Mechanick powers; or, The mystery of nature and art unvail'd ... Together, with a treatise of circular motion artificially fitted to mechanick use, and the making of clock-work, and other engines ... The whole comprized in ten books, and illustrated with copper cuts / By Ven. Mandey, Philomat [and J. Moxon].

Contributors

Mandey, Venterus.
Moxon, J.

Publication/Creation

London : Printed for T. Shelmerdine and T. Ballard, 1702.

Persistent URL

https://wellcomecollection.org/works/xwnazrut

License and attribution

15/-

35178/B

Last plate wanting
(figs. 206-212)

S
26/11/99

R. White sculp.

Vera Effigies Venteri Mandey.
Etatis Suæ 37 Anno 1682

Mechanick Powers;

OR, THE
MYSTERY
OF
NATURE *and* ART
UNVAIL'D

Shewing what *Great Things* may be perform'd by Mechanick Engines, in removing and raifing Bodies of vaft Weights: with little Strength or Force; and alfo the making of Machines or Engines, for raifing of Water, draining of Grounds, and feveral other Ufes.

TOGETHER,

With a Treatife of *Circular Motion* artificially fitted to Mechanick ufe, and the making of Clock-work, and other Engines.

A Work pleafant and profitable for all forts of Men, from the higheft to the loweft Degree: And never treated of in *Englifh* but once before, and that but briefly.

The whole comprized in Ten Books, *and illnftrated with* Copper Cuts.

By *Ven. Mandey*, Philomat.

Mechanick Powers:

OR, THE

MYSTERY

OF

NATURE and ART

UNVAIL'D

Shewing what Great Things may be perform'd by Mechanick Engines, in removing and railing Bodies of vaſt Weights: with little Strength or Force; and alſo the making of Machines or Engines, for railing of Water, draining of Grounds, and ſeveral other Uſes.

TOGETHER,

With a Treatiſe of Circular Motion artificially fitted to Mechanick Uſe, and the making of Clock-work, and other Engines.

A Work pleaſant and profitable to all Sorts of Men, from the higheſt to the loweſt Degree: and never treated of in Engliſh but once before, and that but briefly.

The whole comprized in Ten Books and illuſtrated with Copper Cuts.

By Wm. Maaſer, Publician.

LONDON,

Printed for the Tho. Shanuelane at the Pale-tree, and Tho. Sakad, at the Ring-Sun in Little Britain, 1704. Where is to be ſold, the Hiſtery of [Machinery] Snap, by the ſame Author. Price 6 s.

A TABLE TO THE Several Propositions and Series OF THE WHOLE TREATISE.

The CONTENTS of the First BOOK.

a   The

The TABLE.

The CONTENTS of the Second BOOK.

The CONTENTS *of the Third* BOOK.

The CONTENTS *of the Fourth* BOOK.

The CONTENTS of the Fifth BOOK.

The CONTENTS of the Sixth BOOK.

Prop.

The CONTENTS *of the Seventh* BOOK.

The CONTENTS *of the Eighth* BOOK.

The CONTENTS *of the Ninth* BOOK.

Prob.

The CONTENTS of the Tenth BOOK.

Of

Mechanick

Mechanick-Powers:

OR, THE

Mystery of *Nature* and *Art* unvail'd.

BOOK I.

THE *Mechanick Art* is a Science which contemplates about the quantities of moving Forces, and of the times in which the Motion is made.

The Centre of Gravity of any Body is a certain point within it, having the parts about it every where confisting of equal moments according to which it is born downward, and from whence if a body be conceived to be hung by a Line it resteth while it bears downward, keeping the Position which it had in the beginning, and that Line is always perpendicular to the Horizon.

PROPOS. I.

VArious are the Engins, to which if force be used, their strengths are augmented in a wonderful manner, so that, that which is fit to overcome the resistance of 100 pound weight, may be made sufficient to overcome 1000 pound, yea, 2000 pound weight, and more : I will expound this Proposition, which cannot be done better than by simply exposing to view the Engines, whose forces are increased by the strength of their movers, and we will shew what Experience approves in common Engins; and because almost all Authors recal the other Powers to the Ballance, we will begin with it.

B

Of the Ballance.

BY the *Ballance* we underſtand an iron Rod, hanging freely in the middle point which is called the *Beam*, or *Centre* ; and the effect which daily experience teaches us is this.

Fig. 1. If two equal Weights ſuppoſe of 4 pound each be hung in the points A and B, ſo that the lines A C, C B are equal, they will poiſe each other, or be in *Equilibrio*. But if the weight F be never ſo little removed from the *Beam* or *Cock* C, ſo that the line B C be longer than the line A C, the weight F overcomes and raiſes the weight E ; if you ask why thoſe forces are increaſed by their greater diſtance from the *Beam*, or *Centre*, ſo that the diſtance augmented is equivalent to the weight ; that is, ſuppoſe two unequal weights E and G, and let the proportion of the weight E to the weight G, be the ſame as the diſtance C H to the diſtance A C ; and that the weight at H compenſates or makes amens in the diſtance for that which it wants in the Gravity or weight, ſo that they ſtill remain in *equilibrio*, (or equally poiſed) therefore it is queſtioned, wherefore the diſtance from the beam adminiſters ſufficient ſtrength to it to reſiſt double its weight ; which is ſo far forth a truth, that if the line or rod C H being produced farther in certain diviſions, the ſame weight, ſuppoſe one pound, will according to the ſeveral diſtances equiponderate to any weight, or number of pounds hung in the point A, and this kind of *Ballance* is in uſe every where, for Butchers weigh their meat by it, and Farmers their Hay, &c. Only Note this one thing, which in all Engines ought to be noted, to wit, as often as the force of the power is increaſed by the Engin, ſo often alſo is its motion increaſed with reſpect to the motion of the weight ; as in the former example, while the weight G is at the diſtance C H, being double the diſtance of A C, all things being ſo diſpoſed, if you remove the weight E one foot, the weight G muſt be removed 2 feet, ſince it deſcribes an Arch doubly greater, or as great again.

Of the Leaver.

THe ſecond Engin which is propoſed is the *Leaver*, which is a firm body extended in length, as a Bar of Iron or a wooden Bar of firm ſubſtance, in which three things are always.

ways to be diftinguifhed ; to wit, the power of the Movent, the Weight to be moved, and the point that fuftains the *Leaver,* which is called *Hypomoclion* or *Prop,* being nothing but a Roller or a piece of Timber or Stone laid under the *Leaver,* to fup- port it, even as in the Ballance we diftinguifh three things, to wit, the two Weights and the Beam or Cock ; whence it comes to pafs that the *Leaver* is compared to the Ballance. And becaufe the *Hypomoclion* may poffefs either the middle place be- tween the power and the weight, or it may be in one of the extreams or ends, and that two fold, to wit, either fo that the weight may poffefs the middle place, or elfe the power may be in the middle, therefore there are three kinds of *Leavers.*

Fig. 2.   The firft kind of *Leaver* hath the weight on one end A, the Power in the other end C, and the *Hypomoclion* in the middle, to wit, in the point B, and if the power happen to be equally diftant from the *Hypomoclion,* with the weight, and fo equally moved ; In fuch difpofition if the power can of it felf and without an *Engin* move 100 pound, and the weight A be juft 100 pound, it may move that and no more ; but if the diftance B C be greater than the diftance A B, fuppofe double to it, and being fo difpofed, while the weight is moved one foot, the Power C performs 2 feet, then the fame power being plac- ed in C, will raife or overcome 200 pound in A.

The fame proportion in a manner is faid to be in the fecond kind of *Leaver,* for becaufe the diftance D F exceeds the diftance D E, therefore the power placed in F, will be increafed accor- ding proportion of the line D F to the line D E.

The third kind of *Leaver* increafes not the force of the Pow- er, but rather increafes the force and refiftance of the weight, and leffens the force of the power ; beeaufe the diftance of the power H from the *Hypomoclion* G, is lefs than the diftance G I of the weight from the fame *Hypomoclion* ; and confequently in fuch difpofition the power is lefs moved than the weight.

Of the *Wheel,* or *Axis,* in Peritrochio.   Fig. 3.

THe *Wheel,* or *Axis,* in *Peritrochio* may be varioufly ufed, and this Figure expreffes it fufficiently, The power will be in the point F, and the weight in the point D ; it may eafily be re- duced to the *Leaver* of the firft or fecond kind ; For its *Axis* A B hath the force of the *Hypomoclion,* and becaufe the weight is

in

in D, its diftance will be C D and the diftance of the power applied
in F will be E F; Therefore the active force of the power will
be increafed according to the *Ratio* or proportion of the line
E F to C D, that is, if E F be four times as much as C D, and
the power without an *Engin* may take up 100 pound weight;
it being added to fuch an *Engin* may take up or draw 400
pound weight; Here we fhall offer no reafon, but expofe the
precife effect and experience; Wherein we would note one
thing, that the precife diftance from the *Hypomoclion* doth not
conferr this augmentation, but that diftance from whence
follows the greater motion in the power, will refpect to
the motion of the weight, that is, if the Power H fhould
draw by the rope F H, the diftance H E is not to be re-
garded, but only F E, becaufe although the length of the
rope increafe and confequently the diftance H E; notwith-
ftanding from that diftance it doth not follow, that while the
weight is moved one foot, the power is moved more than
four feet.

Of the Pulley or Windlefs.   Fig. 4.

THE fingle *Pulley* increafes not force, and is reduced to the
Leaver; notwithftanding being fo compofed that the diftance
of the weight and of the Power are equal, and thefe diftances
are D B, B E from the immoveable point B; and fince no
Pulley hath motion, but about the Fixed point B, therefore the
forces are not increafed, if the principle we profecute be con-
ftituted, becaufe the power is as well moved as the weight.
The only benefit that accrues from the *Pulley* in this difpofition,
is that the power may be more eafily applied, and to fhun
the refiftance which may happen by accident, becaufe the rope
being turn'd about an immoveable Cylinder is fretted and
worn.

The Pulley *may be difpofed after another manner.*

Fig. 5.   It may be made fo that the whole *Pulley* may move,
fuppofing one end of the rope faftned in A, and the weight G,
the Power F, and this is commonly reduced to the Second kind
of *Leaver*, for the *Hypomoclion* is fuppofed in B, the weight G
is in E, and the power F is in D, and therefore the diftance
of

of the power is double from the *Hypomoclion*, and while the weight G afcends to H, the Power F will be moved to a double diftance : It is not needful here to fhew all the Combinations of *Pulleys*, but only in this cafe to fhew the double force of the power, and that force which before was equal to 100 pound weight, by this difpofition may be made equal to 200 pound weight.

Of the Wedge.   Fig. 6.

THE *Wedge* is an Inftrument made of follid matter, as *Iron* or *Wood* ending in a fharp point or edge, As A B C D E F, fome Authors ftrive to reduce it to the *Leaver*, in which we are indifferent, and the *Wedge* feems to be a double *Leaver* of the fecond kind, in which the *Hypomoclion* is in the line G H, the weight in R and K, the Power in L and M, but how ill they have refented or reduced it, we will fhew hereafter; However it be, it is certain the force of the Power is increafed by the fharpnefs of the *Wedge*, and the accutenefs of the Angle, becaufe while the bodies which have the force of the weight, go back from one another by the line R K, the *Wedge* is moved according to the line I O : Add alfo, that the power which is ftruck with a blow on the head of the *Wedge*, makes a greater motion, than the Power which is made by weight lying on the head of the *Wedge*.

Of the Screw.   Fig. 7.

THe *Screw* is a moft powerful Machine, or Engin, and is a Cylinder cut with a wreathed circle about it, which may be varioufly conftituted and made : We fhall not attempt to reduce it to the *Leaver*, but 'tis certain, that one man who can alone by his own ftrength raife 100 pound, may by this Engin fometimes raife 10000 pound. For let the weight be be D E, the Power C, in the mean while that the weight is moved according to the diftance which is between two wreaths, or fpires of the *Screw*, it is neceffary that the power placed in the point C abfolves or finifhes a whole Circle; therefore let the diftance between the two wreaths be equal to the line N O, then feek how many times the line N O is

con-

contained in the circumference of the circle C K L, if it be contained 100 times, the motion of the Power will be a hundred fold greater than the motion of the weight, as is proved by daily experience.

PROPOS. II.

Ariftotle's Reafon, why the forces of Powers are encreafed by the force of Engines, is Examined.

A *Riftotle* is the firft that we know of that attempted this; we have often read his whole Treatife which he wrote of *Engines*, and confefs we could never fufficiently find out the univerfal principle of Machines or Engines : For he attempts only to give the reafon of the *Ballance*, and reduces the *Leaver* to the *Ballance*, and the other Machines or Engines he explicates by the *Leaver* : We fhall do two things, Firft, we fhall examine the Reafon which he offers, as the only true and moft likely for the *Ballance* in the middle. Secondly, we fhall try whether thofe things which are faid concerning the *Ballance*, may be faid of the *Leaver*, and whether thofe things that belong to the *Leaver*, may be eafily applied to the other Machines, or Engines : For he propofes fome wonderful things from the Circle, and adds, that thofe things which are done about the *Ballance* are to be referred to the Circle, and thofe concerning the Leaver to the Ballance, and all other Motions concerning Engins he referrs to the *Leaver*.

Ariftotle reafons thus, Every Power moving to the centre of the World is born down by a right line, and the weight thrufts forward, or the weight according to its quantity contributes to fuch motion ; but when weight is moved in a Ballance then it is fuppofed to deviate from fuch rectitude, and by deviation it breaks off and retards the motion preffing forward from fuch power, and by how much more the motion produced by fuch power is retarded, by fo much more decreafes the force of that power in order to fuch motion ; but becaufe that which is neareft the Beam or Cock, is alfo neareft

the

the retaining principal, and deviates more from right motion; therefore the moving power being applied in a point near the Cock, loses more of its force; and that which is more distant from the centre or cock, partakes less of motion; besides the nature of that motion comes nearer to right motion, and therefore its force is less hindred to exercise its power, wherefore that weight which is farthest distant from the Centre is easily moved, and although it be equal to the other weight weighing against it, and less distant from the centre, it will be moved more easier, which to make more plain he institutes a geometrical Demonstration in this manner:

Fig. 8.   Let the *Iron* rod A B be the Ballance, the *Beam* or Cock **A**, about which, as about a Centre, the whole rod A B is moved; and let the weight be B which descendeth by force of its own weight, and describes the arch B H; also let there be another weight C, which while it descends by its own gravity is consider'd according to the disposition of the Ballance, to describe the arch C D Y, less than the arch B E H: Suppose the weight C to descend to the point D, and draw the line D E, which let be parallel to the line A B, Suppose the weight B to descend to the point E, since the natural motion of heavy things is perpendicular, the lines F E, G D measure the natural motion of the bodies or weights, or the motion which is according to their Nature; But the lines C G, F B measure the preternatural motion, to wit, by whose force they are retracted from their lines of Direction, or perpendicular lines; but F B is less than C G; for if equal right lines fall perpendicularly on the Seme-diameter of unequal Circles, that which is in the greater circle cuts of the lesser part because the greatest circle is less crooked: Therefore while those two weights have an equal natural motion, that which is farthest distant from the Centre hath least of the preternatural motion, therefore the easier moved, and therefore hath greater force to move the other, and consequently comes to E in a shorter time, than the weight C comes to D.

Moreover he adds, because the motion of weight is equal in each, the motion which is according to nature is in it self the same to preternatural motion, but it only then happens when in the same time that C comes to D, in the same time also B comes to L; for then drawing the line I L perpendicular, it will be as I L to I B, so D G to G C; in the Triangles A G D, A L I (by *Prop.* 4. *El.* 6.) so is I L to A I, as G D to A C; and as

A

A D or A C to A G or A K, fo is A B to A I, therefore by divifion, it will be as I L to I B, fo G D to G C: When therefore it happens only in the point L, that the proportion aforefaid is kept while the point C comes to D, the point B will come to L, therefore B is moved more fwiftly. Thefe are *Ariſtotle's* words, *Quam igitur ob cauſam ab eâdem potentia celerius fertur, id quod plus a centro diſtat, ex iis quæ dicta ſunt eſt manifeſtum.* And Queſtion 3d. he fays, *Quoniam autem ab æquali pondere celerius movetur eorum, quæ a centro ſunt ; duo verò pondera quod movet, & quod movetur ; quod igitur motum pondus, ad movens longitudo patitur ad longitudinem, ſemper autem quanto ab Hypomoclio diſtabit magis tanto facilius movebit.*

Many things are wanting in this Demonſtration, Firſt, becaufe the weight B is more eafily moved ; he concludes alfo, that it hath greater force to move the oppofite weight, but whether he hath affigned the true caufe, the comparing of the caufe with the effect will fhew ; which that we may confider, we fuppofe the line A B to be double the diameter A C, therefore G C will not be double of the line F B, therefore will not the preternatural mixt motion in the weight C, be double to the preternatural mixt motion in the weight B, and therefore that caufe is not moſt likely and true from whofe Comparifon the proportion of the effect and caufe is not fhown : For it is certain, that the weight of 1 pound in the point B will be equivalent to the weight of 2 pound placed in the point C or T ; Whence we deny this conclufion can follow from that antecedent, that the weight which is fartheſt diſtant is eafieſt moved, therefore if it be diſtant a double diſtance, it will obtain a force doubley greater ; and neither do *Mathematicians* deduce their conclufions after that manner ; although while the diſtance increafes the facility to motion fhould increafe, it doth not follow that it increafes in the fame reafon or proportion : And fo we deny the facility to motion of the weight in B to be double, to the facility to motion which the weight hath in C ; becaufe that contrary which is mixt in C is not double to the contrary which is found in B.

Secondly, *Ariſtotle* fpeaks of the fwiftnefs of *Motion*, and from the Swiftnefs he concludes to the *Power* moving, which we fhall fhew to be falfe. It is certain, that if two Weights fhould be fuccefſively in the point B, one of one pound, and the other of two ; neverthelefs they will be equally or with

equal

equal velocity moved downwards, if they are of the same matter and figure, or if there be found some difference, it will not be in proportion to the weights; Wherefore although we should grant the weight B to be moved with a velocity double to C, yet notwithstanding the force of his reasoning doth not conclude it to have greater force to move the other.

Thirdly, what is said in demonstrating the weight B to be moved with a double velocity or swiftness to C; he either understands while they are joined in the same ballance, or he understands it while they are seperate and in two ballances: If he means the first, there was no need of so much reasoning, neither doth that preternatural mixt motion help any thing. But if these two weights are lookt upon as Seperate, or in divers ballances, that we may examine what force they have, it is falss that that which is farthest distant, is moved with a double Swiftness. *Aristotle* knew not the doctrine of *Pendulums*, for the swinging of divers *Pendulums* are perform'd in equal time, to wit, if in the same time that the weight B being left to its own nature comes to L, in the same time the weight C will come to D, also they absolve each his quadrant in the same time ; Notwithstanding if there be two pendulums C and B, and the Swinging of the weight B be longer than the swinging of the weight C, so that if the lesser dure 2 minutes, the other weight B takes up almost 3 minutes in perfecting its vibration ; Whence howsoever he explicates this Demonstration, he wavers in all things and is far from *Mathematical* conviction. Moreover we will shew, that although the demonstration have some force in that part of the Circle, yet it obtains none in others; for in the first place let the lines O H, Y K be equal, and draw the parallel lines K R, O P ; It is certain, that O P is greater than K R, therefore if there be a weight in R and another in P, one descends in Y and the other in H, the preternatural motion will be more in the weight more remote, notwithstanding in this case the weight which is at greater distance, obtains greater force ; therefore that which hath greater force, is not begat from the lesser mixture of preternatural motion ; which may better be perceived in the points 3 and S ; for if the weight 3 move to S, and the weight X to T ; the lines V T, S Z measure the preternatural motion, and the lines V X, Z 3 the natural motion, and the weight X least distant from the centre or *Beam*, will be more moved by the natural motion than

C   the

the weight 3, and therefore eafier, whence it obtains greater force.

Whofo diligently confiders the parts of each quadrant, will find this mixture of contrary or preternatural motion to be lefs in the leffer circle than in the greater; and the reafon is, becaufe although towards the Diameter A B the greater Circle comes nearer to a vertical line, yet towards the diameter R H it comes nearer to an horizontal line; and fo much for the firft part of this Propofition.

Fig. 9. That which belongs to the fecond part of the fame Propofition, to wit, although we grant that, which *Ariftotle* affigns for the true caufe, why in the ballance the weight moft diftant from the centre hath greateft force, to wit, that it hath lefs of the contrary or preternatural motion, yet notwithftanding we do not find the reafon to be the fame for the *Leaver.* For the power A, may move Circularly, fo that it have nothing of Preternatural motion, fince the power of an *Animal* is indifferent to any different place; therefore fince it hath no preternatural motion admixt, the force of the greater Circle doth not move eafier than the leffer, which notwithftanding is contrary to all experience.

Secondly, that kind of *Leaver* only in which the *Prop* or *Hypomoclion* is found between the *Power* and the *Weight*, may properly be reduced to the Ballance, but the other kinds not fo properly.

Thirdly there are divers *Machines* or *Engins* which are difficult to reduce to the *Leaver*, and by that means to the *Ballance*; and firft for the *Wedge*, We ask whether there be a *Prop* or *Hypomoclion*, and to what kind of *Leaver* it is reduced? What Circle is defcribed from it? What is its preternatural motion? What its natural motion? Surely there is in the *Wedge* the impreffion of the weights refiftance to be exercifed in the parts in which the body touches, as in K R; We ask in what point is the *Prop?* Where the length of the *Leaver*, Which if it be increafed according to the common rules of the *Leaver* the Virtue of the Power will be increaft? If 'tis faid the point of it is the *Prop*, we will fhew 'tis not, becaufe if the point of the *Wedge* fhould be cut off, yet neverthelefs the *Wedge* would have its whole force; If 'tis faid the line K L is the length of the *Leaver*, 'tis falfs, becaufe although that length be cut fhorter, yet notwithftanding the virtue of dividing is not deminifht which is

in

in the *Wedge*, therefore which way foever you turn the *Wedge*, you will fcarce reduce it to the *Leaver*.

Fourthly, Much lefs do we own the comparifon of the Leaver in Screws, which may rather be reduced to the Wedge; for if you own the Axis of the Cylinder, about which the fcrew or fpire is circumvolved to be the *Hypomoclion*. The diftance of the Spires or Screws from that Axis, will be the diftance of the weight from the *Hypomoclion*, according to which diftance the refifting power of the Weight is meafured, whence it follows in the Screw, the Cylinder that is lefs than the other pairs, more eafily overcomes the refiftance of Weight, which neverthelefs is falfe: For neither is this the meafure of the refiftance of the Weight, or the virtue exifting in the Screw, but ought to be deduced from other principles, to wit, from the compreffion of the Spires, for when the Spires or Helices are more thick or clofer together, the ftronger and more powerful are the Screws; Therefore we muft feek another principle of *Machines* or *Engins* more clear and eafie, which being once conftituted, the power of every *Machine* or *Engine* well be unfolded, and the proportion of it to the refifting force of the Weight will be detefted.

PROPOS. III.

Archimedes *reafon Examined.*

Fig. 10. **A**Rchimedes in his fixth Propofition, *Æquiponderantium*, and many others after him, have attempted to eftablifh as the chief principle of Machines or Engins, that in the Ballance, if the weights and their diftance from the Centre be reciprocal, they contift and counterpoife each other.

In the firft place, we referr this to be fettled by the reverend Father *Leotanudus*, and what power his demonftration may obtain; fuppofe A B to be a Rod of a like weight in every part, and divided in the middle in C, and underftand C to be the Centre of Gravity, and C D to be drawn through perpendicular to it; by the point D draw an iron rod D E, which let be fo alike for weight as to confider it wanting all weight, and

let

let D E be greater than the half of C B, and make G D equal to I B, and H K equal to the line A H; when the lines C I and I B (equal to H C) are added, H I and C B will be equal, and so H I will be equal to the half C B, and the remains A H, I B together are equal to the other half; and becaufe A H, H K are equal, being taken from the two equal aggregates H K, K I, A H, I B, the lines K I, I B will be equal. Let two Threds or Lines H G, I E hang up the rod A B, and faften it to the rod G E in the point D, which anfwers the Centre of gravity C, the line from whence 'tis hung up being perpendicular with the line D C, anfwers to the Centre of gravity C; A B will remain equally poifed, or in *Equilibrio.*

The Demonftration. Let the Rod A B be really divided in the point K, that is, feperate the Union, or cut it in two. Firft, fince A H, H K are equal, neither will preponderate or out weigh the other; moreover fince K I, I B are equal, neither will prevail, wherefore as yet they will remain in *Equilibrio*; therefore the whole line will remain in the fame manner as before, being hung by the fame point D, therefore as yet the whole line will be in *Equilibrio:* But fo is the diftance H C of the weight A K from the Centre, to C I the diftance of the leffer weight K B from the fame Centre, as the weight K B to the weight A K; for fo is A K to K B, as its half H K or C I is to K I, or H C its equal; therefore we have this in *Equilibrio* while the whole weight A K is to the weight K B, as the diftance I C to the diftance H C reciprocally, which was to be demonftrated.

We will confider hereafter whether this Demonftration convinces, and affumes nothing as now proved, which notwithftanding fhould be demonftrated.

Fig. 11. *Archimedes* a little after endeavours to prove this fomewhat otherwife, and he fuppofes the Iron Rod to be A B, and he fubftracts from its gravity that which is hung in the middle point G; he hangs 6 equal weights, here 3 and there 3 at equal diftances, 'tis clear that they are in *Equilibrio*, he fuppofeth alfo that all thefe weights are alike, and equidiftant between themfelves: Alfo he fuppofes any weights to gravitate and operate in the fame manner, as long as they retain the fame common centre of gravity.

The Demonftration is clear, in cafe the weights be diftributed according to the difpofition unfolded, before which common

mon centre of gravity of all the weights together will be in G; but if you confider 4 weights B C D E whofe centre of gravity will be in the point I, and the centre of gravity of the weight F L is in H; wherefore the weights will gravitate in the fame manner, howfoever they are difpofed, they keep in a manner their centre of gravity in the fame point H; therefore conjoin the weights F and L in the point H, and conjoin the 4 weights B C D E in the point I, or fo about the point I, that their centre of gravity may be the point I.

Fig. 11.   All thefe weights will gravitate in the fame manner in this difpofition, as in the former; But in the former they were in *Equilibro*, therefore in this fecond difpofition they will be in *Equilibro* : But in the fecond cafe, fo is the weight B C D E to the weight F L, as the diftance G H to the diftance G I therefore it will be in *Equilibro*, when as weight is to weight, fo is diftance to diftance reciprocally.

Thefe Demonftrations are ingenious, but they do but fuppofe thofe things to be the principles of *Engins* which is fought: For firft of all in both Demonftrations he mentions the centre of gravity, but it is not known what that centre is, and this centre of gravity can hardly be proved, unlefs there be conftituted a common principle of *Engins*; In the firft, although it feems clear enough that the divifion being made in the point K, the lines A K, K B lie in a direct line, becaufe that both parts A H, H K and K I, I B are equal; Notwithftanding it doth not appear to me that they ponderate in the fame manner, the divifion being made as before : For the part C K before the divifion, exercifed its gravity with the other part K B, and as I may fay, was ftaid by its parts : But the *Union* being loofed, it exercifes now its own gravitation, together with the other part A C; Whence although it were before in *Equilibrio*, it follows not that it being feperated the *Equilibrium* remains.

I fay the fame of *Archimede*'s demonftration, for I cannot grant that weights have the fame manner of gravitations they fhould have among themfelves, and the fame gravitation they fhould have refpectively to another weight, fo often as they change not the proper centre of gravity : If in one cafe, one of them will be found on one part of the centre, and in the other it will decline to the other part; that is, 'tis doubted whether the weight E tranfported in I being united with other weights B C D in

D in the same point I, hath the same force, and not greater, or lesser.

And that we may shew the Principle sought, the definition of the Centre of gravity is commonly thus given, to wit, 'tis the point dividing the heavy body in two parts of equal moments, but moment is not simply the weight of body, but grows together from the weight and distance, therefore to the understanding of the Centre of gravity the constituted principle is supposed, whose reason we seek; *viz*, Why weights by reason of their greater distance from the centre have also greater force to move.

PROPOS.

The true Reason of increasing power by Engins.

Fig. 12. NOne will require of us a strict demonstration here, because we are busied in phisick matter, and we inquire the principal of natural and sensible motion, which perhaps will not presently occur; one thing I must say, that although I do not effect the thing, yet by removing things out of the way, I shall open a door to let into it; therefore I shall attempt many methods, that so if one arrive not at it, I may make way for another: First, in the ballance I will endeavour to settle that common maxim, while the weights and distances from the Centre are reciprocal it is in *Equilibro*; As if in the ballance A B the weight A of two pound is to the weight B of one pound, as the distance C B of two feet to the distance A C of one foot. If from a piece of timber, you hang a ballance from the point C, to be in *Equilibrio*, so that you remove it so far from the Centre to answer the addition that should be made to the weight, that is, if the weight of one pound hang in the point D, and in A a weight of 2 pound, to make them in *Equilibro* the same weight should be added, and in stead of the same weight you may add the same distance, or so remove it from the Centre that C B be double to C D; Thus a weight of 1 poundbeing placed in B, it will be again in *Equilibro*, experience shews this, but the reason is to be sought.

First,

First, I suppose any heavy body to resist a motion upward, and the greater it is, the greater motion it will resist; so that a greater violence or force is required to move upwards a weight of 1 pound the space of two feet, than to raise the same weight but one foot high, or at least it requires a force to be applied of a longer continuance of time.

Secondly, I suppose while the weight is moved downward, the weight on the other part of it may move somewhat upward, so that it may overcome the resistance which the opposite weight hath to motion upward; also while a weight is moved more down or lower, it produces a greater *Impetus*, together with that motion which would have bin if the motion had bin less; this last part of the supposition seems hard, therefore I shall explain it more largly.

I Suppose thirdly some productive cause of motion to be given, distinct for the most part from the principal agent to which motion is ascribed, as in things projected or cast from one, I think in good *Philosophy* it can scarcely be denied, such like cause besides motion which is succeffive, and no part whereof exists with the other, and therefore the other cannot be the cause, for every effective cause acteth not but when it exists; Therefore while its action exists, it self also exists, and while its action exists the effect exists by such action produced: Therefore while any effect is produced and exists, its cause exists, but while one part of motion exists, another part existeth not, therefore one part of motion cannot be produced from another, and therefore another cause of motion ought to be admitted, but this cause is not the principal agent to which motion is attributed, for first in things projected, the hand which throws the stone is not any more join'd with the stone in conveying it through the air, and therefore produces nothing further, neither can that be attributed to air that some do, to wit, that the hand while it Impels the Stone, impels likewise the contiguous air, and that air other air, untill it make a Circulation, and this last air carries the Stone farther; but on the contrary, in the same precise Moment and time wherein the Stone joined to the hand moves the air just before it, (since Penetration is not granted) in the same time also this air moves the following air, and so consequently makes the whole Circulation at the same precise time, and there is found only the priority of dependence: Suppose the motion of the Stone to be from the

point

point A to B, and in the fame precife time it makes the whole Circulation, and the air which was in E follows in F, neither hath it greater force to farther motion than it hath from the Stone; from the following time I ask whether the motion of the air F depends on the motion of the Stone, or the motion of the Stone on the motion of the air, if you fay the firft, I demand again from whence the Stone is moved, if the fecond, I ask from whence the air is moved, for the paft motion of the ftone cannot be the caufe of motion of the prefent air, therefore it is neceffary to fay fomething is added to the Stone from whence it is carried through the air, and this I call *Impetus,* or force, whatfoever it be.

Moreover I will fhew, *Impetus* being granted, *viz.* While a body defcends it feems to me a reafon to be alledged, why in the firft fpace of time the body defcends one foot, in the fecond three, in the third five, in the fourth feven, and fo on, unlefs the continual production of fome *Impetus* be admitted, which is the immediate productive caufe of motion, which *Impetus* is permanent and may be increafed.

Alfo it follows, that a fecond *Impetus* is not produced, unlefs the firft hath and produces fome motion, let two weights be fufpended in the air, each produces fome *Impetus* in it felf, and alfo in the body which they hang on, let one weight be moved by the fpace of three inftantes, or moments, fo that after that third inftant it hath an *Impetus* as three, let down the fecond weight in the begining of the fourth Inftant, wherefore it hath not the *Impetus* as three as the other weight; becaufe (you'l fay) it remains unmoved, and the other is moved: therefore motion is the condition to the producing a farther *Impetus,* at leaft fuch motion whofe *Impetus* is according to nature.

Which I fhall likewife make good from other experiments: Firft, why while I drive a nail with a hammer of a longer handle I produce a ftronger blow, or ftroak, in like manner, if I lift the arm and the hammer higher, fo that it defcribes a greater circle, the ftroak is made more valid and ftrong; no other reafon can be given, but that by the greater motion (whether as the condition, or as the caufe, it matters not) a ftronger *Impetus* is produced, fo that the power unlefs it be moved, never produces in the begining of its motion fuch *Impetus* in the nail, how great foever the endeavour be, as it

produces

produces while it hath fome motion; fo that if 10 men prefs with their weight upon a nail it doth not enter the wood fo well, as if it be drove with an hammer by one man.

While any one runs a pace, if his feet be ftopt he cannot chufe but fall; and fo a horfe on full fpeed can fcarce be held in, whence they lift up their fore feet, as it were a contrary motion to afwage every concieved *Impetus*; While a boat is carried with a great *Impetus*, and is fuddenly ftopt at the fhoar, all that are in the boat are moved, becaufe now the concieved *Impetus* is conveyed farther they bend forward being ftopt.

And I fhall fhew that a weight of one pound placed a little farther from the Centre than another weight of one pound, will raife it up; fuppofe two weights equal each to one pound, fo placed in a ballance that one is double the diftance of the other from the Centre; whence I thus argue.

The weight of 1 pound while it moves downward 2 feet, may over come the refiftance which a weight of one pound hath to motion upwards one foot: therefore if they are fo fitted in the ballance, that while one is depreffed 2 feet, the other is only raifed 1 foot, it raifes that upward; The antecedent is proved, while the weight of one pound is moved downwards 2 feet, its active force or *Impetus* which it puts forth together with fuch motion, is precifely equal to that refiftance which the oppofite and equal weight hath to motion upwards two feet, but the refiftance to motion upwards one foot is lefs than to motion upwards two feet; therefore while one pound weight is moved downwards 2 feet, the other pound weight may be moved upward one foot; But when two equal weights are fo placed in a ballance, that one is doubly diftant from the Centre to the other, it alfo effects a double fpace to that which its oppofite effects; therefore we have one reafon now, why between equal weights that which is fartheft diftant from the Centre is depreffed, and raifes up its oppofite weight, which may be alfo proved in this manner; when two unequal weights are equally diftant from the Centre the greater raifes the leffer, becaufe the parts of motion downwards are more than thofe upwards, and in like manner when equal weights are fo placed in a ballance, that one is farther diftant from the Centre than t'other, the parts of motion downwards will be more in one than the parts of motion

D up-

upwards, are in the other (or its oppofite) therefore the weight which is fartheft diftant from the Centre will raife the other oppofite being equal to its felf.

The motion upwards of heavy things is againft nature, and the violent motion of them downwards is agreeable to nature; but how much that is which is againft nature, fo much is the refiftance to that; and how much that is which is agreeable to nature, fo much is its inclination and active force to overcome the oppofite refiftance; therefore where there is a greater motion downwards than the motion upwards, the active force of refifting will overcome.

The fecond reafon is; a greater *Impetus* is required to move the fame weight a greater fpace than a lefs, whether the whole *Impetus* be produced together, as happens in things projected or thrown; or fucceffively, as when a weight is drawn.

Alfo a greater *Impetus* is required to move a greater weight fome fpace, than to move a lefs weight the fame fpace; whence I thus argue, an *Impetus* which is required to move a weight of two pound one foot, is double to the *Impetus* which is required to move one pound one foot; But the *Impetus* which is required to move one pound, two feet, is in like manner double to that which is required to move one pound one foot; therefore the *Impetus* which is required to move two pounds one foot, is equal to the *Impetus* neceffary to move one pound two feet, for thofe fame things which are doubled are equal among themfelves: But when two weights are fo placed in a ballance that the weight of two pound is diftant from the centre one foot, and the weight of 1 pound is diftant two feet; while the weight of 1 pound is moved downwards two feet, the weight of two pound is elevated one foot; and one pound weight as moving downwards two feet is in *Equilibrio* with one pound moving upwards two feet: Therefore one pound moving 2 feet, will be in *Equilibrio* with 2 pound moving upward 1 foot.

And that we may render the fame reafon more univerfal, and that we may apply it not only to weights and ballances, but that we may extend it to all *Engins* in general: Suppofe as before, by how much more the power is that is moved, by fo much the greater and ftronger is the *Impetus* produced; therefore if a power while it is moved 1 foot can move 100 pound 1 foot; while the fame power is moved two feet it will move

200

200 pound 1 foot; to clear which point, suppose for explication sake a certain opinion rejected by most *Philosophers*, to wit, that time increases or grows from indivisible Instants succeeding each other; suppose likewise that which necessarily follows from such an opinion, to wit, the slowness of motion is posited in more or less little Staies of rest, which opinion I do not propose that in it I may found my reason, but only that I may shun that confusion which the common sentence begets, concerning the continued composition from parts infinitely divisible; for when they treat of this infinity, 'tis no wonder if they mix obscurity and darkness together; Therefore suppose a power which while it is moved one point may move 100 pound one point, and being fitted in an *Engin* so that while the power is moved two points, the weight is moved only one point.

In such a supposition, the power will be moved the space of one point, the weight all the while no ways resisting such a motion, because the weight as yet is at rest, but when the power is moved to the second point, it hath a double *Impetus,* *viz.* the *Impetus* produced in the mean time while it is moved through those two points, but a double *Impetus* moves a double weight; therefore the power which is moved two points will move a double weight one point, if it be so fitted in an *Engin* that necessarily its motion ought to be double to that which follows in the weight.

And although this opinion Concerning continuals shouldnot be true, and the power should never be moved but the weight should be moved although slowly; neverthelefs since a power exerts a greater *Impetus* when it is most moved; as often as the motion is greater in it than in the weight, so often the *Impetus* will be greater in it, than if it had bin moved equally with the weight; but a greater *Impetus* can overcome a greater weight, therefore a greater motion of a power compared with a lesser motion of a weight can also overcome a greater weight.

To make it clearer, Suppose, to move a weight of 100 pound one foot, an *Impetus* be required as 4, which the power A may produce, and as I may so say, to lift it up while it is moved one foot; there will be required to move a weight of 200 pound one foot, an *Impetus* as 8, but an *Impetus* as 8 is produced from a power if it be moved 2 feet; For more *Impetus* is produced from a power while 'tis moved two feet than while

'tis

'tis moved one foot, therefore that principle remains, *viz.* The Power as moved 2 feet effects the same, as two powers which are moved only 1 foot; and we must not think *Impetus* to be so fluent of nature, as not to maintain and as it were heap together, that is, if the power be moved for some time it should not increase, also its intensive *Impetus* is not resisted by such *Impetus*; in like manner, a weight is not supposed so to resist a lesser motion, as a greater; whence if a power be so compared with a weight, that while it is moved 1 foot the weight is necessarily moved the same, and the resistance of the weight is greater as moving one foot than the *Impetus* which is produced from the power being moved 1 foot, no motion follows; but if an *Engin* thus distributes the same *Impetus*, that the whole be Imployed in moving the same weight half a foot it will make some motion.

Nevertheless because this thing is of so great moment, and contains the most universal Principle in nature, therefore 'tis worth our while to prosecute the thing a little farther, and to apply it in every part that it may appear more plainly.

I suppose first, that 'tis equivalently the same thing to apply a motive power as one, successively to move a body, suppose the space of 5 feet, so that it move in the first time the space of 1 foot, moreover the same power moveth in the second time by another, and so on, and to apply five moving Powers Successively as one; of which to wit, the first moves in the first time 1 foot, the second in the second time following, the third by the third, and so on; for the moving power as one if it be applied to the second time, may as well move another also like it self, therefore the same will be Equivalent whether the same motion continue, or another like to it be Substituted.

Secondly I suppose to move or sustain a body, to be the same, as to apply five powers each of which is a power as 1, and to apply 1 so that it may be a power as 5, as if in one ballance you put a body of Gold of one foot, the same will out weigh 5 bodies of each 1 foot of another matter, which is five times lighter than Gold, for neither hath the moving virtue in it self, as the first quality; for if 5 heats or warm things are put as 1, they can never be produced in the Subject but as one heat: But and if 2 Powers are sufficient to move each of them a weight of 100 pound, If they are joyn'd and

concur

concur together they will overcome or move a weight of 200 pounds; This rule is common in all Equivocal Agents, so if the powers of two candles in some determinate place, each of them produces 1 degree of light acting together in the same place they produce a greater degree of light; so while the Sun in an Eclipse is hid in some parts, the light Shineth more weakly, therefore in these cases extension begets intension, or is equivalent to it.

Suppose two men move unequally, to wit, with a double velocity one to the other; what is in one that is not in the other; And first it is certain that the motion of the one is always double to the other, so that while one is moved one foot, the other only moves half a foot; and while the first passes over half a foot, the other passes over a quarter of a foot; and in whatsoever time assignable, the parts of motion in the one are more than in the other, whence 'tis certain in the second place, if the motion of the power confers to this that it move the opposite weight, while the power hath greater motion it produces a greater *Impetus* in the opposite weight, from whence the argument may be formed.

A power advances its force by motion, therefore while 'tis moved with a double velocity, 'tis equivalent to a double force, but a double virtue or force can move a weight doubly greater, or as great again, therefore a power moved with a double velocity can move a weight doubly greater; the first Antecedent is certain, for a power however it be applied will not move unless it be moved, whether its motion be the condition to this that moves, or whether the motion it self be the immediate cause of motion, it matters not; neither is there need to examin these things, since divers explications arise from divers phisical principles: For some acknowledge no motion which takes not its rise from *Impetus* or force, and consequently to produce a greater motion in a power, they require a more stronger *Impetus*; therefore if a power be moved with a velocity double to the weight, it produces an *Impetus* doubly stronger to that which it would have had if it had bin moved equally with the weight: But if it be moved equally with the weight, the *Impetus* which is produced in it self should be sufficient to move 100 pound such a space; therefore if it be moved with a double velocity it will move 200 pound the same space; being explained, we'll Suppose a free Power to impel lightly some weight.

weight, fo that by the force of its impreſſion it is not moved, it will uſe a greater endeavour and at length moves it. I ask what makes that greater endeavour unleſs a more ſtronger *Impetus* be produced (ſuppoſing always that ſuch *Impetus* is grant- ed) but if the power it ſelf be moved more ſwiftly, it pro- duces a greater *Impetus* : Therefore by the greater motion of a power is adhibited that which is neceſſary, that a weight may be moved doubly greater (or as great again) each part is proved, to wit, while any body is moved more ſwiftly a ſtronger *Impetus* is produced; or the intenſe motion being Secluded what way ſoever from *Impetus*, the ſucceſſion of ſo much local motion is agreeable with intenſion; For the velocity of motion is ſome perfection which cannot be explicated, be- cauſe of the ſucceſſion of motion, and the infinite diviſibility of time. Notwithſtanding in each opinion, velocity or Swift- neſs is ſaid to be ſome perfection of motion : For ſuppoſe in *Fig.* 14 ſome motion in Angles, in as much as ſome think them indiviſſible, let A B C D a potent angle in one inſtant alſo indiviſſible be ſo moved, that leaving the former ſpace A BCD it poſſeſſes the next following C D E F, Suppoſe another angle or as ſome call it, a Phyſical point G H K I be ſo moved, in the ſame indiviſſible inſtant, that leaving the former-ſpace G H K I it poſſeſſes the ſpace L M O N, Surely the former motion is a more perfect motion than the ſecond, and therefore if there be required an *Impetus* to motion, there is required a more ſtronger to effect the firſt motion than the ſecond : But if no *Impetus* be required, but immediately motion be produced from the power, there is required a far ſtronger endeavour to obtain the former than the latter ; Wherefore to conclude the greater endeavour ofPower moveth a greater weight than a leſſer but a greater endeavour of power is advanced while 'tis moved ſwiftly than while ſlowly, therefore while a power is moved ſwiftly, it alſo moves a greater weight.

Alſo the firſt conſequent is plain, to wit, (while a power is moved with a double velocity 'tis equivalent to a double power) for ſure it is, while any power adhibits or uſes an en- deavour doubly greater, 'tis equivalent to two powers each ad- hibitting or uſing an endeavour doubly leſſer. So one horſe if he endeavours much, may draw a determined weight, which he may draw twice as eaſy, and without ſo great endeavour,if another horſe be joined with him to aſſiſt. Wherefore if it be

moved more fwiftly it will be equivalent in order to move a weight of a greater force, although fomtimes the weight doth not increafe its motion; for if the motion of the power be increafed, the motion of the weight is equally increaft.   A power moved more fwift will indeed be equivalent to a greater, but all that perfection which happens to it from motion relates to the making the motion of the weight greater, for a weight of a greater motion refifteth more, therefore in motion thefe two are always taken for the fame, to wit, to move a greater weight to a lefs fpace, and a lefs weight to a greater fpace; for as to move a greater weight a greater endeavour is required, fo to move a weight to a greater fpace, a greater endeavour is alfo required,   The whole artifice of Engins then confifts in comparing the greater motion of the Power with the leffer motion of the weight, and according to the proportion of excefs the Force of the Powers are increaft; becaufe powers increafe not their force but by motion, and therefore motion doubly fwifter, produces *Impetus* doubly greater.

PROPOS. V.

Moveable bodies are equal in force whofe Magnitudes and Velocities are reciprocal.

IT is certain, that the fame body moved with unequal fwiftnefs, will have unequal force; alfo a greater body moved with the fame fwiftnefs as a leffer, will have greater force; and we fee likewife in Engins that weights may be fo difpofed from one place to another, that the motion which is made from one hath the fame proportion to the motion of another; and alfo that weight to weight is made reciprocally in *Equilibro*, fo that the double celerity or fwiftnefs of one pound, will be equivalent to the Subduple celerity of two pounds; We may alfo transfer the fame principle to other moveable bodies, although they are at liberty, that is not being difpofed in any *Engin* : For it hath not lefs force when it is free and loofed from *Machines* or *Engines* than when it is faftned to fome Body,

but 1 pound with the velocity as 2, is equivalent to 2 pounds having the velocity as one : Therefore alſo without an *Engin*, a moveable body as 1 with a velocity as 2, will effect the ſame as a moveable body as two with a velocity as 1. The reaſon is, becauſe the motion or degree of velocity is the ſame in both, in a greater body they are fewer in each part ; in a leſſer more. Neither is there any other reaſon, why while they are joined in *Engins* they are of equal force, and one extenſion compenſates another, and without an *Engin* the ſame will not happen.

Wherfore the moments or forces of equal bodies, or the parts moved are to one another, as their velocities ; and equal velocity, as the magnitude of bodies ; for commonly, moment and force, and parts moved, ſignifie the ſame, except ſometimes moment likewiſe is attributed to bodies at reſt, which have notwithſtanding an aptitude to motion, wherefore what we ſhall ſay concerning moments may be ſaid of forces.

If 2 unequal moved bodies be compared, their force or moved parts will be in proportion compounded of the proportions of the bodies, and of their velocities, becauſe every part of a body is ſuppoſed to be moved with the ſame velocity, or degree of force ; whence it happens, if the motion of one body be communicated to another equally, the velocity will be equal, if the velocities of the greater and the magnitudes of the bodies be reciprocal.

Whence we conclude, if a moved body runs againſt another body at reſt all reflexion being excluded, to wit, if each body be ſoft, they proceed together, and the velocity of the former will be to the velocity of the aggregate of the whole, as the whole aggregate to the firſt movent reciprocally ; For ſince in the former there are ſo many degrees or parts of motion, and each of its parts are diſtributed in the aggregate ; to get the velocity of the firſt movent, the quantity of motion which is always the ſame muſt be divided by the number of parts of the aggregate ; Therefore the ſame number of parts of motion is generated from the aggregate ; in its velocity, as from the firſt movent in its velocity. Therefore if you diſpoſe the aggregate, the firſt movent, the velocity of the firſt movent, and the velocity of the aggregate, ſince the rectangle of the firſt and the laſt is equal to the rectangle made of the 2 means ; ſo will the aggregate be to the firſt movent, as the velocity of the firſt movent to the velocity of the aggregate.

We

We muſt reaſon after the ſame manner in other caſes which may happen; as if there be two equal movents)or bodies moved) which are born in the ſame part,one hath the velocity as 4, the other as 8, and the more Swift incurs or meets in the leſs Swift; I ſay after the meeting, the velocity of the Aggregate is as 6 ; for ſince the Bodies are equal, the parts moved will be as the velocities 8 and 4; wherefore the motion in them will be as 12: but after the meeting the parts moved ought to be the ſame ſo many, therefore the motion in the whole aggregate will be as 12, and in each body as 6; therefore the velocity of the leaſt, before their meeting was 4 and afterwards 6; and of the greater 8 and after meeting but 6.

Thirdly, if two equal bodies with equal velocities meet each other, excluding all reflexion, they will reſt, becauſe theſe velocities meeting one another, deſtroy each other, as when you put contrary qualities in the ſame Subject.

Fourthly, if 2 unequal bodies, ſuppoſe 2 globes one of one pound weight and the other of 2 pound, meet each other directly with equal velocities, ſuppoſe as 4, the Aggregate follows the direction of the greater, and the velocity will be as $1\frac{1}{3}$, for the quantity of motion in the greater is as 8, in the leſſer as 4, while they meet each other the motion of the leſs as 4 detracts ſo much from the greater, therefore the quantity of motion remaining is as 4, to be divided by 3 pounds, there will be in each pound, one degree and $\frac{1}{3}$.

Fifthly, if two equal bodies with unequal velocities meet each other, ſuppoſe one hath velocity as 2 the other as 4; after meeting, Secluding reflection, the quantity of motion remaining will be as 2, each being divided, and therefore the aggregate will be moved as 1.

Sixthly, Suppoſe two unequal bodies one whereof is one pound, and is moved with a velocity as 3: and the other is 2 pound,and hath a velocity as 4; the quantity of motion in the firſt is 3, In the ſecond 10, for when they meet, the leſſer quantity deſtroys ſo many degrees of t'other as it contains it ſelf, therefore, there remains 7 to be divided by 3 pound : Wherefore in the whole aggregate there will be 2 degrees and $\frac{1}{3}$ of velocity.

Fig. 15. If 2 unequal Bodies be placed in two equal Branches or Arms of a Beam (as a pair of Scales) I ſay the velocity of the greater only will be to the velocity of the aggregate, as the aggregate to the greater weight. Suppoſe a

E

weight

weight of two pounds, which if it be moved alone from A in B with a velocity as 4. Put on the other part a moveable body as 1, which fuppofe to move downwards with the fame velocity: And thefe weights being compared as two meeting each other with equal velocity, wherefore fince the quantity of motion in the greater is 8 degrees, and in the fecond 4, and fuppofing them contrary to each other; the motion in the aggregate remaining is as 4 to be divided by 3; the velocity therefore in each will be as 1 ⅓.

If there fhould be 2 equal *Pendulums* placed in two unequal Branches, the manner of reafoning will be the fame. Suppofe then the weights A and C to be equal, but the diftance A D to be double the diftance D C; in fuch difpofition the velocity of the weight A will be double the velocity of the weight C, wherefore the quantity of motion in A will be double: Suppofe the motion in A as 8, in C as 4, which motion fince 'tis contrary deftroys from the motion of the weight A, 4 parts, therefore there remains 4 parts to be divided, fo that that of the weight A have 2 parts, and that of the weight C, 1 part, Therefore there are in A 2 parts and ⅔; and in C 1 part and ⅓.

PROPOS. VI.

Concerning the Proportion of weights, on the ends of the Arms of a Ballance, Varioufly placed from the Horizontal line.

Fig. 16. THE proportion of a weight in C to the fame weight in F, will be as the whole Arm B C, to its part B *u*, being placed between the Centre and the line of inclination F *u* M, which the weight freely makes from the extream F towards the Centre of the world. For the better underftanding whereof, fuppofe on the other Arm of the ballance B D, and in the extream D, a weight placed being lefs in weight than C, as B *u* part of B C which is lefs than B D, It is clear from the 6 Propofition of the 1 book of *Archimedes* of weights, that if in the point *u* you place the fame weight C, the ballance

Fig. I.

Fig. II.
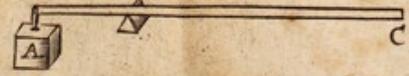
Fig. III.
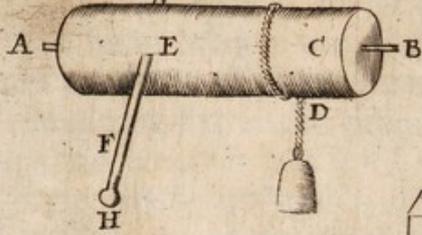
Fig. IV.
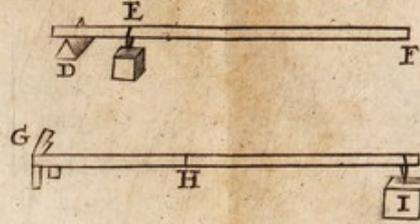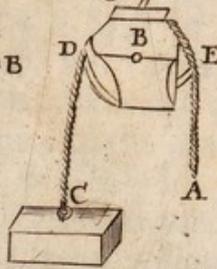
Fig. V.
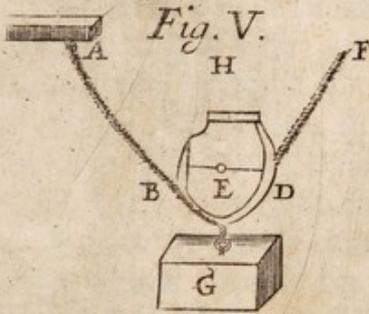
Fig. VI.
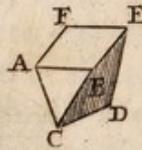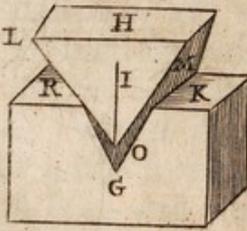
Fig. VII.
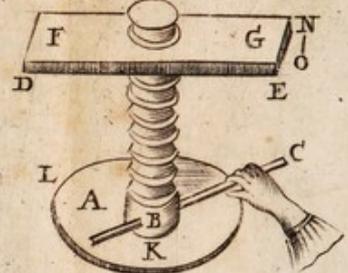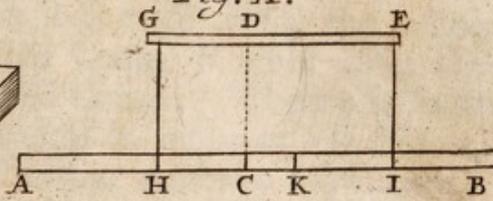
Fig. VIII.
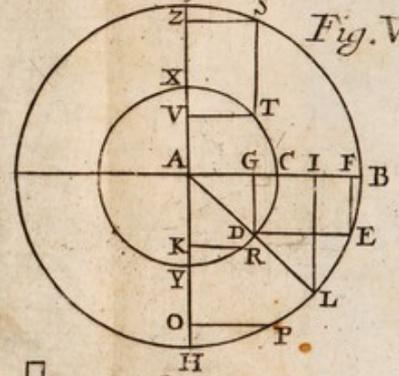
Fig. IX.
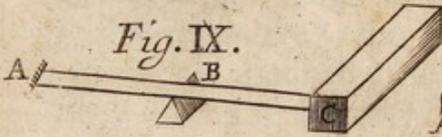
Fig. X.
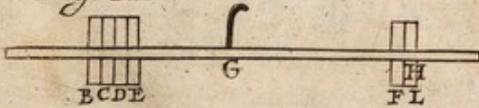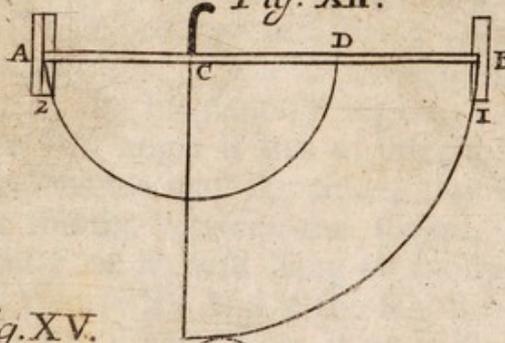
Fig. XI.

Fig. XII.

Fig. XIII.
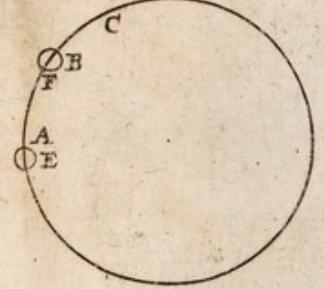
Fig. XIV.
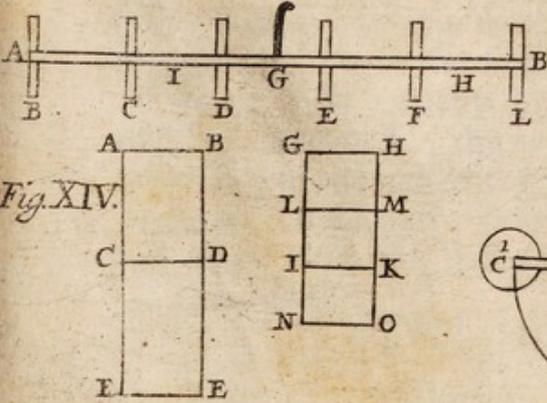
Fig. XV.
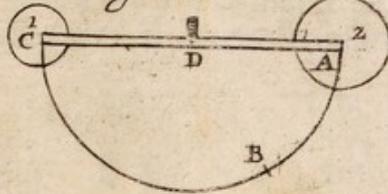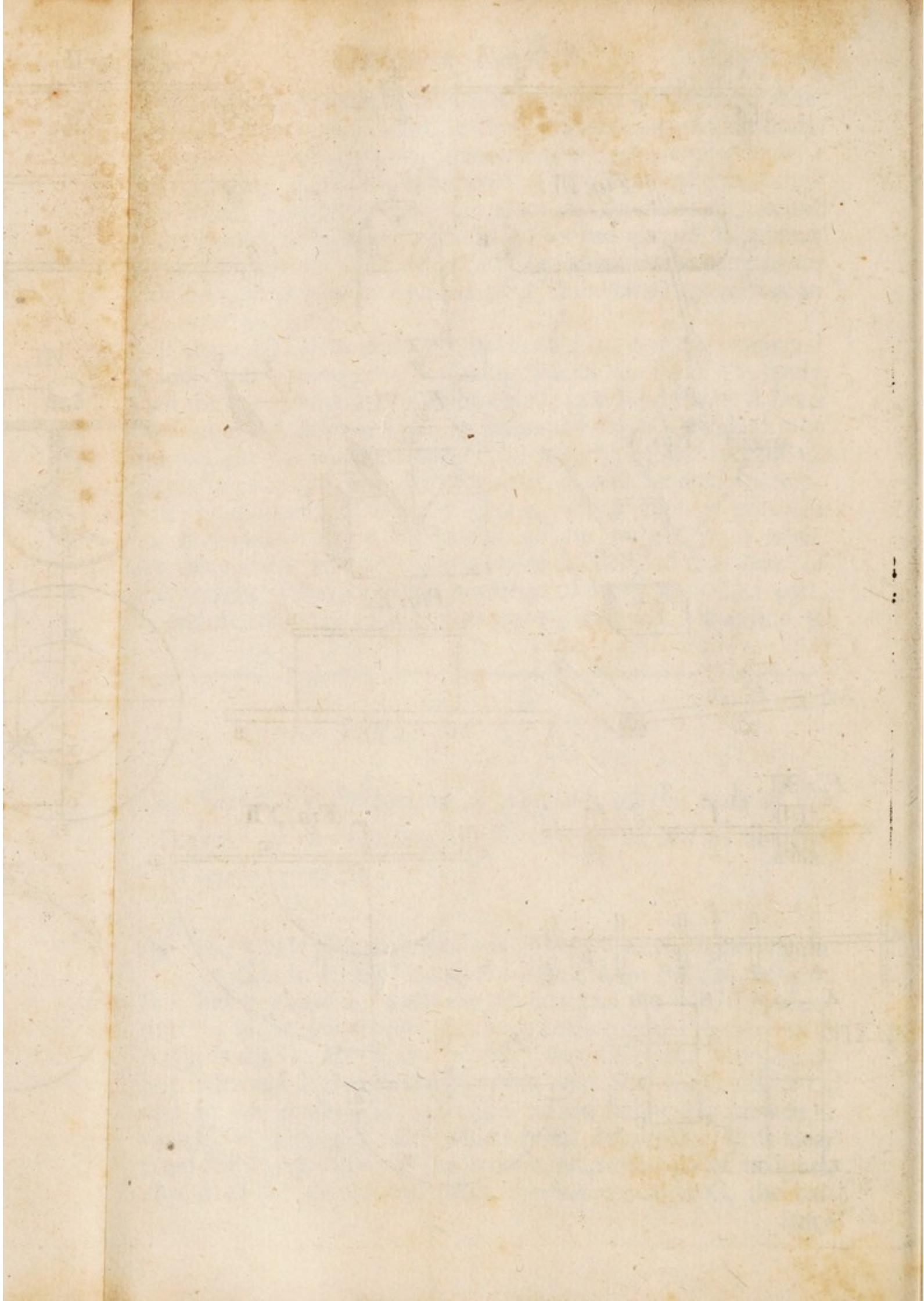
lance will little or nothing be moved from the *Horizontal* poſition. But if the weight F equal to C be placed in the extream F of the arm B F; it is the ſame as if it be placed in *u* of the Horizontal line B *u*: To the better underſtanding whereof, Imagin a perpendicular thred F *u*, and in its extream *u*, the weight to hang which was at F, whence it clearly appears that it begets the ſame effect as when it was in F; which as I ſaid but now remaining fixt in the point *u* of the arm B *u*, it is ſo much lighter than when it was in C, as *u* B is leſs than B C. I ſay the ſame, if the arm be poſſited in *e* B, which we may eaſily try if we hang thred from *u* of the arm B C perpendicular to *e*, in which extream hang a weight equal to the weight C and at liberty from *e* of the Arm B *e*, whence the ballance will remain *Horizontal.* But if the arm B *e* be joyned in ſuch ſite with the *Horizontal* B D, and the weight C be hung in *e* freely from a thred, it will neither aſcend nor deſcend, which is only becauſe it is hung by a thred which hangs as much from *u*, as that which is hanged freely from *e* of the arm B *e*; and this proceeds from this, becauſe it partly hangs from the Centre B : And if the Arm or Beam ſhould be in the ſite B Q, the whole weight would remain hung in the Centre B, even as in the ſite *b* A the whole preſſes to the ſaid Centre. Whence it comes to paſs, that in this manner a weight is more or leſs heavy, by how much 'tis hung Farther from or nearer to the Centre; and this is the only Cauſe whereby one and the ſame weight in one, and the ſame mean becomes heavier or lighter. And although I call the ſide B C *Horizontal*, ſuppoſing it to make a right angle with C O, whence the angle C B Q becomes leſs than a right angle, by the quantity of an angle equal to that which is made by C O and B Q in the Centre of the Elementary region, yet this hinders nothing ſince the ſaid angle is but of inſenſible Magnitude : From the ſame reaſons we may conclude, that if the point u be equally in the middle between the Centre B and the extream C ; the weight F or M will hang or incline according to the half of the ſaid Centre B: And if the ſaid u be nearer to B than to the point C, it will hang from it or incline to it more than the half; and if more towards C, it will be leſs than half.

PROPOS. VII.

How to know what quantity any weight or moving power hath in respect to another quantity, by Perpendiculars drawn from the Centre of the Ballance or beam to the line of Inclination.

Fig. 17. FRom what has bin said 'tis eafy to underftand, that the quantity B u which is almoft perpendicular from the centre B in the 16 *Fig.* to the line of Inclination F *u*, is that which hath led us into the knowledge of the quantity of the force of F in this fite or pofition, to wit, the line F u making with the arm F B an acute angle B F *u*: Neverthelefs for the better underftanding whereof we will imagin in *Fig.* 17. the beam *b o a* fixt in the Centre *o* at whofe ends or extreams there is fixt or hung two weights, or two moving powers or forces *e* and *c*, yet fo that the line of inclination *e* that is *b e* make a right angle with *o b* in the point b; and the line of inclination *c* that is *a c* makes an acute angle or an obtufe with *o a* in the point *a*. Imagin then the line *o t* perpendicular to the line of inclination *c a*, whence *o t* will be lefs than *o a* by the 18 Prop of 1 *El. of Euclid*: Moreover imagine *o a* to be cut in the point *i*, fo that *o i* be equal to *o t*, and in the point *i* hang a weight equal to *c*, whofe inclination make it a line parallel to the line of Inclination of the weight *e*, fuppofing neverthelefs the weight or power *c* to be greater than *e*, in fuch proportion as *b o* is greater than *o t*; without doubt by the 6th. *Prop.* of the 1ft. Book of *Archimedes de equiponderantibus, b o i* will not be moved from its fite, but if in ftead of *o i* we imagine *o t* made one with *o b*, and the power attracted by the line *t c*: *c*, in like manner alfo will touch as *b o t* according to common reafon the fite is not moved; therefore that which was propofed is done, alfo, hence we may eafily note, how much vigor and force of weight or power *c* at a right angle with *o a* lofes, drawing lefs: Hence alfo follows this Corolary, that by how much nearer the centre *o* of the ballance is to the

centre of the elementary region, by so much also it will be lighter.

PROPOS. VIII.

From the two last Propositions all the causes of Ballances and Leavers depend. Fig. 18.

THe force of any arm of a ballance or Leaver that is long, is greater than a shorter, from the Preceeding propositions, that is, a weight placed on the end of the greater or longer arm, presses or endeavours more as it hangs more or less from the Centre.

Wherefore *Ballances* or *Leavers* are not purely *Mathematick* lines, but natural, and hence bodies exist conjoined with matter; now lets imagin *n s* to be a superficies which according to length cuts the Axis of a *Ballance*; and we will suppose its Centre first in *i*, and the greater arm to be *i u*, and the lesser *i n*, and the *Vertical* line *i o*, which let be so much as is the thickness of the *Ballance* from the upper to the lower side; for the better understanding whereof suppose *n s* a *Parallelogram*, and put two equal weights on the ends of the arms, experience teaches that the weight at *u s*, is of more force than the weight at *n x*, and we would know the cause of this effect.

We have already said that *Ballances* or *Leavers* are of matter, and *n s* the medium of its superficies, suppose now *i* to be the Centre, which staies the said *Ballance* or *Leaver*; let *u s* and *n x* be the lines of inclination of the weights, and we will imagin that the said weights hang from the points *u* and *n*, as indeed they do, although they should hang from *s* and *x*, because the point *u* and the point *n* are so conjoined with *s* and *x*, that he that draws one, draws the other also: Likewise we'el imagin the two lines *i u*, *i n*, and *i e* which *i e* makes the angle *o i e* equal to the angle *o i n*; Hence it appears clearly if we hang the weight *u* (which is equal to the weight *n*) at *e*, that hath plainly the same force as the weight *n* hath, and the *Beam* or *Ballance* will neither move up nor down, because
both

both weights equally lean to the centre *i*, by the middle lines *e i* and *n i*, but the said weight being placed in *u*, the line *u i* by which the weight presses to the Centre, is more *Horizontal* than *e i*, and the line of inclination *u s* is more distant from the Centre *i* than the line *e t*; whence the weight in this manner being also more free from the Centre *i*, results and is more ponderous than when it was in *e*, for the reasons mentioned in the two precedent propositions, and for this cause weighs up the weight placed in *n*. But if the Centre were in *o* and we imagin two lines *o s* and *o x*, and suppose the weights placed in *s* and *x*, whence the line *o s* will be more *Horizontal* than the line *o x*, and the line of inclination *u s* will be more distant from the centre *o* than the line *e t*, its weight will also be heavier, because it hangs so much farther from the Centre *o*, and by reasoning as aforesaid we find the same effect to be true: In *Ballances* rightly and properly so called *x i s* or *n o u* may be *Horizontal*, but in all kinds of *Leavers* this only is said by a certain similitude; we may contemplate the same by supposing the Centre in the midle between *o* and *i*, which any one may easily do of himself without any other help.

Mechanick

Mechanick-Powers.

OR, THE

Definitions of the *Leaver*.

BOOK II.

1. A *Leaver* is commonly a piece of a *Fir-pole*, or other Timber, about 6 feet in length, which we use either to raise or move heavy bodies, such as Timber or Stone, or any body of metal, or such like; wherein three points are assigned, first the power of the movent 2ly; Of the weight to be moved; 3ly, The prop, to which the *Leaver* is annext, as to a Centre, describing two arches with a double motion.

2. Hence because these 3 points may be disposed three ways in this length, they produce 3 kinds of *Leavers*. First a *Leaver* of the first kind is that wherein the prop possesses the middle place, and the power and the weight possess the two ends, or extreams of the *Leaver*, as if the Power be in A, the *Prop* in B, and the weight in C.

Fig. 19. A *Leaver* of the second kind is that wherein the weight is placed in the midle, and the power and the *Prop* at the ends.

A *Leaver* of the third kind hath the power placed in the midle and the weight and the *Prop* at the two ends.

Before I enter on the Propositions, I shall premise some things worthy our animadversion.

Fig.

Fig. 20   Suppose the *Leaver* to be *o s*, *u*, *x*, whose *Prop* (or *Hypomoclion*) is in the point *o*, and the weight in the point *n*, 'tis clear that when you would raise it, it behoves also by the help of the hands to raise *u*; now we must consider how the weight *n* endeavours towards *u*, and for this cause we will imagin the right lines *n o*, *n i*, *n e*, *n t*, and *n u*, of which *n i*, is placed towards the Centre of the world, and *n t* makes an angle *i n t* equal to the angle *i n o*: Now placing some power in *i* having equal inclination to the upper, as *n* has to the lower (setting aside the gravity of the *Leaver*) this power (according to common reason) will sustain the whole weight of the said *n*, and if the weight *n* were in *x* directly over *o*, the whole weight would be upon the *Prop*, and so much force or power of the *Prop* will suffice to resist for sustaining, as is the gravity of the weight; but putting it again in *n* 'tis clear that if another power be not opposed from the neither to the upper part of the *Leaver*, the *Prop* notwithstanding being excepted, it will behove the power of some part of the weight *n* (without consideration as aforesaid of the weight of the *Leaver's* matter or substance) that the *Leaver* be depressed from the part, *s*, *u*, and some one part of the weight *n*, because other part of the same weight endeavours it self to the *Prop o*, by means of the line *o n* which makes not right angles with *o x*. But if from the point *t* this kind of resistance oppose it self that the *Leaver* be not depressed or born down,'tis clear by common sence that the power of the weight *n* is divided equally in the middle, whose moiety over *o* resteth,as also the other over *t* being in the middle of the two lines *n o* and *n t*. Now imagin the resistance *t* to be taken away and placed in *e*, it is clear also that the greater part of the weight *n* forces or endeavours to *e* by help of the line *n e*,more than to *o*; since the line of inclination, *n i*, is nearer to *e* than *o*: Because all resistance either in *i* or in *e*, or in *t* or in *u* is instead of a centre as well as *o*, and the work of one helps tother; But if the same resistance be placed in *u*, 'tis clear also that a lesser part of the weight *n*, endeavours to *u* than to *o*; since the said *n i* is farther distant from the centre *u*, than from the Centre *o*, and the proportion of the part of the weight *n* in *o*, to the proportion, of the part of the weight *n* in *u* will not be according to the proportion of the angles *u n i* and *o n i*, but according to the proportion of *u i* to *i o*, which may clearly be comprehended by the converse of this
effect,

effect, that is even, as now we have suppofed *o* and *u* to be two Centres that fuftain the weight *e* of *n*; alfo imagin *n* to be a certain Centre from whence hang two weights *o* and *u*, fo proportioned to each other, that *u i* and *i o* are the certain caufes of the ballance of thefe weights *o s*, which we call a *Leaver* or *Beam* inclined on no part: But returning to the propofitior, we fay, That the weight of *n* endeavoring lefs to *u* than to *o*, that is to *t*, there needs lefs force in *u* than in *t* to raife the weight *n*; and fo by confequence, the farther the point *u* is from *t*, the leffer force is required, and confequently when the force or refiftance in *u* is fo proportioned to that which is in *o*, as is *o i* to *i u* the *Leaver* or *Beam* will not be moved: But when there is a greater proportion of the refiftance of *u* to that which is of *o*, than of that of *o i* to *i u*, then the part *u s* of the *Leaver* or *Beam* will be elevated: But if the proportion be leffer than *o i*, to *i u*, than the *Beam* or *Leaver* will be depreffed on the fame part.

Of *Augmenting Force or Power.*

Fig. 21. IN fome places Bakers ufe a certain inftrument for kneading their Paft, which is perform'd by one man only, which inftrument feems worth our taking notice of, and 'tis thus: Imagine the plain in which he fets who kneads the Paft, and in which the Paft is laid to be T S D, and the triangle T A S fixed, and perpendicular to the fuperficies of the faid plain; and in the Angle A joyn a piece of Wood or Leaver A E as a moveable femidiameter and equal to the Perpendicular of the Triangle, whence A will be the place of the centre, and D O will be the femidiameter which kneads the Paft, and from its end O (which O when D O is Horizontal is found in the bafe of the faid Triangle) comes the piece of wood O V, which with A V is equal to the perpendicular imagined from the angle A of the bafe T S playing too and fro in O and V, that the femidiameter D O may be raifed and depreffed. And V O is equal to A V, and V is in the middle between A and E, whence A V with O V are equal to A E; moreover there are two pieces of wood perpendicular from

F

A

A, and fixt to the bafe and immovable; and fo far diftant from one another, that between them O V and D O may pafs above and beneath, and not depart from the femidiameter D O. In the end of E there muft be a fmall piece of Wood at right Angles with A E, which is held by the hands of fome body which ftands on the forefaid Machine, which man with that wood that is, the femidiametre A E drawing it to himfelf from the fuperficies of the faid Triangle, and then thrufting it towards the fame Triangle, he excites the femidiameter D O upon the Paft with a great force.

In imitation whereof I have fubcribed Fig. 22. *b a u x*, in which we may imagine *u* refembles A in the 21 Fig. and *a* denotes O, and *o* V, and *x* E: we may alfo imagine *u a* to be the bafe of the Triangle *a u o*, to which *o t* the perpendicular of the faid bafe add *u a*; hitherto then *u o* will be equal to *o x*, and to *o a*, we may imagine alfo *a o* fo produced to *b*, that *o b* be equal to *o a*. Alfo fuppofe a weight in *a*, to force towards *u*, whence the line of its inclination will be always *a u*; fuppofe alfo *a o b* to be a Beam or Leaver, and *o* its Centre, whence the force or power of *a* will be proportional to *o t*, with refpect to the force or power imagined in *b*, the inclination of the perpendicular *b a*, which force or power in *b* will be proportionable to *b o* by *Prop.* 7. of this Treatife; therefore if you fhould place a certain power in *b* at a right Angle drawing the line *b o* fo proportionated to the power of the perpendicular *a*, as *o t* is proportioned to *o b*, the Beam *b o a* will not be moved, but any greater portion in *b* will overcome *a*: And when *o x* is equal to *o b*, the fame will happen according to common Senfe, placing the power *b* in *x*. The quantity therefore of the power in *x*, which ought to overcome the refiftance in *a*, which is put againft *u*, ought to have a little greater proportion to refift, which in *a* makes a right Angle with *a o*, than that which is of *o t* to *o x*.

PROPOS. I. Fig. 19.

A Theorem.

IF *in a Leaver, the Power be to the weight as the distance of each from the Prop, reciprocally, it will be in* equilibrio, *or the power will sustain the weight, but not raise it.*

Suppose the power A to the weight C, to be as the distance B C to the distance A B; I say, it will be in *equilibrio,* and the power will sustain the weight C, but not overcome nor raise it; but to the better understanding of the Proposition, suppose the weight C to be 100 pounds, and the power A to be a power able to sustain 25 pounds without a leaver; and as the power A is equivalent precisely to a fourth part of the weight, so also the line B C must be a fourth part of the line A B to make it in *equilibrio.*

The Demonstration. The power is increased in the same proportion in which its motion is increased above the motion of the weight; but in such disposition the motion of the power is to the motion of the weight, as 4 to 1; for if the leaver be understood to be raised in L, so that the power describes the arch A L, the weight describes the arch K C; but the arches are a like, because the angles A B L, C B K are equal; or like arches opposite to the *vertex,* are as their Semidiameters, to wit, as A B to B C, and we suppose A B to be 4 times as much as B C; therefore in such disposition (by the first principle of this Treatise) the power A is quadruplicated, and therefore is equivalent to 100, but a power of 100 is in *equilibrio* with a weight of 100; therefore if as the power A to the weight C, so the distance C B to the distance A B, which is reciprocal, it will be in *equilibrio,* which was to be demonstrated.

PROPOS. II.

A Theorem.

IF the proportion of the Power to the weight be greater', than of the diſtance of the weight to the diſtance of the Power from the Prop, the power will raiſe the weight and overcome it.

Fig. 19. Let the proportion of the power A to the weight C be greater than of the diſtance BC to the diſtance A B; I ſay, The power A ſo diſpoſed will overcome the weight C.

Demonſtration. Suppoſe another power which hath the ſame proportion to the weight C, as the diſtance BC hath to the diſtance A B, this power will be in *equilibro* with the weight (by the precedent propoſition) but the power A is greater than that power (by the 10th propoſition of 5 *Euclid*) therefore the power A is greater than that which is in *equilibro* with the weight C, therefore it will overcome the weight C, and will raiſe it ; which was to be demonſtrated.

PROPOS. III.

A Theorem.

Fig. 23. *IF the proportion of the diſtance of the Power from the Prop, to the diſtance of the weight from the Prop be greater than of the weight to the power, the weight will be overcome, and raiſed by the Power.*

Suppoſe a greater proportion of A B to BC than of the weight C to the power A, I ſay the power will overcome the weight C.

Fig. XVI.
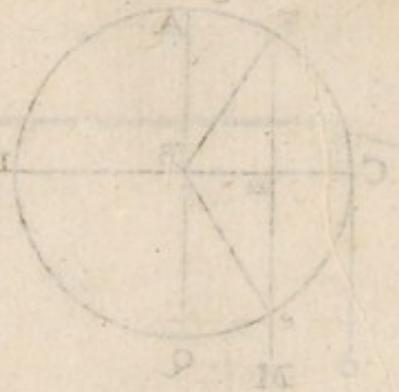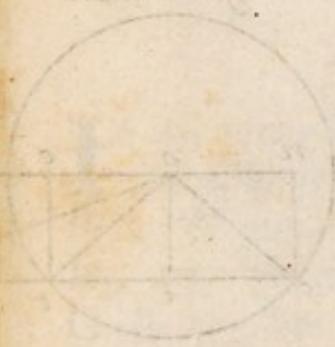
Fig. XVII.

Fig. XVIII.

Fig. XVIII.
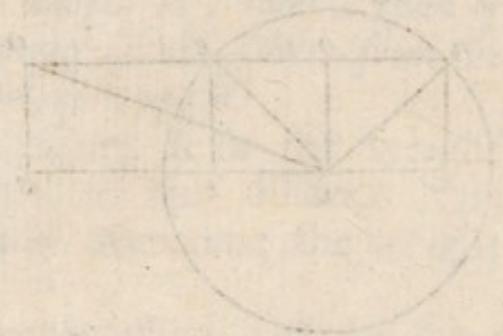
Fig. XIX.
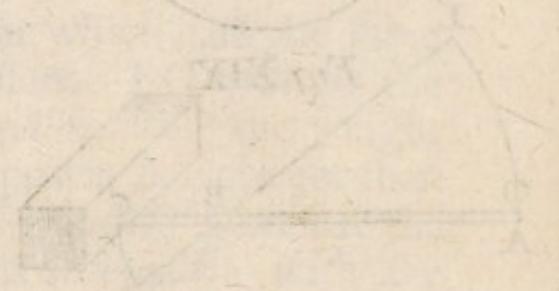
Fig. XX.

Fig. XXI.

Fig. XXII.
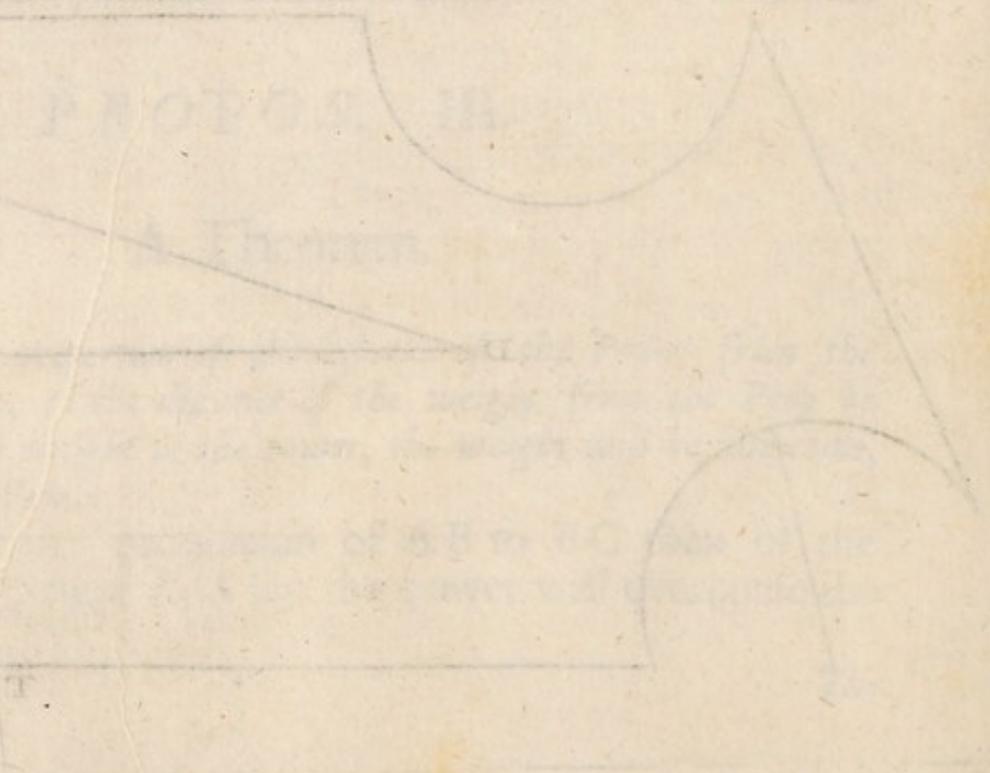
The Demonstration. Suppose another power D equal to A applied in the point D, so that as the weight C to the power D, so D B to B C (it will be by the 10th proposition of 5 *Euclid.*) D B less than A B, and (by the first of this) the power D applied in the point D will be in *equilibro* with the weight C : But the power A equal to D if it be applied in the point A, hath greater motion with respect to the motion of the weight C; therefore by the first principle hath greater force than the power D which is in *equilibro* with the weight C, wherefore that will overcome and raise it; which was to be demonstrated.

PROPOS. IV.

A Theorem.   *Fig. 23.*

IF *the proportion of the weight to the Power be greater than the distance of the power to the distance of the weight, or if the proportion of the distance of the weight to the distance of the Power be greater than of the power to the weight, the power will neither elevate nor sustain the weight.*

First, Let the proportion of the weight C to the power A be greater than of the distance A B to B C; I say the power A is to little to make an *equilibro* with the weight C ; For suppose the power E to which the weight C hath the same proportion as A B to B C, and consequently the proportion of the weight C to the power E will be less than of the same weight C to the power A, and (by the 10th of 5 *Euclid.*) the power E is greater than the power A, but (by the first of this) the power E applied in the point A is in *equilibro* with the weight C, therefore the power A is too little to be in *equilibrio* with the weight C; therefore can neither raise nor sustain it.

Secondly, Suppose the proportion of the distance B C to the distance A B to be greater than of the power A to the weight C; I say, The victory will be in the power of the weight C, for suppose the power E to be as B C to A B, so E to C, and the proportion of the power E to the weight C, will be greater than of the power A to the same weight C, and (by the 40th of 5 *Euclid.*)

5 *Euclid*.) the power of E will be greater than of A; but (by the firſt of this) the power E applied in the point A is in *equilibrio* with the weight C; therefore the power A is leſs than that which is applied in the ſame point of the Leaver, in *equilibrio* with the weight C, therefore the power A cannot ſuſtain the weight C; which was to be demonſtrated

Although in the Figure I have only put a leaver of the firſt kind, theſe proportions agree equally with the 3 kinds of Leavers, ſince in each kind as well the powers as the weights deſcribe Circles.

PROPOS. V.

A Theorem.

A Power is equivalent to ſo many powers equal to it ſelf in force, as its diſtance from the Prop contains the diſtance of the weight from the ſame.

Fig. 24. Suppoſe any power A fit to ſuſtain without a Leaver, a weight of 100 pounds, ſo diſpoſed in the Leaver that the diſtance of A from the Prop contains four times the diſtance B C of the weight from the ſame Prop or Centre; I ſay the ſame power in the point A is equivalent to 4 powers equal to it ſelf in force, and ſo can ſuſtain in this diſpoſition of the Machine or Engin, a weight of 400 pounds.

The Demonſtration. As many times as the diſtance A B contains the diſtance B C, ſo many times the motion of the power contains the motion of the weight, but (by the firſt principle of Machines) how much the motion of the power increaſes above the motion of the weight, it hath ſo much the more ſtrength or force, therefore according to the proportion of A B to B C, the force of the power will be increaſt; but by ſuppoſition A B is four times as much as B C, therefore the power applied in the point A is equivalent to 4 powers equal to it ſelf in vertue or force.

Or the power A equal to 100 pounds, will be equivalent to 4 powers equal to it ſelf in vertue, if it ſuſtains 400 pounds; and it can ſuſtain them (by the firſt of this) if it be as the
<div align="right">power</div>

power A to the weight of 400 pounds, so the distance B C to the distance A B, which plainly appears.

PROPOS. VI.

The Power being placed the same distance from the Prop, and the weight being placed nearer to the Prop encreases the force of the Power.

Fig. 24. FIRST let the weight C be distance from the Prop B the distance of B C, and let the power be in A; I say if the power be always in the point A, and the weight be removed from the Prop B, suppose to the point E, that by how much the lesser B E is, by so much the greater will the force of the power be, in order to sustain or raise the weight placed in E; That is if the power applied in the point A can sustain or support a weight of 400 pounds placed in the point C; I say, If the weight C be removed from the Prop and placed in the point E; It will be as B E to B C so the weight of 400 pounds to that which the power A can sustain.

The Demonstration. For let it be as B E to B D so the weight C to the weight F; I say the weight F placed in the point E will be in equilibrio with the power A, for when 'tis as the power A to the weight C, so the distance B C to the distance A B; as also B E to B C, so the weight C to the weight F; Therefore from disorder'd equality (by 23 of 5 Euclid) the power A will be to the weight F as the distance B E to the distance A B, then (by the first of this) A and F will be in *equilibrio* which was to be demonstrated.

Corollary. I.

Fig. 25. From this Proposition arrives several practises. which naturally or experimentally Workmen make use of for moving of weights, or overcoming the resistance of any bodies; And neither is this Doctrine only useful in raising and removing of heavy bodies, but also in cutting off bodies and parting them from each other, and overcoming any resistance, which I shall only shew in brief, that it may be turned from them to other matters.

First in digging Stones out of Qarries, they often use a Leaver or Croe of Iron, and when the Stone resists much, either by

reason of its greatneſs, or becauſe it will not eaſily be ſeperated from the other to which it adhears, they remove the Prop as near to the weight as may be, that ſo they may move it the eaſier, and for the Prop they commonly make uſe of a Stone; or ſometimes two Stones, as if the Stone E F were to be parted from the Stone D E, if D E be firm, the Prop will be in the point C, and the weight in B, and it will be a Leaver of the ſecond kind and then the diſtance of the power will be the line A C, the diſtance of the weight will be B C; then as many times as B C is in A C, ſo many powers equal to it ſelf will the power placed in the point A be equivalent to.

But if the weight B be ſo drawn back from the body C E which the proportion of the Prop hath, that the diſtance C B be made greater, there may be put between thoſe two bodies, ſome hard body, that ſo the diſtance C B may be leſſened, and the force of the power more and more increaſed.

Fig. 26. In like manner when a Nail is to be drawn with a Hammer, by how much the Nail (which obtains the force of a weight) is nearer the Prop C, the eaſier it is drawn forth; whence when the Nail is drawn out a little way, ſo that the end of the Hammer C cannot reſt on the Board or Timber that the Nail is in, we are wont to put another body between, that the diſtance may be leſs.

Fig. 27. In like manner in Pinchers is a double Leaver of the firſt kind, one whereof is the Prop, to wit, the Nail or Rivet B, about which each part is turned, and by how much leſſer the diſtance B D is, and the diſtance A B or B C the greater, ſo much the more it ſtrains.

Fig. 28. The ſame may be ſaid of Shears, wherein this may be noted, The more they are opened the eaſier they operate; becauſe that when they are more opened the body to be cut, is nearer the Prop B; *Example*, Suppoſe it in D, but when they are ſhut farther, that which is to be cut, ſuppoſe it to be in the point E; whence the proportion of the diſtance of the weight from the Prop is greater than the diſtance of the power from the ſame Prop or Centre; moreover the longer the Arms A B, C B are, the more the force of the power is encreaſt, and thus we ſee Workmens long Shears cuts any kind of Mettal; many other Inſtruments we might mention, which this principle eaſily diſcovers.

When

When we open a Lock with a Key, if it opens hard, we put a Stick into the ring of the Key and turn the Key with it, for by so doing we make use of a longer Leaver, than when we turn the Key with our hand upon it.

When we open Gates or Doors, if we lay hold of them further from the Hinges, they open easier than when we lay hold on them nearer to the hinges.

Also from this we may give a reason why a long Staff or Pike weighs more if it be lifted up by one end, than if nearer the middle ; as also why a long Stick, or Staff, or piece of Timber, is bowed or broke with more ease than a shorter.

Hence likewise a reason may be rendred, Why in Mills some teeth are made stronger and nearer together than others, *viz.* the foremost ; many things we may run through which may be reduced to the Leaver ; as in Navigation, the governing or Steering a Vessel, rowing with Oars, &c.

PROPOS. VII.

A Problem.

To move any weight with any Power by a Leaver of the first and second kind.

Fig. 29. LET there be given any weight B, and a power A, how little soever ; I say the weight B may be moved by the power A, with a Leaver of the first or second kind ; for since the weight B is not infinite, it will have some proportion to the power, therefore divide the Leaver C D, and make it, as the weight B to the power A : So the line C E to the line E D ; suppose the Prop in the point E, and the weight applied in the point D, and the power A in the point C ; I say it will be in *equilibrio.*

The Demonstration. For since the power A is to the weight B, as the distance E D, to wit, of the weight from the Prop, to the distance C E ; to wit, of the power from the Prop (by

the

the firſt of this) it will be in *equilibrio*, but if the Prop be moved never ſo little to the weight, the power will overcome the weight and raiſe it.

We will do the ſame by a Leaver of the ſecond kind, for make it, as B to A, ſo F H the length of the whole Leaver to GH, and let the Prop be at the end as at H, the power at the other end at F, and the weight in the point G, as yet (by the firſt of this) it will be in *equilibro* ; but if the weight be moved never ſo little to the Prop, the power will raiſe the weight, and overcome it.

