# A COURSE OF MECHANICAL, MAGNETICAL, OPTICAL, HYDROSTATICAL, AND PNEUMATICAL EXPERIMENTS

*FRANCIS HAUKSBEE*

DUJAR

# A COURSE OF MECHANICAL, MAGNETICAL, OPTICAL, HYDROSTATICAL, AND PNEUMATICAL EXPERIMENTS

FRANCIS HAUKSBEE

*A Course of Mechanical, Magnetical, Optical, Hydrostatical and Pneumatical Experiments*
*Francis Hauksbee*

**Genel Yayın Yönetmeni:** Berkan Balpetek
**Kapak ve Sayfa Tasarımı:** Duvar Design
**Baskı:** Ağustos 2020
**Yayıncı Sertifika No:** 16122
**ISBN:** 978-625-7147-37-8


853 Sokak No:13 P.10 Kemeraltı-Konak/İzmir
Tel.: (0) 0 232 484 88 68

www.duvaryayinlari.com
duvarkitabevi@gmail.com

**Baskı ve Cilt**
Sonçağ Yayıncılık Matbaacılık Reklam San Ve Tic.
Ltd. İstanbul Cad. İstanbullu Çarşısı No:48/48-49
İskitler 06070 Ankara
**Tel:** 0312 341 36 67
**Sertifika No:** 47865

# A COURSE OF MECHANICAL, MAGNETICAL, OPTICAL, HYDROSTATICAL, AND PNEUMATICAL EXPERIMENTS

FRANCIS HAUKSBEE

## MECHANICKS.

1st Day.SIR *ISAAC NEWTON*'s Three Laws of Motion, or Nature, demonstrated by Experiments.

That the Velocity of Falling Bodies is as the Times of Falling, and the Lines of Descent in the Duplicate Proportion of those Times.

An Instrument to measure the Force of Falling Bodies.

Experiments concerning the Sliding, Rolling, and Falling of Bodies.

That Bodies will ascend as high, as whence they fall by the last Velocity impress'd, when all Obstacles are removed.

That Bodies by a compound Force move in a Diagonal Line.

2d—The Balance and Stilyard, with all their Properties and Uses shewn and explain'd.

The Method of estimating the *Momentum*, or Quantity of Motion in any given Body.

The general Principle of Mechanicks established upon this Method.

Experiments to demonstrate the different Effects of the same Weight of Power acting in different Directions at the same Point of any Engine.

The Resolution of Forces into those of other Directions.

All the various Kinds of Levers explain'd.

3d—All the Phænomena of Pulleys, both single and in all their possible Combinations explain'd.

The Power of the Wheel or Axis in Peritrochio explain'd.

The Wedge, with the Method of comparing its Force, deduced from Experiments.

The Screw, with the manner of computing its Force.

A Compound Engine.

4th—An Experiment of Lifting a Weight by a Chain of Inflated Bladders, with its Application to Muscular Motion.

*Galilæo*'s Demonstration concerning the Strength of the Bones, Timber, *&c.* reduced to Experiment.

The Method of computing the Force of the Air on the Sails of Windmills, and of Ships; and of Water on Water-Wheels, and on the Rudder of a Ship.

Experiments to shew the proportional Advantages of large and small Wheels, in all Sorts of Carriages, as Couches, Waggons, Carts, *&c.*

5th—An Experiment to shew, that the lateral Motion compounded with the perpendicular Projection, does not alter the Line of Ascent or Descent in the projected Body.

The most considerable Objections against the Motion of the Earth, answered from this Experiment.

That the Line described by a Projectile is a Parabola.

The Experiments upon which the Art of Gunnery does depend, most exactly perform'd.

6th—Experiments concerning Pendulums.

The Description and chief Properties of the Cycloid, and the Application of Cycloidal Cheeks for regulating the Vibrations of Pendulums.

An Experiment to shew the Analogy between the Swings of a Pendulum and the Waves of the Sea.

Experiments concerning the Expansion of Metals by Heat.

7th—The Laws of Motion in the Collision of Hard and Elastick Bodies.

Experiments concerning the Centrifugal and Centripetal Forces of Solid and Fluid Bodies in Motion.

Experiments in order to estimate the Centrifugal Forces of Solid Bodies.

## MAGNETICKS.

8th Day. ATtractive and Directive Powers of Loadstones.

The Form or Position of Filings of Iron at the Poles and Equator of a Loadstone.

Magnetick Power acts thro' all Bodies but Iron.

The Attraction of different, and Repulse of corresponding Poles.

The manner of touching and untouching of Needles.

The Law of Magnetick Attraction discover'd.

9th—The Phænomena of *Terrella*, or Spherical Loadstones.

The Direction of Magnetick Needles on the Surfaces of *Terrella* nearly towards the Poles.

Their Variation *East* and *West*.

The Inclinatory or Dipping-Needle, with the Law of the Alteration of that Inclination on the Surface of a *Terrella*.

The Terrestrial Magnetism consider'd.

The Application of the Dipping-Needle to the Discovery of the Longitude and Latitude of Places by Land and Sea.

## OPTICKS.

10th Day.EXperiments to demonstrate, that in the Rays of Light the Angle of Incidence is equal to the Angle of Reflection in all Sorts of Surfaces.

The Method of tracing the reflected Rays of Light from Plain, Convex, Concave, and Cylindrical Superficies, with all their wonderful Properties and Uses, shew'd and explain'd.

11th—Sir *Is. Newton*'s Reflecting Telescope exhibited, and its Construction explained; together with some Specimens of its Uses in observing the Planets and Fixed Stars.

12th—Experiments to shew the Manner of Refraction.

The Sines of the Angles of Incidence and Refraction, shewn to be (at all Degrees of Incidence) in a constant Proportion to each other.

An Instrument to measure the Refraction of Fluids.

The Method of tracing the Refracted Rays of Light thro' Plain, Convex, and Concave Superficies.

13th—An artificial Eye, in which all the Coats and Humours are curiously represented.

The Dissection of the Eye.

The Explication of Vision by the naked Eye, deduced from Experiments.

14th—All the Effects, Properties, and Uses of Plain, Convex, and Concave Glasses, both single and combin'd in Telescopes and Microscopes, shew'd and explain'd.

Several Kinds of Microscopes and Telescopes, with the Manner of applying them to their respective Objects; together with a Specimen of the Uses of such Microscopes and Telescopes.

A Multiplying Glass.

The Magick Lanthorn.

15th—A particular *Apparatus* to manifest and measure the Refraction of Air.

The *Camera Obscura*.

The Theory of Light and Colours, as delivered by Sir *Isaac Newton*, demonstrated by several of his principal Experiments.

The Archbishop of *Spalato*'s Experiment, which discovered the Cause of the Rainbow.

Monsieur *Hugen*'s Experiments, which discover the Causes of Halo's, of the Mock Suns and Moons, and of inverted Rainbows.

Experiments concerning the blending and Production of Colours by Motion.

## HYDROSTATICKS.

16th Day.THAT Fluids gravitate *in proprio loco*, the upper Parts continually pressing upon the lower: That this Pressure is not only propagated Downwards, but even Upwards, and Sideways, according to all possible Directions; That a lighter Fluid may gravitate upon a heavier, and an heavier upon a lighter; That a Fluid may sustain a Body heavier *in Specie* than it self, and even raise it up; That a Fluid may detain a Body lighter *in Specie* than it self, and even depress it. A general Experiment to prove, that a competent Pressure of a Fluid may produce the remarkable Phænomena of the Torricellian Tube, the Pump, Syringe, Syphon, polished Plates, and other Effects of the like Nature.

17th—That Fluids press according to their perpendicular Altitudes, whatever be their Quantities, or however the containing Vessels be figured. The exact Estimate of all manner of Pressures. That the Velocity and Quantity of Fluids running out at a given Hole, is in the subduplicate Proportion of their perpendicular Altitudes. Several Sorts of Pumps. Of the sinking and floating of Bodies immers'd in Fluids; their relative Gravities and Levities; their Situations and Positions. The Phænomena of Glass Bubbles and Images accounted for.

18th—An Instrument to find out the Specifick Gravity of all Liquors. The Hydrostatical Balance explain'd, with the Methods of determining the Specifick Gravities of all Sorts of Bodies, whether Solid or Fluid, thereby. The Praxis of the Hydrostatical Balance,

whereby the Specifick Gravities of several particular Bodies are actually found out. Some Account of the various Uses of such Enquiries.

PNEUMATICKS *illustrated by Experiments for the most part Tubular, being such as were wont to be made before the Air-Pump was invented.*

19th Day.THE several Phænomena of the Torricellian Experiment exhibited and explained. Other Experiments of the like Nature, with Fluids variously combin'd. Several Sorts of Barometers, Thermometers, and Hygroscopes. The Pressure of the Air shewn by Experiment to be different at different Altitudes from the Surface of the Earth.

20th—The Density and Spring of the Air proved by several ways to be as the Force which compresses it, and reciprocally as the Spaces into which it is compress'd. From hence an Enquiry is made into the Limits and State of the Atmosphere.

21st—The Effects of the Weight and Spring of the Air in Syringes, Pumps, Siphons, polished Plates, Cupping-Glasses, Suction: Respiration explained by artificial Lungs; That the Air may be so disorder'd by a violent Impulse, as to require Time to recover its Strength and Elasticity again.

*The more known Properties of the Air established by the Air-Pump, and other Engines.*

22d Day.THE Air-Pump; the Instruments for Condensing and Transferring of Air; their Fabrick, Operation, and Gages explained.

23d—A Parcel of Air weighed in the Balance; its Specifick Gravity to that of Water determined thereby; an artificial Storm, shewing that high Winds may make the Barometer sink much and suddenly.

24th—The Weight, Pressure, and Spring of the Air prov'd several ways; by the Sense of Feeling; by breaking Glass Vials; the Phænomena of Bladders, Glass-bubbles, Fountains; the Gardiner's Watering-Pot; the Diving-Bell, *&c.*

25th—The Torricellian Tube *in Vacuo*; Quicksilver raised to the usual Height of the Weather-Glass, by the bare Spring of a little included Air;*Otto Gerick*'s Hemispheres; and that dense Air has the same Advantage over common Air, as that has over a *Vacuum*.

The Ebullition of Liquors *in Vacuo*; the Quantity of Air contain'd in them; the Sustentation of Fumes and Vapours; the Descent of Bodies *in Vacuo*.

*The more hidden Properties of the Air consider'd by the help of the like Engines.*

26th Day.THE Influence of the Air examin'd as to the Causes of Magnetism; the Elasticity of Springs; the Cohæsion of the Parts of Matter; the Sphericity of the Drops of Fluids; the Ascent of Liquors in capillary Tubes, and between Glass-Planes in the Curve of the Hyperbola, both by the Attractive and Repulsive Power of the Glass.

27th—The Influence of the Air, as to Sounds, Fire, and Flame; the Consumption of Fuel; the firing of Gunpowder; the Effects of rarified, condensed, and

burnt Air upon the Life of Animals.

28th—A Piece of Phosphorus *in Vacuo*; new Experiments concerning the Mercurial Phosphori; Experiments concerning the Electricity of Bodies.

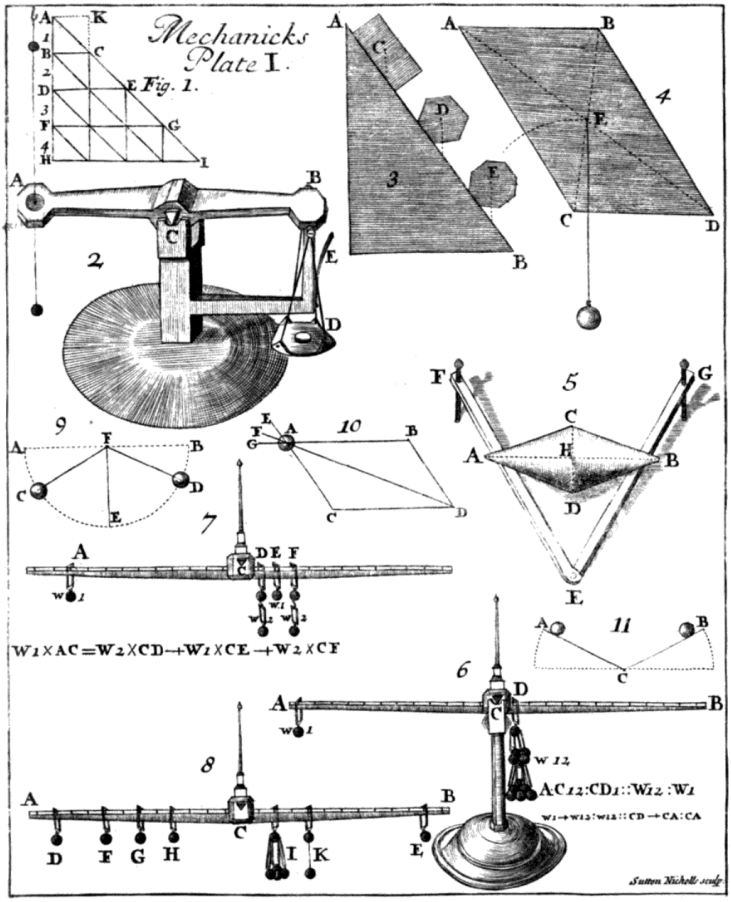
*Every* SUBSCRIBER *is to pay Three Guineas; One Guinea at the Time of Subscription, and the Remainder, the First Day of the* Course.

SUBSCRIPTIONS *are taken in at Mr.* Whiston*'s, in* Great Russel-Street*; and at Mr.* Hauksbee*'s, in* Crane-Court *in* Fleetstreet*; where the Course is to be perform'd.*

## ADVERTISEMENT.

AIR-Pumps, or Engines for Exhausting the Air from proper Vessels, with all their Appurtenances; whereby the various Properties and Uses of that Fluid are discover'd and demonstrated by undeniable Experiments. Engines for the Compression of the Air: Fountains, in which the Water, or other Liquor, is made to ascend by the Force of the Air's Spring. Syringes and Blow-Pipes, with Valves for Anatomical Injections. Hydrostatical Balances, for determining the Specifick Gravity of Fluids and Solids. The Engine and Glasses for the New Way of Cupping without Fire. Scarificators, which at once make either 10, 13, or 16 Incisions. Weather-Glasses of all Sorts, as Barometers, Thermometers, *&c.* Reflecting Telescopes, by which in so short a Length as Six Feet, all that has hitherto been discovered in the Heavens (by the longest Telescopes of the common Construction) may be observed.

**ALL** the above-mention'd Instruments, according to their Latest and Best Improvements, are made and sold by FRANCIS HAUKSBEE, in *Crane-Court* in *Fleetstreet,London*.


Mechanicks
Plate I.
Fig. 1.
2
3
4
5
6
7
8
9
10
11
W1 X AC = W2 X CD → W1 X CE → W2 X CF
AC12 : CD1 :: W12 : W1
W1 → W12 : W12 :: CD → CA : CA
Sutton Nicholls sculp.

1

## MECHANICKS.

### An Explication of the First PLATE.

FIGURE. 1. This belongs to *Galilæo's* famous Demonstration of the Velocities and Times of Bodies descending by an uniform Force, such is that of Gravity here below: And shews that they will ever fall in equal Times, 1, 2, 3, 4, *&c.* according to the odd Numbers, 1, 3, 5, 7, *&c.* or the Trapezia B C D E, D E F G, F G H I, *&c.* and by consequence, that their Velocity will increase uniformly in Proportion to the Lines B C, D E, F G, H I, *&c.* or to the Times of Descent. And that the entire Lines of their Descent will be as the Triangles A B C, A D E, A F G, A H I, *&c.* or as the Squares of those Times, 1, 4, 9, 16, *&c.*

*Fig. 2.* This is a strong Balance for an Experiment to prove the former Proposition, by shewing that any Bullet or Ball, when it falls from four Times the Height, has twice, from nine Times the Height has thrice its former Velocity or Force; and will accordingly raise a double or triple Weight in the opposite Scale, to the same Height, and no more; and so for ever.

