, 7 Lines above the Center of it, without rising or sinking. In one Minute 28 Pounds of Water, or 14 Pints, of two Pounds each, will run thro' such a Hole. The Water's Surface does, indeed, stand something lower, just at the Hole immediately over it, than it does in the rest of the Vessel, where it must be one Line higher; for if it was only a Line higher than the Top of the Hole in the other Parts of the Veſſel, it would ſink juſt at the Hole, not touch the upper end in running out, and only give about 13 Pints $\frac{7}{8}$ in a Minute.

If you would know what is given by circular Holes that are leſs, as by an Hole of half an Inch, or a quarter of an Inch Diameter ; you muſt fix them ſo, that their Centers ſhall be 7 Lines below the Surface of that Water which was one Line above the Top of the Inch-Hole, which is mark'd by the Line F F, as you ſee in the 112th *Fig.* where the Centers A B C D of the different Holes are all in a Line parallel to F F, and not as in the 113th *Figure*, where their upper Edges are at equal Diſtances from the ſaid Line F F. Now if the Hole B is 6 Lines in Diameter, its Area will be but the fourth Part of that of the Inch-Hole, and ſhould give but the fourth Part of 14 Pints in a Minute ; but yet it gives the fourth Part of 15 Pints, tho' the whole Surface of the Water in the Veſſel be but one Line above the Top of the Inch-Hole, which happens for ſeveral Reaſons given in the foregoing Treatiſe. The firſt is, that the Water does not ſink ſenſibly above theſe little Holes, but is nearly even with the other Parts of the Surface ; whereas when the Inch-Hole is open, in order to have the Water be 7 Lines above the Center of this Hole juſt over it, it muſt be above 8 Lines above it in the other Parts of the Veſſel ; for there muſt be 4 times more Water to ſupply the running of a Hole of 12 Lines, than of a Hole of 6. Whence it happens, that the Water which ſucceeds that which runs thro' the great Hole, comes from a greater Diſtance, and conſequently cannot ſucceed ſo eaſily ; beſides, there is but one Line of it above the Hole, whereas there are 4 Lines of Water above the little Hole, which makes it ſucceed faſter. Moreover, it is very hard

hard to make Experiments which will exactly determine how much Water runs out; for one may err in the Bigneſs of the Hole, the Height of the Water in the Veſſel, and the Time of the running out. Beſides, horizontal Jets give ſomething more Water than thoſe which ſpout upwards, and ſomething leſs than thoſe that ſpout downwards.

To determine rightly what an Inch of Water is, and to facilitate the different Computations according to the different Holes and Poſitions of the Ajutages, you may ſuppoſe an Inch of Water to give 14 Pints or 28 Pounds of Water in a Minute; and upon this Suppoſition I have made the following Calculation.

A Pendulum 3 Foot 8 Lines $\frac{1}{2}$ long, from the Center of Suſpenſion to the Center of the Ball, will vibrate once in one Second, and therefore 60 times in a Minute.

If you would know without a Gage what Quantity of Water a Spring gives, you muſt receive the Water of it in ſome great Veſſel; and if in half a Minute, or 30 Seconds, it gives 7 Pints, we may ſay that it gives an Inch of Water; if it affords 21 Pints, that it gives 3 Inches of Water, &c.

According to this, an Inch of Water will give 3 *Paris* Hogſheads in an Hour, and 72 in 24 Hours. A Hole of a Line Bore is the 144th Part of an Inch Bore, and it gives half a Hogſhead in 24 Hours; two Holes of a Line each will give a Hogſhead; and a Hole of 3 Lines Diameter, which is equal to 9 Holes of one Line Diameter, will give 4 $\frac{1}{2}$ Hogſheads in 24 Hours.

It has been found by ſeveral Experiments, that a *Reſervoir*, which is 13 Foot high above the Hole of an Ajutage of 3 Lines, will give an Inch of Water, that is, 14 Pints in a Minute, as it ſpouts upwards.

And

And this we take for our Foundation, in considering the Expence of Water of other Jets.

When the *Reservoirs* have the same Height, but different Ajutages, their Expence of Water is in the the same Proportion as the Holes of the Ajutages; that is, as the Squares of the Diameters of the Holes. Thus if a *Reservoir* of 13 Foot has an Ajutage of 6 Lines Diameter, it will give 4 Inches; and if its Hole is one Inch Diameter, it will then give 16 Inches in spouting upwards, provided that the Pipes which bring down the Water be of a sufficient Bore, according to the Rules which shall be hereafter given. In order to calculate the Expences of Water, take the Square of 3, which is 9; and if the new Ajutage has a Diameter of 5 Lines, you must work thus by the *Rule of Three*; saying, If 9, the Square of 3, gives 14 Pints, what will 25, the Square of 5, give? And you will find for your Fourth Number, 38 $\frac{8}{9}$, *&c.* Here follows a Table of these Proportions.