But a Leaver of the third kind, we cannot uſe to effect the ſame thing, for when the weight is placed at one end, and the Prop at the other, the power which poſſeſſes the middle place will always be leſs diſtant from the Prop, than the weight will; and is ſo far from helping the Machine to encreaſe the force of the power, that it hinders it, and the weight from ſuch diſpoſition of the Machine increaſes its reſiſtance ; for generally ſpeaking, as often as the diſpoſition of the Machine increaſes the force of the power ; ſo often, if the power and the weight change places, the force of the power is abated, and ſo much the reſiſtance of the weight encreaſed.

And this is *Archimedes*'s great Problem, That he would move the whole Globe of the Earth, if he could find but a place to fix a Prop upon, which in Speculation is true, but in practice impoſſible ; for who can practically divide the length of a Leaver into any proportion, eſpecially, if for Example, The Hundredth Thouſand part of a Line were required, for it would make the diſtance of the weight ſo ſmall from the Prop, that the ſeat of the Prop would be impoſſible to be diſtinguiſht from the diſtance of the weight.

PROPOS. VIII.

A Problem.

To place a weight so on a Leaver, that no finite power, how great soever, can overcome it.

Fig. 30. LET the weight A be never so little, and any power B equivalent to it, I say these may be so placed, that the power B, whatever it be, will be unable to raise the said weight. For suppose, as the power B to the weight A, so the distance K L to the distance L M, and the power B in the point K, and the weight A placed in M by (the first of this) it will be in *equilibro*; whence if the Prop L be removed never so little to the power consisting in K, it will be unable to raise the weight; also a Leaver given supposing the Prop thus, we may divide it, that a power being placed at one end, shall not raise the other end of the Leaver; *viz.* If we divide the Leaver K M, supposing the Prop L very nigh the power in the point K, it will come to pass that the power, though very heavy, will not raise the other part of the Leaver L M.

PROPOS. IX.

A Theorem.

Fig. 31. WHen the Centre of gravity of a weight is in the line of the Leaver, the same force is always required to move it, whatsoever site it obtains, so that the force move only downward or upward.

Thofe things which we have demonftrated concerning the Leaver, in the former Propofitions are more univerfal; nor do they fhew divers Circumftances worthy of Note, which here we ought to examine; And certain it is that a living power which is often ufed with a Leaver, fince 'tis indifferent to all motion, it will move as well downard as a thwart. But weights which by their own nature gravitate only, refift motion upwards, and therefore their cicular motion is not fo much to be confidered, as their fimple Perpendicular motion, which, that I may handle every one feverally, I fhall expofe feveral Cafes. And Firft, we fhall take notice of the power forcing only downwards as it were, and fo a weight may be compared in divers manners with a Leaver, for either the Centre of gravity of the weight, or as it were its middle is in the Leaver, and which is the fame, is hanged freely on the Leaver, or it is above the Leaver, or beneath the Leaver: In this proportion we appoint the Centre of gravity in the Leaver.

Suppofe the Centre of gravity of the weight A in the Leaver; I fay, If the power only force downwards, the fame power is required to fuftain the weight in what fite fo ever it is.

The Demonftration. As well the weight as the power tend downwards, wherefore if the cicular motion be confidered, both of the power and the weight, they will be proportionally diftant, or their diftances will be proportional, fince like arches are proportional to the Semidiameters of their Circles; or if the perpendicular motions G E, C H be confidered, they alfo will be proportional, becaufe the Triangles C B H, B G E are proportionals; whence if the power move only downwards, the fame force is required to fuftain or move the weight, whether the Leaver be *Horizontal* or *oblique*.

PROPOS. X.

Fig. 32. **A** *Power moving equally in every different place, moveth a weight more easily, whose Centre is in an oblique beam or leaver, than in an* Horizontal *one.*

Let the power be A, equally able to move a weight in any difference of place, and let the weight be D, whose Centre is in the Leaver; I say, If the Leaver be raised in E, the power will more easily move the same weight, than if the Leaver were *Horizontal*, as A D.

The Demonstration. Weight, or any heavy body, resists only motion upwards, therefore a Perpendicular line is its measure of resistance; Therefore, First let the weight be moved according to the Arch D E, the resistance will be the line E H, Secondly, let it be moved according to the other Arch equal to E F, the resistance will be according to the Perpendicular F I; And it is clear, that the line F I is less than the line E H: Therefore although the same power move through the Arch C B, equal to A B, and so advances the same vertue or force (according to the first principal) you will find less resistance in E than in D, therefore it will move easier while the Leaver obtains an *oblique* site or position, than when it hath an *Horizontal*; which was to be demonstrated.

Corollary.

Hence it follows, That in an *oblique* site a power is in *equilibro* with a weight, although the proportion of the power to the weight be not reciprocally the same, which the distance of the weight is to the distance of the power from the Prop; to wit, because the motion of the weight, according to which its resistance endeavours, is not the Arch E F but the Perpendicular line F I, although the motion of the power, according to which it exercises its activity should be by the Arch B C, but the Arch B C and the Perpendicular F I are not proportional to the distances K B, K E.

Nevertheless

Neverthelefs in an *Horizontal* fite D A, becaufe the Perpendicular Phifically falls in with the Circle D H, the common Rules ought to be obferved.

PROPOS. XI.

A Theorem.

Fig. 33. **I**F *the Centre of a weight be above the Leaver, the weight is eafier raifed above the* Horizontal *line than beneath, from the power only forcing downwards.*

Suppofe the weight A, and its Centre above the Leaver ; fince the weight always preffes downards according to a Perpendicular line ; in an elevated fite it weighs downwards according to the line I F ; and then the true diftance will be the line F E ; but in an *Horizontal* fite the true diftance will be B E : In a depreffed fite it will be D E ; 'Tis certain, that D E is greater than B E, and this greater than F E, and fo in refpect of the power applied in the Leaver, and only preffing downwards, the motion in C will be more difficult than in A, and in A than in I.

But what I have faid is with refpect to the power, its moving fimply downwards ; becaufe if it fhould move equally, or alike in every different place, the proportion of the Doctrine delivered in the 10th Prop. would enfue.

PROPOS. XII.

A Theorem.

Fig. 34. **W**Hen *a weight hath its Centre of gravity beneath the Leaver in a depreffed fite or Pofition, lefs force is required than in an* Horizontal, *and greater in an elevated fite.*

Suppofing

Suppofing the Proof of the former Propofition, this appears clear enough, neither doth it need any further explication, fince in a depreffed fite the Perpendicular cuts off a leffer or fhorter diftance than in the *Horizontal*, and in an elevated fite it cuts off a greater; the fame caution is to be noted.

But when the weight freely depends on the Leaver, it is almoft in the fame manner, as if the Centre of gravity of the weight were found in the Leaver: For always the fame diftance remains to the Prop or Centre, efpecially vertually, becaufe the weight fo moved, is as if it truly exifted in that point of the Leaver whereby 'tis hung.

PROPOS. XIII.

A Theorem.

Fig. 35. **I**F by reafon of the Figure of the Prop, the point on which the Leaver refts be changed, the proportion alfo of the force of the Power, to the refiftance of the weight will be changed.

The Figure of the Prop. may be various, and it may be fo made, that in its motion it may bear the force of one or another point of the Leaver; whence it comes to pafs, that the diftance of both the power and the weight are not the fame; and fo the whole proportion of the force of the power to the refiftance of the weight is changed; as if the Prop. fhould be Sphærical, and the Leaver in an *Horizontal* fite fhould touch it in the point A, but in an elevated fite it would touch it in the point B; The fame I fay if the Prop. fhould be an oblong.

PROPOS. XIV.

The motion of a power oblique to the Leaver, is less powerful than when right.

Fig. 36. IF the power be A, which presses the Leaver according to the oblique line A B ; I say this motion is less powerful or able, than if the same force prest the leaver according to the perpendicular line A C.

The Demonstration. That motion tends not so much in raising the weight, as in drawing back the leaver from the Prop, as the motion A D forces the leaver against the Prop, and consequently it rather resists the Prop. than the weight.

PROPOS. XV.

A Theorem.

A motion so pressing forward to the weight, that it forces it obliquely to the line, according to which it should be moved, is less powerful.

Fig. 37. THE weight is A, which should only move according to the line A B, and the Leaver whose Prop is in C, touching the weight in the point D, and forcing it according to the line D E ; I say, The motion of such weight will be more difficult than if it had been forced according to the line A B; for the force of motion according to the line D E, as composed of a double motion, to wit, as it were of a Perpendicular, and of an *Horizontal* ; I say; as often as 'tis Perpendicular, it resists the subjected plane, and so part of that force is used in vain, in overcoming this resistance.

PROPOS. XVI.

A Theorem.

WHen two Powers consisting at the ends of a Leaver, sustain a weight hung on it, that which is neerest to the weight sustains the greater part of the weight, and that which is further the lesser part proportionally to the distances reciprocally.

Fig. 38. There are two powers A and B consisting at the ends of the Leaver, and sustaining the same weight C; I say, the Power A sustains a greater part of the weight than B; that is, if the weight C be 60 pounds and B C the double of A C; I say, the power A sustains 40 pounds, of the weight, and the power B sustains only 20 pounds: Or that the powers may sustain the weight C, the power in B must be equal to a weight of 20 pounds, and the Power in A equal to 40 pounds.

The Demonstration. The Power A in respect of the Power B is as the Prop, therefore that they may be in *equilibro*, it ought to be as, A C, the distance of the weight from the Prop A, to A B the distance of the power from the same Prop, so the power B to the weight C reciprocally (by the first of this) but A C is by supposition a third part of the line A B, therefore there is required in B a power equal to a third part of the weight, to wit, of 20 pounds ; In like manner, because with respect to the power A, as the power B hath by means of the Prop, so will be the distance C B of the weight from the Prop, to A B the distance of the power from the same, as the power A to the weight C reciprocally, (by the first of this) but C B is supposed to contain two third parts of the whole line A B, therefore also the Power A will be equal to $\frac{2}{3}$ parts of the weight C, to wit, of forty pounds: Which was to be demonstrated.

Corollary. I.

If the weight be precisely in the middle, each power sustains only an half part.

Corollary. II.

Both Powers taken together, ought to be equal to that power which can raise the weight without a Leaver.

Corollary. III.

Hence we may determine whether the Prop be fit to sustain the weight, for it always agrees with some part of the weight, especially in Leavers of the second kind.

Corollary. IV.

In a Leaver of the first kind, the Prop sustains as much of the weight as the power, and its resistance ought to be equal to both taken together.

Corollary. V.

When 2 powers consist at the ends of a Leaver sustaining a weight placed in the middle, we may easily determine how much of that weight each power bears, to wit, by dividing the whole weight according to the proportion, which the powers have with the weight reciprocally; What I have said in respect of the Leavers bearing or sustaining the weight, may also be understood of drawing a weight; As if 2 draw, and the weight A be fixt, not in the midle of the Leaver BC; the Leaver will be moveable only about the point D.

PROPOS. XVII.

A Theorem.

POwers *confisting at the ends of a Leaver, do not bear the weight easier on a longer Leaver than on a shorter.*

Fig. 39. Let the powers be A and B, and the Leaver likewise A B, sustaining the weight C ; and let there be 2 other powers D and E sustaining the same weight, or one equal to it, on the longer Leaver ; I say the length of the Leaver D E adds nothing to the facility ; for let there be the same proportion of A C to C B, as of D F to F E, I will shew in both cases that the same part of the weight is sustained by the power B, as is sustained by the power E, and the same by the power A as by the power D : In like manner (from *Corollary* 2) I will shew in both cases that the powers taken together are equal to the weight, whence the greater Leaver effects no more than the lesser.

Neither doth it seem strange, that the length of the Leaver adds nothing to the force, that is, if two Leavers of unequal length, but divided alike from the Prop, that is, let the proportion of the distance in both be a like, the like effect follows in both.

PROPOS. XVIII.

A Theorem.

WHile 2 *Powers sustain a weight, whose Centre is above the Leaver, in a declined site, the lower Power bears the greater weight.*

Fig. 40.   Let the 2 Powers be A and B, and let the weight be above the Leaver and its centre C, and let the perpendi-

cular be C D : I fay, the power B fuftains greater part of the
weight than if the Leaver were in an Horizontal fite ; For the
weight always acts by a line perpendicular to the Horizon, as
in this cafe by the line C E, when before it acted by C D, there-
fore the weight becomes nearer the power B: wherefore the
power B bears a greater part of the weight (by the prece-
dent.)

But if the weight be beneath the Leaver, the contrary hap-
pens, as in the fecond example, in which the weight hangs
on the Leaver by the line I K, which weight inclines to the
power F, and therefore in this cafe, the power F bears more
weight, than if the Leaver were in an *Horizontal* fite ; Laftly,
if the weight hang freely it will not change the fite. and con-
fequently, neither power fuffers by the declination of the *Lea-*
ver or *Beam.*

PROPOS. XIX.

A Theorem.

WHen a *power draws by a line oblique to the Leaver, its true*
diftance is a perpendicular from the Prop, to the line of Di-
rection.

Fig. 41. Let the Leaver or Beam be A B, and the power
drawing by the line B C oblique to the Beam, to which from
the Prop F is drawn a perpendicular F D ; I fay, the true dift-
ance of the power to be look'd upon, according as the increafe
or decreafe of the vertue, or force, is the line F D.

The Demonftration. Suppofe the power to confift in the point
D, which draws the cord from D in E, and draw the line
F E; In the mean time the Leaver defcends in the point G
draw the line E G, and becaufe in the triangles F D B, F E G,
the fides F G, F B, alfo F D, F E, and the length of the Chords
B D, G E is the fame (by the 8th of the 1ft. of *Euclid.*) all the
angles will be equal, among which G F D, B F E will be equal,
and the common angle B F D being taken away, there remains
the angles G F E, D F B equal, and confequently the arches B G,

                                                              H I

Fig. XXIII.

Fig. XXIV.

Fig. XXV.

Fig. XXVI.

Fig. XXVII.

Fig. XXVIII.

Fig. XXIX.

Fig. XXX.

Fig. XXXII.

Fig. XXXI.

Fig. XXXIII.

Fig. XXXIV.

Fig. XXXV.

Fig. XXXVI.

Fig. XXXVII.

Fig. XXXIX.

Fig. XXXVIII.

Fig. XL.
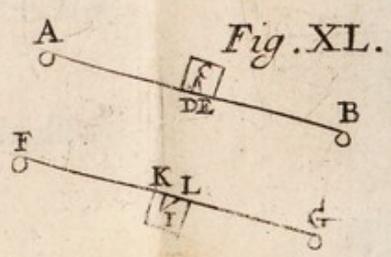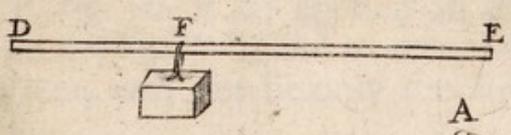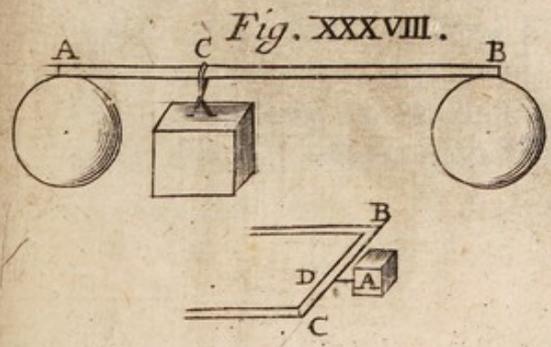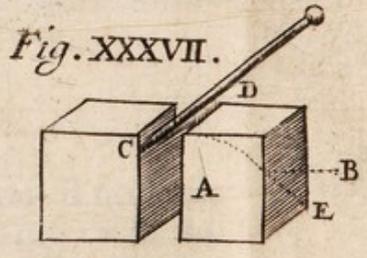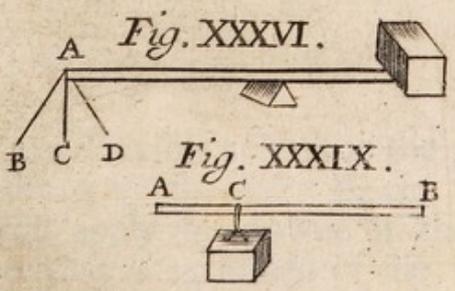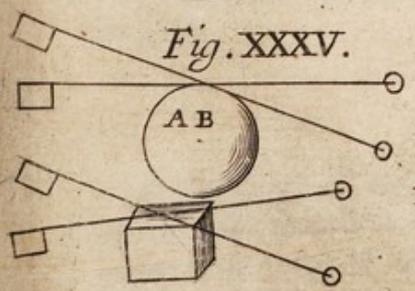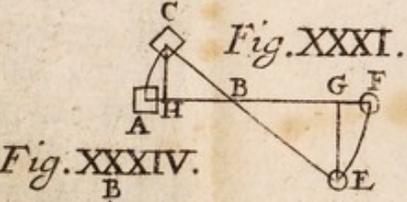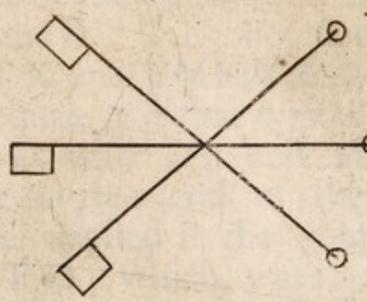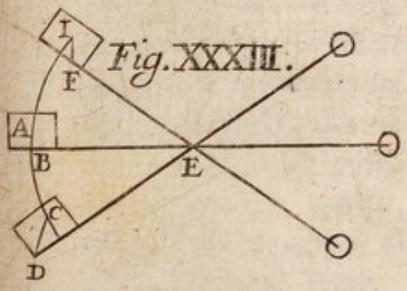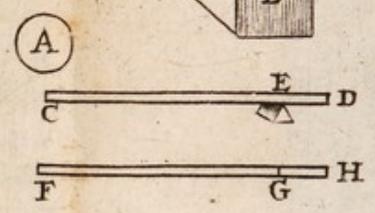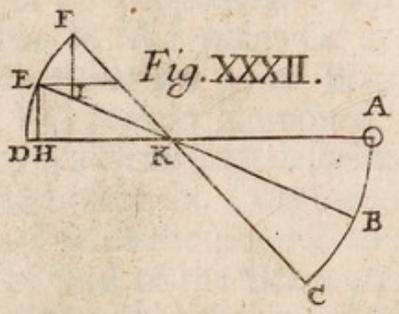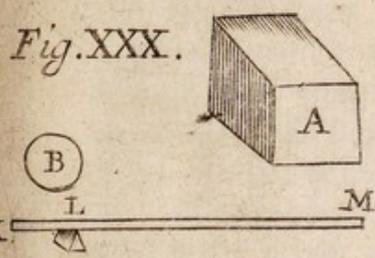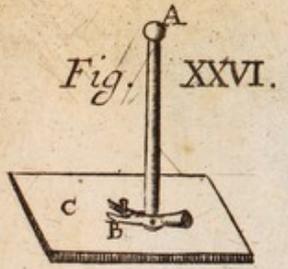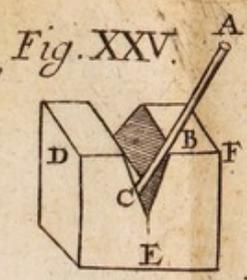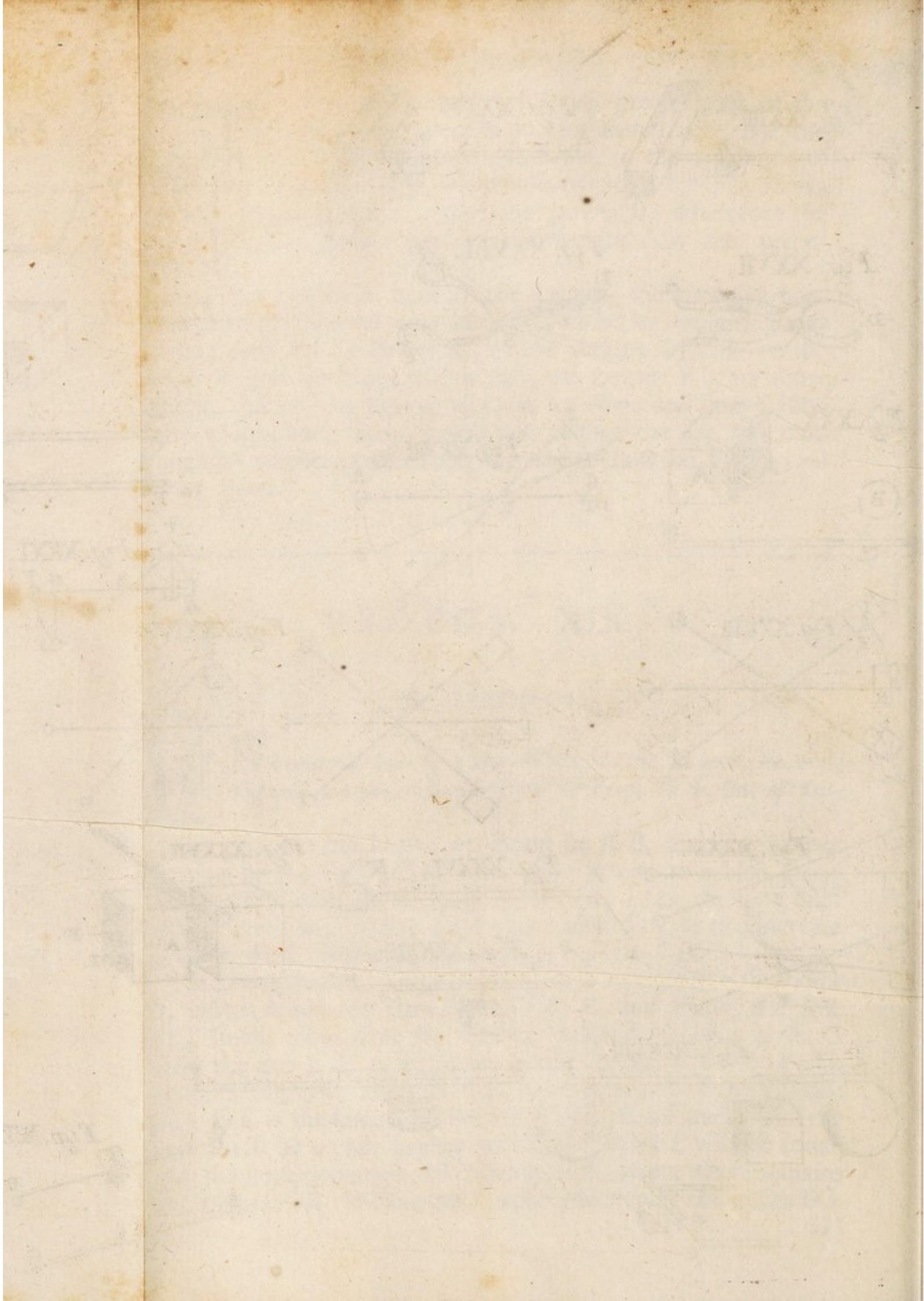
HI equal. But the arch D E according to which the power is moved, is to H I or B G, or A K the motion of the weight, as F D to A F : therefore the true diſtance, according to which the motion of the power encreaſes or decreaſes in the line F D, perpendicular to the line of direction; which was to be demonſtrated.

But if the power be in the point C, and it move upon the Circumference M C, it may eaſily be ſhewn that the arch M C, is equal to the arch B G, and conſequently in this caſe the true diſtance ſeems according to that which is lookt upon as its force to be the line F G or F C, which would be contrary to the precedent part of the propoſition : But the line B C is ſuppoſed to be flexible in the point G, and ſo the power placed in C may move about the point B, as about a Centre, although the Leaver F G remain unmoved. Suppoſing then from the point B, as from a Centre, we deſcribe the arch C O, ſo that the line B O, which may be imagined, be equal to the line B C ; draw a chord from the point O even to M, ſo that in the mean while the end of the Beam paſs from the point B, to the point G, and O M will be the true motion of the power, which I affirm to be equal to the line D E ; For ſince D C or D O is one half part of the line C K, and E M half of the line M G ; then D O and E M will be equal, and that which is common being taken away, *viz.* E O, then D E and M O will be equal, wherefore the power in that end of the line is not more moved than if it were applied in the point D, therefore its true diſtance will be F D ; which was to be demonſtrated.

Corollary. I.

If the line B C be not Flexible, neither in the point B nor any other, but firmly adheres to the point B, the thing will be otherwiſe; for if you apply the power in the point D, its diſtance according to what is examined of the increaſe or decreaſe of the force, will be D F, but if it be applied in the point C, its true diſtance will be the line F C, and its true motion, according to which it moves, will not be only the line M O, but the whole arch M C.

Corollary. II.

Fig. 42. The line of direction which is perpendicular to the Leaver is moſt apt to move, and by it the power hath the greateſt force that it can have at the end of the Leaver; for let the Leaver be A B, the Prop C, and let the line of direction B D be perpendicular to the Leaver A B: I ſay, in any other line of direction, the power is leſs able; for let it be another line B E, which makes an accute angle C B E, and which conſequently falls within the circle, draw to it the perpendicular C F, which (by the preſent) is the true diſtance of the power, and leſs than C B, wherefore when the Leaver draws by the line B E, it hath leſs force than by the line B D. Moreover let there be another line of direction B G, and the angle C B G obtuſe, and conſequently the other angle C B H will be accute, and B H will be within the circle which being divided in the middle in I, (by 3 of 3 of *Euclid.*) C I will be perpendicular to B H, and the ſame C I will be the true diſtance of the power; which ſince 'tis leſs than C B, the power alſo will have leſs force.

Corollary. III.

Fig. 43. The true diſtance of weights which draw by gravity only, is a Segment of the Leaver *Horizontally* placed between the Prop and the perpendicular; let the Leaver be A B, the weight by its gravity drawing downwards in B: Suppoſe the line E F in an *Horizontal* ſite, and draw the perpendicular B C; I ſay, the true diſtance of the weight B is D C, for all heavy things draws by a vertical line to which the *Horizontal* line D C is perpendicular; I ſay, the ſame if the weight were in the point H, the true diſtance would be D G. Whence it follows, that a weight depending on a Leaver *Horizontally* diſpoſed hath greater force.

And here I will add ſomething out of the Learned *Caſatus* his *Mechanics*; ſays he It may perchance be pertinent to our preſent purpoſe, and not unpleaſant to the Reader, if I here declare ſomething of an invention: When I heard a certain man, declairing that a *Bell* of a vaſt weight, was carried eaſily on Braſs Wheels, which by length of time were worn out, but

by

by what artifice, or in what order they were difpofed, or made, he could not tell; Wherefore he confidering with me how it might be done, I happened on this thought, that I efteemed the moft heavy bell, might eafily be repulfed, by diminifhing, or leffening the refiftance, which arifes from the wearing of the Prop, or Stay, and Axis together ; For let B and C be two fmall wheels (*Fig.* 44.) of folid Brafs, whofe diameters are in fome different proportion to the diameter of the axis on which the bell bears, or lies; And let the femidiameter of the Axis be A E, and of the little Wheels B E, in proportion double, therefore alfo the peripheries will be in the fame proportion, therefore while the point I in H compleats a quadrant, the little Wheel alfo is turned about, whofe periphery is equal to half a quadrant ; Wherefore if to the little Wheel there fhould be fixt an Axis, whofe Semidiameter B G is equal to the Semidiameter A E, the rubbing or wearing will be made with ½ part of the Periphery of the Axis of the little wheel B; but becaufe alfo in the little wheel C, the rubbing or wearing, will be made equal with the fame Axis, almoft nothing of moment is gained, becaufe the whole wearing is equal, as if the quadrant E O were turned about in a firm and hollow Prop : And it will rather be a leffening of labour in carrying the bell, if the little Wheels were fixed to an Axis : and fince the Axis is *Cylindrical,* the fubjeƈted Wheels doubtlefs will touch in a line, a fmall part of the Prop; And the Axis of the Wheels fuit or fit with their concave parts in the fuperficies which are worn while the wheels are turn'd round : Unlefs by chance the *Convex* fuperficies of the *Cylindrical* Axis B G, be fomewhat leffer than the concave fuperficies of the Wheel; and therefore they touch each other according to a line as(by the 13th of the 3*d.* of *Euclid.*) 'tis eafy to demonftrate, which doth not often happen.

But 'tis not needful to make fuch folid Axes to the Wheels B and C, For if the axis A E is convenient to bear the weight of the whole bell, a pair of equal Axes will refift or bear double the weight : Therefore 'tis fufficient if each of the Axes B and C, fuftain half the weight ; But fince the refiftance of the *Cylindars,* leaft they be broken, ought to be in triple proportion of their diameters, 'tis fufficient to find two mean continual proportionals betweeen the femidiameter A E and its half ; for that which is next lefs to A E will be fufficient, for the Semidiameter of a *Cylinder* having Subduple Solidity and refiftance,

ance, but still the Semidiameter requires to be less, because the weight bears or presses obliquely on the Axes of the Wheels B and C; whence the weight of the bell on those axes is according to the lines A B, A C, and not according to the perpendicular A D: Therefore as A D to A B, so reciprocally the weight on A B to the weight on A D; but the weight on either axis is as the subduple (or half) Summ to the whole weight; therefore the weight on B A is less than subduple, and the proportion continuing is made less; For when the Semidiameters A E and B E are given, the whole B A is known; and B D, and also its equal B E is known; therefore (by the 47th. of 1st. of *Euclid.*) also A D will be known, whose quadrate you will find, if from the Square of B A you subtract the Square of B D.

Therefore if by *Hypothesis* BA, be 3, its Square is 9; and B D 2, its Square is 4, which subtracted from 9, there remains the quadrate 5, whose root is 2,23 and is the right line D A: The weight therefore on B A to the whole weight of the Bell on both axes B and C, is as 2, 23 to 6,00: But because the resistance of like solids is in triplicate proportion of their homologal sides (and in *Cylinders* the proportion of their diameters is had) if you seek two mean proportional numbers between 6, 00 and 2, 23 which you may do if you draw the quadrate of one extream into the other extream, for the Cube root of the product is the term next to that number whose square you assumed: Therefore first, the Square of 6, 00 being 36, 0000, draw it into 2, 23 and the cube root of the product 8028000 is 431, $\frac{1}{3}$: But the quadrate of the other extream 2, 23 is 49729 being drawn into 6, 00, gives 2983740 whose cube root 310, is the other mean; Therefore the 4 numbers 600,431$\frac{1}{3}$,310,223, are continual proportionals, the fractions being slighted; Wherefore if you make it as 600 to 431, so the semidiameter A E to B N; this semidiameter sought will be sufficient to bear the weight.

And because B E is the double of A E, and A E to B N is made as 600 to 431, B E will be to B N, as 1200 to 431; And according to this same proportion will the Semiquadrants be that are described by them. But the eighth part of the *Periphery* from the radius B E, is equal to the quadrant from the radius A E; therefore the quadrant E O to the Semiquadrant of the radius *B* N, is also as 1200, to 431, Therefore if the rubing upon of the axis of the bell with the fixed Prop and hole, be 1200, the

the Wheel B with its Axis is 431, to which the rubing upon of the other Wheel C with its Axis is equal; and therefore the under Wheels the diameter whereof is only double to the diameter of the axis of the bell, the rubing upon is as 862 to the rubing upon which is as 1200; If therefore the diameter of the Wheels to the Axis of the bell be not only double, but triple or quadruple, the rubing upon will be much leſſer, and the facility in carrying the bell greater.

Mechanick-Powers.

OF, THE

Wheel or Axes in *Peritrochio.*

BOOK III.

Fig. 45, 46. Axes in *Peritrochio*, which in Latin they call *Suculum*, or *Windlace* ; It conſiſts of a *Cylinder*, or round piece A B, to which is fixt an Axis C D, it hath alſo handles or radius's fixt to the *Cylinder*; about the *Cylinder* a rope is turned to which the weight is faſtned; ſometimes the Axis C D, is parrallel to the Horizon, as in *Fig.* 46, and ſometimes it is perpendicular to the Horizon, as in *Fig.* 45. and may be variouſly made, and yet its eſſence; or being, remain unchangeable, and the ſame power perſevering in augementing ; For whether the handles be immediately fixt to the *Cylinder*, as in *Fig.* 46, or whether they be fixt to the Circumference of the Wheel, as in *Fig.* 45. it differs little, for the true length of the radius is the diſtance of its end from the Axes.

PROPOS. I.

A Theorem.

THe *Wheel or Axis in* Peritrochio, *is a Ballance or Leaver.*
Fig. 47.   Let the base of the *Cylinder* be A B, its Cen-
tre, or the Common Section of the base and Axis the point C,
which when't is immovable hath the force of a fulciment or
Prop, let the weight hang from the point A, and the Power
in D, I say there will be found a *Ballance* or *Leaver* of the first
kind, for although the handle B D be not always fixt in the
same plain wherein the weight A is found, nevertheless it de-
scribes an equal Circle to that which it runs over, if it exist in
the same plain; and therefore is found to be a *Ballance* or *Leaver*
of the first kind, And the same Propositions which we have
made of the *Leaver* may be applied to this Engin, since the
increase of the motion of a power above the motion of a
weight is the same; Therefore (by the first principle of this)
the increase of force is the same : But in the second case
in which the weight depends on the point F, the Prop is in
H, and the Power in G, 'tis a *Leaver* of the second kind.
    But if the power be in the point K, the Prop in L, and the
weight depend on the point M, as yet it will be found a *Leaver*
of the first kind, but being thus disposed, the force of the
Power is diminished.
    Lastly, If the *Fulciment* or *Prop* be in the point O, the Power
in P, the weight in R, it will be found a *Leaver* of the third
kind, wherein the force of the weight is increased, and the
force of the Power lessened; notwithstanding, this disposition
is not unuseful when the power exceeds the weight by a lon-
ger interval or space.

Corollary,

Corollary. I.

If the Power be to the weight, as the Semidiameter of the *Cylinder* to the length of the handle, or radius, the power in such disposition will be in *Equilibrio* with the weight: And I suppose the Power to be applied in the extream or end of the radius, and to force the handle always perpendicular; The reason is clear, because (by the first Principle of this) 'tis then in *Equilibrio*, when the Power is to the weight, as the motion of the weight to the motion of the Power reciprocally. But the motion of the weight is to the motion of the Power, as its distance from the Axis, to the distance of the power from the same Axis: For while the power absolves one circle about the Axis, the rope also is once turned about the *Cylinder*, and the weight absolves an equal motion to one circumvolution, or one circle of the *Cylinder*, but Circles are to each other as are their Radius's, Therefore if the Semidiameter of the *Cylinder* be to the length of the handle, as the power to the weight, it will be in *equilibrio*, and the power will sustain the weight; which was to be demonstrated.

But that the force of this *Engin* may be the better concieved, take the Semidiameter of the *Cylinder*, and compare it with the length of the handle, which take from the Axis to the point in which the power is applied; and as often as the Semidiameter of the *Cylinder* is found in the length of the handle, so often is the power multiplied; that is, let there be a man in *Equilibrio* with 100 pounds, and let the Semidiameter of the *Cylinder* be 10 times found in the handle; I say, the same man can with this *Engin* sustain 1000 pounds.

Corollary. II.

But if there be a greater proportion of the power to the weight, than of the Semidiameter of the *Cylinder* to the length of the handle, the Power will raise the weight; for greater force is required to move a weight, and to overcome its resistance, than to make it even, or level.

In

In like manner if there be greater proportion of the length of the handle to the Semidiameter of the *Cylinder*, than of the weight to the Power, the power will be superior to the weight, and overcome its resistance.

Corollary. III.

If the power move the handle by a line, not perpendicular to the same; Its true distance from the Axes or Prop will be lesser: As if in *Fig.* 48. the handle be *B C*, and the power draws by the oblique line *C E*; the true distance of the power according to which we ought to measure its increase or augmentation will be the perpendicular B D (as is shewn at Proposition 19. of a *Ballance* or *Leaver.*)

Corollary. IV.

If a rope be so turned about a *Cylinder* that it makes the folding spiral, or that one Spiral folds on another, it makes the difficulty of drawing greater, or increases the force of the weight; for when the Semidiameter of the *Cylinder* is increased, it makes the proportion of the length of the handle, to the Semidiameter of the *Cylinder* less (by the 10th. of 5th. *Euclid.*) or, that I may speak more plainly, the Semidiameter of the *Cylinder*, is not so often found in the length of the handle; if it happen that the *Cylinder* be not long enough to hold all the Spires, but it shall be needful to put one Spire upon another, since those Spires so put upon one another, necessarily increases the Semidiameter of the *Cylinder*, the same weight will have unequal force, and will sooner move the Clock or Watch, whence it follows that the first hours are unequal and shorter; But if any one would have (for example) the third hour shorter than the rest, let him increase the *Cylinder* of the *Tympane* under the Spire which answers that hour and he will have his desire.

Corollary. V.

Fig. 49. From this propofition you may underftand where-
fore in watches, which are not animated by weights, but by
fprings, wherefore I fay the *Cylinder* about which the ftring or
chain winds is not made *Cylindrical* but Conical, as in this figure,
for when the fprings in the beginning, are more ftretched than
towards the end, therefore they have greater force than the
reft; In the beginning they ought to draw by the Apex of the
Cone, that is, then there is but a fmall diftance from the Axis,
but in the end they draw by the bafe of the Cone, in which
part there is a greater diftance from the fame Axis; to wit,
that greater force drawing from a lefler diftance, or in a fmall-
er motion, may be equal to the force of a lefler drawing from
a greater diftance : For let the force of the fpring in the be-
ginning of drawing, to wit, when 'tis moft ftretched be equal
to one pound weight, and in the end equal to the weight of
4 ounces, or $\frac{1}{4}$ part of a pound; the Semidiameter of the
Circle of the Cone in which the String or Chain is knit, in the
beginning of drawing ought to be $\frac{1}{4}$ part of the Semidiameter
of the Cones bafe, according to which the drawing is made
in the end, for thus the force in each cafe will be equal and
will draw uniformly.

Corollary. VI.

Fig. 50. Hence may eafily be folved a queftion oftentimes
propofed to me, to wit, whether the fame weight hanging on
a long cord hath more force than if it hung on a fhort cord;
or whether it be harder to draw the weight A than the weight
B, which I fuppofe to be equal; The reafon of the difficulty
feems to be becaufe the weight A is farther diftant from the
Axis of the *Cylinder* than the weight B, and therefore feems to
require more force; therefore we fay not any diftance from
the Axis is the meafure of the increafe of force, but that only
from whence follows greater motion; therefore whether the
weight exift in A or in B, while the *Cylinder* is turned round
once, the weight afcends according to a line which is equal

to the Circumference of the *Cylinder*; therefore in each cafe the weight is equally moved, therefore equally gravitates; notwithstanding I exclude the weight of the rope, or cord.

But if thefe weights hang not freely, but the lines B D, A C fhould be of rigid matter and inflexible: Becaufe while the *Cylinder* is turned about, the weight A defcribes a greater Circle than the weight B, the fame weight A will have greater force than the weight B, according to the proportion of diftances.

PROPOS. II.

A Theorem.

WHile *a power acteth by the force of its own gravity, the increafe of the Power doth not always ought to be required from the diftance of the Axis.*

Fig. 51. Although we have toucht upon this propofition already: Neverthelefs we will fit it peculiarly to this Engin, becaufe that 'tis already known, and in common ufe with ftone diggers; the Machine or Engin confifts of a large wheel into which men enter, and in which they walk, alfo a *Cylinder* about which the rope is turned about, and an oblong neck, in whofe extream or end is a Pulley to direct the weight; It may be queftioned, whether the force of the power of the movent applied in the extream of the Wheel be increafed, according to the proportion of the Semidiameter of the wheel to the Semidiameter of the *Cylinder*; to which I anfwer, it is not fo, for when a man walks in a Wheel, and moves by gravity, to wit, by a line tending to the Centre of the Earth, applied in divers parts of the wheel, yea, often times almoft under the Axis, Its true diftance is not to be taken according to the Semidiameter, as if the man were walking in the point A, when he moves by the line A B, his true diftance is C D; as is fhewn in Propofition 19.

PROPOS. III.

A Thorem.

Of the windlace placed vertically.

Fig. 52. ALthough it matters not much how a *Windlace* is placed as to its fite or pofition, yet a *Windlace* whofe Axis is vertical hath this peculiar property, that it may be wrought by animals only, becaufe that (properly fpeaking) animals only have their motion Horizontal, although alfo fome mills are made in which water moves the *Windlace* vertically, yea, and the wind alfo, as we fhall fhew; I have often wondered that thefe kind of *Windlaces* are no oftner made ufe of in buildings, fince by the help of a horfe only, greater ftore of Stones, or Bricks, or Morter, may be conveighed to the upper-parts of the building, than by 4 or 5 men; Wherefore a ver-tical *Windlace* may be worked with a Mill-horfe, and about the *Cylinder* a double rope may be turned about, in a contrary man-ner, fo that in the mean while that one weight rifes, it fends down the other Inftrument. The force of this *Machine* will be very great, for when a horfe can carry more than 300 weight, he will draw much more, or raife by drawing; we will fup-pofe 500 weight, and his force increafes according to the Pro-portion of A C to A B; and for the moft part A C contains 10 lines of A B, from whence it will be, that one horfe alone may raife 5000 pound weight; but if the weights ought not to be fo great, and it feem better to raife more fmall weights with refpited force, than to take up a great weight together, and at once, left the ropes be broke, then you may increafe the *Cylinder* A B to any thicknefs that you pleafe, for then you will leffen the force of the power, and fooner take up the weight.

Neverthelefs becaufe in this *Machine* or *Engin* there feems this incommodity, that the weight being elevated, the *Wind-lace* ought to be turned the contrary way, and there would

be

be fome lofs of time, to turn the horfe the contrary way; firft 'tis certain that if men were placed to this *Windlace*, that inconveniency would ceafe : But if yet you would ufe a horfe, make a compounded *Machine* or *Engin* of two *Windlaces*, having two *Cylinders* with teeth, or toothed *Tympanes*, which vertical *Windlace* may move the other Horizontal, fo that if the cogs or teeth of the *Cylinder* be put to the other, the *Cylinder* will be moved on one part; but if it incur in the other *Cylinder*, the *Cylinder* will be moved with a contrary motion; and 'tis eafy fometimes to move one, and fometimes the other *Cylinder*, with a moveable Leaver about the cardinal point.

Fig. 53. This vertical *Windlace* is commonly ufed by feamen, chiefly in great fhips, fo that thereby they take great weights into fhips, and draw out great anchors which require great force, both by reafon of their weight, as alfo to dig them out and draw them from the earth, wherein they ftick faft; where in one thing is to be noted, that becaufe the Cables or great Ropes are oftentimes fo thick, that if they are rolled about the *Cylinder*, and Spire is put upon Spire, they grow to a great mole, and render the Engin ufelefs, therefore they turn only 3 Spires or 4 at moft about the *Cylinder*, fo that while a Seaman turns one end of the rope round it, the other is rolled away; And that it may always confift in the middle, nor run through the whole *Cylinder*, the *Cylinder* is made broader at the ends after the manner of a Cone, as you may fee in the Figure, for fo the rope is kept in the middle.

Fig. 54. There are reduced to the vertical *Windlace* or Axis in *Peritrochio* your leffer water-mills, in which the water difpofed in the wheel forces it fo, that the Wheel is moved Horizontally, and its Axes vertically; We ufe this Engin when great ftore of water is not at hand, and the greater the wheel is, the greater will the ftrength of the water be, according to the proportion of the diameter of the Wheel to the diameter of the Mill; But in the fame proportion decreafes the velocity of motion in the Mill, for each turning round of the Wheel, anfwers each turning of the Mill, from whence it happens that great care muft be taken that the Wheel be not made greater than is requifite, for if it be there follows a flownefs in the motion of the Mill, and the Engin is rendred lefs ufefull; likewife

if

if the Wheel be made lefs than the refiftance of the Mill requires, there will be no motion.

To the fame Engine are recalled other wheels, which howfoever expofed to the wind, always turn round; for to what wind foever on one part, the Concavity of the little hand turns, the convexity of the other is alfo turned, as if the wind blew directly according to the line A B, the wind will touch the Concavity of the little hand A G B, and the Convexity of the little hand B A, but then it makes greater impreffion while it incurs in the Concavity, than while in the Convexity; becaufe then it eafily flips away, this Wheel is turned from A by G in B: And the impreffion of the wind may alfo eafily be hindred in the little hands A, and then it will be turned more vehemently, to wit, if there be placed fome obftacle.

This kind of Windlace is ufed, as often as we ufe Animals, but chiefly we ufe Mill-Horfes when we work Engins, fuch as Mills, we grind all manner of Corn with, or Nuts, or Olives, or for the Extraction of Oyl; I omit feveral other Engins, which part of them are recall'd to this kind of windlace.

PROPOS. IV.

A Theorem.

Of the double Axis in Peritrochio, or a Wheel.

Fig. 55.   THE moft part of vulgar Engins are not fo fimple, but that oft times they contain a double Engin of the fame kind; I fhall not infift upon the Compofition, which may be made from a double or triple ballance, or leaver; becaufe for the moft part fuch compofure is ufelefs, whence the firft Compofition which may be made for ufe is the double windlace, and fometimes a triple one, according as the thing requires: But becaufe as we have faid, the Windlace is recalled to a leaver, and that continually, therefore it will not be unprofitable briefly to note, how wonderfully a power is augmented by ufing a double Leaver; for let the leaver be A B, its Prop C, alfo let A C be to C B, as 10 to 1;

Sure it is the Power applied in the point A, is equivalent to 10 Powers equal to it felf, applied in the other leaver D F, fo that EF be to DE as 10 to 1; the Power placed in F is equivalent to 10 Powers equal to it felf, in refpect of weight conftituted in D: But if the leaver D F impells the leaver A B, the Power F will be equivalent to 100 powers equal to it felf, in order to a weight conftituted or placed, in the point B.

And the reafon is clear, the point F hath 10 times greater motion than the point D, but when the point D is conjoined with the point A, they make the fame motion; but the point A runs through 10 times a greater fpace than the point B: Therefore (by the firft principle of this) in fuch difpofition of the Engin, the power conftituted in the point F will be equivalent to 100, equal to it felf, in refpect of weight placed in the point B.

Fig. 56. Which Doctrine is applicable to Windlaces, if they are fitted in the fame manner; as if the handle A C be 10 times greater than the Semidiameter of the Cylinder B, and the Rope annexed to the Cylinder B, moves the Windlace E, by the end of the handle D F, which alfo is 10 times as great as the Semidiameter of the Cylinder E: I fay the power A is 100 times encreafed with refpect to the weight G, which is manifeft.

Fig. 57. Notwithftanding, becaufe in this difpofition the Cylinder E abfolves only half the turning about, therefore this Engin is rendred ufelefs in many effects: Therefore if you would know the difpofition in which the leaver D E may always draw, this will be, if the Rope be made (as they call it) perpetually turned round about the Cylinder A, encompaffing the Wheel B C of the Cylinder D, and this Engin may be moft ufeful, efpecially when the two Cylinders A and D are diftant from each other a great fpace; neverthelefs it hath this inconveniency, that oft times it happens that the Cylinder A is moved alone although the Rope draw not; and therefore they make the Cylinder A, rough with hollowings, and alfo they make knots or balls in the Rope which enter into the hollowings, and ftay the Cylinder that it cannot move alone, as in the Figure E appears plainly.

Fig. 58. We ufe the fame Engin, but in a contrary manner when the power overcomes the refiftance of the weight by a long fpace, but a moft fwift motion is demanded; as if the
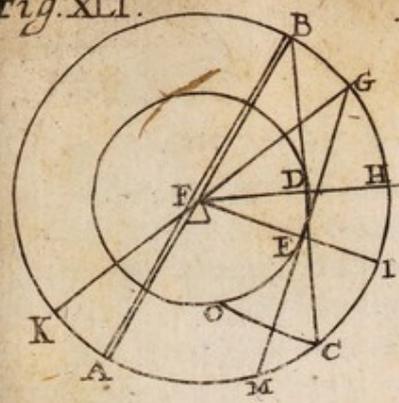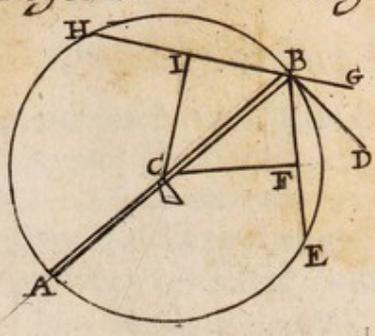
Fig. XLI.
Fig. XLII.
Fig. XLIII.
Fig. XLVI.
Fig. XLIV.
Fig. XLV.
Fig. XLVII.
Fig. XLVIII.
Fig. XLIX.
Fig. L.
Fig. LI.
Fig. LII.
Fig. LIII.
Fig. LIV.
Fig. LV.
Fig. LVI.
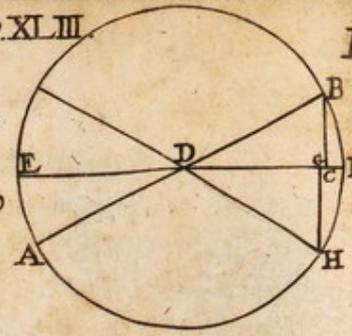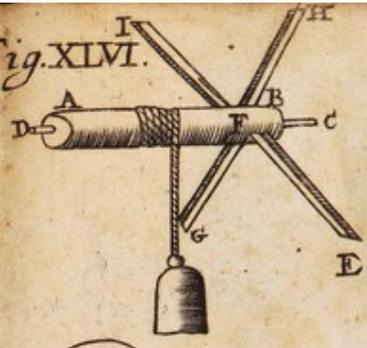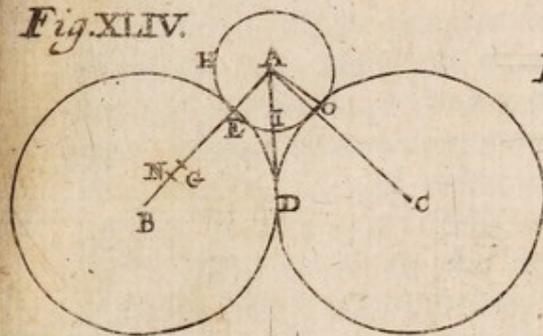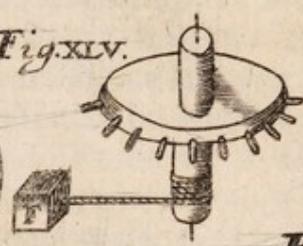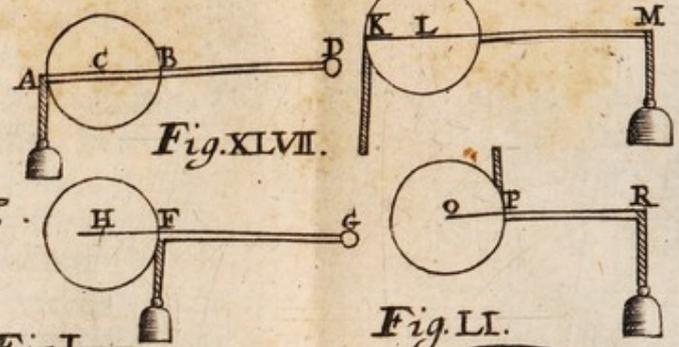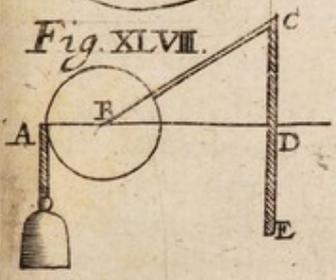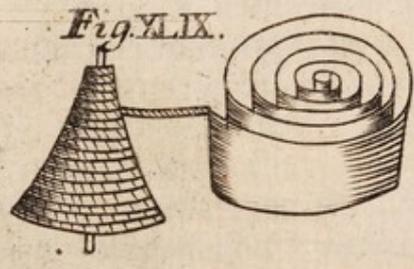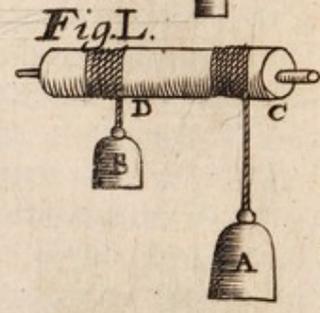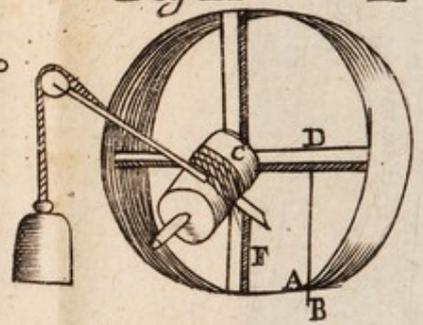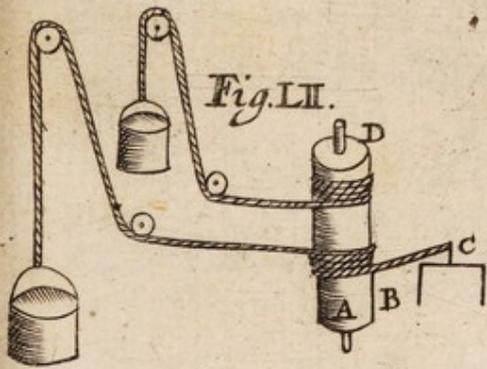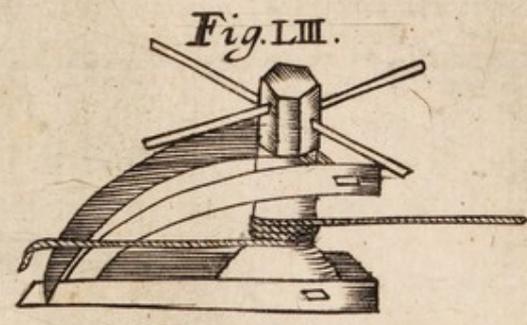
Page. 66.
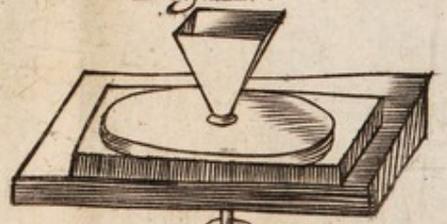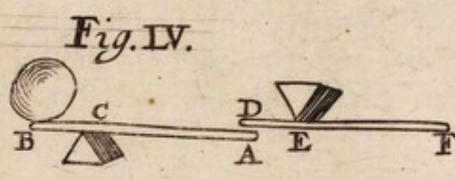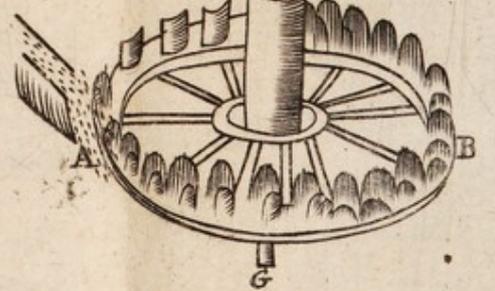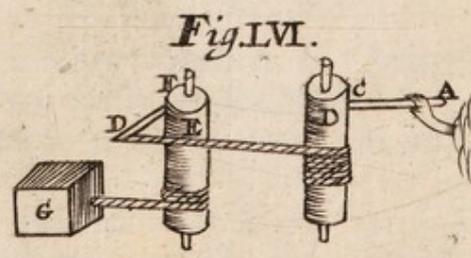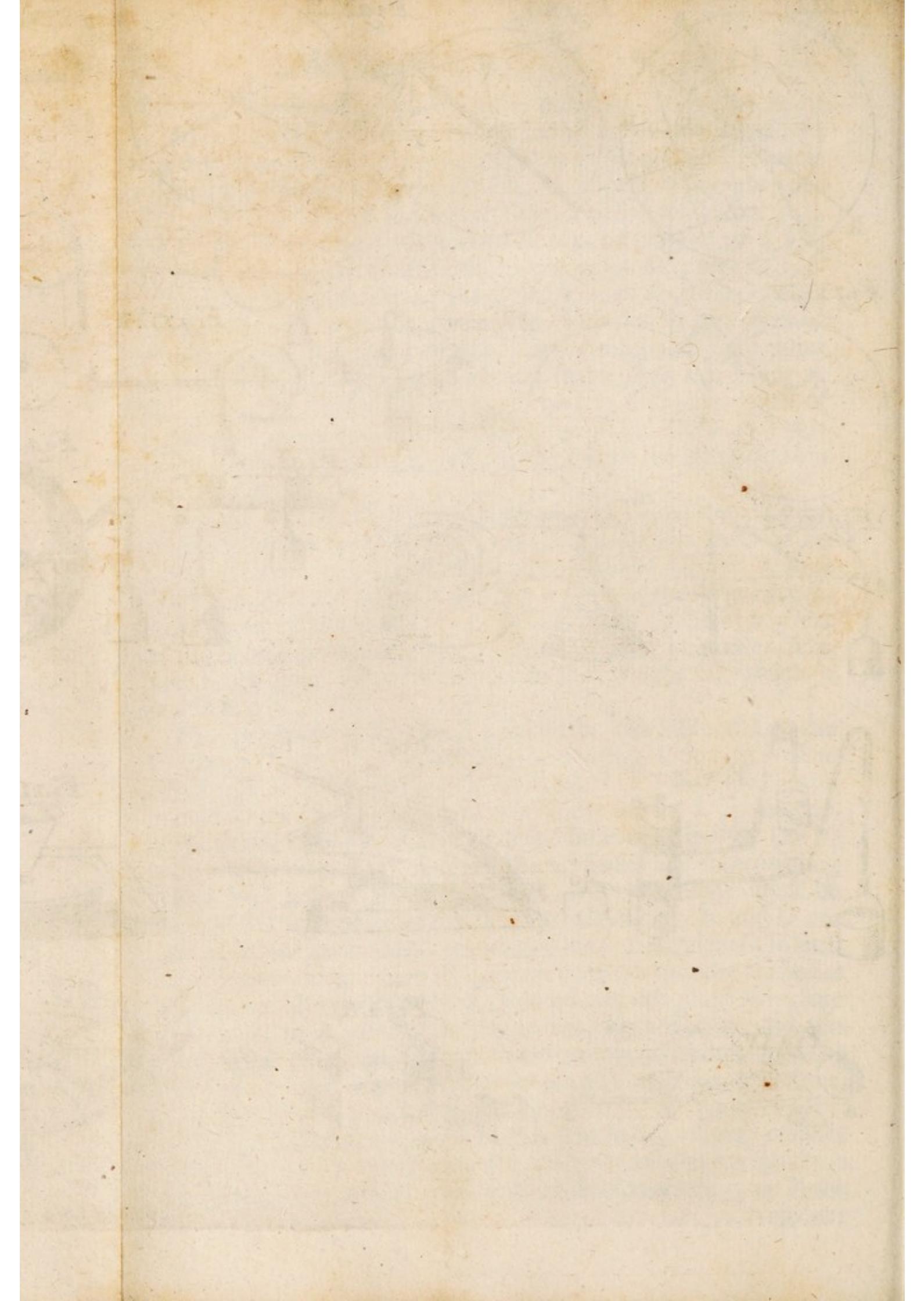
greater Wheel be A about which the Rope is folded, and also about the lesser Wheel B, whose Diameter is contained 10 times in the greater Diameter: 'Tis certain that every circumvolution of the greater will answer 10 Circulations of the lesser; but in this disposition the power is lessened; that is, if the power as 1 be applied at the handle C, you may determine to raise some weight hung to the Cylinder D, there will be required a power 10 times greater to take it up, if it be hung on the Cylinder E. Howbeit this Engin is very useful, because oft times a power overcoming a resistance sustained by a great excess, cannot otherwise conveniently be applied: So they which sharpen Knives, and other edge Tools, on a Grindstone, have greater force than to overcome that resistance, whereby the Iron resists the motion of the Stone while it is held upon it, and requires a swift motion only, which cannot be produced from the power in like manner, because 'tis impossible to move the Arm so swift: In this case an Engin must be used, which encreases the motion, although it lessen the force of the power: This Engin is easie, and much used, and chiefly of Women which Spin; also when they draw out Silken Threads, or double them; also of those that pollish pretious Stones, of Turners, and of many others, and I wonder that 'tis not used by more.

PROPOS. V.

A Theorem.

Of Wheels with Cogs, or Teeth.

Fig. 59. Toothed Wheels are recalled to Axis in *Peritrochio*, and are easily understood by a perpetual leaver; wonderful is the increase of power in using such an Engin.

For since that while one Wheel is 10 times turned about, the other is but only once turned round, it causes each Wheel to increase in a decuple proportion, and therefore as shall

be demonſtrated elſewhere, a number conſiſting of 50 Areth-
metical Figures, is greater than the number of Sands which
the whole Circuit of the Firmament can contain ; but the
number of each Figure added, increaſes in a decuple propoti-
on, and from thence the power follows.

The Demonſtration. Let there be a power in A which can
draw to it ſelf 100 pounds, and let C D be 10 times the Semi-
diameter E F, and let there be ſo many Teeth in the Wheel
G, that E F may deſcribe 10 orbs in the ſame time that the
Wheel G deſcribes one ; Moreover let G be 10 times turned
round while the Wheel L abſolves one circumvolution, and
ſo on ; I ſay, the Power, as 100 placed in A, is able to elevate
a weight of 100000 pounds.

For ſince the power in A runs through a ſpace 10 times
greater than the little Wheel E F, and the little Wheel E F 10
times of the little Wheel M, and the little Wheel M 10
times more than N, and this again 10 times more than the
Cylinder G H : The power A runs through 10000 times greater
ſpace than the weight P ; but the power is increaſt according
to the proportion whereby its motion exceeds the motion of
the weight (by the firſt principle of this) therefore the power
A in reſpect of the weight P, is equivalent to 100000 powers
equal to it ſelf : but A is ſuppoſed to be able to draw to it ſelf
100 pound, therefore 'tis equivolent to 10000 powers which
can each draw 100 ; but 10000 of ſuch powers can draw
1000000 ; Therefore the power in A, by the help of this
Engin can draw 1000000 pounds, which was to be demon-
ſtrated.

But on the contrary the weight loſes as much of its force ;
whence if inſtead of the weight P, a power be placed which
can elevate 100000 pounds, and the weight in the point A
can only elevate a weight of one pound, but the loſs which
the power A ſuffers, is in time, for it ought, to make 1000
Circumvolutions in the ſame ſpace of time that the Cylinder
I, abſolves 1.

Alſo this Engin is inverted, or changed, as often as the force
abounds in the power, and a moſt ſwift motion is required in
the weight, which may eaſily be underſtood by the foreſaid
diſcourſe, to wit, if the handle be in the Axis I, 'tis certain,
that the Axis D E makes 1000 Circumvolutions in the ſame
time that I only makes one.

P R O P O S. VI.

A Theorem.

To recall Toothed Wheels to the Leaver.

Fig. 60. THE whole multiplication of a power by help
of Wheels, is eafy to recall to Leavers, yea he,
that dilligently confiders the nature of Wheels, may eafily con-
fider the perpetual leaver in them, for each Cog of the Wheel
is a Leaver, which are fubftituted to themfelves by turns, fo
that one being deficient another fucceeds it.

And that we may confider the fame in the Multiplication of
leavers, let there be 3 leavers A B, D E, I H, and let A C be
to C B as 1 to 10; in like manner D F to F E, and E I to I H:
I fay the power as 1 in H in refpect of the weight A, is e-
quivalent to 1000 powers equal to it felf.

The Demonftration.   H is 10 times more moved than E or F,
and E 10 times more than D or B, and B 10 times more than
A ; Therefore the motion of the power in H is 1000 times
more than the motion of the weight in A : but if there fhould
be only one leaver K M it would be otherwife, for the leaver
L M would be only 30 times the part K L, and fo the
power in M would be equivalent only to 30 powers equal
to it felf.

To this kind are recalled almoft all Engins of any moment
which we commonly ufe, and which in the following pro-
pofitions I fhall explicate, the Forces whereof if any one
would confider, in general he muft meafure both the motion
of the weight, and of the power, and compare them between
themfelves.

PROPOS.

PROPOS. VII.

A Theorem.

Of Engines moved by Water.

Fig. 61. A Mong others those Engines are most useful, which are rather moved by Inanimate things than by Animals; because that Inanimate things want not nourishment, and are never tired or wearied; but Inanimate things which are wont to Animate Engines, are likewise all those things which cause Motion, as Water, Wind, Smoak, any kind of Weights, Springs, &c. In this Proposition I shall briefly handle those Engins of that kind which are moved by Water: And I find that Water can move an Engin in a double manner, either by an acquired force which can equalize a percussion, or simply by weight or gravity, thus some Wheels are made which bear Water on one part; in which 'tis requisite to know the precise proportion of the Axis in *Peritrochio*: So that the weight of the Water may have the exact proportion of the Power, and we ought to measure its force by the distance from the Axis, which in such case the forces of the handles bears: but when running Water moves an Engine or Machine not by force of weight, but by acquired force, that is done either because Water is conveyed by a plane much inclined, or running into wings, or little hands, but which method is best we will examine when we come to treat of *Hydraulic* Engines.

Fig. 62. But 'tis certain that greater Wheels have most force, for when in Windlaces the power is moved by a longer handle its force is increased, but likewise a requisite time is increast, whence I often find in common Mills unnecessary Expences laid out, to wit, they make the greater Wheels winged, in which the Water dashes, also because a flower motion should follow in the Mill, they add a greater toothed Wheel which runs into a lesser; so that while the greater makes one revolution, the Mill makes

makes 8 Circumvolutions; It is sufficient that the first wheel A B, equipt with little hands, be made less by one half, also the wheel C D to be ½ of that; so that E F shall make only 4 Circumvolutions in each rotation of the greater wheel A B; for the Water hath the same force in respect of the Mill E F, in moving by only 4 turnings about, and the Water will twice as soon turn the wheel A B, being lesser by half; and if we weigh or confider all these things exactly, and according to Mathematical Rules, the same thing would happen if the wheel A B should be eight times lesser, likewise C D should be 8 times lesser; so that each Circumvolution of the Toothed, or Cog wheel, should answer each Circumvolution of the Mill E F.

Which things, as I have said, are true, precisely speaking, notwithstanding we must confider one thing, *viz.* That greater wheels because they depart less from a right line, therefore their little hands are longer forced by the Water; but in lesser wheels each little hand is sooner elevated, whence in all these some mediocrity ought to be observed.

Fig. 63. Not only Mills for grinding of Corn, but also most other Engines, yea, almost all which are made in Water are reduced to this kind; First, all Mills for Corn, which are made on the banks of Rivers, or those that are made in little Ships, and in the middle of Rivers, or other Engins which are for grinding of Nuts, or of Bones to powder, *&c.* Also Engines to make Paper, in which a wooden Cylinder of sufficient magnitude standing out, furnisht with little troughs, takes up wooden Mallots, which bruise and break whatsoever is laid under them to powder; your Gun-powder Mills in like manner consisting in a Cylinder, equipt with like troughs, which take up Pestles of Mortars; for in all these we must confider Axis in *Peritrochio*, as well in the wheel which the Water forceth or driveth, as in the Cylinder and its troughs, taking up Mallots, or Pestles.

Fig. 64. Likewise Mills for Iron, in which also a Cylinder equipt with little hands, takes up and lets down an Iron Mallet of a sufficient greatness.

Fig. 65. And these are of divers kinds, according as they are diversly required to be made, for some are greater, and some are lesser, some pound oftner than others.

Fig. 66. Saws alſo which are drawn up and thruſt down by the handle ; alſo there is another part of the Saw which belongs to another kind, *viz.* to the Screw. Alſo Engines in which Bellows are wrought, or blowed, which belong to the ſame manner, as to motion upwards and downwards, but if four pair of Bellows are to be blowed together, the Axis ought to be made turning, or bowing, four oppoſite ways, that they may be moved in any order, and in each Quadrant.

PROPOS. VIII.

A Theorem.

Of Engines that work by the gravity of Weights.

ALſo Engines are moved by Weights, and the force of their Gravity, as are our Clocks, notwithſtanding I ſhall ſay in general, that all thoſe Engines are not fit to augment the force of Powers, but to ſhorten time, to wit, that that may be done in a ſhort time, which was wont to be done in a whole day ; that is, let an index of hours be moved in a whole day, that it may ſhew the hours properly, if a man ſhould undertake that without an Engine, he would ſpend the whole day ; a weight being ſubſtituted by a man in one minute, in drawing or winding up the weight, uſes as much force as is neceſſary to move the Hand or Needle the whole day.

The ſame I ſay, of Engines for the turning of Spits in convenient places, which have nothing peculiar but their motion of ſtaying, or ſtopping, which we ſhall treat of hereafter ; and theſe Engins are made after four manners, *viz.* with Weights, with Springs, by Smoak, and by ſome living Creature walking in a Wheel ; of Weights and Springs I ſhall ſay nothing, for 'tis moſt certain I have found nothing in them more than toothed Wheels, and Axes in *Peritrochio* ; and the Animals which are commonly made uſe of for the turning of Spits, are Dogs, but Geeſe are better, for they will bear their Labour longer, ſo that if there be need they will continue their Labour 12 Hours.

Prop-

PROPOS. IX.

A Theorem.

Engines moved by Smoak.

Fig. 67. ENgines which are turn'd by Smoak, shew plainly how much force is increased by Axis in *Peritrochio*, for what force can there be less to impel and move a Weight than Smoak, nevertheless while this runs into the winged Wheel A B, all whose wings are bent in the same part, if the wheels are so fitted, that while C D makes four or five Circumvolutions, the wheel E makes one ; and in like manner while the wheel E, or that annext to it F, is turned four or five times, the right line G is only once turned ; A B makes 25 circulations in the same time that G, *viz.* the Spit makes one, I say, from this multiplication of motion in the power, to wit, in the Smoak, or in the wheel, into which the Smoak enters, the impulsive force of the Smoak is increased 25 times, with respect to the resistance of the Spit placed in the point G, and I do not see any thing more in this Engine worth our taking notice of.

PROPOS. X.

A Theorem.

Of Engines working by the Wind.

Fig. 68. THe reason is the same of Mills turned by the Wind, in which also the sails are bent in the same part, for they are not directly opposite to the wind, but every one in one and the same part are somewhat oblique,

almost

almoſt in the ſame manner that Boys make paper Wheels on a Reed; ſo that while they run and hold it in the Air, 'tis eaſily turn'd, and becauſe the force of the Wind and the violence is very ſtrong, the Mill makes more turnings about than the winged wheel in a contrary manner, as in the precedent Engine. And the ſame queſtion may be made of this kind of Wind-mill, which is made of common ones, to wit, whether they may not be more compendiouſly compoſed than commonly they are made; for ſince by the multiplication of the Wheels the motion of the Mill is increaſt, whether or no it would be better to make leſſer wings, whence it will come to paſs that the firſt Wheel will compleat its revolution ſooner, and therefore there will not need ſo much multiplication of the Wheels, that the firſt Mill ſhould obtain the ſame motion; 'tis alſo worth our conſideration that the wind is not applied in one place only, but almoſt in the whole wing or ſail, and therefore the greater the ſail or wing is, the wind will not only have the greater force, becauſe that it makes greater motion in the extream with reſpect to the motion of the mill, but alſo more plenty of wind is adhibited, whence I think 'tis better to uſe longer wings or ſails than ſhorter.

The Art of Mills depends on Axis in Peritrochio.

TO reckon up all the Arts which depend on Axis in *Peritrochio* would be a thing not unpleaſant, but almoſt an endleſs piece of work, and would be rather like a Hiſtory than a Theorey, in which I chiefly write of the principal cauſes of Engines, ſhewing by what ingenuity every one may deſign or contrive Engins after his own manner meet for the purpoſe. And I ſhall inſiſt a little on the making of Mills, that we may know how great profit we receive to the commodity of life from Axis in *Peritrochio*; and although thoſe that are chiefly ordained, are Mills for grinding of Wheat, and other Seeds, that bread may be made of flower, yet ſome part of them are deſigned to other uſes; for as much as the outer Wheel is common to all, which by water running into it, turns it and the Axis about. For if Wool, or Hemp, or Flax, be to be pounded, or any body ground to Powder, if old Rags are to be

be beat to pieces to make Paper, little pegs or pins are fixt to the Axis, which in turning about meet with the pins of Peftles and raife them, and deprefs them, and their weight falling on the matter laid underneath, either batters or breaks it to pieces, or beats it to powder in Mortars.

In the fame manner Peftles may be difpofed to match with their hollow Cylinders, which being elevated by the little pins of the Axis, attract the water into the hollow Cylinders, or rufhing in naturally they admit it through the Cells, then falling down by their gravity, they prefs the Water through the Tub, and force it to afcend to an higher place. Or if you like not Peftles fo great and heavy, and would force Water to a higher place, difpofe a pair of Peftles by a Rope, or Chain, put through the hollow of the upper Wheel, and paffing over the Periphery joins them, or rather overthwart, like weights joined to a Beam, fo that while one is depreft the other is raifed. And the pin of the Axis depreffes the Peftle, by whofe force the water afcending in the Tub is preft, and the other Peftle being lifted up draws the Water placed beneath, which in like manner is preft down after that by the pin of the Axis anfwering its pinion; from hence it comes to pafs that a longer Axis may be added to the Wheel, and more pairs of this kind of Peftles in like manner may be difpofed, and the pins in the Periphery of the Axis fo diftributed, that not only more Peftles may prefs or force down together, but every one after another, if the power turning the wheel be not altogether fo ftrong, if not, and it fhould be ftronger, you may deprefs more together, and raife thofe that anfwer them ; unlefs by chance it pleafe more, to make ufe of two pair of Peftles in the fame manner, with fo many pins placed in the Axis, that in one going round of the fame Axis, the fame Peftle may be depreft twice or thrice.

Moreover to this place appertains, what we fee in many places in the Work-houfes of Hammer-Smiths of Copper or Iron, where alfo the outer wheel being turn'd about, and the force of water failing, the inner wheel in the room turns as if it were turn'd by the hand, which radius of the upper Axis is fixt parallel to the Horizon, and a rule joined to it that may be folded in the Joints, while it lifts up and depreffes that which is overthwart ; on the other end of the fame Axis, taking up in like manner from hence, and depreffing from hence,

it procures an altern or changable motion to the Bellows ; and the other wheel receiving a stronger force of Water falling down, and turning its Axis about, the pins fixt at the other end of the Axis depresses the little rafter or leaver, whose opposite end being raised, is joyned to a great Iron Hammer, which besides the fall of the Axis with pins of it self, lighting or falling upon the subjected copper or Iron being burnt in the fire, beats or hammers it.

In all these the Semidiameter of the Wheel is to be consider'd, in whose little branches standing out the water running into, retains the force of the moving power ; but the Semidiameter of the Axis is not to be consider'd alone, but also the length of the pins that stick out to be added, so that from both is made one only Semidiameter of motion which is communicated to the pestle, or to the depreſt end of the Hammer or Sledge. I say, to the depreſſed end of the Hammer, for the elevation of the Hammer is somewhat greater than its depreſſion that a ſtronger blow may follow ; for neither the little rafter or leaver is altogether equally divided from its Axis on which it ſtays upon, but the Hammer is a little farther from it, than the oppoſite end which is depreſſed, and therefore the depreſſing force is greater than if the leaver were diſtinguiſhed into equal parts. Likewiſe in the motion of Bellows; firſt, the Semidiamer of the wheel is to be compared with the adjoining handle, moreover the radius fixt to the ſuperior Axis, muſt be compared with half the piece that goes a croſs to which the Bellows are joined, and from theſe two proportions is compounded a proportion of motion, or movement of the power, to the motion or movement of the weight moved.

But yet in Mills whoſe grinding ſtone for Corn is turned round parallel to an Horizontal plane, yea, and that very ſwiftly, that the grain may be diſſolved into flower, 'tis not enough that the outer wheel receives force from the Water turning the Axis fixt to it, but alſo the lower toothed Wheel is required to be in the ſame Axis ; and that the members, or parts, of the Engin be not multiplied in vain, they commonly ſo diſpoſe the Mill-ſtones, that the Iron Axis that ſuſtains the upper Mill-ſtone, being furniſht with a place to turn, or run in, obtains the lower place, and therefore the runner as near as may be touches lightly, the upper part of the neither toothed Wheel with its plane, having the ſame Axis with the outer Wheel.

But

But if the Mill-ftones cannot be placed in a plane beneath, or above that which turns the lower toothed Wheel, but only a little beneath, or above, the Axis of the fame Wheel; becaufe the chamfred turning joint joining very near to the Mill-ftone, and fo turning the Stone, is diftant from the toothed Wheel, and this doth not fo convenienly admit of fuch long Teeth which the fame turning joints, or the little rods of the runner, are able to mix with fitly; thereforethere is required another Axis perpendicular to the Horizon with a runner, and a fixt Wheel, which fhall turn about the lower Wheel of this Runner, forcing its little Rods with its Teeth; for the toothed Wheel parallel to the Horizon, being fixt to the fame perpendicular Axis, is turn'd about together, and being joined with the runner of the Mill-ftone turns it round.

Here alfo are many proportions compounded, the firft is the proportion of the Diameter of the outer Wheel, to the Diameter of the inner Wheel in the fame Axis; moreover the proportion of the Diameter of the Runner of the Mill-ftone adhering to the Mill-ftone turning round the Diameter (whether the whole Diameter be allowed, or only that part which is the Diameter of the Circle in the rotation of the Mill-ftone defcribed from the point between the Centre and the middle of the Periphery) and if, as in the fecond cafe, the perpendicular Axis muft be placed between; befides in the Compofition, comes the proprotion of the Diameter of the runner to the Diameter of the toothed Wheel, perpendicular in the fame Axis; from whence it appears to be better, that the Diameter of the inner Wheel be lefs than the Diameter of the outer Wheel, that the force of the Water forcing this may be more ftrong; but alfo we muft take heed that we do not make it too little, fo that its number of teeth fcarce exceed the number of little Rods of the runner adhering to the Mill, for this will caufe it to move too flowly; and if the perpendicular Axis be in the middle, fuppofing this equality of Teeth, and of the little Rods of the runner, one turning round of the outer Wheel will only once turn round the toothed Wheel parallel to the Horizon, and therefore in the fame time the Mill will be only fo many times turn'd about, as the number of little rods of its runner is contained in the number of Teeth of the toothed Wheel fixt in the perpendicular Axis.

But as you increase the number of times of the Mill's turning round, take heed that the difficulty of moving in like manner be not increast more than needs muft ; to wit, if the Diameter of the runner in the perpendicular Axis be excessively lefs than the Diameter of the Toothed wheel in the fame Axis ; if fo be, a power applied in the runner will be moved much flower than a weight applied at the end of the wheel with Teeth, and therefore the difficulty of moving increased : Wherefore all things muft be wifely adminiftred, that neither the force of the moving power be tired in vain, nor the Mill be moved flower or fwifter than need is.

But if it pleafe not, or the difpofition of the place permit not the middle Axis to ftand perpendicular, but it happens more conveniently to be parallel to the *Horizon*, then the Teeth of the inner wheel having the fame Axis with the outer wheel muft not be fixt in the plane, but require to be faftned in the extream Periphery, that they may turn the runner of the fuperior Axis, (whether greater or leffer, according as is needful) and with it the wheel that is Toothed, not in the Periphery, but in the Plane, from which the runner of the Mill is turned.

Neither otherwife than before, is the proportion of force compounded, to wit, of the proportions of Tympanes or Water-mill wheels, or Crane wheels, which have a common Axis, as appears from what hath been faid.

Hence we obferve, becaufe the moving power is Water, that the form of a wheel receiving Water is not to be always the fame ; for thofe wheels which are placed in a running Water would be inconvenient if they have a very large Diameter ; or if but a little Water falling, the Impetus or force will be repelled, if the little hands be prepared to fmall. Therefore wheels of this kind fhould have indifferent Diameters, but the little hands poffefs a very confiderable part of the Axis, being difplaid very nigh the length of the Axis, that fo by much Water running into them they turn round with a ftronger force ; fo in the River *Poe* in *Italy*, commonly the length of this wheel is 15 Feet, the whole Diameter 9 Feet ; the Diameter of the neither Stone is 8 Feet 3 Inches, having 108 Teeth fixed in the plane, and the runner of the Mill is diftinguifhed into 9 Spindles ; and the Stone of the Mill in thicknefs 6 or 7 Inches, and its Diameter 3 Feet 9 Inches : But

becaufe the motion of Water falling from on high is greater than of a running Water, therefore the Diameters of the wheels ought to be larger if there be need, and it fuffices if the breadth of the little hands be very indifferent, as being included in a Channel or Pipe, by which the Water falling decays, or is loft : That is to fay, a little Water falling from a *Plane* more elevated, hath greater force than from a Plane almoft *Horizontal*; and befides a wheel of a larger Diameter is eafier turned although from lefs water, for it hath greater proportion to the inner wheel from the other pairs. Moreover the little hands commonly are plain, or but little bent, fo that the water may run abroad here and there ; neverthelefs fometimes they are concluded on each part with a ledge, or welt, as it were a little Veffel containing water for fometime, fo that the weight of the included water helps the turning, by preffing downwards ; Moreover in an inclined channel, the force of the water is greater in the lower part than in the upper near the beginning of the fall ; to wit, becaufe water naturally defcending hath an accelerated motion, and acquires an impetus from the defcent of the antecedent.

Hitherto we have confidered of Mills which are drove by the force of water, adding nothing concerning thofe which are turned by Men, or by living Creatures, for thefe have nothing peculiar, befides that the Axis of the firft wheel which procures the motion of the reft of the confequent parts, is perpendicular to the *Horizon*, becaufe a power moves eafier in a *Horizontal* plane, than in a vertical wheel, or Tympane, which is trod or trampled on ; and inftead of the outer wheel driven by the water, a Bar is fixt to the Axis, which they either draw by Cattle, or work with Men.

Notwithftanding we will fay fomewhat of Mills which are wrought by the Wind, whether they be for grinding of Corn, or bruifing of Fruit, or whether they be for working of Pumps, whereby waters are drawn from low grounds that are overflowed : For that which belongs to the inner artifice of wheels and runners, are like thofe which are found in our Mills moved by the force of water, unlefs that in thofe, that being remote from a level plane (if fo be a fit place be granted, and the wind caught by a large van) they afcend by a pair of Stairs, and the Corn, or Fruit, is carried into the upper place which they intend to grind, bruife or break, and the

<div align="right">Flower</div>

Flower is transferred from thence: which labour the *Miller* may be eafed of, if by the fame labour whereby the wind turns the prime Axis with its wheels; Sacks full of Wheat, or Flower, may be taken up, or let down, with a Rope drawn about the Axis, being lapt up, or unfolded: That which is chiefly to be confidered in this kind of Mills, is that which pertains to the Vans, or Sails, which receive the wind, for even as the plane of the wheel is not directed according to the running of the water, fo neither have the Sails fuch a difpofure that they follow the leading of the wind: But the upper part of the little Houfe wherein the Axis with the Toothed wheel is contained, is turned about until the Vans, or Sails, are fet againft the blowing of the wind.

And the Vans or Sails are as it were 4 Ladders conjoined at right Angles in the end of the prime Axis, each whereof is covered over with Linen Cloath to refift the wind, which if it be pretty ftrong, the folded part of the Cloath will admit of fome paffage to the wind; notwithftanding thefe Vans or Sails, are not fo equally placed, as to be in one and the fame vertical plane, but the plane of each Sail is placed *oblique* to the other fide, withdrawing it felf by little and little from the wind; whence it makes the wind running between the intervals of the four Sails to repel on the fides, and as it were to fmite the Sails by an Elbow, and fo the Axis is turned according to the Inclination of the Sails; for if there were no *obliquity* of the Sails, and all as it were made one plane in which the Axis would be perpendicular, it would be uncertain in which part the turning would be; that which belongs to the breadth or length of thefe kind of Sails *obliquely* placed, 'tis not doubted but that the breadth of them helps the motion very much, becaufe being placed in the fame *obliquity*, a greater part of the Air runs into a larger than a narrower Cloth; and in a very ftrong Wind, leaft the velocity of the Engin be over much, we find fometimes that covering half the Sails with Cloth will do; but whether or no 'tis worth while to encreafe the length of them, is uncertain: For although a power more diftant from the centre of motion hath more force, notwithftanding, becaufe the ends of long Sails are very much diftant between themfelves, the wind having obtain'd a larger fpace, hath lefs force; as alfo water flows fwifter, and with a greater

endea-

endeavour through a fmall narrow place, than it runs through
a wide open Channel; therefore I dare not intirely define in
thefe kind of Sails, in what place the forces of the moving
power fhould be placed, as it were in the centre of vertue, or
force; for near the Axis to which they are faftned, the di-
ftance is fmall, and the Wind as it were their object being
ftopped, blows more fwiftly : And further from the Axis in a
greater fpace, it flides away more eafily, and lefs incites the
courfe of the Sails ; but for as much as we muft not rafhly
appoint the compreffion of the wind altogether to anfwer the
changeable diftances of the Sails, which are in the fame pro-
proportion as their diftance from the Axis ; neither can it ea-
fily be affirmed, that the force of the Wind by compreffion
doth decreafe in the fame proportion, whereby the fame mo-
tion increafes by the diftance from the Axis, from whence there
would be a compound motion of the diftance from the Axis,
and of the force of compreffion to be equally diffufed through
the whole length of the Sail or Vane, and therefore the centre
of the moving force would be in the middle of the length.
Neverthelefs all things rightly confidered, I efteem the centre
of this force to which the power is underftood to be applied,
to be not far from the middle of the length of the Vane or Sail,
unlefs by chance the Vanes fhould be fuch, that their breadth
be increaft by departing, or being placed further from the
Axis, for fo the diftance being leffened in the ends of the Sails,
the compreffion of the wind is likewife increaft.

But if you imagine any inconvenience to happen, by the
Poles lying upon the little Houfe, and its being turned fo, as
the fails to be again the wind which they receive ; you may
on the top of the Houfe in an open place expofed to all Winds,
place an Axis of fufficient ftrength perpendicular to the Hori-
zon, about which you muft place the toothed Wheel pa-
rallel to the Horizon, from whofe turning about, the Mill at
laft is turned; and the breadth of the fails according to the
length of the Axis, muft be placed in the fame upper part with-
out the Roof, that the Wind blowing, they may receive the
force of it; even as Water flowing, the force is received by
the little hands of the Wheels. But becaufe plain even fails,
feem lefs apt to continue the rotation, fince thofe which are
oppofite to the Diameter, are at laft equally expofed to the
force of the Wind, and would be forced neither to the right

hand

hand rather than to the left, and therefore the turning round would ceafe ; therefore the fails fhould be made a little crooked, or bowing, for by this reafon they will be made fo, that the oppofits will be unequally preft on, and the Wind will attack with unequal force the convex face of the right, but the hollow face of the left Sail, to wit, it doth as it were remove it felf to the Wind, neither is the end of its motion very much oppofed, according to the bowed direction of the Wind ; and I make this hollowing fo bending every way, that receiving the Wind, it receives its whole force: Moreover the particles of Wind incurring in the two Sails that are next each other, are reflected from the convex of one face to the hollow of the other face, and increafes the force, or impulfion ; but if you pleafe not to have four, but five Sails, left at any time two be oppofed by the Diameter, I fhall not deny it. Certain it is, that the length and breadth of thefe kind of Sails help very much, for the larger they are, the more wind they receive, and the longer they are, the further they be from the centre of motion, and have more force : But how the Machine, or Engin, muft be ftopt or ftayed by folding or unfolding the covering of Cloth, that it do not work when the Miller would have it ftand ftill, I fhall not here difpute, where we are only confidering the force of moving ; neither doth the fole ufe of this Mill confift in grinding of Wheat, or other Grain, but alfo in raifing and turning waters another way, that marfhes may be drained, and other things of the fame kind, which prefent body always moving, they are not tyed to a certain time, even as in the work of grinding, which is not always ufed.
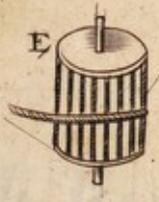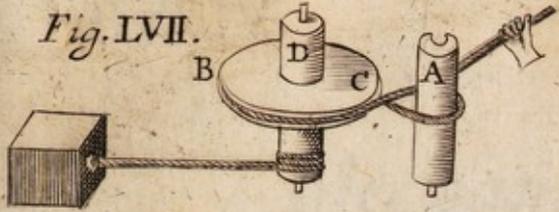
Fig. LVII.