*Fig. 3.* This shews how Bodies upon an inclin'd Plane will *slide*, if the Perpendicular through the Center of their Gravity falls *within*; and will *rowl*, if that Perpendicular fall *without* their common Section.

*Fig. 4.* This shews that an oblique Body will stand, if the Perpendicular through its Center of Gravity cut

the Base; and that it will fall, if it cut not the Base: As accordingly we stand when the Perpendicular through the Center of Gravity of our Bodies falls within the Base of our Feet; and we are ready to tumble when it falls without the same.

*Fig. 5.* This is a Conick Rhombus, or two right Cones, with a common Base, rowling upwards to Appearance, or from E towards F and G: Which Points are set higher by Screws than the Point E. But so that the Declivity from C towards A and B is greater than the Aclivity from E towards F and G. Whence it is plain, that the Axis and Center of Gravity do really descend all the Way.

*Fig. 6.* Is a Balance, in an horizontal Posture, with weights at Distances from the Center reciprocally proportional to themselves; and thereby *in Æquilibrio*.

*Fig. 7.* and *8.* Are two other Balances in an horizontal Posture, with several Weights on each Side, so adjusted, that the Sum of the Motion on one Side, made by multiplying each Weight by its Velocity, or Distance from the Center, and so added together, is equal to that on the other: And so all still *in Æquilibrio*.

*Fig. 9.* Belongs to the Laws of Motion, in the Collision of Bodies to be tried with Pendulums, or otherwise, both as to Elastical Bodies, and to those which are not Elastical.

*Fig. 10.* Belongs to that Famous and Fundamental Law of Motion, that if a Body be impell'd by two distinct Forces in an Proportion, it will in the same

Time move along the Diagonal of that Parallelogram, whose Sides would have been describ'd by those distinct Forces; and that accordingly all Lines, in which Bodies move, be consider'd as Diagonals of Parallelograms; and so may be resolved into those two Forces, which would have been necessary for the distinct Motions along their two Sides respectively: Which grand Law includes the Composition and Resolution of all Motions whatsoever, and is of the greatest Use in Mechanical and Natural Philosophy.

*Fig. 11.* Are two polite Plains inclined to one another, to shew that the Descent down one Plain will elevate a Ball almost to an equal Height on the other.

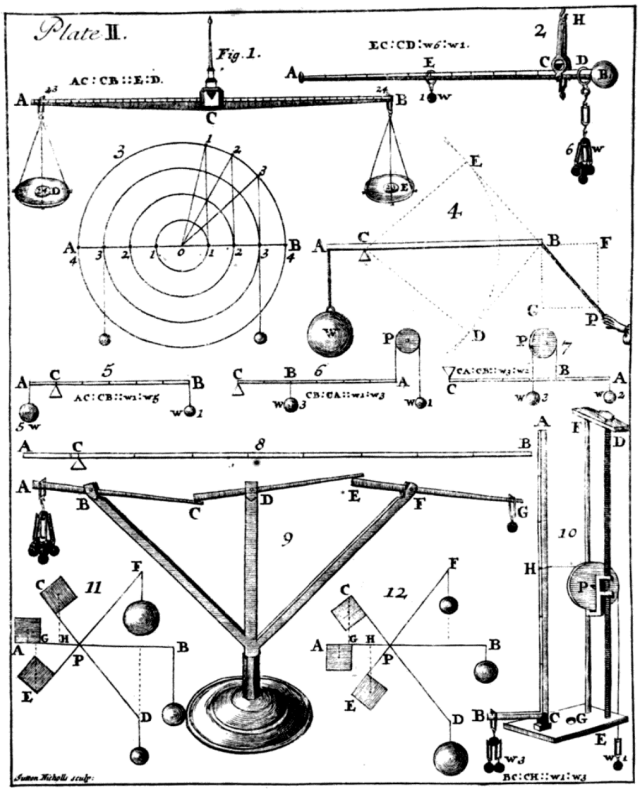


Plate II.
Fig. 1.
AC : CB :: E : D.
EC : CD : w6 : w1.
2
3
4
5
6
7
8
9
10
11
12
AC : CB :: w1 : w6
CB : CA :: w1 : w3
BC : CH :: w1 : w3
Sutton Nicholls sculp.

2

## *MECHANICKS.*

### An Explication of the Second PLATE.

FIGURE 1. Is the deceitful Balance; which yet is *in Æquilibrio* because the Weights 23 and 24 are reciprocally proportional to their Distances from the Center of Motion. Now this Cheat is easily discover'd by changing the Position of the Weights, and putting each of them into the other Scale, which will then be very unequal, or nearly as 11 to 12.

*Fig. 2.* Is that sort of Balance which is called a Stiliard, and of frequent Use among us. It is only a Common Balance, with Weights at Distances from the Center of Motion reciprocally Proportionable to themselves: Only here the Length of Part of the Beam is compensated by a large Ball or Weight B, fixed to the shorter Beam; and one Weight as w removed along equal Divisions is made use of to weigh several others, as 6 w. *&c.*

*Fig. 3.* Is design'd to shew how any Force is diminish'd by its Obliquity; and that a Weight hung obliquely at 3, 2, 1, in the Circumference of a Circle or Wheel, is of no more Efficacy, as to the turning of the Wheel round, than if it were hung perpendicularly at the corresponding Points 3, 2, 1, in the Semidiameter of the same Circle.

*Fig. 4.* Is the Demonstration of the former Case, by shewing that in those Circumstances the Force P B is resolved into two B F and B G, of which B F pulls

directly from the Center, and is of no Use to the turning the Wheel round: And so all the remaining Force is represented by the perpendicular Force B G, which is wholly spent in turning it round. So that as B P is to B G, so is the whole oblique Force, to the real or direct Force: Or so, in the similar Triangle B E C, is B C the whole oblique Radius, to C E the Perpendicular: Or so in the foregoing Figure is O 1, O 2, O 3, the common Hypotenuse or entire Radius, to O 1, O 2, O 3, the Bases or shorter Radij, where the String cuts the entire Radius perpendicularly.

*Fig. 5.* Is the first Sort of Lever, where C the Prop is between the Resistance to be overcome, or Weight to be moved 5 w, and w 1 the Power or Weight to move the other by: And is so like the Case of the Balance or Stiliard, that it needs no particular Explication. A Crow of Iron is of this Sort.

*Fig. 6.* Is the second Sort of Lever, where the Resistance to be overcome, or Weight to be moved w 3, is between the Prop C and the Point A, to which by the means of the Pulley P, the Power or Weight to move the other by, is applied. Bakers Knives for cutting Bread are commonly of this Sort.

*Fig. 7.* Is the third Sort of Lever, where the Resistance to be overcome, or Weight to be moved, w 2 is at one End, the Prop at the other, and the Power or Weight w 3 between them. A Ladder lifted up by the Middle, in order to be rear'd, where one End is fixed, is of this Sort. Only the Force being in this Case nearer the Prop than the Resistance to be overcome, or Weight to be moved, this Sort of Lever diminishes Force instead of increasing it, and is therefore of little

Use.

*Fig. 8.* Is a common Lever of the first Sort, with its Prop and equal Divisions, fit to be used as the Stiliard.

*Fig. 9.* Is a compound Lever of the first Sort, as long as the single one just above it, where a Weight at G, by being doubled three several Times, will raise eight Times its own Weight at A, as well as the other does it at once. This last is therefore of the same Force as the former, and no more; and by being compounded, is less considerable than the other.

*N. B.* Had the Proportion in the Compound Lever, *Fig. 9.* been otherwise, as suppose the Part B C on one Side of the Prop B three Times the Length of A B on the other Side, and the same in the other two Levers C E and E G; then the Weight G being but the 27th Part of the Weight at A, will be in *Æquilibrio* with it.

*Fig. 10.* Is a bended Lever of the first Sort, where C the Prop is at an Angle, and the Force is increas'd with C H, the Distance of the Weight w 1, which by the means of the Pulley P, is applied to the longer Part of the Lever; and in this Lever, the Power is to the Resistance reciprocally as their Distances. An Hammer drawing out a Nail is such a bended Lever.

*Fig. 11, 12.* Shew that Levers or Balances that are even when horizontal, may be uneven in other Positions; that is, too light when the Center of Gravity of one Weight is fix'd to the Lever or Balance above, and it is elevated; or below, and depress'd: Because the Perpendicular cuts the horizontal Line too near the Center in these Cases.

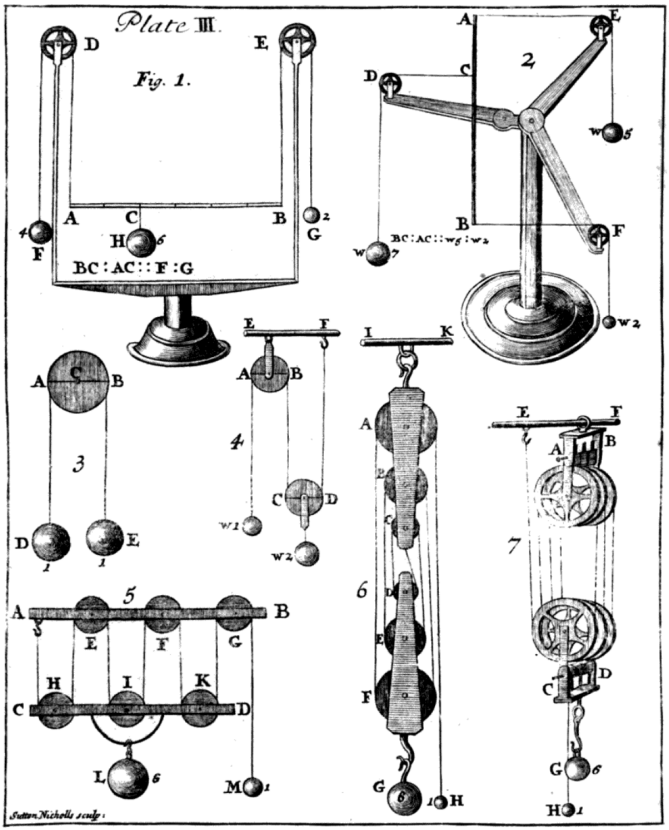


Plate III.
Fig. 1.
BC : AC :: F : G
Sutton Nicholls sculp.

## *MECHANICKS.*

### An Explication of the Third PLATE.

FIGURE 1. Is a Sort of Compound Lever of the second Kind, where the Weight H 6 is unequally born by the Weights F 4 and G 2, which are reciprocally proportional to the Distances C B and C A; and are accordingly *in Æquilibrio*. Whence we see how two Men may bear unequal Parts of the same Weight, in Proportion to their Nearness thereto.

*Fig. 2.* Is another Engine of the same Nature with the former; where the Lines D C, A E, B F, and the Lever A B, are parallel to the Horizon; but the Lines on which the Weights hang D w 7, E w 5, F w 2, are perpendicular thereto; and here a Force or Weight pulling at the Point C sustains the unequal Weights w 5 and w 2 *in Æquilibrio*: Provided the Distances C B and C A be reciprocally proportional to those Weights. Whence we learn, how Horses of unequal Strength may be duly fitted to preserve equally in their Labour; *viz.* by taking care that the Beam by which they both draw a Weight or Waggon, may be divided at the Point of Traction as C, in reciprocal Proportion to such their Strength.

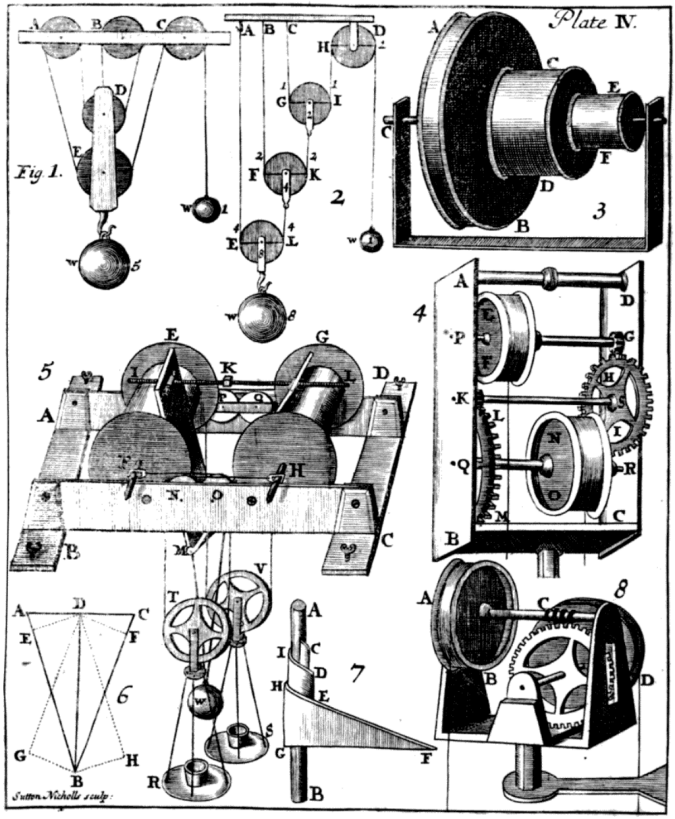
*Fig. 3.* A B is an upper Pulley, of no direct Advantage, but for Readiness of the Motion, as increasing not the Power at all; equal Weights being ever required to raise others.

*Fig. 4.* Is an upper and an under Pulley connect-

ed together; where the upper being of no Efficacy, the lower does however double the Force, as is ever the Case in such Pulleys.

*Fig. 5.* Is a Compound Pulley of three upper and three under Pulleys, all communicating together; where therefore the whole Weight is divided among 6 Strings; and so 1 Pound balances 6 Pound. The last String B M 1, as passing beyond the last upper Pulley, not being here to be reckon'd of any Consequence.

*Fig. 6.* and *7.* These are Boxes of the same Number of upper and under Pulleys with the former; only in other Positions, and depend on the same Principle entirely.




4

## *MECHANICKS.*

### An Explication of the Fourth PLATE.

FIGURE 1. Is a System of Pulleys connected together, whereby the Force is increased by Addition in Proportion to the Number of Cords; so that one Pound, w 1, sustains five Pounds, w 5, as must happen from the Equality of the stretching of the whole Cord, and the consequent Division of the whole Weight into five equal Parts, as equally supported by them all.

*Fig. 2.* Is a System of Pulleys not connected together, whereby the Force is increas'd, for every lower Pulley; according to the Numbers, 2, 4, 8, in a double Proportion; because every lower Pulley doubles the Force of the former; as is evident at the first Sight; since the Velocity of Ascent or Descent of the greater Weight is every Time but half so great as before.

*Fig. 3.* Is the Axis in Peritrochio; or Wheel, with its Axel; where any Weight or Force applied round E F, or C D, or A B, has just so much greater Power to move the Wheel, or entire Machine about the Axis, as the Velocity or Distance from the Geometrical Axis it self is greater. Nor is there any farther Difficulty in this plain Engine.

*Fig. 4.* This is only a Train of Wheel-work; which by Composition of Wheels vastly increases the Force. Thus suppose the Diameter of the Barrel E F, be ten times the Diameter of the Pinion G: And the Diam-

eter, or Number of equal Teeth in G, be one tenth of the Diameter, or Number of equal Teeth in H I: And the Diameter and Velocity of the Teeth in H I, be ten times the Diameter and Velocity of the Pinion K; and the Diameter or Number of equal Teeth in K, be one tenth of the Diameter, or Number of equal Teeth in L M; And that the Barrel N O, be of the same Diameter with the Wheel L M. Then a Weight on the Barrel E F will balance a Weight one hundred times as heavy upon the Barrel N O; which is done by its moving an hundred Times as swift as the other. For the Velocity in the first Barrel E F, to that of its Pinion G, is as ten to one; and that in the Wheel H I, to that in its Pinion K, is also as ten to one. While the Velocities at each Wheel, and its corresponding Pinion in the other Wheel, as well as at the Wheel L M, and its Barrel N O, are equal.

