

Dialling, plain, concave, convex, projective, reflective, refractive. Shewing, how to make all such dials, and to adorn them with all useful furniture relating to the course of the sun; performed arithmetically, geometrically, instrumentally and mechanically: and illustrated with sculptures, engraven in copper, comprised in XIV distinct tractates... / [William Leybourn].

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Publication/Creation

London : Printed by J. Matthews, for A. and J. Churchill, 1700.

Persistent URL

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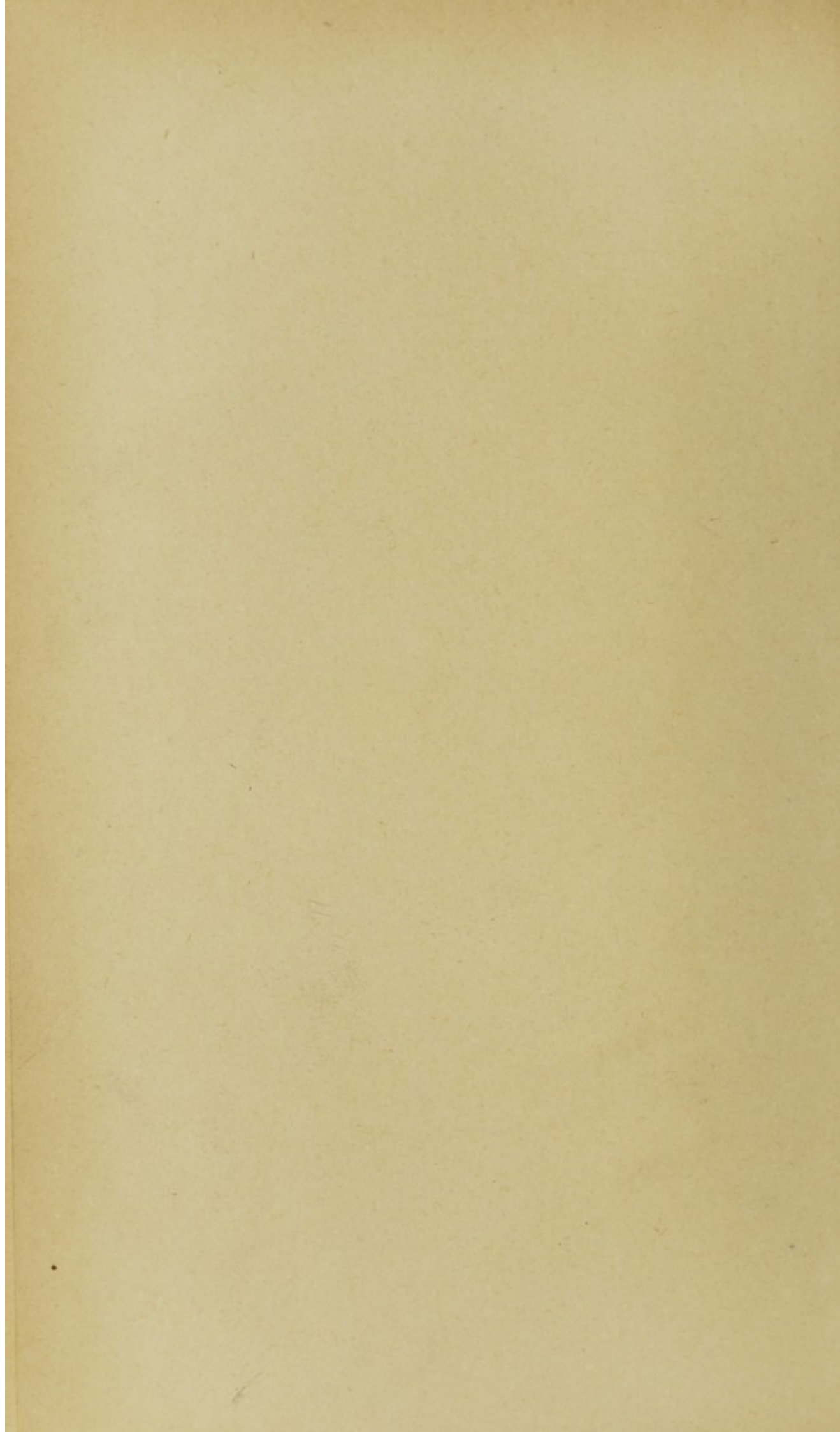