Fig. LVIII.
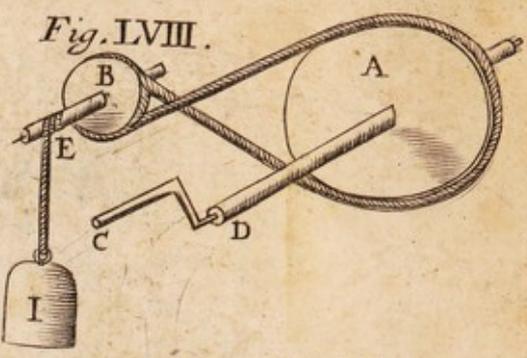
Fig. LIX.
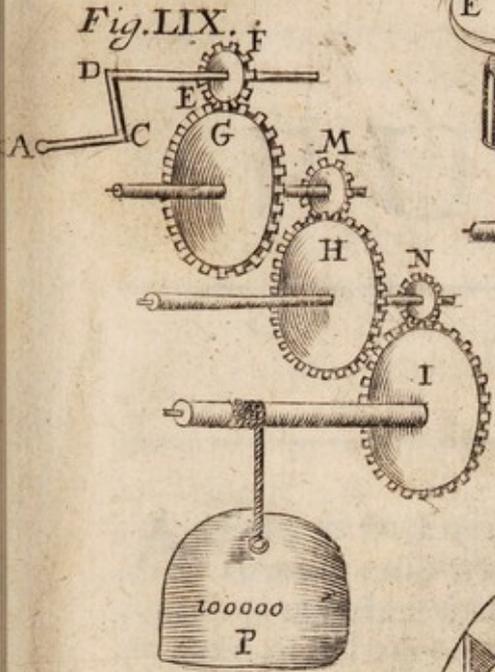
Fig. LXII.
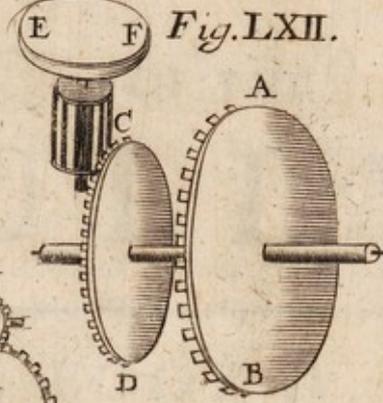
Fig. LX.
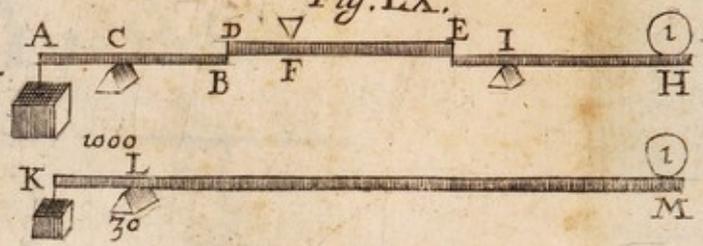
Fig. LXI.
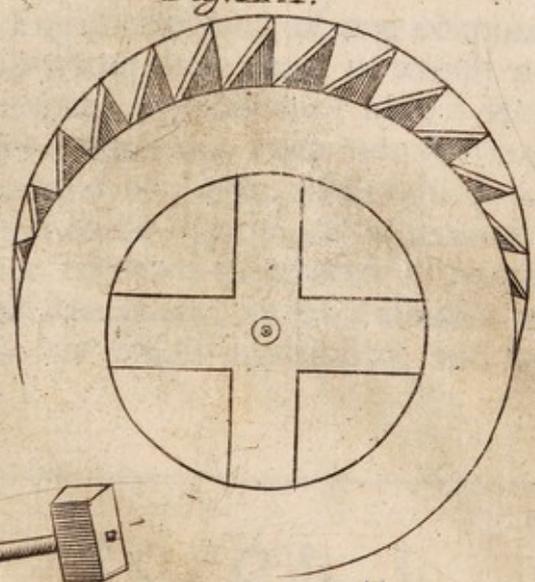
Fig. LXIII.
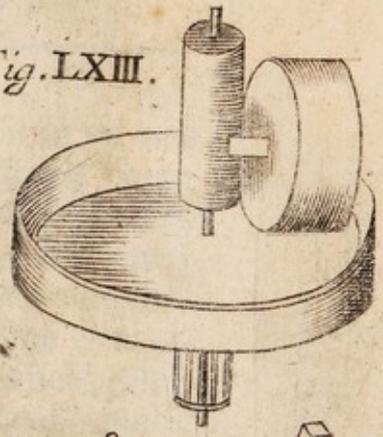
Fig. LXV.
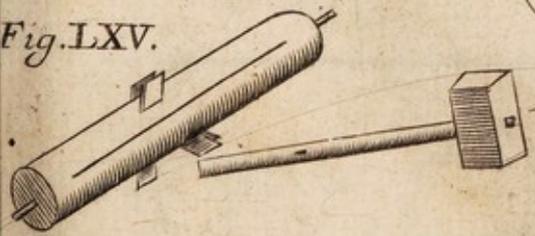
Fig. LXIV.
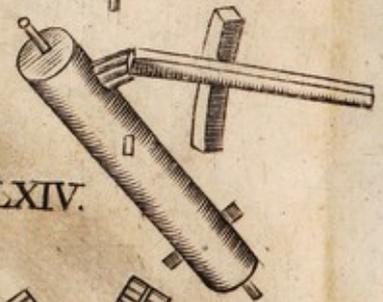
Fig. LXVII.
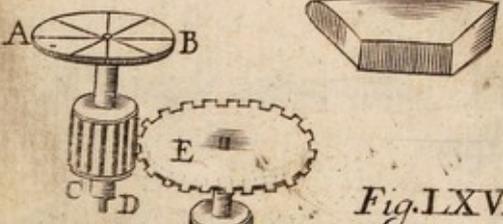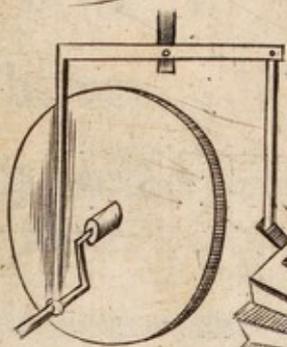
Fig. LXVI.
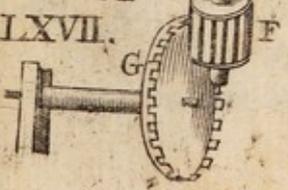
Fig. LXVIII.
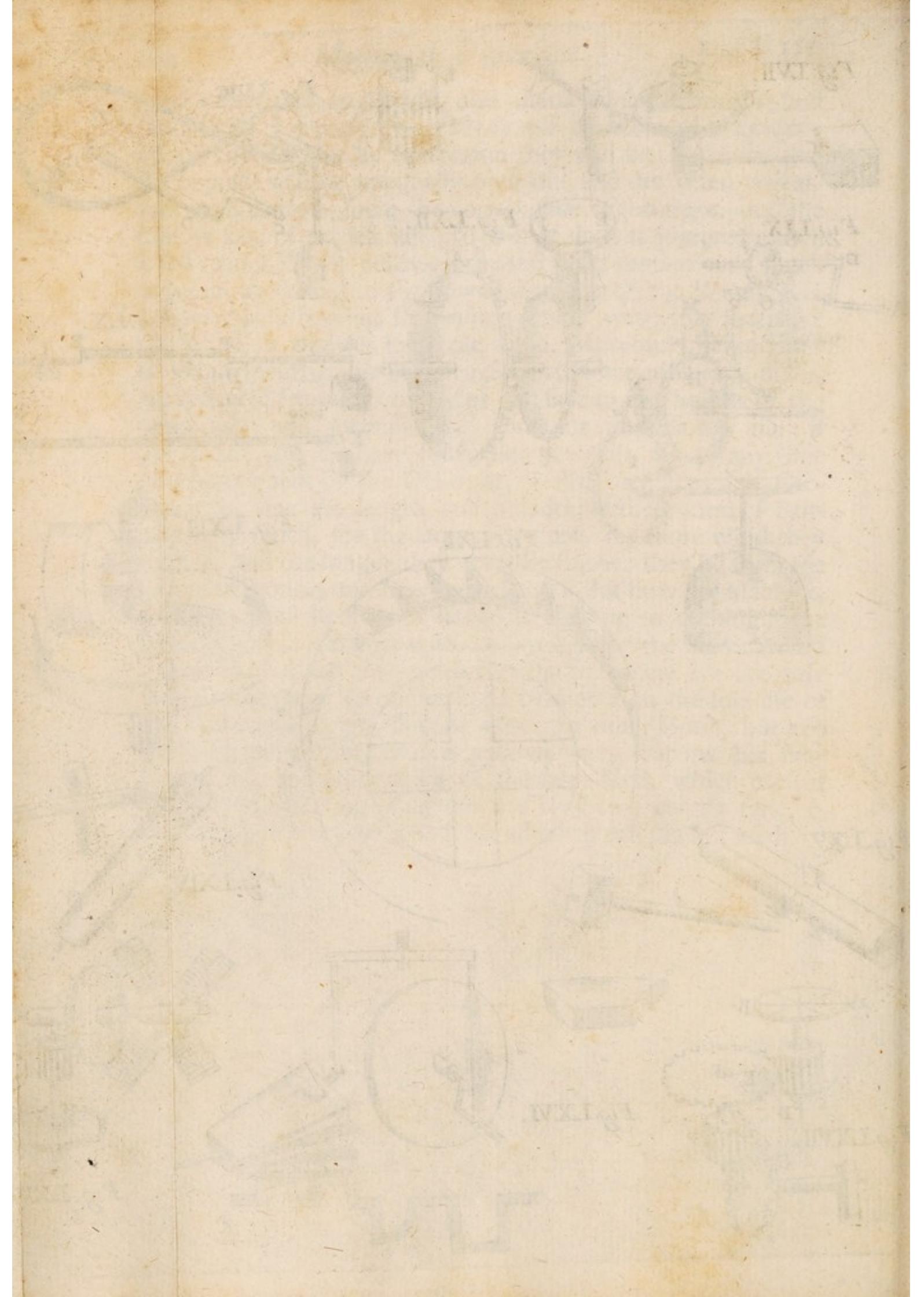
Mechanick-Powers.

OF THE

PULLY, &c.

BOOK IV.

A Pully is an Engin confifting of one or more little wheels turning eafily about their Axis, in which a Rope being drawn about the wheel, we draw, or raife a weight; there is no need of a larger Definition, fince almoft every one knows, and hath feen this kind of Engin, although there are very few that underftand their force rightly, or wherefore they are u-fed; and fometimes 'tis wont to be ufed with one wheel only, and then 'tis called *Monofpaftos*, or of a double wheel, and is called *Difpaftos*, or 'tis trebly multiplied, and is called *Polyf-paftos*.

PROPOS. I.

A Thorem.

A Single immovable Pully neither adds nor dimi-nifhes Force.

Fig. 69. Let there be a fingle immoveable Pully A B, fo that the wheel only is turn'd about its Axis, and let the fnatch block be immovable; I fay, that Pully will not

en-

encreafe the force of the Power, properly fpeaking, fo that the whole advantage which accrues from fuch an Engin, is, that the Rope be not worn, and that difficulty fhun'd which arifes not exactly from the weight, but from the wearing of the Rope.

The Demonstration. An Engin then helps not the Power, when the motion of the Power and of the weight is equal ; but in the cafe propofed, the motion of the weight, and the motion of the power are equal, which I thus make appear: Firft, underftand the weight in D, and the power in E, draw the Rope, and the power drawing the end of the Rope defcends in the point G, and in the mean while the weight D afcends in H, becaufe in both fites or pofitions the length of the Rope is not changed, D A E will be equal to the Rope H A G, and by fubftracting the common fegment H A E, there remains the lines D H, E G equal; but E G is the motion of the power, H D the motion of the weight ; therefore the motion of the weight and of the power are equal, wherefore the weight is neither increaft nor diminifht, and the power hath the fame force only, becaufe if by it felf (no Engin intervening) it be joined to the weight, it moves fo much as the weight ; therefore the force is increafed nothing by this Engin ; which was to be demonftrated.

PROPOS. II.

A Theorem.

A Power is eafily applied by a fingle immovable Pully.

LEt there be two Powers ; fuppofe Men, raifing equal weights, and let one ufe a Pully, and the other no fuch Inftrument, I fay, the firft can eafier apply his force or ftrength to fuch weight, than the fecond ; for either the weight will be placed beneath the Man, or above: If the firft, the endeavour will be fo, that the tractive force of the Man in fuch cafe will be pofited in this; that the Man will be a little bent, the force of the Nerves will endeavour to reftore themfelves to their
<div align="right">wonted</div>

wonted rectitude, or to hinder such bending or crookedness; therefore when a weight is taken up in this manner, oft-times the endeavour is in the knees and the whole Body; or the weight to be raised is placed in an upper place, and then in like manner we must have recourse to the force of the Nerves, but when we use a Pully hung in an upper place, we may apply the weight of our body, besides this kind of force of the Nerves, and oft-times without any endeavour of the Nerves, therefore 'tis not so troublesome.

PROPOS. III.

A Theorem.

Large Pullies *are most useful.*

Fig. 71. ALthough as I have shewn in the first Proposition, that one Pully whose Snatch-block is immovable, neither increases nor diminishes the force of the power ; nevertheless we have said also, it adds to the facility, because that it saves the wearing, or rubbing of the Rope, but there is found some, although but little resistance, in the Axis of the Pully, which ought to be turn'd about ; I say, this difficulty will be lessened, by how much the Orb of the Pully is greater, for than the Semidiameter of the Pully, or Rundle, is as it were a Leaver, and the Semidiameter of the Axis as it were a *Cylinder* in a wheel, or *Peritrochio*; and by how much greater the proportion of the handle is to the *Cylinder*, so much the easier is the motion; as because there is greater proportion of the line G D, to the radius of the Axis, than of the line G B, the resistance is easier overcome, which is made in the circumference of the Axis, while the Pully is turned about it.

There is also another conveniency in large Pullies, to wit, that the Rope is not so often folded, and consequently not so much rubbed, or worn ; but I suppose alwaies Pullys to be moveable about their Axes, for if they should not, we must reason otherwise.

PROPOS. IV.

A Theorem.

A Man may take up a Weight heavier than himself with a single immovable Pully.

THis Queſtion hath been put to me more than once, whether or no a Man can take up, or raiſe a weight heavier than himſelf, with a ſingle immovable Pully (I always underſtand the Snatch-block immovable) or whether a man that weighs 150 pounds, can raiſe a weight of 200 pounds ? But I devide the caſe, to wit, either a man ſo ſingly ſtands, that the force of his weight, or gravity, only inſiſts on the Pavemen, or his Knees, and his whole body ſo indeavours, that the force of this endeavour adhears to ſome other Body; if this ſecond happen, a man may elevate a weight heavier than himſelf, to wit, becauſe, beſides the weight of the man which may be all applyed, there may be alſo a contrary endeavour from the reſiſtance of the Nerves, ſo that while I would take up one, with the Pully I take up more ; ſome Knees endeavour ſo, that they cleave to Benches, or Formes, and lift up the Benches together with them, whence from ſuch endeavour an union is made of the Benches with the Man; that I may better explain my ſelf, ſuppoſe a man has 50 pound weight upon his Feet, and both his hands to lay hold on a Rope faſtned in an upper place, if the weight on the other part be very great, the man may by hanging on the Rope lift up his Feet, and elevate or raiſe the weight of 50 pounds, in which caſe, beſides a weight equal to himſelf, he may elevate 50 pounds.

But if he ſingly ſtands on the Ground, experience teaches us that he will only elevate 150 pounds.

But we muſt argue otherwiſe in drawing of weight inſiſting on the ground, or on an inclined plane, for ſince weight doth not preciſely reſiſt an *Horizontal* motion, a certain rule can ſcarce be made ; for it depends on the evenneſs of the body on which the weight ſtands, or lies.

PRO-

PROPOS. V.

A Theorem.

Many immovable Pullys *neither increase nor diminish the force of a Power.*

Fig. 72. LEt the several Pullys be E F G, whose Snatch-blocks are immovable; I say, although we use them altogether, the force of the power is neither augmented nor diminisht: For let the power be in A, and the weight in C, draw the Rope in B, and the weight ascends in D.

The Demonstration. Forces of Powers are neither diminisht nor increased by an Engin, when the motion of the power is equal to the motion of the weight, but in this case it thus happens; for when the Rope A E F G C, is the same by supposition, as the Rope B E F G D, they will be equal, and the common segment A E F G D being taken away, there remains D C equal to A B; but A B is the motion of the power, and D C the motion of the weight, therefore the motion of the power, and of the weight are equal, and therefore the forces of the power are neither increast nor decreast, which was to be demonstrated.

PROPOS. VI.

A Theorem.

A Weight hung to a movable Pully *its half part is Diminished.*

Fig. 73. LEt the Pully be A, and its Snatch-block movable, and a weight hung to it, and the power in D; I say, the weight will be lessened an half part, suppose the power to be so moved, that the Pully A ascend to E.   *The*

The Demonstration. That the Pully A be placed in E, the power ought to be moved as much as the length of the Chords C F, G D, for from the point C to D, is the same distance as between F and G; but C F, G D taken together, are double the space A E, to which the motion of the weight B is equal as appears, therefore the motion of the power is double the motion of the weight; but (by the first principle of Mechanicks) as often as the motion of the power is double the motion of the weight, the whole force of the power is doubled; therefore in our case the force of the power is doubled in order to such weight, or which is the same, the weight is diminisht an half part, which was to be demonstrated.

But if in stead of the Hook C, there be added one power which shall be equally moved with the power D, we shall find by tryal only an half part of the weight, in the same manner as if they bore two weights equally distant, hung to a Beam or Leaver.

PROPOS. VII.

A Theorem.

A Power applied to a moveable Pully, *diminishes an half part, in respect of a Weight hung on one end of a Rope.*

Fig. 74. IF in stead of the weight B being hung, a power be applied to the same Pully, and the weight hung to the Rope D, I say, the force of the Power is diminisht an half part.

The Demonstration. As I shewed before, the motion of the weight will be double the motion of the power, and therefore (by the first principle of Mechanicks) the forces of the power are lessned, and the forces of the weight increased; which may likewise be said of two weights, to wit, as when the weight B of 100 pounds is made in *equilibrio* in the point D, or which way soever the Rope G D shall require 50 pounds.

Corol-

Corollary.

Hence it follows, that an immovable Pulley is a Leaver of the first kind, of equal Armes, and a movable one is a Leaver of the second kind, or in like manner of the third kind, of equal Armes.

PROPOS. VIII.

A Theorem.

If to move he Wheels of a Dial, or Clock, for 12 Hours, there be required a weight of 50 pounds, and the weight descend 20 feet, keeping the same descent, a weight that shall move the Clock 24 Hours will require to be 100 pounds.

THis proposition which may easily be deduced by the *Corollary* of the precedent proposition, because of the commonnefs of its use, may be proposed in this manner; suppose a common Clock that requires a weight of 50 pounds to keep it in motion, and suppose the place where the weight descends to be 20 foot only, and this descent serves for 12 hours; and we would, keeping the same descent, have a weight to serve for 24 hours, I desire the magnitude of the weight; I say, the weight required must be 100 pounds.

The Demon. Suppose the motion of the Clock and its resistance, to be after the manner of the motion of the other weight, 'tis certain by the supposition that the resistance of the Clock for 12 hours, is less than of a weight of 50 pounds being movable 20 feet; but the motion of the Clock for 24 hours is double of that which is made in 12 hours, and in like manner a weight of 100 pounds as movable 20 feet, is double of a weight of 50 pounds that moves the same space, therefore the motion of the Clock for 24 hours will be less than a weight of 100 pounds moving 20 feet, and will be exceeded by the same excess.

N   And

And the way to fit that weight is eafie, for if it be required precifely to move in a time double to that wherein it did move, it may be done with no charge by help of a Pulley, in that manner as is fhewn in the 7th Propofition, *viz.* If the Rope be faftned firmly at one end, and the other end join clofe to the Cylinder of the Clock.

But if another lefs proportion be required, to wit, as 2 to 3, or as 3 to 4, the Diameter of the Cylinder on which the Rope goes about in the Clock muft be leffened, according to the proportion given reciprocally, that is, if for example it be required, that the weight of the Clock fhould move 18 hours, when before it moved only 12 hours, the Cylinder muft be leffened according to $\frac{1}{3}$ part of its Diameter; but if there be required a quadruple proportion, two movable Pulleys muft be made ufe of. Laftly, If a proportion much greater be required, add one Wheel to the Clock.

PROPOS. IX.

A Theorem.

In Difpafto, *or two Pulleys, if the cord of a movable Pulley be only turned about the Wheel, and is not faftned to its Snatch-block, or weight, but to the immovable point, the power will be only doubled, which draws by the other end.*

Fig. 75. **B**Ecaufe there are many ways which Ropes may be put about Pulleys, from whence follow feveral augmentations of a power; I will undertake to explain this in the firft place, to wit, if one end of the Rope A D C E be faftned in the unmovable point A, or to any other point, as the point B, and be turn'd about the Pulley D, then about the Pulley C, and be drawn by the end E; I fay, the force of the power placed in E, with refpect to the weight hanging at D, is doubled.

The Demonftration. The point E is equally moved with the

point

point F (by the firſt of this) but the point F is moved with a double velocity to the weight hung in D, (by the 7) therefore the point E is moved doubly ſwifter than the weight D ; but E is the place of the power , therefore the power is moved doubly ſwifter than the weight, and (by the firſt principle of Mechanicks) the force of the power E is doubled : Which was to be ſhewn.

Secondly, Let the end E be firmly fixt, or unmovable in the point E, and draw the Rope upward from the power placed in the point A ; I ſay, in like manner the force of the power is doubled, and the Pulley C is uſeleſs.

The Demonſtration. When the Segment of the Rope E C F in this caſe is immovable, it will be the ſame as if the Rope were faſtned in the point F, and one Pulley uſed only, but (by the 6th of this) one Pulley placed in this manner, doubles the force of the power, therefore alſo in this caſe, the forces of the power are doubled : Which was to be ſhewn.

Corollary.

Hence it follows, that if the power be D, and the weight in E, the end of the Rope fixt in the point A ; I ſay, that in this caſe, when the motion of the weight is doubled, the force of the power is leſſened.

PROPOS. X.

A Theorem.

In Diſpaſto, or two Pulleys, if the end of the Rope be faſtened to the movable Snatch-block, and the rope be turned about the ſame wheel, the power will tripled, or threefold.

Fig. 75.   **L** Et the end of the rope be faſtened in the point I of the movable Snatch-block, then turn it about the wheel of the immovable Snatch-block B; and again, turn

it about the wheel of the movable Snatch-block I, and let the power be in the point C, drawing the rope upwards. I ay, the force of the power is tripled.

The Demonstration. Suppose the power C so to be moved, that the Pulley I, touch the Pulley B; In this case there is left only so much of the rope as is required to compass both the wheels, to wit, as much as the portion F B E, and G H I, and the motion of the drawing power from C is equal to the rest of the rope, or to the parts A E, F G, H C; but those parts taken together, are triple the motion of the weight, to wit, the line I E, therefore the motion of the power is triple the motion of the weight, therefore the forces of the power are tripled : Which was to be shewn.

PROPOS. XI.

A Theorem.

In Tripasto, *or three Pulleys. If two Pulleys are immovable, and one only movable, the power is tripled.*

Fig. 76. LEt there be three Pulleys, wherein two of them A and B are immovable, or immovable in the Snatch-blocks, and let the rope be fastned in the point C; then turn the rope about each wheel, as you see in the figure, and let the weight be D; and the power in E: I say, the power is tripled.

The Demonstration. The point E is not more moved than the point F, and therefore the Pulley B is only used for conveniency sake. But the point F (by the 10th of this) is moved triply, or threefold swifter than the weight D, therefore in this dispo-sition the power is triplicated ; which was to be shewn.

But the end of the rope C could not be fastned to the up-per Snatch-block, otherwise one of the upper Pulleys would have been useless.

P R O P O S. XII.

A Theorem.

In Trifpafto, *or three Pulleys, two of them being movable in the fnatch block, quadruplicates the power.*

Fig. 77.   IF there be three Pulleys, wherein the two lower ones A B are moveable; I fay, the Power in C in this cafe is Quadruplicated.

The Demonftration. Underftand the power C to be fo moved in drawing the Rope, that the Snatch-block A B, touch the Snatch block E, there remains about the Pulleys a Segment of the Rope equal to the Segments D E F, I B K, G A H; the reft are drawn by the Power, and meafure the Motion of the Power : But the Segments D I, L G, F H, C K are quadruple the fpace L G, therefore the Motion of the Power is quadruple ; which was to be fhewn.

Notwithftanding, becaufe this kind of drawing upwards is inconvenient ; a Pulley fhould be added in the Upper Snatch-block, and then its force will be quadrupled, for the Pulley is only added for conveniency.

PROPOS. XIII.

A Theorem.

If the Lower Snatch-block be moveable, and the Power draw upwards, the Power is so many times multiplied as are the drawing of the Chords.

Fig. 77. LET the Snatch-block A B be movable, and the Power C draw upwards; or that the Propofition may be more Univerfal, let it draw againft the immoveable Snatch-block, then the Power is multiplied fo many times, as there are drawings of the Chords, becaufe then either the end of the Chord being faftned, is in the upper place, and being drawn, the pairs will be doubly more than the lower Pulleys; but the lower Pulleys double the Power, and by the demonftration, if there be one below, there is no need of the upper one, as is fhewn in Prop. 6. and the force is doubled according to the proportion of drawing. If there be two below, and one above, 'tis fhewn in the precedent Propofition, that the power is quadruplicated; and fo of the reft.

PROPOS. XIV.

A Theorem.

If the lower Snatch-block be movable, and the power draw downwards, the force of the power is so many times multiplied, as there are drawing of the chords, one less.

Fig. 75. 'TIS fhewn that the force of the power in F is the fame as in E, but if the power be in F, and

and its force multiplied according to the number of drawings, to wit, triplicated, and in E there be added one drawing of the Chord; this drawing of the Chord, which is added, increases not the force, therefore ought not to be computed.

PROPOS. XV.

If the lower Snatch-block be movable, and the rope be faftned to the movable Snatch-block, any lower Pulley doubles the power, and renders one upper power only equal to the weight.

Let there be any number of Pulleys in which the Snatch-block of the lower is movable, to which faften the end of the Rope; I fay, If there be one upper Pulley, the power is equal to the weight ; if one be added below the force of the power is doubled, and fo the power will be triplicated, but the reft of the upper ones add nothing, that is, if there be two upper ones, the power will remain tripple of it felf; if another be added below, it will be quintuple, and fo on, which are all demonftrated, particularly in the foregoing Propofitions.

PROPOS. XVI.

If the lower Snatch-block be movable, and the rope faftned to the upper, as many Pulleys as are below, fo many times the power is doubled, the upper ones ferve only for conveniency.

In any number of Pulleys in which the Rope is faftned to an immovable Snatch-block, the power is fo many times doubled,

bled, as there is lower Pulleys, or in a movable Snatch-block: That is, if only one be in the movable Snatch-block, the force of the power is doubled ; if two, 'tis quadrupled ; if three, 'tis equal to fix powers, and fo on, fo that no proportion ought to be had of the upper Pulleys, or of their being in an immovable Snatch-block.

The Demonftration. 'Tis fhewn in Prop. VI. that 'tis fo in one Pulley. In Prop. IX. 'tis fhewn to be fo in two Pulleys, to wit, that the power in both cafes is doubled. In Prop. XII. in three, or more Pulleys 'tis the fame ; the like proportion may be demonftrated in others.

Whatfoever is fhewn concerning the raifing of weight upwards, is to be underftood of any other motion, whether Horizontal, or any other, to which weights refifts ; alfo of any refiftance that we undertake, to overcome by Pulleys.

Alfo as we compare the power with the weight, we may in like manner compare two weights between themfelves ; likewife if you place the power in the place of the weight, and in like manner, if the weight obtain the place of the power, the weight will be increaft with refpect to the power, or the power diminifht, which words are all of one fignification ; and the moving power may obtain the place or the weight, as often as the forces are abounding ; but a moft fwift motion is produced in a weight, which fimply from a power cannot be produced without an Engin, becaufe the power cannot move it felf with fo much velocity ; which principle is to be underftood in all Engins.

PROPOS. XVII.

To difpofe Pulleys fo that according to the number of the Pulleys, the power may always be increafed continually in double proportion.

Fig. 78. THe increafe of power by Pulleys hitherto treated on, feems to proceed only according to Arithmetical

metical proportion, so we shew in the precedent proposition, that according to the number of Pulleys placed in the moveable Snatch-block, the force of the power is doubled; now we will institute another disposition, wherein if there be only one Pulley, the force of the power will be doubled, if two, quadrupled, if three, it will be octuple, if four, the power will be equivalent to sixteen, and so of the rest.

Suppose a weight to be raised being fastned to a moveable Pully B, and let one end of the Rope be fixt in the point G, and the other end of the same Rope reach to the Snatch-block C, in like manner let another Rope F C D be firmly fixt in F, and the other end fixt to the Snatch-block D; let there be a third Rope E D H, one end of which fasten well in the point E, and let the power be in H; I say, the power in H of it self being equal to the weight, being so disposed, is octuple of the weight.

The Demonstration. 'Tis shewn (at Prop. VI. of this) that the power in H is moved with a double velocity of the Snatch-block D, and the Snatch-block D doubly swifter than C; and C doubly swifter, or as swift again as B, therefore H is moved eight times swifter than the weight, and (by the first principle of Mechanicks) will have eight times greater force in respect of the weight; therefore 'tis sufficient that the power be suboctuple of the weight to be in *equilibrio* with the weight,

Or it may be demonstrated by any Leaver, for a Pulley disposed in this manner, is a Leaver of the second kind, in which the weight is precisely in the middle between the power and the prop, or Centre.

PROPOS. XVIII.

A Theorem.

By Pulleys any weight may be moved by any power.

First, If the power be never so little greater than the weight, it may be moved by any Pulley that only helps the application, but if it be equal, and the Pulley disposed after the

second

second manner, the weight will be more easily moved ; but if the power be less, as if it be to the weight as one to eight ; eight Pulleys disposed in this second manner, or eight Pulleys disposed in two Snatch-blocks, will easily overcome the whole resistance of the weight ; to wit, if there be a greater proportion of the motion of the power to the motion of the weight, than of the weight to the power.

Mechanick-Powers.

OF THE

SCREW.

BOOK V.

A Screw is a Cylinder wrought in one or more solid Spires, or Helices swelling out, as appears in the figure.

Fig. 79. AND the use of it is common, for 'tis put into another concave cylinder, cut in like manner into concave Spires, so that the convex Spires or Helices of the former Cylinder, fit to the concaves which are put upon them. The concave Cylinder sometimes is fixt and immoveable, and in this case, the Screw besides its circular motion, hath also a right motion, whereby the whole Cylinder goes forth. Sometimes the Screw is immovable, and the concave Cylinder is only moved, and commonly a simple Cylinder is added to the Screw, into which a handle is grafted or fixt, as in A B the handle B C is adjoyn'd, that it may be moved round more easily ; hitherto Authors have recalled the Screw to the Wedge, and the Wedge to the Leaver, or to the motion of a weight on an inclined plane, as if you understand D E to

be

be the weight, and it be moved round in the Orb, fo that it afcend according to the Spire of the Screw, inclined to the Horizon, or if the Wood D E be immovable, the Screw it felf being turn'd about, which is confider'd by the manner of a weight, its afcent will be by the inclined plane of the Spires of the concave Cylinder F G; but thefe confiderations are fuperfluous and unprofitable, when more immediately the force of the Screw may be meafured from the firft principle of Machines, than by fuch reduction.

PROPOS. I.

A Theorem.

To explane, and meafure, the force of the Screw.

Fig. 79. LEt the Screw be A B, furnifht with its handle B C, for alfo in leffer Screws of Iron which are made ufe of to ftrain fomething, there is added a head furnifht with a notch or cleft, that there may be put in fomething of Iron, which may obtain the force of a handle; And let the power be applied in the point C, and underftand one circumvolution to be made, or the circle C K L to be defcribed in the mean while the weight afcends, from one circumvolution of the Spire to another, to wit, as much as is the line N O. An interval, or fpace, equal to the line N O comprehended between the two Spires, is found 100 times in the circumference C K L; I fay, that it may be in *equilibrio*, there is required fo much power as is only fubcentuple of the weight, that is, if the weight be 100 pounds, it requires a power only equal to 1 pound.

The Demonftration. 'Tis then in *Equilibrio*, when the motion of the power is to the motion of the weight, as the weight it felf is to the power, but in our cafe the motion of the power is centuple the motion of the weight, and the weight an hundred fold of the power it felf, therefore 'tis in *Equilibrio*, whence if the power be a little greater or more than one pound it will overcome the refiftance of the weight.

Corollary.

Corollary.

If the power be applied to the wood D E, so that it move downward by a right line, and not circular, notwithstanding it will compel the Screw to move circularly, and let the weight be in C, the power requires to be centuple of the weight to move it. But if the wood D E be moved circularly, and the weight ascend upwards in a right line with the Screw; as if you feign the weight to be B; the whole circle described by the wood would be compared with the circumference of the line N O, which measures the ascent of the weight in each circulation.

P R O P O S. II.

A Theorem.

The divers uses of single Screws.

Fig. 80. THE use of single Screws are various, and for the most part they are used to strain, as appears in the 79th Figure, in which the Screw A B is fastned in the hole B, also 'tis furnisht with its Spires, but the hole C is single, and consists of no Spires; while the head of the Cylinder arrives in C, and the Screw is turned about, the woods B D, C F, will come, or meet together, and the force of the power will be increas'd according to the proportion of the circle described by the end of the handle A E, to the interval of the Spires, or Helices.

And the same effect follows whether the wood B D be made immovable, and so the wood C F, come to that, or the contrary.

The second kind is, *Fig.* 81. when the Screw is at one end, and the wood to which 'tis fastned, is at the other end, and is immovable, and then the power will be mixt, to wit, of the Screw and Leaver, as in this figure, if the Screw A B, be ingrafted to the wood A C, in the point A, and the piece of timber to which 'tis ingrafted be fixt in the point C; and the

weight,

weight, or that which refifts the prefling, be in the point D?
C A will be a Leaver of the fecond kind.

And that you may meafure the force of this Engin, fuppofe
it a Wine-prefs, and let the beam C A be equal to a weight of
200 pounds, that is, if it lies on a parcel of Grapes, it will
make the fame compreffion as 200 pound weight will make;
and let the Screw be fo made, that each fpire be diftant from
one another one inch, and the handle B E 7 feet, fo that its
whole circumvolution will be 22 feet, or 264 inches, and let
the force of the man that preffes, be equal to 100 pounds; I
fay, the man alone hath fo much force to prefs the Grapes,
as hath the weight of 52800 pounds; the reafon is clear, for
while the man runs over 22 feet, or 264 inches, the beam A
defcends only one inch, and the weight D, which is in the
middle of the Leaver A C, is only moved half an inch, there-
fore the force of the power is increafed, according to the
proportion of 264 to $\frac{1}{2}$, or of 528 to 1; but the power is 100,
therefore the force of the man, ufing this prefs, will be equi-
valent to 52800 pounds; which was to be fhewn.

Fig. 82. The third manner will be, if you make ufe of 2
Screws, which are moved together, or fucceffively after each
other, and one in refpect of t'other, hath the proportion of a
Prop, or Hypomoclion; as if the Screw A be moved, the
Screw B not being moved, the point B will be the Prop, with
refpect to the Leaver A B, which belongs to the fecond kind
of Leaver.

Fig. 83. To this kind of power are recalled the Vices which
Iron-fmiths ufe, likewife the Preffes which Printers ufe, and
many other Inftruments, whofe forces we may meafure by the
fame principles.

PROPOS. III.

A Theorem.

Of Compounded Screws.

Fig. 84. **I** call that a compounded Screw, whofe convex Cy-
linder is not ingrafted, or fitted, into its corre-
fponden

spondent concave, but is mixt with other powers. And first, if the Helices of the Screw be fitted to a toothed wheel, 'tis call'd an infinite Screw, or moving in *infinitum*, the forces of this power are wonderful, for suppose a wheel to consist of 50 teeth, also let the Axis be A, about which the rope goes round; and let the handle B C, be to the Semidiameter of the Axis, as 4 to 1, and let the power of the man be equal to 100 pounds; I say, the man being furnisht with such an Engin, is in *Equilibrio* with a weight of 20000 pounds, and the man will be equivalent to 200 men.

The Demonstration. The handle B C ought to make 50 circumvolutions, while the wheel only performs one, because that every circumvolution of the Screw impels only one tooth: Therefore while the handle B C is turn'd round 50 times, the Tympane A is only once turn'd about; but the circulation of the handle is to the circulation of the Tympane, as 4 to 1, therefore the motion of the power applied in C, is to the motion of the weight, as 200 to 1, therefore by reciprocation, the power as of 1 pound will be in *Equilibrio* with a weight of 200 pound, or as 100 to 20000, which was to be demonstrated.

But if instead of the Tympane A, you use another Screw, to whose wheel the same number of teeth shall answer, one man will be equivalent to 10000 men. If you make use of three Screws in the same manner and order, with wheels answering to them, one man will be equivalent to 100000 men.

Nevertheless, scarce any Engins are ever made so strong, but in practice they become unuseful, because, that either the ropes break, or that which they are fastned to, is not able to sustain, or the teeth, or other parts break, the weight being so extraordinary.

This Engin is most useful, as often as the motion is to be diminisht, as when, for example, we have a wheel in a Clock, which is turn'd round once in every hour, if you desire a motion 12 times slower, the Axis of this first wheel, must have a Screw, to whose spire the teeth of the other wheel, must be ingrafted, which must have 12 teeth, and so you will have a motion 12 times slower; so if in a Clock you have a Wheel, or Axis, which is turn'd about twice in a day, which is furnisht with a Screw, and answers to a wheel, having 59 teeth,

this

Fig. LXIX.
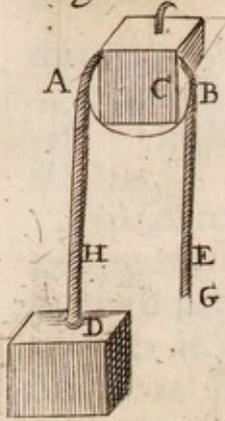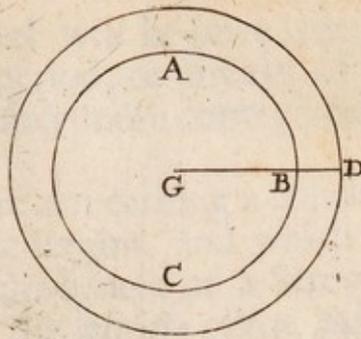
Fig. LXXI.

Fig. LXXII.
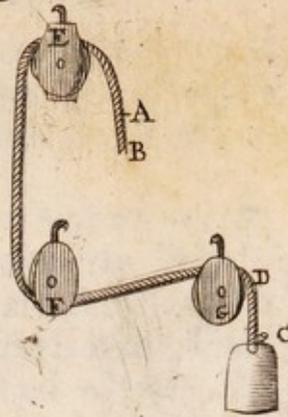
Fig. LXXIII.
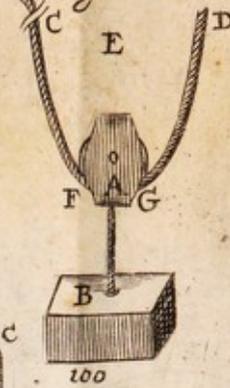
Fig. LXXIV.
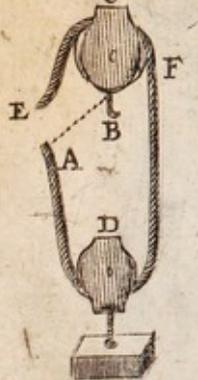
Fig. LXXV.
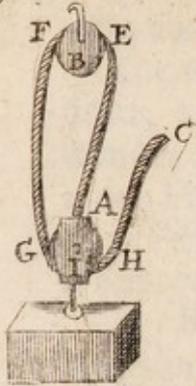
Fig. LXXVI.
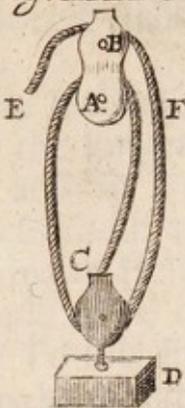
Fig. LXXVII.
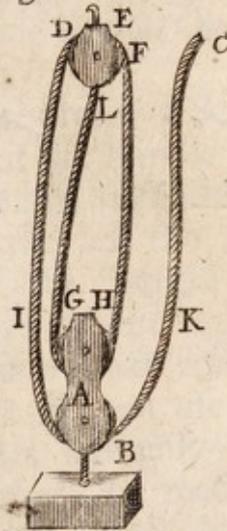
Fig. LXXVIII.
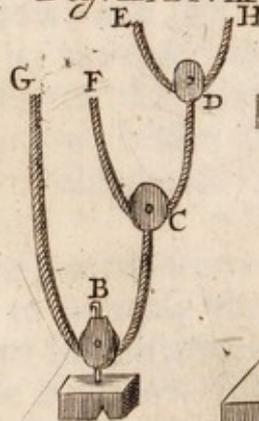
Fig. LXXXI.
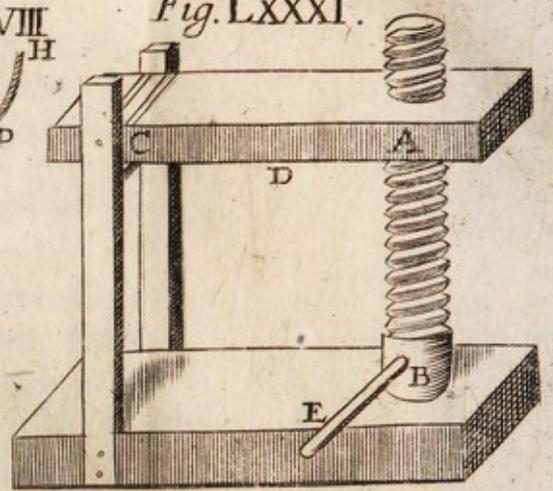
Fig. LXXIX.
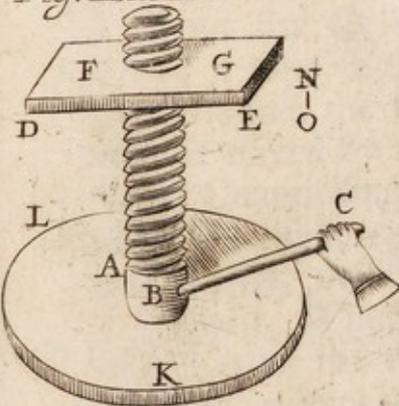
Fig. LXXX.
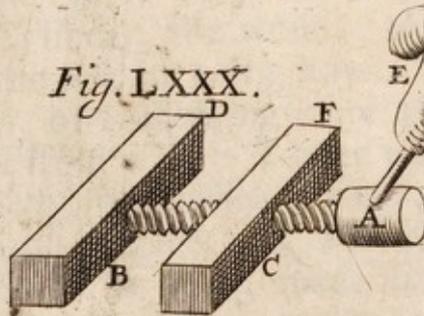
Fig. LXXXII.
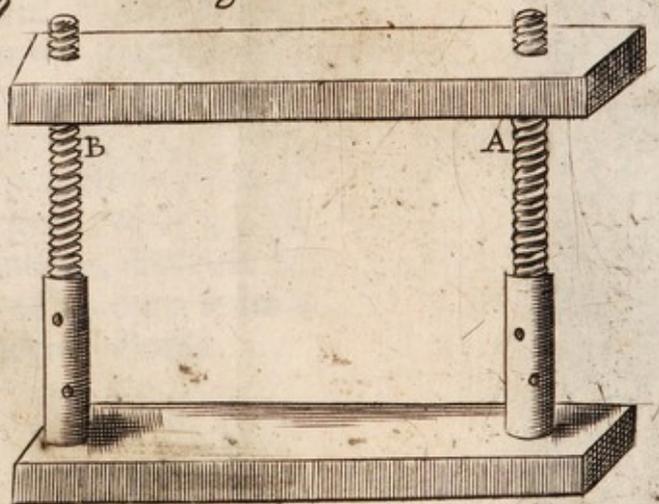
Fig. LXXXIV.
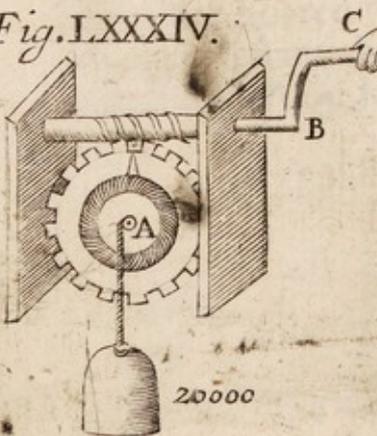
Fig. LXXXIII.

this fecond wheel will be once turn'd about in 29 days and $\frac{1}{2}$, which is the period, or circuit, of the Moon, and fo of the reft. He that defires more concerning the Screw may confult *Ubaldus.*

I fpeak not here concerning a concave Screw, which is one among Hydraulic Engins, and which properly belongs to an inclined plane; the benefit of a Screw are thefe. The firft advantage is, that the motion of the weight is more diminifht by one fpiral line, than by many toothed wheels. Secondly, without any ftay, although the power be relinquifht, the weight fcarcely falls back again, and therefore muft remain where it is.

The more Helices there are in a Screw, and the more oblique, and the longer that the handle is, the eafier the weight is moved; and in a concave Cylinder, (or the mother) the more Helices there are, the lefs the Screw fuffers, for when there are many Helices, the weight is diftributed in them, which would prefs, or lye on one only.

Fig. 85. To this Engin we may refer a certain invention obvious enough, which we do not ufe to increafe the force of power in order to motion, but only to fuftain a weight; For if about any Cylinder there be made a hollow fpire about which a rope is turn'd, if you hold the rope but flightly, or prefs it again the Cylinder, the weight, although it be great, will be ftayed by the Ropes, being adjoin'd to the Cylinder: Thefe Channellings, or Hollowings, are ufeful if any one be minded to defcend from a high Tower without danger, and that fwiftly, or flowly, according to pleafure.

Awgers, Wimbles, and Piercers, are referred to the Screw, which enter the eafier, by being made fharp in the nature of a Screw, as experience teaches, in great Awgers, with which Pipes are boared to convey Water from Fountains, becaufe its apex reprefents the figure of a Screw, which of its own accord enters the Wood fo that there is but little need of Force.

Mechanick Powers.

OF THE

WEDGE.

BOOK. VI.

ALthough the Wedge be a ſimple Inſtrument, and there-fore of ſome, is ſcarcely aſcribed to the number of Engins, nevertheleſs it is of ſuch force, that deſervedly it finds a place here.

The Wedge is a triangular Priſme, whoſe two rectangles, end in a common right line.

And that it may be uſeful, it ought to be made of ſolid matter, as of Iron, or Wood, and ſuch like.

Its uſe is in the cleaving of Wood, parting of Stones, and dividing other bodies that may be cleft, or cloven ; a ſlit being made in the body, the edge of the Wedge is thruſt in, and and a ſtrong percuſſion being added, forces in the Wedge.

PROPOS. I.

A Theorem.

The force of the Wedge explained.

Fig. 86.   DIvers reaſons are alledg'd for the force of the Wedge, and firſt from *Ariſtotle* ; in Queſtion 17, the Wedge is recalled to a double Leaver of the firſt kind, in this manner, to wit, let the Wedge be A B C, *Ariſtotle* under-ſtands

stands the line A B, as a Leaver of the first kind, whose prop
is D, the power in A, and the weight in B, to wit, in the
end, or cusp of the Wedge : In like manner let B C be ano-
ther Leaver, whose prop is in E, the power in C, the weight
in B.

Notwithstanding, this explication is altogether contrary to
the proportion of the Leaver ; for by how much greater the
distance is of the power from the prop, the greater is the
force of the power, in other like cases ; but in this case it is not
so, for if the Wedge be made shorter, and the power be in
K L, and not in A, nevertheless the force of the Wedge will
be the same : I say, the same of the leaver C B.

The second is false, that the Wedge touches the Body to be
divided with its point, or edge, because, that for the most
part the extreams D and E only touch ; neither when we mea-
sure the force of the Wedge, do we regard the proportion
which is found between A D and D B, but how much the
sharper the Wedge is, or the lesser angle it contains, the easier
it divides.

Whence *Ubaldus* in his Mechanicks imagines, that if the
Wedge be recalled to a Leaver, 'tis to be explicated by a
double Leaver of the second kind, whose common prop is in
the edge, or point B, the power in A and C, but the same
instances occur as before ; I add moreover, that a Wedge may
want a point, and nevertheless be as apt to divide as it was
before ; so that the inclination of the planes remains the
same, touching in the points in which the body is to be cleft.

Fig. 87. Wherefore others recal the Wedge to an inclined
plane, as if the body to be lifted up be A, under which the
Wedge B is laid, that body being moved upon an inclined
plane, for 'tis all one, whether the body be drawn upon the
plane, or the plane move under it, for to ascend 'tis thought
the same ; therefore there are in the Wedge two inclined
planes.   This consideration is not absurd, nevertheless, I con-
tend that the whole difficulty remains, to wit, that the whole
doctrine of inclined planes is alike hard, labouring under the
same principle, wherefore

I say, The reason why the forces of the power are increased
by the Wedge, is, because the power is moved much, and
the weight but little, or the greater motion of the power is
compared with the lesser motion of the weight, and are joyn'd
together.   P   Which

Which I fhall fhew, as in the *Fig.* 86. let the Wedge A B C be very fharp, which by one or more percuffions runs into the wood, the fpace B F, in the mean while that the parts of the wood are feparated from one another according to the fpace D E ; if the Wedge contain an angle lefs than 60 degrees, B F will be greater than D E, and the power is moved according to the line B F, and the weight according to the line D E, wherefore fecluding percuffion which way foever, if the power fimply impel the Wedge, its forces are increafed, according to the proportion of the line B F to the line D E.

PROPOS. II.

The fharper the Wedges are, the greater force they add to the power.

LEt there be any 2 Wedges, whereof one is more acute than the other ; I fay, that which is moft acute, confers the greater force to the power ; for by how much the motion of the power, is greater than the motion of the weight, it hath greater force in refpect to that weight. But a more fharp Wedge is fuch, that it requires a greater motion of the power in refpect to the motion of the weight, for in two triangles, having an equal bafe, that which hath the angle oppofite to the bafe moft acute, will have the longeft fide : But in the Wedge, the bafe meafures the motion of the weight, and the fide the motion of the power, therefore Wedges moft acute are moft powerful.

Corollary.

A Wedge whofe angle is greater than an angle of 60 degrees, rather decreafes than increafes the force of a power.

PROPOS. III.

A Theorem.

Divers kinds of Wedges.

Almost all Instruments which Artificers use to divide, or cut with, are recall'd to the Wedge, as all sort of edge tools, Swords, Pen-knives, Nails, Axes, Hatchets, are Wedges, for neither is it essential to a Wedge, that the percussion of another body be forced between the body to be divided, for it may either be simply impell'd, or from a force conceived from the leading motion to divide it; Awgers, and Piercers contain a Wedge.

Of Percussion, or Smiteing.

PROPOS. IV.

A Theorem.

Experiences of Percussion.

I Being in company, some years ago, with my Ingenious friends Mr. *Bankes,* the King's Master Carpenter, and Mr. *Morris Emmet,* the King's Master Bricklayer, since deceased, among other things that pass'd in our discourse, Mr. *Bankes* was pleased to say, that he thought there could be no reason given of the force of Percussion, nor no comparing the proportion of weight pressing a Nail, or such like thing, entred in a board, or Timber, to a blow smitten on the same thing. Indeed the saying was very difficult and abstruse, yet I remember I told him, that the learned and Reverend Dr. *Wallis,* and

Caſſatus had writ ſomething concerning it, and alſo the learned *Dechales*, whole principles I deſign to follow.

Ariſtotles 19th Queſtion touches lightly on the force which is produced from Percuſſion; neverthelefs, he explicates nothing further, and as I may ſay, only propoſes a difficulty, to wit, that although a great weight be laid upon an Ax or Wedge, yet it conduces little or nothing to cleaving, but that a blow ſmitten with great velocity, affects much. Then he ſeeks how much gravity this motion adds; to the better underſtanding whereof, in the firſt place, I ſhall refer to experience.

The Firſt *Experience* then ſhall be, that that Percuſſion is greateſt, whoſe motion is ſwifteſt, from whatſoever cauſe the ſame motion proceeds, whether it be circular, or right, 'tis little different. From whence it comes to paſs, that a Hammer, or Mallet, furniſht with a longer handle, makes a ſtronger blow, becauſe that power can impreſs a ſwifter motion, for if it be moved with equal velocity, whether it be furniſht with a longer or ſhorter handle, the percuſſion would be equal; alſo thence I think may be concluded, that laſting motion adds nothing to percuſſion, unleſs there were a diſpoſition to ſwifter motion. And therefore, if the Hammer ſhould be moved equally about ſome Center, it would not ſmite ſtronger after a laſting motion than after ſome ſhort motion. Alſo 'tis clear, that when ſomething is ſmote with a Staff, or a Sword, the ſtroke is ſtronger about the end, becauſe then the ſtaff is moved about the hand, as about a centre, whence the motion is ſtronger about the end, I ſay about the end, yet not in the end, by reaſon of another proportion.

Secondly, A greater body although it be moved with equal velocity, with a leſſer, produces notwithſtanding a ſtronger blow; for 'tis certain, while two bodies of the ſame matter and divers magnitude fall from on high, they deſcend almoſt with equal velocity, ſo that the difference is very ſmall, to wit, ſo much only as is begat in the reſiſtance of the air proportionally in the leſſer body to the greater, neverthelefs, the greater body impreſſes a ſtronger blow, which effect cannot be only attributed to the greater gravity; for let there be a ſtake ſtuck in the ground, and let two bodies deſcend from an equal height, one of 100 pounds, the other of 200 pounds, 'tis certain that there will be a ſtronger impreſſion from the

ſecond

fecond, which cannot be attributed only to the gravity fimply taken, for if this fecond body be put on the ftake and gravitate on it, or fhould fall on it from on high, the impreffion from a body lefs heavy, would not be fo much : Therefore a heavy body falling, makes a greater ftroke than a lighter body, and this impreffion ought not to be attributed only to the greater gravity.

The Third Experience. While a body is moved about fome centre for a continuance, 'tis eafier ftopt or ftay'd if you lay hold of it by the end, than by any other part nearer the Centre, which is to be underftood if it be hinder'd before the motion, or in the beginning of the motion, for if you wait till the motion be engender'd, it will be otherwife. And the reafon of the firft, is obtain'd from the proportion of the leaver ; the reafon of the fecond ought to be, becaufe the motion is greater in the end, and confequently a greater *impetus* is acquired.

The Fourth Experience. The ftrongeft blow of a Sword is not about the point, nor as fome think about the Centre of gravity, but between the point, and the centre of gravity ; yet in general 'tis true, that a body that is moved, having the greateft part of its weight about the end, a ftronger blow follows than if it proceed from one continuance, wherefore fome make a little channel within the Sword, and include Mercury therein, which conveys the force of percuffion to the point, and makes the ftroke ftronger. Perhaps, while a body is extended in one order, 'tis moved more difficultly, and therefore its velocity is not fo great, and confequently its ftroke not fo ftrong.

Fig. 88. *The Fifth Experience.* While a body fmiteing defcends, it caufes as great a ftroke, if only one part of it fall on the fubjected body, as if the whole body fell on it ; that is, if 2 equal bodies A and B, fall from the fame height, the firft whereof fmites the ftake C only with fome part of it, but the other according to its whole loweft fuperficie, yet an equal ftroke follows, which I have found by experience, that I might confute the opinion of fome, efteeming the Air fqueez'd between the 2 bodies, to confer much to the blow, yea, they will have all cutting or cleaving to be from air included within the Pores, being violently impulfed from the dividing body, for they will have air to be moft fharp, and confequently moft apt to divide.   PRO-

PROPOS. V.

A Theorem.

Divers meafures of Percuffion.

Fig. 89. T IS hard to meafure percuffion that is made by a living power, fince it depends on force, and free and voluntary endeavour, and hath the proportion of the body moving, or fmiteing, for although a greater Hammer effects a ftronger blow in other things of the like nature, yet if it be not fo fwiftly moved becaufe of its heavinefs, the percuffion which follows is the weaker : Wherefore 'tis convenient in the firft place, to reduce velocity to a certain meafure.

Suppofe then a Hammer A B, whofe whole length is 6 feet, which is moved by a man to fmite. I fay, if it be moved equally with the fame velocity which he hath in himfelf in the inftant of percuffion, and in the fpace of one fecond minute, fhall make 4 circulations, that is 144 feet, (allowing the Periphery to be but 3 times the Diameter) : If the fame Hammer fhould fall according to the equality of the force of gravity, and accelaration of heavy bodies, it would not arrive to accomplifh 144 feet in 5 fecond minutes, and it fhould fall from an altitude of 425 feet.

From whence 'tis concluded, that the altitude 425 feet is the meafure of percuffion made by the man, or the Hammer has fo much velocity, while 'tis ftrongly fmote, or impell'd, by the man, as the hammer would have had, if it had fallen fingly from an altitude of 425 feet.

I have been willing to examine the calculation made by *Merfennus*, but could never find it anfwer experience, for we often ufe a *Pendulum* of 3 feet, one fwinging, or ftroke whereof is precifely equal to one fecond of a minute; and we have found in a *Semivibration*, or in the fpace of half a fecond, little more than 4 feet, to be paft over by a body falling, *viz.* about 4 feet and $\frac{1}{2}$; but according to the proportion obferved

ferved by *Galileus*, it fhould be 17 feet in one fecond, where-
fore in the fecond fecond it will be 51 feet, in the third fe-
cond it will fall 85, in the fourth 119, in the fifth 153,
which being all added together, make 425, therefore the
blow of the Hammer ftruck by the man, is equal to that
which is made by the fame hammer falling 425 feet; in this
fuppofition the fpace which is paft over by heavy things, de-
fcending, is reckon'd to proceed according to the feries of odd
numbers.

But whatfoever the comparifon be of the *Impetus*, or force,
produced from a man fmiteing; and the *Impetus* produced by a
weight falling; 'tis certain, that there is no *Impetus* produced
from a man's fmiteing, to which there cannot another be gi-
ven equal to it from a body falling: But hithertoo the whole
difficulty remains, *viz.* how we may meafure the acquired
Impetus, from a body falling from a determined height; let
therefore a hammer weigh 1 pound, driving a nail at one
blow (or percuffion) one inch, whofe force is equal to that
which it would have if it fall from an altitude of 425 feet;
and let it be demanded what weight being only laid upon the
Nail, will force it in one inch, but that weight muft be mo-
ved equal to the fpace, to wit, it muft alfo be moved one
inch.

Many have been the opinions concerning this thing, for
fuppofe a hammer of 1 pound, and 1 foot long, and let it be
made after the manner of a Cylinder, fome think, if there
fhould be a Cylinder made of the fame thicknefs, *viz.* 1 foot;
and 425 feet long, to wit, as much as is the altitude of the
fall, which is equal to the percuffion, and this Cylinder be put
upon the Nail, it will force the nail into the board one inch,
neverthelefs, I fee not on what foundation: for fuppofing the
hammer to be half the length, and to have the fame gravity;
according to this confideration, it requires a weight doubly
greater, which is abfurd, therefore fince this determination
depends on the thicknefs of the hammer, which in this cafe
hath no place, for neither will two hammers of divers figures,
and the fame gravity, have divers effects.

Others will have it, that a hammer of 100 pounds defcend-
ing with one degree of velocity, will have the fame force as a
hammer of 1 pound, defcending with a velocity as 100,
which I eafily grant: But hitherto I think nothing is effected,
                                                    neither

neither is there had such a measure as we require, to wit, some weight to which percussion is equal, or a weight which is moved in the same manner as a nail, although it drive it one inch.

Mr. *Hobbs* reduces all percussion to the first endeavour which the weight hath, but knows not whether the first endeavour given be indivisible and determinate, and so in this explication he wraps himself in questions of continual division.

PROPOS. VI.

The measure of Percussion.

SUppose a hammer of 1 pound, and let it be of any figure, it matters not, which being struck with the force of a man, hath the same velocity, as if it had descended 425 feet, and drove a nail one inch, now 'tis demanded what weight this percussion is equal to: And 'tis certain, that a weight of one pound falling 425 feet, acquires a force to raise 1 pound 425 feet, which I shew in any Pendulum, wherein the weight ascends almost the same as it descends. Therefore this percussion seems to be in *equilibrio* with a weight of one pound, in moving through 425 feet: But if you ask what weight being moved one inch, will be in *equilibrio* with a weight of one pound, moved 425 feet, multiply 425 by 12, it makes 5100 inches, in 425 feet; I say, if a weight of 5100 pounds be placed on the nail, the nail will be forced in one inch; for one pound moved 5100 inches, is in *equilibrio* with 5100 pounds moved one inch, wherefore the percussion of the man seems to be equal to 5100 pounds, which was to be shewn; nevertheless, there is a doubting in this calculation, because that the velocity of the weight ascending, always decreases, wherefore these things cannot be constituted, but according to the doctrine delivered of heavy bodies falling.

PROPOS.   VII.

A Theorem.

The quantity being given of a stake, or nail, driven into any body by a determined weight, from a determined height, to find a weight which will perform the same from any other height.

Fig. 90. Let the weight A be 100 pounds falling from 10 feet high, and driving the nail B one inch, a weight is required, which falling from 40 feet high, will perform the same effect ; I say, it requires a weight of 50 pounds.

The Demonstration. The same effect is produced, if the quantity of motion be the same in both cases : But the quantity of motion is the same, for a heavy body falling from an altitude quadruple, or fourfold, hath double velocity of that which it had : But 100 pound movable with one degree of velocity, and 50 as movable by 2 degrees of velocity, have the same parts of motion : Therefore they seem to have the same effect ; nevertheless, there remains a difficulty which is begat from the reflexion of bodies, which belongs to the velocity of heavy things descending.

PROPOS.   VIII.

To make divers kinds of compound Engins.

Besides the single kind of Engins before mentioned, to wit, the Ballance, the Leaver, the Wheel, the Pulley, the Wedge, the Screw, there may be made many other compound Engins, some of which we will describe, that so not only their great forces may appear, but also that any one may

perceive

perceive a ready way of making Engins for any occasion, and accommodate them to their use.

Mechanick Powers.

BOOK. VII.

Engin. I.

An Engin, whereby a Wagoner may raise his Wagon, or Cart, although loaded ; also by it, the Roof of an House, yea, the whole Case of the House, may be raised.

Fig. 91.   OF Iron, or other solid matter, make 3 wheels, the 2 lesser A and C, and the other greater B ; the little wheel A hath five teeth, and the little wheel C the same ; but the wheel B hath 20 teeth, and so is fourfold greater, and hath one common axis with the wheel C, also make of the same matter a firm Prisme D E with teeth, defend on every side all the case of wood with Iron, in which the teeth are included, the upper part being open, so that the teeth of the wheel A, lay hold of the teeth of the wheel B, and the teeth of the wheel C, lay hold of the teeth of the Prisme D E : But the axis of the wheel A stands out without the side of the case, and is turn'd by the handle G F H, and with the handle the little wheel A is turn'd, which turns the wheel B and C, and the teeth of the wheel C, running into the teeth of the Prisme D E, they move it upward, until the last tooth near E, be in the region of the
wheel

wheel C ; if now D on the top be made hollow, or E on the fide of the Cafe ſticking out, be put under the Waggon, or other weight, and the wheels being turn'd the Priſme aſcends, and going forth of the Cafe, forces the weight upwards ; and if the wheels are turned the contrary way, the weight deſcends likewiſe.

If to this Engin you add a leaver, one end whereof being put under the hollowing D or E, and the other end of the leaver lean, or ſtay on the Earth, and that part of the leaver, next the earth, be put under the Waggon, or other weight, and then turn the wheels, it will make a compound Engin much ſtronger, which you muſt note carefully, for indeed many Engins by addition of the like leaver are much helpt.

Engin. II.

To raiſe a vaſt weight with an Engin compounded of a Pulley, Axis in Peritrochio, and a perpetual Screw.

Fig. 92. MAke the Cylinder C D, in the middle whereof make 4 or 5 Spires of a Screw, which while the handle E F with the Cylinder is turn'd about, the Spires infold themſelves with the teeth of the wheel B, and turn it about: And while the wheel B is turn'd roun'd, the rope B G H, drawn about the Pulleys G and H, is wound about its Axis : By this means, we may with great eaſe raiſe any great weight by the power F. I have cauſed the like Engin to be made, by whoſe means, I did move a Milſtone with ſo little reſiſtance, that with a ſmall Silken Thred, faſtned to the handle F, and pull'd by the hand, I have turn'd about the Screw, and taken it up, being the weight of 200 pounds, and not broke the thread. And if inſtead of the handle E F you fit a wheel furniſht with little boards, this being turn'd about with the breath of the mouth, will raiſe the Mill-ſtone.

Engin

Engin. III.

To take up a Milſtone with an Engine wrought by the Smoak of a Lamp.

Fig. 93. THIS Engine is admirable to the Beholders, to ſee it raiſe a weight of 150 pounds; it is altogether like the precedent, but that it hath a pair of toothed wheels between the Screw A, and the Pulleys, the firſt of them is immediately moved by the Screw, and the ſecond is moved by the firſt, and about its Axis the Rope turns round; and that the Smoak of the Lamp may ſupply the force of the moving-power, the centre of the wheel B C is firmly put into the Axis D of the Screw, whoſe Teeth running in each other, are turn'd round by the Teeth of the Wheels C and B, fixt to the Axis of the wheel F G, parallel to the Horizon; this wheel is ſo made of a thin Iron plate tinned over, that the whole plane of the Horizontal wheel conſiſting of the thin plate, is cut through with Channellings, and way for the Smoak to paſs, in ſuch manner, that while the Smoak of the ſuppoſed Lamp L, paſſes through by the oblique openings of the plate, it turns about the wheel hung to the Glaſſey cover H, upon the point of a Needle, and ſo poiſed, that it may turn round eaſily; and if one Lamp doth not ſuffice, 2 or 3, or more may be added: Alſo there may be more wheels than the foreſaid two, and more little wheels of Pulleys. My Engine which performs the foreſaid effect, conſiſts of eight Wheels and Pulleys altogether.

Engin.

Engin.. IV.

*By whose means a mighty weight is continually raised,
although the Power be not continually applied, but
now and then a little impulse presses it on by it its own
endeavour.*

Fig. 94. APply an Iron, or Stone Globe (or Ball) of a great
magnitude and weight, to a spear of Iron, or
Wood C D, and let the Globe be vibrated together with the
Spear about the Poles A and B; moreover let there be some pretty
little arm E F L, fixt somewhere about the middle of the lit-
tle Axis, or Pin K, but movable without any resistance; join to
this in F a crook F G turning easily in F, let the end E, of the
little Arm, be made like the point of a Sword, or Knife, (or
little tongue) which may touch the Spear, being perpendicu-
lar; then that part of the Spear which touches the little tongue,
must be made sharp in the same form, and extended so, that
the little tongues respect and touch each other.

Then the Globe being thrust with force, or being elevated,
and falling again by its weight, mightily effects the Vibrations
by going and coming back, and each part of the Spear made
sharp in E, hitting against the little tongue of the arm, forces
the pin F G towards G, which by that means, ever and anon,
lays hold on new Teeth of the Wheel H, and turns round the
Wheel, which cannot be turn'd back again, being hindred by
the pin P, endeavouring the contrary. Another little Wheel
being annext to the Axis of the wheel H, turns the Wheel I,
about whose Axis the Rope of the Pulleys L M being turn'd,
takes up the weight N, being fastned to the lowest Pulley;
wherefore, if after the perpendicular stands still, and moves no
longer, it be again raised from the centre and let down, its
vibrations will effect in the same manner as before for some
time, raising the weight in the mean while, although no pow-
er be applied, so that the weight seems to ascend of it self.

Note

Note, That you may add one or two wheels to the wheel I, that the weight may be taken up the easier, and less resist the motion of the perpendicular; moreover in stead of the Pulleys, you may use a Leaver, or a perpetual Leaver, with Axis in *Peritrochio, &c. Thirdly,* the longer the Spear is, and the heavier the Globe is, the longer the motion of the perpendicular endures. *Fourthly,* the upper part of the little Arm E, doth indeed endeavour downwards by its weight, but with so small endeavour, that 'tis easily moved by the Spear; the same end being but little inclined, so that a small part of the little tongue be touched by the edge of the Spear ; and so also the wheel H ought to consist of small saw teeth, otherwise the force of the perpendicular will be too much allayed. *Fifthly,* 'Tis better, that only the upper part C F of the Spear be solid, and the remaining part F D be of a little chain flexible.

This Engin if it be ingeniously made, effects very well, and causes admiration in those that stand by : Besides, if the power be continually applied to the Spear, or to the perpendicular in D, which will move it of its own accord, a vast weight may be taken up with very little labour ; and although the Globe D be very heavy, yet because it hangs freely, it is easily moved. In this case there is no need to make use of the little arm E F L, but 'tis sufficient that the Axis A B of the perpendicular be extended to Q, and there be fitted with a little iron hook, or catch, which may lay hold on the teeth of the wheel Q R: Or the little arm F G may be joyned to the Spear C D in E, and move the Pendulum with an opposite motion, to wit, from F towards G: But this wheel in this case ought to obtain another site than before, to wit, its plane ought to be parallel to the line of motion, which the perpendicular makes ; and its teeth ought to be retain'd by the like pin, left while 'tis free from the Clasp, or Hook Q, it return to the opposite part ; likewise the whole Spear ought to be rigid, or hard. Yea, I confidently affirm, so that the spear which hath the proportion of a leaver be long enough, a vast weight may easily be taken up by one man, with only the wheel Q R, the rope being turn'd about the Axis S of the wheel, although no pulleys be added ; for the leaver hath great force, although it be not in use in taking up weights, *viz.* because they know not the way whereby its motion may be continued ; but we have found the precedent which is altogether

together eafie, and others of the like nature may be inven-
ted.

For let the leaver be A B C, whofe prop is in B, and the
power in A; by weighing down, or depreffing this leaver, its
other end C lays hold on the teeth of the wheel D E, and
moves it, the iron Pin G hindering it to go back; and at the fame
time the rope E F being turn'd about the Axis of the wheel
takes up the weight F; but the prop B ought to be furnifht
with a ring above, in which the leaver muft be put, left it be
eafily moved to and fro, being only a little bent, that it may
be transferred from one tooth to another below it.

Some things to be obferved in the compofition and ufe of
Machines, or Engins. In the compofition and ufe of the Engins
aforefaid, and of others of the like nature, fome things occur
which deferve a peculiar obfervation.

Firft, 'Tis to be noted, that fince in every Engin, that part
which is next to the weight, feels a greater impreffion, or re-
fiftance of the faid weight, and alfo ought to be more folid,
firm, and ftrong : Example, In Axis in *Peritrochio,* or a toothed
wheel and a fcrew, it will be convenient fo to fit them toge-
ther that the weight may be fuftain'd immediately from the
fcrew, and the wheels applied to the moving power ; and the
fcrew ought to be of more folid matter, and made more firm,
fince in toothed wheels they cannot be made fo ftrong, as to
fuftain great weight.

This thing is of great moment, and therefore to be obfer-
ved diligently in ufe, a fcrew, and alfo pulleys are wont to be
applied immediately to a weight, for although a pulley feems
to be lefs firm and ftrong to fuftain a burden, becaufe that the
Axes of the wheels cannot be made fo thick ; notwithftanding
each of them bears not the whole weight, even as neither any
one rope that is drawn, but it is in a manner diftributed to
every one, fo that from all, one as it were makes the refiftance
fit to overcome the weight.

Secondly, 'Tis to be obferved, that fome Engins may move
a weight, or alfo take it up to fome height, and yet notwith-
ftanding of it felf cannot move it to any further height; such
are the wedge and the leaver, the firft of them ferving only for
cleaving, but the fecond, if it be immediately applied to a
weight, 'tis manifeft that it can raife it but a little height :
Wherefore as need requires, it behoves us to ufe divers kinds

of

of Engines ; but if toothed wheels, or fcrews, immediately fuftain a weight in the fame manner that we have declared above, it acquires greater force, and will move the weight to a greater height ; alfo if a weight be immediately faftned to a fcrew, it cannot raife it to a greater height than the length of the fcrew : wherefore the fcrew hath this conveniency, that 'tis firm and fit to fuftain a great weight, but cannot take up a weight very high : But on the contrary , the Pulley and Axis in *Peritrochio* can raife any weight to any height.

Thirdly, In any cafe which may be propofed, refpect muft be had to the power, together with the weight which it ought to move, that an Engin be chofe which fatisfies the intended end, for if the power abound, 'tis in vain to multiply, or augment the Engin, yea, with the lofs of much time : For as much as the more the Engin is compounded, the more time is beftowed in the motion of the weight : On the contrary, it may happen, that fuch an Engin may be chofe, by whofe means the weight cannot be moved by the power propofed, or not without a great deal of trouble. Wherefore according to the rule fhewn before (to wit, the power muft be increafed in the fame proportion, that the velocity of the motion of the power, hath to the velocity of the motion of the weight) Firft, you muft obferve how much weight the power of it felf can raife, or move, without an Engin, then from the known weight which is propofed to be moved, it will be eafie to determine what kind of Engin is required ; where note, refpect muft be had to the proportion of the weight of the Engin, and chiefly to the refiftance of it, which arifes from its parts, rubbing, or wearing, againft each other, for there are fome Engins which make fmall refiftance to the power, as Axis in *Peritrochio*, where there is no other rubbing or wearing, but in its two Poles ; alfo the leaver makes no refiftance by rubbing ; but the fcrew becaufe of its many fpires refifts much, and efpecially if the fpires be not very fmooth, and the convex, and the concave do not exactly anfwer each other ; in like manner the Pulley, the more wheels it confifts of, the more motion it refifts, becaufe of the multiplicity of Axes, which rub, or wear the Poles.

Fourthly, Obferve in any Eugin, the Wedge excepted, (of which by and by) another Engin may be joyned to encreafe

its

its force, fo to the leaver we may apply Axis in *Peritrochio*, likewife we may add the fame to the Pulley. Laftly, We increafe the force of the leaver, by adding the Screw : Alfo the head of the leaver may be elevated by the Wedge, yea, 'tis oft-times ufeful to lay under the leaver a firm and folid body, then between it and the head of the leaver, the Wedge is thruft and drove in.

Fig. 95. Pulleys are not wont to be immediately applied to the leaver, for although the rope A D of the Pulleys may be faftned to the leaver C E in D, and by depreffing the head of the leaver E may draw downward, notwithftanding, becaufe this motion cannot be continued any further, therefore inftead of the leaver, Axis in *Peritrochio* is wont to be ufed, which hath the proportion of the perpetual leaver, as is faid above, for the fame reafon the Screw is not added to Pulleys ; for although this may draw the rope a little more, yet the weight is thereby only but little raifed ; wherefore this artifice may be ufeful in cafe the weight were to be raifed but little from the earth ; laftly, the Wedge can in no wife help the Pulley being immediately applied.

The leaver may beneficially be added to the Screw, yea, without the Leaver, the Screw is not wont to move, as is obferved before, it may alfo ufefully be added to Axis in *Peritrochio*. Alfo the Screw may be helpt by Pulleys, but they are feldom ufed, and the motion is but fmall, as appears by confideration. But no manner of force is acquired from the Wedge, fince it is not applicable to it.

The Wedge only feems not to acquire force by means of other Engins, for 'tis not moved by the force of any Pulleys, or Cranes, as other Engins are, but only by percuffion : Wherefore that the Wedge may acquire greater force, it behoves to find a proportion, whereby a greater percuffion appears ; and this alfo may better be done by other Engins, to wit, if fome great Iron weight made in the fafhion of fome Hammer, be lifted up by the Engin, and then falling by its weight on the Wedge, it forces it in ; but efpecially by the Leaver A B, whofe Prop is C ; if to the end A,   *Fig.* 96. there be fitted a great Iron Hammer, or Beetle, which being elevated by the turning of the wheel G from F towards E, for if the wheel be fitted with Pins, while thefe are born down, they hit againft the end of the leaver B, and together with

R

that depreſſing, they take up the hammer A, which by its weight falling again drives the Wedge D : And the wheel G may be moved by a multiplied proportion, or by other wheels annext to the ſame, or by a capſtand, or any other way : Commonly in Smiths Workſhops 'tis moved by the force of water falling on the little boards of another greater wheel, fixt to the ſame Axis.

Hence it appears, by what artifice Engins are to be coupled, or join'd together, and what is to be obſerved in their combination, or complication, according as there is need of greater, or leſſer motion, for the raiſing of heavier, or lighter weights.

Engin V.

Fig. 97. THE Capſtands, or Windlaces, which obtains a vertical ſite are of great uſe, becauſe that they may be moved only by Animals, or Cattel, which alone properly and vigorouſly move with an Horizontal motion ; nevertheleſs, it hath this inconveniency, that one weight being raiſed up, the Engin ought to be turn'd about with a contrary motion, and ſo much time will be loſt, while the Horſe is fitted for the oppoſite part ; therefore, to ſhun this inconveniency, let the Engin be compoſed of two windlaces A B, C D ; to the Horizontal one of them, faſten ropes with two Buckets (as for example) to draw water, or raiſe another weight, ſo that while one Veſſel aſcerds full, the other may deſcend, you muſt fit to the Axis of the ſame windlace, two toothed wheels, or tympanes G and H, beneath the toothed wheels, let there be another windlace C D, furniſht with another Tympane, or Horizontal wheel G H, which ſuppoſe to lay hold on the wheel G, while the weight E is raiſed, and the empty veſſel F deſcends ; then the weight E being raiſed, move forward a little the tympanes, or wheels G and H, towards B, that the tympane, or wheel G, may forſake the teeth of the wheel, and theſe may be implanted to the other tympane, or wheel H, which may eaſily be done ſeveral ways; for ſo the windlace A B will be turned on the oppoſite part, ar.d

Fig. LXXXV.
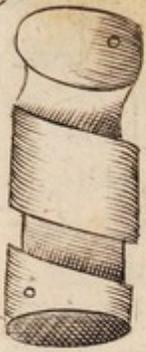
Fig. LXXXVI.
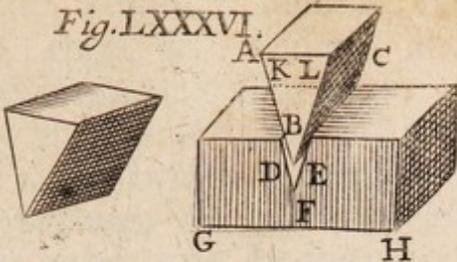
Fig. LXXXVII.

Fig. LXXXVIII.
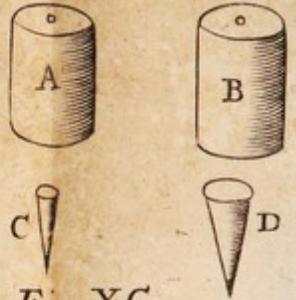
Fig. LXXXIX.

Fig. XC.

Fig. XCI.

Fig. XCII.

Fig. XCIII.
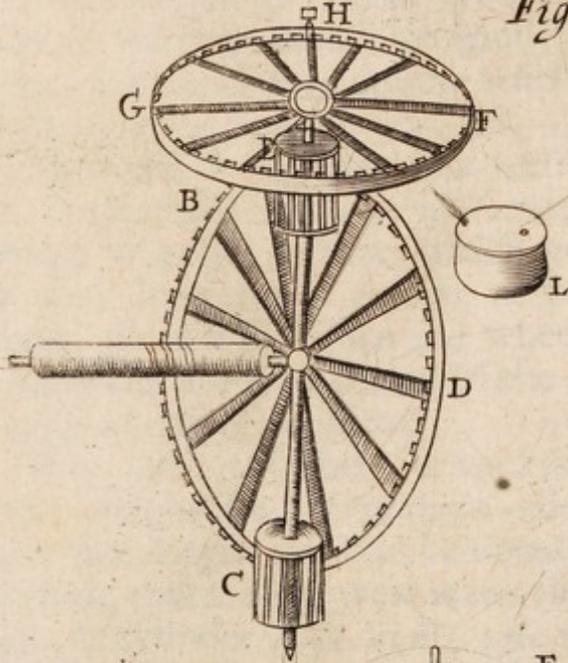
Fig. XCIV.
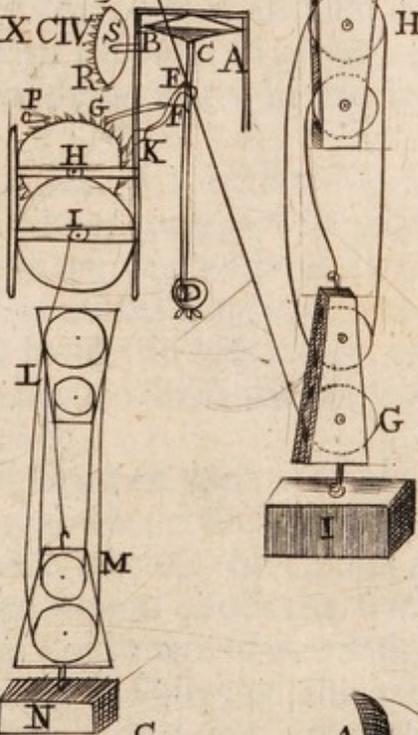
Fig. XCV.
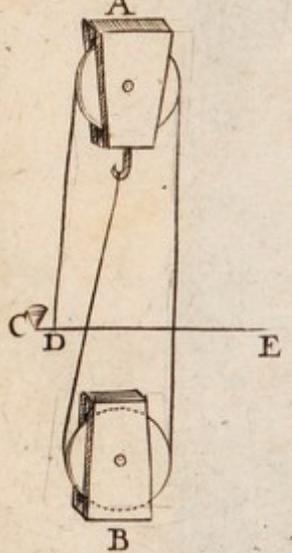
Fig. XCVI.
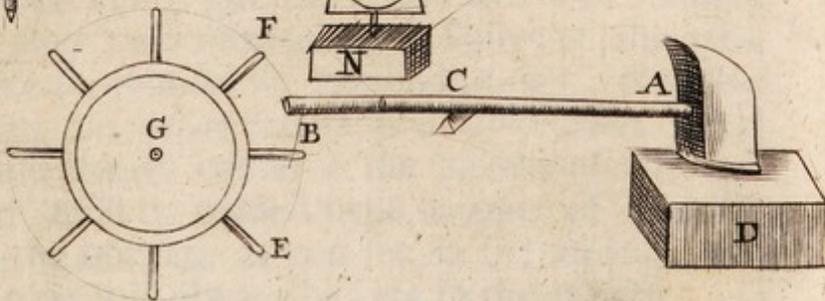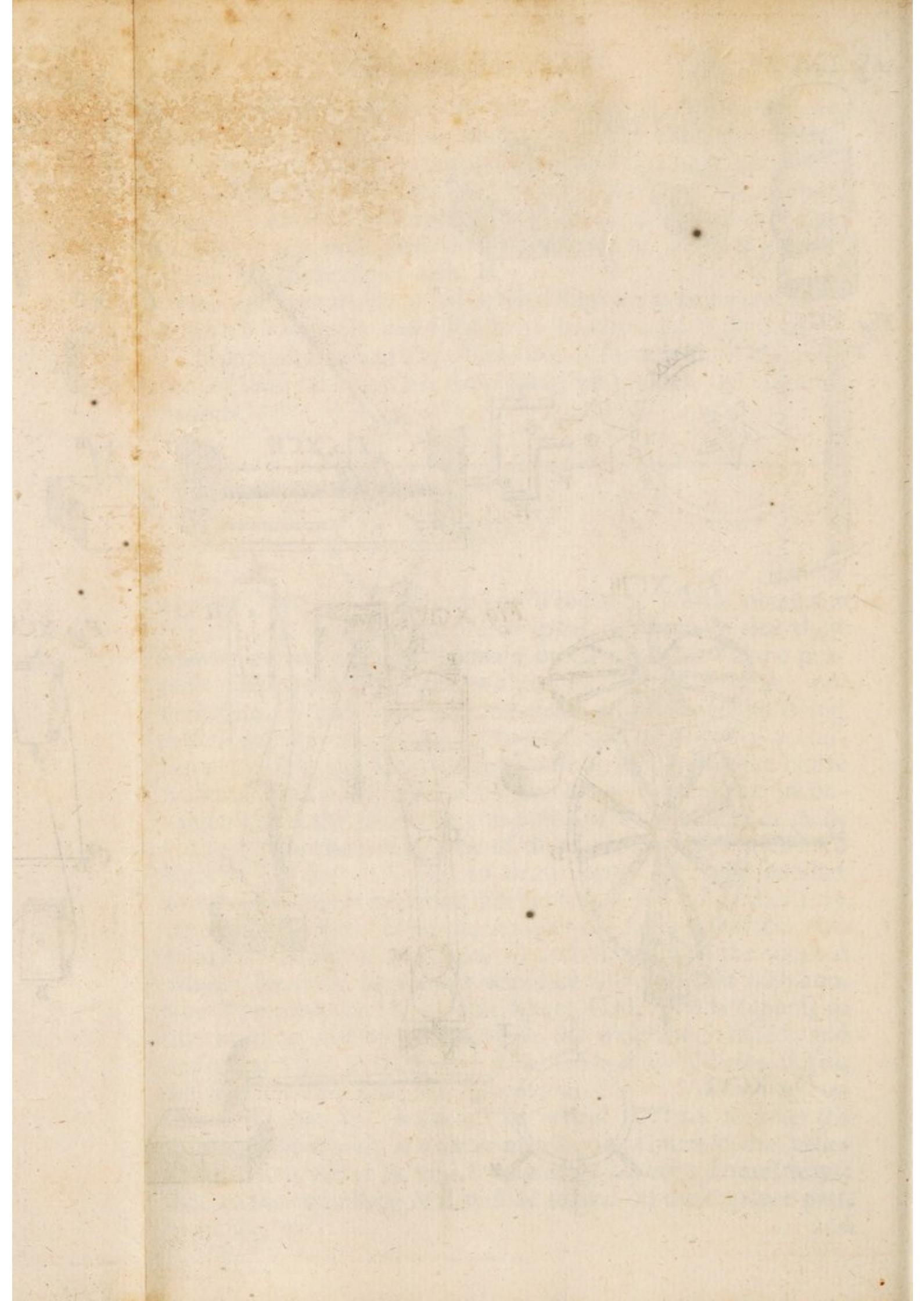
and while the weight F afcends, the veffel E, being emptied in the mean time, will defcend, and they will always afcend and defcend alternately, or by turns; alfo if the power (fuppofe a horfe) be applied to the end I, of the leaver I L, it will turn about to the fame part continually.

Or the tympanes, or wheels G H, may eafily be fitted, fo that always either may be ingrafted to the oppofite teeth of the fame wheel C; but neverthelefs, they muft be made movable about the Axis A B, yet fo, that by means of the Pin, or the fmall leaver, N and M may eafily be joined with the Axis, or Windlace, as often as you pleafe, for fo by alternate force one tympane or wheel, which fhall be firft made firm in the Axis, by help of the leaver, refifting the moving wheels will move the windlace, and take up the weight, while the other free from the pin, will obey the moving wheels in like manner, as if it were not.

But if you would apply men to the vertical capftand, or windlace, fince thefe are eafily fitted to the contrary part, after the weight is raifed, yea, they may commodioufly turn about, left they fhould be giddy with the motion always one way, you may fit a double veffel to draw water in the fame manner, as appears in *Fig.* 98.

Moreover a windlace in a vertical fite, if it be fitted either of the forefaid ways, it will much better perform the effect, than a wheel, or a crane, which many ufe not without danger of their lives, for if a rope, as it fometimes happens, fhould break, thofe which turn the wheel, from the great force preconceived, are thrown out of the wheel, which cannot happen in a vertical windlace.

This fame windlace, or capftand, Seamen ufe, to bring in great weights into their Ships, alfo to draw up their Anchors; in which Engin this is to be noted, that becaufe the Cables are fo thick, that if they were many times wound about the windlace, or cylinder A B, in *Fig.* 99. the Engin would be rendred ufelefs; therefore they only receive 3 or 4 Spires of the rope about the cylinder, fo that while one end of it C, is turn'd about the windlace, the other end D is thrown away; and that the rope fhould always confift in the middle of the cylinder, the cylinder muft be made in the manner of a Cone, broad, or thick in the bottom, as you fee in the figure; and by this means the rope will always be kept in the middle.

Engin. VI.

To remove a Mountain, or heap of earth, from one place to another easily and quickly.

Fig. 100. LET the Mountain, or Hill, or heap of Stones be A, to be removed to the place B; to save time in going and returning from one place to the other, as also, that the motion whereby the Earth, or Stones, is transferred from A to B may be swift, we may make use of the following industry: Erect at the foot of the Mountain, or in its middle, a great and solid wooden column, or piece of timber C D, and erect such another in B, *viz.* E F, affix at top of each piece, or column, the wheels D and F, and make hollow each wheel in the circumference; and put about them a great strong rope, extended parallel to the Horizon : But if the distance from A to B be great, least the rope should be too much stretcht or bent, raise other such like pieces, or columns in the middle, with their wheels made hollow as aforesaid, to sustain the rope parallel to the Horizon ; on the rope thus doubled, here and there hang baskets, which must be so far distant from each other, that they hinder not one another ; and the ends of the pieces must be so placed, that the power applied to the leavers G and H, may be turn'd about their Centres ; for so the whole Rope with the Baskets hanging on it, will be turn'd about successively : Wherefore, if men keep filling the baskets in A, and others unload them in B, the whole hill will be easily transferred from A to B.

Where Note, That the greater the wheels D and F are, the swifter the rope and baskets will be turned about : Which motion about the axis, or piece of timber being easie, may be accomplisht by means of short leavers, that so the motion of the baskets may be greater than the motion of the power about the piece of the timber. Besides the saving of labour, and the gaining of time, which is effected by this Engin, it hath likewise this conveniency, that if between the two places A and B, there should be a river, or stream, or such like in-
accessible,

accessible, as if the Earth were to be transferred from a Mound, or Hill, to the next adjoining Fields, and there were a large deep Mote, or Ditch, between them, you could scarcely obtain your desire any other way.

Engin.   VII.

To draw Water, or Mineral matters, out of deep Wells, or Pits.

Fig. 101. GEorge *Agricola* describes five divers Engins, invented and used to this end, in his 6th book of Minerals ; the first 3 whereof are wrought by men, the other two are turn'd about by horses, in all of them he uses a double Bucket, or Basket, one of which being empty descends, while the other being full is raised up ; in these Engins, if the Pits be deep there is this inconveniency, that when the double rope is of such length, as the depth of the Well, it is necessary that it be turn'd about every where on the Axis of the wheel, and it will take up much space on the Axis, and require the Axis to be the longer ; and by how much thicker the rope is, the Axis requires to be the smaller ; whence it will happen, if the Well be not broader than the whole space of the Axis, on which the rope winds about, the Buckets, or Baskets, will hit against the sides of the Well, and retard the motion ; but if you make the Axis thicker, there will be fewer circumvolutions of the rope, and it will occupy a lesser part of the Axis, but then it will require a greater force of the power to raise the weight, or wheels much greater, to which the immediate power is applied ; moreover, that which makes to the present thing, and is of greater moment, is, that the motion whereby the weights ascend, is for the most part very slow ; wherefore we will describe this Engin, by whose help the weight is raised with a motion doubly swifter than the motion of the power. For let there be a wooden Cylinder A B, erected perpendicularly, turning easily on its

poles,

poles, on whose head fit a little wheel A equipped with small cylindrical staves, being a kind of cog wheel, but in the middle let it be fitted with a leaver, or a double one C C, to which the power is to be applied : And we will suppose the power any way applied in C, the circumvolution of this Cylinder to move circularly through the circumference of six feet, so that four turnings round finishes 24 feet ; and in the same time by means of the little wheel A, the wheel D E too finishes a circuit by only one turn ; but the wheel F G is turned six turns, or times, and then the Axis H I is moved quadruple of the wheel G, to wit, it makes 24 turns, or circumvolutions : Wherefore, if the Cylinder I H (on which the rope whereon the baskets are fastned winds about) be of such a thickness, that in its going round, or periphery, 'tis equal to 2 feet, the basket will ascend 48 feet, *viz.* by a motion doubly swifter than the motion of the power applied in C.

Perhaps some may say, that so many multiplications of wheels is not necessary, if so be the same proportion, whereby the velocity of the motion of the weight increases, or of the baskets, above the velocity of the motion of the power, a greater power also ought to be applied : Wherefore, when the velocity of the weight, is greater than the velocity of the power, it may be obtained by means of one wheel only, all the rest are used in vain.

I answer, that is true indeed, in speaking Mathematically ; but Physically, and in Practice the thing is otherwise, which may be seen at the first view ; for if the power be applied immediately to the Radius's A, B, so that it move the Cylinder C D, with a motion doubly greater than the motion of those radius's, or of the power it self, the power is more tired ; but less, if the other wheels aforesaid come between, or being disposed in any other like manner, so that the circle which the power describes by its motion be greater : The reason whereof may be twofold, the first is, because when in this circular motion, the power being applied to the radius, the radius hath the proportion of a perpetual leaver, and the leaver as is said before, is changed in each point of the Circle, also the motion of the line of direction, (that is to say, according to which the power impresses the force to the leaver) ought continually

Fig. 102.

to

to change, since it ought always to be perpendicular to the leaver; and 'tis manifest, that a power cannot exactly every moment change the direction of its force, so that any force shall be according to a tangent line of its circle, for as much as force recovers by turns, so *Impetus* impresses often times by turns, that therefore the whole *Impetus* cannot be guided to divers lines; therefore since necessarily this imperfection of *Impetus*, subsists in every animated power (of which only we are here speaking) then the motion will be the easier, where the power sustains least of this imperfection: But this imperfection is lesser, if the motion of the power be circular, or the motion of the circle be greater; if so be in a greater circle, the deflexion from a perpendicular line, or tangent, be always lesser, surely in going about, we move more easily by a greater circle, than by a less, as appears manifestly in the practice of horses going about, for as much as while they continually bend, and endeavour to make a new line of motion, they are much tired.

The second reason is, because as appears in the said Engin, *Fig.* 101. the motion of the parts of the Engin decreases, even to the wheel F, which is again moved more swift by the wheels E and D, and also effects a swifter motion in the Axis I H, and in the weight bound to the rope: For from this decrease of swiftness, even to a certain limit of the Engin, and again from a new increase, even to the end of the same Engin, and to the weight it self, it comes to pass, that the power suffers the less resistance: I say, the successive compression of the parts of the Engin, or the endeavour of the *Impetus* is propagated from the power towards the weight; and since the motion is more flow about the middle of this Engin, than in its other parts, there, after a certain manner, is the resistance of the weight gathered together, that therefore the power may suffer the less from this chiefly, because the direction of *Impetus* from the power towards the weight often-times coming unlookt for from new *Impetus's*, necessarily prosecutes its Journey towards the weight, nor cannot reflect it towards the Power.

Engin.

Fig. 101.   Engin.   VIII.