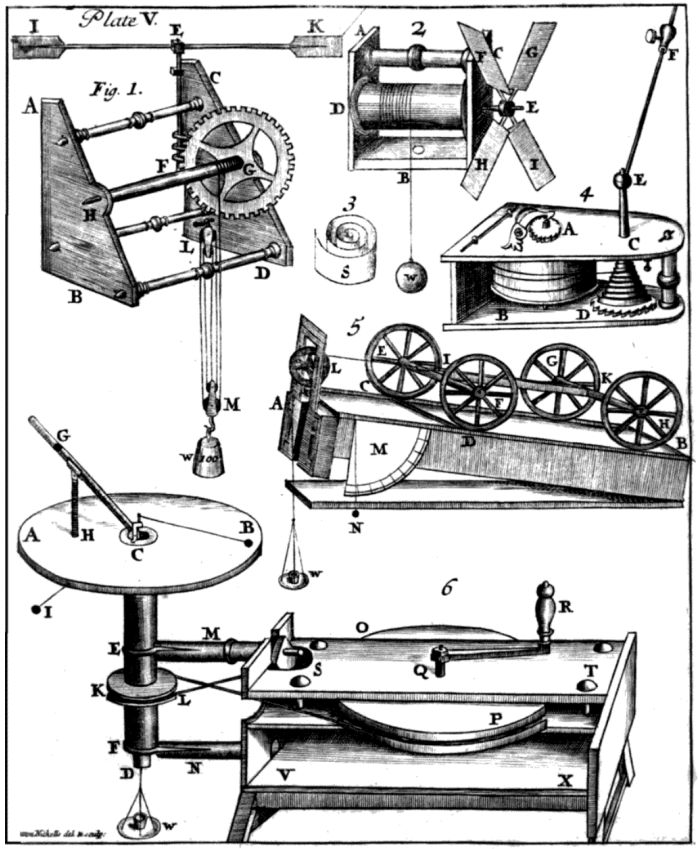
*Fig. 5.* Is a compound Engine, to prove that in a Wedge, as E M G, depress'd by a Weight w, or by its own Weight, or by a Stroke, the Force is diminished in Proportion to the Sine of its Aperture, compar'd with the Line of its Depth: So that when the former Sine is double or triple, *&c.* the Force is diminished one half, or one third, *&c.* This is here prov'd by the Wedges separating two Cylinders, which are drawn together by other Weights, in the Scales R and S beneath, when its Sides are screw'd nearer or farther off, to adjust their Distance to those Weights perpetually.

*Fig. 6.* Is a Wedge by it self, where the Force is increas'd in the Proportion of the Sines of the Angles of Aperture, D F and D E, to the Radius D B; or is resolv'd into two Forces, the one perpendicular, and

the other parallel to the Plain of the Tree or Timber it is to reeve: And this because the Velocity downward is ever to the Velocity side-ways in the Proportion of D B to D F and D E, or to 2 D F. *i. e.* by the Similitude of Triangles, as A B or C B to A C.

*Fig. 7.* Is a Paper Wedge, H F G coil'd round a Cylinder, and so representing a Screw; and shews that its Force must be increas'd in Proportion to the Progress along its Cylinder, when it is compar'd with the Circumferences on the same Cylindrical Surface, or as H F to H G.

*Fig. 8.* Is a compound Engine to explain and measure the Power of the Screw: from whence it appears, that the Force of Screws is reciprocally proportional to the Distance of the *Helix*'s or Threads which compose them.




5

## *MECHANICKS.*

### An Explication of the Fifth PLATE.

FIGURE 1. Is a Compound Engine in which all the several Mechanical Powers are combin'd: as the Wheel and Axle G H: The Balance or Lever I K: the Screw F; which includes the Wedge: and the Pulley L M. The entire Force of this Engine is to be computed by compounding the separate Forces together.

*Fig. 2.* Is a Windmill; whose Force is here represented, by its raising a Weight on a Barrel. The Wind is supposed to blow parallel to the Axis, from E towards D; its several Sails have their Plains nearly 45 Degrees oblique to the Plain through the middle of those Sails: Two of them inclining, and two reclining. By this Means the Wind falling at about 45 Degrees obliquity on the Plain of each Sail; the Breadth of each Sail is a Diagonal of a square, one of whose Sides is parallel to the Direction of the circular Motion, and has its full Force; and the other is perpendicular thereto, and so has no Effect as to that circular Motion at all. And as much as the Side of a Square is lesser than the Diagonal, so much of the whole Quantity of the Wind is lost on every single Sail. But then each Pair along the same Line, by the different Situation of those Sails, agreeing in the same Motion, the whole united Quantity is more than the single Quantity upon one equal Sail directly expos'd to the same Wind, as much as two Sides of a Square are greater than the Diagonal.

But this without the Consideration of the weakning of the Force of the Wind by the Obliquity of Incidence; which alters the former Proportion: for this also diminishing the Force in the same Proportion with the former Diminution of the Quantity of the Wind, the whole Diminution will ever be as the Squares of that Quantity; or as the Squares of the Sines of the Angles of Incidence: wherefore in this Case of Four oblique Sails of 45 Degrees will be equivalent to Two direct ones.

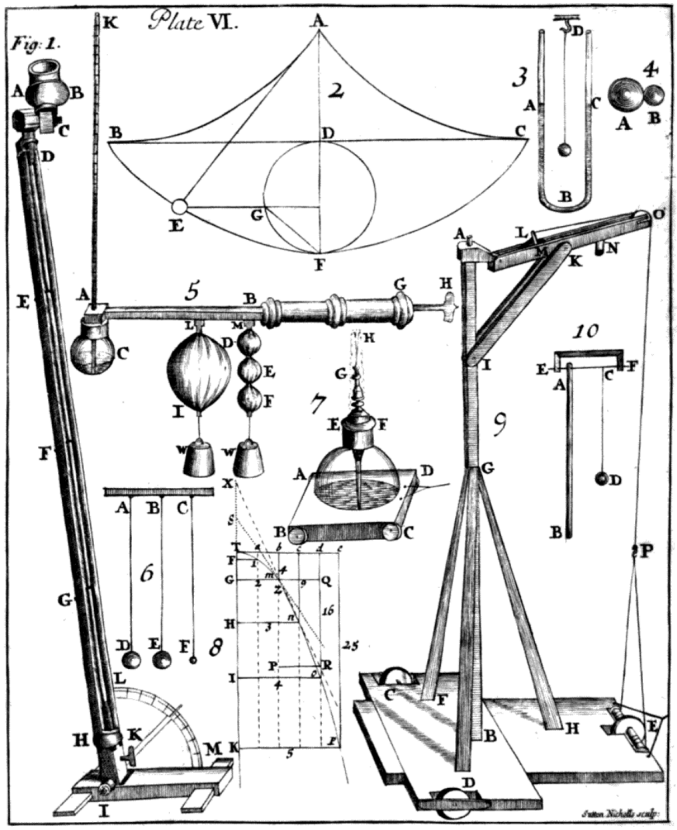
*Fig. 3.* Is the elastical spiral Spring of a Watch, out of its Box, and unwinding it self more weakly, as it is less restrained.

*Fig. 4.* Is the same Spring in its Barrel A B join'd by a Chain to its Fusee C D, or spiral Line about a Cone, which Cone has the Semidiameter or Distance from its Axis in the very same Proportion, greater as the Spring is weaker, and lesser as the Spring is stronger: that so the absolute Force on the Wheels of the Watch may be ever the same, for the exact Equality of their Motion in all Cases.

*Fig. 5.* Is an Imitation of a Waggon or Coach, with its fore Wheels E F, either equal (as here,) or else lesser, or greater, than the hinder G H; to be drawn by a Weight w in the Scale, either upon an Horizontal, or upon an Inclined Plain A B, and to get over any Obstacle as C D: The Quadrant M, and Bullet N, are to shew the Quantity of the Elevation of that Plain, for the Tryal of Experiments relating to all such Sort of Vehicles.

*Fig. 6.* Is a strong Machine, with a Wheel O P, and

its Winch R, and String O P L K, its lesser Barrel K L, circular Table A B, Scale with a Weight w, suspended by a String that comes through the hollow Axis C D, and oblique Tube G C, in which Mercury or a Bullet is included; its Screw H; its Balls I and B, and their Strings; To shew that Motion once begun always continues, till some other Cause stops it: That absolute and respective Motion are entirely different: And to shew withal the Endeavour of Bodies that move circularly to recede from the Center of their Motion, on inclined, as well as horizontal Plains, and that in the same Circle in a duplicate Proportion to their Velocity.




6

## *MECHANICKS.*

### An Explication of the Sixth Plate.

FIGURE 1. Is an Instrument to shew the various Parabola's that are made by Projectils, and particularly the Truth of the several Rules in the Art of Gunnery. Wherein A B is a Tunnel full of Quicksilver, D K is a Glass Tube, let into a Groove or Frame of Wood for its Support, and at K is a fine Stem, accommodated to the Arch of a Quadrant L M, and turning upon its Center, to direct the projected Quicksilver to any Angle; while the Tube's perpendicular Altitude, or the Force that produces the Projection, is either the same, or altered by a different Inclination at Pleasure, according to the Nature of the several Experiments.

*Fig. 2.* Is a Cycloid with its equal Sides A B, A C, and pendulous Body E, oscillating therein. And, *Note*, That by the Make of the Figure, the Line B C is equal to the Circumference of the Circle D G F, by which it was describ'd; that the Length of the Cycloid it self is four times that Circle's Diameter; that every Part of it from F the *Vertex* is still double to the Chord of the Correspondent circular Arch G F; that its included Area B D C F, is Three times the Area of the former Circle; that the Force upon the Pendulum at any Point E, is exactly proportional to the Distance along the Cycloid of the Point from the *Vertex*, as E F; and that therefore the Time of every Oscillation, in all Angles whatsoever, is always equal.

*Fig. 3.* A C B is a Syphon with Quicksilver from A to C, and a Pendulum of half that Length; to shew here also that the Force is as the Line to be describ'd, and that by Consequence the Vibrations in the Syphon are all equal: as also to shew that they are equal to those of a Pendulum, of half the same Length: As is plain from the former Case of the Cycloid, where the Length of the Pendulum is half that of the Cycloid in which the Body moves.

*Fig. 4.* A B are two Spheres, to denote the several Laws of Motion in the Collision of Bodies, whether Elastical or not Elastical, to be tried in the Cycloid, or in a Circle, with proper Corrections: Which Experiments yet are most of them too difficult for such a Course as this is.

*Fig. 5.* Is an Instrument to explain muscular Motion; supposing the Muscles to be some way like a String of Bladders; by shewing that a smaller Quantity of an elastical Fluid may equally raise equal Weights with a larger; and to shew exactly what Quantity is necessary for any particular Effect. For thus will the lesser Quantity of Air, (measured in both Cases by the Gage C A K, as condens'd by the Syringe H A) equally raise an equal Weight to the same Height by the lesser three Bladders, that the greater Quantity raises the same by the one larger Bladder.

*Fig. 6.* Are several Pendulums of several Sorts of Matter, heavy and light; where the Centers of Suspension and Oscillation are equally distant, and the Times of those Oscillations are all equal. This also hints the other remarkable Phænomena of Pendulums; *viz.* that the Semicircular and Cycloidal Times

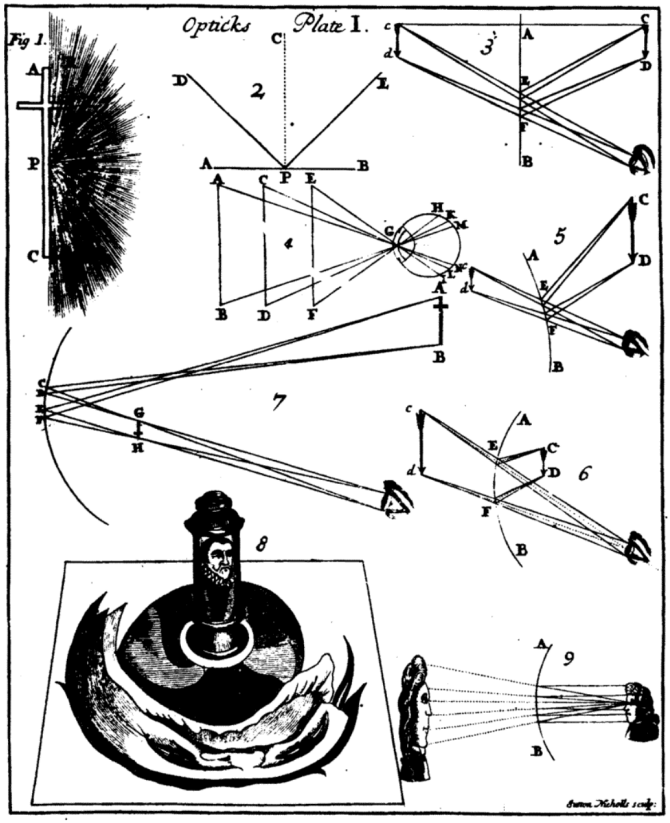
of Oscillation are to each other as 34 to 29: That in both the Length of the Strings of Pendulums are in a duplicate Proportion to their Times of Oscillation; and that the Heights of Roofs, *&c.* may be found from the Times of the Oscillations of Pendulous Bodies fixed to them, on the known Hypothesis that a Pendulum of 39.2 Inches vibrates in one Second of Time.

*Fig. 7.* Is a Fountain running on Wheels, and made by Air condens'd on the Surface of Quicksilver, and so forcing the Quicksilver to ascend through the Pipe G: And is to shew that the Lines of Projectils, or other Bodies, are not alter'd by the common Motion of the whole Instrument or Floor on which they are plac'd; and that all Motions on the Earth, if it move, will be the same as if it stand still.

*Fig. 8.* Is a Parabola with the several Lines belonging to it, in order to demonstrate the Doctrine of Projectils; and particularly the Art of Gunnery.

*Fig. 9.* Is an Engine moving on Wheels, that lets a Ball fall down from a Groove through a Hole, as it is in Motion; to shew that it will then fall on the same Point of the Frame that it falls upon when it is at rest; as does a Stone let fall from the Top of the Mast of a Ship under Sail: and that all respective Motions on the Earth must be the very same, while it self moves as if it were at rest.

*Fig. 10.* Is a Cylindrical Iron A B, swinging on a Pin E F, in the very same time that a pendulous Body D of two thirds of its Length C D does; to shew that two thirds is the Center of Oscillation or Percussion in all such prismatick or cylindrical Bodies.




7

## OPTICKS.

### An Explication of the First PLATE.

FIGURE 1. Represents the Foundation of Vision, and of all Opticks whatsoever, by exhibiting to the Eye a Specimen how the Rays of Light do as well originally, as after Reflection or Refraction, spread themselves in right Lines from each Point in every visible Object, as P, to each other Point, as R, R, R, R, R, every way, to be receiv'd by the Eye in any direct Position whatsoever.

*Fig. 2.* Represents the known Law of Reflection; that the Angle of Incidence C P D, is equal to that of Reflection C P E, or that the Angle of Inclination D P A is equal to the other E P B.