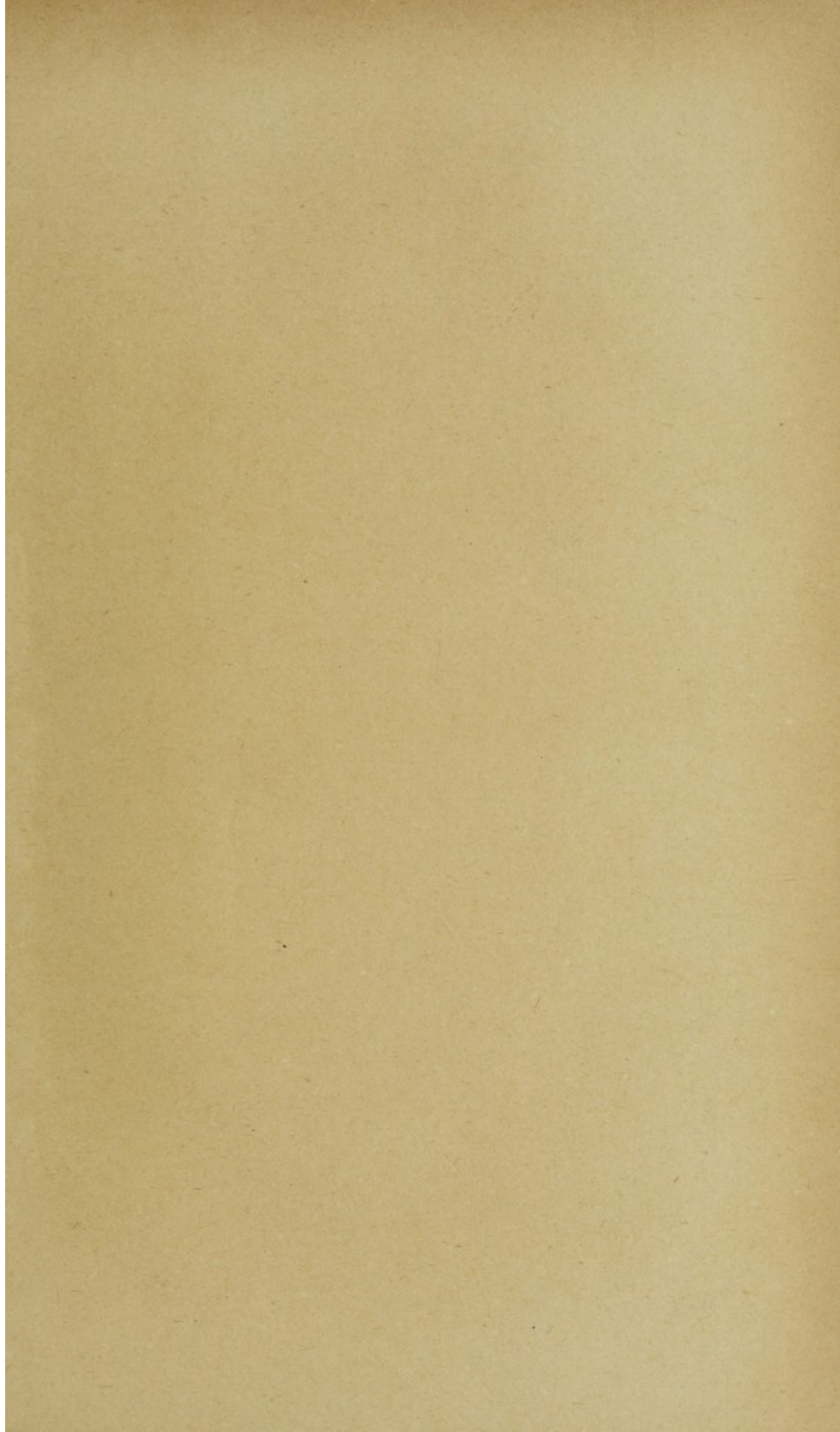


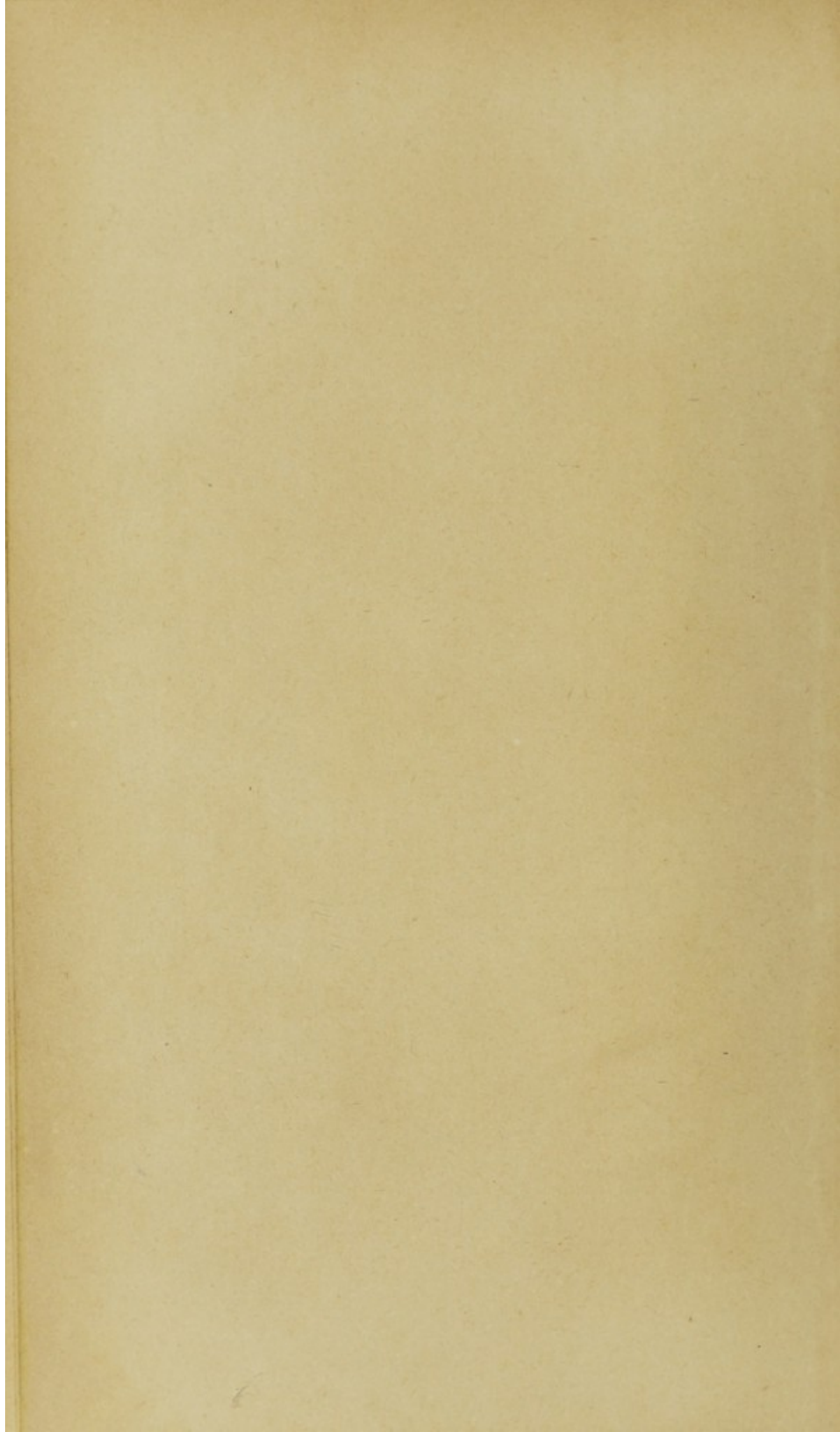


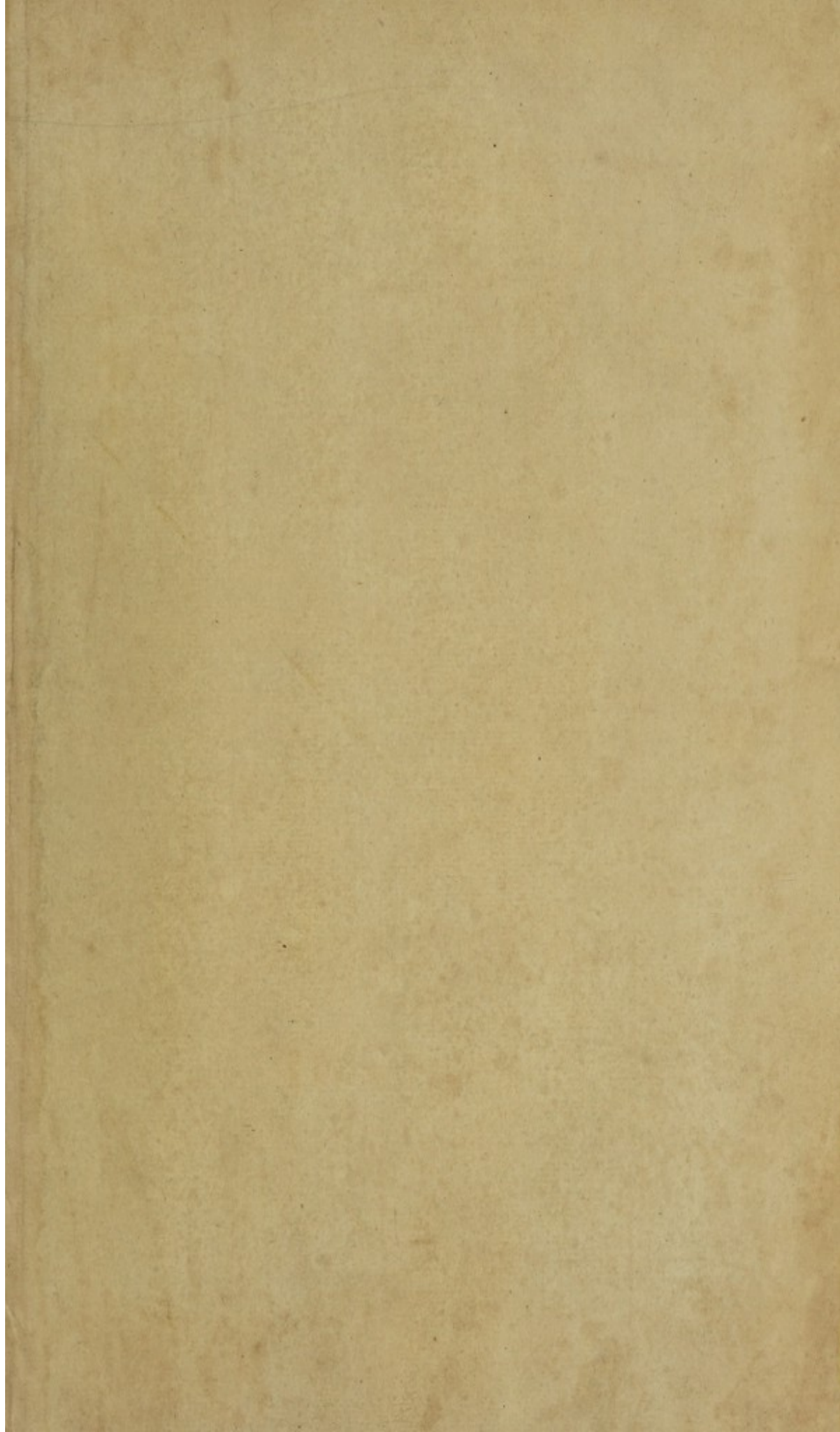
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R. White ad vivum delin: et Sculpsit

D I A L L I N G,

PLAIN, } PROJECTIVE,
CONCAVE, } REFLECTIVE,
CONVEX, } REFRACTIVE.