*To apply a wheel to the precedent Engin, and to others
of the like kind, by means whereof the power is eased.*

BEcaufe the Engin laſt deſcribed, and all others of the like
nature, for the moſt part require the power to be ſuffi-
ciently ſtrong, in as much as it ought to produce in the mo-
vable, a ſwifter motion than the motion which moves it ;
therefore no Induſtry muſt be ommitted, whereby the power
may by ſome means or other be helpt, or leſs tyred. And
that will beſt be done by adding a wheel of ſome heavy matter,
and altogether ſolid to the Engin, as if to the Axis A B of the
precedent Engin, there be faſtned an immovable wheel made
of Stone, L N, parallel to the Horizon : For although at firſt
ſight it ſeems rather be be an impediment, nevertheleſs, it ap-
pears by experience to add much to the acceleration of the mo-
tion, with leſs tyring of the power; for if it be exactly in *Equi-
librio*, ſo that the Axis paſs preciſely through the Centre of gra-
vity of the Stone Wheel, it will reſiſt its circular motion
little or nothing, as from what is ſaid may be eaſily gathered,
and as it clearly appears from what hath been ſaid of circular
motion ; but from another original, whence once it hath con-
ceived an *Impetus*, it retains it long in it ſelf, and the more, by
how much the heavier it is, ſo that for ſome ſpace of time it
will move other wheels and the weight, by only that *Impetus*
conceived at firſt, without any new impreſſion from the Power ;
whence it happens, that although the power ceaſe for a little
time from impreſſing a new *Impetus*, or at leaſt doth not ex-
ert its force always uniformly, or produces an unequal *Impetus* ;
nevertheleſs the *Impetus* conceived by that wheel, ceaſes not to
propigate further, and reduces that inequality, or deformity,
to ſome kind of uniformity and equality, which how much
'tis in the preſent affair may eaſily be collected from what hath
been ſaid before.

But now obſerve, this kind of wheel may be fitted to the
Engin

Engin in divers parts, and fundry ways ; and firft, as to that which pertains to divers parts ; 'tis manifeft in the Engin now defcribed, that it may be applied either to the Axis or Cylinder A B, or to the Axis E N of the fecond wheel, or to the Axis F G (in which cafe it will have another fite, or pofition, *viz.* perpendicular to the Horizon, or vertical) or laftly, it may be placed alfo to the Axis H I : Wherefore 'tis queftionable what place it ought to be fixt, to perform the beft effect. I fay, then it will perform the beft effect, if it be placed there were the greater force of *Impetus* is gathered together, to wit, in that part of the Engin, which ought to move moft fwift ; for fince it better obtains its end by conceiving a greater *Impetus,* and fince by reafon of more gravity, 'tis capable of more *Impetus,*'tis plain that it muft be placed there, where the greateft *Impetus* is conceived : From hence it is that in the Engin defcribed above, 'tis better placed in the Axis I H, than in the Axis G F, becaufe that is moved fwifteft : And better in the Axis G F, than in the Axis A B, becaufe while the Axis G F, is turn'd round fix times, the Axis A B is turned only 4 times ; Laftly, 'tis better placed in the Axis A B, than in the Axis E N, fince this is turned floweft of all. But when 'tis placed in Engins, whofe parts the further they are from the power, are moved flower and flower as fome are, this wheel will be more conveniently placed to the firft part of the Engin, to which the power is immediately applied. But contrariwife in thofe Engins in which the motion is fwifter, the more the parts are diftant from the Power, the wheel muft be fitted to hindmoft parts, agreeing with the more remote parts from the power.

Alfo obferve, wherefoever the forefaid wheel is placed, it ought to be the more heavy, by how much flower it ought to move ; but if it be placed where it moves fwiftly, a lefs proportion of weight will ferve : For as much as it appears from the doctrine of circular motion, that the heavieft wheels maintain the impreft *Impetus* longeft, although they are moved flower than the wheels that are lighter, which lighter wheels, if an equal *Impetus* be impreft they move fwifter, but fooner part with or loofe the *Impetus.*

Moreover, I obferve, and I propofe it as a new invention in this matter of great moment, that 'tis poffible by means of this wheel, to promote the celerity of the motion much in

S   the

the movable, or thing moved, but adds but little to the power.

Fig. 103. For let the Power be applied in H, which moves the Axis A B, and by that means the wheel B C, the wheel D, and at laft by the help of this, the little wheel E, with the axis E I, to which the rope is faftned, and turn'd about, that takes up the weight, or for any other ufe. In this Engin you fee the motion always accelerated from the power towards the weight, or the Extream part of the Engin E I : If therefore there be ingrafted to the Axis E I, a wheel of an indifferent weight, but yet large as F G, this from what hath been faid will notably promote the Celerity of the motion, fo that the fame power may be effect a fwifter motion, ufing only the fame power with this wheel than without it : Now therefore, fince the *Impetus* once conceived, may eafily be continued by this wheel, fome power being added immediately to it, which either continually, or at leaft now and then, and often will renew that conceived *Impetus*: Example, a rivulet of water falling from on high, on the little boards, or rather bucket of this wheel, it will come to pafs, that how little foever this impulfe be, while 'tis in a manner continual, or at leaft often, notwithftanding being added to the impulfe already conceived from the great wheel to this wheel, and fo alfo to the movable, it effects the Celerity.

Secondly, The forefaid wheel may be placed either in a perpendicular axis, fo that it may obtain an Horizontal fite, as is feen in the foregoing Figure, or in an Horizontal axis, fo that it may obtain a vertical fite or perpendicular to the Horizon, as in the prefent Figure : And although in order to motion, the facility differs little, which way of the two you place it ; notwithftanding, I efteem it more neceffary to be placed in a vertical fite, becaufe, when in this cafe, the axis to which 'tis applied neceffarily ought to be Horizontal, the weight itfelf of the wheel lies on two Poles, and fo being divided between two, each Pole fuffers lefs compreffion, and the refiftance is lefs which arifes from the wearing, or rubbing of the fame Poles : But if it be placed on a perpendicular axis, the whole weight of the wheel lies on one Pole, *viz.* the loweft, it may feem to retard the motion of the other wheels : Neverthelefs, becaufe that very often the motion of the axis is wont to be made in a perpendicular fite, bearing on the middle

middle part of the lower Pole, they sharpen it so, that the whole weight is born on a small part of the Cavity, that, as I have said, therefore, the wheel may move the others with more ease.

Lastly, The same wheel, of which we are speaking, may be used doubly in a vertical site : First, so that it stand wholly hang'd up in the air, and equilibriated, as in the preceeding Engin. Secondly, So that it insist or stand on the subjected pavement, and turn'd about upon it ; in which case it hath also more force, than if it were suspended wholly in some axis : But the Pavement ought to be made level and plain, and solid, as of polisht marble, or such like matter, and the circumference of the wheel, which immediately touches the pavement, ought to be exactly turned, that no impediment retard the motion. So the wheel A B being applied to the extream part of the leaver C D, to which *Fig.* 104. leaver in like manner, apply a power moving the Cylinder, or Axis D E, and by this means, the wheel E, and oftentimes other wheels, for while the Cylinder is turned about by the Leaver, the Wheel A B, roles about its Leaver, leaning on the pavement, and from a double motion, to wit, one about its centre, or about the Leaver C D, which is instead of an Axis, and the other about the Cylinder D E, while it runs out from B to F, &c. And in this manner, it may be applied almost to all Engins, but especially, to those with which we use to move great weights. And the greater this Wheel is, the better it performs the effect, so that the weight be in proportion to the power applied.

Engin. IX.

To raiſe the Water of a Fountain always flowing, to any height, by a voluntary motion, although the height be greater than that to which the Water deſcends.

Fig. 105. THIS Invention, if you entertain the perpetual motion, eaſily ſecures to it ſelf the chiefeſt place: For 'tis eaſie to draw Water by a voluntary motion, to a greater height than is that from whence the Water of the ſame fountain deſcends, as is manifeſt in Spiral Engins, but to give it a continual motion, that it ſhall never require the hand of a man, this without doubt deſerves great praiſe.

This Engin contains two buckets, filling them from the fountain, of which while one aſcends the other deſcends continually, without any labour, and ſerves the Water for Domeſtick uſe ; therefore to make the Water aſcend to a ſpace doubly greater, than is the ſpace of the Water deſcending, it muſt be diſpoſed in this manner, as is repreſented in the Scheme.

A, Is a Veſſel, or leſſer Bucket which aſcendeth, this being full, weighs leſs than the Bucket M being full, which deſcends; but being empty that weighs more than this when empty ; Hence 'tis, that while both are filled together from the veſſel S, the Bucket M deſcends, and by its weight draws the Bucket A up: But on the contrary, while both together are emptied, the Bucket A deſcends, and by its weight draws up the Bucket M.

B, Flaps to keep the Water in, tyed with a ſtring to the leaver D, this leaver D turning eaſily about the Axis C croſs-wiſe, while the Bucket is raiſed up on high, hits againſt the piece of timber Z Z, and opens the flap B, and gives way for the Water to paſs through the little Pipe E into the Veſſel X. The ſaid flap B being ſomewhat large, whereby the bucket may be emptied the ſooner ; make the bottom ſomewhat hollow.

low, left the emptying of the Bucket any way hinder ; and a-
noint it with greafe, that the Water may keep in the better.

C, A ftick joined to the bucket a-crofs, and made faft to the
leaver D, which we call an axis a little before, becaufe of its form.

D, A Leaver with a little Wheel, or a Pulley *d*, annext
to its top, the lower end of which leaver, is bound to the
flap B, with a ftring, for this end, that while the Bucket A,
afcends towards the piece Z, and hits againft the Leaver, the
flap is opened and the Water goes forth.

E, A little Pipe, or fmall Tube, joined in the bottom of
the Bucket, fo that it anfwers beneath the mouth of the hole
of the flap, through it the Bucket is emptied within the
veffel X, the Orifice, or Mouth, and its cavity, are not lefs
than the hole of the flap B.

F, Rings on both fides of the Bucket, in which are ingraf-
ted Iron threds, or chords G G.

G, Iron threds, or chords, which muft be firmly extend-
ed, left the Bucket in going and coming hit againft the fide,
and efpecially while the leaver *b* hits againft the piece Z.

H, A round piece of Timber, to which the said Iron
Strings or Wyers are faftned, which Threds or Wyers ought
to defcend from the piece Z, even to the piece H altoge-
ther perpendicular, and to be diftant from each other
fuch a fpace, that they ftrain not the Rings that are fixt to
the Buckets, or at leaft but lightly, that fo the Bucket may
afcend and defcend freely, and without violent wearing.

I, A Rope to which the Bucket A is faftned, paffing over
the little wheel, or pulley K, and within the pulley L, and
from thence extending to the faftned pulley K *e*, to whofe
top it is faftned.

K, A Pulley joined to the piece Z, which muft be large
for many reafons, and a hole in the middle, and let there be
a fmall Axis paffing through the hole, which will bear the
weight of the Bucket and Water.

K *e*, A fixt Pulley, that is, it doth not turn about its Axis,
but is immovable, or rather a fourth part of a Pulley, its Semi-
diameter ought to be equal to the Semidiameter of the Pulley
K, that therefore the motion of the Bucket M, may remain
uniform, that is, that it may remain always in the fame per-
pendicular ; otherwife the Rope of the Bucket M, will raze
againft the Iron threds, or chords G G, and fo the motion
will be hindred.

L, Ano-

L, Another Pulley, which while the rope I draws on both sides, causes the ascent of the Bucket A, to be as swift again as the descent of the Bucket M, and therefore that runs double the space in the same time as this; for which cause the weight of the Bucket M full of Water, ought to be as much more as the weight of the Bucket A being full; but on the contrary, the Bucket A, although it be lesser than the Bucket M, ought to weigh more than it, they both being empty, notwithstanding the excess ought to be indifferent, and so exact, as will suffice that the Bucket A being empty in descending, may draw up the Bucket M being empty.

M, A Vessel, or a great Bucket, which by its descent draws up another lesser A, it hath a flap B, and little pipe E in the bottom, rings F F on the sides, Iron threds or chords G G, as the former Bucket A, nevertheless, the leaver is applied in a divers manner.

N n, A leaver placed upon the Bucket M a-cross, to whose end *n* there is annext a stick *n a,* hanging or dangling, this, while its end *a,* descending with a bucket touches the Earth, raises the leaver N *n,* and opens the flap B, of the bucket M, at the same time in which the flap B of the bucket A is opened.

O o, Two ropes fastned above to the bucket M, and below to the piece Y, or to the Earth, to the end, that M should not ascend beyond its due limits, nor A descend beyond his : 1, 2, 3, 4, &c. are leaden weights to weaken the *Impetus* of the motion in the descent, while they lye successively one after another on the earth, and lessen the weight of the bucket to which they are fastned; but in ascending while they are elevated from the earth one after another, they adjoin new weight to the same bucket; and they may be more or less, according as is necessary.

P, A piece laid athwart a little above the bucket M, having a hole in the middle, through which a rope passes freely without rubbing, to which the bucket is fastned even to the knot Q, which knot when it comes to the piece P, stays the motion of the bucket M, and hinders it, that in descending it dash not against the earth, nor the bucket A in ascending hit against the piece Z Z.

Q, The knot spoke of but now, to it may be tyed a staff a-cross, or overthwart, which may easily be loost and changed as need is.

R, Ano-

R, Another knot with a ftaff athwart, which muft be fo far diftant from the former knot, as is the fpace of defcent of the bucket M almoft to the earth ; this knot may execute the office of the ropes O *o,* if the weights 1, 2, 3, *&c.* be not neceffary.

S, A veffel defigned to receive the Water from the Fountain, it hath a flap, and a little pipe in the bottom, as have the buckets A and M, nevertheless, the little pipe ought to caft out the water from each fide ; and at the fame time almoft, to fill together the bucket A, and the bucket M ; and becaufe thefe buckets are of divers capacities, the faid two little pipes ought to caft out an unequal quantity of water from the veffel S : This veffel muft not be in the middle between the two buckets, but behind after them.

T, A leaver faftned by a ftring or rope, to the flap of the Veffel S to open it ; on the top it hath the table *f* adjoined, that the ftaff V may hit fecurely on it, and raife the leaver.

V, A ftaff fixed firmly to the fide of the bucket M, with a little wheel or pulley on the top ; this when its pulley raifes the leaver T, and opens the flap of the veffel S, while the buckets are filling, the bucket M defcends, and with it the ftaff V, and fo the leaver T is let down, and the flap of the veffel S, is fhut again, until the veffels are emptied below, and above ; M returns back with its arm V, and raifes the leaver T again, and opens the flap of the veffel S, as before.

X, A veffel to receive the water of the bucket A : This veffel ought to be fuch a fpace beneath the piece Z, that while the leaver D hits on the piece, the little pipe E within the veffel unloads the water of the bucket A.

Y, A piece of timber, a ftump, or a ftone, to which the ropes O O are faftned.

Z, A piece of timber to which the pulleys K and K *e* are affixt ; this piece of timber hath the table *b* affixt to it at right angles, on which hits the little wheel of the leaver D, and draws near to the wall, and draws the bucket A with it towards the wall, that the little pipe E may hang over the head of the veffel X ; which may alfo be done otherwife.

This Engin which was made at *Rome* in the Convent of St. *Mariæ de Victoria,* the leffer bucket did contain more than an whole Urn of Water (at *Rome* they fay *un* Barile) but before while they ufed leffer Buckets, the Engin wanted fuccefs.

Note.

Note alſo, that the bucket A ought firſt to be emptied, and then the bucket M, otherwiſe the water as yet contain'd, by the more heavy weight, would deſcend with too much force, but you may obtain that by making the little pipe E of a due magnitude.

Its flaps are of matter, and form, and magnitude, that the water before they are opened, no way runs out; in the foreſaid *Roman* Engin, a palm, or hands breadth was the length, and half a palm the breadth : The matter was Lead both of the little tongue, and the table, in which the hole was, and was ſhut by the tongue : If they are made of wood, they have not ſo good ſucceſs.

The Pulley L hath as much diameter, as is the diſtance between the true Pulley K, and the fained one K e.

The weights 1, 2, 3, 4, &c. are faſtned to the ropes O O, for this end, to ſtop the *Impetus* of the deſcending bucket A ; for beſides the *Impetus* which always increaſes in heavy bodies deſcending, the *Impetus* likewiſe is too much acquired from this, that when it comes to the piece Z, the whole weight of the rope I hangs on the other part of the Pulley K, and increaſes the weight of the bucket M ; but when after the emptying of the buckets, the bucket A being heavier than the bucket M, together with the weight of the rope, it begins to deſcend, and draws with it the rope I, and therefore draws to it the weight of the Rope, and takes away the ſame from the bucket M. T n how much more is added to one, and taken from t'other, ſo much the more the *Impetus* increaſes of the bucket A ; which *Impetus* is weakned by the foreſaid leaden Plummets, while they are raiſed from the earth ſucceſſively.

Alſo beware, left the ropes are made wet by rain, or by water, otherwiſe they will be contracted, and not retain their due length.

Laſtly, 'Tis obſerved in the foreſaid Engin, that the water is raiſed as high again in the buckter A, as it deſcends in the bucket M, by reaſon of the Pulley M, which doubles the rope : But if any one would have the water riſe four times as high, he muſt add another Pulley, and another rope ; in like manner by the help of three pulleys he may make the water aſcend to eight times the height, &c. ſo that the water contain'd in the bucket M, be quadruple or octuple, of that which

Fig. XCVII.
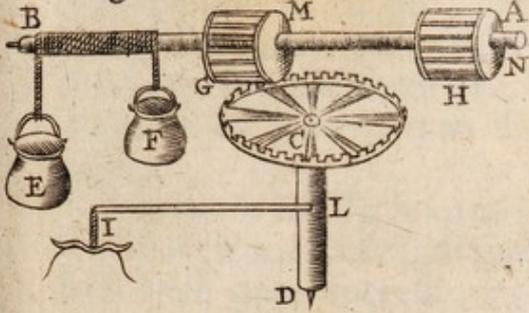
Fig. XCVIII.
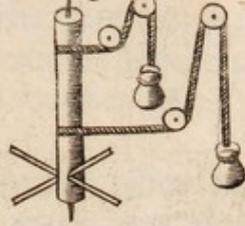
Fig. XCIX.
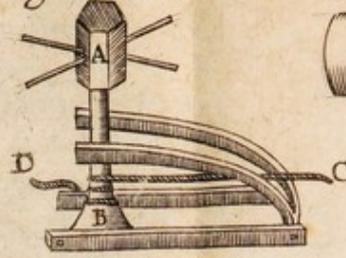
Fig. CII.
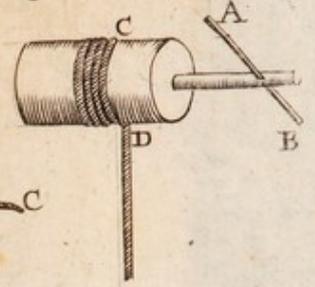
Fig. C.
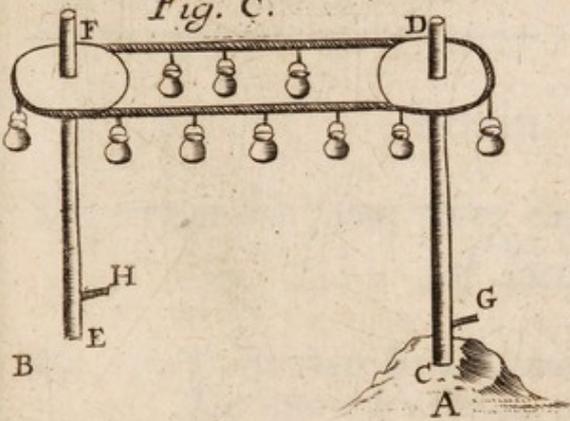
Fig. CI.
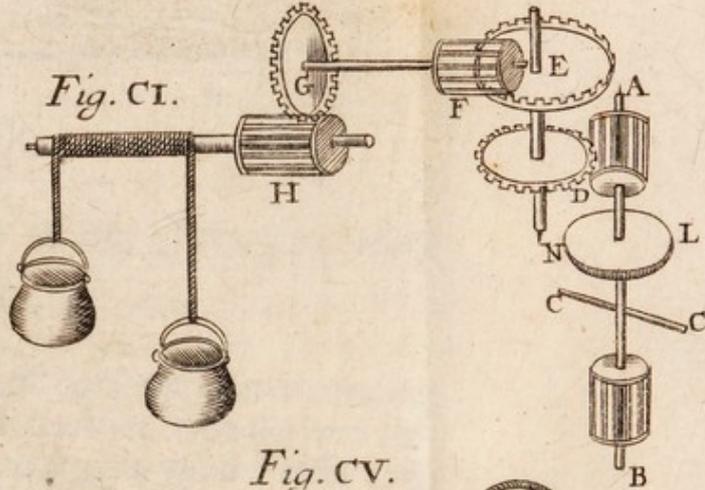
Fig. CV.
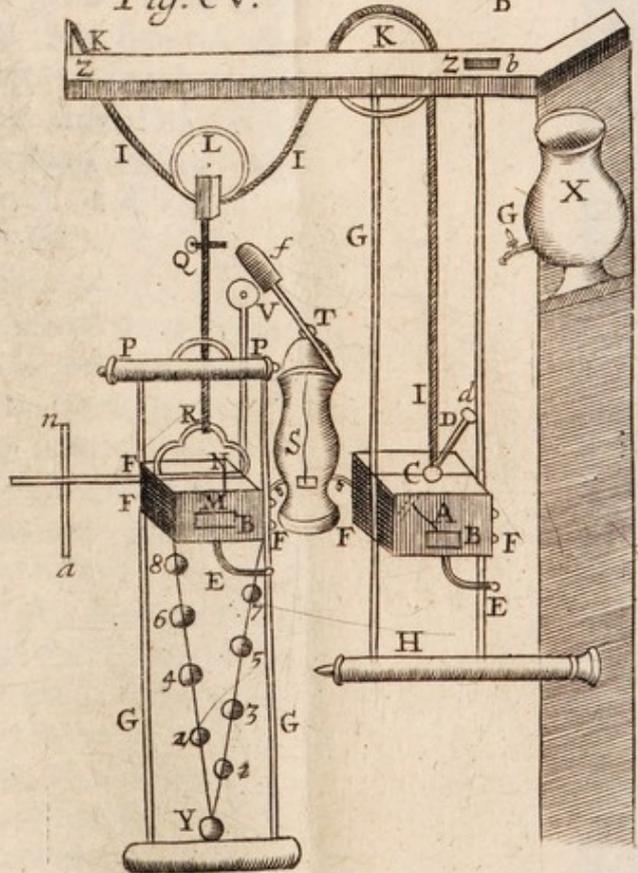
Fig. CIII.
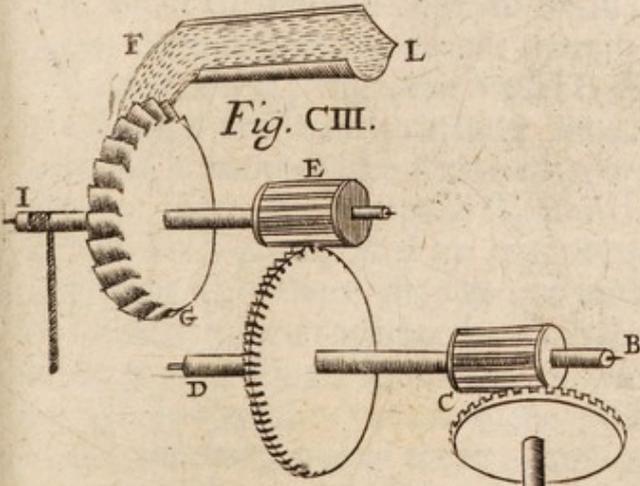
Fig. CIIII.
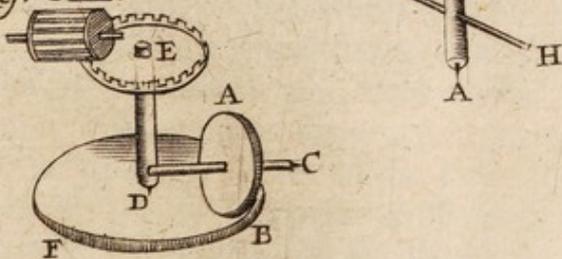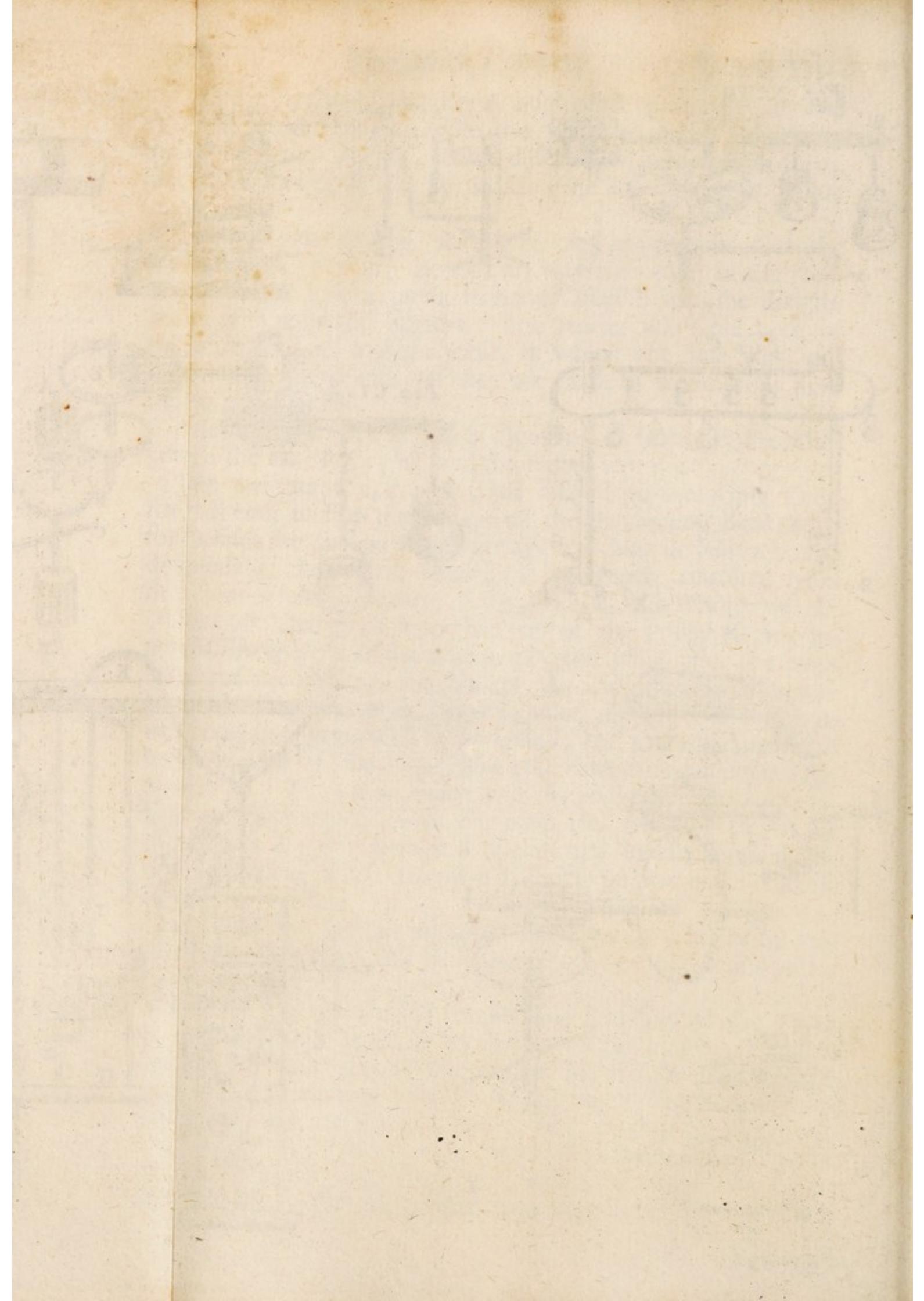
is in the bucket A, yea, and fomewhat more, that the bucket being full, may out-weigh the bucket A, and may draw it downwards; although the bucket A being empty, ought always to be heavier than the bucket M in like manner being empty.

Schottus in his *Technica curiofa* defcribes an Engin fomewhat different from this, which was made at a Noble Man's Houfe at *Bafil* with good fuccefs.

Engin. X.

To perform the fame thing eafily in any given proportion of Height.

Fig. 106. LEt there be a fountain of conftant Water running into the Veffel A, or at leaft let it be derived thither from fome continual Fountain, and you would raife it to the Veffel B, whofe height above A is 20 feet, but from A the water cannot defcend deeper than to C, to wit, 10 feet beneath the Fountain A; nigh the Veffel B difpofe the Axis D E in an Horizontal fite, eafily turning about the extream poles; difpofe fuch another like Axis near the Fountain A, and annex to each of them the Tympane F, and the wheel G I; Tympanes of this kind are divided by Iron Rods, or Sticks, and of fuch a largenefs, that there may be put upon them conveniently little Veffels, joined together by a Chain annext to one another in manner of a Ring; it matters not what fafhion the little Veffels are of, fo that they receive the Water eafily into them, and empty the fame out of them again, we have delineated two of them together in the figure L N; thofe which are put about the upper Tympane hang on the fame, and they extend or reach along to the water of the fountain A, and are dipt into it fucceffively, and draw the fame while the Tympane is turn'd about; but when they come to the top of the wheel, they unload the fame water, and pour it into the upper Veffel B. But from the water of the fame fountain A, the Veffels put about the lower Tympane muft firft be fill'd, which ought to have a little hole open in the bottom, that the water may flow

from

from the Veffel L into the lower Veffel N, and from N into another, and fo fucceffively all the Veffels of one fide are fill'd; for then the weight of them and the water turn about the Tympane, together with the wheel G I of the lower Axis, which wheel running into the other, moves the upper wheel and turns it about with the Tympane of the Axis D E, that the little Veffels draw the water from the Fountain, and raife it into the Veffel B; but becaufe the water ought to be raifed double the height in B, that it defcends in C, therefore the upper crown, or ring of little Veffels, ought in like manner to be as long again (or doubly longer) and therefore that it may be carried about, and raifed from the lower crown, or ring, being but half fo big (or doubly leffer;) thofe little Veffels ought to be leffer, fo that they raife upward in the fame manner fubduple, or half the water, yea, rather lefs, becaufe of the refiftance of the Engin, but the lower little Veffels receive double the water, or fo much as fuffices to move both the Wheels.

The lower Tympane may conveniently hang over the Well, or Pit, defigned for it, within which the Crown or Ring of little Veffels defcending, when they come to C, the little Veffels are unloaded fucceffively, fo that one fide of the Crown is always full of water, and out-weighs the other fide, and turns about the Axis: That if the upper Veffel B being filled with Water, which afcends upwards, it again flows into the lower Veffel A, and the lower part of the Engin is fo accommodated, that the pouring out of the Water appears not by means, whereof the lower Tympane is moved, and the Spectators may eafily be deceived, thinking that Water only to defcend, which at once afcended, that therefore they may think it a kind of perpetual motion.

If the weight of the Water of the lower Tympane be doubly greater than the weight of Water which afcends to the upper Tympane, this Water may be raifed to a double Altitude, and therefore a crown of little Veffels doubly longer muft be ufed; and thofe little Veffels of the upper Tympane will be proportionally leffer in the fame manner, *viz.* if the water be to be raifed triple or quadruple higher, the little Veffels of the upper Tympane, or wheel, muft be triple, or quadruple leffer than thofe of the under or lower Tympane, or wheel, fo that the length of the upper Crown is made amends by the magnitude of the little Veffels of the lower Crown.

Bur

But the little Veſſels of both Crowns may be made equal, and nevertheleſs the Water may be raiſed to any height, to wit, if the wheels G I which bite each other, be made unequal; for if the upper wheel hath its Diameter doubly greater than the under wheel, this will move that with a weight of water doubly leſs, and therefore a crown of little Veſſels doubly leſſer will be equal to the little Veſſels of the upper Crown; I ſay, the ſame of any other proportion, triple, quadruple, &c. wherefore amends may be made divers ways for the height, and plenty of water aſcending, either by means of a greater upper wheel, or by means of greater little Veſſels of the lower wheel, or Tympane, or partly by means of the greater wheel, and partly of the greater ſmall Veſſels.

But if from all the Water in the Ciſtern A continually flowing, the greater part of it is to be raiſed in the upper Ciſtern B, as if you were to raiſe three parts of four of the water, and but one part only to deſcend, than the lower Crown muſt be 3 times as long as the upper Crown, and the little Veſſels of the ſame muſt be at leaſt three times leſſer, if both the Axes of the wheels G and I be equal. But if the wheels G I be unequal, the proportion may be made fit another way; for if the lower wheel be three times greater than the upper wheel, the little veſſels of the Crowns may be made equal, but the lower Crown ought to be three times greater; for in this caſe, while the lower wheel is turn'd about only once, ſuppoſing five of its little veſſels to be fill'd, the upper Wheel is turn'd about thrice, and therefore fifteen of its veſſels draw water, and in like manner 15 veſſels of water they pour into the Ciſtern B.

Alſo both crowns, or chains, to which the little veſſels are faſtned, may be accommodated to one and the ſame upper wheel, but it will be neceſſary to fit to the wheel two wheels with Axes, as is declared before: But if the altitude to which the water is to be raiſed, be ſo high that it requires very great wheels, other wheels may be diſpoſed in the middle between each wheel, which may be moved ſucceſſively by the lower wheel, equally or unequally, according to the proportion of the quantity of water, or the magnitude of the little veſſels; for this will be very commodious, as if the water be to aſcend higher, we add to the Engin one, or more wheels, if not ſo high, we take away the ſame, making no mutation or alteration of the Crowns, or Veſſels; moreover the veſſels of both

crowns

crowns may be always equal, and yet the water may afcend to divers heights, the lower crown remaining the fame and not altered, by only changing the magnitude of the upper crown; for as is faid above, if the water ought to afcend 4 times as high as is the defcent of the other, 'tis fufficient that the crown of the upper wheel be 4 times greater, or fomwhat lefs; and the upper wheel G I, muft in like manner be 4 times greater than the lower, or little more; for fo the upper wheel will be moved 4 times flower, and will raife a fourth part of the water, the crowns, or chains, of both veffels being equal.

Likewife the Wheels and Axes may be multiplied together with wheels annext, and the chains, or crown, of veffels, fo that one be put upon another; for we may make another wheel to exift on the Axis D E, which may be moved by the middle wheel G I, and furnifh it with a wheel, and a chain of fmall veffels defcending into the Ciftern B, and drawing water from thence; moreover that water now raifed into B, may from the crown, or chain H I again be raifed either all, or at leaft, part of it into another Receptacle, or Ciftern, higher, and from this into another as high as you pleafe, all which we leave to the will of the induftrious Artificer, fince we have fhewn fo many ways, it may fuffice.

Engin XI.

To empty ftanding Waters.

Fig. 107. A is a long jagged wheel joined together with ftrong pieces of Timber, defigned for the drawing off, or draining of water; the length may be made at pleafure, according to the proportion of the breadth of the water, alfo it may be made fo broad, that the whole Semidiameter from the Circumference to the Axis be immerft in water, yea, the Circumference may touch the bottom, for as much as the moving force of the wheel may be increaft as you pleafe, and as need requires.

From this wheel A, the Leaver B paffing through the wheel, and the water extends to the Earth, or Shoar, where is erected a wooden receptacle C C; the wheel D is adjoined to the
leaver

leaver B, which comprises the wheels E and F, and these the wheels G and H, and these the wheel I.

The leaver of the wheel I reaches to K, where it hath a strong Iron Ring put about it, which is furnisht with holes through the Circuit, and stands out towards L, that it may receive L within it.

L Q is a Cylinder, whose end L is furnisht with a like Iron Ring bored through in the Circuit, only 'tis a little lesser or straiter than the ring K, that it may be thrust within it, after that the said end L is put within the ring K, both the rings are firmly bound by Wedges and Hooks of Iron driven in through each corresponding hole, that the Cylinder L Q, together with the leaver K, may be turn'd about: In M are Wedges, and Hooks of Iron, which are join'd to the two said iron rings K and L, and made firm, that the axis K and the Cylinder L may be turn'd together, the rope that draws is folded about the Cylinder L Q, which must be lengthned that it may pass above the wheel or pully N; to the rope is hung the weight O, of as many hundred pounds as you please, or necessity requires; this weight, while the rings K and L are firmly joined, turns about the wheel I, and this the middle wheels H and G, then E and F, and at last D and B.

The weight O, how great soever it be, after that 'tis turn'd about with his rope, it may be raised again, or by a man only, it may easily be done with the Engin called *Pancratium* P. which that it may be done, 'tis necessary that the end Q of the Cylinder L Q be not round, but square like the end of a spit, which being turned round, the little Engins are turn'd about, and 'tis bored through that it may receive a Nail, or a Wedge, but the end of the Axis of the lowest wheel of the *Pancratium* ought to have a square hole which agrees with the said end Q, that this may be put into that, and fastned with a Nail, or made firm with a wedg after that manner, that a Spit is thrust into the hole of the round machine, or wheel, that turns the Spit.

Then when the weight O is drawn to, I take away the wedges and hooks M, from the rings that are conjoined to K and L, that L may be freed from K, then I apply the *Pancratium* to the square end Q, and turn about the handle of the *Pancratium*, which when done, the wheels I, H, G, &c. rest, but the weight O is raised, and the leading rope is turn'd about the Cylinder L Q.

After

After that the weight O is raised, join again and make firm one within another the rings K and L, but remove the *Pancratium* from Q, and the weight by its descent will again turn the wheels I, H, G, &c.

From whence it appears, that the chief Artifice is placed in this, that as great a weight as you please may be applied instead of a power, by means whereof while it is moved very slowly, it effects a swift motion in the extream wheel of the Engin; and again, by applying the *Pancratium* P to the Engin, whose Fabrick is declared above.

But because perhaps it requires as much time to raise the weight O with the *Pancratium*, as is that wherein the same weight descends, and therefore great part of the Engins time is lost by this effect; therefore I advise to dispose another Axis T V upon the Axis L Q, and in the mean time while the weight O descends, and the Engin performs its effect, the same *Pancratium* being applied to the Axis T V, may raise another weight X, to be applied again presently to the Engin, as the weight O comes to the bottom, to be taken up again by the same *Pancratium*, while the wheels are turn'd about by the other weight; for so the Engin, or Machine, will never cease from motion, besides that little time wherein the rope being loos'd from the weight, is again turn'd about the Axis L Q, and the fastning it to the other weight now raised above; yea, those iron Rings and Wedges will not require to be used, if so be you can use one continued Cylinder only M L Q, to which the rope may easily be wound about, since this will be free from the weight; Or likewise a double rope may be used, one of which without weight (or at least but a little) may be wound about the Cylinder, while the other is roled and drawn downward by the weight.

This Engin if it be made after the foresaid manner, it will be indeed more simple and easie, and serve for many other uses; as for Example, the lower wheel B will easily be applied to a vertical wheel, which will likewise turn about swiftly a hand mill; in like manner there may be added to the Axis B D, pins to take up Pestles, wherewith mineral Veins may be pounded, or Gun-powder, &c. as is declared before, also there may be many other wheels to turn about to wind silver Thred, and other such like, as will appear to the Confiderate.

Engin

Engin.   XII.

*By whose means the water always ascends to any given height,
supposing also it be but a small stream of water, so it be
but constant.*

Fig. 108. L Et there be a large Receptacle, or Cistern A B, in-
to which the water constantly flows through
some Channel, or Pipe C, below that cistern make two other
cisterns G H, and X Z, in two several places of sufficient big-
ness, according to the proportional quantity of water, which
must descend by turns from the cistern A B, into those two
lower cisterns, as will appear by and by, and for that cause the
Tubes F G, must descend from the bottom of the cistern A B, in-
to the cistern G H, and Y X into the cistern X Z, and these
cisterns must be furnisht with a cover, and the cover must come
close to the side, for they ought to be every where close and
shut, but the cistern A B must be open; those Tubes upon the
bottom of the cistern A B, must have flaps E and D, so that
their mouths may be shut or open: The cistern G H will need
another Tube in its lower part, furnisht likewise with the flap I,
and the same must be as near as may be of the magnitude with
the Tube F G and Y X; the same must be performed in the o-
ther cistern X Z, which in like manner must have the like Tube
Z furnisht with a flap.

Through the cover of the cistern G H, a small hole being
made, descends a rod of mettal O M fitting the hole, to whose
lower part the brass vessel M is soddred fast being inverssed, to
wit, so that the open part of the vessel, or bucket, look down-
wards, and to the other end of the rod O, is fastned the arm
O N, which is so posited in N, that it may easily be moved up-
wards or downwards; to the same little arm O N is affixt such
another like rod, which descends in the same manner into the
lower cistern, and sustains the weight L within the cistern; fi-
nally, that little arm is furnisht with a little wing *a*, hindering
its coming upwards, and 'tis intercepted with a double staff,
or spear, or between the notch P N, 'tis interrupted by the
little arm *b* a thwart; this kind of staff, or notch, on its up-

per

per part P, is faſtned to another ſtaff or leaver P Q V, and to the ſame leaver in Q, is knit or faſtned another rod I Q R, by whoſe means the flap I is opened and ſhut: Furthermore the leaver R S T is moveable about the centre, by help whereof while the flap D is lifted up or opened, the other flap E is depreſt and ſhut, and *vice verſa.*

Theſe things being thus diſpoſed, that ſome determined part of the water which deſcends into the Ciſterns G H and X Z, may aſcend again to any given height, (as for example) into the upper ciſterns A and B; above the ciſtern G H make another veſſel, or ciſtern C E, yet ſo, that it may be ſomewhat lower than the ſuperficies of the water that is in the ciſtern A B, and let it be cloſe ſhut every where that no air enter in. Through its bottom, and through the cover of the ciſtern G H, let the Tube C H deſcend reaching almoſt to the bottom of the ciſtern G H, and almoſt touching the cover of the ciſtern C E. Then from the ſame veſſel C E, muſt aſcend two other Tubes into another veſſel like that before, to wit, the Tube E F, which almoſt touches the bottom of the veſſel C E, and the cover of the upper veſſel D G; and the Tube C D, which aſcends from the cover C of the lower veſſel, almoſt to the cover of the upper veſſel in D; altogether in the ſame manner, two other Tubes G A, D H, muſt aſcend from the veſſel D G, into the veſſel H A. Laſtly, in the uppermoſt veſſel A H, which much be open without a cover, fit a *Scyphon* A P, through which the water is derived, or conveyed, into the ciſtern P Q deſigned for uſe.

Above the ciſtern X Z, in the ſame order muſt be placed ſo many, and altogether the ſame veſſels furniſht with the ſame Tubes.

Then from the ciſtern A B, by opening the flap E F, the water flowing into the lower ciſtern G H being cloſe ſhut, 'tis compell'd by the compreſt Air to aſcend through the Tube A C, into the upper veſſel C E, the Air being excluded in the mean while from it by the Tube C D. But in the ſame time in which the veſſel C E, is fill'd with the Tube A C, its breadth being leſs than the breadth of the Tube F G, the water always fills the ciſtern G H, and forces the inverſs bucket M to aſcend, until at length by means of the leaver, or arm O N, hitting againſt the little arm *b*, raiſes the ſtaff P N, and the ſame work interpoſing P Q V, opens the flap I, and ſhuts the flap Z, and likewiſe by means of another leaver R T S, the flap E is ſhut, and the flap D opened,

pened. Then from henceforth prefently the water from the ciftern A B, begins to flow into the other ciftern X Z, and from thence afcends and fills the upper veffel L, and at the fame time by opening the flap I, the receptacle G H is emptied of all the water, and therefore the inverfe bucket M defcends again, and the weight L in the middle, and the wing *a* draws down again the ftaff P N, and fhuts the flap I, and opens the flap Z; and likewife fhuts the flap D, and opens the flap E, that the water may again flow into the receptacle G H; then by condenfation, or preffing of the Air interpofing, the water which now fhould afcend into the veffel C E, is forced to raife higher into the veffel D G, which being filled, they prefently change turns, and the flaps Z and E are fhut, and I and D are opened, and fo the water afcends from the veffel L into the veffel M; this in like manner being fill'd, the flux of water is changed, and the water afcends from the veffel D G, into the uppermoft veffel A H, afterwards from the veffel M, into the veffel B, while in the fame time the veffel A H is emptied by the *Scyphon*, the water flowing into the common receptacle Q P; then again the veffel C E is fill'd, and after that the veffel L, and in the fame order alternately new water afcends from one veffel to another, as often as the flaps change turns, being fometimes open and fometimes fhut.

Where 'tis manifeft, if the veffels be increafed one above another, the water will be forced to any height although but flowly; and the forefaid veffels ought to be fo far diftant from one another, that the height of one above the other, doth not exceed the height of the receptacle, or ciftern A B, above the cifterns G H, Z X, or the perpendicular altitude of the fall of the water which we conclude to be conftant. Moreover the Tube C D ought to be fitted with a flap, or thin board in C, fo that when the veffel C E is filled with water, the flap or board may fhut it, that the air break not out through the Tube into the veffel above, for fo this air being compreft, forces the water from the veffel C E to afcend into D G; I fay, the fame of the Tubes C D and D H, &c. alfo this artifice may be otherwife difpofed, as fhall feem meet to the induftrious Artificer.

Mechanick Powers.

OF
CIRCULAR MOTION.

BOOK. VIII.

PROPOS. I.

Of mix Motion from Circular and Right, or from two
or more Circular.

WHile a Wheel is moved upon a plane superficies, I say, the
same of a Globe, or ball, the central point only of the
Wheel, or Globe, is moved with right motion, all the other points,
or parts of the moved Wheel, or Globe, are moved with a mixt
motion of circular and right.

This motion of rotation on a plane hath admirable properties
throughout, which being rightly percieved, it will be easy to
understand the other mixt motions: Wherefore we make a
beginning from it ; but yet we first advise that circular motion
truly and Physically consists of many right lines, nevertheless
in this place we will consider it even as if it were altogether
simple motion, but where it will be needful to consider those
small parts of right motion of which circular motion is com-
pounded, there we will make particular mention.

Fig. 109. Let then the Wheel, or orb, be A Z L Q, insisting
on the Plane A D on which it is to be roled, or turned, and let
the right line A D be equal to the arch A Q. so that while the
Wheel is moved towards D, the point Q may touch in the
point D: In this motion 'tis manifest, First, that the Centre of the
Wheel O is moved by the right line O E, for since the Wheel
always

always touches the plane in some point, and the Centre O is always equally diftant from the points of the Periphery, which fucceffively touch the plane, the Centre O will always be in the line O E, and when Q is come to D, the Centre O will be in C, and the Centre O always infifts perpendicularly on the point of Contact.

Secondly, 'tis manifeft that any other point is moved with a mixt motion; for if, for example, we take the point L, over and above the motion of the centre 'tis moved towards Y, fo that if the Wheel fhould not be turn'd about the Centre O, but only moved upon the plane, always touching the Plane A D in the point A (which is to move only by the motion of the Centre) the point L will be moved by the right line L Y, and while A is in D, E will be in Y, O will be in C, and fo any other point of the Wheel will be moved by a right line parallel between the extreams A D, L Y. In like manner, the point L, or any other, will be moved only by a circular motion, if the Centre of the Wheel O be altogether immovable, to wit, L will be moved by the arch L K *e*, *&c*. A, by the arch A T, *&c*. alfo the point N will be moved by another arch of a leffer circle, *&c*. Since therefore the Wheel is moved together by the motion of the Centre towards E, and by the motion of the Orb from L in Q and from Q in A, *&c*. the point L will be moved with a mixt motion from both, to wit, of the Centre, and of the orb, that is, of right and Circular; which may be faid of any other point, the centre excepted.

PROPOS. II.

Any point, except the Centre of the forefaid Wheel, or globe, defcribes a crooked line, which is not circular.

Fig. 109. FOR example, take the point L, and that you may get the line which it defcribes, divide the arch of the quadrant L Q in as many equal parts as you pleafe, fup-pofe three, L K, K A, H Q; alfo divide the line of the plane A D into fo many equal parts, to wit, three, then the point L having paft over the firft part of the arch L K, if it were moved only by the motion of the orb, it will be in K ; but

if

if it were moved only by the motion of the centre it would be in V, therefore let the right line M I be parallel to L Y, and let K I be equal to L K, or A B, without doubt the point L will be in I; For the motion of the orb gives L K, or M K, but the motion of the Centre gives L V, or K I. In like manner, in passing over the arch K H, the same point L will be in G, if you take H G equal to A C, or L V, and parallel to L Y; For the motion of the orb gives L H, or N H, and the motion of the centre gives A C, or L V, which is equal to H G. Lastly, in passing over the arch H Q, the point L will be in E, to wit, if Q E be taken equal to A D, or L Y, for the motion of the orb gives L Q, or O Q, and the motion of the Centre gives A D, or L Y.

Secondly, take the point A, and that you may have the line which it describes, divide in like manner the arch of the quadrant A Z into 3 equal parts, to wit, in T and Y, then in passing over the arch A T, if the point A be moved only by the motion of the orb it will be in T; but if it be moved only by the motion of the Centre it will be in B, therefore if you take T S equal to A B, the point A will be in S. In like manner, in passing over the arch T Y, if the point A should be moved only by the motion of the orb, it would be in Y; but if it should be moved only by the motion of the Centre, it would be in C, wherefore if you take Y R equal to A C, it will be in R. Lastly, in passing over the arch Y Z, it will be in P, if so be you take Z P equal to A D.

From hence it appears, that those are *Curve,* or crooked lines, and yet not circular; wherefore some call them by a proper word, *Whirling-lines;* you may call them as you please.

Also by this you see that the point L, which is opposed to the point of Contact A, is so moved, that the motion of the orb, being added to the motion of the Centre, for each motion is in the antecedent, but nevertheless the point of contact A, is so moved that the motion of the orb is taken away from the motion of the Centre; for the motion of the Centre is in the antecedent, but the motion of the orb is in the Consequent, notwithstanding because the motion of the Centre, is greater than the motion of the orb; it follows, that the point A Simply and absolutely will be moved in the antecedent, to wit, towards D, neither will it wholly go back; to wit, it will be moved towards D, only so much as is the difference X S, be-

tween the motion of the orb A T or K T, and the motion of the Centre A B or S T.

Also take notice that the point L descending in the arch L Q, will be so moved that the motion of the orb adds to the motion of the Centre, the right sines of the arches it passes over. So the motion of the orb L K, adds the right sine M K, to the motion of the Centre K I or L V; and the motion of the orb L H adds the right sine N H, to the motion of the Centre H G or L V, &c. But nevertheless the point A opposite to the point L, to wit, the point of Contact with the plane is so moved in the arch A Z, that the motion of the orb takes away the right sines of the motion of the Centre, so the motion of the orb A T, takes away the sine T X from the motion of the Centre T S or A B, to which T S is equal. But now the point Z is so moved through the arch Z L in ascending, that the motion of the orb adds the versed sines to the motion of the Centre; thus the motion of the orb of the arch Z d, adds the versed sine Z e, to the motion of the Centre D F, wherefore if you take D f equal to A B, the point Z in passing over the arch Z d will be in f, likewise in passing over the arch Z b, it will be in g, for the motion of the orb adds the versed sine Z m, to the motion of the Centre A C, equal to which b g being taken, and in running through in the arch Z L, will be in Y, for the motion of the orb adds the versed sine H O to the motion of the Centre L Y; moreover the opposite point Q so descends through the arch Q A, that the motion of the orb takes away the versed sines from the motion of the Centre; so in passing over the arch Q n, the versed sine Q t, is taken away from n r, which is put equal to the motion of the Centre A B, and so the point Q will be in r; but in passing over in the arch Q p, the point Q will be in B, to wit, p b being taken equal to the motion of the Centre A C, for it takes away the versed sine Q I; Lastly, in passing over the arch Q A it will be in D, and so the versed sine Q O will be taken away from the motion of the centre A D.

Hence you easily see the description of lines, which each point of a circle runs over being roled, or turned, on a plane. Also you see the line which the point L describes in descending, that is to answer the line L I G E, and is equal to the line Z t g Y, described from the point Z in ascending; and the line A S R P described from the point A, answers, and is equal to the line Q r b D,

described

described from the point Q, that ascending, but this descending.

Hence also it is that the points L and Z are moved most swift, but the points A and Q most slow; and the point L is moved Swifteft of all in the beginning, afterwards more slowly: But the point Z by inverse proportion is moved slowly in the beginning, and succeflively more swift. In like manner the point A is moved slowest of all in the begining, afterwards succeffively more swift, but the point Q by inverse proportion is moved more swift in the beginning, and in the end most slow. Wherefore all the points indeed are moved with unequal motion, while they run over the quadrant; but the whole quadrant being compleated, the motion of the point L, and of the point Z come to be equal, so also the motion of the point A and of the point Q.

Moreover you see the Centre O to be moved swifter in the beginning than the point of Contact A, but in the end more slow, and the space which the point O difpatches from O in C, is greater than the space which the point A difpatches from A in P.

Also you see that no point is moved with an equal motion, except the Centre, but by an accelerated or a retarded motion; so that from two oppofite points one is moved with an accelerate, motion, as the point A, but the other with a retarded motion, as the point L.

At length if you take the point B 45 degrees, that is, which difpatches the greateft fpace of all, for the motion of the Centre O S equal to A D, is added to the motion of the orb from B in Q.

Fig. 110. Thirdly take a point within the Circumference, fuppofe the point F: And that you may find the line which it defcribes, make the Circle F 4, G 9, and divide the quadrant F 4 into 3 equal parts marked in the points 2, 3, Then while the motion of the orb comes to 2, the motion of the centre A B or 2, 5 is added to the fine 2, 1 of the arch F 2: In like manner while the motion of the orb comes to 3, the motion of the centre A C, or 3, 6, is added to the right fine H 3. Laftly while the motion of the orb difpatches the quadrant F 4 and comes to 4, the motion of the Centre Q 7, is added to the right fine Q O, and defcribes the line F 5, 6, 7: In like manner, by what hath been faid, you may eafily find the other

lines

lines which the other points of the same lesser circle contain'd within the greater describe. So the point 4 describes the line 4 M N P, while the versed sine 4 R is taken from the motion of the Centre A B or L M; and the sine 4, 5, from the motion of the Centre A C or T N; and lastly the versed sine 4 O from the motion of the Centre A D or G P.

PROPOS. III.

A lesser Wheel included in a greater is so moved, that in it the motion of the Centre is greater than the motion of the Orb.

FOR while the motion of the Orb is made through the whole quadrant F 4, the motion of the Centre is made through the whole right line O V, which certainly is greater than the arch of the quadrant F 4. In like manner the motion of the orb through the quadrant 4 G, is less than the same motion of the Centre O V; But how each point of the quadrant 4 G answers each point of the plane G P, upon which the quadrant of the lesser wheel is understood to move, when the plane is greater than the quadrant, is that famous difficulty which obtains the name of *Aristotle's* Wheel, because *Aristotle* hath proposed it in his 24*th.* question of *Mechanicks*, which *Blancanus* hath explicated, and *Mersennus, Galileus, Cabens, Fabrus,* and others have exposed to view.

PROPOS. IV.

The difficulty of Aristotle's *Wheel, that is, the motion of the lesser Wheel when this is directed by the motion of the greater, and the motion of the greater; when this is directed by the lesser, is best solved and unfolded from the nature of this Circular motion, so far as Physically 'tis compounded of many right lines.*

LEt the Wheel be A C H insisting on the plane C E, whose radius is A C, and within this another lesser, suppose it subduple, A D B is included, whose radius is A B; and let the plane

plane C E be equal to the arch of the quadrant C H, so that while it is turned upon the plane C E, each point of the arch answers each point of the plane; When therefore the lesser Wheel in this motion is carried away by force by the greater, surely the point D will come to F, when the point A will come to G, that is, the radius A D will meet with G F.

Therefore the whole difficulty will depend on this issue, that B F will be double the arch B D, if so be the points of the arch B D ought successively to correspond with the points of the plane, or of the line B F, or each point of the arch B D answers each point of B F, or each point of B C answers two of B F, or the altern points B F by skips remain wholy untoucht; for neither doth any thing else seem to remain which can be said, in truth none of these ought to be said: For if it be said in the first place, that there is so many points in the arch B D, as there are in the line B F, which cannot be said, since this is doubly greater than the arch: But if it be said secondly, that each point of the arch B D corresponds to two points of the line B F, it follows that the plane C E, is double the arch C H, when notwithstanding they are supposed equal; for when the points B C, are in the same radius A C, if the point C touch the point of the plane next following towards E, it will not be perpendicular to the plane C E. Surely A B when it touches the point of the plane B F in B, and is perpendicular to the plane, also A C which is supposed a right line will be perpendicular to the plane C E, which is parallel to the plane B F: Therefore it toucheth not the plane in any other point than in C, which if it should touch it would be also in the other next following point; therefore every point of the arch C H, touches two points of the plane C E, therefore the plane C E will be double the arch C H. Moreover it cannot be said that the altern points, or every other point of the plane B F, are toucht as it were by leaps, and not the other intermediate points, for at the same time in which some point of the plane C E is toucht answering the untoucht point of the plane B F, some point of the arch B D without doubt touches the plane B F, therefore it touches the point of the plane B F, which corresponds to the point toucht by the greater Wheel in the plane C E, for if it should not touch the Centre A, ought to be elevated above the line A G, and consequently the greater Wheel will not touch the plane C E, which is against the supposition; therefore no point of the plane B F remains untoucht.

More-

Moreover this difficulty hath great force againſt thoſe authors who affirm that a body may be compounded of Mathematical points, whether finite or infinite, as may appear to the conſiderate, concerning which I ſhall ſay no more at this time.

Neither can it be ſalved by thoſe who admit proportional parts to act infinitly ; for while they ſay the point of Contact may be made in an undetermined part they ſpeak unconceivably ; for ſince the point of Contact is real and ſingular, I cannot ſee how it can be indeterminate, which if it be determinate, that is, in this place and not in another, than it becomes determinate in this part, and not in another ; moreover 'tis ſomething which touches diſtinct from all that which touches not ; but to touch, and not to touch, are contradictions, and how can that be ſomewhat indeterminate from all that it touches not ? Add, that there is no part in the plane B F, whether determinate, or indeterminate, which remains untoucht ; how then does each part of the arch B D anſwer each part of the Plane B F, when there are as many more in that, as in this ?

Some recur to the greater velocity whereby one Wheel is moved than the other, but if they ſpeak concerning the motion of the Centre 'tis falſe, for there is one and the ſame Centre A to each ; but if they ſpeak of the motion of the orb they do not evade the difficulty by that, for the queſtion is, why the arch B C although it be moved ſlower than the arch C H, nevertheleſs it is meaſured by an equal ſpace, which ſucceſſively touches the whole.

Father *Faber* recurs to the incommenſurability of the plane, to wit, of a right line with the arch of a Circle, for he ſays, that although the right line C E be ſuppoſed equal to the arch C H, notwithſtanding they can by no means agree, howſoever they are divided ; but I ask whether they conſiſt of an equal number of points, ſurely ſince they are equal, they muſt at leaſt conſiſt of an equal number of points, to wit, of Phyſical ones ; or then all are toucht by the arch B D, or ſome remain untoucht, and ſo the difficulty returns : He ſays, the points of the plane B F are right, or ſtreight, but the points of the arch B D are crooked ; and although a right point be equal to a crooked point, and although one whole point is toucht by another point, yet notwithſtanding they are not toucht alike, becauſe the extenſion of the one is not analogous with the extenſion of the other, and he alleadges an example.

It may be objected against this explication in the first place freely, that each Physical point composing a Physical and real plane may be made ; B F is a right line, but each point composing the periphery of the Wheel, or the arch B D, or

Fig. 111. C H is crooked, for why cannot the same points of substance, or matter, which compose a superficial plane, compose a crooked plane? Moreover, when a rod of Iron, or a plate of metal is made crooked by bending, are there not the same points, if not more, in the crooked plane after bending, as was in it when it was a superficial plane? Secondly, also if we admit the points B F to be plane, and the points B D to be crooked, and so these touch not in an adequate proportion each point of the plane B F, nevertheless are there not little vacancies between one crooked point and another, which for that cause leave untoucht the points of the plane A, B, C, &c? Besides, that those crooked points touch not adequately, to wit, in all their virtual parts the plane points A B C, doth not cause that in each instant wherein the Wheel is moved by the motion of the orb, the new crooked point of the Wheel ought not to answer to the new point immediateatly next to that of the plane; if so be the point of the Wheel is equal to the point of the plane.

The same difficulties occur if the lesser Wheel be concieved to be so moved, that its Periphery be equal to the plane on which it infists; for then the greater Wheel will be so moved that its Pheriphery will be double of the other plane which it passes over ; as if the Wheel A B D be turned upon the plane B I, and since the arch B D is equal to the plane B I, the point D will arrive in I, for then the point H of the greater Wheel at the the same time will arrive in L, when notwithstanding the arch C H is as great again as the plane C L ; wherefore each point of the plane C L ought to answer to two points of the arch C H.

Besides in this motion, to wit, when the motion of the greater Wheel, is govern'd by the motion of the lesser Wheel, fomethings happen yet more fingular ; for in the first place, fome points of the greater Wheel go backward, as you may fee after, that the Centre of the Wheel A is come to K, and the point D is come to I, the point H will be in L, and consequently go backward: In like manner the point of Contact C goes backward after that 'tis come to M, and consequently

all

all the points of the Quadrant C H go backwards, but the middle point R, chiefly goes backward moſt of all, for it goes down from R to S as appears, but the other points go backward here and there leſs and leſs ſucceſſively.

Secondly, ſome points neither go forward nor backward, *viz.* in the end of the motion, when the point H comes to L, 'tis diſtant the ſame meaſure as before, from the ſame term, *viz.* from the line C N ; So the point X will be in Z, and the point Y will be in V, and ſo in the end the motion gains nothing of ſpace towards P ; notwithſtanding 'tis to be obſerved, that thoſe two points ſometimes go forward and ſometimes backward, ſo the point X in the beginning goes forward but afterwards goes backward, but the point Y in the beginning goes backward, and afterwards goes forward, but becauſe they go back the ſame ſpace as they go forward, they acquire no ſpace in the end of the foreſaid motion.

Thirdly, all the other points of the arch Y Q N X go forward, that is, in the end of the motion they have acquired ſpace towards P; ſo the point N will come to P, the point Q to O, the point T in *b*, *&c.* nevertheleſs all theſe points go not always forward, as appears from what's ſaid in the 2 *Prop.* but becauſe they go forward more than they go back, therefore in the end of the motion, it appears that they have gone forward ; In like manner we will ſhew, that thoſe points which are in the arch X R Y, and which go backward, do not continually, or always go backwards, but their going backwards appears in the end only, becauſe they go back more than forwards.

Theſe things being noted and obſerved, it will not be hard to explicate all thoſe motions according to our doctrine; for to that which is the chief head of the difficulty, we ſay we ought not to conſider that mixt motion, to wit, of the point H (while the whole arch C H, paſſes over only the ſpace of the plane C L] as one only and ſimple motion, for it is really many and various, for as much as 'tis compounded Phyſically, of many right motions, to wit, 'tis compounded in the firſt place, from thoſe right motions which compound Circular motion, then 'tis compounded of thoſe and of another right motion, becauſe the Centre A, common to each wheel is moved : From whence it comes to paſs, that the point H, in the motion of the orb from H to C, while it goes backward

together

together alfo, while it goes forward, 'tis carried by the centre A, and as it were carried away by force towards P ; notwith-ftanding it doth not go forward and backward, in the fame Phy-fical inftant, as Father *Cabens* contends for in his book of *Meteors*, (for tis impoffible for the fame movent, to be moved by two op-pofit motions together) but fo that fome Inftants it muft go for-ward, and in others backward, which muft needs be faid of fome points, as X and Y, as we have obferved before, to wit, if the whole time, in which the point H is moved, from H going down to L, be fuppofed to be 12 particles, we fay, 'tis moved ; for example, 5 of thofe parts by a right motion from H, or from A in P, that is, by fmall parallel lines of A P towards P ; and the other 7 particles to be moved in the oppofite part in going backward, from whence it comes to pafs, that when the regreffion is greater than the progreffion, in the end of the motion the regreffion only appears, to wit, when it comes in L, and becaufe thofe particles of time wherein fometimes it goes forward and fometimes backward, in each fhort time are almoft innumerable and infenfible, becaufe of the brevity, and makes the progreffion and regreffion by turns, any motion and time being affigned will appear only in the end of the pro-greffion if it be greater, or only in the regreffion if the pro-greffion be leffer.

Hence you fee nothing hinders but that the points of the plane C L, are in number fubduple of the points of the arch C H, when notwithftanding that arch paffes over only that plane C L ; for by the method explicated by us, doth two points of the arch very well fucceffively touch one and the fame point of the plane, to wit, if in the firft inftant the point C of the arch C H, while the arch D is carried by the centre A, touches the point of the plane C, which in the anticedent inftant it touched not ; and in the fecond inftant, another point of the arch next to C, touches that fame point of the plane C, while the motion of the orb goes backward, and, as I may fay, creepeth upon that point C: Then again in the third inftant, the third point of the arch touches the fecond point of the plane, and in the fourth inftant, the fourth point of the arch creepeth upon that fame fecond point, &c.

But it may be faid that cannot be, becaufe the centre A ought to afcend upon the line P A, I fay, this is abfur'd, if the

motion

motion and the circle be confider'd Mathematically, but not if it be confidered Physically, for it afcends and defcends always infenfibly; and that by fome fmall part of the plane only, and the compreffion and tenfion of the wheel, without which it cannot be Phyfically moved upon the plane, as will clearly appear from what follows.

Therefore all occafion of Error proceeds from this, that they would apply to Phyfical motion and Phyfical quantity, a motion Mathematically confidered, or quantity and the nature of a circle, which is not given after a manner conceivable; moreover they confider the motion of the point H, by the crooked line from H in L, all one as if it were one only motion, when notwithftanding 'its manifold and divers; like as they confider, for Example, the form of mixt, as it were one fimple form diftinct from the forms of thofe Elements compounding the mixt, when neverthelefs 'tis not fomething abfolutely diftinct from them, but only in the manner as I fhall fhew in its place; wherefore alfo that mixt Motion may truly be confidered as one fimple motion by one only crooked line, becaufe the rectitude of the fmall parts of which 'tis compounded is not fenfible, like as the leaft particles of Elements are not fenfible in mixt; but notwithftanding 'tis truly compofed of the motion of the fmalleft right lines, fince in nature there cannot be given a motion perfectly circular, as is fhewn before.

PROPOS. V.

A Globe, or Wheel, while 'tis moved upon a plane, whether Horizontal, or inclined, is moved by a mixt motion of a circular and a right, and is determined according to a circular motion from the impediment which is in the contact of the plane on which 'tis moved.

Fig. 112. THat 'tis moved with a mixt motion, appears from what hath been faid; and that the circular motion about the centre arifes from the impediment in the point of Contact; to wit, from fome refiftance and rubbing of the plane is proved, becaufe the circular motion is not the natural by *Prop.* 4. Therefore it ought to arife from fomething without;

out; but circular motion as fuch, is caufed from impediment only fuccefively determining new *Impetus*'s by new tangent lines; but in our cafe when the centre is not impeded, but is alfo moved, it cannot be an impediment to the centre, nor to any thing that adhears to it, fince nothing there is without it, therefore 'tis impeded from the plane only. Secondly, 'tis proved, becaufe if any one pufh forward the Globe A by a pufh tending from C to D, in a line parallel to the plane B E, the Globe neverthelefs is turned on the plain while it goes forward in E, but 'tis rolled in vain, unlefs it fuffers fome refiftance in the contact B; for why is not the whole moved by a right motion, if fo be its *impetus* is impreft by a right line, and parallel to the plane B E?

You will fay 'tis eafily moved, if it be moved by the mixt motion, from the right motion of the Centre and the circular of the orb, but why is it moved fo eafily? Moreover the Centre A, doth not more approach to the Centre of the Earth, by this that the Globe is moved circularly, for 'tis always diftant to the Semidiameter A B, in the Horizontal plane B E: And the impulfe when it is by the right line C D, is eafier deftroy'd if the Globe be moved by the motion of the Centre, together with the motion of the orb, than if it be moved only by the motion of the Centre; yea, 'tis eafier deftroyed if it be moved by both motions than by one only; but chiefly becaufe the motion of the orb is not meafured from that *Impetus* by a right line, but only by the motion of the Centre.

You will fay, when it defcends by an inclined plane, it defcends eafily, if it be moved together by the motion of the orb: For fince in this cafe the Centre of gravity is without the line of direction towards the end of motion, 'tis determined from its Centre, or from its gravity to fuch motion.

I anfwer, neither in this cafe ought the motion of the Orb to move, if there be no refiftance of the plane, for the reafons are mufter'd up; for by this that 'tis moved with a circular motion, it comes not nearer the centre of the Earth, nor to the end of motion, for by how much the motion of the upper points are accellerated, by fo much the motion of the lower points are retarded by that motion of the Orb, as appears by what is faid; therefore fuch motion is in vain, when no impediment is taken away, for *Impetus* acts only to take away impediment, as is often faid; therefore if there be no impe-

diment

diment in the point of contact, why doth the Globe always insisting in the same point on the plane, creep not on the plane? Doth not the *tmpetus's*, whether they be violently imprest on the Horizontal plane, or by their natural gravity on an inclined plane, obtain their end in the same manner, yea, easier, as is said?

Surely if a Globe be stript of all gravity, and then receive some impulse from without by a right line, and should this Globe be in a vacant place, or in such a place wherein it suffers no resistance to motion, or no more in one part than in another, there would be no reason why it should move by the motion of the Orb, but it would be moved only by the motion of the centre, by a line determined from the imprest *Impetus*, whatsoever the same be, whether Horizontal, or inclined, or Perpendicular; for why should it rather move in one part than in another.

You will say from the foresaid Experiments, that while a Ball is thrown through the Air, 'tis moved with a double motion, to wit, of the Centre, and also of the Orb; and yet in the Air, there is no rubbing or scratching with the plane, nor no impediment; yea, it seems, if the resistance which is of Air, 'tis equal about the Ball, that therefore it should not move rather in one part of motion of the Orb than in another.

I answer, the Ball thrown is often so thrown, that at the same time wherein the *Impetus* is imprinted before 'tis separated from him that throws it, is not imprinted by one right line only, but many *Impetus's* are imprinted successively by many lines which compound some crooked line, for the Arm, or that which casts the Ball, while it casts it, is not moved by a right motion, but by a circular, that is, the Ball being separated from the Arm, while those *Impetus's* are propogated in it, and new ones produced by the same lines, the Ball must necessarily be turn'd round about its centre. Hence it is that oft-times also a Ball is a little turn'd about its centre, if it be cast by one continued impulse by a right line, as you may observe: Besides that 'tis always but little turn'd, because 'tis never made so Spherical and perfect, but the Air resists more one part than another; add, that if it be not truly Homogenious, or all alike, so that the centre of the figure altogether agrees with the centre of gravity, since it can scarce be cast by that precise line which joins each centre, if it be not cast by this line, and even,

fo that the centre of gravity be right before, and prefently is feparated from the Thrower, or likewife if it be let drop freely, and falls from on high, it turns it felf until the centre of gravity be placed in the formoft part of the line of Direction, and fo it contains the impetus of rotation which is likewife profecuted towards that part : And this is the reafon why things that are thrown, or caft through the air, are moved with a mixt motion of right from the Centre, and of mixt from the orb, and alfo of thofe that fall of their own accords ; hence a Cylinder whofe heavier part declines downward, while it falls of its own accord from on high, is not turned about the Centre, but fometimes about the axis, from the unequal refiftance of the ambient air.

PROPOS. VI.

In the defcending of heavy bodies on an inclined plane, or through the free air, the motion of the orb, hinders not the motion of the Centre.

'TIS proved, becaufe the impediment which determins the Circular motion in the Globe, is not in its Centre, but in the Periphery, to wit, in the contact with the plane. or in the contact of the ambient air in that part to which the air moft refifts ; and this impediment hinders indeed the motion of the whole Globe, and at the fame time determines in it the Circular motion ; but that circular motion hinders not, nor retards the motion of the Centre, which is like manner tends downwards, whether the Globe be moved circular or not.

Hence one impetus deftroys not another, unlefs when the impediment of the motion of the Centre deftroys the natural impetus, and the inclined plane, or the air while it hinders the motion of the Centre, and deftroys its natural impetus, produces according to the laws of reflexion another impetus by the tangent, and when this impetus produces fuccellively a new one by a new tangent, it makes the motion mixt, or really double, to wit, the motion of the Centre and of the orb.

And

And you may obferve in motion on an inclined plane, not only the motion of the centre to be accelerated, but also the motion of the orb, becaufe when the motion of the orb is produced from the impetus, by the reflection from the direct impetus, if the direct impetus which moves the centre be greater, the reflected impetus is also greater.

Also you may obferve in this motion all the parts to move with unequal motion, as may be gather'd from what has been faid ; from whence 'tis confirm'd again, that they are not moved by an intrinfick principle, for this would be alike efficacious, or powerful in every part and fo would produce an equal effect in them all.

Hence you may gather the reafon of the Experiments following, in which this mixt motion appears from the right and circular about the proper Centre, or Axis.

Experiment. I.

Play Boys make fhort darts with a point, in one end whereof there is a flit cut, and paper folded like a fourfold wing, and put into it, while this quavers, or fhakes, the point goes before, and the paper fo hinders the deflexion that 'tis the caufe that while the dart tends rightly to the mark, 'tis turned together about the proper axis : The reafon this, becaufe the air while 'tis ftruck by thofe wings, refifts the motion, which otherwife would carry the dart, by a right line, and it quavers to and again and hits on the fides of the Wings, and this certain reflection together with the dart, is converted into a circuit, fince this motion is eafy to the dart and hinders not the right motion ; the fame may be faid of an arrow.

Experiment. II.

The like *Phænomena* you may obferve in thofe flitting reeds, which Boys alfo play with, for they fix 3 or 4 feathers into wood, or a bony fheath, which while they ftrike the air, they force that wood or Cylinder to turn it felf about its proper Axis ; but if it be furnifht with only one feather, this circular motion will not be ; likewife if any feather be broke, or not enough fever'd from the other, the circular motion ceafes : But if the feathers are much fever'd from each other, the motion

is flower, *viz.* as well the right motion of the axis, as also the circular motion about the axis : And the feathers ought to be so fitted rising from the bottom to the top a little bent, and made crooked increasing the severing or parting : The reed or little Cylinder of wood always goes before in the motion, and the motion of the Axis ascends more swift, and the circular motion about the Axis less swift ; moreover after the ascent 'tis turned downwards, and the Axis descends with a flower motion than before it ascended, but with a swifter motion about the Axis : And the reed, or little Cylinder, ought to be short and weighty, especially in the end that goes formost, and the feathers must not be too long.

Like to this, is that motion, which boys running make with a double stick, furnisht with a veil, and as it were a little mill turning about the centre, which is fixt to the moveable Staff, or Stick, for those veils, while they run in the air concieve a conversion and circular motion, which is joined with a right motion.

The reason of this *Experiment* appears thus, in the first place, that reed, or little Cylinder, furnisht with feathers goes before with a right motion, because 'tis heavier and endued with a greater impetus, and therefore leads the feathers whose motion the air resists more ; and in resisting it comes to pass that they are reflected from themselves, and so turned about in a circuit together with the little Cylinder. From the air then reflecting, the impetus of the Feathers is imprinted successively by a new tangent, and from this impetus the feathers are turned about, and with the feathers the Cylinder, or reed, but the Cylinder, or reed turns not the feathers as a certain Author supposes, to wit, the right motion of the reed is not retarded immediately, but the right motion of the Feathers, which because they are light, have not sufficient Impetus to overcome the resistance of the air, but mediately and consequently the right motion of the reed is retarded, and determin'd to the motion about the Axis from the like motion of the feathers ; hence if by chance the feathers fall off from the Cylinder in the way, the Cylinder or reed makes a certain longer space, because it hath not the impediment of the right motion from the feathers, but as yet 'tis turned about its proper axis for some little time by the circular Impetus preconcieved, which is not presently destroyed.

Secondly,

Secondly, 'tis turned about the axis to that part, to which the feathers suffer the least resistance of air, for if the air should equally resist all, there is no reason why they should be turned rather in one part than another; hence they ought to be so fitted, that they may strike the air unequally; which will be if they are seperated or divided unequally, and then the motion about the Axis will be Swifter.

Thirdly, one feather only will not do because it hinders the motion but little, neither is there in it an unequal resistance of the air, of which I spake; wherefore there are required two feathers at least, but three are better, because they less hinder the turning about the Axis.

Fourthly, if the feathers are not seperated, the reed is turned about the Axis little or nothing, because the air resists them but little; but if they are much seperated, 'tis moved slower by the right motion, or Axis, but swifter by the motion about the Axis; notwithstanding if they are too much seperated, the motion also about the Axis is slower, because too much resistance of air retards or hinders each motion; wherefore the feathers ought to be so fitted, that they do not impel the air with their whole superficies, but divide it by the edge as it were to cut it.

Fifthly, if the feathers are fitted in a right manner that they be neither too much seperated, nor too close, but a little bowed, with a moderate and unequal resistance of air which their edges divide; then the motion of the reed about the Axis is not only swifter, but also the reed is projected further, because the feathers are more easily broke off from the reed, and a little resistance of air with some inequality suffices to the motion of turning about the axis, since this motion is easy.

Sixthly, It ascends swifter while 'tis extended, than it descends afterwards, as appears clearly; from whence that is confirmed which we have shewn before, that heavy things naturally descending do not increase with the same kind of velocity, whereby the velocity of the same things cast or thrown, decreases while they ascend, and although both in the ascent and descent, the reed, or cylinder, goes before the motion of the Feather; hence while it ascends, because the *Impetus* in the beginning is greater of the Feathers, which are flexible while they suffer the resistance of the Air, they contract themselves, whence it comes to pass that they cut the Air the easier, and

therefore

therefore the reed afcends the fwifter, but 'tis lefs fwiftly turn'd about the Axis; but while it defcends, becaufe it acquires a lefler *Impetus*, the Feathers make a greater fpreading that it may move oftner about the Axis.

Seventhly, If the Reed be lighter, it cannot contain fo much *Impetus*, which eafily overcomes the refiftance of the Feathers; wherefore that it may hold out at length, fo much *impetus* is required, that the Feathers cannot draw themfelves, unlefs from a great refiftance of Air they happen to be very much contracted, which while they are, it cannot be moved about the Axis.

Eightly, If it be longer, 'tis harder turn'd round the Axis, becaufe it eafily fhakes to and again; but the Feathers cannot together hinder the fhaking, and imprefs the circular *impetus* to the Reed fhaking.

Ninthly, If the Feathers are longer than needful, they hinder the right motion, or if they are likewife too broad, or too much feparated, or if they are too fhort, and much contracted, they are not determined to motion about the Axis, for the reafons affigned; wherefore care muft be taken, as well to the length as the breadth, and feparation refpectively to each other between themfelves, and to the gravity, or levity, length, or fhortnefs of the Reed, or Cylinder.

Tenthly and *Laftly*, the motion of the bearing, and about the Axis is mixt of a triple motion, one whereof is from the violent *Impetus* while it afcends, another from the gravity, and the third from *impetus* by reflected motion, fucceffively by divers tangents whereby the circular motion is effected; and from all thefe motions, refults the fpiral motion as is manifeft, and a fpire is conceived about a crooked Cylinder, which poffeffes the whole place of air, or the way which the Reed fucceffively Occupies.

Hence 'tis eafy from what has been faid, to determine the lines which are defcribed by each point of the Reed, and alfo of the Feathers; in which alfo fome trembling motion always intervenes.

Alfo a reafon appears of the motion of the double ftaff covered with the veil, which is turn'd about circularly, while in the interim 'tis conveyed by a right motion Horizontally by boys, as they run; alfo that motion is manifeft to be fpiral, which hath Spires more thick and clofe, in which 'tis moved

more
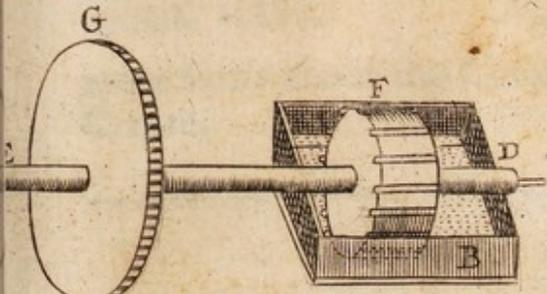
Fig. CVI.
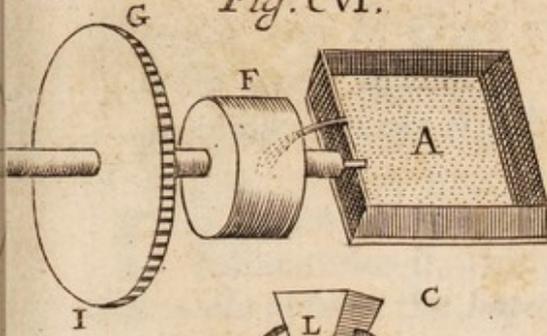
Fig. CVII.
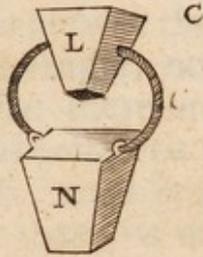
Fig. CVIII.
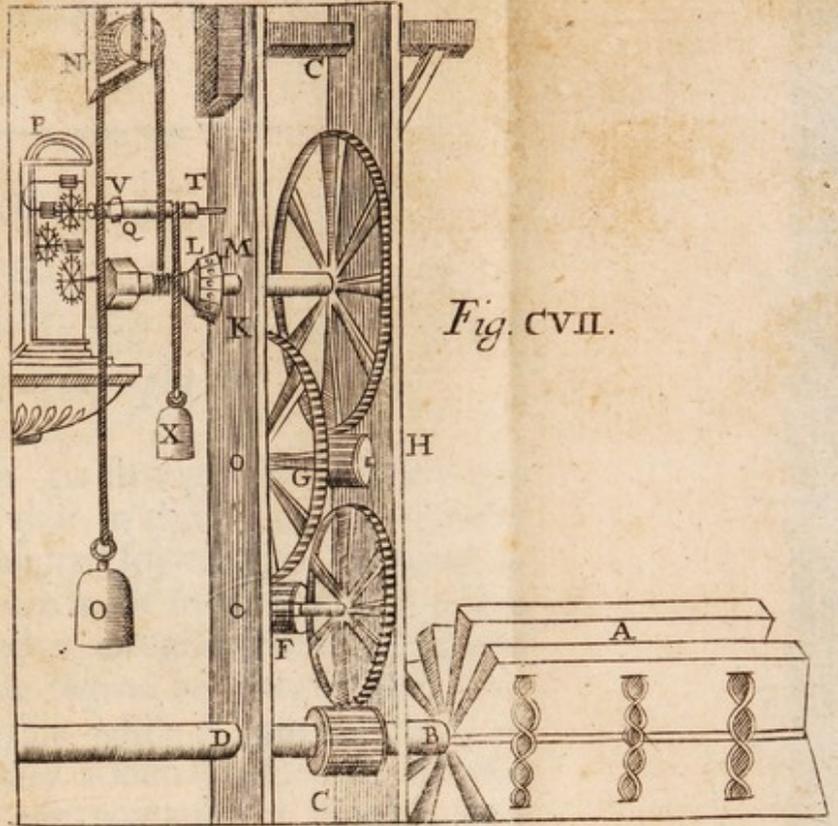
Fig. CIX.
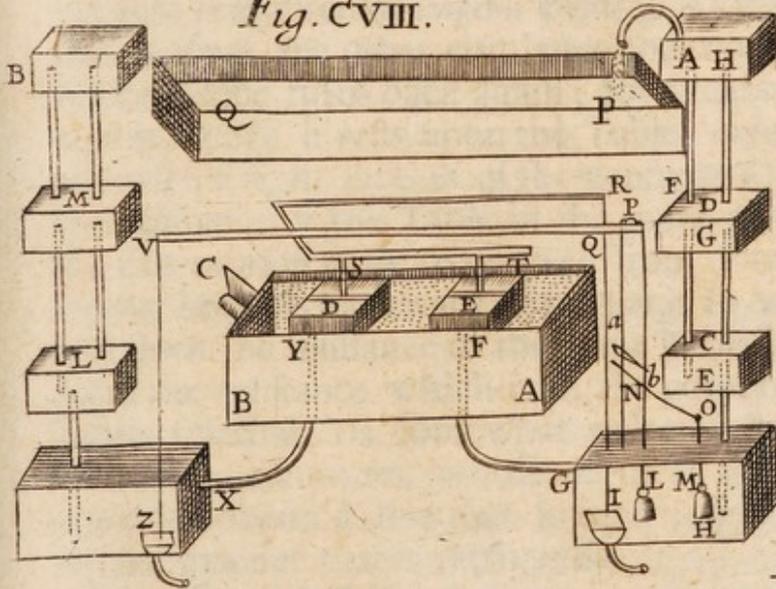
Fig. CX.
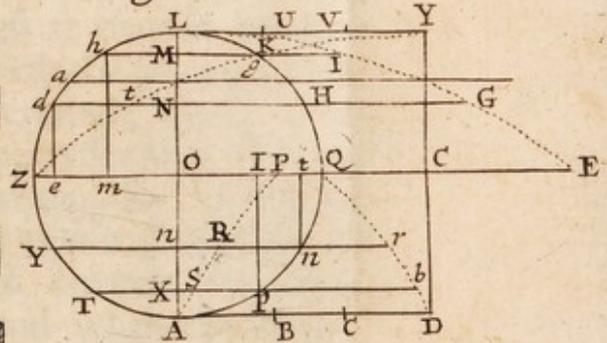
Fig. CXI.

Fig. CXII.
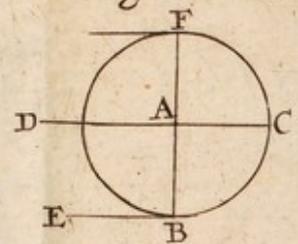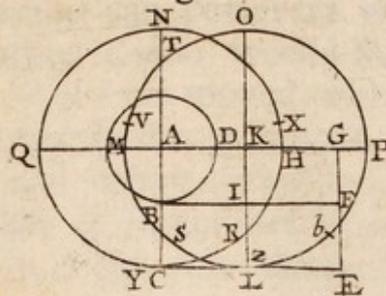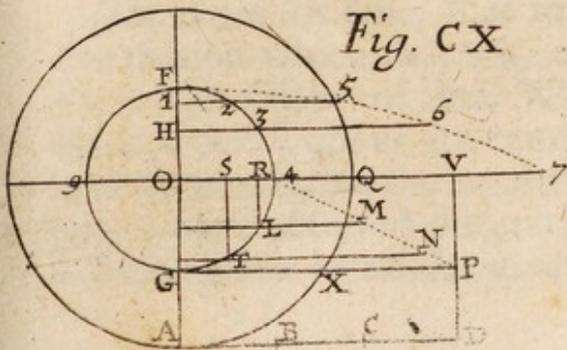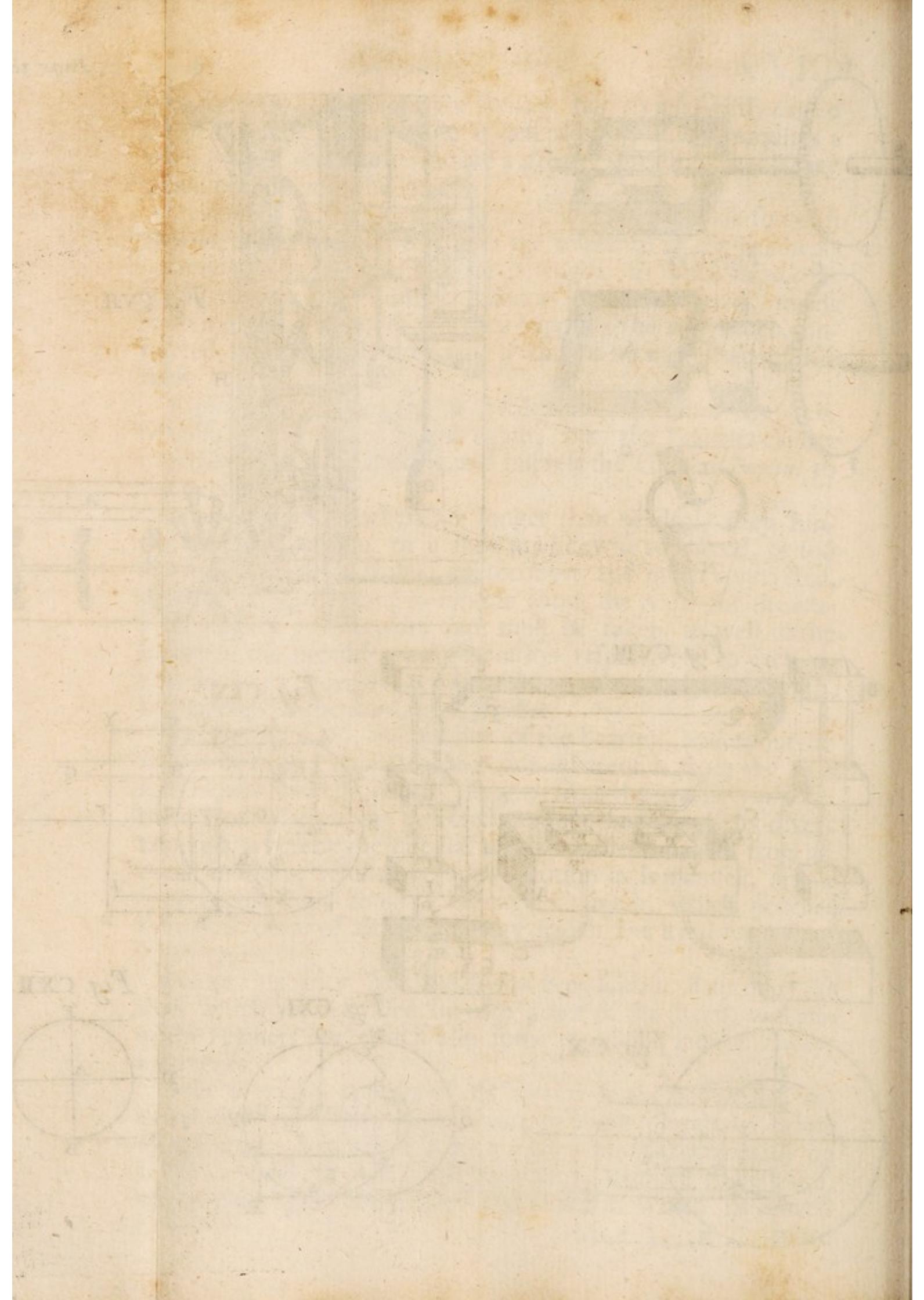
more fwift about the Centre, and flower by the motion of the Centre.

PROPOS. VII.

A reafon may be given why a little Wheel, or little Globe, being preft againft a Table, is firft thruft forwards, but afterwards turns it felf back again upon the Table.

THe reafon is, becaufe while 'tis ftrongly preft again the Table under it, this refifts that in the point of contact, and while at once the *Impetus* is impreft forward by the retraction of the Finger, new contacts are made in other points often times, that therefore it conceives a circular motion contrary to that whereby 'tis moved, if the *Impetus* be only impreft forwards Horizontally; hence 'tis, that while it runs forward, at the fame time 'tis moved circularly about the Centre, by the motion of rotation back again, *viz.* towards the Finger; and becaufe that circular *impetus* continues longer than a right one, this ceafing, the other continues and compleats its effect, and fo the Globe turns back again; for it cannot be turn'd about its centre, while it refts upon the Table, unlefs at once it be moved with a right motion of the centre towards the fame part by the refiftance of the Table in the point of contact, where you fee this motion truly to proceed from fome reflection, for the *impetus* impreft backward after that is fo weak (for 'tis weakned from the refiftance of the plane Table) that it cannot overcome the refiftance which is in the point of contact, from the Tables refifting 'tis fomewhat reflected, and when the circular *impetus* continues, whofe effect is eafily obtained, neither can it be obtain'd but that it muft role back again, therefore 'tis no wonder that it retroceeds.