*Fig. 3.* Shews the Reason why a plain Looking-Glass, as A E F B, exhibits the Object C D by the Image *c d*, which is equal to C D, and equidistant from the Glass A *c* = A C: And in an erect Posture; all depending only on the Equality of the Triangles, whose Vertices are C *c* : D *d*, and have their common Bases below E and above F, which Glass by forming the same Image *c d*, so to the Eye, as if the real Object C D was at *c d*, must needs shew that Picture in the Place assign'd, without any Inequality of Distance or Magnitude, or any Inversion.

*Fig. 4.* Shews the Reason why the same or equal Object, as A B, C D, E F, appears larger when it is near-

er, and smaller when farther off: *viz.* on account of the Inequality of the Angles A G B, or M G N, and C G D, or K G L, and E G F or H G I, and the consequent Inequality of the Pictures made by the Rays at the Bottom of the Eye.

*Fig. 5.* Shews the Reason why a Convex Looking-Glass, as A E F B, exhibits Object C D by the Image *c d*, both nearer to the Glass, and lesser than it self; but still in an erect Posture. All depending only on the different Bend of the Circle between E and its lower Point, between F and its upper Point; which cannot make the Angles of Reflection or Inclination equal, as they must needs be in all such Reflections, without making the Vertices of the Angles, as *c* and *d*, nearer the Glass than C and D: And so the apparent Picture or Diameter *c d* lesser than that of the Object C D, though without any Inversion.

*Fig. 6.* Shews the Reason why a Concave Glass, as A E F B, exhibits an Object plac'd nearer the Glass than the Center, as C D by the Image *c d*, remoter from the Glass, and larger than it self, *viz.* for Reasons just contrary to those under the fifth Figure foregoing.

*Fig. 7.* Shews the Reason why a Concave Glass, as C D E F, exhibits an Object, if it be plac'd remoter than the Center, as A B, inverted, and at different Distances between the Eye and the Glass; according to the Length or Shortness of its own Distance, as B C or A D, *viz.* Because the Rays from the same Point still cross one another, as at G and H, before they fall upon the Eye; and so by forming an inverted Image make it impossible for the Eye to see the Object in any other Position than that the Image has; which Image indeed

it self is the only proper Object of the Eye, in all such Cases whatsoever.

*Fig. 8.* Is a Picture in Confusion; but rectified by a Convex Cylinder, and thereby brought into exact Order again.

*Fig. 9.* Represents an Image in a Cylindrical Concave Surface, when the Eye is in a Plain perpendicular to its Axis; so that lengthways it is as a Plain, and breadthways as a Concave *Speculum*: Which therefore makes the Picture longer, but not wider. The contrary will happen in a Convex*Speculum*, which will make it shorter but not narrower, for the like Reason.

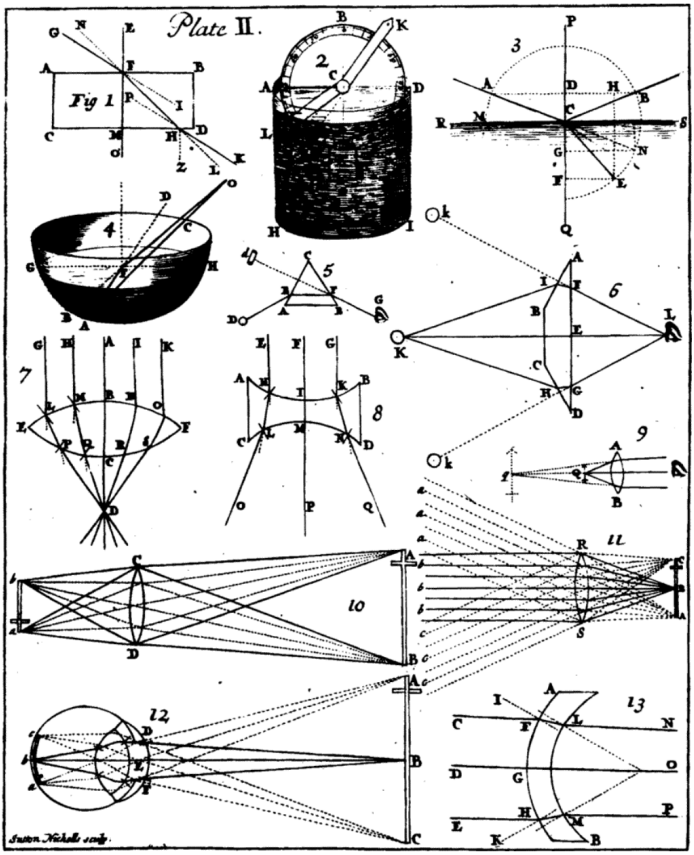


Plate II.
Fig 1
2
3
4
5
6
7
8
9
10
11
12
13
Sutton Nicholls sculp.

## *OPTICKS*.

### An Explication of the Second PLATE.

FIGURE 1. Shews that an Object, as K, seen through a plain Glass, whose Sides A B, C D, are parallel, by the Eye at G, appears out of its true Place; and this so much the more as the Glass is thicker: While at the same time the two Surfaces do exactly balance each other's Refraction, and make the two Rays H K, G F exactly parallel.

*Fig. 2.* Exhibits a plain Method of measuring the Refraction of Fluids at all Angles, and of proving thereby that it is always in one fixed Proportion of the Sines, as the next Figure will explain it. For if the moveable Rule K C L, with its measuring Circle A B D E fix'd by the Prop E, to a heavy Pedestal F G, in a large Glass A H I D, be so far immers'd in the Fluid, that the Center C may be in the Surface of the Fluid, and one of its Legs C L be so far bent from a rectilinear Position, that the Refraction of the Fluid can just make it appear as if it were in a strait Line, the Angle B C K, or its equal M C E, is the Angle of Incidence: And L C E the Angle of Refraction: And L C M the Difference, or the refracted Angle.

*Fig. 3.* Is for the Illustration of the former Proposition, and shews the Sines afore-mentioned; as A D or G N (for they are suppos'd equal, and the Line A C N one strait Line,) is the Sine of the Angle of Incidence,

and F E the Sine of the Angle of Refraction, which Sines do in the same Fluid at all Angles bear one and the same Proportion to each other; till at last, if the Refraction be out of a thick Medium into a thin one, and makes the second Sine equal to the Radius, that Ray cannot emerge at all, but will be reflected back by the Surface into the same Medium whence it came, along the Line C R.

*Fig. 4.* Is a Bason of Water, or other Fluid; to shew the common Experiment of Refraction; where a Shilling, or other Object at A, (which is so plac'd that it cannot be seen by the Eye at O, the Side of the Bason C interposing) is readily seen there, as soon as the Water or other Fluid is put in to the same Bason, and appears to be remov'd to the Point B.

*Fig. 5.* Is the Alteration of a round white Object D, as seen through a Triangular Glass Prism A B C, by the Eye at G, where the double Refraction of the Glass at E and F makes the Object appear at *d*; and that as an oblong colour'd Image; wherein the upper Part is made by the violet Rays, which are most refrangible; and the lower by the red Rays, which are least so; and the intermediate Parts by those that are refrangible in a mean Degree; after the Order of the Colours of the Rainbow.

*Fig. 6.* Shews the Nature of a multiplying Glass A D, and its Plains A B, B C, C D, *&c.* and the Reason why the different Refraction of every oblique Plain, as A B, C D, *&c.* exhibits the same Object K as a different Object k, k, *&c.* according to the Number of the oblique Plains: While the direct Plain B C shews it still in its own Place: And while the Convolution of the

Glass on the Axis K L removes all the oblique Images, but does not remove the direct one, on Account of the Change of the Position of those oblique Plains, and of the unchanged Position of the direct Plain.

*Fig. 7.* Shews the Effect of the Lens, or double Convex Glass, in gathering parallel Rays, as G L, H M, A B, I N, K O, *&c.* towards a Point, as D; because, as in the Case of the Prism above, the Refraction *to* the perpendicular in the Entrance, and *from* it in the Exit of those Rays, do still, by the different Position of that Perpendicular, conspire to unite the same Rays.

*Fig. 8.* Shews the contrary Effect of the double Concave Glass, in scattering the parallel Rays; and that exactly on the like Account; and so this needs no new Explication.

*Fig. 9.* Shews the Reason why a Lens, or double Convex, shews a near Object at Q, as more remote at *q*, because it refracts it so that the Rays from the same Point meet more backward than before: And why it shews the same Object larger also: Which must needs be, because every Point in the Object appearing so much more backward, and yet in the same apparent Angle, its Length and Breadth must every where be proportionably enlarg'd.

*Fig. 10.* Shews how such a Lens inverts Objects, as A, B, *b a*, which it does on Account of the Intersection of the Rays from each Point, in or near the Lens it self: Which necessarily infers such an Alteration: just as the Images of all Objects are in the Eye in an inverted Position, on the like Account.

*Fig. 11.* Shews how a Lens does so refract the Rays from every Point of an Object, that is in its Focus C, and B, and A, that the Rays from each of those Points do become parallel afterward; and also how parallel Rays of different Positions are gather'd in that Focus.

*Fig. 12.* Is the Nature of direct Vision by the Eye, in some Conformity to the 10th Figure: only in this Case the Crystalline Humour is the Lens.

*Fig. 13.* Is the Case of a Concavo-convex Glass, with its parallel Surfaces, as in *Fig. 1*.

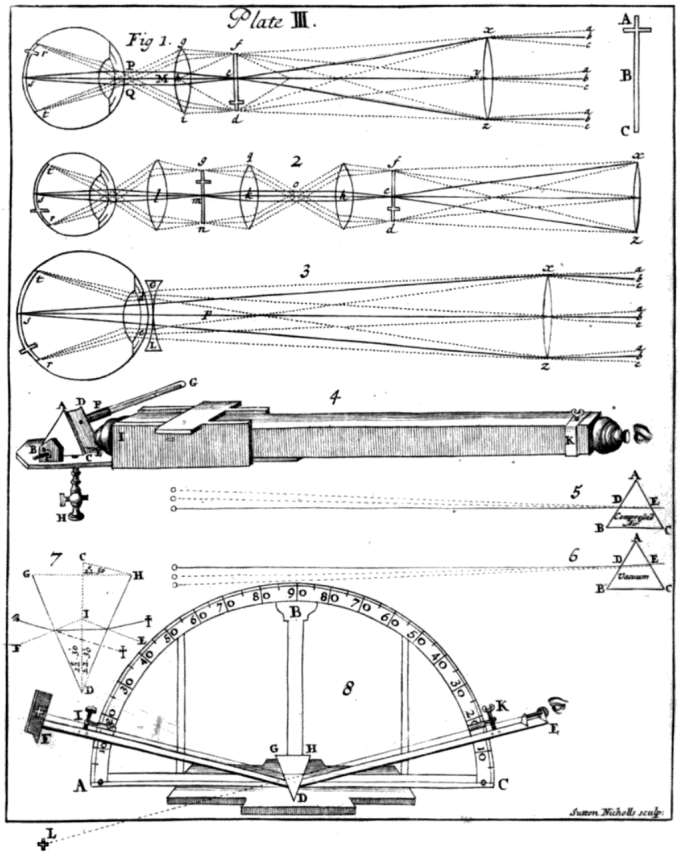


Plate III.
Fig 1.
A
B
C
2
3
4
5
6
7
8
Evacuated
Vacuum
Sutton Nicholls sculp.

9

## *OPTICKS.*

### An Explication of the Third PLATE.

FIGURE 1. Is a Telescope, with two Convex Glasses, the one towards the Object and the Segments of a great Sphere, the other near the Eye, the Segments of a small Sphere *g h i*, and they are to be so placed that the distinct Base or Image may, by the Collection of the Rays, be in the common Focus of both the Glasses *f e d*. By these two Glasses the parallel Rays, or those nearly so, as proceeding from the same Point of the Object A B C, (which is to be suppos'd considerably remote) are made to meet in the intermediate Image *f e d*, at *f*, and *e*, and *d*; and again at the Bottom of the Eye, at *r*, and *s*, and *t*; but in an erect Position; and therefore so as to shew the Object inverted.

*Fig. 2.* Is a Telescope with four Convex Glasses, the one towards the Object, and three nearer the Eye: Whose Images are made in the common Focus of two Glasses, as before. This is like the former; but only that two of the Eye Glasses serve merely to reinvert, or to erect the Image, that so it may be inverted at the Bottom of the Eye; and therefore may shew the Object in its true or erect Position.

*Fig. 3.* Is a Telescope, with a Convex Object Glass, and a Concave Eye Glass; which last, by scattering the Rays, as if they came from a nearer Point, makes the Image inverted in the Bottom of the Eye, and there-

fore shews the Object in its true or erect Position. Only this takes in but a small Part of an Object, an so is less used than the two former Telescopes.

*Fig. 4.* Is a Telescope with a Triangular Prism D B in its Axis; and that Prism's Gage F G for the Demonstration of the Refraction out of *Vacuum*into Air, and out of thinner Air into thicker; and both by the Means of an Object seen through the Prism, as well when the Air is condensed, as when it is exhausted. Where in the first Case the Object is seen higher, and in the other lower than in its natural Situation; as the two following Figures demonstrate.

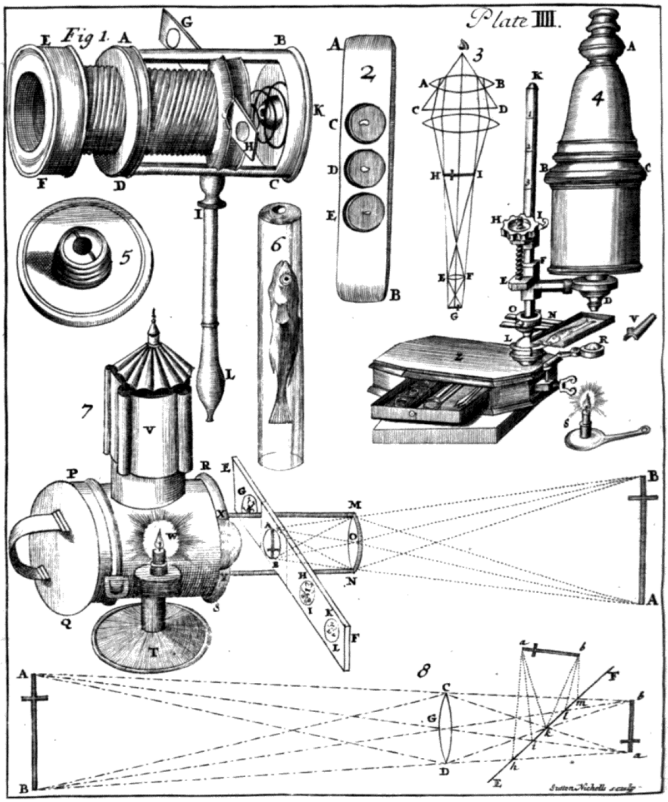
*Fig. 5.* Shews how the Object or Circle which was low at first, is to Appearance *rais'd* as it passes through condens'd Air; by being refracted towards the perpendicular, in its Ingress into a Glass Prism, and from it in its Egress into the common Air again.

*Fig. 6.* Shews how the same Object or Circle, which was high at first, is to Appearance *depress'd*, as it passes through the *Vacuum*; by being refracted from the Perpendicular, in its Ingress into the Prism, and towards it, in its Egress into the common Air again.

*Fig. 7.* Is a Triangular Glass Prism, fitted to receive all sorts of Fluids, and when rightly apply'd to the Semi-circle of the next Figure, does exactly measure the refractive Power of all those Fluids. Where the vertical Angle G D H is 45 Degrees; and by consequence the half Angles C D H, C D G, C H G, are 22° 30', and where all is to be so contriv'd, that the Rays within the Glass may be parallel to G H, and perpendicular to C D, and may fall on each side Plain

of the Glass Prism in an Angle of 22° 30' from their Perpendiculars; that so the Refractions at the Ingress and Egress may be equal, and the Computations easy.