A Table of the Expence of Water in a Minute, thro' several round Ajutages; the Water in the Reservoir *standing at the Height of* 12 *Feet.*

Thro' an Ajutage of 1 Line Diameter,	1 Pint $\frac{1}{2}$ and $\frac{1}{18}$.
Thro' 2 Lines, - - - - - -	6 Pints $\frac{2}{9}$.
Thro' 3 Lines, - - - - - -	14 Pints.
Thro' 4 Lines, - - - - - -	25 Pints nearly.
Thro' 5 Lines, - - - - - -	39 Pints nearly.
Thro' 6 Lines, - - - - - -	56 Pints.
Thro' 7 Lines, - - - - - -	76 Pints $\frac{1}{4}$.
Thro' 8 Lines, - - - - - -	110 Pints $\frac{2}{3}$.
Thro' 9 Lines, - - - - - -	126 Pints

If you divide theſe Numbers by 14, the Quotient will give the Inches of Water: Thus 126 Pints, divided by 14, give 9 Inches. It may be objected, that in ſome Experiments, great Holes give more Water in Proportion than ſmall ones; but that happens by reaſon of other Cauſes, and often great Holes give leſs in Proportion. I made the following Experiments of it. I took a Pipe 6 Foot high, and 6 Inches Diameter, at the Bottom of which I fix'd a Hole of 4 Lines, and one of 12. When the Pipe was full, two Holes were open'd at the ſame time, till the Pipe was half emptied. The Water that ran out at the two Holes was receiv'd in two different Veſſels; and whereas the great Hole ought to have given nine times more than the little one, it gave but about 8 times more.

When the Heights of the Water in the *Reſervoirs* are different, the higheſt give more than the others in a ſubduplicate *Ratio* of the Heights; that is, as the leaſt Height to the mean Proportional betwixt it and the great Height.

According to this Rule, if the Surface of the Water of the loweſt *Reſervoir* is 3 Foot high, and the Ajutage 3 Lines, you muſt take 6, which is a mean Proportional between 3 and 12; and becauſe 6 is to 3, as 14 Pints to 7, therefore we may conclude that a *Reſervoir* 3 Foot high will give half an Inch, that is, 7 Pints in a Minute thro' an Hole of 3 Lines. If the Height was of 4, you muſt take 48, the Product of 4 by 12, whoſe Root is 7 nearly; then as 12 to 7, ſo is 14 to 8 and $\frac{1}{6}$; which ſhews that ſuch a Jet will give about 8 $\frac{1}{6}$ Pints in a Minute.

of 4 or 5 Lines, when the *Reſervoir* is 8, 10, or 12 Foot high, *&c.* But yet we muſt compute the Expence of Water according to the Height of the *Reſervoir* when the Conduct of the Water is free and big enough. Sometimes in making Experiments, we find, that when the Pipes are very unequal, the biggeſt give more Water than according to the ſubduplicate *Ratio.* But the Reaſon of this is, that in order to ſupply a Jet which ſpends a great deal of Water, you muſt pour in the Water with great Swiftneſs, which gives a Shock to the Water of the Veſſel, or artificial *Reſervoir*, and by that Impulſe makes the Water go faſter out at the Ajutage than it would do by the Weight of Water from a real *Reſervoir.*

Concerning the Height of Jets.

The Reſiſtance of the Air hinders Jets from riſing up to the Heights of the *Reſervoirs* ; and the more Air is to be paſs'd thro', the more ſenſible is that Reſiſtance. Here follows a Way of determining this Diminution of Jets from the Height of their *Reſervoir.*

Take a Ball of Lead of about one Inch Diameter, and a Ball of Wood of about the Diameter of the Hole, and whoſe ſpecific Gravity is ſo little leſs than that of Water, that when it ſwims in Water, it may be almoſt all cover'd : Throw them up with the ſame Force, in ſuch manner that the Ball of Lead may go up as high as the *Reſervoir*, or very near; then obſerve where the Ball of Wood will go, and that will be nearly the Height of the *Reſervoir.*

Another Way by Calculation, is built upon this, That the Differences of the Height of the *Reſervoirs*, and of the Heights of the Jets increaſe in a

ſubdu-

ſubduplicate *Ratio* of their Heights: As for Example, if the firſt Jet riſes 5 Foot, and its *Reſervoir* is higher by an Inch, a Jet of 10 Foot will have its *Reſervoir* higher by 4 Inches; for 5 is to 10, as 1 to 2, and the Square of 2 is 4; therefore as 1 is to 4, ſo is 1 Inch to 4 Inches. In this Caſe it is ſuppos'd, that the Pipes are ſufficiently large, according to the Rules which ſhall be given.

A Table of the different Height of Jets.

Height of the Jets.	*Height of the* Reſervoirs.	
Feet.	*Feet.*	*Inches.*
5	5	1
10	10	4
15	15	9
20	21	4
25	27	1
30	33	0
35	39	1
40	45	4
45	51	9
50	58	4
55	65	1
60	72	0
65	79	1
70	86	4
75	93	9
80	101	4
85	109	1
90	117	0
95	125	1
100	133	4

The Friction against the Sides of the Ajutages does something diminish this Proportion in great Heights; therefore it is necessary for great Heights that the Ajutages should have a Bore of 10 or 12 Lines Diameter; for if they were but of 2 or 3 Lines, they would rise to a much less Height than what is found in this Table; besides, the Air resists a little Body much more than it does a great one, as may be seen in Fire Arms, which shoot a great Ball much farther than a little one, or than Shot or Lead-Dust. If a Pipe 136 Foot high throws up its Jet 100 Foot thro' an Ajutage of 12 Lines; it does not follow that a Pipe of 344 Foot, shall, thro' the same Ajutage, raise its Jet 200 Foot, tho' the Height of 344 Foot exceeds that of 200 by 144, which is 4 times 36. In the Velocity of such Jets the Air resists so much, that the Water by the Shock is reduc'd into a Mist, and so cannot rise very high. I have also found by Experience that the Pipes must have a considerable Bore quite to the very Ajutage, and so much the larger, the bigger the Ajutage is. Here follow the Rules for that Purpose.