Therefore 'tis falfe, that any *impetus* can perfevere without the motion which exacts it, as Father *Cabens* would have it; for a little Globe, or little Wheel, is always moved with a circular motion about its centre towards the extrudent, in the fame time wherein the motion of the centre tends forwards; yea, I have obferved diligently, that if fometimes one touch a Globe while it runs forwards, it will not role about its pro-

Per centre, but creep upon the Table, which it always toucheth in the fame point, then the Globe reflects not, nor goes back.

And 'tis to be obferved, that while the Globe tends forwards, the motion about the centre is weak and flow, to wit, becaufe the right motion upon the Table in a manner refifts the contact, for it drives out the motion about the centre into the oppofite part, to wit, forward; but the *impetus* ceafing, whereby 'twas moved forward, the impediment of the motion about the centre ceafes, yea, it acquires a new determination to this motion, to wit, from the reflection of the planes refiftance.

This reafon affigned by us, appears not only from this, that, as I faid, the Globe is not rolled back again, unlefs it be rolled about the centre alfo, in the fame time which it runs forward; but alfo from this following experiment.

Experiment III.

Fig. 113. Grafp the Globe A, fo with your Fingers about the Pole A, and the other oppofite to it, that you may imprint the circular *impetus* about thofe Poles, or about the Axis whereby 'tis moved from E through H to G; and at the fame time, caft the Globe through the Air, fo that it goes by the line E F C, and falls upon the Horizontal plane in B, if that motion about the Axis be fwift enough, either it will ftay in the point of contact B, and yet it will be turn'd about for fometime upon the Axis from C through D in B, or alfo many times 'tis reverted from B towards G upon the plane; where it appears, in fo much as the Globe is determin'd to the motion of roling back again upon the Table, or Pavement, after that 'tis caft or thrown forward through the Air, in fo much *Fig.* 114. alfo it hath the motion about the Centre, while it is borne through the Air; for from this it is that the *impetus* being deftroyed, by which it tends forward, while the Globe falls on the pavement, 'tis neceffarily from thence reflected back again. For the Globe projected in the Air, proceeds by the line A B C D, and in the mean while is turned from B towards C D about the Centre C, while it touches the Pavement E D in D, according to the laws of reflexion it ought to reflect in F, and preceeding further to the fame part

with

with fo much impetus as **D I**; but if that impetus be fmal (even as 'tis when the line **C D** comes near to the perpendicular **C L**) and the impetus whereby 'tis moved about the Centre be pretty ftrong, this prevails over that, and while it perfeveres the Globe muft needs role towards **E** upon the Pavement; hence it does not always go back, but only then when the motion about the Centre is fwift, and it falls upon the pavement by a line which approaches more to a perpendicular.

P R O P O S. VIII.

The motion of a Rope, or of a Ball, or Globe, faftned to the end of a Rope about a Cylinder, is a Spiral motion compounded of many Circular.

Spiral motion is divided into many kinds, one whereof is when the motion is made about the fame Cylinder, fo that the circles are always equal, and this is mixt of circular only and right: Such as we faid was the motion of the reed, or Cylinder, furnifht with feathers; and of the double ftaff provided with a veil, *&c.* and there is another Spiral motion alfo, which is made about the fame firm centre, but by circles or wreaths enlarged or leffened fucceffively more and more, or departing from, or approaching to the fame centre; moreover there is another Spiral motion, in which the wreaths are not only enlarged or leffened fucceffively, but they likewife retire from the former centre, to wit, it always changes the centre, and this is mixt of many circular, and of the right motion of the centre; but the fecond kind of Spiral motion is mixt of leffer circles only fucceffively; the firft **Fig. 115;** fpiral motion is fhewn by the figure **A B**, the fecond by the figure **C D**, the third by the figure **E F.**

These things being fore-known, if we confider the motion of a rope about a Cylinder, whether the rope be turn'd about by the Cylinder by circles, having divers centres in divers points of the Axis of the Cylinder, if it be, 'tis a fpiral motion of the firft kind; but if the motion of any determinate point in the rope be confider'd, as for example, the end of the Rope

or

or the Globe annext to the end of it, then either it may
so be turned about by the Cylinder, that the same centre al-
ways remains in the same point of the Axis, and then it ap-
pears, that since the radius is shortned successively, from that
Globe is made a spiral motion of the second kind, which is
compounded of circular motion only, for there may be per-
ceived so many circular motions, although not perfect, as there
are wreaths, or rather so many new determinations to new
circular motion, as there are conceived *Radius*'s one successive-
ly shorter than another ; or, it may be so turn'd about by the
Cylinder, that the centre is changed at once, and then the mo-
tion of the Globe, or the end of the Rope, will be a spiral mo-
tion of the third kind, such as may be conceived to be made
about the Cone E F, from F in E, which appears to be mixt
from a right motion of the centre, through the Axis of the
Cone, or Cylinder, and of many circular ones intelligible by
Sence ; for it cannot truly be said, that there are many circu-
lar motions, since none makes a perfect circle, yea, no part of
that spiral line is part of a circular line , but if it be taken as a
small part, 'tis a right line from what hath been said before ;
if as a compounded part, it consists of many right lines, *viz.*
of many Tangents, yet not of the same circle, but of divers cir-
cles as appears.

　　Hence 'tis, that if a Cylinder be thicker, and a Rope of the
same length being put on it, 'tis easier and with less imprinted
impetus turn'd about by the Cylinder; to wit, because the parts
of the circumference of the Cylinder are those which resist by
impulse by a right line imprest in the beginning, and by the im-
pediment, or a certain reflection, they determine to new and
new lines oftentimes; and by how much greater the circumfe-
rence is, by so much the less frequent is that new determinati-
on, as appears from what has been said, and so the lesser *im-
petus* is destroyed, as that which is moved by a greater circle
is less wearied or tyred.

　　Secondly, It appears why a Globe doth not ascend, nor is
turn'd about by a Cylinder, if the *impetus* be too weak in pro-
portion to the thickness of the Cylinder, or to the length of
the Rope ; for although it be so great that a right line could as-
cend to that height, yet while it often suffers resistance by re-
flections and new determinations, 'tis much abated.

<div align="right">*Thirdly,*</div>

Thirdly, if it be once turn'd about, it effects all the rest of the turnings about eafily, becaufe the circles are fucceffively leffened, and fo the motion is always leffer, when notwithstanding the former impetus perfeveres almoft the whole time: For if once the imprinted impetus decreafes lefs than the wreaths decreafe, one of the greater wreaths being finifht, the other leffer are alfo eafily and therefore fwifter accomplifht, and the velocity is increafed proportionally to the leffening of the wreaths, not abfolutely but comparatively to the remaining impetus, fince alfo here, as is faid, 'tis decreafed or leffened fucceffively, notwithftanding lefs than the wreaths; for if the wreaths and the impetus were leffened equally, the motion would not be quickned.

PROPOS. IX. *Fig.* 116.

If a Globe, or Wheel, be moved and turned about on a crooked fuperficies which is immoveable, it makes a mixt motion from a double circular.

LEt the crooked fuperficies be A B C, upon which the Globe B D is turned towards C; while the point E comes to F, the Centre of the Globe H comes to G. For the Centre alone is moved only by a circular motion through the arch H G I; but all the other points of the Globe are moved circularly by the motion of the Centre, and in like manner alfo by a circular motion about the proper centre, or axis.

But 'tis to be obferved, that this mixt motion may be confider'd divers ways, for the crooked fuperficies on which the Globe is roled is either convex, or concave; and again, the Globe is turned either on a greater circle, or a leffer, or an equal; if notwithftanding the Concave be equal or leffer, the Globe, or Wheel, cannot be moved, as appears.

Moreover, obferve that the Globe B D, whether it be lefs, or equal, or greater, than the Wheel, or crooked Superficies, on which 'tis moved, may be fo moved that the Line of the moveable Globe B E, which fucceffively touches the Circle A B C is equal to the Line B F, when the point E comes to F; or it may fo be moved that the line B E is leffer, or laftly, fo that it be greater than B F.

Thirdly,

Thirdly, the forefaid Globe may be underftood to move by the motion of the Centre towards C, and in like manner by the motion of the orb towards A, to wit, fo that the point B tends to E and D, &c. and in each cafe the motion of the Centre may be equal to the motion of the orb, or greater, or leffer.

Fourthly, Note, that if *Copernicus* his opinion be true, that the earth is moved with this mixt motion, to wit, by the motion of Centre through a circle of the greater orb about the Sun, and by the motion of the orb about the proper Centre; and the motion of the Centre fhould be greater than the motion of the orb, according to the common opinion concerning the Diameter of the great orb, which the earth runs through in one whole year: Where alfo obferve, that every point of the fame parallel Circle are moved with unequal velocity; for whether we fuppofe the motion of the orb and the motion of the Centre to be towards the fame part, fuppofe towards C, when the point E comes to F, and the Centre H in G, the point B will be in E, and the point D will be in L, wherefore the point of Contact B is moved floweft of all, but the oppofite point D fwifteft of all; that anfwers to the Nocturnal meridian, this to the Diurnal meridian. Or whether we fuppofe the earth to be moved by the motion of the Centre towards C, and the motion of the orb from B in E, D, &c. in this cafe the contrary happens, to wit, the point of Contact B is moved fwifteft of all, for it comes to L, and the point D floweft, for it comes to E; and thefe kinds of motion of divers points of the fame circle will be flower, or fwifter, according to the divers proportions of velocity of the motion of the Centre, and the motion of the orb, neverthelefs all will be by crooked lines, as appears by what has been faid.

Fifthly, after this laft manner, fome Epicicles are faid to move by Aftronomers, to wit, by the motion of the Centre to the Eaft, according to the Series of the Signs, or, as they fay, in the Confequent; fuppofe the Centre C towards A, and the Supream point, or the Planets *Apogæum* D, moved in the oppofite part from D in E towards the weft, and, as they fay, in the Antecedent.

But fince the forefaid motion may be divers according to the divers magnitudes, and proportions of the Circles, it appears neverthelefs from the doctrine deliver'd before, that the

lines

lines of all the points deſcribed by the motion of any circle, may be determin'd howſo'ver 'tis moved on one or another, which may be of great uſe in Aſtronomy.

PROPOS. X.

The Spiral motion of Sphæres may be explicated, to wit, when a Sphære is moved by a motion mixt of Right and Circular, or of two Circular ones.

Fig. 117. FOr in the firſt place, let the Sphære BC be moved by its centre A through the right line A H, and at the ſame time turn it about the axis B C ; moreover every point, except the Poles B, C, deſcribes Spiral lines, as if they were Spires, or wreaths, about divers Cylinders, about the greater Cylinder, truly the ſpire which it deſcribes is from the point F or G, but about the leſſer, which is deſcribed from the point, next to the Pole C or B. But if it be turned about the Axis F G, or any other oblique, it will be another divers mixt motion in divers points, whoſe lines may eaſily be found by the foreſaid doctrine.

In the ſecond place, let the point G be moved through the arch G C, and at the ſame time underſtand it to move about the Axis B C, it will be a Sphærical Spiral motion mixt of a double circular.

Thirdly, let the ſame point G be moved through the right light line G C, while 'tis moved alſo about the Axis B C ; the motion will be conicaly Spiral, mixt of Right and Circular.

Beſides the *Sphæric Spiral motion,* there may be made another motion *Conoid Spiral,* to wit, if a *Conoid* be turn'd about one, or about the other Axis, while its point is ſomewhat moved through a right line ; and 'tis of a threefold kind, *viz.* either *Elliptic,* or *Parabolic,* or *Hyberbolic,* as appears by *Geometry,* and from the *Mechanick* deſcription of thoſe figures.

PROPOS. XI.

In the motion of a globe upon a plane, a three-fold motion may conjoined, so that it may be mixt of a Right and two Circular ones.

THis experiment appears from the game at Billiards in players balls, for while the Centre is moved through a right line, and the other points about the Centre, suppose in a vertical circle, if the globe either by oblique reflexion, or by a new impulse, be never so little turn'd aside about the Horizontal, or other line, it concieves another circular motion also by that line, and so besides the right motion of the Centre there is a double circular. And from this appears the reason of the said plays; as for example, while the ball is moved by the right motion of the Centre, and by the circular motion of the orb together, if the Chord be toucht lightly 'tis turned a little aside and makes another circular motion, from whence it follows afterwards, that the leap decieves the player, because the new circular motion acquires a new determination in the reflection, &c.

PROPOS. XII.

A Globe, or such like body, insisting on a plane cannot move circularly about the Penpendicular Axis, unless at the same time it be imprinted by a double impetus in opposite parts. Fig. 118.

LEt the Globe, or Top, such as children play with of a Conoid figure be A B, resting on a plane in the point B, and you would have it move about the axis A B in an Horizontal circle C D : I say, it cannot so move, unless all under one it be imprest; or forced by a double opposite impetus, one, for example, in C towards the right hand, and the other in D towards the left hand part; the reason is, because if it be forced by one

impetus

impetus only it will be determined to one only right line, and since there is no impediment fuppofed, which may hinder the Globe that it fhould not be moved by that line, it will be moved by it, and fo be turned on the plane in the vertical circle A C D B, but the top will fall to that part towards which the impetus is impreft. But if at the fame time another impetus be impreft on the oppofite part, when thefe two impetus's are not by the fame line, but by two divers lines parallel to each other, either may have its effect by chance, and when one at once hath the reafon of the impediment with refpect to the other, leaft the Globe, or top, profecute the motion by right lines, 'tis determined to circular motion, for neither can thofe two impetus's obtain their effects any other way ; hence it is, that the top being taken by the head, or its end of the Axis A, and being caft off by the fingers in contrary parts we make it Spin, or turn in circuits; and it perfeveres this circular motion a long time, becaufe the impetus is not deftroyed by the weight fince the top is in *Equilibrio*, but the only by rubbing with the plane, and from fome refiftance which every moment changes the determination of the tangent lines; hence the fmoother the plane is, and the fharper the point of the top is, the longer time it fpins, or profecutes the motion.

But when we wind a ftring about the top, and retain the other end of it in the hand, and cafting it from us it fpins, then in like manner that double impetus happens in the oppofite parts; for not only while the ftring D E unfolds, doth it draw towards us the point D, but at the fame time with the fame ftring we throw the top from us like a fling; and the motion of the top endures longer being caft in this manner, by fo much as the impetus's are greater and the ftring the longer, becaufe a power applied remains longer, and while the projected impetus perfeveres the other impetus of the ftring being retracted in the oppofite part, and hindering the former impetus, gives many new determinations to new and new tangents.

While the top is caft, it makes a motion mixt from the right motion of the centre, and of the Horizontal circular, as appears, or alfo of another right motion which tends downwards.

Secondly, when it infifts on a plane, if the fame point on which it infifts be moved only by a circular motion about the axis, then 'tis faid to fleep, yet in truth the motion of the Axis is

but

but little moved about the Centre of gravity which is in the Axis ; but becaufe it either finds it on the plane, or makes hollow fome little trench of it felf, this trench detains the Axis, leaft it fhould go out of it, unlefs afterwards the Axis begins to incline more.

Thirdly, thereupon it moves always by a motion mixt of a circular about the Axis, and of a circular of the ends of the Axis, fo that alfo if any point of the Axis remain immoveable, yet the extream points of the Axis defcribe two circles, one in the plane, the other in the air above.

Fourthly, fometimes another motion of the whole Axis happens to the forefaid motions, which is carried about not in a perfect orb, but fpirally, the Spires, or wreaths, fucceffively more and more contracting untill it begins to fleep ; and this motion is always on that part to which the outer portion of the top by its motion is turned about the Axis ; to wit, becaufe this Spiral motion of the Axis is determined from the circular motion about the Axis ; you fee therefore many motions in a top, one about its Axis in an Horizontal circle, another of the fame Axis, and the Spiral of the Centre ; laftly, another of the turning round of its Axis about fome of its points, by which motion of turning or trembling the forefaid little circles are defcribed by the top and point of the Axis.

But the Impetus of the orb about the Axis ceafing after that, and the turning about and the inclination of the Axis prevailing, the Centre of gravity fo departs from the line of direction, that the Impetus of the orb cannot keep the Axis erect, the top falls ; and then becaufe in it there remains as yet much of the former impetus, it makes ftill fome oblique turnings or Circuits, which although they feem to be made in the oppofite part, yet they are made (if you attend rightly) on the fame part on which the circular motion about the Axis was made ; which when 'tis hindred by the contact of the Plane, therefore afterwards 'tis rolled about upon the Plane, and now is more moved by the motion of the Centre which before was hindred by motion of the orb, or that from this you may know the nature to be loved of the right motion of the Centre, but not of the orb about the Centre.

Mechanick Powers.

Of Circular Motion artificially fitted to Mechanick use.

BOOK. IX.

YOU shall scarce see any ingenious Engin in which either circular motion doth not appear, or at least that which may not be reduced thereto, notwithstanding in this place we shall treat only of those kinds of Engins, or Inventions, which immediately depend on the Principles, and Doctrine of Circular motion hinted at before.

Problem. I.

To make divers kinds of Wheels commonly used in Engins.

GEnerally we make use of two sorts of Wheels, one whereof is furnisht with teeth, and the other hath none; those that have none are single Wheels, and Pulleys, which are hollowed in the Periphery for the Rope to move in, as also Wheels with handles to turn them by: And the first sort of Wheels contains as many kinds, as there are various forms of teeth, which I think fit to describe in the first place, for the better understanding of what follows, and that any one may know how to make choice of those kind of Wheels which he esteems most fit for his occasion.

Teeth, or, as some call them, *Claws*, or handles turning round, their chief use about Wheels is, that they lay hold on, or bite each other, and being folded in each other they cause a reci-
procal

procal motion, and they are various as you may fee in *Fig.* 119. from whence the names of thofe wheels are divers.

A toothed Wheel is, that whofe Periphery fticks out with little handles endued with *Semicylidric* form, as in the arch A F, or a plain fided Prifme, as in the arch E F.

A Fingered Wheel is, that whofe Periphery is garnifht with plain Cylindrick fmall ftakes, as in the arch A B, or fomewhat like Cylinders, as in the arch B C.

A fharp pointed Wheel is, that whofe Periphery is cut in with little handles turning round like the figure of a point of a Sword, or of a tongue, as in the arch E D may be feen.

A Studded Wheel is, that in whofe Periphery little Sphæres, or Convex Hemifphæres are difpofed, or the Concaves are made hollow anfwering to the Convexes in the other Wheel, the firft parcel referrs to the arch C D.

A Starred Wheel, is that whofe Circumference is furnifht with three fided Prifmes having each fide equal, as in the arch G H.

A Snagged, or fawed Wheel, is the fame as the former, only with this difference in the former, the triangular fides of the Prifme are equal, but in this they are unequal, as in the arch G N.

A helical, or fcrew Wheel is, that in whofe circumference chanellings or grooves are made, according to the quantity of the angle of the Axis of the inclined wheel, whatfoever figure the fame hath, which neverthelefs are reduced to four kinds, *Semicylindric,* as in the arch A F, *Trigonal,* as in the arch G H, of four fides, as in the arch K L, *Trapezias,* or unequal 4 fides, as M L.

A hooked, or crooked Wheel, is that which hath hooks dif-pofed in its circumference, as in the arches H K, and N M, you may behold.

Alfo Wheels are named with refpect to the figure of their Wheels, let the teeth be what they will; for fome are called plain Wheels, or *Orbiculates,* in which the bafes of the *Cogs* or *Teeth* are all in the fame plane; others are called *Convex Cylindric,* when the *Cogs* are difpofed in the outer fuperficies of the *Cylinder,* or any circle thereof: Others are called *Concave Cylindric,* in whofe inner *Cylindric* fuperficies the fame *Cogs* are difpofed: In like manner fome Wheels are called *Convex Conic,* others *Concave Conic,* even as is faid of *Cylindric*: Laftly, a Wheel

a Wheel without teeth, and whose Periphery hath nothing sticking out, they call smooth or even.

Note, that all the kinds of teeth, or Cogs described, or any other such like, may be made, not only in the Periphery, or outermost superficie of the Wheel, but also in one or both of the lateral superficies, or Circular, or Cylindric bases.

Problem. II.

To apply Weights, or Powers (moving by their natural gravity) to Clocks, or other Engins.

ALmost all kind of Engins, which are moved by inanimate Power, are usually made with some Wheel, or Cylinder, to which a weight being hung, while it endeavours downwards by its natural gravity, it moves that Wheel, or Cylinder, and that puts the other parts of the Engin in motion, as appears in common Wheel Clocks : And weights may be applied to Wheels many ways, which we will unfold, before we proceed to the making of the Engins: The first way of hanging weights to common Clocks, or other Wheels, which by some determinate time, being placed in the middle and impelling, ought to turn them round, is, that one end of the Chord, or Rope, be fixt to the Cylindric Axis of the Wheel, and the other end sufficiently fastned to the weight, as you may precieve in the Figure: And in this practise you *Fig.* 120. must beware, that the Cylinder be not wanting to the rope, for it ought to have only so much length, that the whole Chord may be turned about it, for if the rope be twice wound about the same Cylinder, that is, if the latter windings of the Rope fall upon the former, it will come to pass that the formost motion (*viz.* while that part of the Rope descends which is wound about the other) the motion will be swifter than that of the latter, to wit, while the remaining part of the Rope descends which is immediately wound about the Cylinder.

The second way is, when weights are hung to each end of the Rope, as appears in the Figure: For the Rope A B C is put upon the Pully D, in whose Periphe- *Fig.* 121. ry there is a hollowing, or groove cut arching so that the Rope may lie in it, and recieve firmly in it the drawing

ing

ing force of the weight, and the weight A muſt not deſcen^d without turning the Pulley about, and conſequently raiſes th^e weight C.

In practicing this Artificers are commonly miſtaken, for ſome in the foreſaid hollowing of the Pulley D, make 6 or 8 ſharp points ſticking out to hinder, leaſt the Rope being drawn by the force of the weight A ſhould not turn about the Pulley.

But thoſe ſharp points render the motion of the Pulley, and ſo of the Clock, or other engin, altogether unequal ; others make the Cavity or hollowing of the Pulley narrower in one place, and wider in another, from whence it follows, that the Rope being unequally diſtant from the Centre makes the motion unequal.

Therefore if the Rope ſlips without turning the Pulley thoſe ſharp points may be uſed, but a greater number muſt be affixt, and they ought to ſtand out all alike, and equal upon the Periphery of the little Wheel; which may be performed more ſafely if you glew on ſome little balls like button moulds or beads to the whole Chord, or fix them in ſome other manner which may be all alike and equally diſtant to each other; and in the Cavity, or hollowing of the Periphery of the Pulley, make little holes or cavities right with the ſame diſtances, which Cavities muſt anſwer the little buttons or beads, and receive them within them one after another : Some inſtead of theſe, tye knots in the rope, being equally diſtant.

Fig. 122. The third manner in uſe is, when the ſpace for the deſcent of the weight is too low, or ſhort, or of too few hours ; or if it be ſufficient, we would notwithſtanding extend the motion of the clock, or dial, to more hours. For then we double the Rope, which may again be done in a twofold manner ; firſt, one end of the Rope is faſt bound to ſome place A, and the other end to the Axis, or Cylinder E, of the Wheel, which it ought to go about; as for example in D, this Rope A B D ſuſtains the little Pulley C with the weight annext to it, and this whole weight together with the little Pulley C ought to be double of that which is hanged to the ſingle Rope; alſo the Rope may be triplicated, quadruplicated, &c.

Fig. 123. if there be added above and beneath other Pulleys, in which caſe alſo the weight may be in like manner triplicated or quadruplicated, &c. In the ſecond place by the

the double Pulley D, C, one of which being annext to the weight C, and the other to the Counterpoife D, and the ends of the Rope B and E are faftned to fome firm immovable place; fo while the weight defcends with the Pulley C, it turns the Wheel, or Pulley A, and lifts up the counterpoife D.

Fig. 124. The fourth manner is by a continual Rope, dif- pofed in fuch manner as the figure fhews, in which A is the loweft Wheel of the Clock, or fuch like Engin, or the pulley annext to the Wheel, and made hollow in the Periphery to re- cieve the Rope firmly, as we have faid before. B is another Pulley like to the former, and moreover furnifht with faw-like teeth, and with a pin C fo faftned to the fide that it endeavours againft the teeth while the weight D defcends, that the Pulley B be not turned about at that time ; but the Pulley A is roled about and lifts up leifurely the counterpoife or weight E an- next to the pulley ; where you fee there is no extream head of the Rope, but it is one continued Rope, and put into the Pul- lies, whence 'tis called perpetual or infinite. When therefore the weight D defcends to the lower part, and the weight E is carried to the upper part, the Rope being taken by the hand in F, and by drawing downwards raifes the weight D again and deprefles the weight E, for the pin C endeavours not againft the motion of the Pulley B, but alone againft the oppofite motion.

The peculiar conveniency of this Rope, and the application or difpofition of the weight confifts in this, that in the fame fpace of time, wherein the Rope is drawn, and the *Fig.* 125. weight raifed to continue the motion of the Clock, the motion of the clock is not interrupted, as hap- pens in others ; for alfo while 'tis drawn upwards by drawing of the Chord in F, it difcharges its office in enforcing the Pul- ley A, which truly is of great moment to the exact perfection of Clocks, and fuch like Engins, and the knowledge of time.

Likewife you fee by this doubling of the Rope, that the flownefs of the weight's defcent is doubled to that it would have by a fingle Rope ; and it might, if need were, be quadru- plicated, and be made greater than any given proportion. You may add to the two pulleys A, B, another Pulley G, and to the Pulley D adjoin another little Wheel about the fame Axis, or if divers, join it at leaft with the other Axis. Then this perpe-

tual Rope being drawn about all the Pulleys, *viz.* A D G D B E A; for so the descent of the weight D will be four fold slower, and therefore the weight ought to be four fold greater, yea, and somewhat more, because of the much rubing of the Pulleys with the Rope, and the resistance, *&c.*

Fig. 126. The fifth manner is this, the Pulley B is understood to be firmly affixed to the lower Wheel of the Clock, the other A stablished somewhere commodiously, and being furnisht with saw-like teeth with an Iron Pin to endeavour against the weight, as is said before; from the perpetual chords of these Pulleys hangs the weight H in the little concentric Pulleys E F G and C D N, one of which is conjoyned immovably to the other, and both together about the common axis of that which turns easily : Moreover below let there be two Pulleys K and L conjoined in their centers to the common beam K L, in the middle whereof hang the weight M. About these and the former Pulleys draw two perpetual chords by this artifice, the first Chord is B L G F E G B, to wit, so that it fold about the Periphery, or circuit of the whole Pulley E F G once: The other Chord in like manner, must be drawn about the whole Periphery, of the lesser Pulley C D N, concentric with the former, so that this whole Chord be A C N D C K A. But now that which is said concerning this last Chord, and the pulleys belonging to it, is, that it ought to be done altogether like to the other, but placed on the other face or side of the Pulleys, which in like manner contains a certain lesser Pully equal to C D N, standing out on the other part and divides the whole office of holding or bearing up with the other; wherefore it behoves the Pulleys A and K to be alike.

That therefore the weight H be drawn with its Pulleys on which it hangs, you must apprehend the Chord A K, either alone or compared with another, *viz.* in E, and drawn downwards; for so it comes to pass that the weight H ascends, yet in the mean while the motion of the Pulley B is not stopt, and consequently neither the motion of the Clock, or other Engin : So likewise it appears in this method, as also in the precedent, that the attraction of the weight may be continued as long as you please without hindering the motion of the Engin. Lastly, it appears in this last method that the motion downward of the weight may be made slow according to any given propor-
tion,

tion, to wit, in that proportion which the diameters of the Concentric pulleys C D N and G E F have to each other ; and in the fame proportion the weight will always be increaſt.

Problem. III.

To appply a Sphærical, or rolling weight, to the Wheels of Clocks, or other Engins, by finite Chords, as well as by infinite Chords,

SInce oftentimes it is neceſſary in the artificial conſtruction of Clocks, and other Engins, to make uſe of Sphærical or rolling weights, two or more whereof ſucceed each other mutually to continue or perpetuate the motion of the Engin, as will appear by what ſhall be ſaid ; therefore we will deliver a double method, whereby it may eaſily be obtain'd.

Fig. 127. Firſt, it may be done by a perpetual Chord, or Thong of Leather twiſted ; for let there be two Pulleys, or ſhort Cylinders A and B, A being fixt to the loweſt Wheel of the Clock, and B ſtabliſht in the loweſt place to which the weight ought to deſcend ; put on each the perpetual chord A B C D A, or a Thong made of the Hide of a Beaſt ; then take another Thong altogether like to the former and put about the ſame Cylinders, or on two other pulleys parallel to the former and diſtant from them ſo much as is the diameter of the Sphærical weight D, which is ſufficient to turn the clock or Engin, this interval of the double Thong being obſerved, joyn one Thong with the other by ranks of certain tranſverſe Irons ſemicylindrical, whoſe baſes are E H I, L M N : And they are eaſily connected if you drive a Nail through each Semicylinder, and the Thong which folds about it, or if by chance the Thongs of the Semicylinders ſtrain in the middle, it will make a Scale, as appears in the Figure P Q, ſo that the Sphæric weight D being placed between the foreſaid degrees will be ſuſtain'd by the lower pair of Cylinders, *viz.* in F. But that theſe kind of perpetual Scales may be turn'd about with the Cylinders A and B with an uniform motion, there muſt be made hollow Semicylindric grooves or Channelings in the Peripheries of the Cylinders, in which are received the convex Semicylinder of the Scale.

If the Sphæric weight D be of a great bulk, the Thongs may be made of double or triple Leather that they break not, or in ſtead of them Iron chains may be uſed.   The

The chief use of this perpetual Scale is to continue the motion of the Clock, or other Engin ; for after that the weight D is descended to the lowest part G, 'tis cast away by the Scale, which will be done either from the Pulley B, or better from some obstacle fitted below for this purpose ; then the Globe breaking out from the Scale in the lower groove G, lifting up some pestle of Iron by means of a Thred or Chord, opens an entrance to the other Globe in the upper groove E, that it may succeed in his place on the top of the Scale; but the former Globe deposed in G is lifted up again to the groove E, by an artifice which we will shew in the following *Problem*, that it may again descend by the Scale, *&c.*

Fig. 128. *Secondly,* it may be done thus, affix the Pulley H to the lowest Wheel of the Engin, which ought to move and turn easily about its Axis, having in its Periphery Saw-like Teeth with the Pestle R, which being fixt in some place of the Wheel, and fitted with a plate of metal pressing ; put the Rope L H K upon this Pulley, fastning to one of its ends L some little Box or Basket wherein the Globe may be received, and to the other end K, hang a weight of such gravity, that it may draw up the Basket free from the Globe, from the bottom Q to the top, where now it appears in the figure, which the Pestle R will not hinder, which hinders only the opposite motion of the Pulley H, and that the Globe may be contain'd within the Box or Basket, and not slip out of it, erect two or more rules P Q and M N, *&c.* But after that the Box with the Globe is descended to the bottom Q S, the Globe must run out of the Box, either by mangling the rule N, or by the declivity of the bottom Q S; Lastly, the Box or Basket being freed from the Globe, is lifted or raised upwards by the weight K, and being advanced to P M, takes in there the other Globe equal to the former, and that the Clock, or other engin, may be kept in motion while it is let down in Q, and raised again in M, we will shew by and by.

Problem

Problem. IV.

To convey weights, moving an Engin up to the upper part, after their descent to the lowest part.

Fig. 127. THis may be done many ways; first, by the perpetual Scale described in the preceeding Problem, for if you understand a Toothed Wheel joyned to the Pulley A, and firmly adhearing to the same Axis, if then this toothed Wheel be moved together with the Pulley A by any superstructure, or any other way from the power impelling the Supream Wheel, or part of the Engin, and the motion be made from A towards C, the Globe, or weight D, will be raised gently from the bottom to the top, whence it devolves again to animate the Clock, or other Engin, by the artifice explicated in the precedent Problem.

Secondly, the Artifice in the same third Problem, explicated in the second place may easily be applied to the drawing Sphærical weights, from the bottom to the upper most part. For let there be a toothed Wheel A B C to which there may be others made according as the thing requires; place the Pulley D E on the axis of this Wheel on which a Rope being put, let one end of it sustain the Sphærical weight P within its Box or Basket, and on the other end hang the Counterpoise N, a little lighter than the Basket P without the Globe, or weight, that from this that may be taken up. The Pestle B furnisht with a little wing lays hold on the Snags of the Pulley, and detains it against the endeavour of the weight P. Also make a certain dovetail D F in the Periphery of such bigness, that it may be equal to a quadrant of the Circle, or exceed it, in the middle of this make a long slit D F, through which the common axis D of the Wheel and of the Pulley may pass; moreover make a moving leaver H G F C made firm somewhere about the point G, with which Leaver the foresaid dovetail is linked in the point F: Then in the point A fix a spar, or bolt A K, furnisht with a pressing wing and movable about the point A, and near this bolt place a Leaver full of corners or nooks K L M N movable in the point M.

These things thus disposed, If by the motion of the Wheel A B C the weight be elevated leisurely to the top of its altitude,

and

and being flipt from the Basket or Box into the groove or Channel leading it to the defigned place for animation of the Clock, notwithftanding the empty basket will be moved by the power raifing it, untill it hits againft the Leaver CGH and lifts it up a little, and the Leaver being raifed takes up together with it the dovetail FD : And this Peftle B being ftretcht at length through the whole thicknefs of the Pulley in this part to the dovetail ; in the mean while that the end H of the leaver CGH being depreffed lays hold on the bolt AK and detains it, at the fame time the Peftle B being lifted up without the Snags of the Pulley, the basket P, although empty, yet heavier than the counterpoife, N will turn the Pulley, and it will defcend to the bottom that there it may again receive another Sphærical weight to be drawn up in the fame manner.

For the counterpoife either of it felf, or by making a certain knot in the Rope will raife the nooky Leaver N M L, and by it withdraw the bolt A K that it detain not any longer the end H, which being loofed, the dovetale D F falls off, and then the Peftle B being fent down lays hold on the Jags of the Pulley that the attraction of the weight may be made again.

If you fear left before the Peftle B being drove away by the Snagged teeth of the Pulley, and the Pulley with the Basket fhould begin to defcend before the end H is laid hold on by the bolt A K ; then hang fo much weight to the arm G H of the Leaver as fuffices to raife the dovetale with the Peftle B; and that the weight be not raifed fooner than the basket af-cends upwards, detain this arm G H by a certain crook or hook made after the fame manner as the hook N H in the fol-lowing Figure. But then in ftead of the arm F C, the arm M N will be produced, that that being raifed from the basket will withdraw the hook fuftaining the endeavour downward of the end H which is heavieft ; Moreover it will reftore it to its former fite afcending with the Impetus of the counter-poife N.

Alfo note, that when the Wheel A B C is often turn'd about in drawing of the weight, and conveys the Peftle B every where with it felf, that when the attraction is finifht, the Peftle B will be found in the upper quadrant that is above the dovetale, which always certainly happens, if in the Rope or little chain of the Pulley you make little knots or buttons for

that

that purpose, according as 'tis shewn in the second Problem.

Fig. 130. *Thirdly,* the same Pulley may be freed from its Pestle by another artifice; let the same Wheel B stick fast to the axis C, and the Pulley D movable thus, that it may be moved to and fro by the Axis A C; Then after that the Basket E is brought to its height, it will raise in the first place the knotty Leaver E F G fixt movably in F; and this by the little arm G H drives out the hook H N, whereby the other knotty Leaver M L K is sustain'd, to whose arm L K so much weight must be hung as is convenient, that the other arm L M laying hold on the Tube M P, joyned to the hole of the Pulley D, may draw the Pulley by the Axis A C towards C, although against the ordinary resistance of the force of the Hælix C P: And in this manner, those jagged teeth of the Pulley are withdrawn from the Pestle B, and the Basket E descends with its weight, by turning round the Pulley together freed from the obstacle of the Pestle; notwithstanding in the mean while the little arm L M touches it highly, and detains the Tube ending in the rundle, in which the contact may be facilitated by adhibiting the little Wheel, or a turning Cylinder, &c.

The arrival of the Counterpoise will make the Pulley repair to its place, for this when the impetus of the knotty Leaver M L K, lifts up the end K, it places it in the hook H N; which being done the pulley is forc'd into its place, by the pressing Hælix led about the Axis.

Hence also you must take care, in making the Pestle B, that it be not let or bore down from its little wing, deeper than the incisions, or Jags of the Pulley.

Problem. IV.

To fit an irregular finite, and disorderly moving power, so to an Engin, that it shall make a well order'd regular, or wholly equal motion.

SInce Regularity and equality appears in no other motion more than in the Circular, which of its own nature seems to require equality; we shall in this place declare those things which are for obtaining this equality of motion, which truly are of great moment in Engins, especially in the construction o

thof

thofe that meafure time. And of thefe kind of Irregular powers fome are perpetual, or infinite, and others finite which do execute their office to time. We fhall treat of thefe laft in this place, and of the former we fhall fay fomething hereafter; heavy things being hung at liberty whether hanging from an Engin, or fome Wheel, are called regular powers, becaufe whether they are hung high or low, they always obtain equal force or moment; notwithftanding if they are placed in fome ambit of the fame Wheel according to a divers fite, and the fame inclination, they acquire divers moments as appears from what has been faid elfewhere; but 'tis needlefs to reduce this irregularity of weights to regularity, fince that may eafily be done.

Therefore irregular Powers which we commonly ufe in the conftruction and motion of Engins are Springs, that is, certain thin pieces of mettal in manner of an Hælix, or wrapt up in Spires fuch as are commonly ufed in watches, concerning which fomething is faid before.

Firft, the refiftance of the faid thin pieces of mettal is lefs in the beginning while they are bent or drawn than in the end, and in like manner when they are drawn or bent have greater force, and make a greater endeavour to reftore themfelves into their firft ftation in the beginning of reftitution or reduction than in the end, and this force increafes or decreafes not uniformly, and with a proportional increafe to the adductive or reductive motion, but with another certain increafe or progreffion not as yet certainly known, of which in its place.

Secondly, if the thin piece of mettal be bowed or bent into a Spire, or larger Spieres, the bending refifts lefs, and makes lefs force to reduce it felf than if it be bent in leffer Spires; hence 'tis, that in this fecond cafe it hath greater force whereby it defires to reftore it felf, but obtains leffer motion.

Thirdly, Springs, or the fame thin pieces of mettal being bowed into a Spire or wreath, may be drawn more violent either in the Centre, or in the Circumference, or in both parts together; if the thin plates confifting in the extream which is in the circumference, the plate will be drawn by the wrefting of the other extream being in the Centre, it refifts the drawing lefs than if remaining centrelly immovable in the extream, the plate be wreathed about in the Periphery, the reafon is, becaufe in this fecond cafe it ought not only to out go the refift-
ance

ance of bending, but also the other of rubbing, or weaving of one volute upon the other, which resistance nevertheless it hath by accident.

Fourthly, Springs are made weaker by degrees by often drawing them, but they are more weakned if they never restore themselves, but if always, or for a long time, they continue drawn or pull'd ; hence they have greater force in the first making of an Engin, but lesser after long using them.

Fifthly, if they remain sometime free, that is, without drawing, they recover some of their strength which they had lost before.

Sixthly, *Jo. Helmont* in his Book entituled *Med. Physic. de tempore, Num.* 50. affirms, That the said Springs of Clocks or Watches are wont to be more strong, or stubborn, when the North wind blows, which notwithstanding is not as yet well known to me, neither doth the cause of this *Phænomena* easily appear, unless you'll say from *Cold,* which is wont to be more rigid when the Wind is Northward.

These things being noted, the irregular force of Springs may be reduced to uniformity divers ways : First, when these thin pieces of Mettal are wont to be made every where of the same breadth and thickness, they exert their force unequally in the beginning and in the end ; if the parts near the Centre be made thicker than the other, or broader with a due proportion, and then the drawing to, or lapping up being made in the Centre, the resistance will be equal and uniform in the whole drawing, or wreathing, and consequently they will make the force equal in their whole restitution, until they come to their first state, or condition ; moreover on the contrary, if they are made thicker in the parts nearest the circumference, and then the drawing be made in the circumference, from the opposite reason there will be an inequality of force to compensate or amend that unequal thickness or breadth of the thin plate ; notwithstanding this way, whereby the inequality of this thickness compensates, the inequality of force is not used, perhaps because 'tis more laborious, and neither is it easy to find the proportion, whereby the thickness ought to be increased gradually ; yet if it were reduced into practice, it would be far more useful and certain than the other.

The second way more obvious, and used in regulating the Springs in ancient Watches, is, by an unequal pression of

the

the ftrongeft part of the Spring, and that is made in a certain changable Orb like the figure of an heart, for this Orb when the fpiral plate makes lefs force, is alfo lefs preffed from the other plate, or hindering wing ; but when it exerts greater force in like manner that force is abated, fo that 'tis reduced to a certain quality ; alfo this way is fcarcely ufed now among modern Artifts, when notwithftanding 'tis lefs laborious, and, as Experience teaches, oft-times more ufeful than others ; perhaps 'tis defpifed becaufe 'tis more fimple, to deter others from inquiring into an Art which is more fubtil, which they would do, if it were eafier and fimple.

Fig. 131. The third way, which is at this time moft in ufe is, a Hælyx of Steel included in the Cylinder A B C D, movable about the durable axis E F ; this axis paffes by the centre of the Hælix, and detains its central end firmly, and left it fhould be turn'd about together with the Spire or Wreath and Cylinder, 'tis hindred by a jagged wheel G H, firmly put into an axis, and a little bolt or peftle H I, which ftrives againft the Jags of the Wheel : To the fide of the Cylinder a Cone is made, or fome other fuch body fharpned at top like to a Top C K M, movable about the axis L M, the Periphery of this top is made in the manner of a Screw, with channellings or cavities made round it to receive a chord or chain, one end whereof is faftned in the point of the Cone K, and wound about the Cylinder, the other end of the chord is faftned to the Cylinder in D ; thefe things thus conftituted, the inequality of the refiftance of the fteel fpires, or wreaths, drawing irregularly is made fit or meet by the deformity of the top, which where the refiftance of the fpire or wreath is leaft, the greater Periphery being turn'd receives the chord, whereby the Cylinder is drawn about, carrying about the included end of the fpire or wreath fixt to the Cylinder ; and where the force and refiftance of the thin plate is ftronger, the chord being then in the fharpned or leffer part of the top or cone, eafily fuftains that greater force by leffer diftances from the centre or axis, and by allaying it, tempers it.

You fee then the whole perfection of Clocks, or Watches, which confifts in uniform motion, or equality, depends on the framing the forefaid cone or top ; which I defire Artifts diligently to obferve, and to take great care in the making of it, that the moving force of the fpiral thin plate be rendred

<div align="right">dred</div>

dred every where equally valid ; neither is it sufficient, as they are wont, to try it by hearkning to it whether the sound be sharper or graver in the swiftest motion of the jagged little wheel G H, since 'tis not easy to distinguish the least difference of sound ; wherefore 'tis rather to be done some other way, and Father *Schottus* proposes two, the first is by weighing, *viz.* by a weight hung on a long arm leading the Cone about, for if which way soever the Cone be turn'd about, the same weight endeavours equally against the adduction or reduction of the Spire, the Cone or Top will be perfect.

Fig. 131.   The second way is measuring by time, for, says he, the little Wheels being set at liberty in a swift and free motion ; take some very short Pendulum, and by its vibrabrations examin the circumvolutions of the lower Wheels, for if the circumvolutions of each wheel be in equal space of time, it argues that the cone or top is perfect : In the same manner, the circumvolutions or turnings round of the jagged little Wheel G H may be examined by a Pendulum, to wit, whether they are made in equal time, notwithstanding if there be added weight to the foresaid little wheel the motion is rendred more slow.

Problem.   VI.

To mend the unequal motion of Clocks, or other Engins, by applying a Pendulum.

THe chief fault in Clocks, and all Engins that measure time, is the irregularity of motion, for no kind of Clocks to this very day is found, whose motion is so equal or uniform, that it errs not at least a minute from the true measure of time, in one day or 24 hours, although it hath been the study and endeavour of many ingenious men; in the first place, we are indebted to *Mathew Campane* to this end, that by the accurate measure of time Geographers may obtain the knowledge of Longitude, and what proficiency they have made in it, you will understand by what follows.

Truly 'tis doubted whether any man can by application of a Pendulum, compleatly perfect the little jagged Wheels of Clocks, and take away their inequality ; therefore the Author of that famous Invention, deserves to be followed and praised

of all Men ; and fince there are divers ways of application in this kind, fome whereof we have defcribed juft before, it remains that we reckon up fome others in this place, either more ingenious, or alfo more ufeful.

Fig. 132. Let there be a Pendulum I L, with a wire fixt to the Axis C D, which refts on the two poles C and D, and in the middle part of its Axis, faften here and there two little wings, or thin plates of mettal, extended according to the length of the Axis, or in an Horizontal fite, above this Axis let the upper wheel of the Clock A B be turn'd, being made by a peculiar art ; to wit, let it be made in form of a Zone, with a double row of Teeth difpofed to the end of the Zone in fuch a double order, that when the Teeth, or little Keys. that ftand out, being confiderably diftant from one another, each tooth of one row, anfwer to the middle fpace of teeth of the other row ; for fo by turns they will hit againft the aforefaid two wings, to wit, one tooth or little key of the row towards the right hand, on the righ wing, and the other row on the left hand, on the left wing ; again, the other on the right, on the right wing, from whence are made the Altern Vibrations of the Pendulum. If then each of the two rows confifts of ten teeth, in all they will make twenty ; and the Pendulum muft be of fuch length, that each compofed Vibration anfwers one fecond of time, there may be fitted on the fame Axis of the wheel the Tympane F with fix teeth, which will be moved by the wheel G H of 36 teeth, for this will abfolve one circuit in the fpace of a Minute ; fo that an Index faftned to its Axis, may note every fecond in a circle divided into 60 equal parts ; and beneath the Wheel G H, another may be fitted, which may be turn'd about in the fpace of an hour, and its Index may fhew the minutes, moreover another which may fhew the Hours, &c.

But fomething offers it felf worth our noting in the application of Pendulums to Clocks ; in the firft place, if a weight doubley or tripley greater be hanged to a Clock, it is not the reafon of moving it notably fwifter, or the caufe of making the hours vifibly fhorter, becaufe in this cafe the Pendulum is forced more vehemently, and therefore makes greater arches in its Vibrations ; it feems that it ought to move more flowly, and to make the hours longer, if it be true that is faid in the Book of Pendulums, that the Vibrations which are made in a

greater

greater arch from the fame Pendulum are longeft; but expe-
rience tells us, that the Hours are fomewhat fhorter if weights
are hung much greater, and the reafon is, becaufe the wheel
which is called Serpentine, or the wheel meeting with the
beam of the Ballance by way doth not permit each Vibration
to run through the whole Arch which they would run through,
and therefore cuts them off a little fhorter.

Secondly, For this reafon Pendulums ought to be a fmall mat-
ter longer than if they were altogether at liberty, leaft each of
their vibrations be made in a fhorter time than is meet.

Thirdly, You ought not to ufe a ftring or little chain, be-
caufe they will bend, but a wire, or in greater Pendulums, a
rod of Iron, or other Mettal.

Fourthly, Since in thefe kind of Clocks the augmenting or
decreafing of weights fignifies little to the fwiftnefs or flownefs
of motion, but the fwiftnefs or lownefs depends almoft wholly
on the length or fhortnefs of the Pendulum; therefore that
Clock may be reduced to the juft meafures of Hours, the Globe,
or Ball, ought to be fixed to the lower end of the Rod, in fuch
manner, that it may be raifed or deprefied, and that may be
done if there be a fcrew made on the end of the Rod, which is
engrafted to the Globe more or lefs, and binds it very well
that it flide not down, which inconveniency may be prevented
by another concave Screw P, which keeps the Globe aways in
the fame place.

Fifthly, 'Tis better to hang a heavier weight to a Clock, or
make ufe of a ftronger Spring, and to apply a Pendulum a lit-
tle the longer.

Sixthly, The Vibrations ought not to be too great, but the
Pendulum ought to fwing backward and forward to the height
of 30 or 40 degrees in its arch.

Seventhly, Clocks made with Pendulums, require much grea-
ter weight or ftronger Springs than others, which are regula-
ted by the ordinary fimple poifers, fo that fometimes a triple
weight is required to it, than is required to a Clock without a
Pendulum; neverthelefs for divers reafons, according to the
manner or fafhion, a Pendulum may be fitted, it may require
more or lefs weight in the precedent artifice, unlefs the little
wings of the Axis C D be made long, it will require a great
weight; as appears from the principles of Mechanicks.

Eighthly,

Eightbly, Greater Clocks which are furnisht with greater Pendulums, in like manner require weights in the same proportion, or also in a greater than the times of the Vibrations have, or which is the same, in subduplicate proportion of the lengths of the Pendulums; for Example, let a Clock have a pendulum of 36 inches, or 3 feet, which makes each Vibration in one second, and another with a pendulum of 9 inches, which absolves the vibrations in half a second, so that in one hour that makes 3600 vibrations, and this makes 7200; since the pendulum of the first Clock is quadruple of the other, to agitate it, is required a quadruple force or weight; because it ought to move but doubly flower, also the Serpentine wheel, or that which incites the pendulum, must be moved doubly flower, and therefore the weight hung to the lower wheel will have a double weight, therefore a double weight suffices to move a pendulum of quadruple length through like Arches; for a double weight, if it have over and above a double poise of another weight, is equivalent to a quadruple weight.

Fig. 133. Notwithstanding 'tis to be Noted, if the longer pendulum be inforced in a point proportionally distant from the centre of the pendulum, a weight as little again will suffice to move the long pendulum, as if the pendulum A C, receive an impulse from the upper wheel in the point B, and another longer pendulum D F, receive an impulse in the point E, and let the proportion be the same of A C to D B as of D F to D E, a weight doubly lesser is required to move the longer pendulum than to move the shorter pendulum; for if the disposition of the wheels be the same, or the velocity the same as the upper wheel, an equal weight is required as appears, but in a longer pendulum the upper wheel is moved doubly flower, and so the weight hung to the Clock hath a double poise, therefore a weight doubly less suffices. But if the pendulum D F be impelled in G, so that D G be a mean proportional between A B and D E, than an equal weight in each Clock is required, and only double the weight is required in the Clock of the pendulum D F, when the pendulum is incited in the point H, so that D H be equal to A B, and the Globes C and F are supposed of equal weight, but if the weights are unequal, then their proportion ought to be had, which may vary diversly.

Problem

Problem. VII.

Another way of fitting a Pendulum to a Clock.

Fig. 134. HEre we will defcribe the way moft in ufe of fitting Pendulums to Clocks, the ferpentine or encountring wheel, muft be placed in an Horizontal fite, and the beam of the Ballance alfo ftretcht out Horizontally on the fame ; the wheel furnifht with jagged teeth, muft have its number unequal to this, that two little flaps, or wings, of the Beam of the Ballance, may lay hold on the teeth by turns, according to the ufual manner, which little wings ought therefore fo to be joined to the beam of the Ballance, that their planes make a right angle, and the Axis of the beam ought to be extended precifely through the centre of the Wheel ; but becaufe if the Pendulum be immediately join'd to the beam of the ballance, its weight will burden it too much, therefore a handle is added to the beam, boared through in the extream point, to which hole is fixt a rod hanging at liberty that it may eafily agitate.

But you muft take care that the lower little arm poffefs a middle fite between each little wing of the beam of the Ballance, left one vibration of the pendulum be greater than another, and make the motion very incongruous and lame; in the reft obferve the precepts already delivered; fome fix a Globe unmoveable on the end without any Screw, moving the centre of the Spear or Wire, they raife it or deprefs it to reduce the vibrations to the exact meafure of time, for when the centre is raifed, the pendulum runs through a leffer arch, and fooner difpatches each vibration, fpecially becaufe 'tis refifted by a leffer impulfe, and it makes the vibration flower, if it be depreft for the contrary reafons ; yet you muft take care that the centre be not beneath the axis, nor that it be elevated much above it; laftly, the length of the little arms are determined by practice, and by the wheels.

Problem

·Problem. VIII.

To amend the Irregularity of all Clocks and Engins, meaſuring time otherwiſe than by the manner of Pendulums.

I Know ſome have not been wanting, who are willing to adopt Pendulums to watches, or portables Clocks, nevertheleſs they laboured in vain ; for the ſmallneſs of the Watches, and the diverſity of their Scituations, with the continual agitation of the pendulums, while they are carried about, cannot eaſily admit them to vibrate uniformly ; and although the pendulum may be ſo fitted, that being librated between many circles or rings, after the manner of a Sea Needle, it may always obtain a perpendicular ſite ; however the agitation of the whole watch will make the vibrations of the pendulum to run ſometimes in this, ſometimes in the other part, hindering their equality altogether, beſides that, the ſpace which the beam requires, is much greater than the magnitude of Watches will conveniently admit ; wherefore perchance more patly, the whole watch with its pendulum appled to it after one of the foreſaid preſcriptions, may be hung within 3 or 4 little circles, which may eaſily be included in a Sphærical caſe of the Watch.

Since therefore the application of Pendulums to theſe kind of Watches, or other portable Engins, are either uſeleſs or altogether difficult, the illuſtrious *Hugenius* (for his new Invention, now known to all the World) hath found out another way, which I could not paſs by in this place, it being very profitable and ingenious, therefore accept it as taken from Letters of the ſame Author.

The Miſtery of the Invention conſiſts in a thin plate of mettal or ſpiral creſt, having faſtned to it at the lower end a Catsgut String, or an Inſtrument of an equal weight, but greater and more ponderous than is wont, and movable of its own accord to and fro upon its points ; and the other end is faſtned to a little part or covert ſticking up above the upper part of the Clock, which being once vibrated to the tongue of the Ballance of the Clock, compreſſes and releaſes its ſpires one after another, and drawing to it ſelf a little help coming from the wheels of the clock, maintains the motion of the Inſtrument or Ballance ſo truly, that although it makes greater or

leſſer

lesser digreſſions, its reciprocations nevertheleſs throughout are
equal in time one to another.

Fig. 134.   In the figure of the former Clock the plane is
A B, the circle of the Ballance, or compaſs about the tongue
of the ballance C D, its axis or lance E F ; the wing or ſpring
turn'd into a ſpire G H M is faſtned to the ſpear of the bal-
lance in M, and to the thin plate of mettal on the upper plane
of the Clock in G, ſo truly, that all the ſpires of the ſpring
cleave to theſe two props hanged up in the air, touching no-
thing beneath : N O P Q is a certain covering, or propping,
in which the other point of the ballance is turned : R S is one
of the toothed Wheels of the Clock, having a certain motion
of the poiſer impreſt on it from meeting with the next wheel,
and this wheel R S is folded into the Tympane T, made faſt
to the axis or ſpear of the poiſer, whoſe motion is by this means
as much maintain'd as there is occaſion.

This Invention of *Hugenius* may be uſed not only in Watch-
es, and portable Clocks, but alſo in others which are put into
motion by hung weights; and to which he adds, That a clock
made by the foreſaid Artifice may be ſerviceable in finding
the Longitude at Land and Sea, which I am not eaſily indu-
ced to believe, for neither is the inequallity of motion of Clocks
more correſted by this Invention than by Pendulums, as you
may eaſily underſtand by what is ſaid, nevertheleſs 'tis very
uſeful, becauſe it may be fitted to portable Clocks, or Watches,
which cannot ſuffer a Pendulum.

Fig. 135.   I obſerve that the ſpear of the ballance E F may
agitate, and unleſs I am miſtaken, more beneficially by a Zone
or double wheel with ſmooth teeth, or little keys after that
manner, whereby a pendulum agitates in the fifth problem, to
wit, if the little keys C, D, G, H, *&c.* by turns, or one after
another, hit againſt the two little wings A and B, here and
there fixt to the ſame ſpear or lance ; for ſince this ſpear ought
to be much thicker and ſtronger than commonly they are wont
in common Clocks, and more reſiſts the impulſes of the wheel
S R, by reaſon of the ſpire G H endeavouring againſt it, the
poiſing wheel commonly call'd Serpentine is not ſo uſeful,
which is wont to agitate the common ſpear of the Ballance.

Problem. IX.

A Clock that makes no Noise, and yet hath a Pendulum.

Fig. 136. IT will not be unpleafant in this place to defcribe a kind of a Clock which we found in Father *Mili-et*'s third Book of Statics, or art of ballancing, *Prop.* 59. where he hath thefe things.

This kind of Clock, or Watch, is moft ufefull, becaufe no found of the Poifer is heard, and therefore may be ufed in a Bed-room without fear of difturbing ones reft.

The Lord *Setale* hath had many of this kind made, and the Artifice was thus: The Clock confifts of 4 wheels, and one axis furnifht with little wings or Pinions.

The firft wheel was furnifht with 96 Teeth, and difpatcht half a circulation in an hour.

The fecond had in the axis 12 little Teeth, and in the circumference of the wheel, it had 72 little Teeth, and it accomplifht 4 circulations in one hour.

The third had 6 little teeth in the axis, and in the circumference 60 little teeth, and finifht 48 circulations in an hour.

The fourth had 8 little Teeth in the axis, and in the circumference 80, and finifht 360 circulations in an hour.

The axis furnifht with wings which is defcribed in the Figure *e e*, had 8 little teeth, and finifht 3600 circulations in an hour, and fince every circulation made one compounded vibration, there was 3600 compounded vibrations, and 7200 fimple ones; one compounded vibration is equal to a fecond Minute, and a fimple one to half a fecond minute, the length of the pendulum was 9 inches.

The whole Artifice confifts in the axis B C, and in the handle of the pendulum H I K, which may be turned about the point G, as about an axis, and the point K was ingrafted in the point 6 of the axis, furnifht with rings, which axis while it turns, inforces the arm K I, and draws it in by turns; which you may eafily conceive, if the arm K I be at right angles with the axis B C, and be ingrafted in the point 6; the reft may better be conceived if the thing be put into Execution, than can be expreft in words.

<div align="right">Problem.</div>

Problem. X.

To determine the number of Teeth and Wheels in Clocks which have Pendulums.

THis practice ought not wholly to be neglected, which is most useful in directing Artificers, especially since it also contains a method of beginning, and reckoning the number of vibrations and circulations of wheels, which is very. necessary in the construction of all other Engins.

The foresaid Author began these reckonings, together with the foresaid method in divers forms of Clocks, beginning from a Clock which consisted of two wheels only; for although it is difficult to fit that pendulum, nevertheless if it be accomplisht it will be very exact, since the meeting of many wheels induce always a greater inequality in motion.

Fig. 137. In the first place therefore (saith he) let there be two wheels, the first or lower of 120 teeth, which is supposed to finish two circulations in hour, wherefore it will be equivalent to a wheel of 240 teeth : The second wheel hath a little wheel of 5 teeth, wherefore while they pass through 5 of the teeth of the greater wheel, the second finishes one circulation, therefore you must know how many times 5 is found in 240, which you will know by Division, and the quotient will be 48, wherefore the second wheel makes 48 circumvolutions in one hour : And it appears, that the second wheel of 35 teeth, each of which effects two single vibrations, since it touches the poiser twice ; wherefore each circulation makes 70 vibrations, multiply 70 by 48 and you will find 3360 single vibrations in an hour, the Pendulum will be Feet $3\frac{1}{2}$, and somewhat more.

Fig. 138. I will propose another not unlike the precedent : Let the same wheel have 120 teeth which will make two circulations in an hour, and therefore will be equivalent to a wheel of 240 teeth: The second little wheel shall have 6 teeth, divide 240 by 6 and the quotient will be 40, the second wheel then will be turn'd round 40 times in an hour, and shall have 45 teeth ; and because, as I said but now, each tooth touches the poiser twice in each circulation, this number will be doub-
led

led and will make 90, which number multiply by 40, and you will have 3600 single vibrations in an hour, that is, each single vibration will be equal to a second minute; the length of the Pendulum muſt be 3 feet 3 inches and $\frac{1}{10}$ of our Engliſh feet.

Or if inſtead of the 6 teeth of the little wheel you put the teeth of the little wheel 5, for then the ſecond wheel compleats 48 circulations in an hour, and there will be 4320 vibrations in an hour, the length of the Pendulm will be about two feet.

In the like manner, if there be given the firſt wheel making two circulations in an hour, and of 150 teeth; the ſecond wheel, or that which encounters with it, ſhall have a little wheel of 5 teeth: Wherefore the diviſion being made of 300 teeth (which are in two circulations) by 5, it will make 60 circulations: Suppoſe 60 teeth in the ſecond wheel, that is, 120 vibrations in each circulation, it will make the number 7200, and the Pendulum about 9 inches, that is, each ſingle vibration will be equivalent to half a ſecond minute.

Fig. 139.

The ſame things being obſerved, except that the firſt wheel compleats only one circulation in an hour, you will have the number of vibrations 3600, and the Pendulum will be 3 feet, that is, each vibration will be equal to one ſecond minute.

Which Examples I have put only, becauſe you may learn the method of finding out other numbers, which ſhall ſeem more fit.

A Clock with three Wheels.

You can ſcarcely make Clocks with Pendulums which ſhall have only two wheels, unleſs you make the Wheels very great, and abundance of teeth: Wherefore the greater are commonly made of three Wheels, and the leſſer of four: I ſhall exhibit in this place ſome numbers: A Clock hath 3 wheels, the firſt of which hath 112 teeth, and the ſecond little wheel 7, the ſecond wheel hath 60, the little wheel, or axis of the third wheel hath 8 teeth, the meeting wheel 15, you will have the number of Vibrations thus, Divide 112, the number of teeth of the firſt (which in each hour is once turn'd about) by 7, to wit, the axis of the ſecond, and you will find the ſecond to be turn'd about 16 times; and the ſecond hath 60 teeth, wherefore multiply 16 by

Fig. 140.

Fig. CXIII.
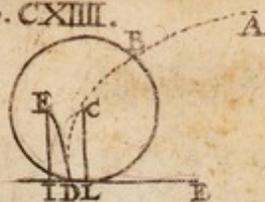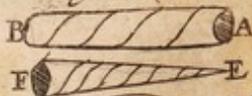
Fig. CXIIII.

Fig. CXV.

Fig. CXVI.
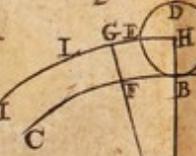
Fig. CXVII.

Fig. CXVIII.
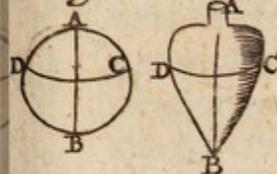
Fig. CXIX.
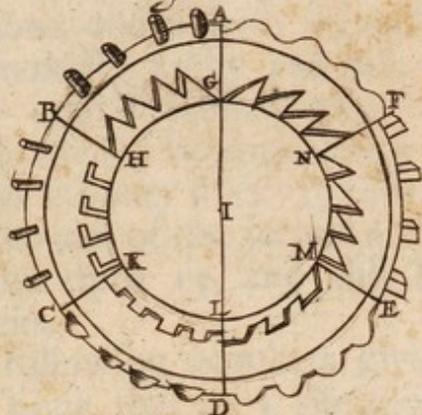
Fig. CXX.

Fig. CXXI.
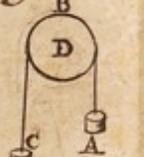
Fig. CXXII.

Fig. CXXIII.
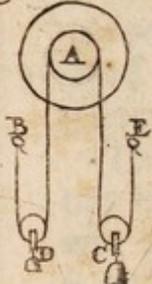
Fig. CXXV.
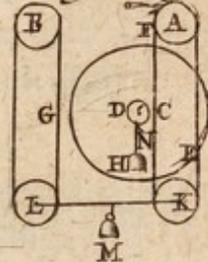
Fig. CXXVI.

Fig. CXXVII.
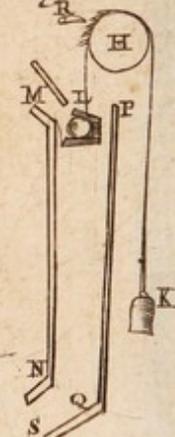
Fig. CXXVIII.

Fig. CXXIIII.
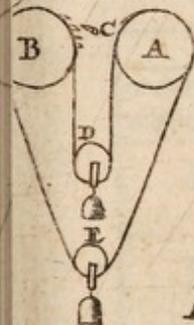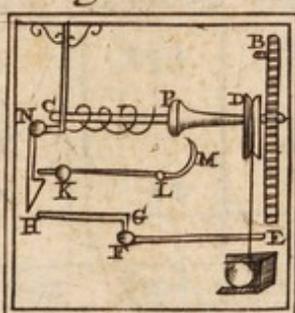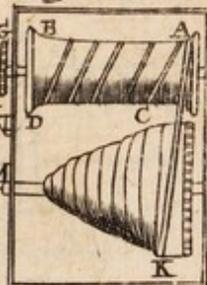
Fig. CXXX.

Fig. CXXXI.

Fig. CXXXIII.

Fig. CXXIX.
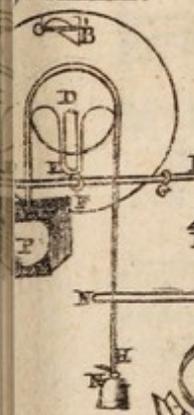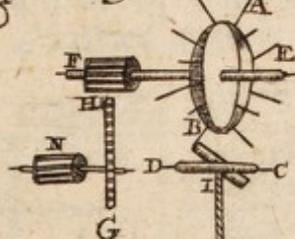
Fig. CXXXII.

Fig. CXXXIIII.
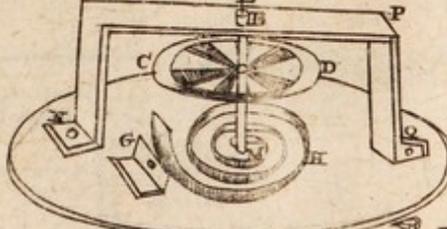
Fig. CXXXV.

Fig. CXXXVI.
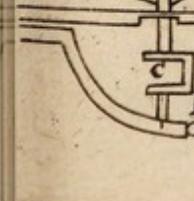
Fig. CXXXVII.
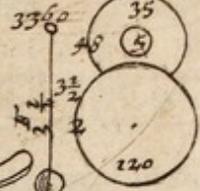
Fig. CXXXVIII.

Fig. CXXXIX.
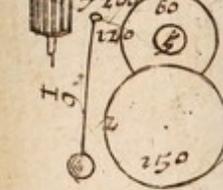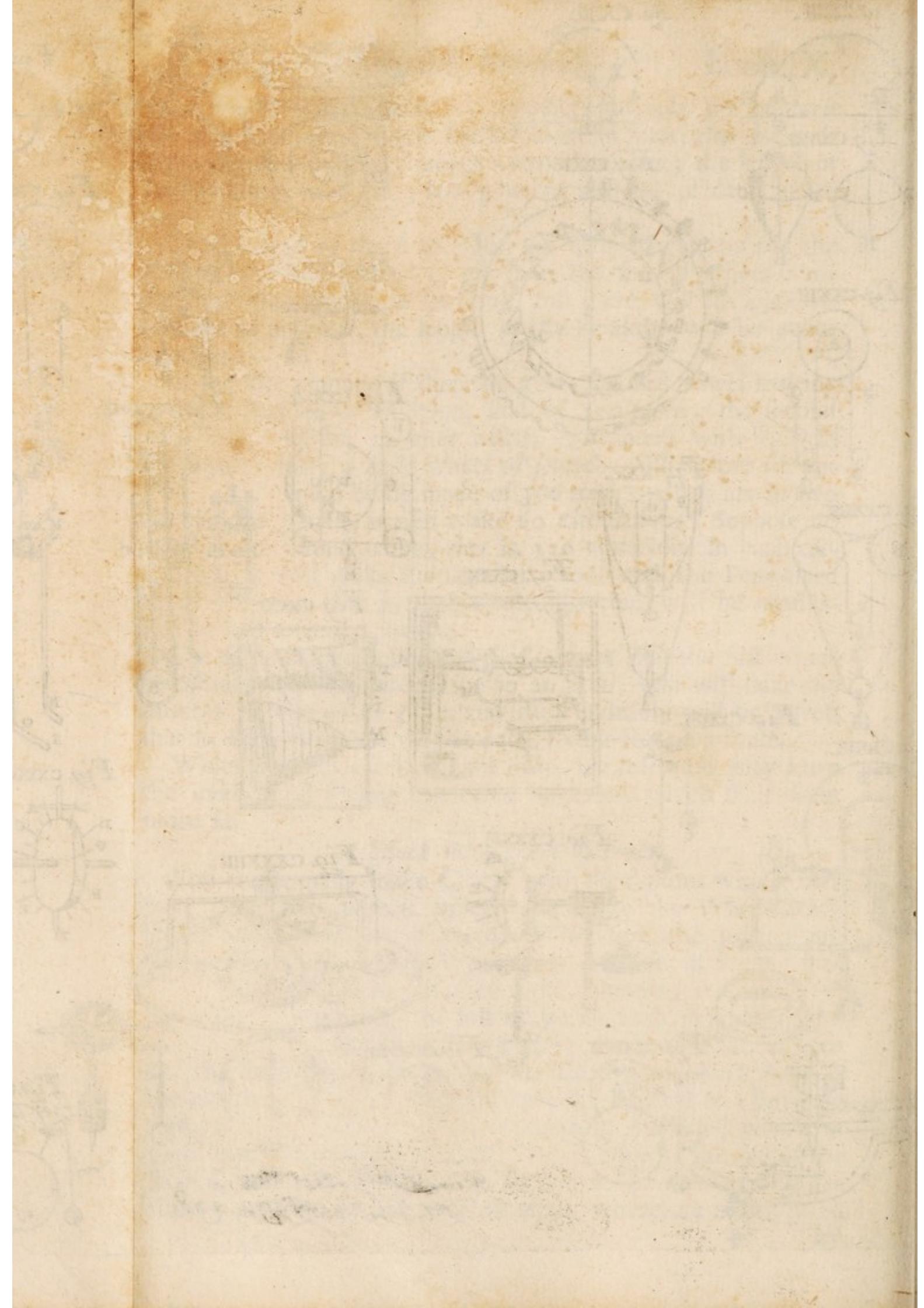
by 60 and you will find 950, therefore it passes over 950 teeth of the second in an hour, which number you must divide by 8, the axis of the third, and you will find the third to make 120 circumvolutions, and it hath 15 teeth which make 30 single vibrations, multiply 30 by 120 you will have 3600 single vibrations, and each equivalent to a second minute, the length of the Pendulum must be about three feet.

The same is better done by other numbers: Let the first have 96 teeth, the axis of the second 6, the second 45, the axis of the third 6, the third 15, and this length of 3 feet is best for great Clocks.

The 3 following numbers give the number 7200 vibrations in an hour, that is, 2 vibrations in one second minute, to wit, the going and returning, and the length of the Pendulum 9 inches.

order of wheels.	Vibrations 7200		Vibrations 7200.			
	Circumvolutions.	Teeth of wheels.	Circumvolutions	Teeth of wheels.	Circumvolutions	Teeth of wheels.
3	144	25	144	25	144	25
		5		5		5
2		48		60	$14\frac{2}{5}$	50
	15	5	12	6		5
1	1	75	1	72	1	72

Length of Pendulum 9 inches.   Pend. 9 inches.   Pend. 9 inches.

In the succeeding Table the numbers described give the Vibrations 7600 and 10000, with the Length of the Pendulum 8 inches and 4 inches and $\frac{2}{3}$.

order of wheels.	Vibrations 7600.				Vibrations 10000.			
	Circumvolutions.	Teeth	Circumvolutions	Teeth	Circumvolutions	Teeth	Cir.	Tee.
3	200	19	200	19	200	25	200	25
		6		5		5		5
2	20	60	20	50	20	50	20	50
		6		6		5		5
1	$1\frac{1}{2}$	80	2	60	$1\frac{1}{3}$	75	$1\frac{1}{4}$	80

Length of Pendulum 8 inches.   Pend. 8 inches.   Pend. 4 inches $\frac{2}{3}$ $4\frac{2}{3}$

The

The following Numbers are for a Clock, which makes 10800 Vibrations in an hour, or 3 in one second minute, the length of the Pendulum 4 inches and ¼, and others also, as may be seen in the following Table.

10800		10800		1440		11400		11400		10944		9600	
216	25 5	216	25 5	288	25 5	300	19	300	19 5	283	19 5	320	15 5
22½	28 5	18	60 6	28⅘	50 5	30	50 5	25	60 6	24	60 6	26⅓	60 6
1½	75	1½	72	2	72	2	75	2	75	2	72	2	30

The following Numbers are for a Clock with 4 Wheels, the number of Vibrations in an hour are 10800, to wit, 3 Vibrations answer one second minute, the length of the Pendulum is about 4 inches ⅔.

10800		10800		10800		10800	
360	15 6	360	15 5	360	15 6	360	15 6
60	36 6	60	30 6	60	36 6	60	36 6
7½	48 8	9	40 6	8	45 8	8	45 7
1	60	1	54	1	64	1	56

These Tables were made by the foresaid Author, wherein the Printer had committed some Errors which we have amended, that they may be useful to Artificers.

If in the last Table you take the numbers proposed, changing only the number 15 of teeth of the upper wheel, and in its place using a wheel of 20 teeth, you will have a Clock which

which will compleat 14400 Vibrations in an hour, to wit, 4 in one fecond minute, and the length of the pendulum will be Inches $2\frac{1}{4}$; neverthelefs becaufe many Artificers will have the meeting wheel to have an odd number of teeth, they obferve the precedent numbers, to wit, fo that only the laft wheel but one which finifhes 60 circulations in an hour hath 48 teeth irftead of 36 teeth, and makes the fame number of Vibrations 14400.

Wheels are divided many other ways, and the Clocks are commonly furnifht with Pendulums; fome are fo difpofed, that the ferpentine, or encountring Wheel, is turn'd round 60 times in an hour, and is furnifht with 60 teeth, and finifhes two vibrations in one fecond minute; or hath 30 teeth, and finifhes one vibration in a minute, then the number of the teeth themfelves infcribe the minutes which appear confpicuous through a round hole, or through a little opening made in the front of the Clock.

Problem. XI.

To correct perfectly the inequality of motion of Clocks, or other Engins that meafure time, having Pendulums, by applying a double Pendulum, and by Cycloides.

ALthough a Pendulum applied to a Clock (as we have faid) effects this, that if the impulfive caufe of motion of the wheels be too fwift, or too flow, its vibrations tempers it, each of which when they meafure a determinate time, either they agree to the too much celerity of the wheels, or they ftir up and excite their heavinefs and dulnefs, whence for the moft part the irregularity is taken away; notwithftanding becaufe while the Pendulum refifts the unequal impulfes of the wheels, their vibrations muft needs contract fome irregularity to themfelves, fo that fome make their excurfions thro' greater and others thro' leffer arches; and it appears by what has been faid, that thofe Pendulums finifh their arches in fhorter time which make the leaft arches, and thofe in longer which make greater or larger arches: Hence 'tis, that by application of a Pendulum all the Irregularity is not wholly corrected, unlefs the Clock be fo fitted that the vibrations be truly regular and uniform.

And

And this irregularity of Vibrations may proceed from a threefold head; the firſt is, the various temper of the air thro' which the globe paſſes, for if it be thick it reſiſts more, if heavier, the motion is not only conſequently hindred by the greater denſity, but alſo the weight of the globe is rendred leſs ponderous, that therefore they have leſs ſtrength to cut the air, and it renders the motion of the wheels and the *Impetus* more faint and weak. The ſecond is, the impulſive force of the wheels, or other power, continuing the vibrations, which if it be irregular, induces in like manner at leaſt ſome, if not all, the Irregularity in the vibrations, and theſe two heads may be referred to outward cauſes. The third is from within, or from the nature of the vibrations themſelves, which are, as we have ſaid, that if a globe fall by its own weight, in ſwinging it will make many vibrations, yet they will not all be of a like continuance.

The irregularity of Vibrations which proceed from the firſt head may wholly be taken away, if the Clock with the Pendulum be included in a caſe of glaſs, or ſuch like receptacle, wholly unpaſſable to the air (which how to perform we ſhall ſhew hereafter), wherefore it remains that we ſpeak to the two other.

To the Irregularity of the third head, which is as it were inbred in the ſimple vibrations themſelves, a remedy ſeems to be found by the induſtrious *Hugenius* by the following ingenious practice, the whole Art conſiſts in a double arch of the figure of a Cycloid, within which the Pendulum agitates.

Fig. 141. Let the Pendulum be A B, which is agitated to and fro by indifferent arches B C, B D of 20 degrees, and let this Pendulum hang by a thred or ſmall cord A E of one inch more or leſs, according to the length of the Pendulum, whoſe remaining part E B muſt be ſtiff; diſpoſe here and there near the centre A two bowed thin plates of mettal A G H and A F I, ſo that they touch the lines A D, A C, in the points F and G, and the curvity ought to have the figure of a Cycloid ; ſo it will come to paſs that if the Pendulum make greater vibrations, and runs out beyound the lines A C, A D, it will touch the Cycloid in the points F and G, and its length will not any longer be A D but F D, and ſo when the Pendulum is made ſhorter, its vibration continues leſs time : But why the Author choſe rather the figure of a Cycloid than another Curve doth not ſufficient-

ly appear, nor doth his Demonſtration ſeem to be lawful,
whereby he pretends to ſhew by this Cycloid that the length
of the Pendulum is made leſſer and leſſer ſucceſſively, while
it hits againſt the thred A E, and that that leſſer length preciſe-
ly compenſates the greater length of time of the vibrations
which are made by the greater arches.

The manner of deſcribing the Cycloid, according to the Au-
thor, is two fold : Firſt, deſcribe a Circle whoſe diameter A B
is equal to half the length of the given Pendulum ; take in the
circumference any number of equal parts both ways from the
diameter as A C, C D, D E, E F, and A G, G H, H I, I K, and
join the parallel lines C G, D H, E I, F K, then make the right
line L M equal to the Curve or arch A D F, and divide it in-
to as many equal parts as there are in the arch, to wit, into 4
parts, one of theſe parts of the line L M transfer from C to N,
and the ſame transfer from G to O ; moreover two of theſe
parts L M transfer from D in P, and from H in Q ; likewiſe
three of them from E in R, and from I in S : Laſtly, all four
from F in T, and from K in V, and by the points A, O, Q,
S, V draw a line, and alſo by the points A, N, P, R, T, and
they will be portions of a Cycloid, between which the Pendu-
lum muſt be hung from the Centre A ; the right line L M
which is to be equal to the arch A D F, he teaches to find in
this manner : Make X Z equal to two chords, ſubtending the
arches A D, D F, then take X Y equal to the Chord A F, of the
whole arch A D F, take the third part of the difference Y Z,
that is Z A, and add it to X Z, and X A will be a right line e-
qual to the arch.

The ſecond way is Mechanically ; on a plain Table, place a
Ruler A B half an inch in thickneſs, make alſo a little wheel or
cylinder of the ſame thinkneſs C D E H, whoſe Diameter make
equal to half the length of the pendulum ; then a thred or ſtring
F C H E being faſtned in the point F of the rule, and in ſome
point E of the Cylinder, ſo that part of it be wound about the
Cylinder, and the other part extended on the ſide of the rule
F C ; in the ſame Cylinder fix an iron ſtile D I, which ſhall
deſcend a little below the lower baſe, and exactly correſpond
to the circumference of the Cylinder ; theſe things thus diſ-
poſed, if the Cylinder turn about on the ſide B A, towards A,
ſo that the ſtring be always wholly ſtrecht, the ſtile with its
point I, will deſcribe the cycloid line I K, and in the ſame

manner, you may defcribe another like and oppofit unto it, and you will have the figure M K I, which reprefents the fpace between the two crooked pieces of thin mettal, between which the pendulum ought to agitate, fo as to make all its vibrations in equal times.

Another late invention of *Mathew Campanes* confifts altogether like to a double Pendulum, which is fo fitted to the Clock, that one of them moves and makes a certain number of vibrations, the other refting, and by turns while the firft refteth the other finifhes the fame number of vibrations; and in this manner, 'tis agitated by one after tother, that as foon as one refteth, the other begins to move; for if a pendulum of its own accord and proper weight falling from fome certain height of its arch, make 100 vibrations in the fpace of one minute of an hour; 'tis certain that another exactly like the former will efect the fame number of vibrations in the fame fpace of time, provided it fall of it felf from the fame height; to wit, the impediment being removed in the fame manner which detain'd the pendulum from falling from that Altitude; wherefore if two pendulums are fo fitted in a Clock, that they are both every where alike, and falling from an equal height finifh 100 vibrations in one minute, they will move one after another, nor will one begin to move until the other has finifht 100 vibrations, and no irregularity can intervene in the meafure of motion, fince each compleats 100 vibrations in one minute precifely.

And the Clock may be fo difpofed, that while one pendulum makes its vibrations, the other pendulum not only refts, but neither any of its wheels of the Clock are moved, befides fome one defigned for the purpofe, that as foon as the other hath made 100 or 60 vibrations, it removes the impediment which detain'd both the pendulum and the Clock, and detains the pendulum firft in agitation to reft at the fame inftant that the other together with the Clock begins to move; then again, the Clock with the pendulum refteth the impediment being removed from the motion of the other pendulum.

This may be done many ways, as any one inftructed and exercifed in Mechanicks may eafily underftand; the Author fhews one way, which becaufe he hath not fufficiently explained it, 'tis in vain to defcribe it here.

And although I think this kind of Clock furnifht with a
double

double pendulum to be most exact, and scarcely to err one minute in an whole day, that is, in 24. hours, if it be well kept in some Chamber, and be placed in an unmoveable site; yet if you make use of it in Navigation to find the Geographical Longitude, I cannot esteem it wholly to satisfie what is desired, for two Reasons; first, because it can scarce be in the agitation of a great ship, but the whole Clock must conceive some motion, or at least a light shaking or trembling in it self, although it be artificially fixt on movable poles, or hangs on movable circles; from which trembling or shaking, the vibrations of the pendulums must needs suffer some irregularity.

The second reason common to all kind of pendulums is, because while the pendulum is moved together with the ship, it makes not a circular motion, but another motion mixt of a circular and a right; yea, if the ship besides an Horizontal motion be agitated by other motions, chiefly upwards and downwards, as happens many times in an unquiet Sea, the motion of the Pendulum will be mixt of a Circuler, Horizontal, and of other motions both right and crooked, nor at any time uniform, from whence it comes to pass, that while the centre of the pendulum is irregularly moved, its vibrations will be irregular, and it will run through some times greater and some times lesser arches, or rather crooked lines, and altogether unlike between themselves, as we have shewn before.

Problem. XII.

To reduce the continual moving, and irregular Powers of Clocks and Engins, to a regular and uniform motion.

SInce in the preceeding Problem we have taught ways and means whereby the finite and irregular motions of Powers may practically be reduced to equality of motion, nothing seems now to be wanting, unless 'tis to shew how to obtain a motion equal and uniform in powers infinite or continul, which otherwise of their own nature are irregular; which, if it be done, we shall attain to a motion continual, and altogether equal; nevertheless I do not mean that continual motion which is altogether mechanical, or purely artificial (of which in its place) but the other which is called *Physico-Mechanic*, because that it partly consists of Art, and partly of Nature; for since no moving

power

power feems to be continual or perpetual, unlefs it be natural, or depends immediately on a natural caufe, as we fhall manifeft hereafter, and thefe kind of natural powers or virtues in nature keep not always an equal order ; it is requifite to find out an art whereby we may effect that their force, although unequal, may neverthelefs be ferviceable to the perpetuating of a motion equal, and altogether uniform.

Therefore I call all thofe perpetual moving powers, or natural and irregular, to which we are apt either immediately or mediately to apply new weights, or regular powers, within fome finite and determinate time fucceffively, and always to the Engin being once made.

And all the induftry and art which is to ufed in this matter, may eafily be gathered from what we have faid in Problem the 5th, for if we fuppofe a Clock to be made, whofe motion according to the rules prefcribed juft before is abfolutely uniform, and it fhould go fo for eight days by fome weight hanged to the lower wheel, that in that fpace of time, it fhall want no help, if then within that fame time of 8 days an infinite power, or a perpetual natural one be artifically applied, that fhall be fit to raife another weight equal to the former, and to depofit it in the place of the former, fo that forthwith the weight of the Clock likewife fhall defcend to the bottom, and be placed in the fubjected channel, the Clock will be moved again by that new advanced weight, according to the artifice in Problem the 5th. aforefaid, and that will alfo keep it going 8 days, it is plain that the motion of the Clock will be equal and perpetual.

But Note, that you muft ufe two weights at leaft, one whereof muft be hung to the Clock, while its regular motion moves forward, the other by an irregular power (fuppofe Wind, Rain, Heat, Drought, &c.) is fubftituted in its place, before that hath difcharged its office.

Moreover thefe two weights ought to be Sphærical, that one may eafily fucceed the other, the devolution being made by a channel, or plane, fomewhat declining, as in the fame 5th problem is fhewn.

Laftly, 'tis convenient that the motion of the Clock be long enough, and lafting, before the weight defcend to the loweft place, for this reafon, that the natural powers may ferve turn a fufficient time in the interim, that the other weight that comes

in place of the former be drawn up; for although the fore-
said power be perpetual, yet it acts not always, or at least so
little sometimes, that although at some times it be more strong,
oft-times neverthelefs a time may be expected for some hours,
or also days, wherein force convenient may be attained by the
succeffive and irregular series of natural caufes; that you may
more clearly understand what is meant when we speak of per-
petual motion, for then we describe various perpetual motions
Physico-Mechanic, from whence it appears of what use na-
tural powers are, and by what art they are applied, that their
force although irregular may notwithstanding perpetuate a re-
gular motion to any Engin; I will offer only one Example in
this place, by which you may easily judge of the rest. 'Tis
already known to Artificers, that by small Breaths, or from the
smoak of a Kitchin Fire, spits are wont to be turn'd, that is to
say, difpofe in the centre of the Chimny (which if it be Cy-
lindrical it will be the better) a crofs, or some wheel, furnisht
with wings made of Tin, in the same or like form as is before
described, for so while those wings hit obliquely against the
Smoak, they carry the wheel about, and if there be in the axis
a toothed Tympane, it conveys that together with it self, by
which means it moves other wheels annext to it; a weight
fomewhat Sphærical put into a little Basket, may be raifed to
a certain height, and there put down according as we have
faid at *Problem* 5th. And to raife this weight which is fit to
animate the Clock in motion 24 hours, it will not be needful
that wood be always put on the fire, but a fire a few hours
will be fufficient each day, if the Clock which is to animate by
the weight raifed by the Smoak, be proportioned to that weight.
Wherefore in this, and any other like artifice, firft you muft
examine how much weight may conveniently be raifed by a
natural power in a limitted time to a perfixt height, and then
make the Clock or Engin proportioned to fuch weight.

What we have faid concerning Smoak, may take place in
Wind blowing, and Wings impelling, which will raife weight
by annexing wheels, alfo if any one in a City, or the Gate of
an House, difpofe a threfhold, or little Bridge, with an occult
leaver, or a fpring of thin mettal plate a little elevated, fo that
by the entring or going forth of Men, of Horfes, and of Cha-
riots, a weight may be depreffed oft times in a day, from each
force a weight of fome bignefs may be raifed a little, and fo
by

by repeated motions may be drawn to a defigned height for the perpetual animating of any Engin.

Problem. XIII.

A Clock animated, or going by Sand, perfevering in motion many days, and fhewing the Hours, and alfo Striking.

AFter the application of weights, or moving powers, we come to thofe Engins, or meafurers of time, in which the circular motion is moft apparent, and fince there are many Hour-glaffes that belong to perpendicular motion, or to an inclined plane, it remains for the perfecting of them, that we fhew how (approaching to circular motion) it may be effected that they may turn themfelves by motion of their own accord after the flowing or running of the Sand, and that not once, but many times one after another, that therefore we may not only be freed from the inconveniency of attending the laft flux of the Sand, while we are converfant in any other bufinefs, but alfo that it may not want any help of the hands for feveral days, and each turning about may fucceffively fhew the Hours, or likewife Strike : Mark what follows.

Fig. 143. Suppofe A B an Hour-glafs with Sand, fuch as is commonly ufed, in the middle whereof fix a tranfverfe axis G H, and in an Horizontal fite, and to the fame axis let there be firmly fitted two Pullies, or rather Cylinders here and there, movable with the axis by means of weights Q and R hanging from them; above the Hour-glafs make another Horizontal axis I K, movable about the poles I K, to whofe fide annex an immovable arm L M, with a weight M affixt to its end; and in the middle in like manner, let another little arm N O parallell to the former defcend, which may be detain'd in its extream part O, or rather elevated together with the weight M, by a little wing ftanding out from the upper bafe of the Sand, fo that being hindred by the weight M, the Sand cannot be wholly turned by the weights Q and R, notwithftanding it will remain in a fite not altogether perpendicular, but fomewhat inclined ; and the weight M muft be fo proportioned to the weight of the Clock, and alfo to the weights Q and R, that it may be detain'd in the faid inclined fite, untill all the fand be defcended from the upper glafs A into the lower one B, and when all the Sand is run into the lower glafs B, it will obtain

g eater

greater weight, that therefore while the Sand endeavours to be placed in a perpendicular fite, or in the line of direction, the weight M will rife higher, and at once will free the little wing O from the little arm N O, from whence follows the turning of the Hour-glafs by means of the weights Q R, and the lower part B will be placed in the upper part, and will be detained by the little arm N O, by means of the little flap or wing P, untill the Sand is again run out; for then it will again be turned as before, and fo fucceffively until the weights Q and R are quite defcended; but becaufe the little Cylinders C E, on which the ropes fuftaining, the weights Q R are turn'd about, may be of a fmall bignefs, and becaufe after every hour they make but half a revolution, it appears that the motion of the Clock and the turnings may be extended to many hours.

But if you would fit an index to fhew the hours, that you may eafily obtain by means of two little teeth, fixt on the end G of the axis G H and oppofite to each other, which fucceffively and by turns one after another, every turning of the Hour-glafs will move forward the wheel G T, furnifht with fo many teeth as there are hours defcribed in the circle, which may be noted by a ftanding index fixt in the centre of the fame wheel; but if in like manner you affix an hour wheel in a convenient place to the fame Engin, which may be moved forward by means of fome toothed Tympane, or wheel, by the fame axis, you may caufe the number of hours to be heard by ftriking on a Bell.

Many other ways the index may be fitted to the fame Engin, and the ftriking of the hours may be made, as will appear by what we fhall fhew hereafter, when we fhall treat of the indexes of Clocks, and their ftriking.

Problem. XIV.

A Clock moving by the Confumption of Oyl in a Lamp.

Fig. 144. MAke a Lamp whofe part A B entertaining the Oyl, is like a Column or Cylindrical, fhut clofe every where, except in its loweft part C, where the Oyl enters flowly through a little opening into a veffel annext C L, while the other Oyl is confumed by the flame L; in the foremoft part

E e

I N make a certain channel, and folder or glue it to the fore-said Cylinder, within which on the upper part make a fecret or hidden pulley I, with an axis E F, prefenting or conveying on the outward vifible face the index of the hours defcribed in the circle G H.