*Fig. 8.* Is the Semicircle, with the Glass Prism full of its Liquor rightly apply'd thereto; and both Arms of the Index E D, F D, equally elevated above the horizontal Line A C. This shews the Proportion of the Sine of the Angle of Incidence to that of Refraction, in this Incidence of 22° 30'; which Proportion of Sines being the same in all other Angles, we hence learn that Proportion accurately and universally.




10

## *OPTICKS.*

### An Explication of the Fourth PLATE.

FIGURE 1. Is the Apparatus for Microscopes: Containing A C a Cylinder of Brass or Ivory; to which, near the Eye at K, the Microscope it self, or very small Sphere of Glass set Ivory, is apply'd; G H a small Slice of Ivory, and its *Muscovy* Glass Circles, with the fine Objects upon them, inserted in their true Place; E F a Convex Glass, screwed into the former Cylinder, and at a due Distance casting Light on the Objects; with I L, the Handle of the Microscope.

*Fig. 2.* Is only one of the Slices of Ivory A B, like G H before-mentioned, set by it self; with the double Circles of *Muscovy* Glass, and kept down by circular Wire; between which, on one of those Glasses, the small Objects are commonly plac'd.

*Fig. 3.* Is a Scheme to demonstrate how the double Microscope comes to magnify so much. Where G is the small Object; which, if there be Light sufficient, may by the small Microscope Glass E F, placed very near the Object, be cast into a larger Image H I: Which by the Means of the two Eye Glasses, are reduc'd into a Compass fit to enter into the Eye. And here by the way it is to be noted that die small Glasses, whereby single Microscope do magnify so much, and whereby the Magnitude is in Part increas'd in this double Microscope, is only a very small spherical Glass, or Segment

of it, which does so suddenly reduce distant Rays to Parallelism, or nearly to it, that a small Object, which by its great Nearness could not be otherwise seen, is hereby made visible.

*Fig. 4.* Is the double Microscope, with all its Apparatus and Contrivances, as to the Position of the Object, the Light to be thrown upon it, and the Elevation and Depression of the Instrument it self, as the Case requires, *&c.* all which the Figure does plainly shew to the Eye.

*Fig 5.* Is a circular Plate of Ivory, with a small Sphere of Glass in its Center, and a Screw round the Center, to be put upon the first Figure at B C, as a single Microscope.

*Fig. 6.* Is a small Fish, represented in a Cylindrical hollow Glass, so as it is to be placed when the Circulation of Blood in its Tail is to be seen by the single Microscope.

*Fig. 7.* Is the Magick Lanthorn, with its Pedestal T: its Lamp W; its double Convex Glass X Y; its Pictures inverted upon the Plate E F; and its large or gygantick Images at B A projected upon the white Wall, to the Surprize of the Spectators.

*Fig. 8.* Is the Demonstration of the *Camera obscura*, or dark Chamber; which will shew the Object as A B erect. Where C D is the double Convex Glass, ready to form an inverted Picture *b a*: Which by the Reflection of the plain Speculum E F, plac'd obliquely in an Angle of 4°, is formed in an erect Position at *a b*, for the View of the Spectator.

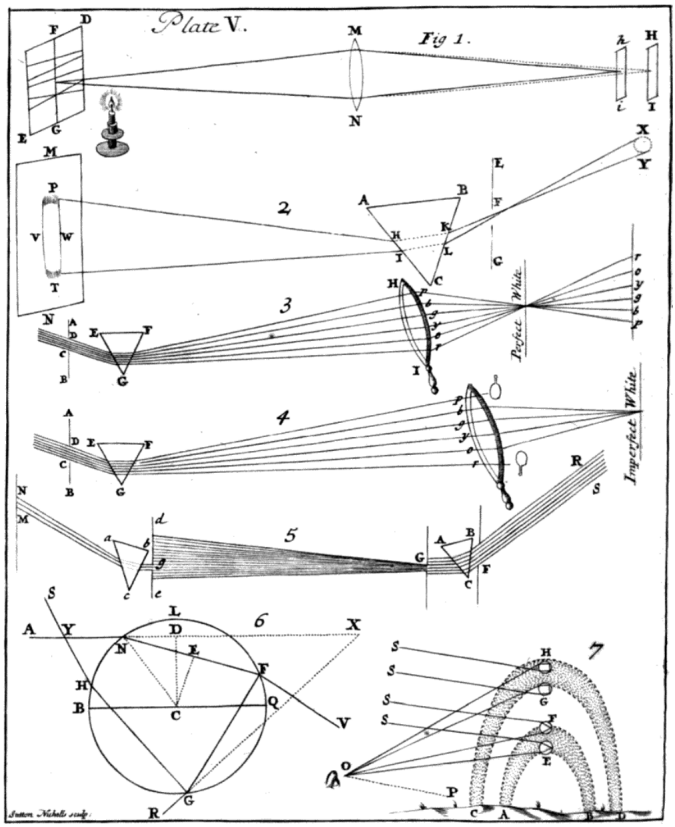


Plate V.
Fig 1.
2
3
4
5
6
7
Perfect White.
Imperfect White.

# *OPTICKS.*

## An Explication of the Fifth PLATE.

FIGURE 1. Is one of Sir *Isaac Newton*'s Experiments, to shew the different Refrangibility of the Rays of Light, of the different Colours, Red, Orange, Yellow, Green, Blue, Indigo, Violet. Where D E is a Parallelogram of Pastboard, having the one half D G blue, and the other half F E red; both strongly illuminated by the same Candle: and having black Silk wrapped several times round it. M N is a Lens or double Convex Glass interpos'd, which gathers upon white Paper the blue Rays sooner at *h i* than the Red at H I: As appears by the Distinctness of the Colours and of the Silk at those and only those Distances. Where also at somewhat above 12 Feet from the Colours to the Images, the Distance between *h i* and H I is no less than an Inch and half.

*Fig. 2.* Is another of Sir *Isaac*'s Experiments to the same Purpose: Where X Y represents the Sun: E G, a Window, with a small round Hole at F: within which is a Triangular Glass Prism A B C, by which the Rays of the Sun are differently refracted upon a white Wall or Paper M N; and become an Oblong Image P T; the Violet seen at P as most refracted; and the Red at T, as least refracted: And the intermediate Colours seen in intermediate Places, according to the different Degrees of their Refraction.

*Fig. 3.* Is another of his Experiments, to shew that White is a Mixture of all Sorts of colour'd Rays; where D C is a Hole in the Window, which admits the Sun's Rays. E F G a Prism, casting its oblong colour'd Image upon a Lens, or double Convex Glass; which collects all those Rays into its Focus. In which Case, the Point of Concourse exhibits a perfect White Colour; tho' upon their Separation again, the oblong colour'd Image appears again, only in an inverted Position: as the crossing of the Rays in the Focus must of Necessity occasion.

*Fig. 4.* Is the last Experiment improv'd; by shewing that the White Light made by the Mixture of all the Colours is but imperfectly so, when any of the several Colours are intercepted in their Passage to their Focus, or Place of Mixture.

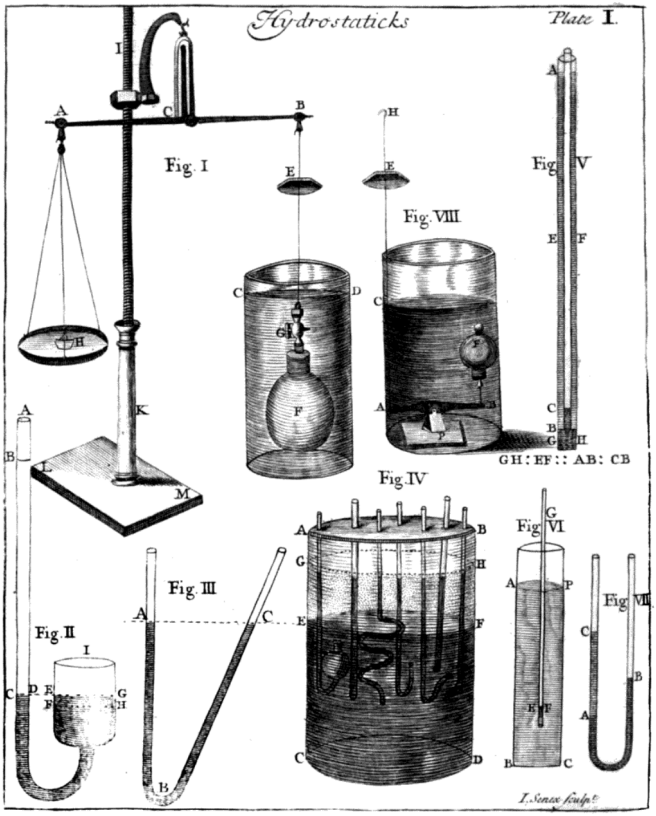
*Fig. 5.* Is the *Experimentum Crucis*, or determining Experiment. Where B F is the Hole that lets in a large Ray of Light: whose middle Part, after it has pass'd through the Prism A B C, is let through a lesser Hole at G, and forms an oblong colour'd Image at *d e*: where another small Hole lets thro' one Colour only; which passing through the Second Prism *a b c* it is refracted again, and cast upon N M. And here it is most remarkable, that the two Holes and second Prism are kept immoveable; and so the Rays G *g* fall upon the second Prism in the very same Angle, whatever Colour they are of, and that by the Motion of the first Prism, all the Colours may successfully pass through the same Holes. Yet is the Refraction by the second Prism never then able to produce any Variety of Colours; but exhibits the Image always of that Colour

alone, which falls upon it before the second Refraction.

*Fig. 6.* Is a Figure for the Explication of the several Refractions and Reflections of Light, which cause the *Phænomena* of the Rainbow. Thus if the greatest Crowd of Rays enter in Parallel to B Q along or near to A N, the round Drop of Water L B G Q will refract Part of those Rays to F, whence Part of them will be reflected to G: And going there out of the Drop, will be thereby refracted to R, which double Refraction will so separate the several Colours, and make them go out in Angles so sensibly different, that as the Eye is placed a little higher or lower, it will see a different Colour; and that in Angles as A X R, of about 41 Degrees; and this is the Case of the primary Rainbow, which appears in about that Angle from the Axis B Q, or its Parallel A X. Thus also, if the same Line A N be now suppos'd to represent another Drop, and that some of the Rays at G are reflected a second time, and so pass out at H, and are there refracted to S; here will be a weaker Impression, but a like Refraction and Separation of the Colours as before; and the Eye placed a little higher or lower will also see different Colours, tho' in a contrary Order to the former; and that in an Angle, as A Y S, of about 52 Degrees and a half; which is the Case of the secondary Rainbow.

*Fig. 7.* Are the two Rainbows themselves, r presented as they appear in Nature. Where A E B F represents the Air full of spherical Drops of Rain, in such Parts as the Angles E O P, F O P are about 41 Degrees from the Axis O P, which Axis is the Line from the Sun's Center, through the Eye of the Spectator, to the

Center of the Rainbow: And where C G D H represents the same Air, full of the like Drops, in such Parts where the Angles G O P, H O P are about 52 Degr. and a half. Where also the Rays S E, S F, S G, S H, coming from the Sun's Center, are represented as parallel, by reason of its vast Distance. These Rays, when they fall upon the higher Quadrant of the Drop, as at S E, S F, come to the Eye at O in about an Angle of 41 Degrees, after two Refractions, and one Reflection; and so cause the primary Rainbow: the Red is without, by the least refrangible Rays at F: and the blue within, by the more refrangible Rays at E. But when they fall upon the lower Quadrant of the Drop, as at S G, S H, they come to the same Eye at O, but in an Angle of about 52 Degrees and a half, after two Refractions, and two Reflections, and so cause the secondary Rainbow. Which is Blue without, by the more refrangible Rays at H; and Red within by the least at G. Where note, that because the Angles F O P, E O P, as well as those H O P, G O P, are ever the same, the same Colours must still be circular, or appear in the Surface of a right Cone, whose Axis is O P, and whose Sides are the Lines turned round thereon, as O E O F, and O G O H.


Hydrostaticks
Plate I.
Fig. I
Fig. II
Fig. III
Fig. IV
Fig. V
Fig. VI
Fig. VII
Fig. VIII
GH : EF :: AB : CB
I. Senex Sculp.

12

## HYDROSTATICKS.

### An Explication of the First PLATE.

FIGURE 1. Is a Balance, to weigh Water in its own Element, and in the Air; and to prove that its Weight is the very same in the former Case as in the latter. For when the Glass Bottle F is exhausted of Air, it will indeed require much more Weight to counterpoise it in the Air, than in the Water; by Reason of the much greater Weight of the Water thrust out by it, than of the Air; yet when upon the Admission of Water within, you weigh it again in the Air, and then in the Water, the additional Counterpoise now necessary is the very same; and shews that the real Weight of the Water admitted, is the same in both Elements. This Figure does also shew how Trials may be made to shew the respective Weight of those Bodies in Fluids that sink in them.

*Fig. 2.* Is an inverted Syphon, to shew why Fluids ever press according to perpendicular Altitude, and not according to Quantity of Matter: As the small Quantity of Water in the smaller Tube is a Balance for the great Quantity in the greater, and stands upon the same Level C D E G; because in all possible Motions and Vibrations of the Fluid, the Velocity in the smaller must, by the Make of the Syphon, compensate the Quantity in the larger; the one ascending or descending as far as B D, while the other ascends only as far as

E H, and so the Force is equal on both Sides, as is the known Case in the Stiliard also.

*Fig. 3.* Is to shew the same equal perpendicular Height or Level in a common Syphon inverted.

*Fig. 4.* Is a Number of hollow Tubes, of all Shapes and Directions, to shew that if their lower Orifices be put under tinged Water, and Oil be poured on the Surface of that Water, from G H to E F, the tinged Water will equally be pressed upwards through all the Tubes, according to all Directions; and will stand upon a common Level; tho' somewhat under the Surface of the Oil, because Oil is lighter than Water.

*Fig. 5.* Is for the same Experiment with Water on the Surface of Quicksilver; into which Quicksilver a hollow Tube is inserted before the pourings in of the Water. For the Water will press upon the Quicksilver, and raise it in the small Tube, till it bears the same Proportion to the Height of the Water, that the Specifick Gravity of Water bears to that of Quicksilver, or about a fourteenth Part so high. Which, by the by, is one ready Way also of finding the Specifick Gravity of Quicksilver to Water, by measuring their several Altitudes.

*Fig. 6.* Is to shew how Water in a very small Tube may elevate Quicksilver it self, when it is thrust more below the Surface of the Water, than the Difference of their Specifick Gravity requires; and that it will rise or fall as you thrust it lower, or raise it higher; and will at last fall out at the Bottom, if you raise it too high.

*Fig. 7.* Is to shew that Fluids of different Specifick

Gravities, as Water A B, and Oil A C, will stand at unequal perpendicular Altitudes, in Proportion to their Quantities, and Difference of Specifick Gravities.

*Fig. 8.* Is a Part of a Compound Balance, to be joined to that of *Fig. 1.* for the weighing of Levity, or of the Power of Ascent in a Body, as F, lighter than the Fluid wherein it is; and will shew that that Levity is the Difference of the Weight of that Body, and of an equal Bulk of the Fluid: Which is also the respective Gravity of those Bodies which are heavier than their Fluids, as may be tried by the same Balance of *Fig. 1.* alone.