A *Reservoir* of 5 Foot, having an Ajutage of 6 Lines, must have the Pipes close to the Ajutage, about two Inches in Bore. The best Figure for bringing the Pipe to the Ajutage must be as is represented in the 114th *Fig.* by A B C; that is, the Bend in B must not be at right Angles, as in the 115th *Fig. a b c d.* And for mean Heights, as far as 10 or 12 Foot, there is no occasion for a long Pipe at the going out of the Water, as *c d*, for the Friction would considerably retard the Jet; but the Thickness of the Metal is enough to be be bor'd through, as in *Fig.* If the *Reservoir* is 21 Foot 2 Inches high, and the Hole of the Ajutage 6 Lines,

Lines, the Jet will not riſe to 20 Foot, if the Conduct-Pipe be but a two Inch Bore, becauſe the Friction will be too great in that narrow Tube, where the Water will run twice as faſt as when the *Reſervoir* was but 5 Foot high; and therefore it muſt be wider, that the Water may run down ſuch a Pipe to ſupply the Jet with the ſame Velocity: Then inſtead of 2 Inches, the Bore of the Pipe muſt be 2 ¾ nearly; becauſe the Velocity being in a ſubduplicate *Ratio* of the Heights, the Velocity of this laſt Jet will be double that of the other, and conſequently the Square of the Diameter of the Bore of its Pipe muſt be double the Square of the Diameter of the other. On this Rule depends the following Table.

A Table of the Diameter of the Pipes and the different Adjutages, according to the Height of the Reſervoirs.

Height of the Reſervoirs.	*Diameters of the* Ajutages.	*Diameters of the* Pipes.
5 Feet - -	3, 4, 5, or 6 Lines -	22 Lines
10 - - -	4, 5, or 6 Lines -	25 Lines
15 - - -	5, or 6 Lines - -	2 ¼ Inches
20 - - -	6 Lines - - - -	2 ½ In.
25 - - -	6 - - - - - - -	2 ¾ In.
30 - - -	6 - - - - - - -	3 In.
40 - - -	7, or 8 Lines - -	4 ¼ In.
50 - - -	8, or 10 Lines - -	5 ½ In.
60 - - -	10, or 12 Lines -	5 ¾ or 6 In.
80 - - -	12, or 14 Lines -	6 ½ or 7 In.
100 - - -	12, 14 or 15 Lines-	7 or 8 In.

A Table

If the Jet has an Ajutage of 12 Lines, and the *Reſervoir* 84 Foot high; the Jet will riſe to near 65 Foot. If the leaſt Pipes near the Ajutage be of 7 or 8 Inches Diameter, it will give near 40 Inches; and thro' an Ajutage of 14 Lines it will give 54 Inches, which amount to 3888 *Muids* or Hogſheads in 24 Hours; and if the *Reſervoir* be 50 Foot ſquare, it muſt be about 13 Foot deep to ſupply the Jet 24 Hours; and to play it only 12 Hours, it may be but a little more than 40 Foot ſquare, and 10 Foot deep, to contain 1944 Hogſheads. If the Jets do not play continually, and Cocks be fix'd in the Conduct-Pipes to ſtop the Water at Pleaſure, their Water-way muſt be equal to the Bore of the Pipes; for if it was leſs, their Friction would diminiſh the Height of the Jet. The Pipes ſhould be wider in thoſe Places to admit of proper Cocks.

When the *Reſervoirs* are very high, and the Pipes at bottom are of 5 or 6 Inches Diameter, they are in danger of breaking by the Weight of the Water; and the leſs their Bore is, with the more Difficulty they break when their Thickneſs is the ſame. The following Rules may be obſerv'd. Suppoſe that an Height of *Reſervoir* of 30 Foot cannot break or unſolder a Copper Pipe of $\frac{1}{4}$ of a Line thick, but that it cauſes it to break when the Pipe is thinner, as only the 5th Part of a Line; if you make the Pipes wider, without raiſing the *Reſervoir*, you muſt increaſe the Thickneſs in the Ratio of the Diameters; for on the one hand, the Weight of the Water is in a duplicate *Ratio* of the Diameters, wherefore if the Diameter is double, the Weight of the Water will be quadruple, and the ſolder'd Circumference double, which renders the Reſiſtance double. Therefore there only remains the ſimple Ratio of the Diameters, if you ſuppoſe that the Water, by its Weight, cauſes the Parts of the Metal and of the Solder to ſeparate from each other, as the Parts of a Stick, which ſhould be pull'd perpendicularly. Thus if the Pipe be 6 Inches Diameter for an Height of 30 Foot, the Metal will be half a Line thick; if it be a Foot Diameter, it muſt be one Line thick.

When the *Reſervoirs* are higher, the Diameters of the Pipes remaining the ſame, the Thickneſs of the Metal is to be increas'd in direct Proportions of the Heights. Thus for a *Reſervoir* of 60 Foot, the Pipe being 3 Inches wide, muſt have a Thickneſs of half a Line; and for a *Reſervoir* 120 Foot high, it muſt be a whole Line thick.

If the Pipes are both higher and wider, the two Proportions muſt be obſerv'd. Thus if the Pipe be 60 Foot high, and its Diameter 8 Inches, you muſt take half a Line, becauſe of its Height of 60 Foot; and for its Diameter you muſt work by the *Rule of Three*; ſaying, as 3 Inches are to 8 Inches, ſo is half a Line to $\frac{3}{4}$; which ſhews that the Thickneſs of the Metal muſt then be 1 $\frac{1}{3}$ Line thick.