Thefe things being done, put Oyl into the Lamp, or Cylin-der A B, upon which let a cube D of light matter (as Cork, or Wood) fwim, and to this you muft faften a thred, or cat-gut D C G I M, *viz.* that it may defcend from the upper fuperficies of the Oyl to C, and being put about the little pullies C C, it may afcend to I, and be folded about that pulley; and laftly, let the other end M fuftain a weight, yet of lefs gravity than to draw downwards the cube D, which muft always Swim up-on the Oyl, and while the Oyl confumes, it defcends with the Oyl, and draws the thred, or Cat-gut, with the weight M, and turns the pulley I, together with the hour Index.

Note, That the magnitude of the little pulley I, muft be pro-portionate with the defcent of the Oyl, and of the cube D; wherefore we muft obferve how much the cube defcends in one hour, to the end that the little pulley moving, the index I may be moved orderly.

Moreover the receiver muft be uniform, and of one thick-nefs, and muft make ufe of the fame number of threds that the Oyl may be confumed uniformly, and the Lamp may be fill'd with Oyl, either by a little door, or wicker, beneath C, or by fome hole in the upper bafe of the Cylinder A, which after-wards muft be diligently fenced from the Air entring in with a Screw.

If the axis of the little pulley I be fo fitted within the Cy-linder A B, that its end F ftick out on the out-fide by a hole made in the fame Cylinder, and turn about the Index, you will obtain the fame effect without the channel on the exterior part I N, which is made to caufe the artifice to feem occult and mi-fterious; but that hole muft be fo fitted to the movable axis with-in it E F, that there appear no admittance for air into the Cy-linder A B, for if there be, the Oyl will wholly defcend, and be poured out without the veffel C L.

Alfo the index of the hours may be made in the upper bafe A, of the Cylinder to fit, fo that the bafe it felf be for the hour circle, which may eafily be obtained many ways, as will appear to any induftrious Artificer.

Laftly,

Laſtly, Beſides the circle and the hour index, there may be applied a toothed wheel, by whoſe means the hours may ſtrike; and if to make it more ingeniouſly, you would place a little Bell within the Lamp to give notice of the hours, you muſt ſolder or glue an open tube ſpirally to both ends of the inward ſuperficies of a concave Cylinder, deſcending about the Cylinder; and through this tube, or channel, deſcends the Oyl while it waſts by degrees, and a globe of light matter ſwimming on the Oyl within the tube; then all things being ſo fitted, that in each hour the motion of the Globe in deſcending, finiſhes one whole ſpire, and then it hits againſt a peſtle, or ſome flap, or wing, which looſes the movable wheel from the weight, as is wont to be done in common Clocks with wheels, ſo after the finiſhing of each ſpace of the ſpires, the Globe unlooſing the ſame wheel, cauſes new ſtroaks of the hours on the Bell.

Problem. XV.

To make a pulley Clock, or a Clock of meer pullies without any toothed wheels.

Fig. 145. THis artifice is propoſed by Father *Schottus*, lib. 9. *Tecnic. Cap.* 10. *Prop.* 47. Let there be (ſays he) a little pulley A B about its axis, or alſo with a movable axis, to this join the perpendicular M N P, by the artifice in Problem the 3d, and that by means of a little rod M A; from the little pulley A B, ſuſpend the pulley C D, by means of a perpetual knotty little chord, whether thoſe knots be made of firm little balls diſpoſed or fixt to the rope, or knots made by bending the chord it ſelf, and cavities or hollowings of equal ſpace from one another, to anſwer theſe knots in each pulley A B and C D; the pulley C D hath in its axis a little pulley E F made faſt, from whence is ſuſpended in the ſame plain manner the pulley G H; and ſo henceforward the pulleys may be continued as many as are needfull; from the lower pulley, *viz.* to the little pulley I K, of the pulley G H, hang the weight L, ſufficient for the motion of the pullies, and of the perpendicular; all the axes of the hanging pullies muſt be moved not within a firm hole, but within a certain ſlit, or notch, cut from the top to the bottom, that while thoſe perpetual chords and

the knots are contracted, or diftended, the axes of the pullies may be raifed, or deprefled; the reft that belongs hereto, as the proportions of the pullies to each other, are eafily underftood from what is faid before, all thofe pullies being agitated by the force of the weight L, will be moved circularly, and the perpendicular N P, freely moving in its centre or point of fufpenfion, will be agitated by the little pulley A B, and the little rod A M: See the problem before cited, and the other ways of applying pendulums to Clocks before defcribed.

According to the Author, the Pullies muft be fo difpofed that their axes move within the flit, or notch, and that caufes the Engin to work ill, for when the axes gravitate unequally from the other Pullies, or from the weight L hung to the Pullies, they are crooked or awry, and do not retain an horizontal fite as they ought ; wherefore the axes fhould rather be put into firm holes, and left the chords be fhrunk or ftretched by wet, or drought, they may be wove of metallic threds, or wyres ; but if you ufe common chords the axes muft be put into flits, and not into holes, but the pulley ropes ought to be doubled, and the weight hung to the lower little pulley, to wit, to the axis of the pulley C D, another little pulley equal to E F muft be fixt, and you muft anfwer the fame in the oppofite face of the pulley ; which little pulley in like manner with another perpetual chord muft fuftain the fame pulley G H, or rather another altogether like it, and annext to it : Laftly, another fmall pulley like to I K muft anfwer on the oppofite face ; then the weight L will be parted in the middle, and will be fuftain'd partly by the little pulley I K, and partly by the other oppofite.

Problem. XVI.

To render the motion of a Pendulum continual for many hours, or alfo whole days.

Many Artifices have been invented in the laft years of this Age, and various ways thought on of rendring or effecting the motion of Pendulums continual, that they may perfevere for many hours or days with the fame perpetual velocity ; from whence alfo this advantage follows, that all the vibrations are made in equal times ; fome of thefe kinds of

Artifices

Artifices I fhall defcribe in this place, which feem to me moft meet for the purpofe, for any one of his own ingenuity may take occafion to think of others.

Fig. 146. Firft then, let the Pendulum be A B, to which at right Angles join the little arm A C, and let the upper wheel, or toothed Cylinder be D E, which being turn'd about draws with it another little arm D C, made faft in the bafe of its Cylinder near the circumference being round in the middle, and with a fmooth pin, fo that the little arm may be freely moved about this pin, and confequently while 'tis turn'd about the Cylinder, or wheel D, the little arm D C may be deprefs'd, or bore down, which conjoin in C with another little arm, and the angle C being inlarged will fuddainly caufe the lance of the Pendulum A B to be lifted up, which is join'd in A to the wood I L from whence being fufpended 'tis detain'd, but neverthelefs it freely turns about the fmooth pin A faftned to the wood ; then fome fufficient weight being added to the lower wheel G, from this motion follows the motion of the wheel above it F, and this being in the middle (as it is wont to be in Clocks) turns about the uppermoft wheel E D, which drawing with it the little arm of the pendulum, the fame imprints a motion to the pendulum, as long as there is new rope which fuftains the weight annext to the wheel beneath, or loweft wheel.

Note, inftead of the Cylinder, or little wheel D E, you may fit a toothed Cylinder having a crooked handle, which will lay hold on, and turn about the little arm D C, fuch as is the Cylinder M.

Note alfo, by how much leffer the proportion of the diameter of the little wheel D fhall be to the arm A C, fo much leffer will the arches be that are defcribed by the motion of the pendulum A B.

Fig. 147. In the fecond place let the pendulum A B be movably fixt in A, in its lance faften the arm M G, which may eafily run fometimes into this, fometimes into that part, and fuftain it parallel to the horizon ; from the middle part of the fame arm M G ftretch out wood or iron like a little fork, or two teeth, made hollow, fticking out as at L, which in its cavity or cleft admits the pulley E F, immovable and in an oblique fite put into the axis C D ; let this kind of axis be furnifht with a toothed Cylinder, which will be turn'd about by

the

the wheel N, by means of the weight P being added to it, or by means of other wheels, as you pleafe : The Engin being difpofed in this manner, while the axis I H is turn'd about of the lower wheel ; in like manner the middle axis C D is turn'd about by the toothed Cylinder, and with it the little pulley E F, which fince it obtains an oblique fite, it caufes the arm G M, into which it is put to run to and fro, and moves the pendulum A B.

Fig. 148. Thirdly, Suppofe the pendulum D B, hanging from the arm A C, immovably fixt in C, and let the lance of the pendulum be ftretcht out fomewhat above the point A, from whence 'tis fufpended, to wit, in D ; then fit the axis E F, fuftain'd in the middle by the arm F, to which join the toothed Cylinder L, and let this axis be ftretched out through the hole of the arm F towards A. Laftly, in the extream part of it near A, let it be furnifht with a concave Cylinder, and being cut oblique, fo that the fection G D make an Elliptic figure ; the Point A from whence the lance of the pendulum is fufpended, muft be in the fame horizontal right line with the axis E F, and with the arm A C ; moreover it ought to be precifely in the centre of the fame fection G D, although becaufe of the cavity of the Cylinder the point of hanging remains free in the air.

Then while the toothed Cylinder L is turn'd round together with the axis E F, the Cylinder D G is turn'd all under one, whofe extream or end being an oblique Section, hitting againft the lance of the Pendulum it unites a motion like to the precedent.

Fig. 149. Fourthly, let the Pendulum be A B, whofe axis A C carries with it two toothed Cylinders D and E, which in like manner here and there, lay hold on the toothed wheel D E, but with interrupted teeth, fo that while one Cylinder lays hold on the wheel on one part, the other Cylinder lyes upon the oppofite part of the wheel which wants teeth, and therefore the whole wheel ought to be divided into many rows of teeth in an odd number, and 'tis convenient to make each row of three teeth, and between one and the other row, a fpace of teeth left vacant, as much as is occupied by three teeth ; fo as often as the weight fhall be hung to the lower wheel H K, this being turn'd about, will move the toothed Cylinder F, which being in the middle, will move the fore-faid

said toothed wheel, which biting the toothed Cylinders D, E, one after another, somtimes on one, somtimes on the other opposit part, will move in like manner the pendulum A B alternately.

And as in the foresaid Engins, each vibration of the pendulum is made in a determined part of time ; to wit, in one second minute, or in 20 third minute, &c. the proportion of the wheels and of their teeth must be observed, as in this last Engin, if we would compose each vibration of the pendulum to answer one second minute ; in the wheel D E, dispose 25 rows of teeth with as many vacant spaces between, the Cylinder F must be furnisht with 8 teeth, the wheel H K must have 96 teeth, the Cylinder G likewise consists of 8 teeth, beneath which will be another wheel of 96 teeth, to which hang a weight ; for in this manner 3600 compound vibrations will be made in each hour, each whereof will be equal to one second minute ; then make fit the weight hung to the lowermost wheel, with the length and weight of the pendulum A B, in such manner, that the lower wheel be once turn'd about in an hour precisely, for so it will come to pass that the Cylinder G will be turned 12 turns, and the Cylinder F, together with the wheel D E 144 turns, and at last the pendulum will finish 3600 compound vibrations.

Instead of the wheel D E of discontinued teeth, you may use a toothed wheel common to Clocks, if instead of the Cylinder of teeth, laying hold on it, you use two little handles, which by turns shall urge and move forward those teeth of the wheel, by laying hold of them.

Inventions of this kind are excellent, not only in being serviceable in continuing the motion of the pendulum, but also in making of Clocks most exact as is obvious to every considerate person ; which Engins or Clocks have this utility and conveniency, that they scarce make any noise in their motion, since the pendulum is instead of a Ballance, which in common Clocks cannot agitate without noise.

<div align="right">Problem</div>

Problem. XVII.

To make a Clock to shew the hours on both sides, after a new method, which by a weight hung to either of its sides prosecutes its course, and the index of the Clock proceeds forward in both motions consequently.

THE Author before cited teaches this Artifice : See the last Figure of the preceeding Problem, where we have taught the method of continuing the vibrations of a Pendulum ; for if you rightly understand the construction of the Artifice of this Engin, 'tis manifest from thence, that if, while the perpendicular A B is agitated, the wheel K H suddenly changes its turning about to the opposite part, that is, it begins to move to the right hand, when before it moved to the left hand, the motion neverthelefs of the perpendicular will in no wife be hindred ; because that in whatsoever place of its arch, the perpendicular A B lays hold on unawares from its first acquired *impetus*, it will continue the same vibration ; but for the following vibration, it will have the favoring impulse to it self, for as much as the parity of the rest is the motion instituted by the wheels in this, or that part.

The same may be obtained other ways, as is explained in the foregoing Problem, but chiefly by the *Figures* 146 and 148, but yet easier by application of a Pendulum, which we have taught at Problem 5 ; it only remains then that an index be applied so, that although the turning of the wheels be made on the opposit part, yet it always proceeds forward in the same part.

Fig. 150. Let the axis A B be continually movable together, with the toothed Tympane B, firmly adhearing to the axis, which forces the wheels of the Clock on both sides to this, or that part.

In the first place, fix on the same axis, two wheels with fingers, or claws, within which smooth holes being bored in the centre, and the axis being smooth will move freely ; moreover put upon the axis two other Cylindrics G H, and I K, with faw-like teeth or jags, each whereof must be firmly put into the axis, and turnable together with it, the jags of these wheels bend to the opposit parts, and are stifned in the opposit parts by wedges, or little pestles C G, E I, each of which is furnisht with

a little

a little preffing wing in preffing its power, that the pins bending forward to the Jags, admit the motion without much refiftance, and thefe pins are conveyed by the finger'd wheels C D, and E F, to which are fixt fmooth little pins holding them at liberty; laftly, to the two finger'd wheels, there muft be added a third C E movable with the axis L M, and its fingers folding in both the fingers of the wheels C D and E F, it may be expedient that the wheel C E referrs to another fite, to wit, vertical, (if neceffity require it) the circle of the wheel being put in points defigned.

Therefore the Tympane B with the axis and jag wheels G H, I K fixt in it, are turn'd in either part, for prefently either of the jag wheels will be bound by its bar or pin, and render its finger as it were continual, which with the axis leads it with it felf, and the wheel C E together; and becaufe this infolds its fingers with the other wheels, it impells it but in the oppofit part, in which its bar or peftle hinders not in as much as the oppofit jags, holding the former and admitting the motion on that part; now if the Tympane B change its turning to the oppofit, then that which was firft hindred by the peftle or bar will be loofed, but that which was loofe lays hold on his jagged wheel, which then firft begins to move in the fame part, in which his finger'd wheel moved before, and fince the finger'd motion is the fame now as before, becaufe continued in the fame part, therefore the motion will be continued, and the half of the Fingers C E ; to which therefore an hour index being fitted, will always move forward into the fame part whitherfoever the Tympane B with the whole Dial is carried.

Note, Firft, That the wheel C E advancing always in this or that part, depends on the jaggs or faw-like teeth, reciprocally inclining, and turning towards this or that part, whence if the fite of both of them be changed by inverting both the jag wheels, and the other face being applyed to its finger'd wheel (the peftles or bars of the Jaggs being alfo changed) the motion of the wheel C E will be likewife changed.

Secondly, if the wheel C E be led about by the hand in that part in which it was firft impelled by the fingers C D, and E F, both thofe fingers will be moved, but the axis with the faw-like teeth wheel, refteth by force of this Conftruction if nothing elfe hinders, and may in the interim be turned in this or that part, while 'tis not moved fooner than the axis L M.

.F f

Thirdly,

Thirdly, but if you will lead about the wheel C E by the hand in the oppofite part, and not in it which it was decreed to move, no motion at all will follow, but the whole fyftem will be firm, and will ftick, fo that the refiftance of the hand detaining the wheel exceedeth, 'tis neceffary to apply a proportionate power to the tympane B on each part of it, which is no lefs a Paradox than the former; this conftruction extends it felf to many other Problems of motion, as the deducing the librating motion into Circular, to the recalling whatfoever irregular motion to a well order'd Circular, &c. as will appear in what follows.

Problem. XVIII.

The Hydraulic Clock of Father Bettinus.

THis kind of Clock is indeed very ingenious, and the invention of Father *Bettinus*, and afterwards increaft and enlarged in many things by Father *Efchinardus*, of whofe work alfo I have often obferved not without great pleafure of mind, the like Engin made in the *Roman* College, which performed the effect beft of any: Therefore left our work fhould want fomewhat of thofe things which fcent moft of Ingenuity, we have tranflated this from *Bettinus*.

The outward Artifice of the Hour Tympane.

Fig. 151. You fee the exprefs form of the Tympane conveyed from the axis through the centre, whofe apparent Pole is H, and the other pole not apparent, and of the chord I K L M N P, whofe two ends are fixt in I, and the little pulley K (if you pleafe of Brafs) with a fmall weight ftretching out the rope lightly, that beyond L it adheres about the occult pole: But the great weight under the pulley N while the rope endeavours to draw the chafed axis, and as it were toothed, afterwards moves the Tympane together with the Tympane and the number 4 afcends, and after the Tympane movable pieces either of wood or iron toothed, whofe form and art we will fhew hereafter, and fome fuch you fee Q, R, while they hit againft the movable and changing plate of mettal S, it connects the handles T V X, being drawn together they raife the little hammer on the fide of the little Bell Y to ftrike the hours.

The

The art of changing the numbers in the hole, where 4, as it were, lies hid under the circular plane, as also the art of setting at liberty the teeth under the plane of the opposite Tympane, we will shew hereafter.

Sect. II.

The inward artifice of the Tympane.

Fig. 152. ONe of the circular planes being drawn aside the Tympane immediately shuts, and that on the other part opens, as you see in the figure annext; behold there appears to you the superficies of two concentric cylinders A B C, D E F within the Tympane, within the concave of the lesser the stays or props are G, H, in whose holes the axis of the Tympane is put, within the convex of the lesser, and the concave of the greater is the plane K, which is join'd to the cylindric superficies, and to the circular planes shutting the Tympane; through the little hole I of the small plane I K passes water to run, when the Engin is moved by force of the weight, and descending in C, the water is prest by the plane K I.

Therefore while the rope about the little toothed wheel, after H by the force of the weight weighing down to the parts beholding the left hand as F E, thrust through G, H turns the axis together with the Engin, and the plane K I descends and hits against the water, and presses it towards the parts beholding the right hand as M A; in the mean while the water nickles down through the hole, and by little and little the plane K I intercepts the middle between the water, until the water running between more and more through the hole I, and the plane K I ascending to the parts towards A D (or beholding the right hand) most part of the water which flows beneath the plane increases the force of the weight hanging about the axis H, and causeth the plane K I which now is idle in the parts A D with a little water (which it hath not as yet deeply flowing above it self) at length 'tis turn'd by A D with a swifter motion towards C (or to the parts beholding the left hand) and from thence it descends again and the water presseth, which again flows through the hole, &c. and so perpetually by turns the Engin is turned, the Orb compleating a rotation once in each hour.

The

The art is, that the dropping of the water continue an whole hour, whiles that after a flow and infensible motion of the Engin for an hour, unexpectedly the Engin turns, in the beginning of the dropping ; in which revolution the hour is ftruck on the back part of the Tympane, but in the forepart the note or figure fhewing the hour on the dial plate is changed.

Sect. III.

An eafy and moft ingenious Art, whereby the number of hours are always changed, and alfo the hours are ftruck in the hour Tympane without the artifice of other vulgar movers.

Fig. 153.

THE invention of which ftriking and changing you fhall have here in a double figure : And firft, that which belongs to the changing of the numbers fhewing the hours ; fuppofe on the fore part of the fhut Tympane, the plane to be drawn afide with the inclofed little boards.

The circle A B C D expofes to the eye that plane on the fore part, to which is affixt in E and F the Hexagon plane, leffened in on fide P Q a half part of one of the other fides ; and that Exagon is the excentric to the circle A B C D, having a hole G common with the circle (which is the centre of the circle) in which the axis of the Tympane is conveyed through. The hole under A is that, under which the number of the hour Indexes appear on the other part in the little boards, which muft be noted in the hinder part of the little boards, but in the figure for plainnefs they are noted in the face apparent to the eye ; you fee thofe little boards joined to little thin plates of mettal with corners, the ends whereof are movable about the fixt little pins within the little boards.

The outward form of the art you have in the feperate H, and at I and K ; imagine then the little board H to be in his place between I K, and to ftand upon the fide P Q, which is only fit to receive one little board, the other fides being large enough for two, as you fee in the Figure ; then while H between I K fhews the number (which you muft conceive on the other part) of the firft hour through the hole A ; and the circle A B C D is turned with the Tympane flowly fuppofe towards A, the little boards 7, 8 fit themfelves to the fide M L, and 6, 5, to the fide L R, 4, 3, to the fide R Q, and by reafon of the obliqui-
ty,

ty, the little board H being removed from the fide P Q, in its place fucceeds 2, and fhews it felf under a form. Moreover H and 12 fit themfelves to the fide P N, 11 and 10, to the fide M N; 9 and 8, hang down beneath L M, and 8 fucceeds in the place of the middle 7 hanging down, &c. and three always hang down without, and beneath one fide as you fee 6, 7, 8, beneath M L; and by this ingenious, eafy, fimple, and wonderful art the little boards change by turns, and one after another they fhew the hours, the number of hours being infcribed under an open bright hole.

Fig. 154. But that which belongs to the ftriking of the hours is thus; fuppofe on the back part of the fhut Tympane, the plane being drawn afide with the inclofed toothed little boards, that plane on the inner part expofed to the eye is reprefented by the circle S T, to which is affixt in V X a pentagonal plane excentric in the circle S T, having a common fquare hole (which is the centre of the circle) in which the axis of the Tympane is put through; there are 6 little boards quadrangular with teeth (according to the number of hours to be ftruck) having bafes fomewhat lefs than the fides of the Pentagon, and they are made faft by the corners with thin plates of mettal movable about the ends as you fee in the Figure, and as is done in the little boards of the hour indices in the antecedent circle.

That you may underftand the form and art the better, you have fet a part Z, fuppofe the thin plate (by whofe impulfe the little hammer is led to ftrike the hours) to be in *a*, and the circle in the Tympane to be turn'd from S towards *a* T, the litlit board B with 6 teeth or claws ftriking againft in *a*, founds fix tinklings on the bell for the hours, and prefently falls down beneath *a*; then B being oblique to the parts T, the little board *d* fits it felf to the fide *e*, and fo of the reft in the Orb, as is faid before of the little boards of the hour Indexes.

And it muft be noted and effected, that the little boards with teeth of the circle S T, fo agree with the little boards of the Circle B D of the antecedent figure, that they ftrike the hour, which is prefently fhown under the hole, the number of the little board in the circle B D being changed.

Alfo you muft take care that the hour plate infcribed in the firft Figure, *Section* the Firft, be diametrically oppofit to the plane K I of the figure in *Section* the fecond, through the hole

of

of whofe plane the water trickles down; and let the fame hour plate be oppofite to the little toothed board ftriking the hour (not fhew'd in the plate) of the next following number, fo that when the fhining hour eye is below the Horizon of the hours Diametrically oppofit to the little *Bell,* and in that eye they number of the hour is changed, in the fame moment the toothed little board ftrikes the hour, which being changed the hour immediately appears above the Horizon.

About the hole I, in the plane K I, through which the water flows on both parts above and beneath the plane K I, in the back convex of the Engin are two broad holes, through which the water is poured into the Tympane, and when need requires is prefently all taken out, and through the fame holes appears the leffer hole I, in the plane K I, that it may be lookt after if any thing hinders the running of the water through that little hole, and thofe two greater holes on the back part of the Tympame, may eafily be fhut and open'd by two brafs thin plates affixt with wax, or other fit glue.

And becaufe in the beginning of the hours the Tympane is turned flower, afterwards always fwifter, becaufe of a leffer refiftance of Water, therefore in one of the circular planes fhutting the Tympane is put a thin plate of lead in manner of an hook, decreafing by little and little, &c.

Sect. IV.

Obfervations of Father Efchinard, *to be practifed in making the forefaid Engin.*

THis Author learned in Experiments advifes in the firft place, that the Tympane be divided in four equal parts by Parallelograms of thin plates of mettal, one whereof ought to be boared through with a fmall hole, as is faid, but each of the reft are to be boared with a double hole much greater, one near the fafcia, the other near the inward axis of the Tympane; for hence it will come to pafs, that after the water hath paft through by the fmall hole in an hours time, then having obtain'd a freer paffage, it permits the veffel to be turn'd about with a fwifter motion, that in the interim the hour may be fhown by a fign of the little Bell, or the next ellapft, or the next to come; for unlefs the other thin plates

<div align="right">are</div>

are made with greater holes, the Tympane will rather return
than run forward ; wherefore likewife an inftrument may be
made divers ways for ftriking the bell, to wit, by making it fo
that thofe points take up fomewhat in their fwifter motion af-
ter the manner of a Leaver, as is wont to be done in large
Clocks with wheels, one end of which Leaver while it falls
down draws the thred to it felf, and raifes the hammer ; alfo
fharp points fixt to the tables may be fo faftned to the hinder
fuperficies of the tables, that they may directly behold the
Tympane, as alfo the centre of the Pentagon may be other-
wife taken, &c.

Secondly, The iron plates being wafht over with tin, corrupt
prefently, unlefs it be fenced by fome Sandarac, or varnifh, fit
for the bufinefs ; Copper cover'd over with tin, or tin only of
it felf, fo that it be very thin, is beft of all.

Thirdly, Beware left the place of the fmall hole be fo, that
after fome time the magnitude of the hole be changed.

Fourthly, The Tympane muft be $\frac{3}{4}$ of one Palm at leaft,
both in length and breadth, for if it be lefs it will not fucceed
fo well.

Fiftly, The moft fit water he takes to be rain water diftill'd,
but if the veffel be made of glafs, hot water will be better ;
and the quantity of water ought not to fill much lefs than half
the Tympane, but efpecially it ought not to come to the inner
axis, wherefore that axis will be the better, if it be made as
fmall as poffible ; the other things to be compared with one a-
nother are, the littlenefs of the hole, the quantity of water,
and the force of weight ; but chiefly you ought to take care
left that hole be ftopt, which ought to be at leaft as big as
one arch.

Sixthly, He denies that the thing may be done with Quick-
filver inftead of water, both becaufe it requires a greater hole
to flow out at, and therefore alfo a greater Tympane, as alfo
becaufe it will pafs out moft heavily ; laftly, becaufe all mettal
corrodes, and therefore the Tympane ought to be glafs, which
will be difficult to be made : Alfo he denies duft, or fand, to
be fit for that fervice, fince it ought to pafs through a fmall
hole by being compreft in the middle, which is done by thofe
thin plates of mettal, which cannot be obtain'd by duft : He
concludes, if any Liquor be found in which heat and cold doth
not govern, that is moft fit, fo it doth not corrupt the matter of
the Tympane.   Seven-

Seventhly, He afferts another fuch like Engin of his own com-
pofing, wherein he hath made a perfect Hexagon in the axis
for the Pentagon, and about it feven Tables are gathered to-
gether in the fame manner as above, every one of which bears
before it one of the feven Planets defcribed with its proper
Character. Laftly, in the foremoft face appears a circular thin
plate of mettal, but that for one circular hole it hath fix, each
being defcribed upon with fome cœleftial Sign, beginning,
viz. from *Aries*; then while the axis is turn'd about the
Planets are moved to the Weft, but fo, that in every cir-
cumvolution they go back to another Sign placed after it in
due order.

Eighthly, He teaches in what manner one Tympane, fo it be
large, may fuffice for ftriking the quarters of hours; fays he,
make a Veffel, which divide in 4 parts by 4 thin plates, and
then divide it again, but in a contrary manner, that is, let it
be cut by the plates in the Section which makes a circle, and
take away, as it were, $\frac{1}{3}$ part of the veffel, whence there will
be, as it were, two Veffels in the manner of one, then either of
thefe will be divided in 4 parts; the plates which divide the
leffer Veffel ought all to be double in a place, to wit, nigh the
fafcia, and nigh the axis, to be opened with large holes, and
the plates of the greater veffel are boared double in a place,
but with an unlike hole, to wit, one nigh the Fafcia very
fmall, and the other the axis much greater; for this is necef-
fary to communicate the air to every part of the Veffel, other-
wife the water will not pafs freely through the fmall hole;
laftly, put the water in fo to the leffer veffel that it may almoft
touch the axis, but in the greater veffel as little as may; be for
hence it comes to pafs, that when all the water in the grea-
ter Veffel fhall pafs through the firft fmall hole, before that
(fince 'tis but little) the impediment of the fecond thin plates
hinders, in the mean while the Clock will be moved fwifter,
but becaufe this way it rather returns than goes forward,
therefore 'tis reftrained by the water put in the leffer Veffel,
which in the interim paffes through the great hole; then
while the Clock in this manner is moved, after every quar-
ter of an hour it ftrikes on the little Bells the number of quar-
ters elapft.

Note this one thing diligently, *viz.* left that flow motion be
too fhort, as not to fuffice for the ftriking of the Bells as often
as

as is required; also note, that hence it necessarily happens, that the outer face of the Clock is a little changed; for otherwise it will follow, that in the middle of the second hour, the number of the hour appears not longer, which evil we may easily cure many ways.

Hence he concludes, that this second division of the Tympane may also distinguish the Tympane for so many hours, for hence, says he, proceeds great benefit, for you may as you please make the motion more or less slower for striking the bell, *viz.* if you put more or less water into the lesser vessel, although you leave the greater vessel untoucht; but in this case 'tis sufficient, if the greater vessel only be divided with so many thin plates; for the other plates are put only to restrain the too slow motion, as is said before.

Ninthly, Because those things which are said seem not fit to the striking of greater Bells, three vessels are to be made in this manner: Two of them must be divided into 4 parts in the main, as is said of the lesser vessel for the quarter hours, the third must be also divided into 4 parts, but the same altogether after the manner of the greater vessel for the quarters; the water in the first two vessels is put in as you please, but the same must be observed as in the lesser vessel for the Quarters; and in the third you must observe that which we have said of the greater vessel for the quarters: But now if to the end of every quarter the third vessel (as is usual in great clocks) lift up somewhat, so that it being raised a free course is permitted to the other vessels, to wit, to one of those in the end of the hour for striking the hours, and the other to every quarter for striking the quarters, the thing will be accomplisht.

Tenthly, The foresaid Clock hath this peculiar, that it makes no noise, nor the motion of the Ballance, nor the Wheels disturbs not nocturnal rest: Notwithstanding if you would make use of it to rouze you from sleep at an appointed time, you may easily do it, by taking all the teeth from the Tables, except one of them, which you must fix in such place and order, that after the prefixt number of hours it may strike on the bell, or make some other noise, as is wont in excited Clocks, of which we shall speak hereafter: There are also other ways more easier, as if you use to it the percussion of a weight, whereby one part of the equilibrated table depresses a

G g   Cliggut

Cliggut, fomething fallying out into the room, and you may encreafe or diminifh the percuffion of the weight, by making a greater or leffer hole in the other three plates, which have large holes for the fwifter motion, *&c.* But if you add one wheel, you will find feveral eafy ways.

The Author concludes, that hence all thofe Engins may be fupplied by a fhort Compendium, which are not wrought but by many Wheels, efpecially in thofe which want temperate motion.

Moreover he adds many other things to equip this Engin, and, *Firft,* he fays, the veffel may be fo accommodated in the outmoft part, that at what time the Clock is moved fwiftly, whether before or after the Strokes on the bell, little boards being placed, or fuch like, as is wont in Hydraulic Organs, it will utter a confort of mufick, either in fome Cimbal, or on little Bells harmonically difpofed.

Secondly, If the Clock be hung after the ufual manner to a wall, and to its fide, fome plane table be made faft to the wall through the length, that it be parallel to the horizon, upon that table may be placed the Sun in its courfe, a hidden ftring being drawn which tends rightly to the Clock, which may be drawn by the veffel in its circulation ; and on the wall you may difpofe in right order (in the way through which the Sun runs its courfe) the heavenly houfes, whence each hour, a little Image poetically adorn'd appears, which fhews the hour on the right hand next elapft of the Sun, and on the left hand it leads fome of the heavenly Signs, or fome fign of the *Zoliack* addicted to that houfe, *&c.* thus thofe little Images will appear every one to his time ; put crofs in the way by which the Sun paffes, fome little board, fo that when the courfe of the Sun being moved by the fwift motion of the Clock, being carried in its courfe, it hits againft one end of the little board ; which if the little board be placed in manner of a leaver, it may fo be accommodated that while one of its ends is drawn, by the fervice of the other end with fome ftring added to it, the little image is brought forth to the Sun, and there left.

Thirdly, Befides that heavenly motion, that number which fhews the hour next elapft may be fo accommodated, that the fame fite and face may ferve, as well in its Apogeon, as in its afcent and defcent, to wit, if there be put to the little plate

on one of its parts some tin, a little heavier, being so affixt to each table, that it may most easily be turned about its centre.

Fourthly, Almost in the same manner, in that circular superficies whose half part always appears divers small Images may be affixt, so that they always remain aright, by means of Tin, or some other heavy thing added to their feet, and in going forward they may shew the quarter hours, *&c.*

Hitherto we have added no Wheel, but if we add one or two, you will attain many fine effects. First, a toothed wheel may be so placed on the vessel, that its axis may fall right on it, and on the extream circumference of the vessel many iron stiles may be put, which while the vessel is turn'd about they move the overthwart wheel placed above, by hitting against its teeth, moreover you may constitute a Load-stone on part of the wheel placed above; now if you fasten an Image with a wyre, with an iron stile in it hands, according to the motion of the Load-stone, it will shew the hour, *&c.*

Problem. XIX.

To make the Indexes of Clocks, so that they shall describe not only Circular, but any other Figures by their motion.

IF any one would adorn the Index of a Clock with the Arms of some Prince, or City, to dispose it in the form of a shield, of a heart, of a cross, *&c.* so that the same being artificially made, or a small image, or any other sign performing the office of an Index, the numbers of the hours being inscribed on the parts of its figure, in whatsoever order they are disposed in, it will shew successively; or that an Eagle with its bill, or a Lion with its tongue, *&c.* There are divers Artificers in Father *Schottus Technica*, *Book* 9. *Chap.* 5. the most useful whereof we will here impart.

Fig. 155.   To describe the most difficult figures of moving Indexes assume the artifice of a Parallelogram made in this manner: First, of solid matter, *viz.* of iron make four rules A H, A K, K L, H M, which in the points A, H, C, K, so join with curious small pins, that the square may freely be stretched wider, or contracted narrower; then to those portions or parts standing out on each side C L, C M, join by the same ar-

tifice

tifice as many more rules, but fhorter, and if you will, decreasing in the fame proportion, and in the connecting or joyning points, freely turning.

Secondly, On that face of the Index that lies hid towards the Clock, conceive a hidden toothed wheel C D E F G B, to wit, fo as thofe Indexes that are wont commonly to turn once in 12 or 24 hours, in this being made hollow, or any other way fitted, underfland a little Channel A C, fo that within it a little nail, or pin C, may be put fticking out from the Parallelogram towards the Wheel, and may run to and again, this way and that way, without refiftance.

Thirdly, Fix a fmall pin A in the Center of the toothed Wheel, and then between it and the other little pin C, which ought to run in the little channel or groove, a Spring, or fome impulfing Spire, being put between by a Wyer of a competent thicknefs in the manner of a wreathed Cylinder fcrew, drawing afide as much as is requifit the little pin C, from the other fixt pin A; which Spire perhaps may more conveniently be made of a Serpentine plate drawn and bowed.

Fourthly, Propofe now any figure which you would have the hour index defcribe with its point; fuppofe a Hexagon, or figure of fix fides: Cut then in the plane of the Index a fix fided hole C D E F G B, whofe Center is A.

Fifthly, Upon the whole Parallelogram, and the hole that is cut, place fome figure, as of an Eagle, or a Dragon, &c. fo that its neck touch the texture of the Parallelogram and hide it, and the other part of the body be fpread over to the hole that is cut; Moreover that Parallelogram being wove in the neck of the figure by more of the fame Rules placed between, in the likenefs of a net, and move artificially after the manner of feathers, or the Scales of a fifh, &c.

The hour Wheel then intercepting the pin C in its groove, carries it a long with it; and this from the drawing preffing plate placed between A C, and the cut. Sexangular hole, or included between other limits, will caufe the Eagle, having a crown, crofs or ftar on its head, or a Dragon with his tongue or fting, to defcribe the fame figure, and to fhew the hours defcribed in its limb.

In the defcribing of other figures, as of a heart, a rofe, a fhield, &c. the Induftrious will find it eafy; another motion may eafily be given over and above, to a Lyon, an Eagle, or a
Dragon,

Dragon, &c. that this fpread his Tail, that tofs its Spires, the other open its wings, &c. and that either by the fame artifice, or otherwife.

Problem. XX.

To perform the fame more Compendioufly.

ALthough the forefaid Artifice is univerfal, and extends it felf to many figures, yet this prefent Propofition may be reduced to practice, with lefs charge and trouble, efpecially to the eafier; as Ellipfes and Polygons, and moreover may be applied to other Paradoxical affections.

Fig. 156. Let A B C be a rod of mettal, having a round hole in A, but in C where it bends, it ends in a little ring, or other erect hole C E, through which paffes another rod D E F, which bending in the like little ring F B, and in like manner made faft to the former rod, and clofe or touch each other fo lightly, that they are carried on one within the other to and fro freely; in the end D is made an arrow, a little Star, or other fuch like fhewing Apex.

Secondly, Underftand in that plane in which the number of hours are infcribed fome figure, *viz.* a Square to be defcribed G H I K, and nigh to its defignation cut a channel or groove of any depth, and its breadth, fo that ftanding out from the litttle ring it may receive the point B, that it may run freely in its Channel.

Being placed then, and fixt to the hole A in the Centre of the quadrate, and to the ftyle B in the fame cavity, if this whole joining together of the Index in the point A be turn'd about by the Axis of fome Wheel, or led about circularly any other way, the end D muft needs defcribe a Square figure, or another after the fame manner, as is the Channel in which the ftyle B is led about.

Note, firft, the fame Inftrument may be more ingenioufly made of two rules, in one of which a little channel is drawn out in length, and the curfor runs to and fro in the other by turns; but the Artifice may be fo cover'd, that the contraction and diftenfion of the rules cannot eafily be noted, in producing the rule D E F beyond the centre A, &c. *Secondly,* If between

the rings E and F you put a wire, or a divided plate of mettal, it will not be neceſſary to hollow it in the plane, but only cut it out from the thicker plane being laid upon the other, or by the rules that frame the Poligon.

If you affect Paradoxes, hence you may eaſily deduce, *Firſt*, that by the continual drawing and revolution of one and the ſame common compaſs, you may deſcribe a triangle quadrate, *&c.* for if one foot of the Compaſs be fixt in the hole A, and and the other firmly lay hold on the Style E ſticking out, and being led about by the compaſs, the ſtyle will deſcribe ſuch another Figure D, and was the little hollowed Channel, or another ſuppoſed plane terminated by a certain figure.

Secondly, If you would deſcribe a circle by the ſame opening of the compaſſes, and not from the Centre of the Circle, you may do it almoſt in the ſame manner, which doth not require that the point A with the foot of the Compaſs be in the middle of the figure, as is manifeſt.

Thirdly, you will increaſe the admiration, if you add the deſcribing a Triangle, a Square, an Ellipſes, *&c.* greater or leſſer, with one opening of the Compaſſes, and you may effect it thus ; Produce the length D E F towards A, and let the little ring or Curſor B F, have a ſcrew, or turning joint in F, that the compaſſes remaining at the ſame diſtance, and only the relique D E F being drawn from, or intruded from all the reſt, and the foreſaid turning joint may be faſtned in F: More may be added by the Ingenious.

Problem. XXI.

To make and incite a Chronometric Index to an Elliptic figure, by a certain and peculiar method.

ALthough both the foreſaid Artifices ſerves to deſcribe Ellipſes, yet the Author adds another, taken from a peculiar Geometrical Inſtrument of *Guido-vbaldus*, or rather deduced from the ſame foundation.

Fig. 157. Three planes, or thin plates, are to be conceived, the firſt is of an indefinite figure, which is deſcribed by the Elliptic Index A B C D, this is boared through in the middle in the round hole H E F G, and moreover cut in with four ſlits

at

at right angles which are I E, K F, L G, M H, and join'd together with a round hole, the length of the flits is as much as the Semidiameter of the hole.

The other Plate P L is circular, which hath on that part some Index which is laid open to the view of Spectators, being put upon the former flits, and therefore touches the forefaid hole of the former plate.

The third plane of the orb is I K L M, touching the same hole on the other part of the middle, and of the flits of the plate, and this therefore lies hid all within; its Centre is the fame with the Centre of the round hole, and it hath Glued or Soldred to it, two Segments above and below the Centre, being cut through by a circle on its Periphery, that perfectly fills the fides of the hole, and razes while they turn within the hollow of it; the thickness of these Segments is the same as the flits of the plate, with which they are therefore equal and alike.

The confpicuous Orb P L hath its Centre in that point, which is pofited in the Periphery of the Segment H E, Glued to the hidden orb M I K L; In this point a hole is made through each orb, to wit, the confpicuous P L, and the occult M I K L, to which hole afterwards a fmooth little pin is put, to join each orb freely.

In the confpicuous orb P L on one face which beholds the middle, or flit plate, are fixt two little round nails I and N, of the fame thickness as the breadth of the flits, within which they ought to run to and fro moft freely; the length or height of the little nails or pins is the fame as the thickness of the flits, and the plates, or fomewhat leffer, left thy touch the occult orb through thofe flits, and raze it in the motion; they are diftant from each other the interval I N, equal to the diameter of the hole.

In the inner and occult orb make the hole R fomewhere, into which enter fome little nail fticking out for that end in the diurnal Wheel of the Clock, whether it be turn'd once in 12 or 24 hours, the Centre of which Wheel ought exactly to anfwer to the centre N of the hole H E F G, and alfo of the occult orb I K L M; the diftance of the hole R, and of the little Nail anfwering it, will be the fame viz. R N; it is the fame, if in the diurnal Wheel of the Clock a hole be bored through, and in the point R of the orb a little pin anfwering it be fixt.

The forefaid pin then being entred in the hole R, will caufe the occult orb I K L M to move about, being laid hold on

by

by the Wheel of the Clock, and will carry it forward from
R towards M; and at the same time a hand being formed, a
Lilly, the Sun, or such like, the Index P will proceed for-
ward to the opposit part, and by its apex describe the Ellipsis
A B C D, to which hours unequal spaces are described distinct-
ly, which nevertheless are finisht in equal time, to wit, hourly,
by the Index.

Since the conspicuous orb P L, on this face, on which 'tis
beheld, is altogether plane and whole, you may for ornament
inscribe on it, either the Effigies of the 7 Planets, or the
figures of the 12 Signs, which indeed have no other use, than
that they are turned about wonderfully to and fro with the
orb, that he that is ignorant of the structure, and its make,
can hardly conceive it, because that the orb is moved with a
double motion, one by which its Centre E is carried circularly
about to the Periphery of the hole E F G H, and the other
Elliptic, whereby the other parts of the orb are carried.

The Internal F H between the two Segments is therefore
left, that the little nails I and N may pass in a right motion
through it diametrically opposit without obstruction from one
slit to the other. See Guidubaldus *in the Demonstration of the*
Planisphere, *and* Bettinus *his Comments on the* 28th. *Proposition of*
the 6th. *Element of* Euclid.

Problem. XXII.

Divers ways to make a right lined Index to shew the hours, or
quarters of hours, by a right motion, and then to return
back again.

Fig. 158. MAke a plane Wheel A B C D E F, whose middle
part D E F A is furnisht with teeth, but none
in the other parts, the axis A G H D lies directly over, or upon
the Centre, or diameter of this Wheel, carrying two toothed
Tympanes A and D, also two toothed Wheels G and H, which
all firmly adhere to the axis A D: *Thirdly*, make the Oblong
I K L M, three of its sides being of solid mettal, and the fourth
K M is closed by the figure of the Sun, or any other sign, mov-
ing forward by a right lined Index, which nevertheless may
be placed most conveniently in the middle of the oblong;

Fourthly,

Fourthly, to the two longer sides I K and L M, make the teeth of the Wheels G and H to agree to the teeth of the other, *viz.* to the face of those sides which the Wheels G and H behold and touch, for that oblong is conceived to lie upon the Wheel G and H, and these to cover over the sides I K and L M.

The half toothed Wheel moving then in the first place from A towards B, will move the Axis A D, with the Tympanes and Wheels in the second motion, with which in like manner is carried on the oblong with the Sun K M from K towards B; and the length of the sides I K, L M of teeth ought to be in the same ratio to the Wheels G and H, as the Semiperiphery D E F A to the Tympane A or D equal to it; Secondly, and because the plain Wheel is furnisht with teeth only in the middle part, which begins to impel the Tympane A First with its teeth, the Tympane D opposite to it is hindred by none, much less when the whole axis and Wheels are turned, and by an unanimous consent both wheels G and H the sides of the oblong, are so long forc'd forward by an uniform motion, as the channel'd Cylinder A is impelled; *Thirdly*, when first the toothed Semicircle approaches to the Tympane D, and begins to set its teeth in it, in the same moment the Tympane A is freed from the force of the teeth, and is turn'd to the opposite part, being led by the other; from whence also the oblong removes the track out of the way to the opposite part, as long as the toothed Semicircle forces, which it ought to perform 12 or 24 hours, or, if you please, but one hour: *Fourthly*, this whole artifice is hid beyond a certain table equal to the oblong of the Index, which therefore is divided into 12 equal parts, or hours, and the number of the hours are described in a double row, the uppermost of which from 1 to 12 shews the Astronomic hours from Midnight to Noon, and the lower from Noon to Midnight, or otherwise.

It may be done easier, for the weight in the space of time in its descent of the whole height, either in a plane vertically erected in some place, the same horary intervals may be designed; and the same perpendicular motion of the weights may easily be translated into an horizontal one, by a Pulley put between, on which put a small chord, and bind it to the descending weight; or if you find that inconvenient, fit a Pulley, or Cylinder, in some Wheel of the Clock, measuring time by its motion, for a Chord being folded to the Cylinder ac-

H h   cording

cording to the various magnitude of the Pulley, or to the number of its revolutions made in an hour, will give divers horary intervals in the plane defigned on the Wall, or other plane of a competent length, in which, if you pleafe, you may hide the Artifice, and within or behind the table of the right lined Index you may place a piece of load ftone from the weight by the forefaid little chord to move forward flowly being loofe, and without the table; in the fight of every one, may be moved by the hidden load-ftone an Iron gilt with the Sun, or *Phaeton* driving a rofey Chariot, a Chamelion, or a kind of Sea fifh, &c.

Problem XXIII.

To Effect the fame another way more ingenious than the former.

Fig. 159. BEcaufe the forefaid Author appoints in the firft practice, that the toothed oblong forcing the Index, and lying hid behind the table, while 'tis conveyed to and fro of its own accord, requires another fpace equal to the table to which it allows and extends it felf: and in the latter way, whether he appoints it by finite or perpetual Chords, he doth it either by attraction of fmall Chords, or of the Index by a fmall chord, from whence 'tis moved forward, therefore I have thought on the following way whereby both thofe defects may be remedied.

Let therefore the whole length of the table of the right lined Index be A B, or C D; take a chord, or fmall rope, fix times the length of A B, and join the ends to make it perpetual, as E A B F D C E; Put this about two Pullies, or Cylinders E and F, moving freely about their Centers, fo that the fmall Chord pafs occultly under the upper border, or limb of the table A B, and of the lower C D; Secondly, let there be alfo fome Index: as G, fo fitted that it may move forward to and fro through the whole length of the table freely, which may be done thus; it may run to and fro within two little Channels, or grooves, cut in the upper and lower limb of the table, or by two other metallic Chords, or wyers, ftrongly extended and hung in the fame limbs, and it ftrains them lightly with its

loofe

loose little holes, or rings, through which the chords are tranf-
mitted ; then the Index G will be moved forward in thefe
channels, or wyers, perpetually by the little rope to and fro in
this manner : Becaufe the perpetual little chord is fix times the
length of A B, divide it into fix parts, as A B, B F, F D, D C,
C E, E A ; moreover in the three points of divifion A, F, C,
omiting one interval, or fpace, bind or faften juft fo many in-
forcing flexible obftacles with this condition, that paffing by
the perpetual fmall chord through the two loofe rings of the
Index G, *viz.* of the upper and lower, the obftacle hitting
againft the ring of the Index moves forward the Index ; and
the Index arriving and confifting at the extream fide A C or
B D, the obftacle being drawn by the perpetual chord, never-
thelefs going forward paffes through the little ring of the In-
dex overcoming that fmall matter of refiftance. To this end
you muft take fmall ftalks cut off from the Quils of Birds, or
Horfe, or Swine's hair, or the ftrings of a wood-like White-
thorn ; then thefe three obftacles being conveyed overthwart
by the perpetual chord in the points A, F, C, and fixt ; con-
ceive now one of the pullies E or F to be annext with fome
wheel of the Clock, as with the diurnal when you would
have the Index to be of 12 or 24 hours, or with the hourly,
or quarterly, *&c.* if the Index ought to be hourly, or of quar-
ters : Let it be hourly, and either of the pullies E or F to move
regularly circular by the hour wheel of the Clock from
whence it will be incited, or by another perpetual chord, or
by a toothed Wheel, *&c.* And make the motion of the
Pulley, and of the perpetual fmall Chord, furnifht with the ob-
ftacles, or fmall ftrings, or hairs, the upper from B to A, and
the lower from C to D. Underftand now the Index G, to be
brought by the horfe hair, or other ftring A, from B D to A C ;
Then becaufe the Index cannot pafs further, the horfe hair
notwithftanding being drawn by the perpetual chord, it will
pafs through the ring of the Index, which it will lay hold on,
and will pafs forwards towards E. At the fame time the hair
or ftring C applies to the lower ring of the Index, and the In-
dex being free from the former hair A, draws it back with it
felf from C towards D, then the Index hitting againft B D the
Margent of the table, this lower hair will pafs through its ring,
in the mean while the other hair F is now found above, which
Index that it may remove it forces away, and this reciprocation

of the Index endures as long as the motion of the Clock, if you diligently obferve what follows.

Firft, Obferve the Compendium in the beginning of this Problem; for whatfoever is without the table A B C D of the Index, you will contract to a lefs fpace, if you wind about the Pullies E and F once or twice thofe portions A E C, and B F D of the perpetual chord; for in this manner thofe Cylinders, or Pullies, muft needs be moved near to the table of the Index, and always to its top, as the Centers of the Pullies E and F anfwer to the extream limbs of the table A C and B D.

Secondly, to continue that reciprocation of the Index without any error, you muft take great care that the precedent obftacle, or hair, pafs through its firft ring, and leave it before the fucceeding one fieze his, which you may eafily obtain if you do not permit the Index to come to the extream terms A C and B D, but a little before it touches them, 'tis forc'd to ftand ftill, and is freed from the former mover, that the other comming too, which was firft difpatcht by the former obftacle, may find out the Index, which will be done in a fhort time.

Thirdly, Becaufe at the firft afpect of this Index you cannot know whether it goes forward or backward, therefore the thing may be fo ordered, that one Index in going may turn to the fpectators a face of one colour, and the other in returning a colour contrary to the former. If yet the number of hours or quarters above, be gone forward from A to B, and the lower from B C, it will be known prefently at the firft afpect, whether the Index goes forward or backward.

Problem XXIV.

To make the fame power which moves the hour Index to ftrike the hours alfo.

FAther *Schottus* thinks it may be done by a fpring, or fteel fpire; for fince each fpire after this manner hath two ends, central and circumferential, one of which being drawn, each returns to the oppofit parts; fays he, one end, *viz.* the Central, may force the Wheels of the Index, and the other the ftriking Wheels, or the contrary; And he affirms that the irregular

force

force and refiftance of the fpire may be made fit by the artifice delivered by us before, notwithftanding this muft be diligently obferved, that fome certain time muft be appointed by the Artificer, wherein the Clock is to be drawn up, and then according to the number of Pulfes of each hour the other loofe end will be made fit, the Cone of this other end forcing the chronometric Wheels ; But in this practice fome difficulties occur, wherefore I efteem the following practifes of the fame Author more apt.

Fig. 124. Firft, therefore conceive in the Figures of Probl. 2*d*, the two Pullies A and B, to be fitted to the two whirling fiftems of the lower Wheels, that is, to their axes; one indeed to the Chronometric fyftems, or circumagent Index, and the other to the ftrokes defigned ; for 'tis manifeft from the right underftanding of hanging of weights, that one and the fame weight D ferves both for the carrying about the Index continually, and to the ftriking of the hour Wheels.

Note, Firft, the Pullies A and B in *Fig.* 124. muft be underftood to be fo placed as you fee them defigned in *Fig.* 125. *Note,* Secondly, if you do not make ufe of a perpetual chord, but a finite, then you muft conceive that Chord to be perpetuall diffected, and to each end a weight, or poyfer, to be hung to continue the Chord within the Pullies A and B. *Note,* Thirdly, both ways here requires this weight D to be as heavy again, as that which is fufficient to carry about the other Wheels all at once : If therefore to each fingle weight that motion fhould be effected, you may make ufe of this following (although more laborious) practice.

Fig. 160. *Secondly,* make the Axis A B ftrong, and like a tree, or Cylindric, and ftablifht in the points A and B, put on to this two toothed Wheels C D and E F, each of which fhall have in its Centre a Cylindric Tube A G and B H, join'd or faftned together moving freely about their Axis A B: And to the ends of thefe Tubes G and H, muft be faftned a little orb, or Jagged Wheel G and H, having but few jags, or teeth, as 12 or 16, but very deep ; *Thirdly,* to the fame Axis A B between each Wheel in the middle place, put the Pulley K I made hollow for receiving the Rope, to which that one only weight muft be bound, and this Pulley alfo muft be movable about the unmoved

Axis

Axis A B; and in the Bases or Planes which behold each Wheel, must be Bolts or Bars, on both sides the same number, and made by the same Artifice on both sides; *Fourthly*, the Bar therefore M L, whereby the Pullies are joyn'd together, hath first of all a hole, through which and the ear or ring made fast in the Pulley, passes the little round Axis, moving freely in the joints forsaking that Bar: The same Rail or Bar towards the Axis of the Pulley, holds out a certain hook, or little arm, athwart, as in Leavers full of corners or nooks; and lastly, towards the other end L 'tis bent like a hook, or bill. *Fifthly*, the Rails or Bars being fitted in this manner in the ambit of the Pulley in any number, as 3 or 4, so that all together they answer the Jags of the Wheels G and H, understand between the Jagged little Wheel G, and the Pulley I K, some Lilly, or like flower to be put, cut out of a thin plate of mettal, whose little Leavers sticking out towards the Centre of the Pulley, press the points or little arms of the Bars or Rails, that in this manner the bars L M, strive or strain always against the Cuts of the Jagged Wheel, and the same is done by the face of the other Pullies. *Sixthly*, to the Tubes, or hollowed Axes of the toothed Wheels, must be put some Cylindric Segments N and Q, upon the foresaid Axes or Tubes, movable freely to and fro; and join them to some firm Beam N O P Q, that according to the motion of one Cylindric Segment, the other may be moved with a reciprocal motion. *Seventhly*, make some ballance C K E, movable in the Centre K, about which the half toothed Wheel is conveyed with it, whose teeth answer to the slits or cuts of the Beam O P; A little arm is erected in the upper part of the same Ballance answering the little tongue, or cock, of common ballances, to this is affixt the Sphære R of a competent weight. *Eighthly*, to the Tube or hollowed Axis of the Wheel C D, is put the little orb A, or smooth Wheel, movable together with the former, neverthelefs it hath in some certain place of its Periphery one triangular tooth erected of unequal sides, and of such form as you see in Wheels, with Jagged, or saw-like teeth, so that it's *Hypothenuse* rises up slenderly from the ambit, or Periphery, and at length is ended in the precipice of the *Cathetus*, this little tooth about the end of any hour, lifts up slowly the little arm C, then when the ballance C K E is inclined it pulls up the little orb A.

These

These things thus prepared, underſtand *Firſt*, the Horometric Syſtem to be the ſuperſtructure of the toothed wheel C D, and the ſyſtem ſerving to excite the ſtrokes is of the other wheel E F; moreover from the pulley K I is hung ſome competent weight by the Artifices propoſed before in Problem the 2d.

Secondly, Underſtand the ballance C K E with the weight R to be inclined towards the chronometric Wheel C D, for ſo it will come to paſs, that the Wheel half toothed K forces the Beam O P towards the ſame toothed Wheel C D, and together with the Beam, each Cylinder N and Q.

Thirdly, One of the hour Cylinders, *viz.* N, when in this manner it goes back from the jagged Wheel G, it thruſts down all thoſe hooked rails or bars in its inciſions; and by the contrary reaſon the Cylinder Q being moved to the jagged Wheel H, lifts up all the rails or bars on that part, ſo that the jags in the little Wheel H are in no wiſe laid hold on by them.

Fourthly, When in this manner the weight hung from the common pulley hath a connection with the Wheel C D, and none with the other Wheel E F, that Wheel only will incite, and not this, and that will be done in an hours ſpace, until the tooth ſticking out in the little orb A, begins to take up ſlowly the little arm C, and with it the whole ballance C E, and alſo the weight R.

Fifthly, The weight R being inclined beyond the line K R towards P, ſuddenly ruſhes to the oppoſite part with the cock of the Ballance, and together with the half toothed Wheel K, impels the Beam O P, and the Cylinders N and Q towards B; wherefore the Cylinder N lifts its hooked Bar, and the Cylinder Q lets it down, and this being received within the jags of the Wheel H, make firm the Pulley K I with the Wheel E F, and its Wheels pertaining to the ſtriking, which unlocks the arm K E, by a certain Leaver which the Figure doth not expreſs.

Sixthly, The hour being declared by ſtriking, the ballance C E is again lifted up with the weight R, to the oppoſit part by inclining towards O, and that is done by the *Phonotactic* Wheels, eſpecially by thoſe which are thruſt on immediately from the Wheel E F, and which for every blow or ſtroke is

wont

wont to go once round, and carries in it's Axis a certain heart, by help whereof through Leavers difpofed to that purpofe, it may be done very eafily, the Impetus of the Wheels approaching from the collected motion.

Note, *Firft*, in ftead of the Pulley K I, a toothed Tympane may be placed, which may be moved by another inferior Wheel, and it's weight, for the fame effect will follow, by increafing the weight of the clock as much as the thing requires: Notwithftanding the forces of which may be hindred by a fpring, or fteel fpire, but only in a fixt, or ftanding clock, for in a portable one the fame foundation remaining of fhutting by the bar L M, the other furniture of the Leavers will be otherwife difpofed to work changes. *Secondly*, when the *Phonotactic* Wheels are incited by the weight, the motion of the Index ceafes the fame time, but after that manner that either 'tis of it felf but little, or 'tis compenfated from elfewhere; alfo it may be fo made that between thofe ftrickings, the Index fhall not move forward at all, but the more free defcription of the artifice, the brevity of time excludes. *Thirdly*, if the *Chronometric* Wheels are incited not by a ballance, but by a Pendulum, the Artifice may be effected eafily, that that may be apprehended and included in the uttermoft term of its arches, and then the weight being reftored to its Wheels, 'tis unloofed into Vibrations, otherwife the motion of the Pendulum once ceafing, it cannot be ftir'd up again by the weight only; the reft I leave to the Ingenious to confider. Thus he.

And truly this practice is very ingenious.

Problem.

Problem XXV.

To cause any strong blow or stroke usually struck on great Bells, by a Hammer, and by great Weights, to be effected by much lesser weight, and fewer toothed Wheels.

Fig. 161. L Et the Wheel ABCDEF be divided into 6, 8, or more parts, in the division of which points make so many joints for certain equal arms and equiponderant hammers, or Iron balls, or Globes, to be fixed, yet so, that the motion of any arm run not out beyond the quadrant of a circle, *viz.* DGH: To the Axis of this Wheel place a Pulley with a weight and one toothed wheel, which shall turn about a certain axis with a ballance, to retard the motion of the whole Engin, and also the impetus caused by this ballance, &c.

Rails or Bars then being advanced shutting up the motion of the Engin, after which some hammer, to wit, DG must be conveyed perpendicular to an Horizontal site, and a little beyond the hammer falls down with a force, and describes by its fall the arch G H, and on the brim of the objected Bell strikes a stroke, or blow, and because it touches only the extream of the Bell, 'tis presently withdrawn by the Engin from proceeding any further, otherwise if the hammer should rest a little while, it would hinder the found of the Bell, some steel plate should be put between by the side, which should draw the Hammer immediately from the bell, and not hinder it from tending downwards: And in this manner, much lesser weight being disposed, forces the Hammer and makes the strokes more valid, because the Engin is as it were Æquilibrated: The same may be performed by Iron Spheres, or Globles, falling from on high on the bell, which Globe is again raised to the height by a screw with a small power. Or so many Globes may be placed in an upper place, as are required for all the striking of hours for the whole day, as also of each hour, *First,* one of them is freed from the obstacle that it may fall on the Bell, afterwards two, and after that three, &c. according as the number of hours require: The hours may be adorn'd divers other new ways to shew the distance of hours, for first,

if you would shew not only the hours, but also the quarters, you may do it by many small bells, to wit, make use of five little bells, whose sounds ascends by degrees in a Musical increase or proportion; and for the stroke of the first quarter, the meanest or lowest little Bell will sound Do, or, ut; for the second quarter Do, re; for the third Do, re, mi, then follows the stroke of the hour sol, sol, sol, &c. so often as the present hour requires.

Secondly, the same may be effected by means of musical Chords, to wit, if you extend them on a table made thin and hollow, either Parallel to each other, or as radius's meeting in one point; and they may be so fitted and tempered that two opposits give a Harmony, beginning from perfect and proceeding to imperfect, for these kinds of Harmony being incited, each hour by a diurnal Wheel with two chords, will signify the hour decreed in a bed chamber, which may be heard in a night without the trouble of noise; and the Impulse of the chords may be repeated three or four times, left the hearing be deceived, if you have a musical Instrument with keys, you may use a Phonotactic Cylinder direct to the Clock, with a weight hung to it, by which it will be turn'd about.

Thirdly, the thing may be effected likewise by the Pipes of Organs, for if the Phonotactic Cylinder be made and applied to the keys of the Organ, and the Bellows being drawn either artificially by some easy Engin, or being once drawn persists so, and they must descend by little and little each hour while the sound of hours is required to be made.

Fourthly, the Strokes of the hours may be made by a military Tympane, or drum, and that most easily, as to any Industrious person will appear; yea, we affirm it is not difficult by Engins to exhibit to the ears, any strokes or blows wont to be declared by Tympanes, with as much dexterity, as it can be done by the most skilful Musick Master, both as to the Celerity of the blows and the difference of inequality of Percussion, and also as to Harmony or the sounds of Tympanes in Musical consort. *Lastly*, there is no Musical Instrument, the Tube or Trumpet perhaps excepted, but it may be so fitted to a clock, as to make divers Harmonical sounds each hour.
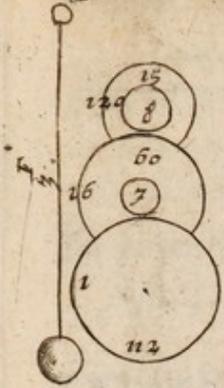
<div align="right">Problem.</div>
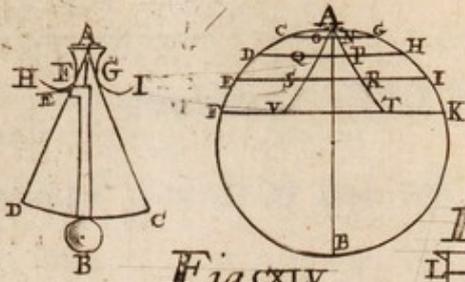
Fig. CXL.

Fig. CXLI.

Fig. CXLII.
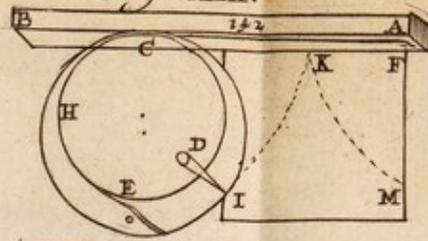
Fig. CXLIIII.
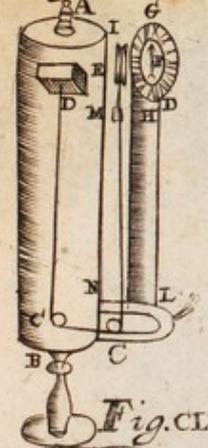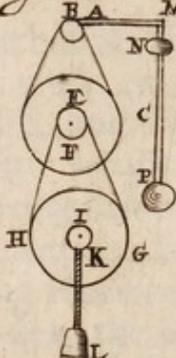
Fig. CXLV.

Fig. CXLVI.
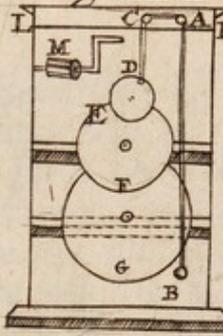
Fig. CXLVII.
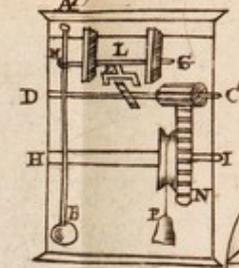
Fig. CLII.
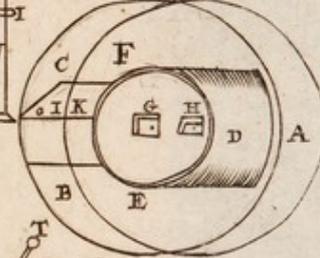
Fig. CXLIII.
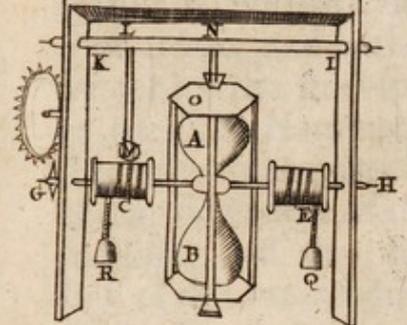
Fig. CL.
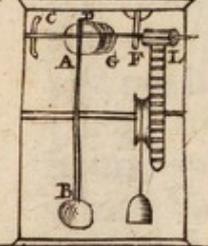
Fig. CLI.

Fig. CXLVIII.

Fig. CXLIX.
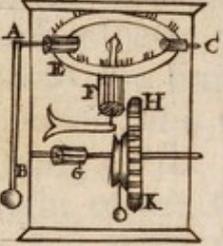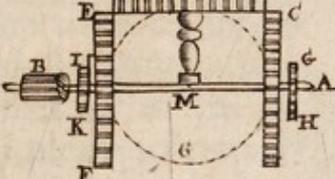
Fig. CLIIII.
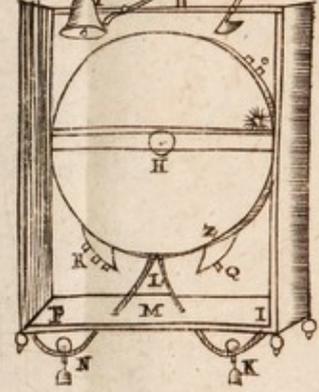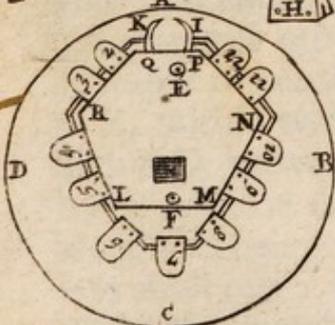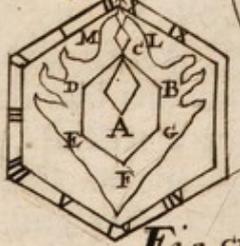
Fig. CLIII.

Fig. CLV.
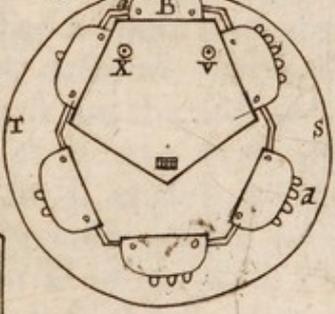
Fig. CLVIII.
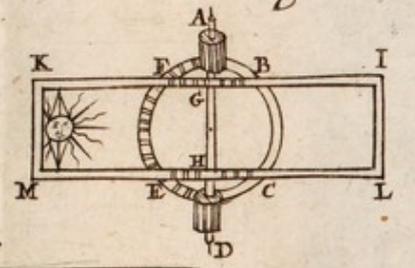
Fig. CLVI.
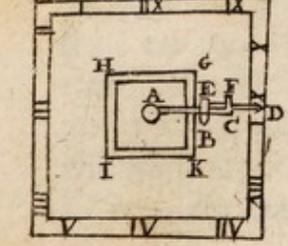
Fig. CLVII.
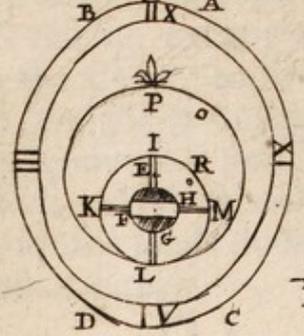
Fig. CLIX.

Fig. CLX.

Fig. CLXI.

Page. 292.
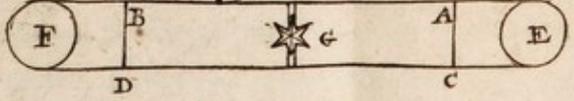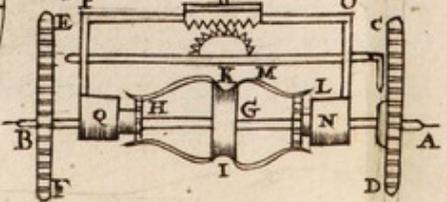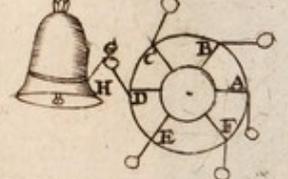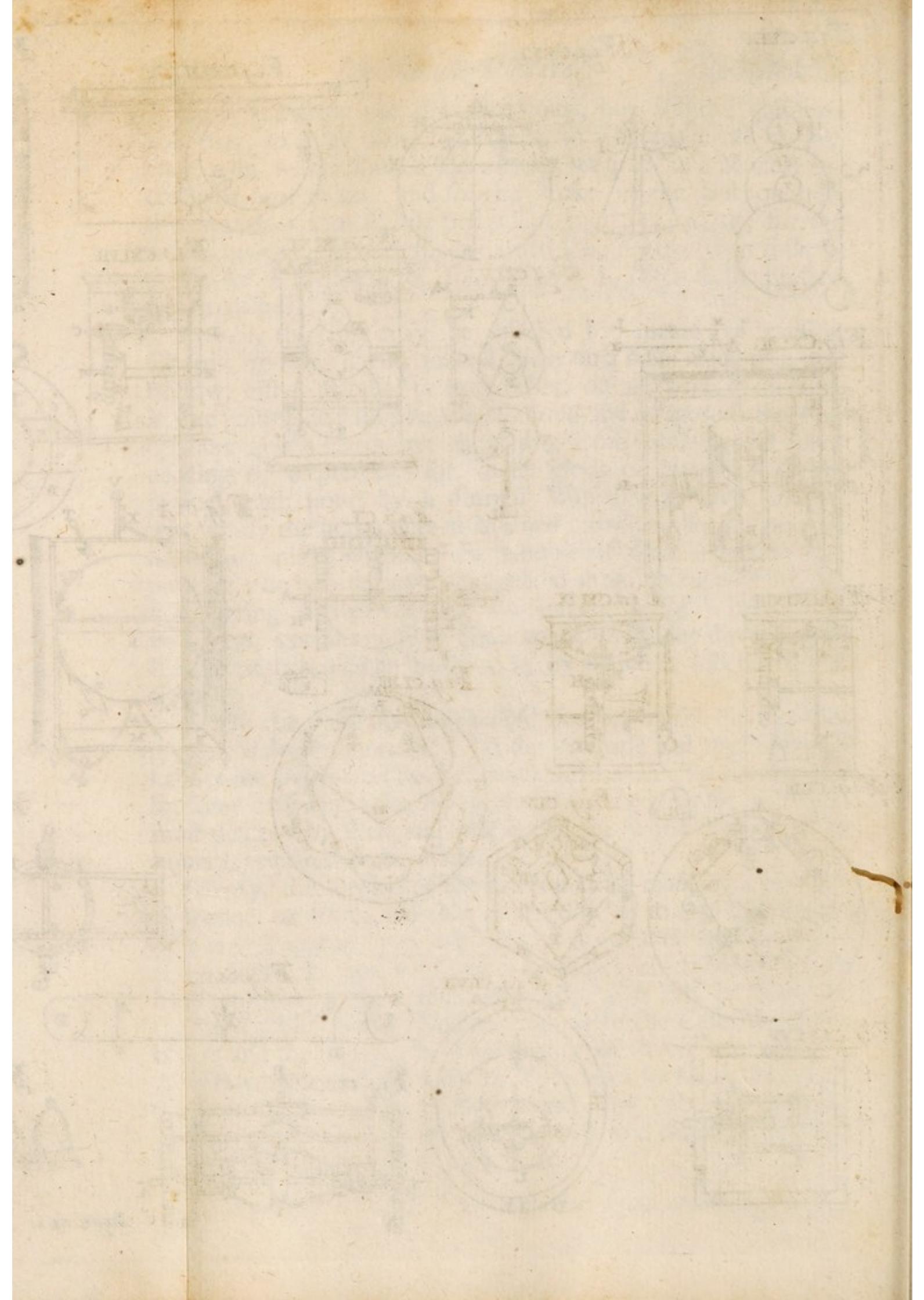
Problem XXVI.

To procure excited Sounds at appointed times by many Artifices.

THis Father *Schottus* teaches at Propoſition the 25th. thus, inclose a Steel ſpire with two little Wheels and a little Hammer, within a little bell, and this little Engin ſtands upon 3 or 4 feet, and hath a little tongue ſticking out downward, by which the ſteel ſpire being firſt bent, the motion is imparted to the little Hammer; If then the little Engin be placed above the Index of the clock lying Horizontally, or applied vertically about the centre of the Index, the feet of the little Engin being ſtabliſht, and that little tongue ſticking out, directed to the line of the hour which you deſire to excite, then the Index of the Clock being conveyed to the little tongue, and opening the incloſure of the little Hammer gives the ſtroke required; and after that whenſoever you pleaſe to remove it you may, and put it again to the little Engin.

Fig. 162. *Secondly*, if a Clock be required ſhewing only the hours, and to hang to the wall of a room; In the wall nigh which the weight of the Clock deſcends faſten in A a little arm, or Leaver A B, movable in A, on the end of the Leaver B, bind one end of a ſmall chord, than to a little Bar fixt in C caſt over the other end of the ſmall chord, to which bind a little ſpar or piece of a ſtick C D; laſtly, faſten a third little Bar in E, within which and the end D of the ſtick put the light ſtick E D between, ſo that it may ſtick faſt between the little bar E and the end D of the ſpar or piece of ſtick, and the weight G being hung will therefore ſtick faſt, under which you muſt put a braſs baſon, or ſuch like body of ſound, in which the weight G falling, excites a ſound; then lift up the weight F impelling the Clock, to ſo many hours as you deſire it to excite, for the weight E being ellapſt in a determined time, the ſtick being conveyed ſlowly to E D bares it down, and caſts it downwards: And this obſtacle being taken away, the ſtick C D being looſed ſends down with a force the weight G into the baſon underneath.

Thirdly,

Thirdly, for excited founds for Souldiers, or Husbandmen, to a determined time, you may prepare them eafily in this manner, take a piece of match, fuch as Souldiers ufe, of one thicknefs and denfity every where, try diligently how much the fire will confume of it in an hour, then allowing the length of the match for as many hours as you pleafe, note the end, and extend the whole in length upon fome piece of timber in an Horizontal fite, and a little elevated from the earth : Then in the firft fign noted in the match, bind a little chord, and to the fame fome weight, *viz.* a ftone, and the other end of the rope or chord bind about and make faft to fomewhat, as to a wall, or a tree, &c. for it will come to pafs, that when it hath burnt to the noted fign, it burns or deftroys that end of the little rope, and the ftone falls into fome Veffel or table placed juft under, it and fo makes a noife.

Many other fuch like may be thought on which may either be applied to Clocks, or may effect it themfelves, that at an appointed time they may waken and raife up them that fleep by fome noife ; For in the firft place all kind of Clocks which we have defcribed before, to wit, which are moved in defcending by an inclined plane, that may eafily be done, if while they come to fuch a line of the hour, they run againft fome obftacle, from whofe repulfe or removal, a found is made, or fome other noife excited ; *Secondly*, we may obtain it by all hour glaffes of fand or water, for being increafed by degrees by the weight of the water or fand falling down, it may be made, that when it increafes to fuch a magnitude the other weight fhall prevail, which either lifts it up, or being freed from the Impediment it fhall fall down, &c.

Problem

Problem XXVII.

Divers Ornaments applicable to Clocks, and such like Engins.

THE Ornaments which may be added to Clocks, and other Chronometric Engins, are innumerable, for besides those which belong to their Indexes, and the other before mentioned, the ingenious Artificer may easily invent many other, some whereof we will shew briefly.

First, a Clock may be made which not only declares the hours and quarters, but also the minutes and seconds, and that either with divers little bells, or by a musical Instrument of Chords or Pipes.

Secondly, the noise of the foresaid Harmony may be made, either before those strokes can publish the Musical consort, not only in small bells, or any other Instrument, or also more together, which may easily be done by Phonotactic Cylinders, as is shewn before ; and not only by those Cylinders, but also by an oblong plane, to wit, if you have a thick plate of mettal or a wooden table, to which fasten so many small bolts, or pins, and distant a due proportion between themselves as the Musical tone requires, so that while that plane is moved upward and downward to the right hand, or to the left, his small pins sticking out, hits against the Organ, or other Instrument, &c. And this oblong plane may be moved here and there by a retrograde motion, as is said before concerning the Index of the like plane at Problem. 17, in which case, notwithstanding it behoves the whole thing to be doubled, to wit, one answering to one half of the oblong plate moved in one part, and the other to the other half in the return of the same plate.

That the Clock, or Instruments, may be rightly applied, the following things are to be observed. *First*, the toothed Wheels of Clocks which the Cylinder turns about, ought to be scituate in the middle of the same Cylinder, or in both ends of it, for if it be applied to one end only, some inequality easily happens to the motion, by the resistance of raising the Hammers,

mers, or depreffing the little hands, &c. and the Cylinder muſt be exactly turned : *Secondly*, for each ſmall bell (if you will make the ſounds on bells) let there be two Hammers, two little hands, and two rows of holes in the Cylinder, to wit, that any note although ſhort in the tune, may be expreſt, when they are doubled, or repeated many times, for if thoſe notes be many, to wit, tailed or twice tailed following immediately, it cannot ſo well be ſtruck by one Hammer, and preſently raiſed. *Thirdly*, the fewneſs of holes for one touch, may be ſupplied by the diverſity of ſmall pins, more or leſs, ſtretched out without the hole in which they are faſtned : *Fourthly*, to greater Hammers, or greater reſiſtings of Elevation, Poiſers or weights muſt be hung as much as need requires ; *Fifthly*, the little hands and ſmall pins, are moſt exactly of a length. *Sixthly*, for accelerating the motion of the Cylinder, thoſe wings which catch the wind, or ſmall weights inſtead of them, are movable, that they may be moved more or leſs to the Centre of motion. *Seventhly*, when the motion of the Cylinder acted by weights, is ſlower in the beginning, a ſtay muſt be put between, of one touch, or a touch and an half, to gain the Impetus, before the little keys or pins begin to publiſh the ſtrokes : *Eighthly*, if the Conſort of muſick preceed the ſtrokes of the hours, care muſt be taken that the key opening the ſtriking Wheel of the hour be movable, leſt when the tunes are ſome ſhorter than others, the ſtroke of the hour may be a long time expected.

Thirdly, as Indexes of Clocks, and other Engins, belong to the Senſe of the eyes, and of the ſound to the hearing, ſo to the ſame hour meaſurers, other ornaments may be added, which belong to Odour or ſmelling ; for it may be made that every hour, or at other appointed times, a box or ſmall ciſtern may open, in which ſome odoriferous body ſmelling very ſweet is cloſe ſhut, and the Odour will diſperſe it ſelf into the whole room ; in like manner cocks of ſmall fountains may be opened, ſending forth Odoriferous liquors, which liquors may be divers, according to the diverſity of the hours of the time ; yea, they may be ſo fine and full of Spirituous rectification, that they may reſolve into air, and by their ſubtilty vaniſh, their Odour only remaining. Neither is it neceſſary to uſe many fountains or ſpirital Engins, if ſo be you make a ſmall Engin, out of whoſe cock only, divers liquors run forth every hour :

Alſo

Also Odours may be made either by means of perfuming fire which may be excited every hour, to wit, by percuffion, that the next fweetned matter may be burnt; Or being moved into an occult furnace, or lamp, the matter may be moved to them, or rather thofe to it.

Fourthly, It may be made, that the clock every hour or appointed time, fhall atchieve divers offices of truft, as it were a fervant, and be dilligent in the Bed-chamber defigned to various Offices; fo Cloks may be made which at a prefixt time of night fhall ftrike fire and kindle a light; and in the fame manner they may be fo fitted, that they may fend forth water from a fountain, at certain hours for the wafhing of hands, or draw it from a well, or fo as to fnuff candles dexterioufly, at appointed times: Alfo a clock may be made, which being placed on a Table, may reprefent *Bacchus* fitting on a Tun, and at certain times fill pots with divers kinds of wines: Alfo a Statue may be made in the top of the Clock Turret, that may unfold a ftreamer in the morning, and fold it up in the evening; and many other fuch like as thefe may be performed.

Laftly, other Inftruments may be added to Clocks which may fhew the degrees of heat and cold, and alfo of moifture and drynefs, or which fhall foretel when it will be rain and when fair weather, yea, and they may fhew the winds at any time in an inclofed chamber.

Problem XXVIII.

To make a Chariot, or fhip, with an Index of Miles, for the meafuring of a Journey.

Fig. 163. MEafure the compafs or Periphery of the Chariot Wheel propofed, and for example let it be ten feet; To the Axis of this Wheel A B, fit a fmall tooth E, running on another Wheel C D, furnifht with 50 teeth: Again this Axis I E muft have a fmall tooth, like to the fmall tooth of the former Wheel in E, which folds into the teeth of

the

the Wheel E F, divided into 12 equal parts, each of which confifts of 10 teeth, fo that all the teeth of this Wheel are 120; Moreover in its Centre G an immovable Index is difpofed, which will tell the number of Miles and hundreds of Paces that hath paffed by the Chariot in the Journey; for each circumvolution of the Wheel A B, that is, every two paces that is made in the Journey, one tooth of the Wheel C D is moved forward by means of the fmall tooth C, and therefore fince the Wheel C D is furnifht with 50 teeth, its whole circumvolution will be compleated after 100 Paces, and then it moves forward the Wheel E F by means of the little tooth E; then fince every part of divifion of the Wheel E F confifts of 10 teeth, after every 10 circumvolutions of the Wheel C D; that is, after 1000 Paces, or one mile of the Journey, the Index after that will note another number of Miles; in the fame manner altogether the thing may be done in a Ship, provided that a Jagged Wheel like to the Wheels of Mills be fo fitted to the fide of the Ship, that it may freely move about the axis, while its Jags hit againft the water; and this Wheel will be inftead of the Wheel of the Chariot A B, to which others are added, as we have faid; for the whole Artifice confifts in this, that the circumvolution of the firft Wheel which anfwers the length of the Journey be multiplied proportionally to the other Wheels C D and E F, which may be done eafily, and divers ways.

Problem XXIX.

The method of making Archimedes's *Screw for the raifing of water feveral ways.*

Fig. 164. ARchimedes his Screw is no other than a Column or Cylinder, on which a Tube is wound about fpirally, or in the nature of a fcrew, as appears in the annexed Scheam, where A B reprefents the Cylinder in an inclined fite to the Horizon, and C D fhews the Tube drawn about it fpirally; and this Tube if one end of it have an open mouth C, put in the water, fo that the water enter into it, and then the

Cylinder

Cylinder being duly inclined, and it being turn'd about by the two poles, or ends of the Axis E F that it stays upon, it will come to pass that the water-serpent by little and little will ascend to the top, and run out at the other mouth D.

This ancient and moft ingenious Engin, owns the moft Ingenious *Archimedes* for its inventer, which firft ufed it to empty water out of the great fhips of *Hiero*, King of *Syracufe*; then the *Egyptians* ufed the fame, (witnefs *Diodorus Siculus*) to draw out the water from the fields drowned by the River *Nyles*, and *Cardan* in his book *de Subtil*, makes mention of a Blackfmith that made this kind of Engin, and imagining himfelf to be the firft inventor of it, for joy ran out of his wits.

How much the Cylinder, or its Axis E F, ought to be elevated above the Horizon is not eafily determin'd, as will appear by what follows, although commonly Mechanics (with *Vitruvius*, Book 10, Chap. 11.) require fuch an inclination as conftitutes *Pythagoras* his triangle E G F, to wit, fuch that the fide or Bafe E F which refembles the Axis of the Cylinder fhall be to the fide E G, which is the Horizontal line, as 5 to 4, and the fide E G in which the other fide F G falls perpendicularly, is to F G as 4 to 3.

And the Tube and its Spire muft be fo fitted about the Cylinder, that each Spire be more or lefs inclined, and more or lefs nearer each other by turns.

Befides to the fame Cylinder, (which may be greater or fmaller) there may be put about, two, three, or more Tubes, fo that one fuccefsively after another may draw the water beneath, and may pour it out in the fame order above.

Some hide the Tube, or Tubes, within the hollow of the Cylinder; or they make the whole cavity, except the Axis in the middle, into a Spiral pipe, or Channel, after the manner of winding ftairs, for firft they make the Channel fpirally about the Axis of fmall timber, then afterwards they cover the whole all over, that the whole Engin feems a meer Column, the myftery lying hid within; Father *Chriftopher Grumberger* made a tranfparent Channel, or fpiral pipe, covering it over with a Selenite ftone, or looking Glafs, that it may appear to the eye ooking on it, how the water afcends.

If about the Cylinder you fit little boards fuch as is ufed in mill Wheels, or a Wheel furnifht with little boards be fitted about the fame, near the lower part B, this part may be fo kept above the

water of the River flowing, that the little boards may be forced by the water, and turn about the Cylinder, for so the water may be conveyed from the River into a meadow, or any other place that you will have it.

Moreover you may raise water to any height in a narrow place, *viz.* within a Tower to the top thereof, as we have known done at *Augusta* in *Germany*; to wit, if the spiral pipes be multiplied, so that the water being raised by the lower spiral, and being poured out in D into some receptacle, or Cistern; hence it may be raised higher again by another Spiral, and so successively by more spirals, as high as you please, all which Spirals may be moved by one power, *viz.* by the water of a River underneath, or by another animated Power.

Thus much as to the making and common use of the Screw, or Spiral pipe, and you will scarce meet with any thing else among writers, but that which contains the reason wherefore the water ascends by the spiral pipe, contrary to its natural gravity, you will hear the same story among all of them that I have read; water indeed always descends in the spires of a Tube, and flows naturally to the lowest place, but nevertheless in the mean while by turning round of the Cylinder 'tis conveyed to a higher place; likewise the weight of the water it self, while it advances the spiral Tube, or pipe, helps its advancment: Some say 'tis done by a certain mixt motion joyn'd together, of the descent and ascent of heavy bodies, which while they affect to descend by their proper motion, they run through the Spiral of their own accord, and the spiral by the turning about of the screw, the weight running down leisurely, and obliquely and as it were by stealth, raises it up by degrees, I say, you will find these, and such like expressions, or meer words which sound altogether the same thing.

That we may therefore shew the true cause of this motion clearly and manifestly without ambiguous words, we must observe some Experiments approved by us.

First, Not only water, or other Liquor, may ascend by the Tube of the screw, but also one, or more Globes of any solid metallic matter.

Secondly, by how much greater swiftness the screw is turn'd about, not only a greater quantity of water ascends proportionally to the greater swiftness, as if the motion of the screw be doubly swifter, the quantity of the water will be doubly

greater

greater, which in equal time will be poured out of the upper mouth of the Tube, but a much greater proportion, so that it may happen that the motion of the Cylinder about its axis being put double, the quantity and consequently the velocity of the water ascending is triple, or also quadruple, or quintuple; and this appears clearly, if instead of water we place Bullets, or small metallic globes in the channel of the screw; for it will come to pass sometimes, that the screw being turn'd about, the Globe will ascend but very little, or if it ascends a little, it presently slides or falls down again in the Tube, but the velocity of turning about being increast, it only ascends, all the other circumstances remaining the same.

Thirdly, the lesser the axis of the screw is elevated from the Horizon, the greater plenty of water ascends, and with more ease, so that the screw be turn'd with the same velocity, and all other things alike.

Fourthly, There is not the same proportion of quantity of water ascending through a narrow Tube of a screw, to the quantity of water ascending through another broader Tube, as is the Basis of the narrow Tube to the Basis of the broader Tube; for example, let the narrower Tube be A, and the Tube B doubly broader (or as broad again,) I say, through the Tube B there does not ascend a double quantity of water the other things being alike, but less then double, and therefore if there should be two Tubes of A, and only one Tube of B, although the largeness of this, or the inward cavity be equal to the double largeness of the other two Tubes, notwithstanding it will not draw an equal quantity of water, so that they are all of an equal length, and in the same manner alike, or the screws are turn'd alike.

These things being noted, I say, in the first place, that 'tis false which they commonly affirm (as is said before) that the water does descend in any manner in the Tube of the screw, and much less to make a mixt motion by the ascent and descent: And this appears in the first place chiefly by an experiment of a Globe turn'd about in a Cylinder through a glass Tube, so always ascending as 'tis never discern'd to descend (I speak in respect of the Tube) for it runs towards the upper part of the Tube, never going back untill at length it break out at the upper mouth of the Tube; the same which appears in the upper

superficies of water afcending; and certainly it feems to be implied in the terms that the fame heavy body fhould afcend and defcen'd together at the fame time, for it will be moved together with two oppofite motions, which is contrary; as we have fhewn before.

The reafon then why the water, or Globe, or any other heavy body, afcends through the fpiral Tube of the fcrew, ought to be fought from the adherence of the water, or other body, to the inward fuperficies of the Tube, either from fome roughnefs of the fame fuperficies, or alfo of the folid Globe afcending, by reafon of which the motion of bodies is hindred in their defcent by an inclined plane, which how it happens in the fcrew will be eafy to explain from what is faid.

I fay, then the water, or Globe, doth not always move in the Tube, fo as always to go forward further, but by fome little fpace of time, wherein the Cylinder is turn'd about, the Globe refts in the fame part of the Tube; but becaufe the fame time, in which the Globe refts with refpect to the Tube, that part of the Tube on which the Globe refts, afcends by the turning about of the whole Cylinder, it comes to pafs alfo, that the Globe refting in that part, in the mean while is raifed higher from the Horizon, and the other parts of the Tube immediately following, obtain a lower fite with refpect to the Globe, which therefore are conftituted in a plane fomewhat inclined; then the reft of the Globe ceafing in that part of the Tube, it defcends by that inclined plane to the lower part, and there it refts again (for as much as if it fhould pafs further, it ought to afcend, which is contrary to its natural gravity) and while it refts in that part, 'tis transfer'd again together with the Tube into an higher fite, from whence it again roles down by another inclined plane on the other part of the Tube; and fo by degrees is moved forward even to the upper mouth of the Tube; and the reafon of this interrupted motion, or interpofition of reft, is, as I faid, the adherence or roughnefs of the fuperficies both of the Tube and alfo of the Globe; for it comes to pafs that by fome little ftays the motion is intermitted, while the movable body finds refiftance in the rough plane.