John. SHEWING,
How to make all such *DIALS*, and to adorn
them with all useful

F U R N I T U R E

Relating to the
Course of the S U N;

PERFORMED
ARITHMETICALLY, GEOMETRICALLY,
INSTRUMENTALLY and MECHANICALLY:

AND
Illustrated with SCULPTURES, Engraven
in COPPER.

Comprised in XIV. Distinct TRACTATES, the Contents
whereof follow next after the *Preface* to the *Reader*.

The SECOND EDITION Corrected, and two *New Tractates* added.

Collected, Methodised, and Published,
By WILLIAM LEYBOURN.

L O N D O N:

Printed by J. Matthews, for Awnsham and John Churchill at the
Black Swan in Pater-Noster-Row, MDCC.

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TO THE READER.

MAny of the following *Miscellaneous Tractates* lying obscurely and indigested by me several Years, at length, namely, *Anno* 1678. having some vacant time, I (amongst other things) took those Papers into my consideration, and perfected such of them as were incomplete; adding to that Store other things of the like nature: After which, communicating the same to several persons Mathematically affected, and more particularly with this (laudable and useful) Part thereof, namely, *DIALLING*: I was often-times importuned to make the same Publick; the which I was the more inclinable to, for that not much of this *Variety* hath been hitherto Published in the English Tongue. But finding the Overtures of such who deal in the Publishing of Books, to be in no measure sufficient, either to satisfy me for the pains I had then taken therein, much less to bring it forth in its due Lustre; I (at length) adventured to make an Essay towards the Publishing thereof by way of *Subscription*, but finding that not to answer my expectation neither (there having been of late so many abuses put upon Persons, willing to promote ingenious undertakings) I fully resolved to let it lie dormant, as (the more part of) it had done several years before. But at length, (partly by Subscriptions, and a particular Encourager) it is arrived to this perfection; and an Extract of the Particulars herein contained, you shall find immediatly after this Preface.

And now give me leave to prevent the Calumnies of some (already) Detracters, and to take off the aspersions of a Plagiarist, to acquaint thee from whence all that is herein contained had its issue. Therefore.

1. The *Introduction*, and the Eight first *Chapters* of the first *Tractate*, as things common, (but necessary for all *Tyro's* to be acquainted with) I pass over, only take notice, that the Second, Fourth and Fifth *Chapters* thereof, which concerns

the laying down, finding the Poles and Centers, and measuring the Sides and Angles of Spherical Triangles upon a Projection; I know not where you will find any thing thereof, except in my *Geometrical Exercises*, the which *Precepts* there delivered I have here (and in a brief manner too) applied to *Dialling*.

2. For the remaining part of the first Tractate, the Examples are all (or most of them) the same as are Mr. *Wells* in his *Sciographia*, which I made choice of (indeed) to ease my self of Calculation; My intent (at first) being to have done the Work of the First Tractate by *Projection* only, and not by *Calculation*: But Mr. *Wells* his Book being out of Print, and not likely to be restored, I inserted his *Calculatory* way also; and the rather, that the young Practitioner may discover what Harmony there is between *Spherical Projection*, and *Trigonometrical Calculation*, and the reason thereof also.

3. The Second Tractate was, partly a Translation out of *Magnon*, by Mr. *Thomas Gibson*: And the Third is partly Mr. *Samuel Foster's*.

4. As for the Fourth Tractate; it is an enlargement of the Appendix to *Stirrup's Dialling*, written by me above 25 years since, and yet, in it, you will find several things, which I am sure, no other Book will afford you.

5. The Fifth Tractate is of the same kind with the Fourth, and teacheth how to perform the same things by a different Artifice.

6. The Sixth consisteth of *Tables* subservient to the inscription of *Furniture* into *Sun-dials*, some few whereof were only transcribed (though much enlarged, and otherwise disposed) out of *Kirkerus*; but the most of them, were (to my great pains) Calculated *de novo*, and the *Description*, *Construction* and *Uses* of them all, wholly by me added.

7. The Seventh Tractate came to my hands in a Latine Manuscript of Mr. *Samuel Foster's*, written with his own hand in Anno 1640. and was delivered to me (when the other Tractates were almost Printed) by a real honourer of the deceased Author, and my very worthy Friend *John Twisden*.
M. D. C. L.

8. The Eighth Tractate is no other then the *Meridians* of a *Globe* set to any Latitude and difference of Longitude, and *Meridians* or *Hour-lines* drawn on the Concave Superficies of the same.

9. The Ninth Tractate is wholly Mr. *Samuel Foster's*, and some

some part thereof was Printed by me in his *Miscellanies*, Anno 1659.

10. The Tenth Tractate also, is wholly his; and was (together with some part of the Ninth) transcribed from a Manuscript of his, which he (for the excellency of many things contained therein) Entituled *GOLD*. And for those Pieces which follow (as Supplement to) this Tenth Tractate, I need not declare, their respective Titles will here save me that Labour.

11. The Eleventh Tractate of *Refracted Dialling*, is Mr. *Foster's* also, and was formerly Printed in his forementioned *Miscellanies*.