If you ſuppoſe the Solder to hold faſter than the Parts of the Metal, you may conſider the Plate of *Fig.* 114, in which the Ajutage is, as the weakeſt Part, and which muſt break in its Middle, or near the ſolder'd Part, at the Edges; and becauſe a Wooden Ruler can, when it reſts upon both Ends, ſuſtain a Weight double of what it would do, if it was twice as long; and if the Weight be diſtributed along a Ruler in ſeveral ſmall equal Parts, it may, without breaking, ſuſtain twice as much as if the Weight was all in the Middle: It follows, that if the Plate was ſquare, and that it could be laden with a Height of Water of 20 Foot, without breaking; it would be able to ſuſtain but half the ſame Weight if it was twice as long, and no wider; but then

then it would be laden with twice as much Water, and consequently it would be able to sustain but ½ of it: Therefore according to the Doctrine of *Galilæo*, its Thickness ought to be doubled to make it strong enough. The same thing would happen if it was round; for on the one hand the Weight of the Water would be doubled, but its Resistance would be also doubled, and being round, it would resist proportionably.

Therefore for Pipes of different Diameters, and equal Heights, you must increase the Thickness of the Metal of the Plate, which has the Ajutage, according to the Ratio of the Diameters, if the Plate is the weakest Part.

When the Water is carried a great way, as 1000 Fathom, the Friction diminishes the Height of the Jets, and the Expence of Water, especially if the Tubes be too narrow. These following Rules may be observ'd.

If you have a *Reservoir* of 80 Foot, and Water enough to supply 6 Jets of 9 Lines each, you must take the Square of 9, which is 81: Its Product by 6, gives 486, whose square Root is about 22; which shews that the 6 Jets of 9 Lines each give as much as one single one of 22 Lines. And because a Jet of 22 Lines Diameter gives much more Water than one of an Inch; namely, in the Proportion of 484 to 144, the Squares of 22, and of 12; the Diameter of the Pipe must also be in the same Proportion in respect of 7 Inches, agreeable to an Height of 8 Foot. Therefore as 12 is to 22, so is 7 to 12 and ⅞ nearly; which shews that the great Pipe, as far as the Place where it it is branch'd out to the several Jets, must be 13 Inches Diameter, and that each Branch must be a 7 Inch Bore; and in such a Case the Jets will rise higher than 60 Foot, and the Jets will riſe to 65 Foot, notwithſtanding the long way that the Water is carried, if the main Pipe be 14 Inches Bore. Other Computations may be made according to the ſame Rules.

In very high and large Jets, the Ends of the Pipes and their Ajutages muſt be pretty near in the manner repreſented in *Fig.* 116 at ABCD: For ſuppoſe the Pipe ABC to have 7 Inches Diameter, you muſt reduce it to half by narrowing the Pipe, and make the Part FD three or four Inches high; then make a ſecond narrowing quite to the Ajutage; and if its Hole is one Inch in Diameter, an Height of 6 Lines at right Angles will be ſufficient for directing the Jet; and if it ſhould riſe but 50 Foot, 3 or 4 Lines would be enough; for the higher DE is, the more will the Jet fall ſhort; and the ſmoother the Bore of the Ajutage is, the finer will the Jet be.

To divide the Water for ſeveral Jets,and know how much you ought to allow for each, (which will alſo ſerve for diſtributing the Water of a Spring to ſeveral Perſons) you muſt have a Gauge-Veſſel, whoſe Holes are ſquare, and not round: As for Example, if AB (*Fig.* 117.) be the Top of the Gauge-Veſſel, and CD the Height of the Water, you muſt have your ſquare Holes about two Lines below the Surface CD, along a ſtrait horizontal Line EN. Now if it be divided into ſeveral Squares an Inch high, as EFPH, thoſe Holes will give more than an Inch; for if circular Holes give 14 Pints in a Minute, ſquare ones will give a Quantity which will be to 14, as 14 to 11; which Proportion of 14 to 11, is nearly that of the Square to the Circle, whoſe Diameter is equal to the Side of the Square. If then a round Inch, or Circle of an Inch Diameter gives 14 Pints in a Minute, a ſquare Inch will give almoſt 18 Pints; for

for 11 is to 14, as 14 Pints to 17 $\frac{9}{11}$. You muſt therefore divide E F into 14 equal Parts; and if E R contains 11 of thoſe Parts, the Rectangle or long Square E R S H will be nearly equal to a round Inch, and will give one Inch of Water, that is 14 Pints, in a Minute, provided the Water of the Gauge-Veſſel is kept at the Height C D. You may make ſeveral Figures equal to E R S H under the ſame Line, as R L T S, L M V T, *&c.* If you would give half an Inch, you muſt divide one of the long Squares, as *z r o g*, into two Parts down the Middle by the Line X Y; and then it will give half an Inch, that is, 7 Pints in a Minute; and in other Diviſions you may uſe the ſame Method, taking a Third, as *i k a q*, or a Fourth, *&c.* You will alſo have this Advantage, that if the Water of the Spring ſhould decreaſe, and fill but the Third, the Half, or the two Thirds of the Height of the Holes in the Gauge-Veſſel, every Perſon will want in proportion to the Quantity which they uſed to have; which can never happen when the Holes are round; and if there be a little more Friction in proportion in the leſſer than the greater Holes, that is recompens'd, becauſe the Water follows beſt to ſupply a ſmall running out. If you would give 3 or 4 Inches, take 3 or 4 entire Holes, each equal to E R S H, as E M V H, for the 3 Inches.