Fig. 165. And there is another reafon befides the forefaid refiftance of Roughnefs, or adherency of bodies, which very much moves forward fuch motion: to wit, the impreft Impetus.

petus of motion in the oppofite part of the Globe, or water. Let the Horizontal line be A B, above which the axis of the fcrew A C is raifed, and let the fpiral Tube be D E I L M N. Now, for example, if the Globe of lead be in part of the Tube E, and the Cylinder be turn'd about with a motion from E towards G D; while the Globe refts a little in part of the Tube E, in as much as that part together with the Globe refting is raif-ed by the turning about of the Cylinder into a place nearer the horizontal line, *viz.* into P, and in the mean while, the part of the Tube H is depreffed to Q; from whence it comes to pafs that part of the Tube is conftituted in the inclined fite P Q, and therefore the Globe, which was found in P defcends through that part of the Tube, or inclined plane from P in Q, where you fee now the Globe advanced higher above the Horizon; for the point Q is more diftant from the Horizon A B, than the point E, where the Globe was before; again in Q, becaufe of fome refiftance which it cannot over-come through the little ftay of time refting, 'tis raifed as be-fore with part of the Tube in the fame point Q, then an-fwering to the time; from whence again after refting, it falls down in the other part of the Tube, and fo fucceffively in de-fcending it truly afcends, but not fo as to afcend in the fame time in which it defcends, and therefore it cannot be faid, truly fpeaking, that it afcends in defcending, nor that that motion is properly compofed of afcent and defcent. Wherefore it afcends in that part of time in which 'tis hindred by the adherence to the inward fuperficies of the Tube, or its roughnefs, that 'tis not moved forthwith, but it defcends after that fmall ftay, or little reft, and becaufe it defcends more oblique than before it afcended, therefore the defcent is lefs, confider'd abfolutely and in a perpendicular line than is the afcent; and therefore after all the defcents it will be found higher above the Horizontal line.

Add, that after each defcent, to wit, after the defcent from G in E, it doth not prefently reft in the loweft place E, due to it naturally, but by the acquired impetus in defcending by the inclined plane G E, it afcends alfo further, *viz.* to H, e-fpecially fince the point of the tube H defcends in the mean while, and paffes away the globe, that therefore it may fhun the fteepnefs from E in H, by being fucceffively lighter, and afcend eafier.

　　　　　　　　　　　　　　　　　　　　　　Finally,

Finally, to the facillitating of this motion of the globe the impreſt Impetus of the tube concurs to the oppoſite part of the motion of the globe, for it is found by experience, that the Globe deſcends more ſwift on an inclined plane, being moved (for example) from the Eaſt towards the Weſt, if in the mean while that it deſcends, the inclination remaining the ſame, the plane be transfer'd by an oppoſite motion, to wit, from the Weſt towards the Eaſt; ſince therefore while the Globe deſcends, by the inclined part of the Tube from G in E, or alſo while it aſcends further from E in H, the Tube by the Circumvolution is moved by an oppoſite motion from H towards E and G, it come to paſs from ſuch motion, or from the oppoſite Impetus of the Tube, it acquires a greater velocity : But likewiſe this muſt be obſerved, that as often as the oppoſite Impetus of the Tube, or of the inclined plane a-vails to the velocity of the motion of the globe, ſo often the Globe ſuffers ſome rubing or wearing with the plane that lies under it : Wherefore from the beginning to the end, all the reaſon of the motion of the Globe in the ſpiral Tube of the ſcrew, ſeems to be founded on the foreſaid adherence, or re-ſiſtance of bodies in the contact of ſuperficies.   And what we have ſaid concerning the Globe, the ſame may altogether be ſaid of water, or of any other body, notwithſtanding we have made uſe of the Globe, in the example, becauſe if the experiment be made, as we have oftentimes done in it, all theſe things clearly appear, which hitherto we have ſaid ; And that the Globe may be manifeſt to the eye, and the reaſon of its motion may be obſerved, either we muſt make uſe of a glaſs Tube, or the ſecret hollow channel about the Cylinder muſt be of tranſparent ſtone to ſee through ; or you may eaſily put a double wyre about the ſpiral Cylinder, ſo that that Iron thred, or wyre, touch not the Cylinder, but ſtand above it about half an Inch, and the ſame diſtance alſo between it ſelf, and therefore ſome quadrangles intercept the ſpace of way, on which the Globe is placed as it were on a channel, or groove.

From what hath been ſaid 'tis manifeſt, in the firſt place, how the motion of bodies which are raiſed by means of this Engin, are reduced to motion by an inclined plane.

Secondly,

Secondly, a reason appears why the turning the Cylinder about with a greater velocity, or more swiftly, that it doth not only raise greater plenty of water proportionally, but also makes the same ascent more abundantly easy; for since the opposite motion of the Tube avails much to the ascent of the water, as we have said, by how much swifter this motion is, which is made by turning about of the Cylinder, by so much the more the ascent of the water is advanced.

Add, that that little space of time which the water or the Globe rests in some lower part of the Tube 'tis raised higher, that therefore the rest ceasing it ought to descend less, and after the descent 'tis now much higher raised above the Horizon than before: moreover, since that little stay of the Globe happens from the impediment, or roughness of the Tube, suppose the Globe to be in E, and some impediment or roughness in the Superficies of the Tube, to be in its way on the part towards H ; when this kind of roughness is moved forward towards P or G, and let that which raises the Globe be as far as P, if the Tube be moved more swiftly, it impresses a greater Impetus, and raises it higher.

Thirdly, 'tis manifest also, why if the screw be less elevated above the Horizon, that the water ascends the easier, I say, the easier, that is, with less force and labour of him, or that which turns the Cylinder : (for if the Cylinder being turn'd about with the same swiftness, an equal quantity of water should ascend, whether it be more or less inclinded) the reason is manifold : First, because when the Axes A C are more Elevated the weight gravitates more upon the prop of the Axis in A, but less upon the prop in C, but if the Axis be less raised above the Horizon, or comes nearer to an Horizontal site, the whole weight is distributed to the Props A and C with less inequality, from whence it comes to pass that the Circumvolution or turning about is easier. *Secondly*, and chiefly because the entrance of the water into the Tube by the lower mouth D, resists and strives against the weight or pressure of the water which is in the whole Tube, and that weight or force of pressure is not computed from the quantity of water which is in the Tube (for that is always the same whether the Cylinder be more or less inclined) but 'tis computed from the greater or lesser perpendicular C B; therefore when the perpendicular C B is greater, the water existing within the Tube presses more, and resists more the

enter-

enterance of the water by the mouth D, since therefore that force or pressure ought to be overcome by the power turning the Cylinder, as often as the mouth D draws new water, it appears why the screw being elevated higher is moved with more difficulty: Hence you may be satisfied that 'tis false that some say, that water therefore ascends easier by a screw less elevated, because the way and acclivity of motion is lesser, as if water in ascending by a plane more steep is also more wearied, which is foolish: Hence also it is, that a solid Globe is elevated almost with equal facility through the Tube of the screw, whether the Cylinder be more or less inclin'd; for in this case each reason aforesaid ceases, and the second reason ceases wholly, since in each circumvolution of the Cylinder a new Globe is not raised, but that only which is moved forward in the Tube: And the first reason also hath scarce any room, if we suppose the Cylinder alone not to gravitate much upon the Prop or stay on which the ends of the axis rest upon.

And from hence it appears why it cannot be determined, how much the inclination of the Cylinder ought to be elevated above the Horizon; for this ought to be consider'd not absolutely, but with respect to many other things, and chiefly to these three, to wit, to the velocity whereby the Cylinder is turn'd about; for if it be turn'd about more swiftly it may be more elevated, and nevertheless the water will ascend through the tube. Secondly, to the greater or lesser adherence of the water, or other Liquor, to the inward superficies of the spiral tube; for when this adherence is greater, the water doth less gravitate upon the lower mouth of the Tube, and besides it more easily contains the Impetus from the motion of the Tube in that manner which is shewn a little before. Thirdly, and chiefly to the obliquity of the winding compass of the Tube; for if the spiral or winding compasses be thicker and closer together, and more near each to other, the Tube will be longer, and therefore the way and motion of the water longer before it comes to the upper part of the Tube, but nevertheless by reason of the greater obliquity of the spiral, the lower water gravitates less, and ascends easier, and therefore the Cylinder may be raised higher above the Horizon.

According to the variety therefore of these circumstances the inclination of the Screw may be varied: Notwithstanding this universal precept must be observed, to wit, that the Cylinder

A C

A C be never elevated above C, to such an height, that the spiral of the Tube D E or I L or M N appear parallel to the Horizon A B; for the point of the Tube D ought to be higher than E, and the point I higher than L, and so of the rest; otherwise the water being in part of the Tube D E, will flow out at the mouth D before it be moved forward any further in the Tube.

Fourthly, from what is said, that question may be resolved, to wit, whether or no 'tis most convenient to have one large Tube to turn round with the Cylinder, or many small ones: Father *Grymberger* affirms, that if one spiral Tube circumscribe the whole Cylinder, such a simple screw will pour out as much water, as if there were many Tubes, and somewhat more, and he assignes this reason, because many spirals of a Tube by reason of their thickness which they must have ought to occupy more room in a Cylinder than the thickness of one. But although this be most true, yet our question is not whether more water may ascend by one Tube only than by more; for example, unless three Tubes taken together are equal to one other larger Tube, 'tis certain that greater plenty of water may ascend by that one larger Tube; but the question is, whether or no supposing that those three Tubes, be exactly equal to the Capacity of one larger Tube, and let the Cylinder be capable, that is fitted either to the three small Tubes, or to the other larger one, I say, 'tis to be consider'd, whether to make use of the one large one, or those three small ones?

And to this Question I answer, It would be better to use three small Tubes (so that they do not gravitate more by their weight on the prop sustaining the Cylinder) than one larger; and not only because (as we have said appears) in the foresaid experiment) that they raise more water; but likewise because it ascends easier, and with less strength of the power moving the Engin. The reason is, because although the three Bases of the lesser Tubes be equal to one Base of the larger Tube, and they are supposed all of an equal height, nevertheless it gravitates or presses less in the triple base, or in the lower mouth of the smaller Tubes, than the water gravitates in one base only, or in the mouth of the larger Tube, and that therefore because although the Capacity of the three Tubes be equal to the Capacity of the one Tube, nevertheless

L l the

the inward superficies of the three Tubes is at least doubly greater the inward superficies of the one larger Tube, and since the adherence of the water is greater where the superficies is greater to which it adheres, and since it ascends easier and gravitates less upon the base when the adherence is greater, it appears to gravitate less on the bases of the three Tubes, and in them the water ascends more easily. I add also, that the water is easier drawn if it be drawn successively by many Tubes by one circumvolution of the Cylinder, than if the whole be drawn with one turn by one Tube.

From the foresaid greater adherence of the water of the smaller Tubes it comes to pass also, that although the Cylinder be turn'd about with less swiftness, yet the weight of the water cannot so easily overcome that adherence and fall back again downward, as happens in wider Tubes, which unless they are moved swiftly the water by its weight easily goes back more.

Hence also we esteem it a thing not altogether impossible to to make a screw with such artifice, that by means thereof the perpetual motion may be obtain'd, for the ascent of water or of other heavy bodies seems easiest of all by the screw.

And that this motion may be rendered yet easier, some ingenious things occur to my mind which I believe may be made use of with some profit.

The first is, when you put one or rather more Tubes about a Cylinder, within each of which you may put cotten thred, extended from one end to the other ; for by this means the adherence of the water increases, and creeps along more easily through the Tubes, although the quantity be less, all one as if one large Tube were divided into many small ones.

Fig. 166. The Second is, since the rubing or wearing of the Poles of the Axis on the Prop or stay on which they rest, is the chief impediment of all, to the Circumvolution of the Cylinder, and since there is a greater rubing and resistance on the lower Prop A, by the greater gravitation there than in B, the rubing may be hinder'd, if not wholly, at least in great part, by affixing a Wheel, or rather a Tympane C D, to the lower part E of the Cylinder A B, which Tympane must be hollowed within or void, not only the lower part D, by reason of its lightness will swim upon the water, but also it will sustain the
Cylinder,

Cylinder, so that its Pole A within the notch of the Prop may be turn'd about without any resistance.

Fig. 167. The third is, that the Cylinder be made of light matter, for the lighter it is the easier 'tis turn'd; wherefore it will be sufficient to fit the Tubes so, and to turn them about in Spirals, that they will need no Cylinder to sustain them; for it will be sufficient if in the extream heads of the Tubes, you fit two little Wheels A B, C D with their Axes fixed in the Centers. For unless they be very big and large, and the Cylinder very long, they cannot easily be bent by the water, or by their proper weight, and especially if they are made of rough matter, *viz.* of thin Iron plates cover'd over with Tin or Glass, *&c.* Or if you fear the bending of the Tubes, you may fit here and there in stead of the whole Cylinder, two or three rulers extended according to the length from A to C, and from B to D, which rules or Spears support the Tubes, least they bend in the middle. Likewise you may so turn about many small Tubes spirally, one immediately near to another, that they being all united together, make one whole Cylinder, or rather a Tube, which resembles a Cylinder made hollow within.

Fourthly, If you desire to raise not Water but a solid Globe by a Pulley, you need not make use of a Tube; two iron wyers turned about spirally parallel to each other, and fastned to the extream heads in the Circumference of the little wheels A B and C D, will be fit for that purpose; and those wyers ought to be somewhat less distant from one another, than the thickness or diameter of the Globe; for so the Globe will be detain'd within each wyer always in the lower parts of the spirals, and will ascend by degrees by those spirals being turn'd about.

Fig. 168. Also it may be made of two thin plates of Mettal, or of one only made hollow after the manner of a Channel or Groove; yea, we have made a screw fit to take up a leaden Globe or Ball of an inch Diameter, of thick paper or pastboard turn'd about spirally, to wit, the Tube of them which compose a Tellescope we have cut spirally, so that the Globe is detain'd within the spiral cleft, and will ascend by the same cleft, the Tube being turn'd about. Moreover one plate of mettal only may be turn'd about a Cylinder which ascends spirally, and sticks out every where above the superficies of the Cylinder,

one

one or more inches, according as the magnitude of the Globe to be raifed requires, and the plate muft be of fuch a breadth, as is the Diameter of the Globe, or a little more, and erected perpendicularly upon the fuperficies of the Cylinder, and one of its fides faftned to the fame Cylinder; then the Cylinder being elevated in an oblique fite to the Horizon; for Example, in the fite A B, and the Axis leaning or ftaying upon its prop, the hollow plate of mettal D C is fitted under the Cylinder, which remains unmoveable in the fame oblique fite, and then being diftant a little from the fpiral plate, fo that as it were, it is razed by the fubjected channel or hollow plate being turn'd about. Then if you place a Globe on this, and turn about the Cylinder, the fpiral will move forward the Globe by that inclined Channel from D in E, and from E to F, &c.

The fame power or ftrength muft be applied here, as a fcrew hath to raife water, or another body, of which we have fpoken elfewhere concerning the common Screw; for as you fee the motion or elevation of weight by this fcrew of *Archimedes*, is indeed a motion by an inclined plane, where that univerfal principle always takes place, that the increafe of force is taken from the proportion of the velocity of the power moving, to the velocity of the weight moved; wherefore, if for example, as in the prefent figure the fpiral being four times turn'd about, the Cylinder be 12 feet, and the Globe afcend from D to F, in the plane or inclined Channel D C two feet, the power as 2 may raife the weight as 12.

What we have faid hitherto concerning a Cylindric fcrew, may alfo be underftood of a Conic fcrew, for inftead of a Cylinder we may ufe a Cone to which the Tube may be fpirally turn'd about, as is commonly known. And although fome prefer a Cone before a Cylinder, yet we fee not any effect that it performs better; therefore fince a Cylindric fcrew is eafier prepared, we may ufe the fame moft fafely, and perhaps moft profitably, at leaft in many cafes.

Many other things occur which may be faid concerning this Engin, which in our opinion are very Ingenious, for writers have fcarcely fhewn any thing worthy of confideration to Pofterity in this matter although it be very capacious, as may be eafily underftood from thofe things which we have briefly fhewn, with which we fhall conclude this ninth and laft Book.

of.

of *Mechanick Powers.* Giving all honour and Praiſe to that great Maſter of Arts, and Fountain of all Wiſdom, the Omnipotent God Bleſſed for evermore.

I had here put an end to *Mechanick Powers,* but meeting with ſome new inventions relating thereto, lately publiſht in *France* by an able *Mathematician,* which if put in practice may be uſeful and beneficial in Engins ; I thought fit to add them by way of Appendix, and they are theſe that follow.

APPENDIX.

BOOK X.

Of Epicycloids, *and their uſe in* Mechanicks.

Definitions.

Fig. 169. IF the circle A B D be rouled or turn'd about upon the arch A *b d* of any Circle, the point D which is the extream or end of the Diameter A D, will by its motion deſcribe the Line D 14, 15, 16, 17 *d,* which is called an *Epicycloid.*

The circle A B D is called the generating circle of the *Epicycloid.*

The arch A *b d* is the Baſe of the *Epicycloid.*

If the generating circle roul on the out ſide of the circle of the Baſe, the *Epicycloid* is called *Exterior,* or *Outer* : But if the generating circle roul on the inſide of the circle, the *Epicycloid,* is called *Interior,* or *Inner.*

The ſpace contain'd by the *Epicycloid,* and by its Baſe, is called *the ſpace of the Epicycloid.*

The

The Dimension of the Space of the Epicycloid.

Lemma 1.

Fig. 170. LET the Semicircle be A P *p* B, whose diameter is A B, and its centre K; having drawn the line P *p* Parallel to A B, and meeting the circle in the points P *p*, from any point C of the diameter A B drawn longer, draw the lines C P, C *p*;

I say, the sum of the right lines C A, C P, is to the sum of the right lines C B, C *p*, as the difference of the right lines C B, C *p* is to the difference of the right lines C A, C P; or else, which is the same thing, the Rectangle made of the sum of the lines C A, C P and their difference, is equal to the rectangle made of the sum of the lines C B, C *p* and their difference.

Lemma 2.

Fig. 171. In the Triangle C A V if the right lines P X, *p* G, B M being parallels to the base A V, cut the side C A, so that the sum of C A and C P, be to the sum of C *p*, C B, as the difference B *p* the Segment of the last, is to the difference P A of the first.

I say, that the Trapezias M *p*, A X are equal between themselves.

Lemma 3.

Fig. 172. Let the Semicircle be A D E B, and on its diameter A B prolonged or not prolonged, let the point C be taken, and draw any right line D E Parallel to the diameter A B which meets with or touches the circle in the points D, E; From the Centre C, with the Semidiameters C A, C D, C E, C B, describe the arches of circles A F, D P G, E *p* H, B I, which meet with any right line as C F drawn from the centre C, in the points F, G, H, I.

I say, that the foursided mixt figures A F G P, *p* H I B are equal between themselves.

Demon-

Demonſtration.

Make the right line A *f* equal to the arch A F, which muſt make with the diameter C A, the right angle C A *f*; having drawn C *f*, draw alſo the right lines P *g*, *p h*, B *i*, parallel to A *f*.

'Tis evident by conſtruction that the triangle C A *f* is equal to the Sector C A F: In like manner, the Triangle C P *g* is equal to the ſector C P G, wherefore if from the equals C A *f*, C A F, you take away the equals C P *g*, C P G, the remain will be equal, to wit, the Trapezia A P *g f*, and the four ſided mixt figure A P G F. We may demonſtrate in the ſame manner that the Trapezia *p h i* B, is equal to the mixt figure *p* H I B.

But by the firſt *Lemma* the ſum of the right lines C A, C P, is to the ſum of the right lines C *p*, C B, as the difference of C *p*, C B which is *p* B, is to the difference of C A, C P, which is A P; wherefore by the 2d. *Lemma* the Trapezia A *f g p* will be equal to the Trapezia *p h i* B, and the mixt figures A F G P, *p* H I B which are equal to the Trapezias are alſo equal between themſelves.

Lemma. 4.

Fig. 173. If the circumference of the Semicircle A B D be divided into equal parts between themſelves in the points E F G B H I, &c. and the number of theſe parts be even and indefinite, and on the diameter A D prolonged or not prolonged you draw from the point Y as a centre the arches of a circle, whoſe radius's are the diſtances Y A, Y E, Y F, Y G, &c. and let the length of the arch A *d* deſcribed by the point A be equal to the circumference of the Semicircle A B D, and let the Arch A *d* be divided into as many equal parts *e f g h* as is in the Semicircle A B D : Then having drawn the Rady from the centre Y to the diviſions *e f g b h*, &c. then you will have the mixt four ſided figure A D X *d* divided into an indefinite number of little mixt four ſided figures which will have the following properties.

Becauſe the equal diviſions of the Semicircle may be drawn by the points of diviſion of the right lines K E, I F, H G, &c. which will be parallel to the diameter D A of the circle; therefore by the 3d. *Lemma* the four ſided figures *d y* R *k*, X *z a* 4, will be equal between themſelves being equally re-
moved

moved from the extreams: But also those which are contain'd between the same circles will be equal between themselves, because of the equal divisions of the arch A *b d*; wherefore the 4 sided figure A *e* E *r* will be equal to the 4 sided figure X *z a* 4.

We may demonstrate in the same manner that the 4 sided figure 2 X 4 *t* is equal to the 4 sided figure *d* 3 *f k* or A *e* 18 *q*, and so of the rest.

'Tis evident in each Sector, as Y X 4 or Y *d k*, that the four sided figures are equally removed from the extreams, as 2 X and 3 *u* are also equal between themselves; for the 4 sided figures X *x* and *d u* are equal, the 4 sided figures X *t* and *d s* are also equal by the foregoing *Lemma*: Wherefore if the greater be taken from the lesser, the remains which is the 4 sided figures 2 *x* and 3 *u* will be equal, and so of the rest.

Lemma. 5.

The same things being put as before and in the same figures, if you draw the diagonal line D L M N O *d*, compounded of an indefinite number of small right lines, which in the 4 sided figure A D X *d*, divides in two diagonal wise all the small 4 sided figures, which are in the diagonal from the angle D even to *d*, as appears in the figure, by the lines D L, L M, M N, N O, *&c.*

I say, that the 4 sided figure A D X *d* is divided in two, equally by the diagonal D O *d*,

'Tis not difficult at all in this place, to grant that the small diagonals which are from right lines, divide in two equally their particular quadrilaters, or 4 sided figures, and that the difference which is between the true division and this, is not found considerable, and seeing we may always find a less magnitude than any given, because that the quadrilaters which are divided, are supposed indefinitely small as is commonly accepted in the use of Indivisibles.

Now by that which is demonstrated in the precedent *Lemma*, 'tis evident that the Quadrilater A L is equal to the quadrilater X R; In like manner the Quadrilater *e* M is equal to the Quadrilater 4 Q; the Quadrilater *f* N equal to the Quadrilater 5 P, and so of the rest.

Where-

Wherefore all the like Quadrilaters together on one side of the Diagonal D L M N O P, &c. will be equal to all the Quadrilaters on the other side. But the line D L N O P *d* which divides diagonal wise all the small Quadrilaters which are in the diagonal, is suppofed to divide alfo in two equally all thofe quadrilaters; therefore this diagonal, which may be confider'd as a crooked line, divides equally in two all the great Quadrilater A D X *d*; which was to be Demonftrated.

Scholium.

If we fuppofe that the point Y which is taken on the diameter A D is infinitely lengthned from the circle A B D, there may be right lines perpendicular to the Diameter A D, in ftead of the Arches of circles, which pafs through the points D K I H A, of which A *d* is one, which is put equal to the circumference of the Semicircle A B D, and which is divided into fo many equal parts, as is the Circumference A B D; and laftly, inftead of the mixt Quadrilaters, or 4 fided figures, as thofe before, you will have Parallelograms, which being equally removed from the Extreams, will be equal between themfelves, and thence it follows likewife that the diagonal which divides diagonal wife all the little Parallelograms, which are from one angle to the other, will divide the whole great Parallelogram into two equally.

Lemma 6.

Fig. 169. The fame things being put as before, if you make the Semicircle A B D to fet forward, fo that the diameter A D be placed on the part *e* 8 of the Radius Y 8 *e*, and that the point A agree with the point *e*; 'tis evident that the point *l* of the diameter will agree, or be in the point L of the Radius Y*e*; Moreover if we make it to pafs even to the Radius Y *f*, and that the point A fall on the point *f*, the whole diameter A D will agree with the right line *f* 9, the point *m* of the diameter of the circle A D B will agree with the point M, and fo of the reft: Whence 'tis evident, that all the points of the diameter A D, as D *l m n*, &c. defcribe the diagonal line D L M N *d*.

Demon-

Demonstration.

But if inftead of removing the circle A B D, we concieve it to roul on the bafe A b d; when the point E of the circle is come to e, the diameter of the circle E 10, will be joyned with the right line e 8, for by the Hypothefis the arches A E, A e are equal in length; and from the fame, when the point F is come to f, the diameter F 11 will be joyned to the diameter f 9, and fo of the reft. But if you mark the diftances A l, A m, A n, on every diameter, as E 12, F 13, &c. it is evident, that while the circle A B D rouls on the bafe A b d, the points l m n 7 p q of every diameter meet one another in the diagonal line D M N O P d: For when the point A of the circle is come to e, the point 12 on the diameter E 10 will be in L, becaufe that the diftances 10, 12, D l are equal; and by the fame reafon the point 13 will be in M, &c.

But moreover, when E 10 is placed on e 8, and the point 12 on the point L, the point D of the circle A B D will be in the point 14 on the arch l 14 z: For the Semicircle 8, 14, e reprefents the Semicircle E D 10; and as the arch 10 D is equal to the arch D K by Conftruction, when the point 10 by the movement of the circle is come to the point 8, the point D will of neceffity be on the point 14 in the arch L K L 14 z; fo that the portion L 14 of this arch will be equal to the Portion L K of the fame arch: In like manner, when the point 11 is come to the point 9, the fame point D will be on the point 15 in the arch m l M 15, fo that the arch M 15 will be equal to the arch m l, &c.

PROPOS. I.

Fig. 169. IN the precedent Figures 'tis demonftrated that the fpace of the moiety, or half of the *Epicycloid*, A b d 17, 16, 15, D, is equal to the half of the Quadrilater A b d X D, joined to the generating femicircle A B D.

Fig. 173. I have fhewn before that the line D M O Q d divides the mixt quadrilater A b d X D in two equally, it remains then to demonftrate that the fpace D L O Q d 17, 16, 15, D, contained by the line D M O Q d, and by the half of the *Epicycloid* D, 15, 16, 17, d, is equal to the generating femicircle D B A.

By conftruction, the whole generating femicircle is divided into mixt Quadrilaters, as m l r n, and into two trilined, or
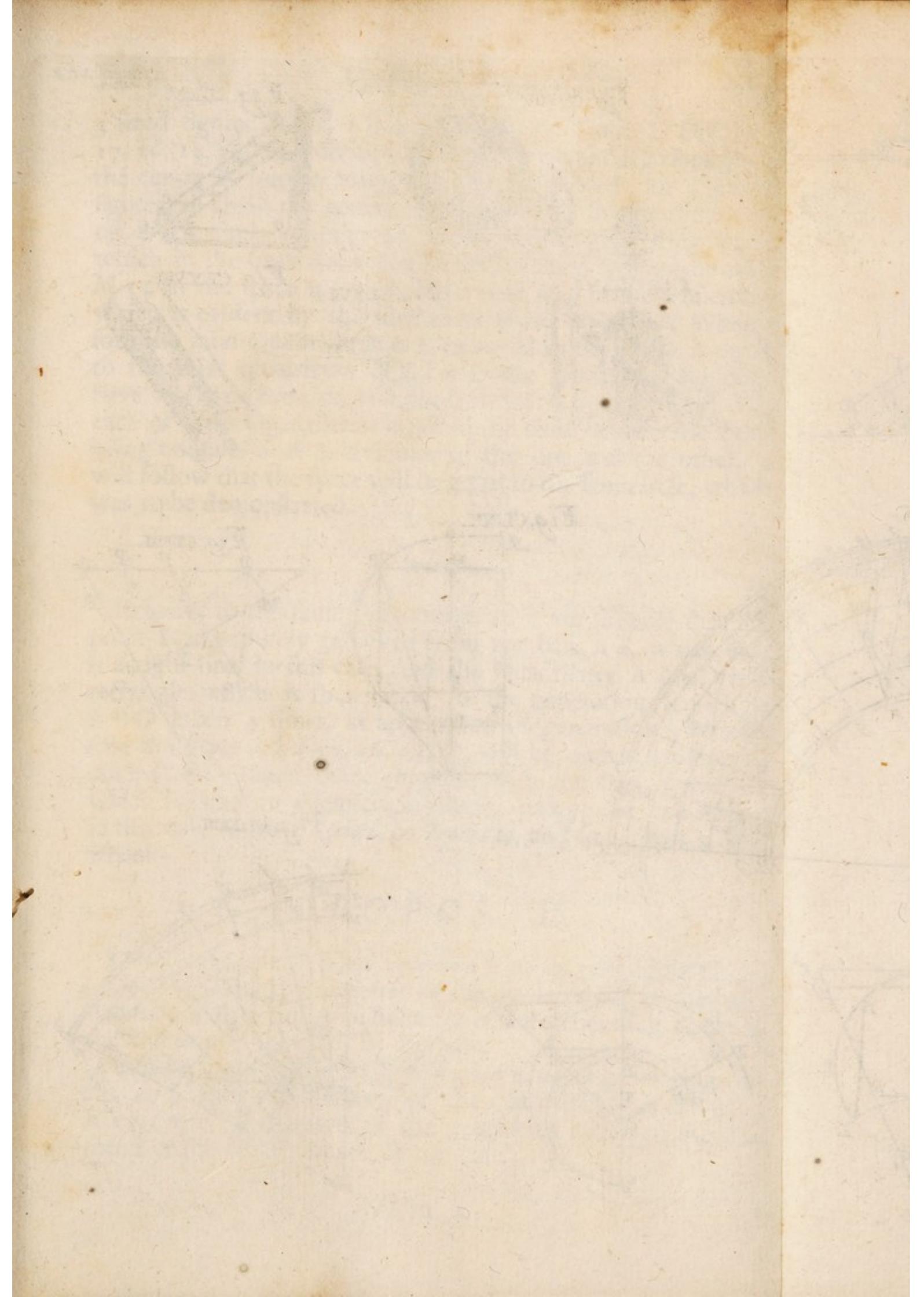
3 lined

Fig. CLXII.
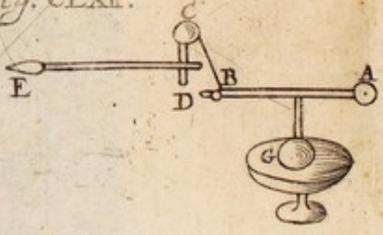
Fig. CLXIII.
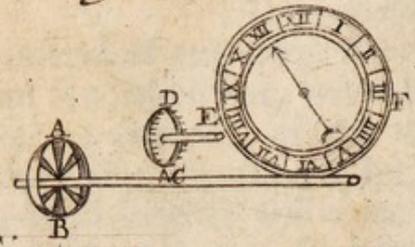
Fig. CLXIV.
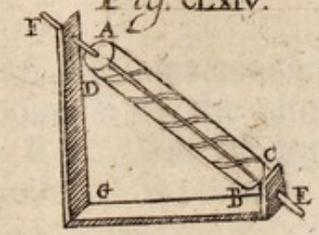
Fig. CXV.
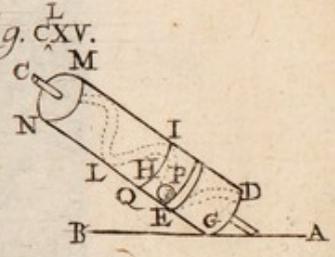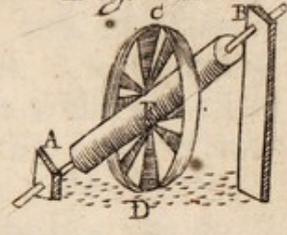
Fig. CLXVI.

Fig. CLXVII.
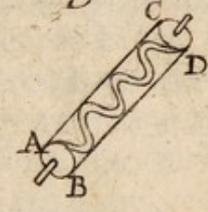
Fig. CLXVIII.
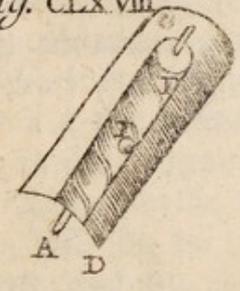
Fig. CLXIX.
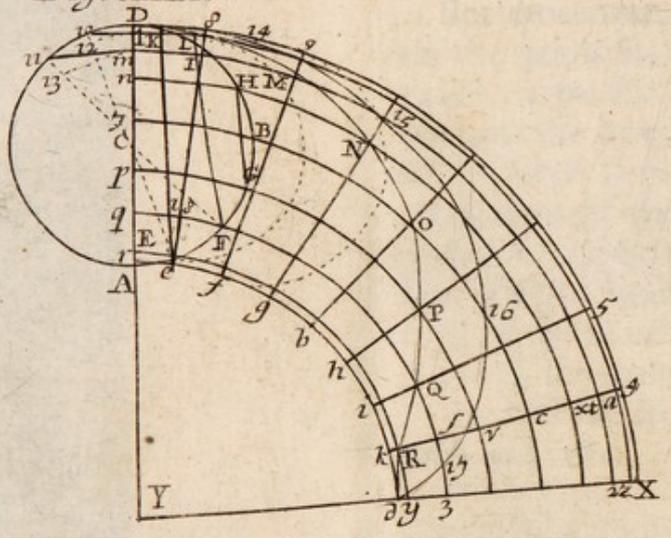
Fig. CLXX.
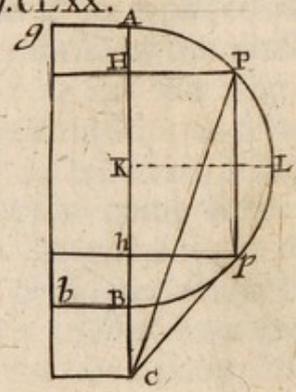
Fig. CLXXI.
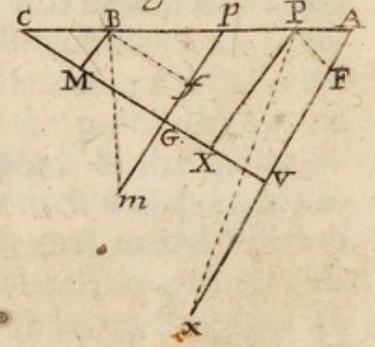
Fig. CLXXIII.
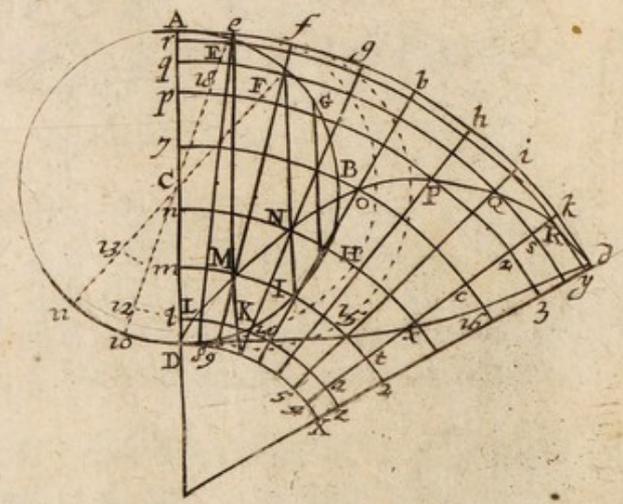
Fig. CLXXII.
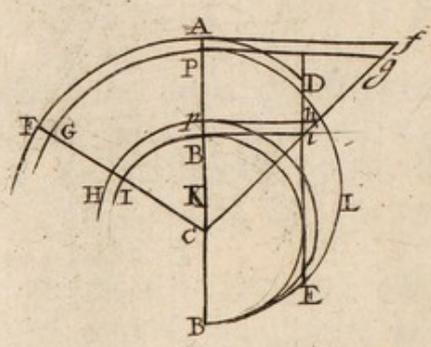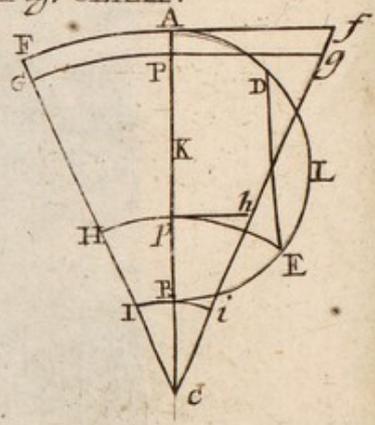
3 lined figures D K *l*, *r* E A : But also the space D M O Q *d*
17, 16, 15, 14, D, is divided by the same circles described from
the centre Y, into so many 4 sided, and 3 sided (or 3 lined)
figures, as are in the generating semicircle ; so that the arches
of every circle contains so much in the generating circle
which in the space are equal between themselves, as the arch
M 15 in the space is equal to the arch M *l* in the semicircle,
which is evident by the formation of the *Epicycloid* : Where-
fore the mixt Quadrilater, as L 14 15 M in the space is equal
to the mixt quadrilater L K *l m* in the semicircle, for they
have the same breadth, and are inclosed in equal arches : But
each of these Quadrilaters equal in the circle and in the space
being consider'd as Indivisibles of the one and the other, it
will follow that the space will be equal to the semicircle, which
was to be demonstrated.

Scholium.

Keeping to the same Demonstration, if we suppose that the
point Y is infinitely removed from the base A *d*, which base
is a right line in this case, and the Quadrilater A *d* X D is a
rectangle, which is then equal to the generating semicircle
A B D taken 4 times, as appears by its generation : Where-
fore the space A *b d* 17, 16, 15, D, will be equal to the semi-
circle A B D, taken twice together with the same semicircle
which is equal to a semicircle taken 3 times ; the line *d* 16 D
in this case is called *Cycloid*, or *Trochoide*, and sometimes a little
wheel.

PROPOS. II.

THe space of the outer *Epicycloid* is to its generating circle,
as 3 times the diameter of the circle which is the base,
together with 2 times the diameter of the generating circle to
the diameter of the circle of the base.

But the space of the inner *Epicycloid* is to its generating cir-
cle, as 3 times the diameter of the circle which is the base,
less 2 times the diameter of the generating circle, to the dia-
meter of the circle, which is the base.

Mm 2

Of

The Dimension of the Lines of Epicycloids.

Of the touching of Epicycloids.

Lemma 1.

Fig. 174. LEt the circles be E B F, F H which touch each other outwardly in F. Having join'd the centres K C by the right line E K C which paſſes by the point of contact, or touching F; from the extream E of the diameter F E, draw a right line E B, prolonged to the other circle in H. I ſay, that the arch F H is greater in length than the arch F B.

Lemma 2.

Let the 2 circles be E B F, F H I, which touch each other in F, from the centre K of one of the circles draw the line K B I, meeting them both in B and in I. I ſay, that the arch F H I is greater in length than the arch F B.

PROPOS. I.

Problem.

To find the point of Contact, or touching of the outer Epicycloid.

Fig. 175. LEt the outer *Epicycloid* be G H M, whoſe baſe is the circle G A, deſcribed from the centre C. And let the generating circle I H A D of the *Epicycloid* be placed in ſuch manner, that the deſcribing point H be on the *Epicycloid* in that point in which the touching is made : If by the centre C of the circle of the baſe, and by the centre O of the generating circle you draw the right line C A O I, and by the extream I of the diameter A I you draw the right line I H to the point H.

I ſay, the right line I H touches the *Epicycloid* in the point H.

Lemma 3.

Fig. 176. Let the two circles be F A E, F R D which touch each other in F, having their convexities of the ſame ſide, and that the centre C of the circle F R D be out of the diameter F E of the circle F A E; having drawn a right line E A D from the extream or end E of the diameter F E, which cuts the circle F A E in the point A, and the circle F R D in the point D.

I ſay,

I fay, that the arch F R D is more in length than the arch F A.

Lemma 4.

Fig. 177.   Let the two circles be F S, F R which touch in F, and that have the convex parts of the fame fide, and let the centre C of the greater be on the diameter of the leſſer lengthned; if you draw the line C R D from the centre C which cuts the 2 circles in R and D.

I fay, that the arch F R of the leſſer is greater in length than the arch F D of the greater.

PROPOS. II.

To find the touching of the inner Epicycloid.

An Advertiſement.

THere are three kinds of inner *Epicycloids* ; the firſt is when the Diameter of the generating circle is leſs than the ſemidiameter of the circle which is in the baſe ; the ſecond, when 'tis equal to it ; and the third, when 'tis greater ; we have ſhewn at the end of the Dimenſion of *Epicycloids*, that is among the interior or inner, that thoſe that are of the firſt and third kind or ſort, are the fame ; for that whoſe diameter of its generating circle is leſs than the ſemidiameter of the circle of the Baſe, is the fame as that which on the contrary, the Diameter of its generating circle is greater than the ſemidiameter of the circle of the Baſe, if the circle of the baſe is the fame, and that the generating circle of this laſt, have its diameter equal to the difference which is between the diameter of the Baſe, and the diameter of the generating circle of the firſt ; wherefore I ſhall ſpeak only here of thoſe *Epicycloids*, whoſe diameter of the generating circle, is leſs than the ſemidiameter of the circle of the baſe.   For that which is of the ſecond kind of inner *Epicycloids*, 'tis a right line equal to the diameter of the circle of the baſe.

Fig. 178.   Let the inner *Epicycloid* be M H, whoſe baſe is the circle A B M, and its centre in C, and let the generating circle I H A of the *Epicycloid*, be ſo placed on the baſe, that the point deſcribing H be on the *Epicycloid*.   From the centre C of the baſe having drawn the radius C A to the point touching A of the generating circle with the baſe, which paſſes alſo by the centre of the circle.   I ſay,

I say, that the right line I H drawn from the extream I of the diameter of the generating circle to the defcribing point H, will touch the *Epicycloid* in the fame point H.

Lemma 5.

Fig. 179. Let the femicircle be S T A R, whofe diameter is S R, and let the circumference be divided into any number of equal parts that you pleafe, fo they be even. From the points of Divifion having drawn the perpendiculars to the diameter S R, and the touchings as T B which are terminated at the neareft perpendiculars which are beneath.

I fay, that the fum of the touchants, as T B, without counting the firft which is infinite being drawn by the point S, and the laft; is greater than the circumference of the femicircle, without counting the firft and the laft arches of Divifion.

Lemma 6.

The fame things being put as in the precedent *Lemma*, it may be demonftrated, that the divifions of the circle being indefinitely fmall, the fum of the Touchants cuting as thofe before, without having regard to the firft and laft, differ not fenfibly from the circumference of the circle, leaving out the firft and laft arch of Divifion.

Lemma 7.

The fame things being as before, it may be demonftrated that the fum of the parts as A B which are cut off from the perpendiculars of the Diameter of the circle, between the circumference A and that which is cut off B of the upper touchant T B, which is the neareft, may be found lefs than any fmall quantity which may be propofed, and by confequence the points as B, may be confidered as on the circumference of the circle.

Lemma 8.

Fig. 180. In the circle D H B whofe centre is C, and the touchant D A in D, terminating in the Radius C B A lengthned;
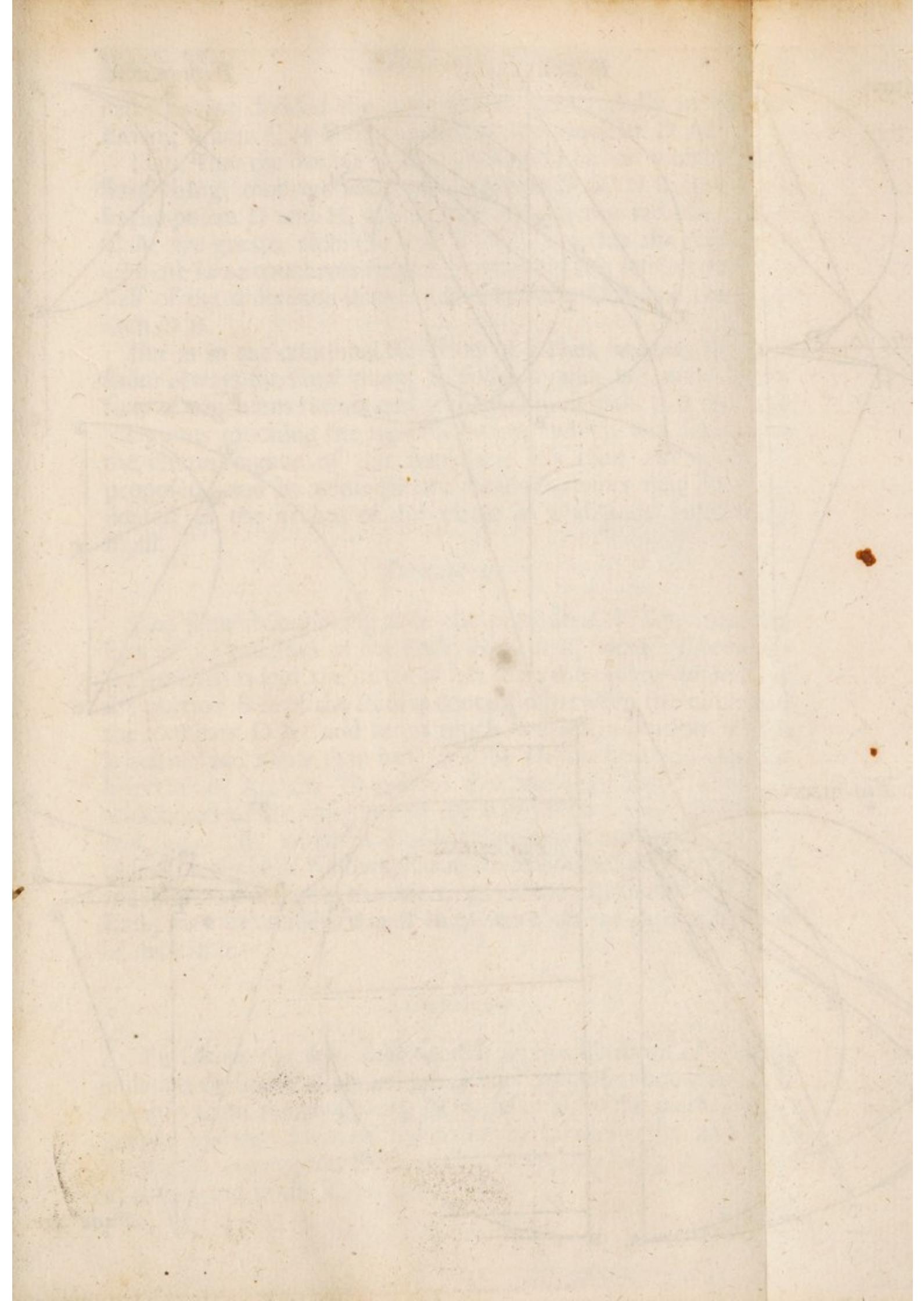
Fig. CLXXIV.
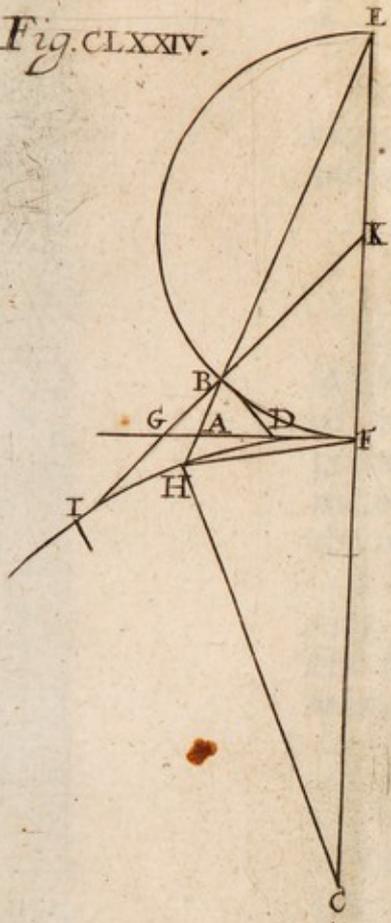
Fig. CLXXV.
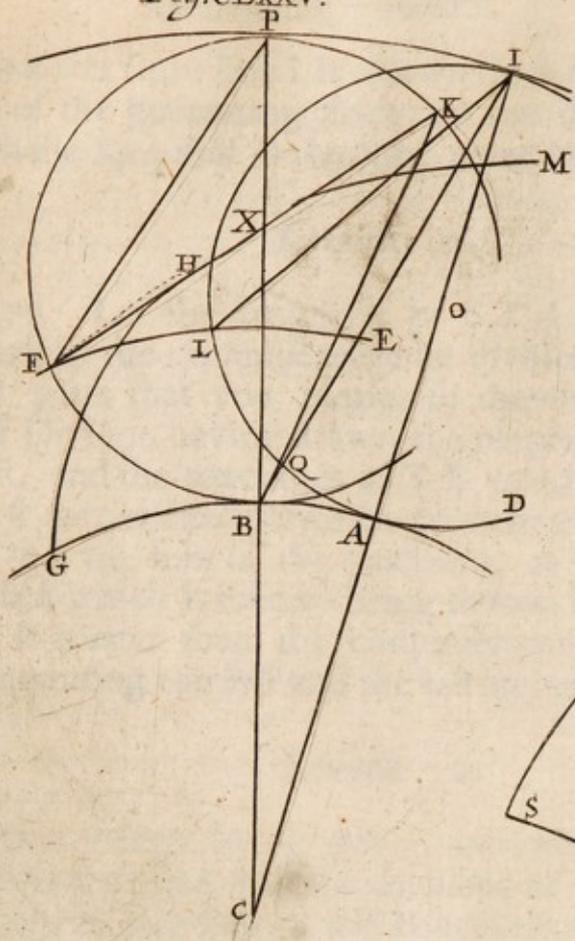
Fig. CLXXVI.
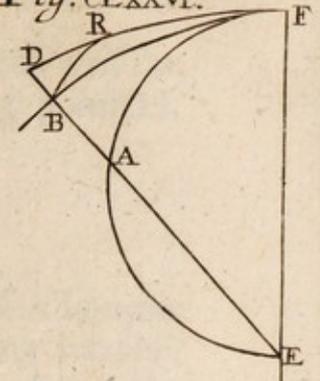
Fig. CLXXVII.
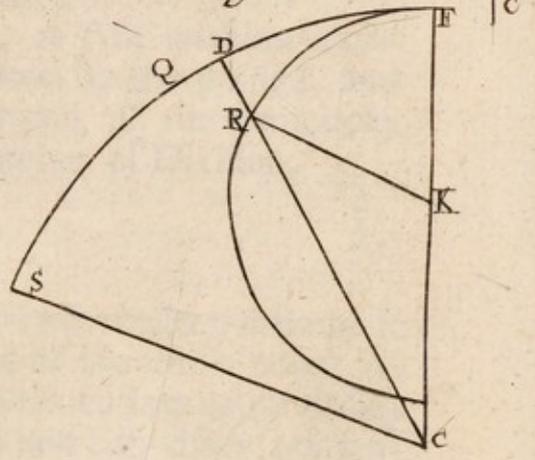
Fig. CLXXVIII.
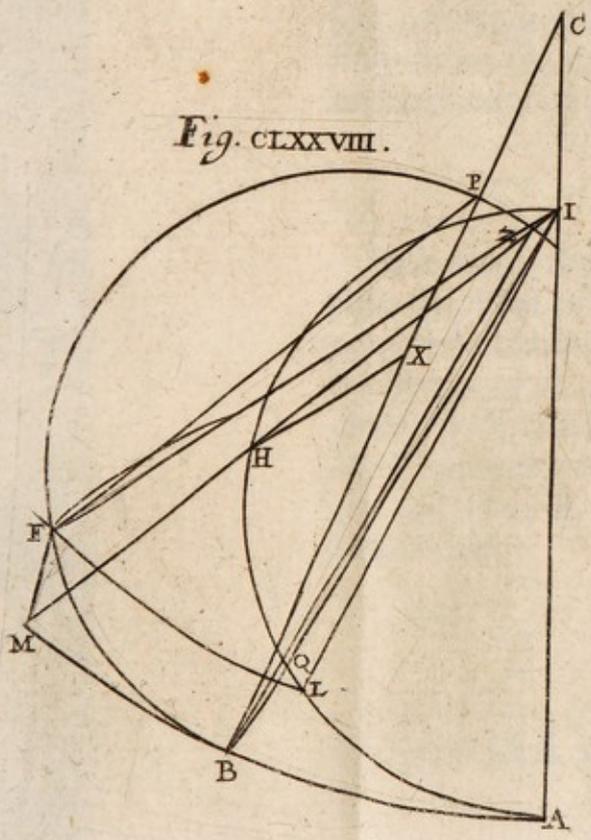
Fig. CLXXIX.
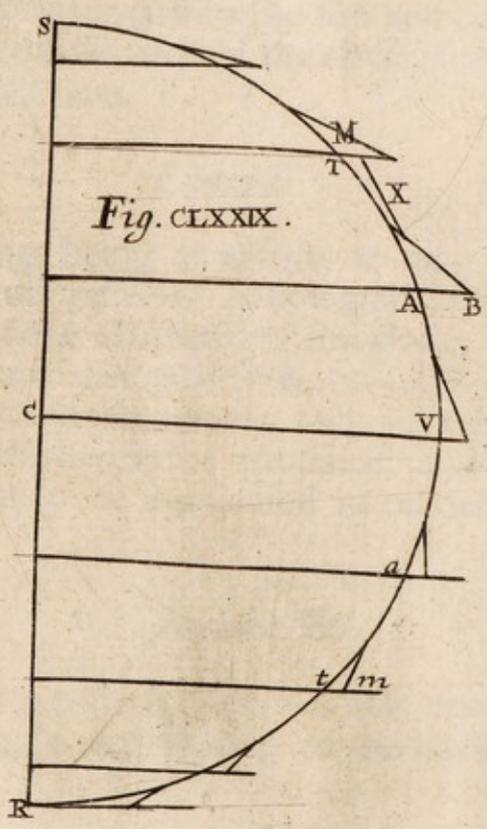
Fig. CLXXX.
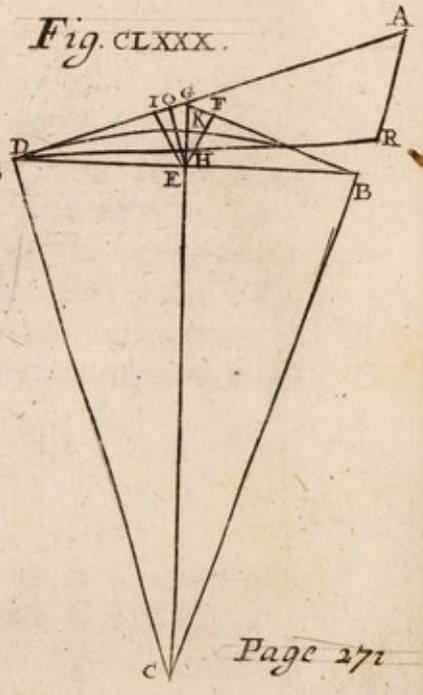
ned; having divided the arch D B in two equally in H, and having drawn C H G terminated by the touchant D A.

I say, that the double of the touchant D G, or which is the same thing, that two touchants together D G, H R, touching in the points D and H, and terminating at the radiusses C G, C A, are greater than the arch D H B, but that the difference of these same touchants from the arch D H B is left less than the half of the difference between the touchant D A and the same arch D B.

But as in the continual Bisection of arches, we may demonstrate always the same thing, it follows, that we may find a sum of touchants terminated at the Radij, which past through the points touching the next following, which will differ from the circumference of the semicircle less than any quantity proposed; and by consequence these touchants may be considered as the arches of the circle in a division indefinitely small.

Lemma 9.

The same things being as in the precedent, I say, that the sum of the portions of the Radij H G, B R, contain'd between the touchants and the circle is less than the moiety or half of the portion B A of the Radius contain'd between the circle and the touchant D A; and for as much as this diminution which is augmented more than half, will be always by the continual bisection of Arches, 'tis evident that we may find a quantity which will be the difference of the Radij between the touchants and the circle, which will be less than any small quantity proposed; whence it follows, that in the division of the circle into indefinite small parts, the meetings of the touchants with the Radij may be consider'd as if they were on the circumference of the circle.

Lemma 10.

'Tis said in the 6th. *Lemma*, that in the divisions of a circle indefinitely small, the portions of the circumference differ not sensibly from the touchants, being lessen'd by the method proposed; and that these touchants may be taken for the arches of the circle, we may now demonstrate the same thing in the Epicycloids, and in the Cycloids.

Lemma

Lemma II.

Fig. 181.   The femicircle B D A being divided into parts indefinitely fmall as D F, and by the points of divifion as F, having drawn the lines M F Z perpendicular to the diameter A B, and by the extream B of the diameter A B, and through all thofe points of divifion as D, having drawn the right lines B D M terminating in M in the perpendiculars M F the neareft to the loweft.

I fay, that the fum of all the portions, as D M of the lines B D M in the femicircle, is equal to the double of the diameter A B.

P R O P O S.   III.

I Say, that the bignefs of the crooked line of the outer Epicycloid is equal to the right line, which hath the fame reafon or proportion to the diameter of the generating circle taken 4 times, as the fum of the diameters of the two circles, to wit, of the generating, and of that of the bafe, to the diameter of the circle of the bafe.

P R O P O S.   IV.

THe crooked line of the inner Epicycloid is equal to the right line, which is to 4 times the diameter of its generating circle, as the difference of the diameters of the circles of the bafe and of the Generatour, to the diameter of the circle of the bafe.

P R O P O S.   V.

Fig. 182.   IN the firft place, I fay, that when the Diameter of the generating circle is equal to the diameter of the circle of the bafe, the Epicycloid degenerates into a right line fince, 'tis nothing but the diameter of the circle.

Secondly, If the diameter A B of the generating circle of the inner Epicycloid, is greater than the femidiameter C B of the circle of the bafe, but lefs than the whole diameter; I fay, that the inner Epicycloid is the fame as that which is defcribed
bed

bed by the circle D E F, whose diameter D E is the difference between the diameter A B of the generating circle, and the diameter G B of the circle of the base, and the diameter D E will be less in this case than C B, we may find the bigness of this *Epicycloid* by the 4*th. Proposition.*

Thirdly, if the generating circle have its diameter greater than that of the circle of the base, the *Epicycloid* which will be described by the generating circle will be an outer *Epicycloid,* which will be the same as the Exterior which will be described on the same base, by another circle whose diameter is equal to the difference of the diameter of the generating circle and of that of the base.

Lemma 12.

What is said at *Lemma* 11. touching the likeness or proportion of D Q to D M towards the parts of the base of the *Epicycloid,* will be the same as for the parts above the point D.

This *Propos.* is evident, since we may make the triangles alike with the parallel lines on both sides the point D, as appears in the Figure.

Lemma 13.

Fig. 83. Let the Semicircle be A M C I, whose circumference divide into parts indefinitely small as C I, I X, from the points of division C I X having drawn the perpendiculars C B, I E, X R to the diameter A M, and the Chords A C, A I, A X, which meet with the Perpendiculars of the nearest divisions from above to the points F R.

I say, in any Segment of the circle which you please, that all the portions together of the Chords, as C F, I R, contain'd between the circumference of the circle and the upper perpendicular, are equal to the double of the Chord A C; and by the same reason all the portions taken together in the semicircle, are equal to the double of the diameter, which is also the Chord of the Semicircle.

N n

PROPOS.

PROPOS. VI.

Fig. IN the *Epicycloid* P D, whofe top is P, and any arch P D
184. from its top, the generating circle B D A being put fo
that the defcribing point be in D, and that the diameter A K
B in this Pofition tend to the Centre C of the bafe.

I fay, that if we make it, as C A the radius of the bafe, is
to C K compofed of the Radius of the bafe and of the Radius of
the generating circle, fo the double of the Chord B D of the
arch B D of the generating circle which anfwers to the arch
P D of the *Epicycloid*, is to a fourth Proportional, that line
will be equal to the arch P D of the *Epicycloid*.

Of the motion or rouling of Epicycloids, *and of the* Cycloid.

Lemma.

Fig. LET the line DTFB be always crooked on the fame
185. fide about which apply a flexible line ; if we open
or unfold part of this applied line, fo that its part A B betwen
its extream A and the curve in B be ftretcht out, then by con-
fequence it will be a ftreight line.

I fay, that the right line A B touches the curve or crooked
in the point B, from whence it begins to extend it felf.

The line defcribed by the end A of the flexible line which
is always ftretcht out in its opening, is faid to be defcribed by
the rouling of the curve. D T F B.

PROPOS. I.

The Line defcribed by the rouling of an Epicycloid, *is an*
Epicycloid.

Fig. LET the *Epicycloid* be B D L, its generating circle F D E,
186. its centre P, and whofe circular bafe is A E L and
the centre C, the top of the *Epicycloid* let be the point B.

If from the centre C and the Semidiameter C B we defcribe
the circle B F M, which let be the bafe of the *Epicycloid* B G K,
whofe generating circle will be F G H, which has for its dia-
meter F H or B I, which may be determin'd by faying, as C A
is

is to C P, fo is 2 E F or 2 A B, to a fourth proportional E H
or A I ; and having taken from A I the diameter A B of the
generating circle, there remains B I or F H, which will be
the diameter fought.

I fay, that the *Epicycloid* B G K is defcribed by the Roling
of the *Epicycloid* B D L. By conftruction, and by the prece-
dent Propofitions of the dimenfion of the lines of *Epicycloids,*
it appears that the Curve of the Semi *Epicycloid* B D L is e-
qual to the right line A I or L K.

Now let the flexible line be fitted about the Semi-epicycloid
B D L, of which the portion from the point D even to the top
B will be extended in the right line D G ; this right line D G,
by the precedent *Lemma* touches the *Epicycloid* in the point D ;
Wherefore if we put the generating circle of the *Epicycloid*
in the pofition F D E, or the defcribing point being in the point
D ; it is certain by the property of Touchants of *Epicycloids* that
the right line D G touchant, paffes through the extream F of
the diameter E F, in the pofition F D E of the generating
circle.

Having prolonged C E F to H in the circle I H K concen-
trique in the circle of the Bafe, which is defcribed on the
Semidiameter C I ; on F H for a diameter defcribe the Semi-
circle F g H. I have demonftrated that the extream G of the
flexible line ftretcht out from the point D, will be on the circle
F g H.

If the point G is not on the circle F g H, and the right
line D F G meet, if it may be the circle F g H in any point g ;
then draw H g ; becaufe of the Semicircle F g H, the angle
F g H is right, and the rectangled Triangles E D F, F g H will
be like, becaufe of the equal angle at the point F. Wherefore
E F will be to F H, as F D to F g ; and being compounded, E F
will be to E F more F H, that is E H, as D F to D F more
F g, that is D g ; and by doubling the Antecedents 2 E F or 2
A B, they will be to E H or A I, as 2 F D to D g.

By *Propof.* the 6th. of the dimenfion of *Epicycloids,* and by
conftruction ; as 2 A B are to A I, fo C A is to C P : But as
C A is to C P, fo is the double of the Chord D F to the
bignefs or Magnitude of the portion D B of the *Epicycloid,*
which portion by the roling is equal to the right line D G :
Wherefore by equal reafon 2 A B are to A I, as 2 D F are to
D G. But I come to demonftrate that 2 A B are to A I, as 2

F D are to D *g*; then 2 D F are to D G, as 2 F D are to D *g*, and by confequent D G will be equal to D *g*: then the point *g* of meeting of the right line D F G, and of the circle F *g* H, will be the extream G of that line.

It remains now to demonftrate that the point G is in the *Epicycloid* B K, whofe generating circle is F G H. By conftruction C A, is to C P, as 2 A B are to A I; by dividing, C A is to C P lefs C A that is A P, as 2 A B to A I lefs 2 A B; but by doubling the Confequents, C A is to 2 A P which is equal to A B, as to 2 A B to 2 A I lefs 4 A B; and by compounding, C A is to C A more A B that is C B, as 2 A B to 2 A I lefs 4 A B more 2 A B, that is 2 A I lefs 2 A B, or only 2 B I, as it appears in the figure.

But in taking the half of the Terms of the laft proportion C A is to C B, as A B to B I: But alfo as C A is to C B, fo is the length of the arch A E to the length of the arch B F.

Now by the generation of the *Epicicloid* B D L, the arch of the bafe A E is equal in length to the arch of the generating circle F D; but becaufe that the two circles F D E F G H touch each other in F, the line D F G cuts the two arches alike F D, F G, whofe lengths keep between themfelves the fame ratio or proportion as thofe of the Chords F D, F G, or thofe of the diameters F E, F H: Then the arch F D is to the arch F G, as F E to F H; or as A B to B I, which is alfo as C A to C B, or as the arch A E to the arch B F: But the arch A E is equal to the arch F D; then the arch B F is equal to the arch F G of the circle F G H, and by confequence the point G is that which defcribes the *Epicycloid* B G K; which was to be demonftrated.

For the inner *Epicycloids* we may demonftrate the fame thing, only changing the form of the proportion: And for the *Cycloid* 'tis eafy to behold by the fame demonftration, that the line which is defcribed by its roling, is the *Cycloid* equal to that which is roled.

Corollary I.

Hence it follows alfo by *Hypothefis* that the 3 lines C A, C B C I are continual proportionals: For C A is to C P as two A B to A I, in dividing and doubling the Confequents, C A will be to 2 C P lefs 2 C A, as 2 A B to 2 A I lefs 4 A B: But 2 C P lefs 2 C A are equal to 2 A P or to A B; and as 2 A B to 2 A I lefs 4 A B, fo A B to A I lefs 2 A B; wherefore C A is

to A B as A B to A I lefs 2 A B: But in compounding, C A is to
C A more A B which is equal to C B, as A B to A B more
A I lefs 2 A B, which is equal to B I; and by Altern propor-
tion C A is to A B, as C B to B I; laftly, being Compounded
C A is to C A more A B which is equal to C B, as C B to C B
more B I which is equal to C I.

Corollary 2.

'Tis evident as yet that the line which is defcribed by the
roling of a circle, is the laft of all the outer *Epicycloids*, that is
to fay, that whofe centre of the generating circle is at an
infinite diftance; or that which is defcribed by the end of a
right line which roles about a circle in the Touchant, which
doth agree with the roling of the circle.

'Tis eafy to demonftrate that the fuperficies of the figure of
this kind of *Epicycloid*, when the defcribing line runs over the
whole circle of the bafe, or that it comes again to the fame
thing; The figure defcribed by the roling of the whole circle,
without comprehending the circle which makes the roling,
is equal to one third of the circle, which hath for Radius the
circumference of the circle of which the roling is made.
What I fay of the whole circle, the fame is intended of every
part of this Figure. For the figure defcribed by the roling of
any arch of a circle, without comprehending any thing of
that circle, is equal to $\frac{1}{3}$ of the Sector of a circle, which has
for Radius the circumference of that arch, and of which the
arch is like to that of which the roling is made; It will be alfo
the fame thing for the roling of a greater arch, and of the
whole circle. For that which is the crooked line of this
Epicycloid, or of that which is defcribed by the roling of an
whole circle or of any arch, which fhall be always equal to
half of the circumference of the circle or of the arch of which
we take $\frac{1}{3}$ of the fuperficie, for the fuperficie of the Figure de-
fcribed by the roling.

PROPOS. I.

Of the ufe or advantage of Epicycloids *in* Mechanicks.

Fig.
187.   LET the right line A D be a determined length, and
movable on a Plane about its extream A; and on the
fame plane let there be another right line C B, indeterminate
towards

towards B, and movable on the plane about its extream C: if the Extream D of the line A D is led into E and R, by the line C B, which moves it felf on the point C.

I fay, that if the lines A D, C B, be placed on the line C A which joins the Centers of movement, and the points D and B be put one upon another, there will be two powers equal between themfelves, which will act with all their force on their lines in the points D and B, that is to fay, (with direction at right angles) thefe powers will be in *Equilibrio*; but if the lines change their pofition, as A D into A E, and C B into C B E, the Powers equal to X being applied always in the fame manner to their lines, and to the fame places, they will be no more in *Equilibrio*, but to make them in *Equilibrio*, we muft have another power Y greater than X applied in B, on C E, and this Power Y ought to be fo much greater, as the line C B E is removed from C A.

From the centre C and Semidiameter C D or C B, having defcribed the circle B B, 'tis evident that C E is greater than C B. But from the point E having drawn E G perpendicular to A E, and E F M perpendicular to C E, and by the point A having alfo drawn H A M parallel to C E, if from any point F of the line E F we draw the line F G parallel to C E, the two triangles F E G, M E A will be alike, for they are rectangled, and their angles in the point E are equally together to a right angle, becaufe of the right angle A E G.

If we fuppofe now the part E F indifinitely fmall, 'tis evident that the line C E cannot be moved from E to F about the point C, without caufing A E to move to G about the point A. But it follows from the Laws of *Mechanicks*, that to make an *Equilibrio* between the power X applied to the extream or end E of the leaver A E, which moves according as the line E G, and between the power Z applied to the end E of the leaver C E, which moves according to the line E F; it is neceffary that X be to Z as E F to E G, that is to fay, as A M to A E: In fine, if we fuppofe the power Y applied to B on the leaver C E in the point B, 'tis evident, that to make an *Equilibrio* between Z and Y, it is neceffary that Z be to Y, as C B to C E: It follows therefore, that for to make an *Equilibrio* between X applied to E on the end of the leaver A E, and Y applied in B on the leaver C E, it muft be that X muft be to Y in the compound proportion, of A M to A E, and of C B

to C E, which is the fame as that of the rectangle A M, C B, to the rectangle A E, C E. But in the rectangle triangle A M E, the fide A M will be always leffer than the Hypotenufe A E; and by conftruction C B will be alfo always leffer than C E, whence it follows, that the power Y will always be greater than the power X, and that the more the lines C E, A E are removed from the line A C which joins the centres of the movement, the more the power Y ought to be greater for to make *Equilibrium* with the power X.

Fig. 187. We may likewife demonftrate the fame thing after another manner, in keeping to the common principle of the ballance, or leaver. For if on M A lengthned, we take A H equal to A E, and confider C E and M A H as two horizontal Leavers, the points of whofe props are in C and in A, and that the end E of the leaver C E have a weight called Z, this weight will have the fame endeavour on the point E of the elbow leaver H A E, as on the point M of the right leaver or ballance H A M. For 'tis evident, that the weight X in the point H, will be to the weight Z, as A M to A H, or A E its equal. But now if inftead of the weight Z applied in E on the end of C E, we fubftitute a weight Y applied to the point B of the fame leaver C E, for to make the fame endeavour as Z in E, it will be, that Y will be to Z, as C E to C B: Then the weight X will be to the weight Y for to make an *Equilibrum* in the compounded proportion of A M to A E, and of C B to C E, as before, whence follows what was propofed.

Corollary.

It follows from this demonftration that a power applied in B to the end of the Leaver C B, will not act equally againft another power applied in D to the end of the line A D in the meeting of its extream D, when thefe lines are differently pofited, their powers will always be applied in the fame points of their lines C B, A D, and they will act perpendicularly; But then one muft be fo much greater as the line C B is more removed from C A.

If you intend the contrary, the power which acts muft be applied to the end D of the line A D; for this force or power ought to be lefs when the line A D is more removed from A C, than when 'tis nearer.

PROPOS.

PROPOS. II.

Fig. 187, 188. THe same things being put as in the precedent, I say, that if on the circumference of the circle B B as a base, we describe the Epicycloid B H, whose generating circle is D E R, and Radius the line A D, the crooked line of this Epicycloid being join'd to the Radius C D of the base, and not making with it the same mixt line, as in the position where it was described, in any place which C B is placed out of C A; and the end D of the line A D, being put on the Epicycloid in E, the power Z which is applied in E, at the end of A E, as 'tis in the precedent proposition, will be in Equilibrio with the same power Z, which is applied in B to the end B of the line C B, and which acts on the point E by means of the curve of the Epicycloid B E.

Fig. 188. 'Tis easy to see in this figure by the forming of the Epicycloid, that in any position, which the line C B is in, which is joined to the Epicycloid, the Arches B B will be always equal in length to the arches D E of the circle D E R; wherefore let C B be in any place, and the power applied in B cannot move it self through one arch B B, without moving the other force applied in E on the end of the leaver A E, by an arch E E equal in length to the arch B B; whence it follows, that the powers being equal they will remain in Equilibrio; which was to be demonstrated.

Fig. 189. We may also make this Demonstration as in the precedent proposition; and we shall find that the same method which is managed in the inequality of powers, will lead us here to equality by compounded Reason: For if we suppose that the end E of the leaver A E hath the power X A, which acts according as E G perpendicular to A E, and that in the point E at the end of C E, there be a power V which acts according as E F perpendicular to C E; 'tis evident by the nature of the Epicycloid, that the line N E drawn by the end N of the diameter D A N to the point E, will touch the Epicycloid in that point; and that as when the point E of the end of the leaver C E shall have run over a space E F indefinitely small, the same point E of the end of the leaver A E will be come to G, where the line F G, parallel to E N, meets E G perpendicular to A E; for the small portion F G of the Touch-

Fig. CLXXXI.

Fig. CLXXXII.

Fig. CLXXXIII.

Fig. CLXXXV.

Fig. CLXXXVI.

Fig. CLXXXIV.

Fig. CLXXXVII.

Fig. CLXXXVIII.

Fig. CLXXXIX.
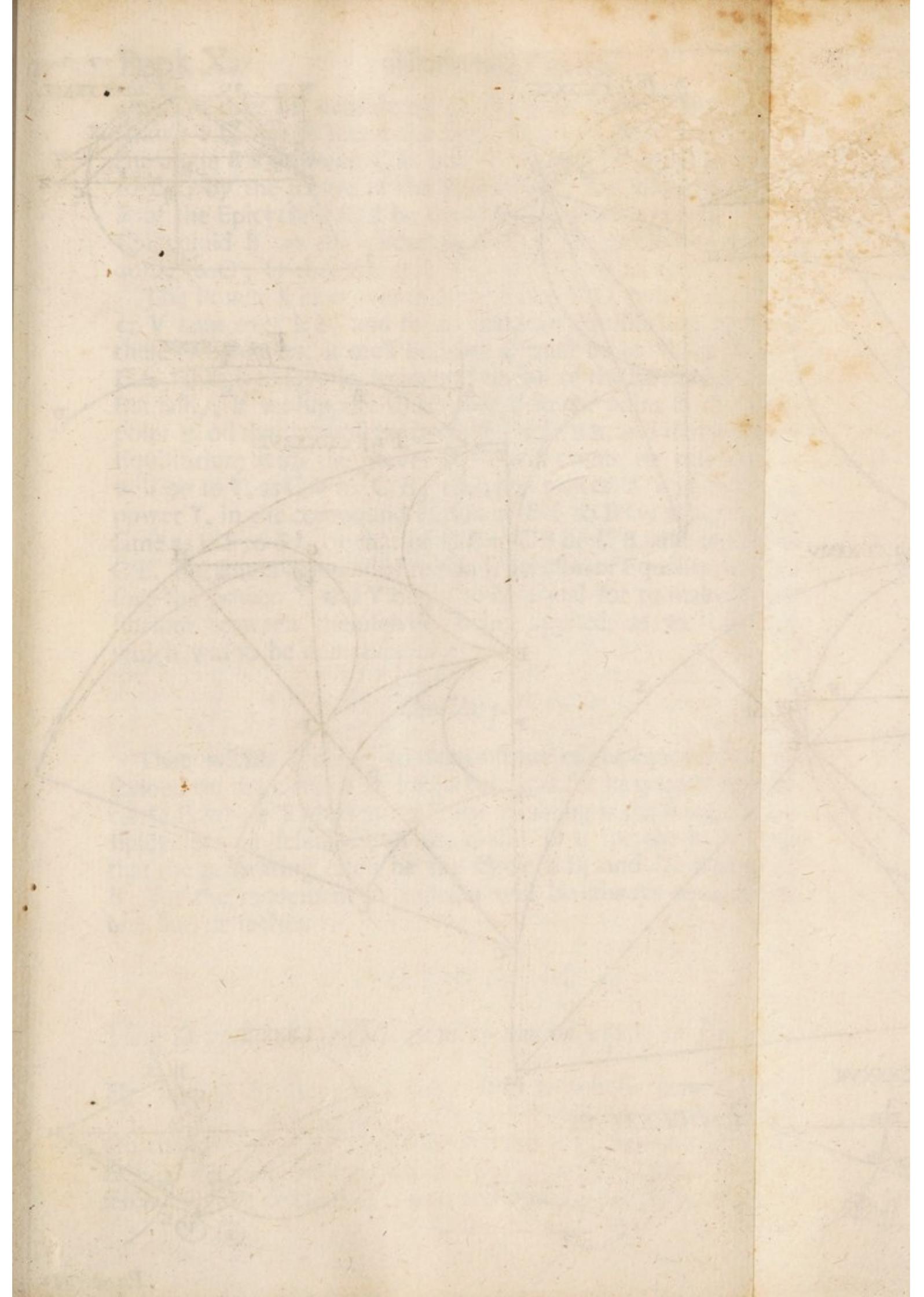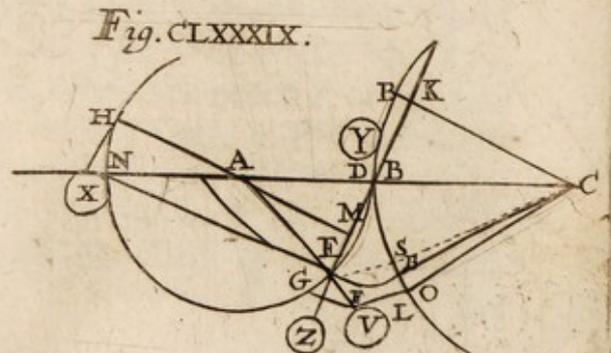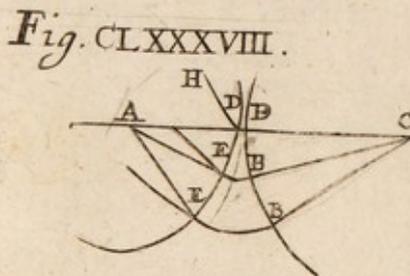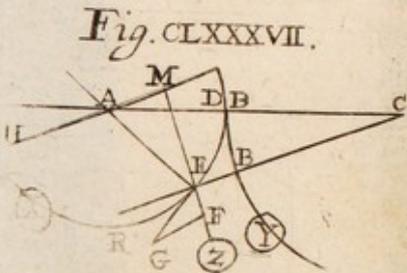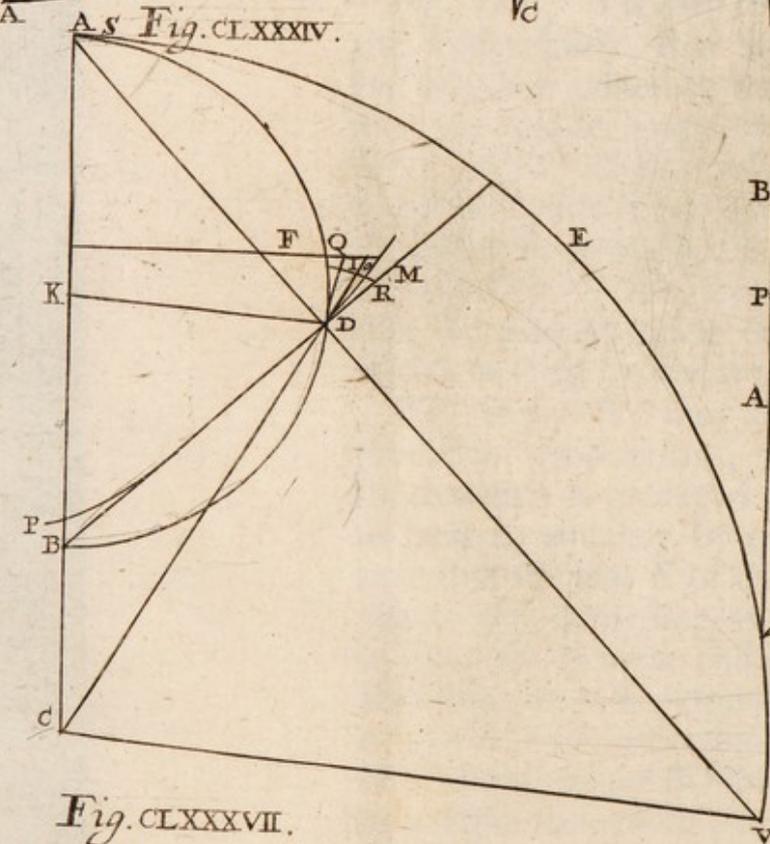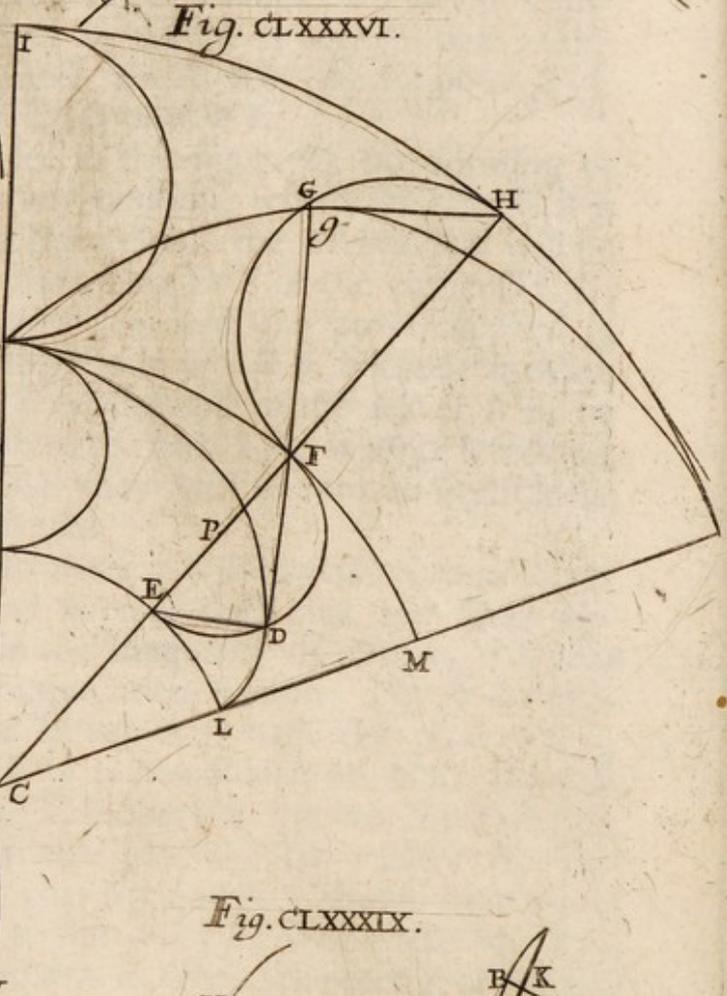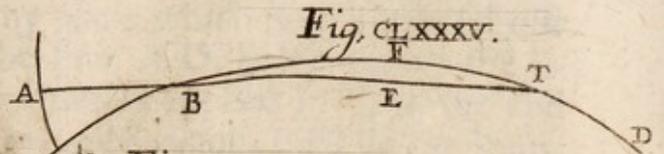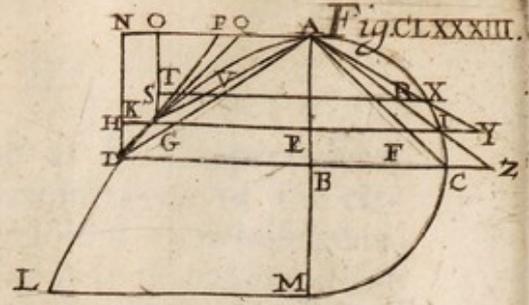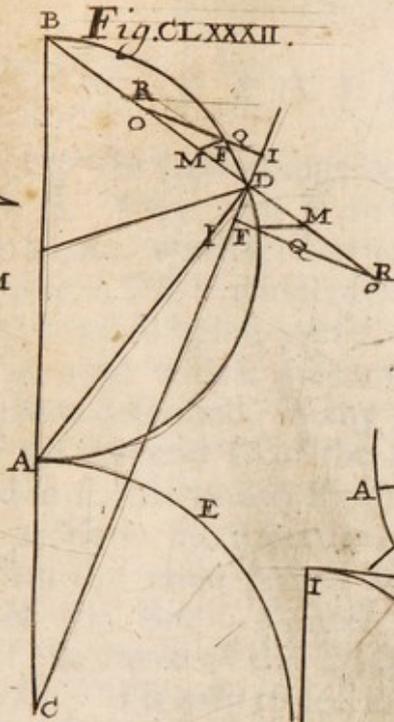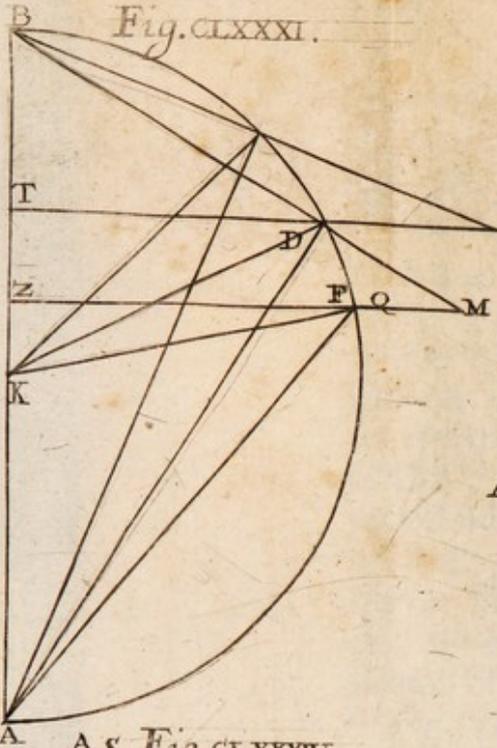
ent E N may be confidered as the fame curve. But having drawn F C which meets the circle B B in L, the arch S L of the circle B B between C E and C F, will be equal in length to E G by the nature of the Epicycloid; for when the point E of the Epicycloid fhall be come to G, the beginning of the Epicycloid B on the circumference of the circle B B will become to O; fo that the arch B O will be equal to S L.

The Power X runs over then the fpace E G, when the power V runs over E F, and for to make an Equilibrium between thefe two powers, it muft be, that Z muft be to V, as E F to E G, that is to fay, in reciprocal reafon of the fpaces run over. But laftly, if we fuppofe the power Y in the point S, or in the point B, on the circumference of the circle B B, and that it makes Equilibrium with the power V, it will come to pafs that V will be to Y, as C B to C E; then the power X will be to the power Y, in the compound reafon of E F to E G, which is the fame as E F to S L, or that of C E to C S or C B, and of C B to C E. But this compounded reafon is a reafon of Equality, wherefore the powers X and Y ought to be equal for to make Equilibrium between themfelves, being applied, as we fuppofe, which was to be demonftated.

Corollary.

That which I come to demonftrate of the Epicycloid defcribed on the circle B B, for its bafe and for its generating circle D E, whofe Radius is A D, the meaning is the fame, if the Epicycloid be defcribed on the circle D E for the bafe, and that the generating circle be the circle B B, and its Radius C B; for the movement or motion will be always equal from one fide or tother.

P R O P O S. III.

How to make the Application of motion equal to Engins.

Fig. 190. L Et there be a circle B O L whofe centre is C, and another circle D E F whofe centre is A : On the circle B O L, as a bafe, and for a genenerating circle D E F, defcribe the Epicycloid B V H, and divide the circumference of the circle B O L into any number of parts, as here

into

into eight in the points B K L, &c. and to each of these points apply a portion of the Epicycloid B V H, in K I, L M, which will be the same as if the Epicycloid had been described, beginning in the points K L, &c.

We may likewise take as great a portion of the Epicycloid as we please as B V H, and by this means make the divisions of the circle lesser or fewer. The figure B V H G may be the tooth of a wheel which may be limitted by the right line H G, which tends to the centre C of the circle, or by any other line as you please, which is indifferent, since this part of the tooth doth not cause any effect. We may also hew a little the space between two teeth, as D N O, to give the more liberty to the meeting of the parts of the other wheel D E F.

We may then form a wheel on the model of a circle with its teeth, and make it move on the centre C.

Now if we apply another wheel to the hinder part of it, whose centre is in the point A in the Horizontal line A C, and that instead of teeth, on the circumference D E F, we apply only in this example the pegs or pins of wood D E F, &c. which we suppose indefinitely small and perpendicular to the plane of the wheel; 'Tis certain by the precedent proposition, that in any position that we place the wheel B O L whose teeth meet the pins of the other wheel D E F, they will be in Equilibrio, if the moving forces applied to the Circumferences of the two wheels be equal between themselves.

Let then for this effect a weight Q be hung from the circumference of the wheel B O L, equal to the weight R, hung and applied to the circumference of the wheel D E ; these two weights will then abide always in Equilibrio in any manner that the teeth of the wheel B O L meet the pins of the wheel D E F.

But if we apply a weight P to the circumference of another wheel S T, which hath its centre common with that of the wheel B O L, and which is fastned with it, this weight P will be to the weight Q, as C B to C S, the weight P will be still in Equilibrio with the weight R, in all the different meetings of the two wheels; for the weight P making Equilibrium with the weight Q, it will also be in Equilibrio with the weight R.

PROPOS. IV.

THings being difpofed as in the precedent, I fay, it matters not whether the divifions of the wheel B K L be equal between themfelves, that is to fay, that the teeth be equally diftant one to another, nor the pegs D E F on the circumference of their wheel.

It matters not whether it have one or more teeth of the wheel B K L, which act all together on the pins of the wheel D E F, for there will be no more but the fame force which will be applied againft that of the wheel D E F. If it have but one, as B V H, all the force of the weight P, will act againft that of the weight R, in meeting with the peg D.

Fig. 190. If you would have two together, as B V H and K I, of which the firft acts on the peg D, and the other on the peg E, 'tis evident by the conftruction of thefe teeth, that K I will have as much force or power on the peg E againft the weight R, as B V H on the peg D againft the fame weight R; and by confequence the force of the weight P diftributes it felf equally to thefe two teeth, each of which counter-ballances the moiety of the weight R : It will be the fame thing, if you have three or more which act all together.

Thus it matters not if you have one or more teeth which work all together, and 'tis indifferent what part of the tooth meets the peg againft which it acts, fince it will have always the fame force; which was to be demonftrated.

PROPOS. V.

THe Engin being difpofed, as before, for to make an *Equilibrium*, between the two weights P and R; I fay, that if you augment the moving force of the wheel B K L; or, which is the fame thing, if you add fome weight Z to the weight P, this force, or this new weight will act equally in all the different encountrings or meetings of the toothed wheel E K L with D E F, on the force, or on the power; or laftly, on the weight R applied to the wheel D E F.

Since to make an *Equilibrium* between the weight P, augmented by the weight Z, and the weight R, you muft augment the weight R with the weight Y, which muft be to

the

the weight Z (which makes the augmentation of the weight P) as C S to C B, and then the two weights R and Y together will make through all an *Equilbrium* with the two weights P and Z together ; 'tis evident, that in any poſition which theſe two wheels are in, the weight Z will be always in *Equilibrio* againſt the weight Y ; and by conſequence the two weights P and Z together prevail always with the ſame force againſt the one weight R, which is meaſured by the weight Y, ſince it wants this weight to make the *Equilibrium*; which was to be demonſtrated.

P R O P O S. 6.

WE may place the Superficie of two Wheels in the ſame Plane, and inſtead of the pegs or pins which ſhould be faſtned on the Wheel D E F, we may make the teeth at the end of this Wheel, and give them what Figure we pleaſe: But then the teeth of the other Wheel whoſe figure will be in the *Epicycloid*, ought to have a figure compoſed of thoſe of the *Epicycloid* and thoſe of the teeth propoſed, this compounded figure forms it ſelf, as I ſhall explain in the following Examples.