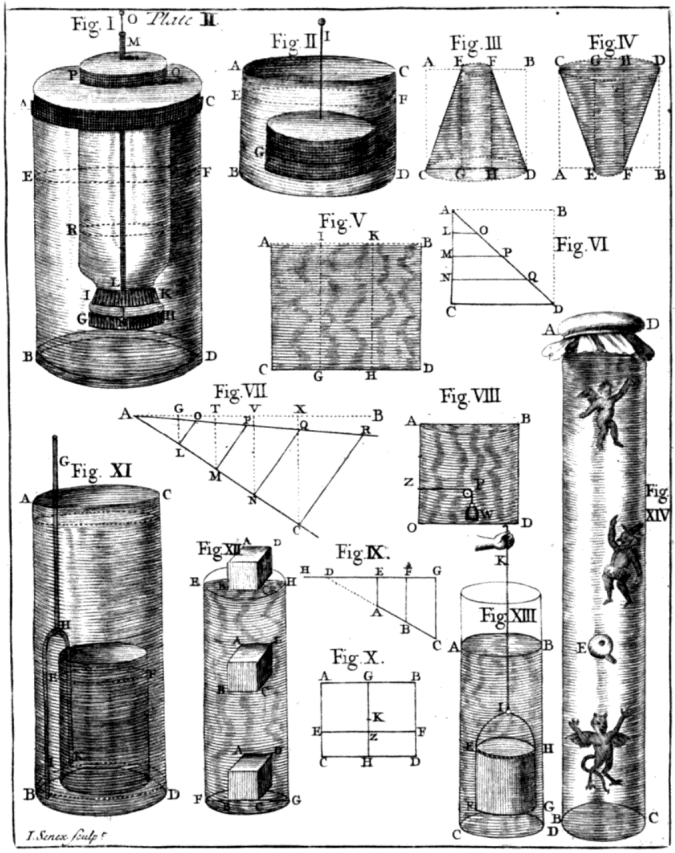


Fig. I
Plate II.
Fig. II
Fig. III
Fig. IV
Fig. V
Fig. VI
Fig. VII
Fig. VIII
Fig. XI
Fig. XII
Fig. IX.
Fig. X.
Fig. XIII
Fig XIV
I. Senex sculp.

## *HYDROSTATICKS.*

### An Explication of the Second PLATE.

FIGURE 1. Is a large Glass Vessel A D full of Water as high as E F. Within this is a lesser Glass Vessel P H, open at both Ends, but somewhat narrower at the Bottom. Through the middle of this goes a strong Wire M N, to which is fixed at the lower End a Plate of Lead G H, with wet Leather to its upper Surface, to be applied to the large lower Orifice of the lesser Glass I K, to keep out the Water from entring into the same any otherwise than by a slow Insinuation. This is to shew that a Plate of Lead, or other Metal, may be supported by Water, and not sink in it, where the Water is kept from pressing on its upper Surface, so long as its Depth under the Water is greater than its Specifick Gravity requires; and that by Consequence while Water is gradually admitted over it, it will not sink till the perpendicular Height of the Column of Air between E F and R S bears no greater Proportion to the Thickness of the metalline Plate (with what is annexed to it) than the Specifick Gravity of the Metal bears to Water.

*Fig. 2.* Is a cylindrical Vial or Glass A D, with a small Cylinder of Wood below G H fixed to its Bottom, and made very smooth at Top; and another like Cylinder of Wood above G H, made equally smooth on the lower Side, that it may as exactly as possible fit the other; with a strong Pin I, fixed in its Axis. Upon

these Two, when laid close, is pour'd Quicksilver, till it covers them both as far as E F. This is to shew, that there is no such thing as positive Levity; but that Wood is so far from rising in Quicksilver of it self, that till a sufficient Force pulls it up, and permits the Quicksilver to insinuate between the two Plates, the upper is fastned to the lower by that Quicksilver: Tho' upon the first Insinuation of the same it immediately and violently emerges of it self: As Dr. *Moor*'s Famous Trencher did in his Bucket, to his great Surprize; till he was forc'd to solve it by the Introduction of his Spirit of Nature.

*Fig. 3*, and *4*. Are Vessels of equal Altitude, but unequal Bases, and of the same Quantity of Water; to shew that Fluids ever press according to their Bases, if their perpendicular Height be equal; and according to their perpendicular Height, if their Bases be equal, whatever Figure they are of.

*Fig. 5.* Is a cubical Vessel full of Water, in order to compute the entire Quantity of the Pressure its Sides and Bottom sustain. And that the Bottom alone sustains the whole Weight of the Water; as is most evident.

*Fig. 6.* Is to shew that each Side of the same Vessel sustains a Pressure equal to half the Weight of the same Water. For since the Pressure at every point, as L, M, N, C, is equal to the Altitude of the Water above it, A L, A M, A N, A C, by erecting equal Perpendiculars L O, M P, N Q, C D, and so at all the intermediate Points, and summing them up, we shall have the Triangle A C D as the Sum of all the Pressures; which being half the Square A C D B, made by as many Per-

pendiculars equal to the longest C D, and bearing the whole Weight of the Square over it A C D B, shews that the Pressure on every physical Line, as A C of a triangular Prism, and so on the whole Side represented by it, is one half of the whole Water. So that since each of the four Sides sustain half, and the Bottom the whole Weight notwithstanding, the entire Pressure is three times the Weight.

*Fig. 7.* Is a like Method of Computation for an inclined Plain's Pressure, and how to estimate it; *viz.* by the Weight of Water equal to the Prism represented by the Triangle A R C, where the Lines L O, M P, N Q, C R, are erected perpendicular to A C, and equal to L G, M T, N V, C X, respectively.

*Fig. 8.* Is to determine the Center of Pressure Z against such a Plain; at which if an equal Weight W directly pulls along Z P over the Pulley P, it will just balance the Water, and evenly sustain its Pressure.

*Fig. 9.* Is to shew that this Center of Pressure is no other than the Center of Percussion or Oscillation about an Axis, as D. For the Pressures being as the Perpendiculars E A, F B, G C; and the Percussions, as D A, D B, D C, the Radij of the Circles of Motion; and E A being to F B, as D A to D B; and F B to G C, as D B to D C: The Percussions are still as the Pressures; and so the Center of Percussion, the same with the Center of Pressure.

*Fig. 10.* Is for the Computation of the Quantity and Center of the Pressure on any erect Rectangle under Water; according to that Rule, that the Depth of any Bodies or Surfaces Center of Gravity is to be taken

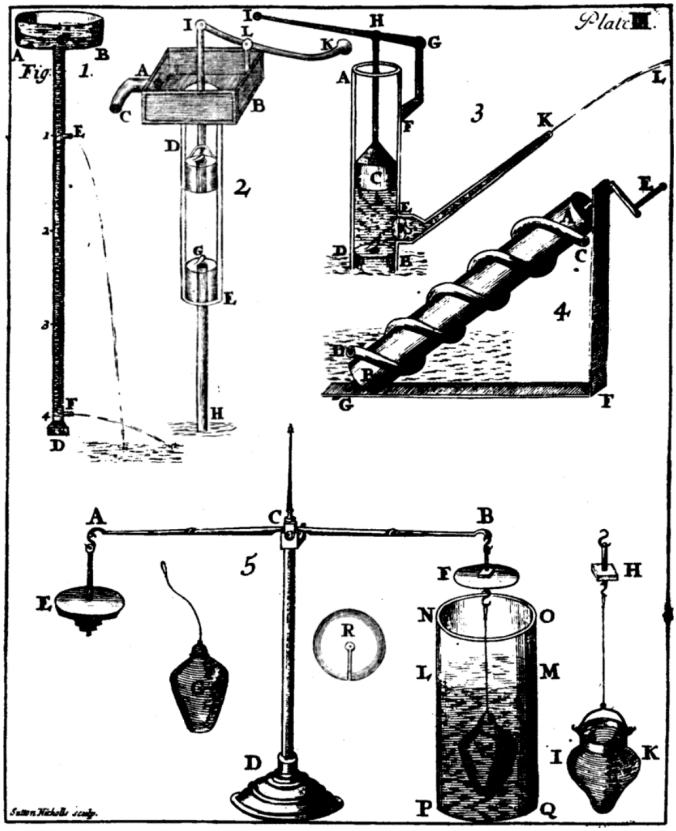
for the perpendicular Altitude of all the Pressures, as a Mean between them.

*Fig. 11.* Is a large Glass Vessel A D, containing Water near the Bottom; with another smaller Vessel F K with Water almost to its Top. There is also a Syphon B H K, with an hollow Stem G H, communicating with both its Legs. To shew that if you stop the Top of the Stem of the Syphon while you pour Oil into both Vessels, a considerable Height above the Bend of the Syphon, and then unstop it, the Oil will press upon the Water in both Vessels, and force it to ascend in each Leg; till meeting at the Bend, it run down the longer Leg, out of the higher Water into the lower. This is to shew how the Air pressing upon Water may raise it up, and cause the known Effects of Syphon, Pumps, Syringes, *&c.* Which used to be ascribed to Nature's Abhorrence of a *Vacuum*.

*Fig. 12.* Is a Cube at different Depths of the same Water; to shew how it must have the same Weight in one Place that it has in another, because the Water and Cube have ever the same Proportion of Bulk and Gravity to one another.

*Fig. 13.* Is a Bucket under Water; to shew it can have there no respective Gravity, or cannot preponderate; tho' it has ever the same absolute Gravity.

*Fig. 14.* Are a Bubble and Images of the same Nature, made of Glass, Air, and Water; all so nicely pois'd, that by the Pressure or Relaxation of the Air included, which is done at the Bladder A D, the Bubble and Images rise and fall after a surprizing Manner.




14

## *HYDROSTATICKS.*

### An Explication of the Third PLATE.

FIGURE 1. Is a Tube full of Water, with Two Holes E, F, for the Water to run out at, the one F four times as much below the Surface of the Water A B as the other; (the Vessel to be still kept equally full all along:) to shew that the Velocity and Quantity of Fluids that run out, are in only a subduplicate Proportion of the Altitude of the Fluids, or twice so much in a Fourfold Altitude. Not can it be otherwise: For twice the Quantity running out, with twice the Velocity, implies the Force or Pressure to be Fourfold, as the Fourfold Altitude requires; and so for ever.

*Fig. 2.* Is a Pump; where G M is a hollow Cylinder, reaching to the Water below, with a Valve G, which will be lift up by the ascending Water, and permit its Entrance into the Body of the Pump; but will not permit its Return when it is attempting to descend. D is the Sucker, with its hollow Cylinder, and a like Valve: which Sucker is pulled upward or thrust downward by the Handle I L K. When it is pulled upward, it leaves the Body of the Pump a Vacuum: whence the Air's Pressure on the Water's Surface below raises it up into that Space, and fills it; and when it is thrust down, the Water, which is stopp'd by the lower Valve from going back, is forc'd through the Valve in the Sucker D, into the Cistern above; whence by its own Gravity it runs out at the Canal A C.

*Fig. 3.* Is a Forcing Pump, in the main made like the other, only without a Cistern; and the Exit is out of the Side through a Hole, with a Valve opening outward, but shutting inward, in which the Sucker when thrust downwards forces the Water out sideways with great Violence.

*Fig. 4.* Is *Archimedes*'s Spiral Pump C D, made of only a Cylinder, with a hollow Spiral Tube wreath'd about it; where the Fluid partly descending, and partly ascending, all the way, makes its flowing along the more easy, till upon its Arrival at the Top it runs out at C.

*Fig. 5.* Is the whole Apparatus of the Hydrostatical Balance. The Glass Bubble G is heavier than all Fluids but Quicksilver, and is to be put into all those Fluids: The Bulk of Water in ours is 830 Grains *Troy*. If when pois'd in Water it sink more by any Number of Grains, that Number of Grains substracted from; if less, added to those 830, do by their Proportion to 830 give the Specifick Gravity of all such Fluids to Water. I K is the Glass Bucket, which in Air is in Æquilibrio with the Scale E: And because when it is let into Water, it will be no longer an Equipoise to the opposite Scale, but lighter; the Scale R is to be added to the Part H, by which the Bucket is suspended, and that will restore the Æquilibrium in Water. By this Solids and Quicksilver are weighed first in Air, and then in Water: The Difference of which Weights being the Weight of an equal Bulk of Water, by its Proportion to the first Weight in Air, gives the Specifick Gravity of the Solid compared with Water: And if that Difference still divide the Weight in Air, for all sort of Bodies, we may

have a Table of the Specifick Gravities of the Solids; as by dividing 830 by the Sum or Difference of the other Fluids, we may have a like Table of the Specifick Gravity of Fluids, such an one as here presented the Reader.

## *HYDROSTATICKS.*

### A TABLE of the Specifick Gravities of several Solid and Fluid Bodies.

| | | | |
|---|---|---|---|
| FINE Gold | 19,640 | Calculus Humanus | 1,700 |
| Standard Gold | 18,888 | Oyl of Vitriol | 1,700 |
| Quicksilver | 14,000 | Oyl of Tartar | 1,550 |
| Lead | 11,325 | Bezoar | 1,500 |
| Fine Silver | 11,091 | Honey | 1,450 |
| Standard Silver | 10,535 | Gum Arabick | 1,375 |
| Bismuth | 9,700 | Spirit of Nitre | 1,315 |
| Copper | 9,000 | Aqua Fortis | 1,300 |
| Cast Brass | 8,000 | Serum of Human Blood | 1,190 |
| Steel } Soft | 7,738 | Pitch | 1,150 |
| the same } Hard | 7,704 | Spirit of Salt | 1,130 |
| Piece } Spring Temper | 7,809 | Spirit of Urine | 1,120 |
| Iron | 7,645 | Human Blood | 1,040 |
| Tin | 7,320 | Amber | 1,040 |
| Glass of Antimony | 5,280 | Milk | 1,030 |
| A Pseudo Topaz | 4,270 | Urine | 1,030 |
| A Diamond | 3,400 | Dry Box-Wood | 1,030 |
| Clear Crystal Glass | 3,150 | Sea-Water | 1,030 |
| Iceland Crystal | 2,720 | Common Water | 1,000 |
| Fine Marble | 2,700 | Camphire | 0,996 |
| Rock Crystal | 2,650 | Bees-Wax | 0,955 |
| Common Green Glass | 2,620 | Lynseed Oyl | 0,932 |
| Stone of a mean Gravity | 2,500 | Dry Oak | 0,925 |
| Sal Gemmæ | 2,143 | Oyl Olive | 0,913 |
| Brick | 2,000 | Spirit of Turpentine | 0,874 |
| Nitre | 1,900 | Rectified Spirit of Wine | 0,866 |
| Alabaster | 1,875 | Dry Ash | 0,800 |
| Dry Ivory | 1,825 | Dry Maple | 0,755 |
| Brimstone | 1,800 | Dry Elm | 0,600 |
| *Dantzick* Vitriol | 1,715 | Dry Firr | 0,550 |
| Allom | 1,714 | Cork | 0,240 |
| Borax | 1,714 | Air | 0,001 ¼ |

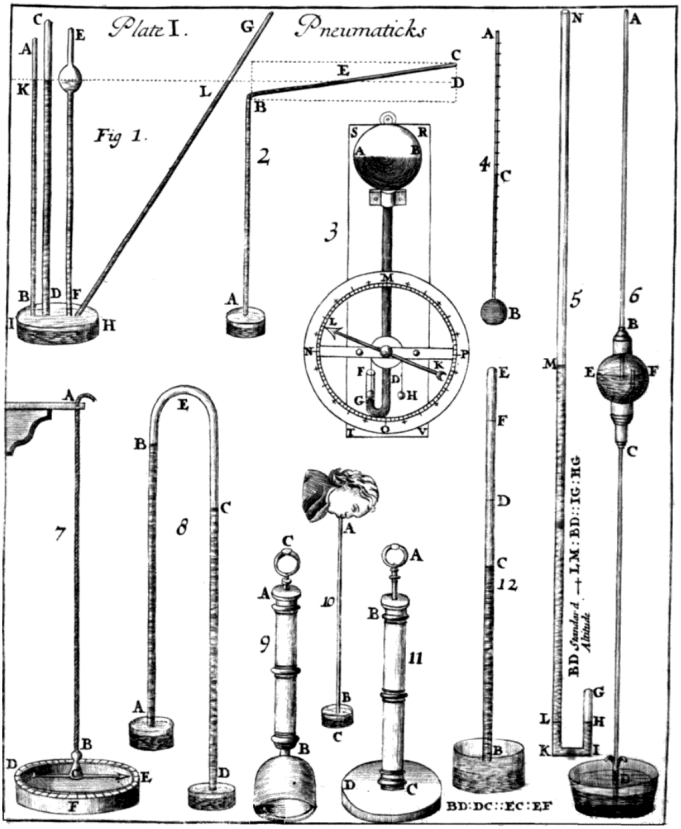


Plate I.
Pneumaticks
Fig 1.
2
3
4
5
6
7
8
9
10
11
12
BD. Sander d. :: LM : BD :: IG : HG
Abduct.
BD : DC :: EC : EF

15

## PNEUMATICKS.

### An Explication of the First PLATE.

FIGURE 1. Are several Torricellian Tubes or Barometers of different Shapes, Bores, and Positions; but where the perpendicular Altitude of the Quicksilver in the Tubes, above the Level of the Surface of that in the Bason, is ever the same, or between 28 and 31 inches high; which is the known Counterpoise between 32 and 36 Feet of Water; and to the entire Atmosphere in its several States and Elevations, where the Bases or the several Tubes are supposed equal.