Theſe Rules may be applied to any Difficulty that may ariſe concerning *Jets d'Eau.* As for Example, if you have a *Reſervoir* or a Spring 40 Foot above an Ajutage, which can give 20 Inches, and you would employ it all to play one Jet; you muſt look at the Table, and you will find that an Ajutage of 3 Lines, having its *Reſervoir*, at the Height of 40 Foot gives 25 $\frac{2}{3}$ Pints in a Minute. Then by the *Rule of Three* ſay; If 25 $\frac{2}{3}$ Pints are given by 9, the

Square of 3, what will 280 Pints (which 20 Inches give in a Minute) be given me by? And you will have 98 $\frac{2}{11}$ for your Fourth Number, whose square Root is 10 nearly; and that shews that the Ajutage for such a Jet must be of almost 10 Lines in Diameter, and that in rising 35 Foot, it will take the 20 Inches, if it plays continually. But if you would have the Jet play only 12 Hours by Day, you may, during the Night, let the Water run into a great *Reservoir* which shall hold 720 *Muids*, or Hogsheads, and have Water enough for a Jet of 14 Lines, or for two of about 10 Lines, to play 12 Hours together.

THE

THE TRANSLATOR'S ANNOTATIONS.

Page 4. TO *underſtand why this Aerial Matter*, &c.] That the Particles of Air have a centrifugal Force, (that is, that they repel each other from their reſpective Centers) is prov'd from its Denſity being equal to its Compreſſion; and from this Principle may be explain'd the Reaſon why the Air in Water takes up more Space when in Bubbles, than whilſt it is inviſibly diſpers'd, and, as it were, diſſolv'd in Water. For when ſeveral Particles of Air are got together in the Form of a Bubble, their Centrifugal Force exerts its ſelf, ſo as to make them recede farther from each other than they would do if there were Particles of Water between them; which, by their Attraction, bring the Particles of Air nearer together than their repelling Force would otherwiſe allow: So that if for Example, 20 Particles of Air form a Bubble, there will be ſo much interſpers'd Vacuity between them, that the Space taken up in the Water by that Bubble will be much greater than the Sum of the Spaces of the ſaid 20 Particles, when they are diſpers'd and inviſible in the Water. To make this plainer, let us ſuppoſe A B C (*Fig.* 118.) to be three Particles of Air, the neareſt to each other that their repelling Force will allow of when there is nothing between them; now if two Particles of Water *d e* (*Fig.* 119) capable of attracting Particles of Air, get between the said Particles, they will, by their Attraction, bring A B and C so near together, as to be in the Position of *Fig.* 120; the Particles of Water in this Case acting counter to, and diminishing some of the Air's repelling Force. But if the Particles of Water *d e* be remov'd, the Particles of Air will be restor'd to all their repelling Force, and they will recede from each other as far as A B C (*Fig.* 118.) as they did before. Further, Let the *Fig.* 121. represent some of the Particles of Air which make up a Bubble in Water or in Ice; if there be not room between the Particles of Air 1, 2, 3, 4, 5, 6, for Particles of Water to get into this Spherule of Air towards its middle Particle 7, then that middle Particle and the other round about will repel each other so strongly, as to leave pretty large Vacuities intersspers'd as *l*, *m*, *n*, *o*, *p*, *q*; but if Particles of Water can insinuate themselves between the Particles of Air, so as to get into the middle of the void Spaces, *l*, *m*, &c. all the Particles of Air will be brought nearer together, and take up less room than before, as in *Fig.* 122. where 1, 2, 3, &c. represent the Particles of Air, as before, and the Black Circles, those of Water. Now if the Particles of Water get from between those of Air, the Particles of Air will again repel each other with their full Force, and so make a larger Bubble. Besides a large Bubble of Air is less press'd in Proportion to its Bulk than a small one; because the Pressure of the Water upon it is always as its Surface; whereas the expansive Force of the Air is as the solid Contents of each Bubble; which encreases as the Cube of the Diameter of the Bubble, whilst the Surface encrease only as the Square of the said Diameter. This apply'd to the Facts which the Author relates in his

Account of the Experiments of freezing Water, will account for the Dilatation or ſtrong Rarefaction of the Air in the freezing Water, which happens when the Particles of Air can better come at each other, as thoſe Particles that are purely aqueous become fix'd; for Cold, that in all other Caſes condenſes the Air, could never rarify it here.

That there is ſuch a Principle in Nature as Repulſion, without Contact of the Particles of Matter, is certain from Phænomena; tho' the Cauſe of it cannot yet be aſſign'd.

Page 11. *To explain the Reaſon of this* Viſcouſneſs, *&c.*] This Viſcouſneſs may rather be call'd an *Attraction of Cohæſion*, by which the Parts of Bodies cohere ſtrongly in Contact, but act but very little upon one another at a ſenſible Diſtance; for ſeveral Experiments confirm that Property in Nature; as that of a Drop of Oil of Oranges moving between two Glaſs Planes, and advancing ſwiftly as it comes nearer to the touching Ends, (*ſee Philoſ. Tranſact. Numb.* 332.); that of Water riſing of it ſelf between two Glaſs Planes, and in Capillary Tubes; and ſeveral others, too long to mention. I ſhall only take Notice of one Proof more, becauſe I don't know that any Body yet has obſerv'd it. The 123d *Fig.* repreſents a broken piece of an hollow Cylinder of Glaſs, which was an Air-Pump Receiver: H I is a Crack in the Glaſs, of which only the part H B is viſible, till, by pulling the Ends K and F, you open it farther; as for Example, to I. Now if an Eye plac'd at E, endeavours to ſee an Object at C, when the crack'd Part A is interpos'd, it will not ſee the Object, becauſe the Rays coming from C to the lower Lip of the Crack H I, juſt under A, are by that