Lastly) What is said concerning the Dial set up in the King's Majestie's Privy Garden at *White-hall*, Anno 1669. is but an Extract of what the Maker thereof did write concerning the Explication and Use of the said Body of Dials: I did here (together with the Figure thereof) insert this Abstract for the benefit of Students in this *Gnomonical Science*; thereby to whet their inventions, so as to put in practice what is taught in these Tractates, and from this President to invent others of their own; which how to perform the ensuing Precepts will not be found deficient; If they be deemed Redundant they will be found so to Talkers only, and Doers of thing, and to such I say as much.

What is more added in this Edition, (besides the Errors in the former Corrected) Are,

First, A Supplement to the First Tractate, shewing a general and easie way, to Project Hour-lines upon all sorts of Plains, according to the Rules of *Stereographick Projection*.

Secondly, To the second Tractate is added a third way of *Geometrical Dialling*, shewing how to inscribe the *Stile*, *Substile*, and *Meridian-line*, in all Plains.

Thirdly, To the Ninth Tractate, I have added several ways, whereby to make *Dialls* upon Plains, upon which the direct Beams of the Sun can never shine (without *Reflection*) which shall shew the *Hour* of the Day by the *Sun*, and by the *Stars* in the Night Season.

Fourthly, The Fourteenth Tractate is wholly added and treateth of the Five *Platonick* (or *Regular*) Bodies shewing the manner how they Cut them in *Stone* or *Wood*, as also of two *Polyhedron Bodies*; one called the *Hex-octahedron*, (or *Canted Cube*). the other *Hex-icosahedron*; the one consisting of *Fourteen*, the

To the READER.

other of *Twenty six Plains*: And how to furnish them in the *Sun Dials*.

Having given you this general account of the several *Treatises*, and from whence they have been deduced, I now refer you for farther satisfaction, to the following *Contents*; but principally to the *Book* it self; in which, I hope, the ingenious Practitioner will find variety of Matter, both *Practical* and *Delightful*; And for as much, as the several *Mathematical Treatises* which I have already Published, have found so good acceptance in the World, I doubt not but *This* will receive the like entertainment, and be as kindly received as his *Fellows*: and upon that account I commend it to thee; Wishing thee both *Delight* in the *Reading*, and *Profit* in the *Practising* of what is herein contained: And so, for this time, I bid thee Farewel; Resting,

Thy well wishing Mathematical

Friend,

William Leybourn.

THE

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A Necessary Introduction.

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Plain Dialling, Demonstrated.

Shewing, How (by Projecting of the Sphere upon the Plain of the Horizon, suitable to any Latitude) to draw the Hour-lines, Stile and Substile, proper to any Plain) in their true Places and Positions. — And upon the Projection to express the Spherical Triangles, from which all the Requisites belonging to any Dial are to be Calculated, And how to Calculate the same — And to measure the Stiles and Angles of all such Triangles upon the Projection it self.
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<i>Geometrie:</i>	{ The Principles thereof { Practice, and with the { Demonstration. Theoretical and Practical. The Description of the Circles of the Sphere.
<i>Astronomie:</i>	{ The Use of the Globes, { Celestial, and { Terrestrial. To project the Sphere <i>in Plano</i> upon any Circle, { Right, or { Oblique.

And upon these Foundations, the following Superstructures.

The Use of
Geometrical
Instruments,
in the
Practice of

Longimetria, or the
Mensuration of { Heights,
Depths, } as of { Trees, Towers, &c.
Mines, Wells, Descents,
&c.
Distances, } Churches, Towers, &c.

Planometria, or the
Mensuration of { Board,
Glas, } Or any other Superficies.
Pavement,
Tiling, &c.

Stereometria, or the
Mensuration of { Timber, groing or squared,
Stone, regular or irregular.
Cask, commonly called Gaging.

Geodesia, or the Measuring of Land divers ways, and by several Instruments; to draw the Plot of a whole Mannor or Lordship; to cast up the Content thereof; and to beautify the same with all necessary Ornaments thereunto belonging.

Trigonometria : { Or, the Mensuration of Triangles, both { Plain, and
Spherical.
The Application thereof, in the solution { Geometry.
of Problems in { Astronomy.
{ Geography
{ Navigation.
{ Fortification.
{ Dialling, &c.

Navigation : { The Principles thereof, and the { The Plain Sea-Chart
manner of Sailing by { Mercator's Chart.
{ The Arch of a great Circle.
Arithmetically, by the Tables of { Sines.
Tangents.
Logarithms.

Horologigraphia,
Or
Dialling : { Geometrically, by { Scale, and
Compasses.
Instrumentally, by the Sector, Quadrants, Scales, and other Instruments accommodated with Lines for that purpose.

A L S O

IF any would have their Land or Building Surveyed, or Measured, and a Plot thereof made; or any Sun-Dial, or Dials about their House or Garden (of what kind soever, Fixed or Moveable) he will prepare or make for them such as shall be desired.

A NECESSARY INTRODUCTION,

Consisting of
DEFINITIONS and *PROBLEMS*,
Geometrical and Astronomical :

For the more easie Apprehending, and ready Performing
of the several Matters and Things contained in the
following *TRACTATES*.

PROBLEM I.

*From any Point in a Right Line given, to erect another Right Line, which
shall be Perpendicular to the Right Line given.*

Definition 1.] **A** Point is that which hath no Part, and is the least
imaginary Thing; as this Point or Prick noted
with [Z •]

Definition 2.] A Right Line is a Line drawn equally between two given
Points, and is the shortest distance between them, as is this Line X Y, which
is the shortest distance between the two Points X and Y.