*Fig. 2.* Is a Diagonal Barometer, where the Alteration of the Perpendicular Altitude of 3 Inches, by the Obliquity of that Part B C of the Tube A B C, (as a Diagonal is oblique to the Sides of its Parallelogram,) is increas'd to 20 or 30 Inches Sideways, for more Nicety of Observation.

*Fig. 3.* Is a Wheel Barometer, where by two Weights G and H on a Pulley, by which a Hand is turned, the one of which plays freely in the Air, and the other rises and falls with the Quicksilver in the Tube, the Divisions are larger and more obvious than in the ordinary Barometer: as they are in the Diagonal one; for the like greater Nicety of Observation.

*Fig. 4.* Is a common Thermometer, to determine the Quantity of the Heat of the Air, or of any Liquor, by the Rarefraction of Spirit of Wine contain'd in the

hollow Ball at the Bottom, and its consequent ascending to the several Divisions on the small Tube.

*Fig. 5*, and *12*. Are to shew that the Air's Density is as its Compression, the former upon a greater Compression, and the latter upon a greater Rarefraction; and that accordingly, in the first Case, B D the Standard Altitude, or about 29½ Inches, and L M the Additional Altitude of Quicksilver pour'd in higher than the Level H, taken together, is to B D the Standard Altitude alone, as I G the inverted Part of the Tube when full of common Air, to H G the Part full of condens'd Air: And in the Second Case, B D the Standard Altitude, is to D C the Depression by the Air, as E C the Part of the Tube full of the expanded Air, to E F the Part at first left full of common Air.

*Fig. 6.* Is Monsieur *Azout*'s noble Experiment, to determine, that 'tis certainly the Air's Pressure that raises the Quicksilver in the Barometer. The Instrument is nothing but a double Barometer communicating together, by the Means of a small hollow Pipe in the Middle: Its lower Tube is stopp'd at the Bottom with a Bladder; and when the entire Cavities are full of Quicksilver, the Bladder is prick'd or cut, and the Quicksilver runs out: Hereupon the upper Barometer's Tube, and Part of its Bason, becomes empty; while the lower is yet full: But upon the unscrewing a Screw, and letting Air in above the upper Bason, that Air presses on the Quicksilver's Surface, and raises it into its Tube; while the same Air pressing down the upper Part of the under Tube, depresses the Quicksilver therein at the same time.

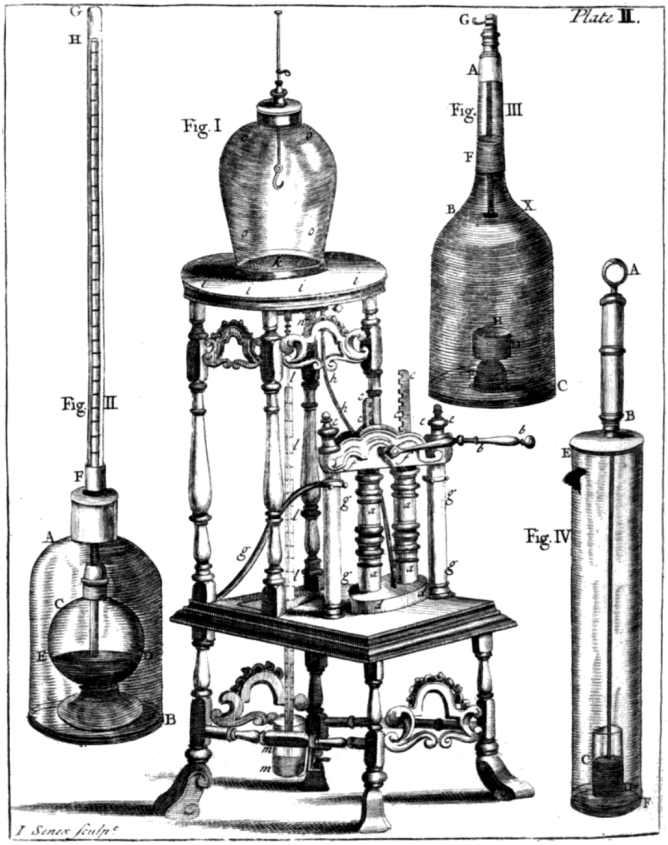
*Fig. 7.* Is a Hygrometer, or Cord, with a Needle or Index in a Circle, to measure the Air's Moisture by its shrinking up, and consequent Revolution one way; and the Air's Dryness, by its Extension down, and consequent Revolution the contrary way; and both measured by the Degrees of the Bottom Circle.

*Fig. 8.* Is a Syphon above 29½ Inches high, along where no Suction nor Art can make the Quicksilver run, as it uses to do when it is of any less Altitude.

*Fig. 9.* Is the new Sort of Cupping-Glass, whence the Air is suck'd out by a Syringe, and where by a Valve it is hindred from returning.

*Fig. 10.* Is an Example of Suction; and will shew that Quicksilver can thereby never be rais'd to 29½ Inches.

*Fig. 11.* Is an Example of a Weight raised by a Syringe, as Water uses to be; and still shews, that all is proportionable to the Power of the Air's Pressure, and is limited thereby.




16

## *PNEUMATICKS.*

### An Explication of the Second PLATE.

FIGURE 1. Is the Air-Pump, with its Receiver and Gage, as ready for Use; *a a*, *a a* are two strong hollow Cylindrical Barrels, in which are suppos'd to be Suckers, with their Handles *c c*, *c c* notched; into which Notches a Cog-wheel falls, which Cog-wheel moves upon the Axis *f*, when the Engine is put into Motion by the Winch *b b*. *g g*, *g g* are two Cylinders of Wood, fixed to the Frame of the Air-Pump, with Screws at the Top, on which the Nuts *e*, *e e* do run, and press down the upper Piece *f f* upon the Tops of the Brass Barrels, to fix them both at Top and Bottom. *h h*is a Swan-neck'd, or small bended hollow Brass Pipe, leading from the Top-Plate *i i i i*, or rather from the Brass hollow Piece above *n n*, which communicates through that Top-Plate with the Cavity of the Receiver. This Pipe is screwed to a bottom Brass Piece, included in the Box *d d*; which is perforated not only lengthways, but also upwards, in three Places: The Middle one for a Communication with this Swan-neck'd Pipe, and at the two Ends through small Cylinders; inserted into the two Brass Barrels *a a a a*; and 'tis by this Threefold Communication, that the Air is pump'd out of the Receiver. *l l l* is the Gage; which is no other than a common Barometer, or Weather-Glass; with its Bason of Mercury *m m*, fix'd to the Engine by a particular Contrivance, and its Index or Boxen Receptacle, with Inches, and its Cork to support that Index upon the

Surface of the Mercury, and to rise and fall with it; for the Exactness of measuring the Height of the Mercury from that Surface. Only this Barometer is open at the Top, and communicates, as does the Swan-neck'd Pipe, with the Cavity of the Receiver. *n n* is a Stop-cock, that communicates also with the Cavity of the Receiver, and either excludes or readmits the Air, as you see convenient. *k* is the Bottom of the Receiver, ground true to fit the Brass Circle below it; to which it is affixed by the Hand at first, and afterward by the Pressure of the Air, with wet Leather instead of Cement.

*Fig. 2.* Is a Barometer Tube, open at the Top H, and included in such a Receiver G B, as gives room for it to stand upright, and yet permits the Air to go backward or forward on its Surface, according as you pump the same out of or readmit the same into that Receiver. And this is done so, that the included Air C D, which supports the Mercury, by pressing on the Surface of that in its Bason E D, is confin'd within. This small Quantity of Air, on the Extraction of that in the Receiver, will, by its Elasticity, raise the Mercury almost as high as the usual Standard: And thereby shews, that the Spring of any small Part of common Air presses equally with the whole correspondent Column of the Atmosphere.

*Fig. 3.* Is a Contrivance to make an Explosion of Gunpowder in Vacuo: Where H D is a red hot Iron, standing on its Pedestal E, within a Receiver G C; and F is a Cock made above like a Dish, to contain the Gunpowder; which by the pulling up and thrusting down a strong Wire, with a Hole like the Eye of a Nee-

dle, is in a certain Quantity let fall every time upon the hot Iron; and on the Explosion produces Flame, and fictitious Air; but very little Sound, by reason of the Absence of the Air that should convey it.

*Fig. 4.* Is a Syringe, which will suck up the Water in the Glass C D, when it is in the open Air; but will not do the same under the Exhausted Receiver E F, unless for so small an Altitude as the remaining Air can sustain.

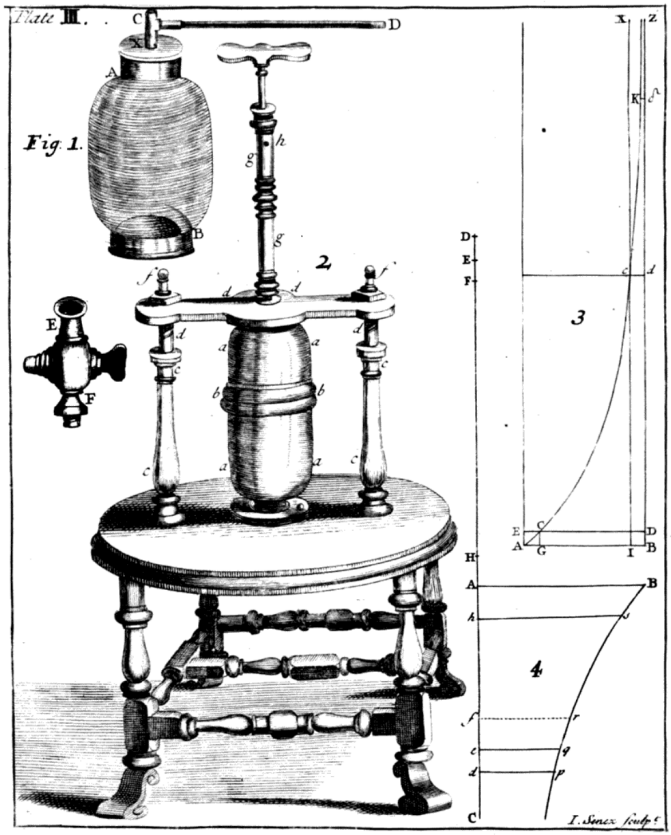


Plate III.
Fig. 1.
C
D
A
B
g
h
2
E
F
3
4
I. Senex sculp.

## *PNEUMATICKS.*

### An Explication of the Third PLATE.

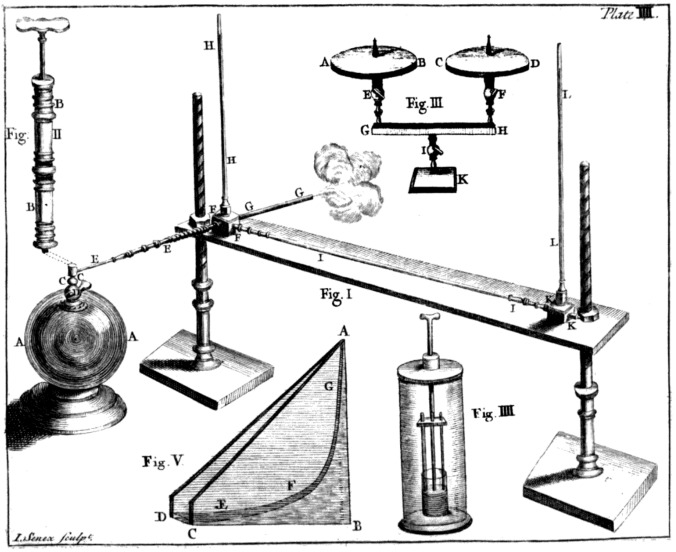
FIGURE 1. Is a large strong Glass Receiver, or Condenser, Arm'd with Brass Circles at both Ends, and fit to receive and bear the Pressure of Air considerably condens'd, when crouded into it by a Syringe fitted for that Purpose. It has also annexed to it a Gage C D, to determine the Quantity of the condens'd Air within. This Gage consists of a hollow Tube, Hermetically seal'd at D, with another smaller included, open towards D, and Hermetically seal'd at the other End. In this smaller Tube is left a little Quicksilver: This Quicksilver is by the Air at D in the larger Tube, which communicates with the condens'd Air in the Receiver it self, and so is of the same Density with it, crouded inwards towards C every time of the Admission of new Air; and by its whole Length from the End near D, compar'd with its Distance from the End near C, it determines the Proportion of the Density of the included Air to that of the common Air. *Note*, That the Syringe to be made use of with the Receiver, is the same with that represented in the next Figure, as joined to the condensing Engine it self; and acts by pulling up the Sucker above the Hole H, for the Admission of a full Cylinder of common Air, and then crouding it down into the Receiver; at the Bottom of this Syringe is a Valve, that hinders what is once crouded in from returning back again, as is necessary on all such Occasions.

*Fig. 2.* Is the usual Brass Condenser it self, with a Stop-cock E F near it; to be interposed between the Syringe and the Receiver upon Occasion. The Instrument, besides the Frame, is composed of a Recipient of Brass, made of Two Hemispheres, or what is equivalent to them, closed together by a Ring of wet Leather, to keep in the Air; and because in this Case the dense Air within endeavours forcibly to disjoin these Hemispheres, they are confin'd down close by a strong Piece of Iron, and Screws belonging thereto. The Syringe already describ'd, is represented as join'd to it after the same manner that it is when the Air is thereby intruded. This Brass Recipient will bear Air very much denser than the foregoing Glass one, tho' it being not transparent as the other is, cannot be so pleasant, nor so well shew the Mutations that happen to Animals or other Bodies in condens'd Air as the former.

*Fig. 3.* Is the Logarithmick Curve A C *c*, with its Ordinates A B, C D, *c d*, K δ representing Absolute Numbers, and its Abscissæ, C G or D B, I *c*or B d and B δ, representing their Logarithms, whose famous Property it is, that one Ordinate as A B, is to another Ordinate as C D, or *c d* or K δ, as that unlimited Space between the Curve and Asymptote above the one, is to that above the other; and whence is deduc'd the Proportion of the Air's Rarity at all Altitudes whatsoever; that at 7 Miles high it is 4 times as rare; at another 7, or 14 Miles, it is 16 times as rare, and so for ever, in a Geometrical Proportion of Rarity, compar'd with the Arithmetical Proportion of its Altitude; tho' all this is here upon the Hypothesis that the Distances are not so great, that the real Gravity of the Parts be sensibly

diminished. For in that Case,

*Fig. 4.* Gives the Scheme, which is made use of to discover the Air's Rareness, even at such Distances, as imply a considerable Alteration in that Gravity; whence it will appear, that the Density of the Air is diminished in that Case more than 4 times for every 7 Miles of Altitude.