that Surface of Glaſs reflected to G, and ſo does not come to the Eye; whilſt the Rays that come from R, and fall upon A, are reflected to the Eye, and enter it; ſo that it ſees only the Crack in the Glaſs, inſtead of the ſmall Object at C. But if the Eye looks at an Object plac'd at D, it will ſee it as plain as if there was no Crack in the Glaſs, notwithſtanding the Part B of the Crack is interpos'd as much as the Part A was before: So that the Rays from D go directly to the Eye at E, without being reflected downwards to F, as in the former Caſe; neither are the Rays coming from *r*, to the Crack at B, reflected by it to the Eye, but they paſs on to F. If whilſt every thing elſe remains as before, you pull K and F to open the Crack farther, than it was viſible before, *r* B will be reflected to the Eye, D B to F, the Object D will diſappear, and only the Crack be ſeen at B; for now the Rays of Light, which, when they came to B, were attracted by the Surface of the loweſt Part of the crack'd Glaſs (and therefore went ſtrait on to F) do not come near enough to that Surface, to be within the Power of its Attraction; and the Caſe becomes the ſame as when A was the Point of Incidence; but if you let go the Ends K F, the Lips of the Crack will come ſo near together, that the Ray *r* B will be attracted by the lower Part of the Glaſs, as before, and paſs on to F, whilſt the Ray D B paſſes on to the Eye, and the Object at D is again ſeen, whilſt the Crack at B diſappears. It may therefore be concluded, that the nearneſs of the Particles, and not the hook'd Figure, is concern'd in this ſort of Cohæſion. Nay, there are ſome Particles of Matter that may have an attractive Faculty on one Side, and a repulſive on the other; as may be gather'd from a Conſideration of the Fits of eaſy

Reflection,

Reflection, and Fits of easy Transmission of a Ray of Light, according as it offers different Sides to the Refracting Body. *See Sir* Isaac Newton's *Optics, last Edition.* Page &c.

Pag. 37. *It is very probable that the Moon,* &c.] This Conjecture implies a *Plenum*, or that our Atmosphere reaches beyond the Moon; both which Suppositions are false. But there may be a Wind or Current of Air from the Poles towards the Equator when the Moon is New (as also when it is Full;) because as the joint Attraction (or Gravitation) of the Sun and Moon raise a Tide in the Ocean at the New and Full Moon, they must also raise one in the Air, which therefore will flow in from the Polar Regions. And this will answer our Author's Phænomenon, tho' he has mistaken the Cause.

Pag. 74. *The whole Quantity of Water that rises,* &c.] Tho' in dipping a small Tube in Water, the Quantity that rises of it self may be no more than a large Drop; yet a far greater, nay, an immense Quantity of Water will be sustain'd above the Level of the other Water by the Attraction of Cohæsion, by means of a Capillary Tube. For if there be a Funnel, as A B C (*Fig.* 124.) full of Water, and whose wide End stands in a Vessel of Water, as B C, and the Top of the Funnel A ends in a Capillary Tube open at A, the whole Water will be sustain'd; the Pillar A *a* by the Attraction of the Circle of Glass within the Tube immediately above it, and all the rest of the Pillars of Water as F *f*, D *d*, E *e*, G *g*, &c. in some measure, by the Attraction of the Parts of the Glass above them, as F D E G; and that the small Pillars or Threads of Water D *d*, and E *e*, do not slide down to F *f*, and so go quite down, seems to be owing to their Cohæsion with the Pillar A *a*, which is sustain'd by the Capillary Tube A; for if

of the Wire close to the Bottom, without any *Mercury* betwixt it and the Glass. But if instead of Iron, you use a Silver Wire of the same bigness, the *Mercury* being more attracted by the Silver, will immediately get under and buoy it up ; neither can you then see the Wire thro' the Bottom of the Dish, tho' you keep it down with your Finger. Yet if the Silver Wire be foul or smoak'd, it will be kept down like the Iron, because the Foulness about it keeps the *Mercury* so far off from the Silver, as to be out of the Power of the Attraction of Cohæsion.

If Cohæsion was owing to hook'd Particles, as our Author supposes with the *Cartesians*, there must be second Hooks to hold the first, and third Hooks to hold the second, and so on *in infinitum*, which is a very unphilosophical Supposition.

Pag. 92. *You must weigh it in Water*, &c.] To be very exact, the String by which you suspend any thing in Water, ought to be a Horse-Hair, because that is of the same specifick Gravity with Water. But the best Machine for those Experiments is the Hydrostratical Balance, invented by the late ingenious Mr. *Francis Hawksbee*, F R S. and describ'd in Dr. *Harris*'s *Lexicon Technicum*, P[t]. 2.

P. 92. *Specifick Gravity of Gold*, &c.] The Specifick Gravity of fine Gold without Allay, is to that of Water as 19 to 1.