[X ——— Y]

Definition 3.] A Right Line is said to be Perpendicular to another
Right Line, when it maketh the Angles on either side of the erected Line
equal, that is, so that the erected Line inclines not, either to the Right-hand,
or to the Left; but standeth upright upon the Line from which it is erected:
As in [Figure I.] The Right Line A B, is said to be Perpendicular to
the Right Line C D, upon which it is erected, for that it inclineth neither to
the Right or Left-hand; and because the Angles on either Side thereof are
equal; namely, The Angle A B C, on the one side, equal to the Angle
A B D, on the other side; either of which Angles are Right Angles, and
the Right Line A B, so standing, is Perpendicular to the Right Line C D,
upon which it is erected.

Practice.] **L**ET the Right Line given be C D, and let it be requi- *Figure*
red to erect another Right Line, which shall be Perpen- 1.
dicular thereunto, from the Point B.

Open your Compasses to any convenient small distance, and setting
one foot in the Point B, with the other make the two small Marks E and
B F, on

F, on either side equi-distant from the given Point B. — This done, Open the Compasses again to any convenient distance, (greater than the former) and setting one foot in the Point E, with the other describe the obscure Arch G G, (over the given point B, as near as you can guess) — Again, (the Compasses being still open at the same distance) Set one foot in the point F, and with the other describe another obscure Arch H H, crossing the former in the point A: So is A, a point found, through which, if you draw a Right Line from the given point B, that Right Line A B, shall be *Perpendicular* to the given Right Line C D, and from the point B, which was required to be done: And the Angle A B D, on the one side thereof, is equal to the Angle A B C, on the other side; and both of them are Right (or Square) Angles.

Note, An Angle is always signified by Three Letters, as a Point is by One: The middlemost of which Three representeth the Angular point, as in this Case the Letter B — B, being the Angular point, and the Lines A B, and B C the Sides, containing the Angle B.

P R O B L. II.

How to erect a Perpendicular, when the given Point is in (or near) the end of the given Right Line.

Practice. **T**Here are several ways to effect this; of which I will here shew you only Two, as being the best.

Figure
II.

Let A B be a Line given, and from the point A, towards the end thereof, let it be required to erect the Perpendicular A C. — First, Open the Compasses to any small distance, and setting one foot in the given point A, with the the other describe an Arch (or part) of a Circle F E D; — And (keeping the Compasses still at the same distance) set one foot in D, and make a mark in the Arch at E, and setting one foot in E, with the other describe another Arch of a Circle A F G, crossing the first Arch in F. — Again, Set one foot in F, and with the other describe the small Arch H H, crossing the former in the point C, through which point C, draw a Line from the given point A, and that Line shall be Perpendicular to the given Line A B, and drawn from the point A, as was required.

A Second Way.

Let B (the extreme end of the given Line) be the point given. — Open the Compasses to any convenient distance, and setting one foot in B, pitch down the other foot at adventure in the point K; so one foot resting in K, turn the other about till it cross the given Line A B in L, and draw the Right Line L K at length, and set the same distance K L, (at which the Compasses already stand) from K to M; so a Line drawn from B through M, shall be Perpendicular to A B, and from the given point B, as was required.

P R O B L. III.

From a Point above, to let a Perpendicular fall upon a Right Line under it.

IN this there are two Cases. — *First*, When the given point above, is over (or near) the *Middle* of the given Line: And — *Secondly*, When the given point is just (or near) over the *End* of the given Line.

Practice. **I**N the *first Case*; Let NO be a Right Line given, and from the point P (over it) let it be required to let fall the Perpendicular PQ. — *First*, Open the Compasses to any convenient distance, greater than the Distance between P and Q; and setting one foot in P, with the other draw an obscure Arch of a Circle, cutting the given Line in the points R and S. — *Secondly*, Divide the space between R and S, into two equal parts in the point Q; So a Right Line drawn from the given point P, to the point Q, shall be Perpendicular to the Line NO. Figure III.

Note, To avoid the dividing of the Space RS, into two equal parts, to find the point Q; if you have room (either above or beneath your Line) you may set one foot in S, and opening the Compasses to any convenient distance, make the Arch YY, and removing the Compasses to R, make the Arch ZZ, crossing the former in Æ, so a Line drawn through Æ and P, shall be perpendicular to NO.

In the second Case; Let V be the point given; — *First*, From any part of the given Line NO; as from T, draw a Right Line to the given point V, which divide into two equal parts in X. — *Secondly*, Set one foot of the Compasses in X, and with the distance XT describe the Arch (or Semicircle) VOT, cutting the given Line NO in O; so shall O be the point, to which from the given point V, if you draw a Right Line, it shall be a Perpendicular to the Line NO, and from the point V; as was required.

P R O B L. IV.

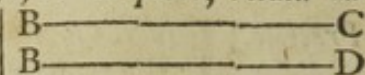
To divide a Right Line into Two equal Parts, and at Right (or Square) Angles.

Practice. **L**ET AB be a Line given, to be so divided. — Take in your Compasses the length of the given Line AB, or any other distance, greater than half the length thereof; and setting one foot in the end A, with the other draw the Arch CDE. — *Secondly*, (the Compasses being open at the same distance) Set one foot in B, and with the other cross the former Arch (both above and below the Line) in the points F and G: So a Right Line drawn (or a Ruler laid) from F to G, shall cut the given Line in H; so shall the given Line AB be divided into Two equal parts in the point H, and at Right Angles, which was required. Figure IV.