Example 1.

Fig. 191. The moſt ſimple of all Figures is the Circular ; wherefore I propoſe at firſt ſight the figure of the teeth of the Wheel B E F in a circle. Let the wheel be B E F, whoſe centre is in A, which hath its teeth of a circular Figure, as B O P, and whoſe centres will be on the circle D G M, which hath its centre common with thoſe of the Wheel A ; let the centre of the other Wheel be C ; having drawn the right line C A which joins the centers of the two Wheels, and which meets with the circle B E F in B, from the centre C, and with the Radius C D deſcribe the circle D I, on which as a baſe make the *Epicycloid* D V H, which hath D G M for its generaing circle. Now if from all the points D V H, of the *Epicycloid*, as Centers you deſcribe the circles O N L equal to the circle which forms the teeth of the Wheel B E F, the crooked line O N L which touches all the circles, and which will be Parallel to the *Epicycloid*, will form the figure of the teeth of the Wheel B K, that is to ſay, that part of the tooth which acts againſt the part of the circular tooth which it meets in its motion, for to the other parts of the teeth which it meets not with, I have already ſaid that they may be

made

made of what Figure you pleafe ; but you ought always to make choice of thofe which are moſt durable, and moſt proper to refiſt the force of the motion.

I fay now, if you apply equal powers to thefe Wheels within the diſtances of their centers C D, A D, in any place that the teeth meet, you will have an *Equilibrium* every where; only it muſt be obferved that the meetings of thefe Teeth muſt be always under the line A C.

By the 3*d.* Propofition in any place that the *Epicycloid* D V H is applied to the point D of the Wheel D G M, in making it move about the Centre A, it will make an *Equilibrium* between the equal Powers.   For if one of the powers caufe the other to move, it will caufe it to run over a fpace equal to that which the fame runs over it felf.   But by conſtruction of the tooth O N L, we fee that the crooked line O N L meeting the circle B z P makes the point D fo much advance, as if the *Epicycloid* D V H met it: For the diſtance between the *Epicycloid* D V H, and the crooked line O N L is every where, that of the Semidiameter of the Circular tooth B z P.

For example, when the centre of the tooth D is come to G, and that the *Epicycloid* D V H is placed in I G, its point G being joyn'd to the centre of the circular tooth, 'tis evident that the arch D I of the circle of the bafe will be equal in length to the arch D G of the generating circle D G M ; But then the crooked line O N L will be placed in *o n l*, and the circular tooth E *n p* which hath its centre in G, will neceffarily touch in the point *n*, the crooked line or curve *o n l*, for the fhorteſt diſtance, from the point G of the *Epicycloid* to the curve *o n l* will be in the point touchant *n* of the circle E *n p*, and of the curve.   So when the point D of the *Epicycloid* is come to I, the point O of the curve will be come to *o*, the arch O *o* will be equal to the arch D I, and the curve *o n l* which meets the circular tooth in *n*, will be made to advance its centre in G on the *Epicycloid* I D, and by confequence the arch D G will be equal in length to the arch O *o*, or D I.

I have faid that the teeth ought not to begin to meet or rencounter themfelves but underneath the line A C, that is to fay, that the bending O N L is not proper for to act on the circular teeth, but when the point O of the curve O N L is come to D ; and by confequence this curve O N L begins not to act againſt the curve or bending of the circular tooth, but in the
point

point Z, where it is cut by the circle D G M, and it continues always in the Rencounter or meeting in its part Z P, in descending beneath the line A C. We may then lessen all the part Z B of the circular tooth, since 'tis not useful in the movement, or motion, and finish it on the circle Z D. We may also finish the teeth of the other Wheel by the curve L N O, and by the circle O D, which will be the ground of the teeth; But in this construction we ought to distribute the teeth after such manner in each Wheel that they begin to rencounter or meet one another only in the line A C, and that they do not hinder one another above, which will always be easy to do.

Also note, that the curve L N O Parallel to the *Epicycloid,* begins always out of the circle O D I, and afterwards that it is between, or within; and lastly, that the diameter of the generating circle is greater than D B, which is easy to demonstrate by the generation of the *Epicycloid*; but I consider not in this place but the part O N L of this curve which is without the circle O D I when 'tis in this kind.

We ought always to avoid in the teeth of Wheels to make them work above the line A C which joins their centers, because the wearing or rubing in them is very great, and that on the contrary 'tis not almost considerable in them below, supposing that the motion of the Wheels will be from above to beneath the line A C. In the mean time if you would that the teeth of these Wheels work in rencountring themselves above A C, it must be in the making, as I shall shew by and by, after I have shewn a general method for making the teeth of one Wheel in different manners, those of the other being always given the same.

Example 2.

Fig. 192. Instead of the Centre D of the circular tooth proposed, as in the precedent example, I take another point like that where I please, as B on this tooth, and by means of this point I find the figure of the tooth B N N, which ought to work with the proposed; but for to cause the tooth proposed to act or work in as many parts as is possible, we ought to chuse a point in this tooth which may be the nearest to the Centre C of the other Wheel, in the motion of this point
<div align="right">chosen</div>

chofen about the center A of the Wheel unto which 'tis faſt-
ned, and this point will be the point B in this Example.

From the centre C and with the Radius C B defcribe the circle
B K, which will be the baſe of the *Epicycloid* B V V, whofe
generating circle is B G G defcribed from the centre C and
Radius A B; then from the centre A having drawn the Ra-
dius A G, from the centre C, and by the Radius C G we may
defcribe the circles G V, which cut the *Epicycloid* in V, and
by theſe points V we may draw the lines V H I, which make
the angles C V I equal to the angles C G A. Then on the lines
V H I we may apply the figure B z of the tooth propoſed in
the ſame manner as 'tis applied to the line A B, in making it
agreeable in the point B or V, and we may draw the curve
line B N N that ſhall touch the curvature or bending of the pro-
poſed tooth, in all theſe different Poſitions, which ſame thing
will happen for the circle, if we take on V H the Magnitudes
V H equal to B D the radius of the circle of the propoſed tooth,
and that from the points H for a center we defcribe the cir-
cles N equal to thoſe of the tooth.

It plainly appears by this formation of the curve B N N
that in any poſition that it meets the circular tooth, the point
B of the curve B N N being beneath A C, there will be every
where an *Equilibrium* between 2 equal Powers applied to theſe
Wheels in the diſtances C B, A B, from their centers C A : For
we may demonſtrate, as in the preceeding example, that in any
poſition that the curve B N N is applied to the circular tooth,
it will be difpoſed to make its way in the point B on the cir-
cle B G, a ſpace equal to that which the ſame point B makes
on the circle B K. For example, if the point B in runing over
the ſpace B K on the circle B K, the ſame point B comes to
G, by means of the *Epicycloid* B V, which muſt be placed
in K *u*, but the curve B N N will be placed in K *n*, and its
point N will be applied in the point *n*, of the circular tooth B Z,
tranſported in G *n*, which will have its center in *b* on A G,
and by conſequence the curve K *n*, which acts on the circu-
lar tooth G *n* in the point *n*, makes the point G to advance,
ſo much, as if the *Epicycloid* ſhould be placed in K G, and
joined to the curve K *n*.

'Tis eaſily ſeen, that if the tooth of the Wheel B K is formed
as the curve B N N, it will begin to act on the circular tooth
B Z, in the point B on the line A C : For ſo ſoon as the point

B of.

B of the curve B N N is come to A C, and that it touches the point B of the circular tooth, the 2 teeth begin to act one against the other, and to measure how much the tooth B NN descends its different points N, as they are applied in different places of the circular tooth B Z.

Note, that if we take the lines V H I equal to B A, all the points I will be in the circumference of the circle A I I, whose center is in C; and moreover, that all these points I will be the Centers of the generating circle of the *Epicycloid*, in the different positions whence it describes the points V.

Lastly, we may take the point B for the Commencement of the *Epicycloid* in what place you please, whether within or without the tooth, instead of taking it in B on the curve of the proposed tooth, as is done in this example, and we may find always a curve for the tooth which ought to work with those proposed, and which ought to make an *Equilibrium* between two equal Powers, which I shall explain in the following Examples.

Example. 3.

Let the right lined tooth be Z D, which makes with the Radius A Z the angle A Z D, and let the point be D of this tooth which ought to begin to work with the tooth of the other Wheel B K; having taken any point B in the line A D C which joins the centers, and which passes through the point D, determining to what place the tooth A Z D should be made to move on its center A; or if the point D be not determin'd on the tooth Z D, and that there be given the point B of like position to the line Z D, or to the angle A Z D, having drawn A B which cuts Z D in D, we may place the line A B on the line A C, and describe the circle B K from the center C, and the Radius C B; this circle will be the base of the *Epicycloid* B H M, of which the generating circle is B G, described from the center A on the Radius A B.

Then to all the points G of the circle B G, having drawn the Radius's A G, and from the Center C, and for the Radij C G having described the arches of the circle G V, which rencounter in V the Epicycloid B V M, I draw C V, and afterward V H I, which makes the angle C V I equal to the angle C G A; on V I, I apply the line H Z in the same manner that

L Z

D Z is applied to B D A, that is to say, that V H is taken e-
qual to B D, and that the angle V H Z, is equal to the angle
B D Z, the lines H Z will intersect them all, whence we may
draw the curve line D N which will touch them, this line D
N will be the figure of the tooth which we seek, and which
ought to be applied to the wheel B K.

'Tis evident by what is demonstrated before of the forma-
tion of the second teeth on the first which are given, that the
curve D N of the tooth applied to the wheel B K meeting the
right lined tooth D Z below the line A C, and beginning in
the point D will make every way an Equilibrium between 2
equal powers applied to the 2 wheels in the distances of C B
and A B, that is to say, in the extream of their Radij; for if
we suppose that the line C B have transported the point B to K,
the Epicycloid B V M will be placed in K G, and the line A B
will be placed in A G, so that the arch B G will be equal in
length to the arch B K by the property of the Epicycloid.
But then in this position, the tooth will be in A S *d*, and the
curve D N being put in E *n*, its point *n* which is the same as
the point N, will touch the tooth in *n*; and even as in all the
points as G and K the motion will be equal, there will be eve-
ry way an Equilibrium between the two equal powers.

Where Note, That we ought not to determine the length of
the right lined face Z D of the tooth towards D; for it may
happen in some cases that the curve D N may not be touchant
to all the lines, as H Z, for these lines H Z intersect not, their
extream H being determined and they rencounter not the next;
and if we should draw the curve line D N N through all the
points as H, it would happen that only the end or extream D
of the tooth would work, and would notwithstanding make
the motion equal, but this is not that which is proposed in this
place.

Example 4.

Fig. 194. We may yet make another sort of right lined
tooth, the face of which tends to the center of its wheel, and
by this means the tooth which acts against it, has not its face in-
clined to the circle on which it is fastned, as in the preceeding

P p   Exam-

Examples, and this kind of tooth is one of the easiest to execute in great Engins, and most useful for the motion.

Let the face be F D of this right lined tooth which tends to the center A of its wheel, and which is placed in the line A B C which joins the centers of the wheels. By any point B of the line A C, and from the center C, describe the circle B K which is the base of the Epicycloid B V, whose generating circle is B G, described from the center A and the Radius A B; having drawn all the Radij A G, and the lines C G which are the Radij of the circles G V which rencounter the Epicycloid in V, whence the angle C V I will be made equal to the angle C G A. Lastly, whence we may draw the curve D N N which will touch all the lines V I in their different positions, and which will be the figure of the tooth which ought to be applied to the wheel B K. This tooth D N N rencounters the face F D in all its different positions, and will make every way an Equilibrium between 2 equal powers applied to their wheels in the distances of C B and A B. For the curve D N N being placed in *d n*, which is fastned to the Radius C K and rencounters the face A F D of the tooth proposed in *n* in the position A G, will make the same effect on the point G, as the Epicycloid D V placed in K G, as I have made appear in the preceeding example.

'Tis easy to behold by what is explained before, that it will not be difficult to form the tooth which we seek, that which is given being of another figure than the circular or right lined, as Parabolique, Hyperbolic, and the same in the Epicycloid.

PROPOS. VII.

ONe may describe an Epicycloid on a base which is concentrick to the wheel which carries the proposed tooth, and by means of this Epicycloid, we may find the Figure of the second tooth, as in the preceeding proposition.

Fig. 195. Let Z D be the figure of the tooth proposed which is applied to the wheel Z, the center whereof is A; and on this first tooth mark the point D, which ought to begin to work or act with the second tooth that we ought to apply to the other wheel, place the tooth Z D in making it turn

with

with its wheel about the center A, so that its point D be on the line A C, which joins the centers of the 2 wheels; in this position of the tooth Z D, having markt any point B that you please on the line A C, from the center A, and with the Radius A B describe the circle B G, which will be the base of the Epicycloid B V, whose generating circle is B K, described from the center C and Radius C B.

'Tis evident by what is demonstrated before, that the Epicycloid B V being fastned to the Radius A B, will so much advance the point B from the Radius C B, as the same point B advances on the circle B G in any position that the Epicycloid shall be, as if it is transported to G K, the arch B K will be equal in length to the arch B G, and so the difference being every way the same of these arches, they will also be equal in length, in manner as if the Epicycloid is placed in G K, the point G will not advance any space, but will be on its arch B G, and it makes not so much to advance the point K on the arch B K.

Now to all those points K of the circle B K, having drawn the Radij C K, and afterwards A K, and from the center A and Radius A K, having described the arch K V which cuts the Epicycloid in V, and the line A C in F, whence the arch K L will be equal to the arch V F, and then drawing L A which will cut the arch B G in G, whence 'tis evident, that the portion B V of the Epicycloid may be accommodated in G K.

Having made the angle C B I equal to the angle C K A, and B I being equal to K A, whence also the angle B I *g* will be equal to the angle K A G, and on *g* I equal to A B, or to A G, if we apply the curve E N Z of the tooth given D Z, in the same manner that it is applied on B A, as if we transport it so that the point B be put or placed in *g*, and the point D in E.

Lastly, the Curve of the proposed tooth in all its different positions will form another curve N N D by a line which will touch them all, which will be the figure of the second tooth which we seek, and which ought to be applied to the wheel B K, or to the radius C B D in the manner which 'tis described.

'Tis evident, that this curve N N D will so much advance the point B on its arch B G, as the same point B advances on B K : For when the point B is placed in K, the curve N D will advance the tooth Z D in S *n* d, for the point *n* of this

curve which rencounters the tooth in the pofition S *n d*, rencounters it in the fame manner, and in the fame place as the point N which it forms. So the *Epicycloid* will be in the pofition G K, and by confequence two equal powers being applied to thefe two wheels in the diftances of their Radii A B, C B, will act every way equally, and will make an *Equilibrium* in all the Rencounters of the teeth of the two wheels.

<div align="center">

P R O P O S. VIII.

</div>

To apply a little Wheel inftead of a Tooth to the Wheel of an Engin.

Fig. 196. **I** Have noted in the 6th. Propofition, That the fecond Tooth ought not to begin to work with the firft, but on the line A C ; becaufe that the wheels having their motion above or below this line, the faces of the Teeth which rencounter themfelves in their removing one from another, do only rub one another in making their efcape, which caufes not any fenfible hinderance to the motion; whereas when the rubing is made by the rencountring of the parts which venter or come upon one another, the Impediment to the motion is very confiderable, and is that which we chiefly ought to avoid in Machines and Engines.

Behold here a particular conftruction for the Teeth of Wheels of a great Engin, where the faces which rencounter themfelves or meet, are made fo that they touch one another without rubing or wearing, and what remains is only made on the Axis, or Pivot.

The conftruction of thefe Teeth is the fame as thofe of the firft Example of the 6th. Propofition, but the Application is different : In the 6th. Propofition the circular Tooth propofed is ftayed firmly by the Wheel; but in thofe here that is a little wheel which is movable about its centre D, on an axletree, or pin, placed at the end of the Radius A D ; there will be then no other fretting, or wearing, in this Engin, than that of the little wheel B Z P on its axis; for the circumference will apply it felf every way, without fretting, or wearing, on the Curve of the other Tooth O N L.

<div align="right">

'Tis
</div>
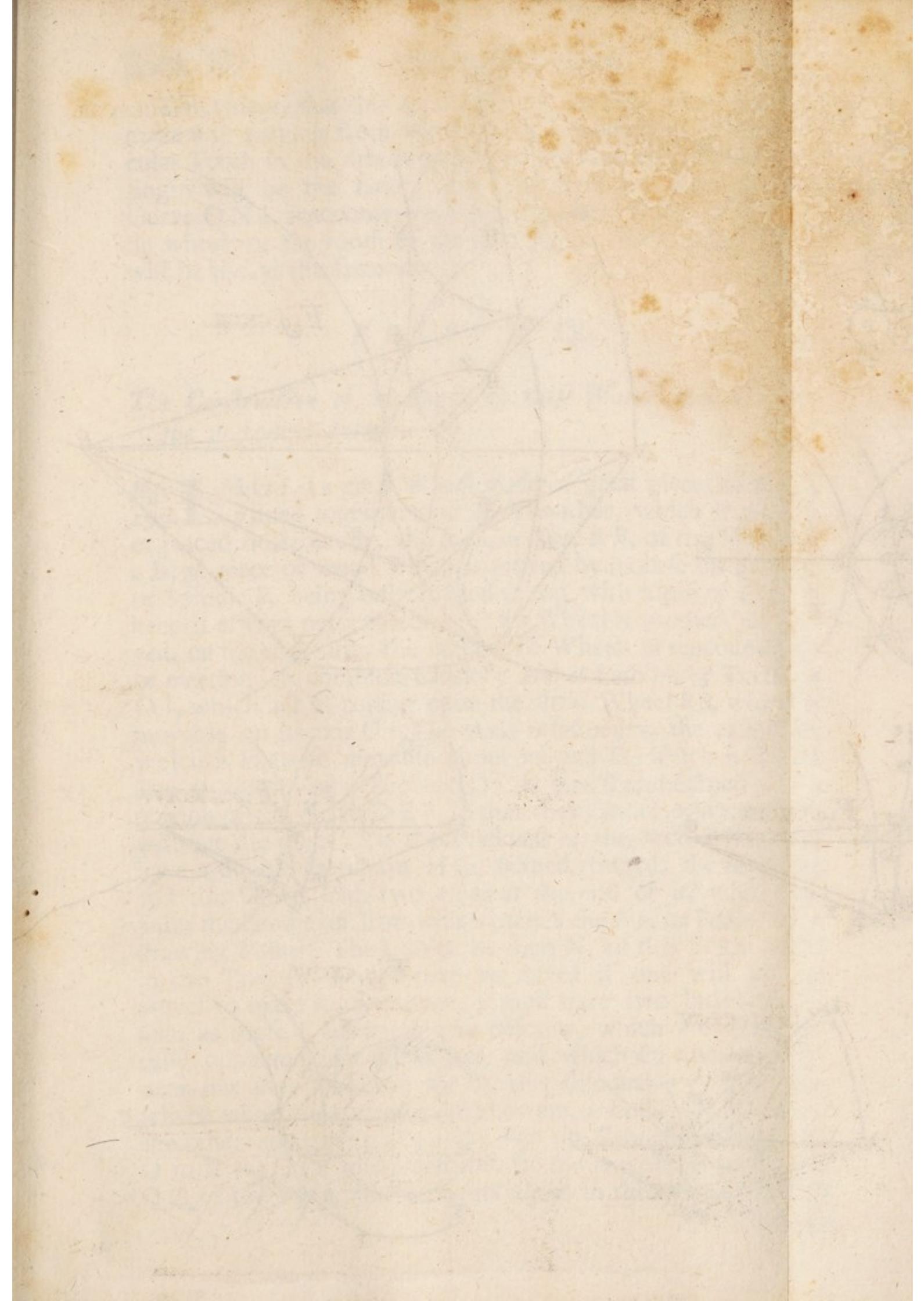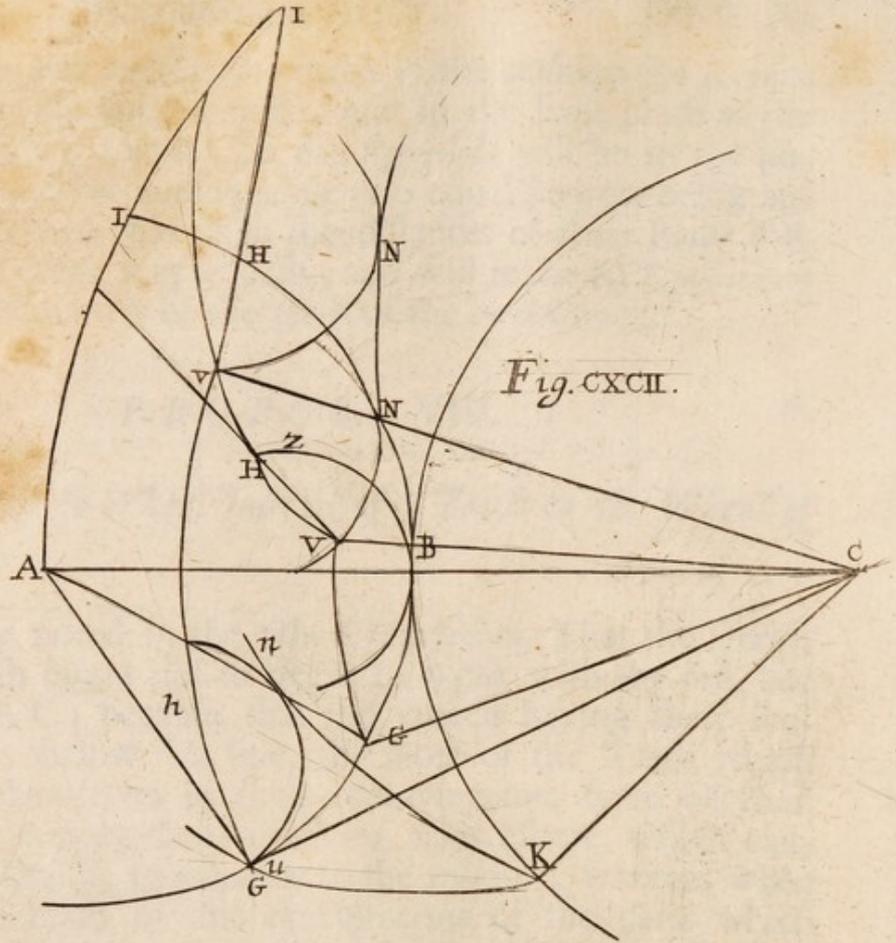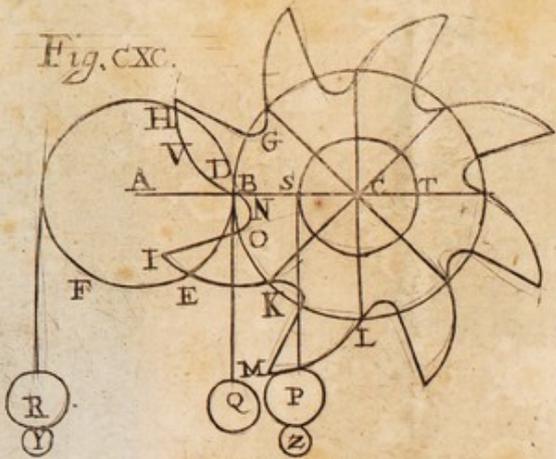
Fig. CXC.

Fig. CXCII.

Fig. CXCI.
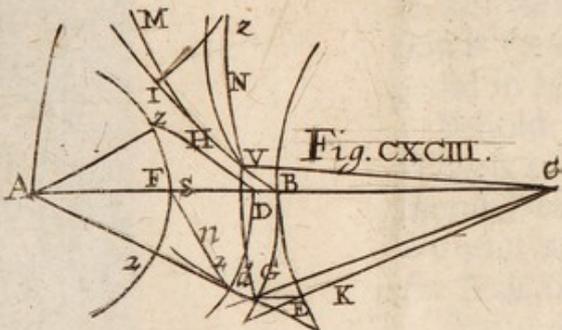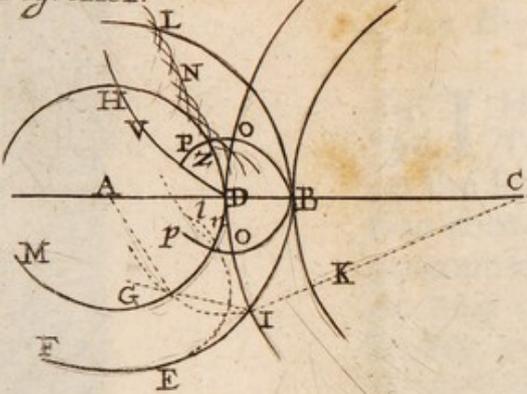
Fig. CXCIII.
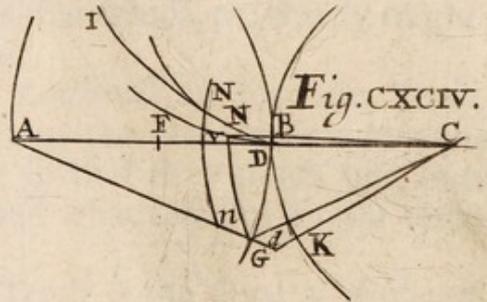
Fig. CXCIV.
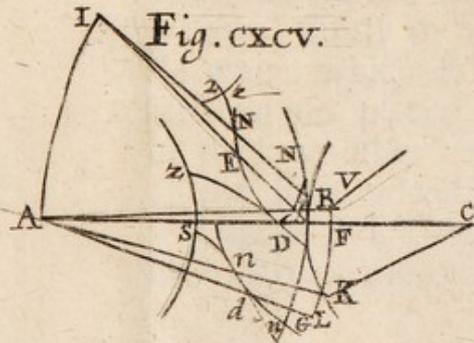
Fig. CXCVI.
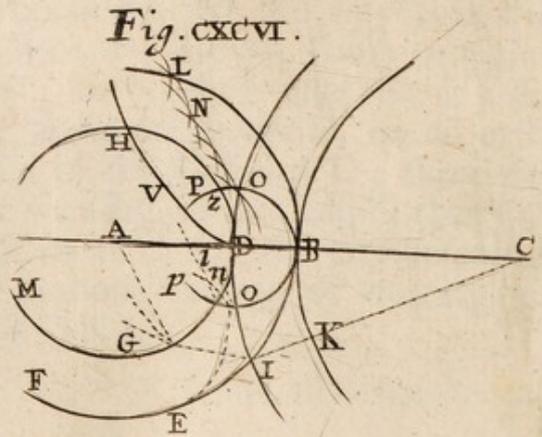
Fig. CXCV.

'Tis evident, that this application of the little wheel cannot make any varying from what I have demonstrated of the circular Tooth in the 6th. Proposition, and that the effect of the Engin will be the same : For it matters not whether the Curve O N L rencounter or meet the circle O Z P of the little wheel, or the tooth of the same figure, since its center D will be always the same way.

PROPOS. IX.

The Construction of an Engin to raise Water according to the precedent Form.

Fig. 197. L M O I is a great Wheel made of great pieces of wood joined together one with another, which is posited or placed horizontally, the Axis, or Tree A B, of this Wheel is a large piece of wood which is moved by its base on a Pivot, or Spindle P, being only fastned at top with a pin of Iron to keep it always perpendicular : This Wheel is toothed, or waved, on the edge after the manner of Wheels in rencountring, or meeting, in common Clocks ; and it hath but 5 Teeth, as O I, which act in passing upon the little Wheel R S, which is movable on its axis C : This Axis is fastned to the arm D C, which is likewise movable about its axis D, which is stayed firm at any union : The arm D C is join'd and fastned to the portion of the circle D E F, so that they cannot move the one without the other ; on the thickness of the arch E F it must have a double flat chain H G, fastned towards the top in E, and this Chain hath two rings at the end of it, which sustains the handle of Iron which carries the Pin, or Pestle, of a drawing Pump : The Leaver, or Arm N, of this Engin passes in the Tree in B, and may be stayed if one will by the wheel to make it more firm ; it must have two little Wheels, such as those I am coming to describe, which are diametrically opposite under the Wheel, and which do always act by turns one after another ; for by this disposition of the little wheels when one appears in the bottom, or hollow of the wave, the other appears on the top : But the Wheel turning from O to I, the little wheel descends in the rencounter to the part O Q of the wave, and amounts again in the other, we must

consider

confider but the part O Q of the wave, for there is but that
that works for to lower the little Wheel which raifes the
Peftle, or Sucker, of the drawing Pump, and which fuftains
all the weight of water; the little Wheel mounting again in
the other part of the wave makes not any effort or endeavour
againft the Wheel, for it follows only the hollow turning, or
winding of the Tooth, not being raifed but by the weight of
the Peftle, or Sucker, and its handle, and of the Triangle D E F,
which fall again beneath by their proper weight, which we may
make very near equal to that of the little wheel.

All the effort of the Wheel is made only by its weight in
fuch manner, that if it is as heavy as the weight of the Co-
lumn of water which it ought to fuftain in the body of the
Pump, the diftance of the Leavers being compenfated, 'tis evi-
dent that there will not be any confiderable rubing on the
pivot P: But it muft be always fomewhat heavier, fo that it
may not go out of the Iron wherein the Pivot plays, for other-
wife it will work on the two little wheels all the time, which
muft be avoided.

The number of Teeth of this Wheel ought to be odd, fo
that it may have always one of the two little Wheels oppofite
which work, and that the power which moves the leaver N,
may act always equally, and not by jumps or skips, as it com-
monly happens in thofe Engins which have not one or two
wheels. 'Tis in this that the principle direction of the con-
ftruction of Teeth, and the pofition of fmall wheels confifts:
For which, that we may always keep to the rule in the form
of the Teeth, we muft have refpect to the proportions of the
height and length of the Teeth with the diameter of the
wheel.

We muft obferve that 'tis not poffible that the face of the
Teeth, or of the waves of the wheel, fhould work in every place
on the little wheel at equal diftances from the Axis of the
wheel, becaufe the motion of the wheel is circular and hori-
zontal, and that of the little wheel is vertical or perpendicu-
lar; for it happens that when the Teeth rencounter the little
wheel in their lower part, and from their point, if the Axle-
tree of the little wheel is equally removed from the Axis of
the wheel, it will be nearer when the little wheel is towards
the moiety of its defcent, which will be eafily known in the
plane; this difference of removing will caufe a little fretting or

wearing

wearing of the face of the Tooth with the little wheel : But thefe are fuch faults which are impoffible to be wholly avoided in Engins, and we ought to refpect thofe which have the leaft, or the leaft confiderable, for the moft perfect.

For the conftruction of the Teeth of the great wheel of this Engin, we ought to confider them as if they were in the fame plane as thofe of the little wheel, and when we have determin'd the figure, we apply it on the wheel to the place where it rencounters, or meets the little wheel, ferving as a profile or fit fize cut from the figure of the Tooth.

Fig. 198. Having determined the center D of motion of the arm D C of the little wheel R S, and the fize D C of the arm, from the center D, and by the Radins D C defcribe the circle C E, on which draw the line A B C touching in C; on the line B A for a bafe, and C E for the generating circle defcribe the Cycloid C V V, and through all its points V V as centers defcribe the circles N equal to thofe of the little wheel ; I fay, that the crooked or curve line S N N which touches all thofe circles will be the figure of the Wave.

If we imagin that the right line B A moves from B towards A on the fame with the Cycloid C V V which is faftned to it, 'tis evident that every point B of the line B A will have fo much of the way as the point C will have about the center D, being moved by the Cycloid V V: For if the point C of the line B A is tranfported in T through the fpace C T, the Cycloid C V will be placed in T E, and the point C will be arrived at E, on the arch of the circle C E: But by the generation of the Cycloid, the arch C E is equal in length to the right line C T, then two equal powers one of which moves the line C T on the fame, and the other moves the point C about the center D, will make an Equilibrium every where, for we ought to confider the right line B A as the circumference of a circle whofe center is infinite or endlefs.

But now if inftead of the point C of the Radius D C, we apply the little circular wheel R S, whofe center is in C, 'tis plain by the conftruction of the curve S N N that it will have the fame effect on the center C of the little wheel in rencountring its circumference, as if the Cycloid C V V fhould rencounter only the point C: For the center C being put or placed in E, the point N of the curve S N N will be placed in *n*, fo that E *n* will be a fhorter diftance from the point E of the curve.

In

In the conftruction of the Teeth of this Engin, one ferves not all the curve S N N form'd on the whole Cycloid, but only on one part, and that which you pleafe, for otherwife it would happen that the waves would be too great. We may then take for Example in *Fig.* 31. the middle part N X of the whole curve S N X F, which is formed on the half Cycloid C N; fo the bottom of the wave will be formed by the circle of the little wheel in the pofition N Z P, and its point will be in the point X; we may give very near the fame figure to the part of the Wave which mounts up again and works not, to the intent that the little Wheel may roul away more eafily in remounting within the bottom.

Fig. 199. We muft note, that when the little Wheel is come to the end X of the Wave, the center M of the little Wheel is not fo far as it may be from the point X, that is to fay, that the line M X is not perpendicular to B C: But as the point X defcribes a line parallel to B C, it works only on the circumference of the little Wheel, until that the point M is come within the line M X, perpendicular to B C; the center M of the little Wheel will defcribe then in that place a fmall arch of a circle equal to thofe of the little Wheel, and it will happen that the point X of the wave will be blunted or dulled a little in the fucceffion of the work, which will not happen if one ferves for all the curve N X F; for the wave will not be one point from its extream F, as in the point X, becaufe that the Touchant of the curve in F is Parallel to B C, and the Touchant in X is inclined to the fame line B C: 'Tis evident, that the work of the point X will only endure fo much more time as the little Wheel is more great; for the arch which the point M defcribes, will be greater for drawing the point M, in the line drawn by X perpendicular to B C, than if the Radius of the little Wheel fhould be leffer: There is ftill one inconveniency in a great little Wheel; for it muft have greater ballances on one fide, and on the other under the wave, becaufe that it moves on two points one of which is its Pivot, and the other is that of the arm and of the Portion of the circle which carries the chain, which will not be fo confiderable in a fmall Wheel: But if the little Wheel be very fmall, it muft take away a greater portion of the curve N N, to form the wave that it may have always the fame Elevation in the peftle, or rod of the Pump.

'Tis

'Tis eafily feen that the chain which is faftned to the portion of the circle ferves to raife the Peftle always perpendicular, which is a very good ufe in thefe forts of Pomps : For other-wife if the handle which carries the Peftle, be only faftned to a Leaver movable about an axis as D in this Engin, it will happen that the Peftle will be drawn fometimes to one fide, and fome-times to the other, and wear unequally in the body of the Pomp in working, which will deftroy it in a third part of the time, as I have obferved in fome rencounters.

PROPOS. X.

We may likewife apply the fame conftruction to wings, or to the Axle-tree of Mills, which have their Wheel vertical, and which are for Powder, for Paper, for Fulling, for Forg-ing, &c. or it may raife Peftles, very near as you fee re-prefented in this figure.

Fig. 200. I Shall here reprefent only two of thefe Peftles, but we may put as many as we pleafe, or as many as the mover of the Wheel can make to go ; you muft always put two wings oppofite, as A B and C D, to work on each Peftle, to the end that when one of thefe Wings as B having quitted the little Wheel E from the arm of the Peftle, and that it is fallen, then immediately the other Wing A, which is oppofite to B, begins to relieve it.

We may alfo obferve that if we have two Peftles, it behoves that the wings which belong to each one, will be applied one after another, to the axis of the Wheel, as we fee here, where the Azis is to 4 Panes, becaufe that it hath four wings and two Peftles, and where the wings A and B are applied to the two oppofite faces of the axis, and the two other wings C and D, which belong to the other Peftle are applied to the two other oppofite faces of the fame Axis : If we would then have three Peftles and fix wings, we muft cut the Axis, or Tree, into 6 panes, or fides, and if we would have four, we muft cut it into 8 fides, unlefs we apply two Peftles on the fame face, and then there needs but half of the faces to the tree.

But it muſt be obſerved that we do not place the wings to-
gether, which are applied to the ſame face, but to mingle
them with the others, that ſo the Endeavour, or effect, may
diſtribute it ſelf equally on the Axis, or tree, that is to ſay, that
the raiſed Peſtles ſhould not be together.

I do not repreſent in this figure but one of the kinds of
making the motion equal, which is by giving a crooked figure
to the wings which are faſtned to the Axis of the Wheel, and
by placing the little Wheels to the end of the arm of the
Peſtles, although there be yet another, in making the arms
of the Peſtles of a curved or crooked figure, and in applying
the little Wheels to the end of the right wings of the Axis of
the Wheel: But I will explain theſe two kinds in the con-
ſtruction of the Curves or Crooks.

I have not given here the conjunction of this Engin, nor the
manner of ſtrengthning all the pieces, 'tis ſufficient for him
that regards the Mechanicks to ſhew the diſpoſition, the reſt
belongs to the Art of Carpentry.

The firſt kind. Fig. 201.

The firſt kind of applying the Curve to this Engin is that
which is repreſented in the precedent Figure; let the point C
be the Center of the Axis of the great Wheel, and C A the
diſtance from the Center to the handle of the Peſtles, on
the right line C A having determin'd the point B, which is the
extream A B, of the arm of the Peſtle, and which is the Cen-
ter of the little wheel which we apply to the end or extream
of the arm; and from the center C, and by the Radius C B,
having deſcribed the circle B D, make the *Epicycloid* B V V on
the circle B D, for the Baſe, the generating circle having
its center at an infinite diſtance, that is to ſay, that the circum-
ference of this circle is a right line, and that the *Epicycloid* B V V
is the laſt of all, which is alſo the Curve line deſcribed by
the roling of the circle, as is noted before.

Then from all the points V of this *Epicycloid*, having deſcribed
the circles N, equal to the circle E F of the little Wheel, the
Curve E N N which touches all theſe circles will be the faſhion
or form of the arm of the tree, or axis of the Wheel.

Following the ſame method of demonſtration, that I have
obſerved before, it is evident that in whatſoever Poſition the
arm

arm E N N of the axis, shall be in turning about its axis C, it will have always equality of motion between the center of the little Wheel which rises perpendicular, and the point B which it moves about from the center C: For if the center of the little Wheel B is transposed in H, following the line B H parallel to A G and perpendicular to A C, through the Curve E N N transported in L *n n* about from the centre C, it is evident that the point H, will be found on the *Epicycloid* B V V, removed in K H, with the Curve E N N removed in L *n n*: For the shortest distance from the point H to the Curve L *n n*, will be equal to the Radius of the little Wheel E F: But by the Formation of the *Epicycloid* B V or K H, the arch B K of its Base, will be equal to the arch of its generating circle, which is here the right line B H, which represents also the way from the center B of the little Wheel, while the same point B describes the arch B K : But the ways B K and B H being equal, and the Powers equal applied in B, of which the one acts to the end B of the Leaver C B, and the other to the end B of the infinite Leaver B A, or determin'd to what distance you please in A, for the length of the Leavers ought not to be consider'd when the Powers are directly opposite the one to the other, it will follow that you will have on every side an Equilibrium between the two equal Powers.

We do not consider here the rubing, or wearing of the handle of the Pestle throughout the hollowing of the wood it runs in, for to make it raise perpendicular, for we suppose that the Bodies are exceeding smooth, and that the rubing or wearing hinder not in any manner the motion.

The Second kind. Fig. 202.

In the Second manner it must be that the arm of the Pestle is of a curve figure, and that the little Wheel is applied to the end of the arm of the Tree, or Axis of the Wheel.

The figure of this arm, or wing, is not determined : Since there is no regard, but to the length from the axis of the tree, even to the centre of the little Wheel, which works on the arm of the Bar, or Pestle ; it behoves only to take heed that the Figure as C K D, which we give to this arm, or wing, hinder not the motion of the arm of the Pestle.

Let then, as before, the handle of the Peſtle be A G, and the center of the Axis C, having drawn the Perpendicular C A on A G, mark on A C the Radius A B of the little Wheel, and by the point B draw the line B E parallel to A G, which will be the Baſe of the Cycloid B V V, whoſe generating circle will have the length C B for its Radius: If from all the points V of this Cycloid, we deſcribe the circles N equal to thoſe of the little wheel, the Curve line N N which touches all theſe circles will be the Figure of the crooked arm which we ought to apply to the handle of the Peſtle.

'Tis evident by the generation of the cycloid, that if we move the cycloid B V on its baſe B E, in what place ſoever 'tis placed, as in E D *u*, the end B of the Radius C B being removed by the cycloid in D, the arch B D will be equal in length to the right line B E of the baſe ; but if in ſtead of the cycloid we uſe the curve N N, we ſee clearly, as in the precedent propoſitions, that this curve will make the ſame way to the point B, from the end of the Radius C B, in rencountring the little wheel A F, whoſe center is in B ; for the curve *n n* which rencounters the little wheel, cannot advance its center, or make it move forward, but from the diſtance of that center to the cycloid, which is that from the Radius of the little wheel: But as theſe motions, or movements, are every where equal, there will be an Equilibrium between the two equal powers applied, as in the precedent example, which does not require any long explication after that which I have ſaid of other Engins.

There is only in this caſe one difficulty for the conſtruction of this Engin; for as it is, that the little wheel lays hold on the arm of the Peſtle below, if the arm of the Axis, or Axletree, which carries the little wheel, be right or ſtreight, it rencounters the curve before that the little wheel touches it ; we muſt then bend or make crooked the arm a little, as the line H K D ſhews ; to the end that the little wheel begin to rencounter the curve F N N, when its center B is in the line C A : But as it is difficult to make theſe ſorts of curves H K D, unleſs it be of Iron, we may alſo make to ſerve an arm every way right or ſtreight which ſhall bear or carry the center D of the little wheel, but then the arm muſt be double, and the little wheel muſt be applied between two to the end, for the

<div align="right">crooked.</div>

crooked arm of the peſtle F N N will paſs between theſe two ſtreight pieces which bear the little wheel.

We muſt obſerve here, as in all the other Engins, that the little wheel be ſmall; for when the crooked arm which it rencounter or meets, ceaſes to work by a perpendicular line drawn from the center of the little wheel to the curve, it ought to ceaſe in the Rencounter, or diſcontinue to meet it, which is not poſſible, becauſe it ſerves but one part of the Curve: It happens then that the extream of the arm works ſtill by its point on the little wheel, in making it turn on its center until it be entirely got away, and in the motion, the *Equilibrium* between the powers is not found any more, which is a defeɕt in the Engin, which we muſt avoid and leſſen by making the little wheel of a ſmall Diameter.

P R O P O S. XI.

Of the Length and Diſpoſition of the Teeth of Wheels.

Fig. 203. I Have already demonſtrated, that it is not neceſſary that the teeth be equally diſtributed on the wheel, when they are of a regular figure to make them aɕt equally one with tother; for if we have but one, it will be as if we had more which work, the powers applied to theſe wheels aɕt always in the ſame reaſon or proportion, the one with reſpeɕt to the other. But we muſt take heed that when one tooth as O N L, which is cut as L, ceaſes to work on the other Tooth P Z, that is to ſay, when the Touchant in L of the curve O N L, is alſo Touchant in the ſame point L of the curve P Z of the other tooth, there muſt be two other already of the two wheels which work together; for otherwiſe the extream L of the tooth N L rencountring ſtill only by the point L, the curve P Z will not be moved as before, and the motions of the two wheels will not be equal between themſelves: It is not poſſible in this caſe to reɕtify the motion in ſeeking the figure which rightly agrees with the Teeth of the wheel A, to make the point L work equally on the Tooth P Z; for the point L rencounters the Tooth P Z, in the ſame points where it already is rencountred by the curve N L. But when another tooth begins to work, or hath workt already, when the point L ceaſes to work regularly on the Tooth P Z, the point L ceaſes alſo

to rencounter the tooth P Z; but becaufe the wheel to which 'tis faftned is moved always with an equal motion by the rencounter, or meeting of the other teeth of the wheel C, which makes it go further than the point L alone fhould do, for this wheel A will have always the fame way, as if the Tooth P Z fhould be rencountred, or met, by the curve O N L prolonged, or lengthned; then the point L will remove afide from the tooth P Z, and they will work together only fo much as they can do it regularly, which is a great advantage to an Engin.

We ought alfo to take heed that the Teeth of one wheel rencounter not thofe of the other wheel above the points, where they ought to begin to work, that is to fay, towards G, above the line A C, which joins the centers of the wheels for the reafon of rubing or wearing, as I have already taken notice of before, for the rubings which are made of bodies, which go one on another are always very great, and on the contrary thofe that are made by flipping, are very inconfiderable, wherefore we ought to difpofe the Teeth in fuch manner, that they trouble not, nor hinder one another before they begin to work, and that there be a convenient length and depth given them, for power to difengage themfelves eafily the one from the other.

We may yet note, as I have done, that the part of the tooth which works not, may have what figure you pleafe, and that we ought only to feek thofe which gives it moft conftancy or ftedfaftnefs, and which may ferve for difingagement. Neverthelefs it is left to be done as workmen ufe in their common difcoveries of giving to teeth the fame figure of both fides, as well to inure to make thefe teeth all equal, as to ferve alfo to the motion of the Wheels, when we would make them turn in a fence contrary to that which is necffary for the ufe of the Engin; which we are oblieged to, oft-times in the building and taking of them too pieces.

PRO:OS.
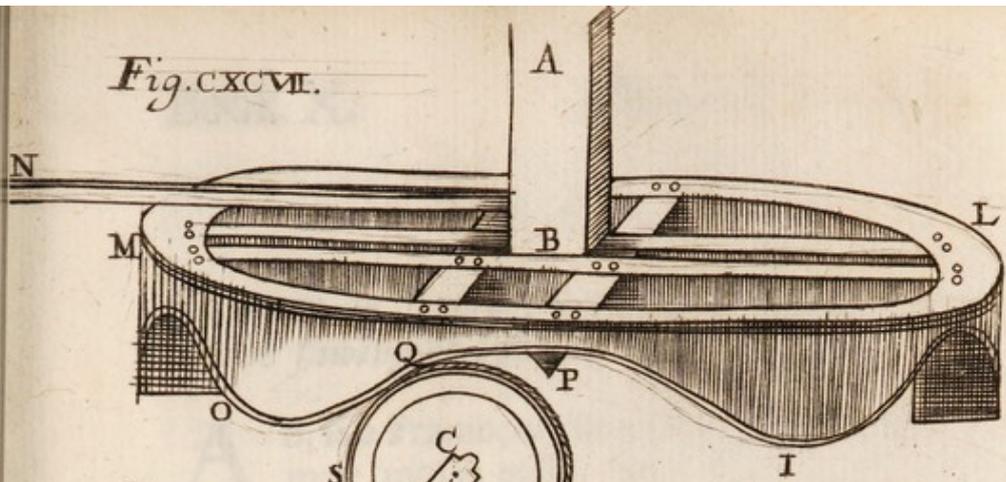
Fig. CXCVII.

Fig. CXCVIII.
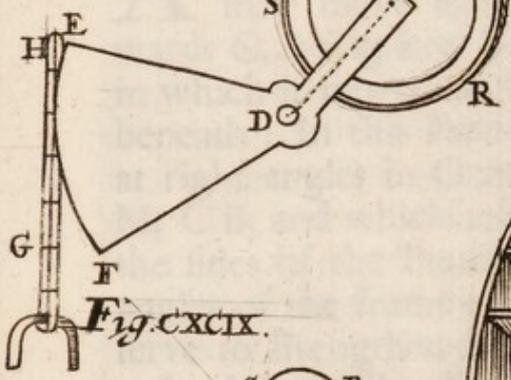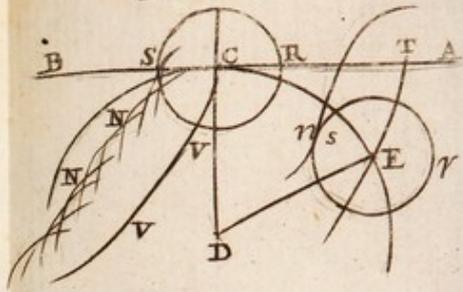
Fig. CXCIX.
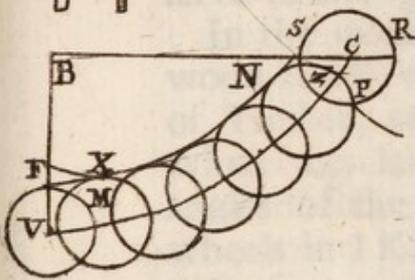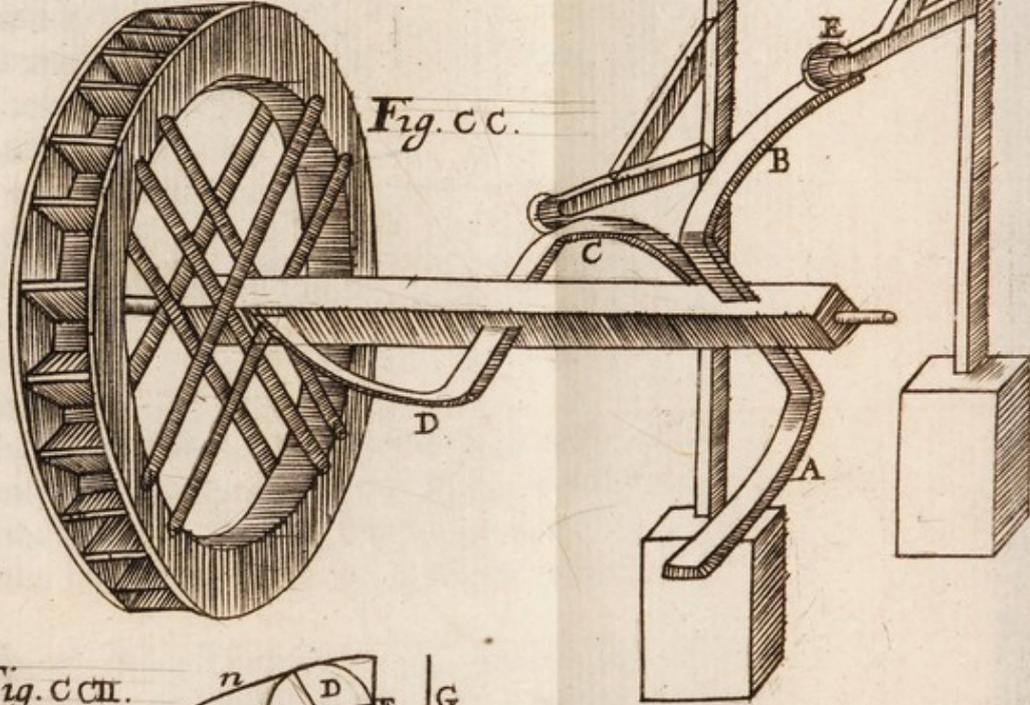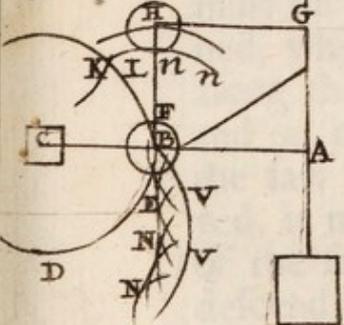
Fig. CC.

Fig. CCI.

Fig. CCII.

Fig. CCIII.

Fig. CXCVI.

Fig. CXCVII.

Fig. CXCVIII.

Fig. CXCIX.
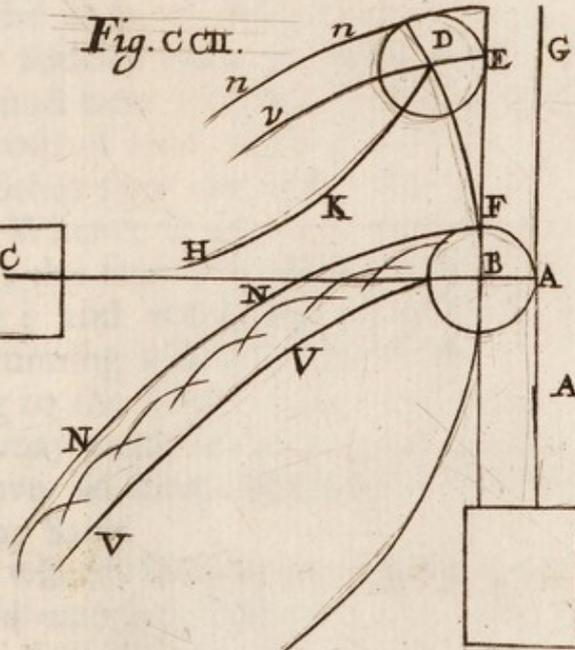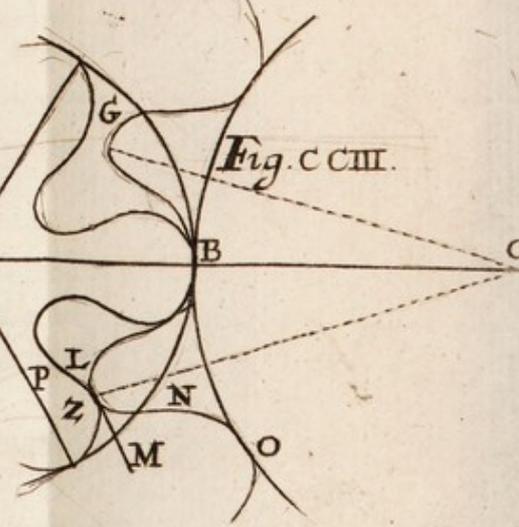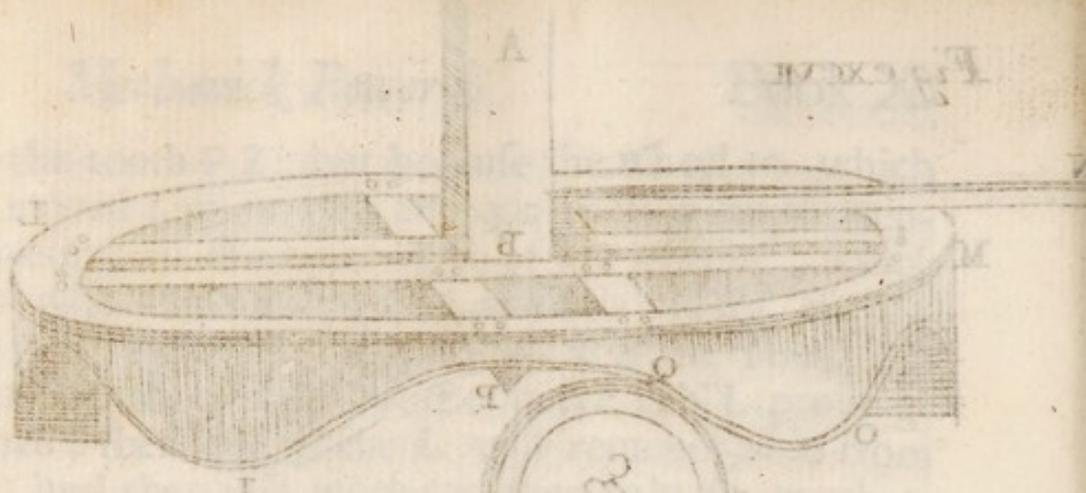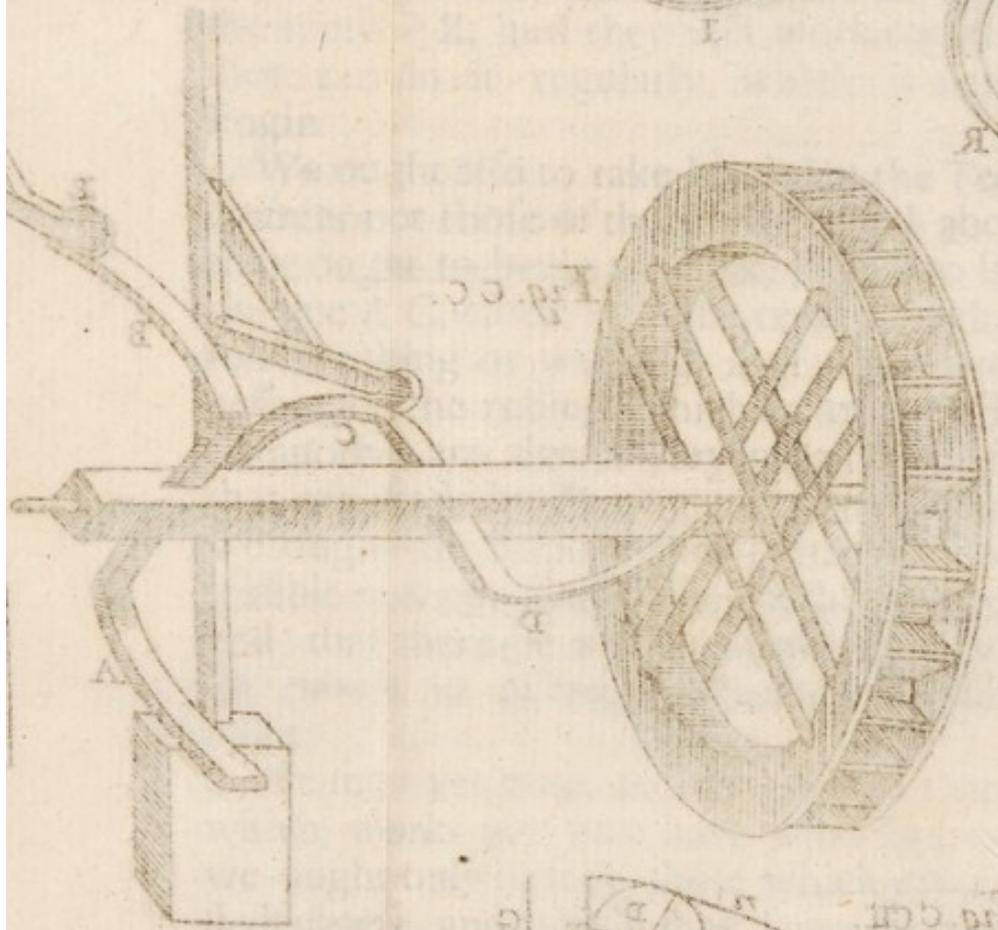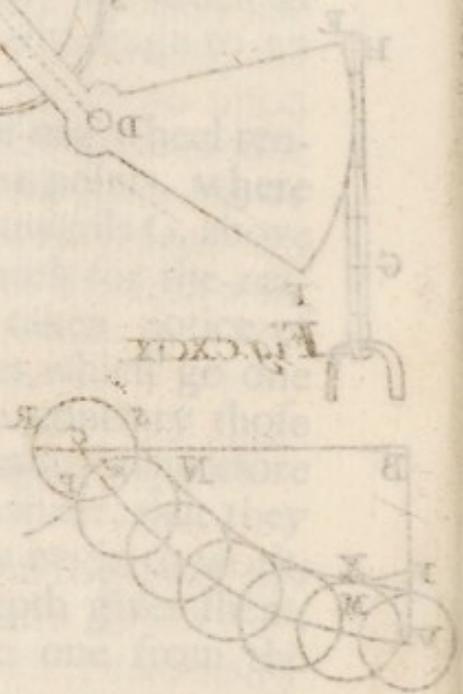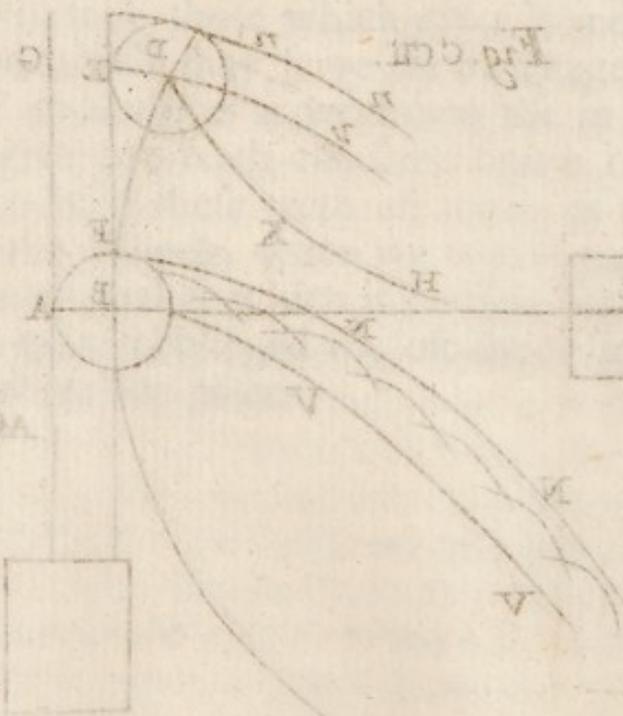
Fig. CC.
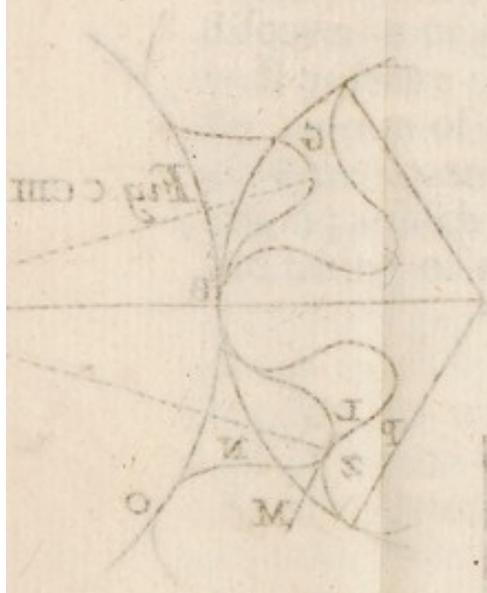
Fig. CCI.

Fig. CCII.

Fig. CCIII.
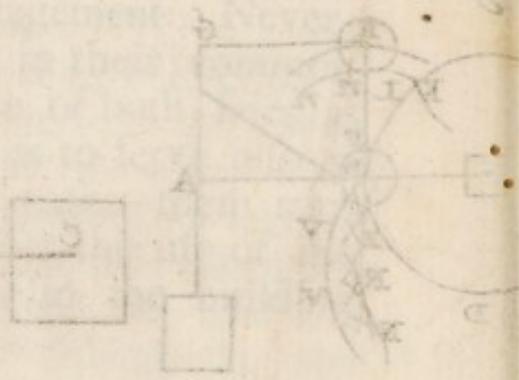
PROPOS. XII.

To make an Engin which serves to move several Sawes for the sawing of Stones. Fig. 204.

A B, is a Frame, or Shas, in manner of a square figure, which may move easily from C towards B, and from B towards C, being kept within a kind of hollow gutter of wood, in which it moves on little wheels which are faftned to a piece beneath : In this Frame you have two pieces of wood joined at right angles in G and in F, with the pieces of the Frame A M, C B, and which are detained by two bonds or braces from the fides of the Frame, there muft be alfo in the two other angles of the frame two bonds or braces in D and in E, which ferve to ftrengthen it.

In the middle of this Frame there muft be a Triangle of wood H I K, which is fuftained in the middle on a large piece of Timber, or Axle-tree L, on which it is well ftayed, and when this large piece of Timber, or Axle-tree, turnes, the angles of the Triangle, which are furnifht with fmall little wheels in I K H, come to rencounter the pieces of wood G F one after another, making the frame A B to move from one fide to the other in the hollow gutter, by forcing it in G, and afterwards in F.

Towards the ends of the pieces of wood A M, C B, there muft be two rods of Iron, as M B, which muft be well faftned, which muft bear two hands of iron N O, which may run along thefe rods of Iron, where they are engaged at one end, and on the other they are well faftned to one of the arms of the faw P. Whence it appears, that when the Frame is moved, it makes the faws P to move which are on the two fides of the frame ; and according as the faw works, the hands defcend by running a long the rod M B.

According to the force of the power which turns the axle-tree L, we may apply many Triangles, as H I K, which will make to move fo many Frames, as A B, which makes to go, twice as many Saws.

The little wheels which are applied to the angles of the Triangle, and which facillitate the motion of the frame, are of great ufe, becaufe they take away the rubing which would be

be made againſt the pieces G F, if there were none but the
angles of the Triangle which hit againſt them. But although
theſe little wheels are applied to the angles, the motion is ne-
vertheleſs unequal ; and for to make it equal, it behoveth that
the faces of the pieces G F which are rencountred, or hit a-
gainſt by the little Wheels, muſt be formed in a crooked line,
which is demonſtrated and explain'd all along before in the
Treatiſe of *Epicycloids.*

Fig. 205. How to make the bending of the face of the
pieces G F ; from the centre L, and with the radius L I, equal
to the diſtance which is between the axis of the tree L of
the Engin, and the centre of the little wheel, having deſcri-
bed the circle I F, draw a part of the Cycloid I S on the right
line I Q, which touches the circle in I, and which will be
the baſe of the Cycloid, the circle I F being the generator,
and the beginning of the Cycloid being in I ; then on all
the points of the Cycloid, as a centre, deſcribe the circles R
which muſt be equal to the little wheel, and you may draw
the line R R, which will touch all the circles towards the con-
vexity of the Cycloid. The line R R will be the bending of
the face of the pieces G F : We may prolong the line R R
towards V, adding to it a part of the right line, even to the
place where it is faſtned in the piece A M of the frame : You
muſt obſerve, that the little wheel in working ought to ap-
ply it ſelf in the curve or bending R R, in the ſame manner
that the circles R R are placed, that is to ſay, that the pieces
G F ought to be a little more bending towards the middle of
the Frame.

P R O P O S. XIII.

*To change the direction of Motions, or Movements, by the
means of toothed Wheels.*   Fig. 206.

Et the wheel be A B which turns on a vertical Tampin C,
whoſe teeth are placed perpendicularly on the plane of
the Wheel.

If we would move this Wheel A B Horizontally, by means
of the arm D E, and that its teeth rencounter, and enter in the
Spindles of the Lantern G F, which moves on its Horizontal

<div align="right">Tampin</div>

Tampin M N, it is evident that the Horizontal movement of the Power applied to the arm D E will be changed into a vertical movement or motion about the Tampin, or the Axle-tree M N, of the Lantern.

Also by means of an Horizontal motion we may raise the weight P, whose Chord is wound about the Roll O, which hath its axle-tree common with that of the Lantern F G.

But if instead of the Lantern F G, whose spindles are parallel to its axle-tree, we would make another, as H I, whose Spindles are inclined to the axle-tree K L, in what angle we please; it is evident, that the horizontal motion of the power applied to the arm of the wheel, will be changed into a motion inclined to it, in what angle one will about the axle-tree K L.

Only note, that the Spindles of the Lantern H I, which rencounter the teeth of the wheel A B, must find themselves places horizontally in the rencounter, to the end, that they may be applied in the same manner, as if this Lantern were like to the other G F.

P R O P O S. XIII.   *Fig.* 207.

The description of a Wind-mill, together with the Computation of the force of the Wind on its sails.

THey are commonly of two sorts, but they differ not but in this, that in the one the whole body of the mill turns on a Tampin, to expose the sails to the wind; in the other, the body is of stone, and none but the upper part turns to expose the sails to the wind. In these the Lantern and the stones ought to be placed in the middle of the Tower, that the teeth of the Wheel in all their different Positions may rencounter always equally the Spindles of the Lantern.

A B is the great Axle-tree, at whose end the Sails are fastned, and which serves for an axle-tree to the Wheel C D. The teeth of the Wheel C D enter into the Spindles of the Lantern E F, whose Axle-tree G H N is vertical, and which being stayed by the upper stone I K, makes it turn on that beneath L M, which is immovable.

So that the vertical motion of the Sails, and of the Wheel is converted into the Horizontal motion of the stones.

The

The Wheel hath commonly 48 Teeth, and the Lantern 10 Spindles, so that each turning round of the Wheel, or of the sails, causes near 5 turnings round of the stones to be made; whence you may observe, that perhaps the stones make not the whole, or more than one turning round, in one Second of time, and by consequence the sails will also make one turning about in 5 seconds: Therefore if the wind be to violent, we abate one part of the sails to reduce them from this swiftness.

It is not likely that the ordinary manner of using the force of wind, to turn the stones of mills is the most advantageous that is possible to be found, which is that which hath oblieged many active workmen to seek after, other sorts of Mills to the wind, and above all the Horizontal, to the end that the sails may be exposed directly to the wind, and profit by all its force; but all these sorts of inventions have not prospered. We may perhaps believe that the Wind-mills, such as we have seen were not made at first sight in the perfection that they are at present, but that the continual use which is made of them, hath made many defaults to be seen, which one amends afterwards.

Behold the Computation of the force of wind against the sails of a mill, according to the inquiry which was made by Mr. *Mariot*, in his book of the *Motion of Waters.*

Fig. 208. A B represents in this Figure the Axis or Axletree of a turned Cylinder, and the Rule G H a cross at right angles: And I L is another rule, placed perpendicularly on the first G H, and stayed also in the Cylinder. M N O P is a small thin table, even as the precedent Rules, which is likewise placed perpendicularly on the Axis A B, and Bias so, that it makes with it an angle of 45 degrees, and with respect to the Rule G H.

If we suppose now that one Cast of water beat directly against the Rule I L, towards the point Q, and that it turns the Cylinder according to the order of the letters *a b c d,* but that the weight R placed towards the end H, of the Rule G H, makes an Equilibrium with the force of the cast of water Q, that is to say, that it hinders the Cylinder from turning; It is certain, that if the same cast of water beat against the Table M O, also in the point S, which being also so far removed from the Axis of the Cylinder, as the point Q,

and

and that the direction of this Caſt be perpendicular to the Table, it cannot ſupport the weight R, becauſe that its direction will not be according to the motion of the Rule I L, which is in a plane perpendicular to the Axis A B; but it cannot at that time ſupport that weight which ſhall be to the weight R, as the ſide of a Square to its Diagonal.

And if the ſame Caſt is parallel to the Axis A B, and that it hit againſt the Table M O in the ſame point S, it muſt ſtill diminiſh in its attempt in the ſame Proportion of the ſide to the diagonal of a ſquare, becauſe that this Caſt falls obliquely againſt the Table under an angle of 45 degrees.

It is then evident, that this double reaſon of diminution ought to reduce the weight R to its moyety, or half part.

Now the wind which beats againſt the ſails of a Windmil, beats, or blows, obliquely, and if it rencounters each ſail under an angle of 45 degrees, it follows then from what hath been ſaid, that it will not have but a moyety of the force which it would have, if it rencountred directly, and if the ſail, be placed on the Axle-tree, as the Rule I L on the Axis A B. If we ſuppoſe then that the whole force of the wind be as 80, it will be redcuced to 40 for theſe two cauſes.

But there is yet one cauſe of Diminution of the force which comes from the ſame obliquity, for it will have a leſs breadth of wind which rencounters the ſurface of the ſail, than if it had been directly oppoſite, and this diminution will be ſtill in the ſame reaſon, or proportion, of the ſide of a Square to its diagonal, which will in the end reduce the whole force of the wind meaſured by 80, to $28\frac{1}{4}$.

But if the obliquity of the ſail is leſs than 45 degrees, that is to ſay, if it is more expoſed to the wind, whereof we ſuppoſe the direction parallel to the axis A B, and that the angle be of 60 degrees on one ſide, and 30 on the oppoſite, then the firſt cauſe of diminution reduces the force from 80 to the moyety 40, but the two others unlike, for they reduce not but from 40 to 31 very nigh ; which gives us to underſtand, that it is better that the ſails of windmils have this obliquity than that of 45 degrees.

By theſe ſuppoſitions of Mr. *Mariots*, if the ſwiftneſs of an indifferent wind is of 24 feet through each ſecond of time, as one may know by experience ; one wing or ſail directly oppoſite to the wind, and which hath 144 feet in its ſuperficies

will suftain a weight of 210 pounds, if the diftance from the fupport, or the centre of motion, as the Axis A B in the precedent Cylinder, even to the place as R, where the weight is placed, is of 12 feet from the fame, as the diftance from the centre of the fail.

But if the fail have only 6 feet in breadth, and 24 feet in length, it will have the fame fuperficies of 144 feet, and its Centre will be alfo 12 feet from the Axis; wherefore it will fuftain as yet the 210 pounds, having 12 feet of diftance from the Axis: But if the diftance from the axis to the Centre of the fail is of 15 feet, it will fuftain 262 pounds and $\frac{1}{2}$.

But through thefe three caufes of diminution they fuppofe the angle of the fails of 60 degrees, with the Tree, or Axis, where they are faftned, the force of the wind reduces it felf to fuftains 101 pounds and $\frac{3}{4}$, having 15 feet of diftance from the Axis: And becaufe there are four fails, the force of the windwill fuftain 407 pounds at the diftance of 15 feet from the Axis of the fails.

But the femidiameter of the wheel being fuppofed of four feet, if we make it as 4 to 15, fo 407 to 1526, this will be the number of the pounds which meafures the force of the wind againft the Spindles of the Lantern, in the fuppofition that it makes 24 feet in one fecond; there is no regard of the rubing, or wearing, in all thefe Calculations.

In the horizontal Mills you cannot have about but one fail, againft which the Wind acts directly, and it muft be made of an extraordinary greatnefs, for to caufe the fame effect as the 4 vertical fails of ordinary Mills, as 'tis eafy to compute by the precedent Suppofitions.

PROPOS. XIV. Fig. 209.

Of Wheels, and of Lanterns, with their Elbows, or crooked Axes, for the moving the Suckers of Pumps.

IF the power turns the wheel vertically, we muft only bend the ends of its Axis, as you fee here in the figure G H. But if the motion of the power be horizontal, as if it be applied to the arm C D of an horizontal wheel A B, you muft adjuft the Lanterns E F, fo that their Spindles enter in to the

the teeth of wheel, and that their crooked axes may work the effect that we defire.

In each crook of the Axis you may put a kind of little ring I, which is faftned to the end of the Iron of the fucker K. fo that in the motion of the Lantern, the crooks of the Axes raife them and let them fall alternatively, or by turns one after another, thefe raife and deprefs the Peftles, or Irons, to which the Suckers are faftned in the body of the pump, this alfo makes it give one ftroke of the Iron to each turn of the Lanterns.

We may make the diameter of thefe Lanterns a fifth part very nigh of that of the great wheel, to the end, that for each going round of the great wheel, the Lanterns may make five. But however commodious this Proportion is, we will not make a Rule, becaufe it muft have regard to the fwiftnefs of the power which may be too great for this proportion, and which will move the Rods, or Peftles, too nimbly.

PROPOS. XV.

In toothed Wheels the number of Teeth muft not contain ex-actly fo many times the Teeth of the Pinions, or Spindles of the Lanterns to which they are applied.

THis Rule concerns only the execution, and we ought to have regard to make it fo, that the teeth of the wheels do not always rencounter the fame teeth of the Pinions, for when they rencounter, or meet different ones, they grow perfect in rubing and in ufing themfelves one againft the o-ther, and by degrees they make very nigh the figure which behoves them, for to act equally in their different rencountes, and in the different lengths from their Axes, which is explain-ed in the Treatife of *Epicycloids* before.

It behoves to practice this Rule exactly, that the number of the teeth of the Wheels, and of the Pinions, muft be Primes between themfelves, that is to fay, that they do not admit of any other common meafure than Unity, and fo the fame tooth of the little Wheel, or Pinion, rencounters not the fame tooth of the great Wheel, but after that the little one hath made fo many revolutions, or turns, as there are teeth in the great wheel.

But becaufe there is but little difficulty to make one divi-
fion of two prime numbers, we may make the number of
teeth of the great Wheel ; for example, of 48 or 60, and
thofe of the Pinions of 6 or 8, and in the Mills, the great
Wheel of 48 teeth, and the Lantern of 10 Spindles, to the
end that the fame teeth may meet as few times as is poffible ;
for if the Wheel have 60, and the Pinion 6, the leaft num-
bers which keep the fame proportion will be 10 and 1,
wherefore the fame teeth of the Pinion of 6, rencounter not
them of the Wheel but after 10 revolutions ; and if the
great Wheel have 60, and the Pinion 8, the teeth of the
Pinion rencounter not the fame teeth of the Wheel, till after
15 revolutions, becaufe that 15 and 2 are the prime Num-
bers between themfelves, which exprefs the relation of 60
and 8 : Laftly, if the Wheel have 48 teeth, and the Pinion
or the Lantern 10, the teeth of the Lantern rencounter not
the fame teeth of the Wheel but after 24 revolutions, for
the numbers 24 and 5, are the two prime numbers which
exprefs the relation between 48 and 10, and 'tis this which
makes us fee that we cannot find a number of teeth which
is more proper for the Wheel, and for the Lantern of Mills,
for the divifion into 48 parts is eafy, and may be done very
exactly, and that of 10 is commodious, and may be re-
duced to 5.

PROPOS. XVI.

Of oblique and interrupted Movements, or Motions.

Fig. IF the chord D of the weight P, be wound about on
2 10. the roller of the beam G, and that the chord F
which ought to draw the little wheel E, by means of the
pulley L, on which paffes the chord F, for to go to faften
it to the top of the little wheel E, paffing alfo on another
pulley I, which is faftned to the top of the little wheel E,
and which is ftayed at laft in M towards the pulley L ; 'tis
evident, that when the roller turns round for to draw the
chord F, it windes at the fame time the chord D, which is
twifted on the roll G, in a contrary fence of the chord F :
But if the chord F is twifted on the roll G of 6 feet long, the
weight

weight P defcends at the fame time from 6 feet high, and will alfo at the fame time be raifed by the motion of the little wheel throughout the hollow it runs in.

But the Chord F having been drawn the length of 6 feet, it will not make the little wheel to advance but 3 feet; for as it paffes through upon the pully I, and is ftayed in M, it doth not advance the pully I, and the little wheel E, which are faftned together, but the half of its movement, or motion.

Wherefore when the chord F is twifted on the Roll G of 6 feet long, and that the chord D is alfo twifted or wound about of 6 Feet in length, the little wheel E will not have made but 3 feet of its way; and by confequence the weight P will not be raifed up again, but 3 feet by the motion of the little wheel E; it appears then to be defcended 3 feet, which is fo much as the little wheel hath made of way on the hollow groove, wherefore it defcends by this means by half a right angle, or it defcends fo much as it advances.

Laftly, if the chord D which is faftned to the round beam, is all wound up, and that it begins to wind it felf about in the fame fence as the chord F, then the weight P rifes again; but it rifes three times as much as it advances towards L: For if the chords D and F are wound about of 6 feet on the Roll of the round beam, the weight ought alfo to be raifed to the height of 6 feet by means of the chord D, and it ought alfo to be raifed 3 feet by means of the little wheel E which draws it, and which paffes over 3 feet, while that its chord is drawn 6 feet; then the weight will be raifed 9 feet while that it runs over only 3 feet in length, which is the motion of the little wheel E.

But when the chord D is wholly wound of the round beam, or cyclinder, and that the weight begins to rife, if you make a ftop to the chord F, as in R, in place which it paffes at that time over the pulley I, fo that the cord cannot any more turn on the pulley, the fame thing will happen as if it were faftned at the top of the little wheel E, and the weight will be raifed 6 feet, by the motion of its chord D, and 6 feet by the motion of the little wheel E, it will then have run over 6 feet in length hanging, while it is raifed 12 feet.

Now if the parts of the Roll of the round beam on which the cords D and F are wound, are of different diameters, it will make the movements or motions, different, and in different

proportions of thofe which I come to explain; but it will be eafy to determine them, the Diameters being given, or elfe, the motions being propofed, it will be eafy to find the Diameters of the Roll which will ferve them.

We may alfo by the fame means make it fo, that one part of the way of the weight fhall be Horizontal, and the other part rife or defcend perpendicularly, or obliquely, which requires no long Explanation; I fhall fay no more of circular motions in rifing, or defcending, feeing they only depend or belong to the figure of the hollow groove. There is in an all thefe motions many little cautions to be obferved, which muft be left to the induftry of the Artificer.

We may alfo make many motions different and oppofite the one to the other, with one and the fame motion, by the means of pulleys, referring from one to another which change the direction of the motions, which ferve chiefly to make the changes of the Decorations, or Ornaments, of the two wings of Theatres; for one axis only A *(Fig.* 211.*)* which bears the Tambours, or Cylinders B C, of different diameters, coming to turn by means of a counter poife, or weight, makes to advance towards the middle of the fcene beneath the Theatre, the falfe frames or fhafhes D, which bear or carry the Ornaments or Decorations by the means of the chords C E, B E, which are faftned to thefe fhafhes, or frames, and which are wound about on the Tambours in a contrary fence: Thefe fame fhafhes D advancing, and thofe of G retiring at the fame time, whofe place they take, by means of one or two chords I, which are faftned to thefe two fhafhes, which pafs above the pulleys that refer from one to another H, which are thofe in the walls of the two fides. The motion or way of thefe two fhafhes will be more or lefs according to the proportion of the Tambours, or Cylinders, which bear the cords of their motion.

PROPOS. XVIII. Fig. 212.

How to raise a weight by an oblique motion.

LEt the weight be P which is to be raised obliquely from P to A, the Engin which serves for the movement being at the height of A.

Make a hollow groove A B composed of two pieces of wood which are only removed one from another, so much as to leave room for the chord to pass freely which sustains the weight P, and which must be placed Horizontally; the chord C D H which sustains the weight P, is stayed firmly in C towards the end B of the hollowing, and passes in the overture between he two pieces of wood of which 'tis made; it passes also above the little wheel E composed of three pieces, *viz.* of two little wheels, or rollers, at its ends, and of one pulley between two, on which passes the chord C D H. Towards the end A of the hollow groove there is a Cylinder, or round beam G with its arms for to draw the cord F, which is fastned to the top I of the little wheel.

'Tis easy to behold by the construction of this Engin, that when the chord I F draws the little wheel E from B towards A, the weight P raises obliquely, or a slant, from H to A, and that the elevation of the weight P will be equal to the length of the hollow groove A B.

We may also make it that the Elevation of the weight P shall be in what proportion we please with its Horizontal way; for Example, that the weight P be raised 20 feet hanging, while it passes over 60 feet Horizontally.

For this effect we may place the motion of the chord F, which draws the little wheel E from B towards A at the end B of the hollow groove with a pulley towards A.

Also the round beam, or Cylinder, being placed towards B which draws the chord F, will advance the little wheel from B towards A. But then it will cause the cord C D H which sustains the weight P to be twisted on the roll of the round beam, and that it will not be fastned immoveably in the point C, as before; the place of the roll where it is twisted, must have its diameter smaller than the same where it twists the cord F, when the Cylinder makes the little wheel E to advance on the

S f   hollow

hollow groove, and then the chord D will be twisted in a contrary sense to that of the chord F, to the end that it may wind off, as the other twists about. The proportion of the diameter of the part of the roll of the round beam where the chord F winds about, to the diameter of the other part where the cord D is twisted, or wound about, ought to be as the Horizontal way to the difference of the two ways, which is the same as 60 to 40, or as 3 to 2. For then when the chord F draws (for example) the little wheel E on the hollow groove through the space of 6 feet, that part of the roll where the chord D is twisted will have wound 4 feet, and by consequence the weight P will not be raised as yet but 2 feet, although it have run over 6 feet of Horizontal motion.

It will be the same thing for any other proportion of Elevation; only we must Note, that if we would have the weight P make a greater motion in height than in length, for example, if we would have it rise 30 feet hanging, while it runs over but 10 feet in length or Horizontally, it behoves that the diameter of the roll for the chord F be made to the diameter of that part of the roll for the chord D, as 10, which is the Horizontal way, to the difference 20 of the two ways. For if to each bout of the Cylinder the chord F make 3 feet of way, the chord D will make 9, for the circumferences of the rolls are in the same reason or proportion as their diameters; and by consequence the weight P rises 6 feet, because of the diameters of the parts of the roll, and it rises still 3 feet in the same time, which is equal to the Horizontal motion.

As to the swiftness of the motion we may give it what we please, for if the cylinder cannot draw the chords which make the motion with so much swiftness as we require, it must be done by means of a counter weight very heavy, which we may raise to an height equal to the Horizontal motion, and having fastned this counter weight to a chord wound about on the roll, where the other chords which serve to the motion are likewise twisted, but in a contrary sense, when we let loose the counter weight it will turn the roll with a great swiftness.

We commonly moderate this motion by means of a chord, which serves to make the tricker, or detainer, and which being applied against any body where it slips and retains afterwards, with the hand we may let it loose to such a proportion of swiftness as we would give to the Engin. **This**

This same tricker, or detainer, serves also to render the motion equal, which will otherwise be very unequal becaufe of the acceleration of the counter-weight in defcending.

When one chord ferves it felf, of many which are placed one from another for to raife the fame weight, or which is the fame thing, which fuftains it in feveral places, there muft be inftead of the little wheel E, a fhafh or frame of wood, ufed as M M, in which there muft be rolls, as N, which ferve with the pulleys to pafs the chords above, thefe rolls turn on their Axes which enter in the long pieces of the fhafh or frame. This fhafh muft run along on the two pieces of the hollow groove, being drawn through the hook O where we faften the chord which ferves to its motion ; but it behoves that the fhafh be kept on the hollow grooves that it fall not from one fide to the other.

We may alfo inftead of the hollow grooves, make one chord only to ferve, being well ftretched out, on which muft pafs a pulley, as R, which fuftains another S, which ferves to fuftain the chord of hanging motion which the pulley R runs along in, in rouling on the chord which ferves for the hollow groove.

I fhall not fay any thing concerning the manner of making thefe hollow grooves, and their detainer in different places to render them folid, becaufe it belongs to workmen, which work in Carpentry or Joynery.

We may alfo make of thefe forts of movements which crofs themfelves without trouble or confufion, for if one ferves to the fhafh, as I have explained before, it is eafy to fee that the hollow grooves may be cut and interrupted in any place in a fmall fpace of 4 or 5 inches, which may ferve for the paffing of the chord which fuftains the weight, which moves it felf with a different motion from that which is borne on the hollow groove which is cut, without which the motion of the weight will be hindred ; for the fhafh having its long pieces fupported on thofe of the hollow groove, it may pafs eafily above the overture of the hollow groove.

What I have faid concerning the raifing of Weights, may be applyed to their defcent.

F I N I S.

A Catalogue of Globes, *Cælestial and Terrestrial,*
Spheres, Maps, Sea-Plats, *Mathematical In-*
struments, and Books, made and Sold by J. Mox-
on, *at the Sign of Atlas in Warwick-Lane,*
London.

Globes 24 Inches Diameter. The price 20 *l.* the pair.
Globes near 15 Inches Diameter. The price 4 *l.*
Globes 9 Inches Diameter. The price 2 *l.* 5 *s.*
Globes 8 Inches Diameter. The price 2 *l.*
The *English Globe,* invented by the Right Honourable the
Earl of *Castlemain,* 12-Inches Diameter; the price ordinary
made up 3 *l.* best made up 5 *l.*
Concave Hemispheres of the *Stary Orb,* which serves for a
Case to the *Terrestrial Globe* 3 Inches Diameter, made portable
for the Pocket, price 15 *s.*
Spheres, according to the *Ptolomaick* System, 14 Inches Dia-
meter, price 3 *l.*
Spheres, according to the *Ptolomaick* System 8 Inches Diame-
ter, prices 1 *l.* 10 *s.*
Gunter's *Quadrant* 12 Inches Radius, Printed on Paper, and
pasted on a Board, with a Nocturnal on the back-side, price
5 *s.*
Gunter's *Quadrant,* 4 Inches Radius, Printed on Paper, and
pasted on Brass, with a Nocturnal on the back-side, and a
wooden Case covered with Leather fit for it. A new Inventi-
on contrived for the Pocket, price 6 *s.*
A large *Map of the World,* 10 Foot long, and 7 Foot deep,
pasted on Cloth and coloured price 2 *l.*
A *Map of all the World,* 4 foot long and 3 foot deep, pasted
on Cloth and coloured, price 10 *s.* in Sheets 2 *s.* 6 *d.*
Six *Scriptural Maps,* 1. Of all the Earth, and how after the
Flood it was divided among the Sons of *Noah.* 2. Of *Paradise*
or

or the *Garden* of *Eden*, with the Countries circumjacent inhabited by the Patriarchs.

The 40 Years Travel of the Children of *Israel* through the Wilderness. 4. Of *Canaan*, or the *Holy Land*, and how it was divided among the Twelve Tribes of *Israel*, and travelled thro' by our Saviour and his Apostles. 5. The Travels of St. *Paul* and others of the Apostles, in the propagating the Gospel. 6. *Jerusalem*, as it stood in our Saviours time, with a Book of Explanations to these Map, Entituled, *Sacred Geography*, price of of the Maps 6 s. Book 2 s. to be bound up with Bibles.

BOOKS.

A Tutor to *Astronomy and Geography*, or the Use of the *Globes Cælestial and Terrestrial*; by *Joseph Moxon*, A member of the Royal Society, and Hydrographer to the King's most Excellent Majesty, price 5 s.

The use of the *Copernican Spheres*, teaching to solve as the *Phænomina* by them, as easily as by the *Ptolomaick Spheres*: By *Joseph Moxon*, &c. price 4 s.

Wright's Correction of Errors in the Art of *Navigation*, p. 8 s.

An Exact Survey of the *Microcosm*, being an *Anatomy* of the Bodies of *Man* and *Woman*, wherein the Skin, Veins, Nerves, Muscles, Bones, Sinews, and Ligaments are accurately delineated : Engraven on large Copper Plates, Printed and curiously pasted together, so as at first sight you may behold all the Parts of *Man* and *Woman* ; and by turning up several Dissections of the Papers, take a view of all their inwards, with Alphabetical References to the Names of every Member and part of the Body : Set forth in Latin by *Remelius* and *Michael Spaher* of *Tyrol*, and Englished by *John Ireton* Chyrurgion ; and lastly, perused and corrected by several Artists : Now corrected by *Clopton Havers*, M. D. and Fellow of the *Royal Society*, price plain 15 s. coloured 1 l. 10 s.

A Tutor to *Astrology*, or *Astrology made easie*, price 2 s.

The Use of a Mathematical Instrument called a *Quadrant*, price 6 d.

Mechanick Exercises : Or, the Doctrine of *Handy Works*, in nine Monthly Exercises. The First Three, *viz*. Numb. I.

Numb.

Numb. II. Numb. III. teaching the *Art of Smithing*. The Second Three, *viz.* Numb. IV. Numb. V. Numb. VI. teaching the *Art of Jonery*. The Third Three, *viz.* Numb. VII. Numb. VIII. Numb. IX. teaching the *Art of House Carpentry*. Accommodated with fuitable Engraved Figures, by *Joseph Moxon*, &c. price of each Monthly Exercife 6 *d*.

Mechanick Dyalling ; Teaching any man, though of an ordinary Capacity, and unlearned in the Mathematicks, to draw a true Sun-Dyal on any *Given Plain*, however fituated ; only with the help of a ftraight rule and a pair of Compaffes ; and without any Arithmetical Calculation, by *Jof. Moxon*, p. 1 *s*. 6 *d*.

Mellificium Menfionis : Or, the marrow of meafuring comprifed in 6 Books with Copper Plates, fhewing a new and ready way of Meafuring, Carpenters, Bricklayers, Plafteiers Joyners, Glaziers and Painters works, and all Superficies and Solids, price bound 3 *s*. 6 *d*.

At the place aforefaid, you may have alfo all manner of Maps, Sea-plats, Drafts, Mathematical Books, Inftruments, &c. at the loweft prizes.

ERRATAES mended thus:

Page	L.	
3	27	To the Proportion.
4	12	with.
5	30	Strike out [*be*]
7	10	Lefs.
11	20	Will.
11	31	Leotaudus.
12	5	A B.
12	*ult*	the Comma to be after [*before*]
13	36	ftrike out [*they fhould have*]
13	37	ftrike out [*they fhould have*]
14	13	Propofition IV.
27	12	Hang a thred.
28	30	*c* in like manner.
39	5	Diftant.
41	15	Foremoft.
53	5	Strike out [*in*]
53	20	Leaver.
53	23	then E M.
53	24	and D O.
53	26	ftrike out [*in*]
55	6	add [*or rubing.*]
57	12	Axis.
	14	Axis.