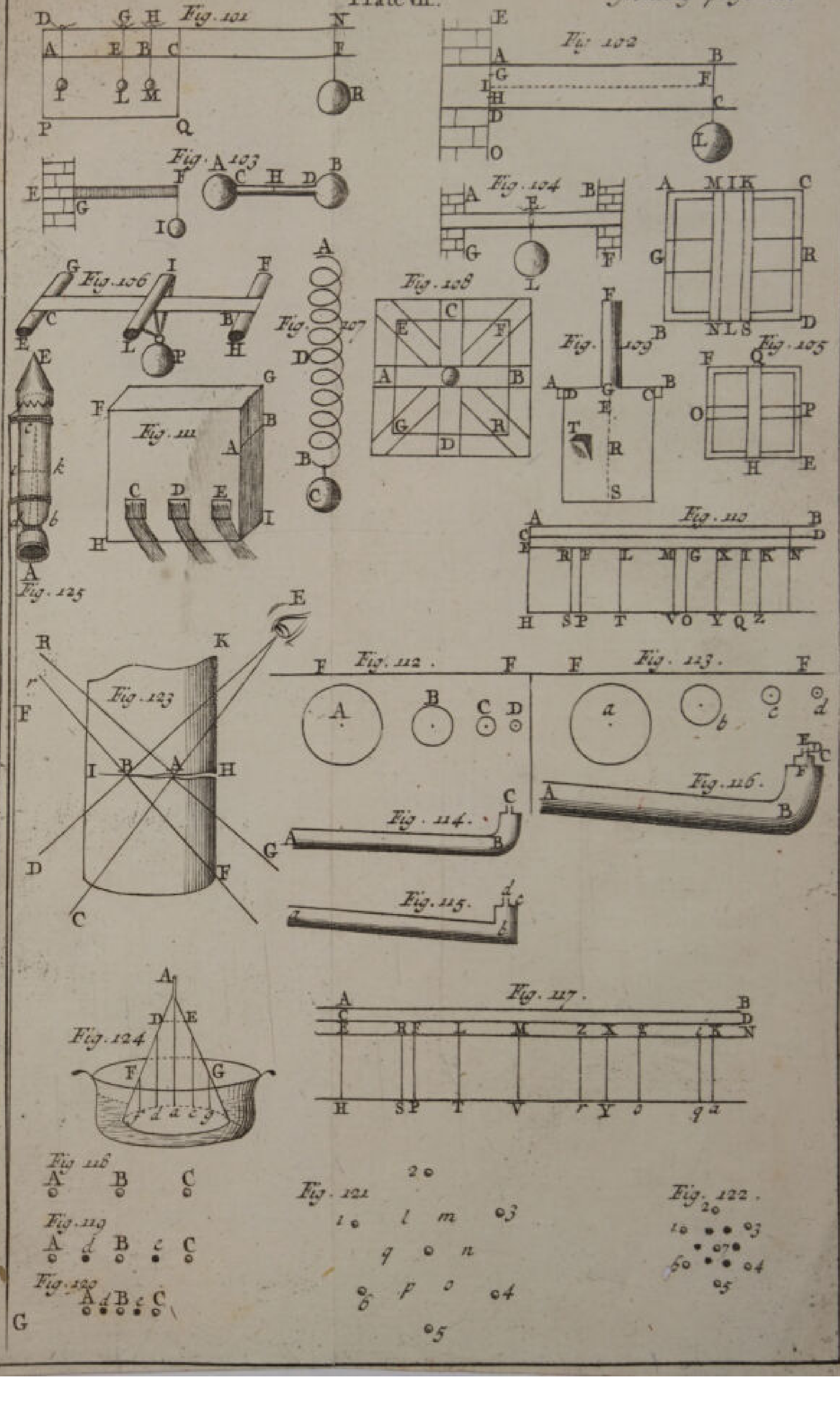
P. 96. *A great Heap of Spunges*, &c.] See the Annotations to *Page* 4.

P. 111. *Those that go 7 or 8 Foot under Water*, &c.] Those that go under Water in the Diving Bell (*see Phil. Trans. Numb.* 349) may go down 100 Foot under Water without feeling any Pressure, because the Air in the Bell being condens'd in proportion to the increas'd Pressure of the Water, is breath'd by the Diver in the Bell; and therefore getting into all the Cavities of his Body, enables him to ſuſtain this additional Preſſure, as much as breathing the common Air makes us ſuſtain the uſual Preſſure of the Atmoſphere; which, when the *Mercury* ſtands at 30 Inches, is above 32000 Pounds upon a Man of a middle Stature. But if a Diver without a Bell went down 20 or 30 Fathom under Water, he would ſuffer ſo much from the great Preſſure, as hardly to come up alive, tho' he ſhould go down in the Copper or Braſs Diving Engines, which communicate with the ſuperior Air, becauſe the Arms and Legs are only cover'd with Leather.

P. 116. *A Rocket riſes by the Impulſe of the Flame againſt the Air*, &c.] The Author here miſtakes the Reaſon of the Riſe of a Rocket, which is no way owing to the Air's Reſiſtance; for, firſt, if we ſuppoſe the Air's Reſiſtance equal to the Impulſe of the Flame, it will be as if the Rocket had no Vent; and therefore in that Caſe, it muſt either burſt, or remain immoveable. If the Impulſe be greater, the Air's Reaction againſt the Flame coming downwards, cannot impell the Rocket upwards, unleſs the Flame ſhould be a ſolid Body. Laſtly, if the Impulſe be leſs than the Force of the Air, no Flame can come out of the Rocket.--- To underſtand the true Reaſon of the Riſe of a Rocket, we muſt firſt conſider it as if it had no Vent at the Choak or Mouth A (*Fig.* 125) and was ſet on Fire in the conic Space *b c d*; the Conſequence of which would be, either that the Rocket would burſt in the weakeſt Place, or that if all Parts of it were equally ſtrong, and able to ſuſtain the Impulſe of Flame of the Powder, the Rocket would remain immoveable. Now as the Force of the Flame is equal every way, let us ſuppoſe its Action towards A and towards E

to

Plate VII. fronting page 288.