PROBL. V.

A Right Line being given, to draw another Right Line which shall be Parallel thereunto, at any distance required, or thro' any Point assigned.

Definition.] **R**ight lined Parallels, are such Right Lines, which being drawn upon the same Plain, and infinitely extended on either side, would never concur or meet; but always, in all parts, retain an equal distance; and such are these two Right Lines BC and BD.



In the describing or drawing of Parallel Lines, there may fall out Two Cases or Varieties. As,

1. *It may be required to draw a Line Parallel to another Line, at a certain given distance.*
2. *The Parallel may be required to be drawn through an assigned Point.*

And of this Kind there are two Varieties: For,

1. *The given Point may be over or under the given Line. Or,*
2. *It may be Oblique to the Line given.*

Figure
V.

Practice of the First Case.] **L**ET EF be a Right Line given, and let it be required to draw another Right Line Parallel thereunto, at the distance of the length of the Line G.

First, Take in your Compasses the length of the given Line G, and set one foot in the point E, (or in any other part of the given Line, towards the end thereof) describing the small obscure Arch IK:--- Then move the Compasses to F, (near the other end of the Line) and describe another small and obscure Arch LM:--- Lastly, Lay a Ruler to the very top of these two Arches, so that the Ruler do not cross but justly touch either of them; Then if by the edge of the Ruler you draw a Right Line NO, it shall be Parallel to the given Line EF, and at the distance of the length of G, which was to be done.

Practice of the Second Case.] **L**ET PQ be a Right Line given, unto which you are to draw another Right Line Parallel, which Parallel must pass thro' the given point R.

First, Set one foot of your Compasses in R, and with the other take the nearest distance to the given Line PQ; which is done by opening or shutting of the Compasses, till the moveable point of them do only touch the given Line PQ; and there describe the Arch ST:--- Secondly, The Compasses at the same distance, set one foot in P, (or any point towards the other end of the given Line) and with the other describe the Arch VX:--- Lastly, Through the given point R, and the very top of the Arch VX at Y, draw the Right Line RY, and it shall be parallel to the given Line PQ, and shall also pass through the given point R; which was required to be done.

Practice of the Third Case.] **L**ET AB be a Right Line given, to which another Parallel Right Line is given to be drawn, which shall pass through the Point C.

First,

First, Take in your Compasses the distance from C to B, the end of the given Line. --- *Secondly*, Set one Foot in A, (the other end of the given Line) and with the other describe the obscure Arch FG. --- *Thirdly*, Take in your Compasses the length of the given Line AB, and setting one Foot in C, with the other describe the Arch DE, crossing the former in the point H : So a Line drawn from the point C, through the point H, shall be parallel to the given Line AB, which was required.

P R O B L. VI.

To make an Equilateral Triangle, whose Sides shall be all equal to a Right Line given.

Definition.] **A**N Equilateral Triangle, is such a Triangle as hath all its Sides equal one to another.

Practice.] **L**ET Q be the Line given, to which make the Line MO equal ; Then, Take the length thereof in your Compasses, and setting one foot in M, with the other describe the Arch AA. --- Again, Setting one foot in O, describe the Arch BB, cutting the former Arch in N. --- Lastly, draw the Right Lines NO, and NM, and they shall include the Equilateral Triangle MNO, as was required. Figure VI.

P R O B L. VII.

To make a Triangle of any three (possible) Right Lines given.

LET the three Lines given be C, D, and E. --- *First*, Take the longest Line C, in your Compasses, and make the Line FG, equal thereunto. --- *Secondly*, Take in your Compasses the Line D, and setting one foot in G, describe the Arch HH. --- *Thirdly*, Take the Line E, and setting one foot in F, describe the Arch II, crossing the former Arch in K. --- Lastly, Draw the Right Lines KF, and KG, and they shall constitute a Triangle, whose three sides shall be equal to the three given Lines, C, D, E, which was required. Figure VII.

P R O B L. VIII.

To make a Geometrical Square, whose four Sides shall be equal to a given Right Line.

Definition.] **A** Geometrical Square is such a Figure whose four Sides are all equal, and its four Angles, all Right (or Square) Angles.

Practice.] **L**ET the given Line be S, take the length thereof, and make the Line TV equal to it, Then on the end T, erect a Perpendicular TX, equal also to the Line S. --- Again, Set one Foot of the Compasses in X, and with the other describe the Arch PP. --- Also, set one foot in V, and with the other describe the Arch RR, cutting the former Arch in Z. --- Lastly, Draw the Lines ZX, and ZV, and you shall have constituted a Geometrical Square, whose Sides shall be all equal to the given Line S, as was required. Figure VIII.

P R O B L. IX.

To divide a Right Line given, into any number of Equal Parts.

Figure IX. *Practice.* **L**ET the Right line G be the line given, to be divided into five equal parts.