18

## *PNEUMATICKS.*

### An Explication of the Fourth PLATE.

FIGURE 1. Is a compound Instrument, to shew, why in a Storm the Mercury in the Barometer vibrates so much, by a parallel Case in an Imitation of such a Storm. A A is a large hollow Brass Sphere, into which by the means of the Syringe in *Fig. 2*. Air is crouded till it is 8 or 10 times as dense as usual. H F and L K are Two Barometers, with their Basons in the Boxes F F, K K, which Boxes communicate by a long hollow Tube I I. E E is a Brass hollow Tube, to convey the crowded Air near the Surface of one of the Basons of Quicksilver, which Air passes out of that into a larger hollow Pipe G G, and so into the open Air. Upon the turning of the Stopcock C to give vent to the condensed Air, it rushes with great Force along the hollow Pipes E E, G G; and as it passes not far off the Surface of the Bason of Quicksilver F F, it causes the Mercury in both the Barometers H H, and L L, to descend and vibrate several Inches, as the great Storm made Barometers descend and vibrate in Chambers at a distance from it.

*Fig. 3.* Is a Transferrer; containing one common hollow Stem I (here represented as screw'd to a square Piece of Wood, and thereby held upright) with its Stopcock I, and its Horizontal Hollow G H with which it communicates. Upon this Horizontal Piece

two more hollow Stems are erected, and communicate therewith. These also have Stopcocks E and F, and to these are screw'd Two Brass Plates A B and C D, on which Two Recipients may be fix'd, and may communicate with the rest. By this means the whole Instrument may be apply'd to the Air Pump, and one or more of its Recipients exhausted; and afterward any Factitious or Natural Air may be transferr'd from one Receiver to another, as Occasion requires: Of which Instrument Mr. *Boyle* made great Use in his Second Continuation of Experiments.

*Fig. 4.* Are very small or capillary Glass Tubes, of different Bores, let down into Tinged Water, in Vacuo, to shew, that by the Attraction of the Glass the Water will be elevated, contrary to the ordinary Law of Hydrostaticks, and that to a considerable Height; and what is chiefly remarkable, is, that the Altitude of the Liquid in the Tubes is the same in Vacuo as in the open Air, and is always in an exact reciprocal Proportion to the Diameters of their Bases.

*Fig. 5.* Is the noble Improvement of the former Experiment by Mr. *Hauksbee, Sen.* upon which the Learned Mr. *Ditton* has written a small Treatise. It is done by two Glass Plains, A C B, A D B, meeting in an Axis at A B; and being about a Tenth of an Inch distant at the greatest Aperture D C. These Plains are Erected in Spirit of Wine, and are like a Series of Tubes of all different Diameters less than D C, which must therefore elevate the Fluid a little at D C, and higher all the way to B, where the Elevation ought to be Infinite; the Tops of the elevated Columns will form an Hyperbola, E F G, with its Two Asymptotes, the Surface of the

Fluid D C B, and the Line B A. *Note*, That if the Angle at D C be altered, the Bigness of the Hyperbola will be alter'd, while its Species remains; but that if the Angle A B C be alter'd, the Species of the Hyperbola will be alter'd also, though it will still be a true Hyperbola, and that if the Glass be clean, to a surprizing Degree of Exactness.

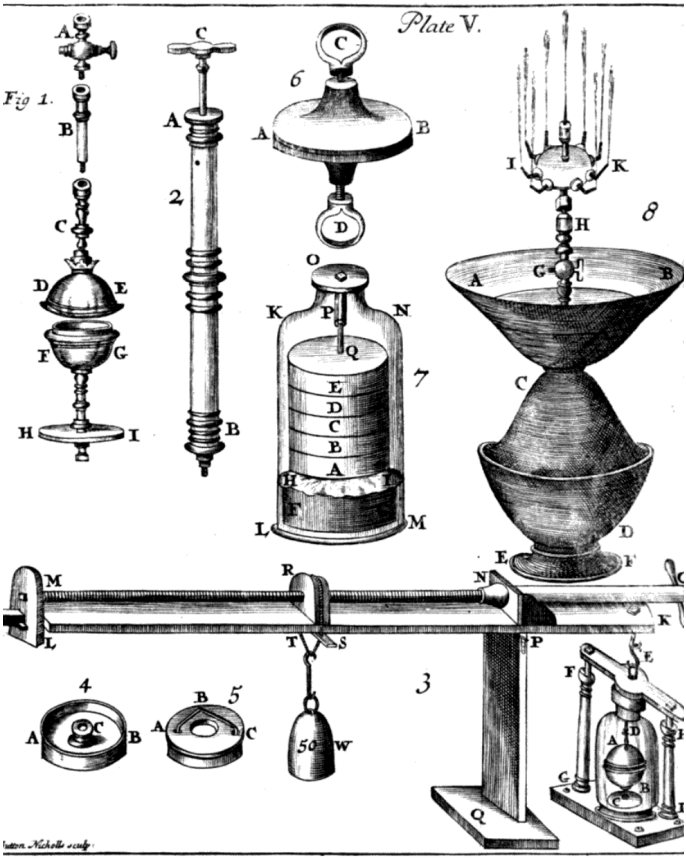


Plate V.
Fig 1.
2
6
7
8
3
4
5
50 W

## *PNEUMATICKS.*

### An Explication of the Fifth PLATE.

FIGURE 1. Are *Otto Guerick*'s Hemispheres, with their several Screws and Apparatus at large, set separately by themselves. They are designed to prove that the Force of the outward Air, when the inward is extracted from between them, is equal to the Weight of a Column of Quicksilver of about 29 Inches and a half: Of Water of about 34 Feet: And of Air to the Top of the Atmosphere, all pressing upon the same Base with the largest Circles of those Hemispheres.

*Fig. 2.* Is the Syringe, with its Hole; to be screw'd on to the Top of the Receiver of the next Figure; in order to thrust Air into it, for the Improvement of the former Experiment; or to shew that tho' common Air be left in the Hemispheres, yet if that on their outward Surface be made twice or thrice as dense, they will still sustain an equal, or a double Weight respectively, before they are separated.

*Fig. 3.* Is that Instrument included in such a Receiver D B, and that Receiver kept close to its Basis by a cross Piece and Screws, as in the Condenser before: Together with a newly contriv'd Stiliard, to which the upper Hemisphere is hung; with its fixed Base, and its Gage, to measure the Degrees of Condensation of the Air, where by the Proportion of S P to P K, the Weight 50 w. is equivalent to greater Weights, and sh-

ews how many Pounds are required to separate the Hemispheres in all Cases. If the Diameter be 3 Inches and a half, they will sustain about 150 Pounds; and so in all other Proportions.

*Fig. 4.* Is the Plate which covers the upper Part of the Receiver. And through the Hole C the Piece D E slides, which takes hold on the upper Hemisphere.

*Fig. 5.* Shews the Gage of the same Instrument; this is like that for the Glass Condenser before describ'd, and contains a bended Tube, whose open End is in a small Basin of Mercury; and the other is Hermetically seal'd: For this Mercury crowded by the condensed Air in the Receiver, will croud the Air in the small Tube closer in Proportion to its Density, and so will afford us the Knowledge of the Quantity thereof.

*Fig. 6.* Is a like Experiment of the Cohesion of polished Plates of Brass, or of Marble; when the Air is excluded by a little Oil, and an exact Application. This Cohesion may be weighed by the Stiliard, as well as that of the Hemispheres; and is equal to the same, upon the same Base; provided a Ring do prevent their side or sliding Motion; and provided the Air can equally be excluded from between the Plates, as between the Hemispheres. Which last yet is almost impossible to be done.

*Fig. 7.* Is a Number of great Weights, kept steady one over another by an Iron Rod passing through them, and pressing upon a Bladder half blown, plac'd below them: This Bladder, by the Elasticity of its included Air, gradually elevates all those Weights; as soon as by the Extraction of the other Air out of the

Receiver, wherein they are all included, its Counterpoise is gradually taken away.

*Fig. 8.* Is a Number of *Jet d'Eaus*, or Fountains, made by condens'd Air, in a large Copper Vessel C D, pressing on the Surface of Water at the Bottom of the Vessel; into which Water a hollow Brass Pipe is immers'd. For if there be then a Stopcock at G, to open or shut the hollow Pipe at Pleasure; and several smaller Pipes at I K, communicating therewith, turning upon Balls or Joints, and plac'd in Order, we shall have a very pleasant Set of these *Jet d'Eaus*, or Fountains; all whose Water will be caught by the Bason A B, which Water may be again let into the Vessel C D, by unscrewing the Pillar in the Center of the Bason.

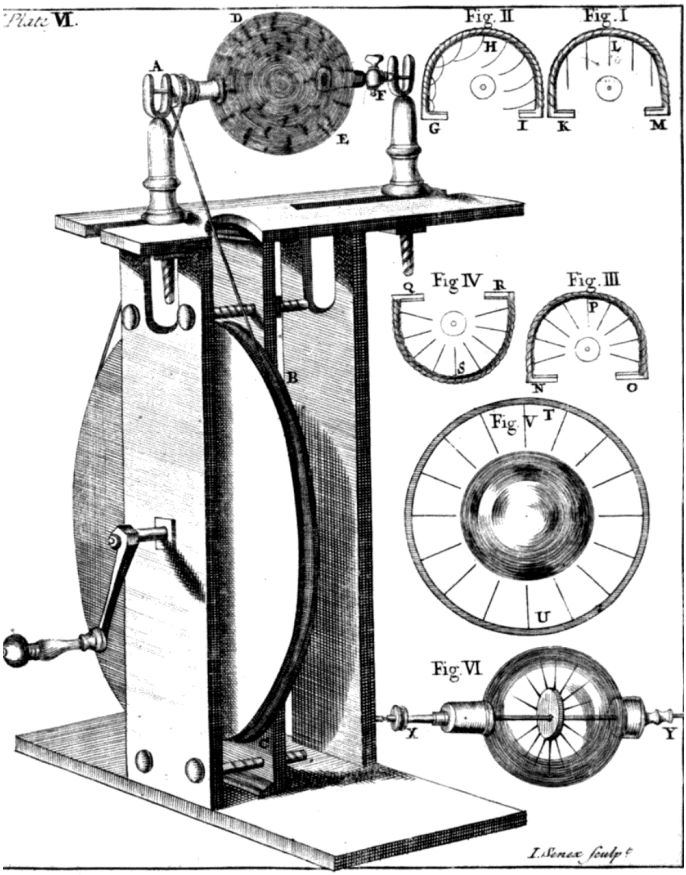


Plate VI.
Fig. II
Fig. I
Fig IV
Fig. III
Fig. V
Fig. VI
I. Sonex. sculp.

## *PNEUMATICKS.*

### An Explication of the Sixth PLATE.

This Plate is in Reality but one compound Instrument or Apparatus, for trying the Electricity of Glass, and its Luminousness, when put into Motion, and rubb'd upon to heat it. Wherein B C is a Wheel, with its String A B C. D E is a Sphere of Glass, whose Air has been drawn out by the Air-Pump: This is turned round by the former Wheel-string at A. F is a Stop-cock, whereby the Air is exhausted, and may be readmitted at Discretion.

In *Fig. 1.* K L M is an Arch with Threads of Cruel or Yarn upon it, as they hang about the Glass D E, (here represented by a smaller Circle within the Arch) before it is turned round or heated by rubbing.

*Fig. 2.* G H I is the same with the former; only the Threads are here represented as they hang at the Beginning of the turning round of the Globe, before it be heated by Friction; being plainly bent one way, by a Wind arising from that Convolution.

*Fig. 3.* N P O is the same; only with the Threads pointing towards the Sphere, or its Center, when the Arch is in an upright Posture, and some of the Threads hang partly downwards, and this upon the Spheres being heated sufficiently.

*Fig. 4.* Q S R is the same, with its Threads pointing

the same way, though in a downward Posture, when some of the Threads thereby are forc'd to stand erect.

*Fig. 5.* T U is a Circular Arch, in an horizontal Position, when the Threads point towards the same Center, in the same horizontal Plain.

*Fig. 6.* Is another Sphere, communicating with the Air, and to be apply'd to the same Wheel in the Room of D E, where-into is inserted an Axis with a Circle affixed to it; at the Edges of which Circle the Threads are placed. These upon the Friction and Heat of the Glass extend themselves outward, and point from the Center to the Circumference, contrary to the former. In both Cases the Threads, when under the Influence of the Electricity, will be moved by the Finger, even without Contact, nay by the Finger and Breath, even through the Glass it self; so subtle are these *Effluvia*. The Light is made when the Air is exhausted, and diminishes as you readmit it. It spreads and branches it self inwardly like Lightning, when about half that Air is readmitted. The Colour of that Light is always Purple. It spreads at some Distance, and makes the Edges of a Cravat look a little like the milky Way, by the great Number of Sparkles it emits: Which may also be felt by the Flesh, with a crackling Noise that accompanies them. If you also sufficiently rub and heat a large Tube of Glass, either solid or hollow, it becomes strongly Electrical, even through Glass it self; tho' not so much through Muslin. Other Heat than that by Friction signifies nothing. It will attract and repel Leaf Gold, and the like small and light Bodies, after a strange manner, by turns; when once they have been fully repell'd they cannot be made to touch them,

till they have been reflected from some other Body. If they lye between two Pieces of Wood, laid pretty near, the Electricity fails of its Effect. With other Circumstances very surprizing and unaccountable.

**FINIS.**

Transcription note:

The original punctuation and ortography of the book have been faithfully preserved; words which are spelled variantly, or inconsistently capitalized (e.g., *Axel* vs. *Axle*, *crowded* vs. *crouded*, *blue, red* vs. *Blue, Red*, etc.) have been left as such.

Likewise, the (mis)spelling of names like Galilæo, Azout, Hugen, Guerick, has been retained.

The following typographical mistakes have been corrected, taking into account recurrences across the text:

Page III, 25th day:

The Ebullition of Liquors in *Vacuo* → The Ebullition of Liquors *in Vacuo*

Mechanicks, Explication of the 2nd Plate:

Figure. 1. Is the deceitful Balance; which yet is *in Equilibrio* → Figure 1. Is the deceitful Balance; which yet is *in Æquilibrio*

*Fig. 3* → *Fig. 3.*

[Fig. 10]: perpendiculary → perpendicularly

[between Fig. 9 and 10]: N. *B.* → *N. B.*

[Fig. 10]: and in this Leaver → and in this Lever

Mechanicks, Expl. 5th Plate, Fig. 3:

us it is less restrained. → as it is less restrained.

Opticks, Expl. 1st Plate, Fig. 3:

Looking-glass → Looking-Glass

Opticks, Expl. 2nd Plate:

*Fig. 8.* Shows → *Fig. 8.* Shews

[Fig. 10]: on the like Acccount. → on the like Account.

Hydrostaticks, Expl. 1st Plate:

[Fig. 5]: specifick Gravity of Water → Specifick Gravity of Water

Hydrostaticks, Table of Specifick Gravities:

Spirit of Nirre → Spirit of Nitre

Pneumaticks, Expl. 2nd Plate:

[Fig. 1]: ‘tis by this Thteefold → ‘tis by this Threefold

[Fig. 2]: small Part of ccmmon Air → small Part of common Air

Pneumaticks, Expl. 5th Plate:

[Fig. 6]: as between the Hemispheres → as between the Hemispheres.

Pneumaticks, Expl. 6th Plate:

[Fig. 6]: througn Muslin → through Muslin