to be able to lift 40 Pounds; but as the Directions of those Forces are equal and contrary, they will destroy each other's Action: Then if you imagine the Rocket open'd at A, the Action of the Flame downwards is taken quite away, and there remains a Force equal to 40 Pounds acting upwards in the Direction A *c* E, which carries up the Rocket with its Stick F G. This will appear by observing that when the Composition of the Rocket is very weak (so as not to give an Impulse greater than the Weight of the Rocket and Stick,) it will not rise; if the Composition be only slow, the Rocket will not rise at first, whilst the Action of the Flame upwards is only against *c*, the Vertex of the hollow Cone; but when the Composition is consum'd as far as *b i*, the Flame acting upwards against a greater Surface, namely, against *b i*, the Rocket will then rise up. The Use of the Stick is to keep it perpendicular; for if the Rocket should begin to tumble, moving round the Point A (which is the common Center of Gravity of the Rocket and Stick) the End G of the Stick F G would beat so much Air, and with such Velocity, upon account of its Distance from A, that the Reaction of the Air, by Resistance, must restore the Stick, and consequently the Rocket to a perpendicular Position; but when the Composition within the Rocket is quite consum'd, and the Impulse upwards is ceas'd, the common Center of Gravity will be brought down to F, the Velocity of G diminish'd, and that of E increas'd; so that the Rocket will tumble over, and fall with the End E downwards. All the while that a Rocket burns, the common Center of Gravity is getting downwards, the faster and the lower, the lighter the Stick is; so that sometimes it tumbles over before it is burn'd out; but when the Stick being heavier, the

Weight

Weight of the Rocket bears a leſs Proportion to that of the Stick, the common Center of Gravity will not get ſo low, and the Rocket will riſe ſtrait, tho' not ſo faſt.

The Mean between theſe muſt be found by poiſing the Rocket and Stick acroſs your Finger: If you would uſe a light Stick, poiſe ſo as to have the Center of Gravity juſt at A, the Mouth of the Rocket; and for a heavy Stick, let not the Center of Gravity be lower than 5 or 6 Inches off from the Mouth.

Pag. 129. *Air is 756 times rarer than Water*, &c.] The Denſity of Water to that of Air, is found to be betwixt 800 and 900 to 1, by comparing ſeveral Experiments together.

P. 133. *The* Paris Muid, *&c.*] Tho' I have given the Word *Barrel* to expreſs the *Muid*, every where but in the *Practical Rules for Jets*; yet ſince it comes ſo near to our *Hogſhead*, I would have the Reader call it every where *Hogſhead*.

P. 153. *The Length of the Thread*, &c.] By comparing the *Engliſh* and *French* Meaſures together, as I have given their Proportions before the *Preface*, it appears that the Length of a Pendulum, *Engliſh* Meaſure, is 39 Inches, and two Tenth Parts of an Inch.

P. 154. *In the Countries near the Equator*, &c.] Tho' the centrifugal Force of thoſe Parts of the Earth near the Equator takes off from the Gravity of Bodies in the Torrid Zone; yet that Cauſe is not ſufficient to anſwer for the ſhortning of Pendulums in the Proportion above-mention'd. But if another Cauſe be taken in, namely, that the Earth is higher at the Equator than at the Poles, by about 17 Miles, thoſe two together will anſwer for the Diminution of Gravity, as we come nearer to the Equator.

Pag. 225. *The Velocity of the Water is ſtopp'd by the Friction,* &c.] Our Author does not allow enough for the Decreaſe of the Velocity of Water running thro' a long Conduct-Pipe. For if the Height of a *Reſervoir* be ſuch, that thro' a Hole of 1 Inch and ⅝ it ought to give 90 Ton of Water in an Hour; which, according to Monſieur *Marriote*'s Experiments, it muſt do, if the Water of the *Reſervoir* be about 100 Foot above the Hole, and the Conduct big enough; yet at the Diſtance of 1400 Yards thro' a Pipe of the Bore of the Hole all the way, it will not give above 5 Ton in an Hour. The Experiment of this was tried at the *Right Honourable the Earl of Caernarvon*'s, by Mr. *J. Lowthorp* (M. A. F. R. S.) and my ſelf; and the ſame ingenious Gentleman aſſures me, that he has often tried it, and found ſuch a Deficiency; but what is moſt ſurprizing in the Experiments of this Nature which he has made, is, that the Quantity of Water diminiſhes rather in Proportion to the Length that it runs, than to the Friction againſt the Sides of the Pipe; for if a ſeven Inch Pipe and a three Inch Pipe run the ſame Length, as for Example a Mile, the Deficiency will not be directly in Proportion to the Diameter, as it ought to be on account of the Friction, but nearly in Proportion to the Quantity of Water that each Pipe ought to give.

Page 266 *A Table of the Expence*, &c.] Tho' this Table differs from that of *Page* 174, in having the *Reſervoir* only 12 inſtead of 13 Foot high above the Ajutage, and ſeems likewiſe to differ from what he intended by what he ſays before; yet as the Difference is not great, and he makes his Calculation afterwards according to that Height, I thought proper to leave it as I found it in the *Dutch* Edition, rather than to alter all the Numbers.

Page 269and 201. *Take a Ball of Lead, &c.*] The Ball of Lead ought to be thrown up with the ſame Velocity as the Ball of Wood, which it cannot have, unleſs it be thrown with a Force as much greater as its ſpecific Gravity is greater than that of the Word.

N. B. *A full Account of the Reaſon of the Water's riſing in, and being ſuſtain'd by ſmall Tubes, has been lately given in one of the* Philoſophical Tranſactions *by Dr.* James Jurin, F. R. S. *where he has confirm'd what he aſſerts by a great many very curious Experiments. See* Phil. Tranſ. *Numb.* 355.

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