First, Upon any line drawn at pleasure, as the obscure line H K, with your Compasses opened to any small distance, run along the same Five times at the figures, 0, 1, 2, 3, 4, 5, (because the line given is to be divided into five parts).—Then, take in your Compasses the distance from 0 to 5, and with that distance, make the *Equilateral Triangle* 5 L 0.—Again, take in your Compasses the given line G, and set that distance from L to M and N, drawing the line M N (which will be equal to the given line G).—Lastly, Lay a Ruler from L, to the points 1, 2, 3, and 4, in the line H K, and the Ruler will cut the line M N in the points 1, 2, 3, 4, dividing the same line equal to G, into five equal parts, as was required.

Note, This *Equilateral Triangle* thus made, is capable of dividing any other line into five equal parts, be it either greater or lesser than this given line G, if the length thereof be set from L, on both sides of the Triangle, and the line drawn cross from side to side, as in the figure you see the line Q R, which is shorter, and the line P O, which is longer than M N (which was equal to our given line G) are both of them divided into five equal parts.

P R O B L. X.

How to divide a Right Line in such parts as another Right Line is before divided.

Figure X. **L**ET the line A B be a Right line unequally divided in the points 10, 20, 30, 40, 50, 60, 70, and 80. And let it be required to divide the two lines, *viz.* C D which is longer, and E F which is shorter, into the like unequal parts.

Of the given line A B make an *Equilateral Triangle* A S B, and extend the sides S A and S B to G and H, and farther if occasion be.

Then, take the shorter line E F, and set it from S to E, and from S to F, and draw the Right line E F.—Also take the longer line C D, and set that from S to C, and from S to D, and draw the line C D.

Now if you lay a Ruler to S, and to the several unequal divisions of the line A B, where the Ruler so laid doth cross the two other lines, it shall also divide them into the like parts.

P R O B L. XI.

To any three Points given, which lye not in a Right Line; to find the Centre of a Circle, whose Circumference being described, shall pass through the given Points.

Figure XI. **L**ET the three points be A, B, C,—*First,* Set one foot of your Compasses in one of the given points A, and extend the other foot to B, another of the given points, and draw the Arch of a Circle G F D.—*Secondly,* (the Compasses being kept at the same distance as before)

Set

Set one foot in B, and with the other foot cross the former Arch GFD, with two small Marks or Arches, in the points D and F, and draw the right line DF.—*Thirdly*, let one foot of the Compasses in the third given point C, (they still keeping the same opening) and with the other foot cross the first drawn Arch GFD, in the points E and G, and draw the right line EG, crossing the former right line DF in the point O, So shall O be the Centre of a Circle; in which, if you set one foot of the Compasses, and open the other to any of the three given points, the Circle so described shall pass directly through all the three points A, B, and C, as was required.

PROBL. XII.

Two Points within a Circle being given, how to find the Centre of the Arch of a Great Circle, which shall pass through those given Points.

Definition.] **A** Great Circle upon the Sphere, is such a Circle as divideth the Sphere or Globe into Two equal parts; and so, the Arch of a Great Circle, described upon a Plain, is such an Arch, as divideth the Periphery or Circumference of the Fundamental or Primitive Circle given, into Two equal Parts.

Practice.] **L**ET GBHD be the Fundamental or Primitive Circle given, whose Centre is C; and let the two points within the same, through which the Arch of a Great Circle is to pass, be X and Y. *First*, Through one of the given points X, and Centre of the Circle C, draw a right line XC, extending it infinitely towards F; upon this line from the Centre C, erect the Perpendicular CB, and draw the right line BX, cutting the Circle in G, through which point G, and the Centre, draw the Diameter, or right line GCH. *Lastly*, Through the points B and H draw a right line, extending it till it cut the line XF in R, so have you found a third point, viz. R, through which the Arch of the great Circle to be described must pass; and now having three points, X, Y and R, you may through them (by the last Problem) draw the Arch of a Circle, namely the Arch AXYLR, whose Centre will be at K, and whose Arch will divide the Primitive Circle into two equal parts in the points A and L: And that it doth so, is evident, for that the right line drawn from A to L, doth also pass through C the Centre of the Primitive Circle.

Figure
XII.

ASTRONOMICAL DEFINITIONS.

BEING

The Description of a Material Sphere or Globe, and of the Points, Lines and Circles thereon described and belonging, how they are situate upon the Globe, and to what Use each of them serveth.

WHosoever intends to attain any competent Knowledge in the Art of *Dialling* with Profit, must not be ignorant of the *Rudiments* and *Principles* of *Astronomy*; such, I mean, as relate to the *Sphere* or *Globe*; of which I have lately published a Book of the *Uses* of the *Globes*, *Celestial* and *Terrestrial*; and to be well acquainted with the several *Points*, *Lines*, and *Circles* thereon described; and to know to what *Use* each of them are appropriate: To the attaining whereof, I premise these following *Definitions*.

I. Of a Sphere in General.

Figure
XIII.

Definition.] **A** Sphere (as it is defined by Euclide) is a solid Figure; made, when the Diameter of a Semicircle abiding unmoved, the Semicircle is turned round about, till it return to the same place from whence it began to be moved: So that all the Rayes drawn from the Centre to the Superficies of a Sphere are equal.——The Axis of which Sphere is that fixed Right Line, about which the Semicircle is moved.——The Centre of the Sphere, is the same point with that of the Semicircle.——And the two extream ends of the Diameter of the Semicircle, are the two Poles of the Sphere.

The Circles that are described upon the Superficies of a Sphere, are in number Ten: Of which Six are called Great Circles, because they divide the whole body of the Globe into Two equal parts.——The other Four are called Small or Lesser Circles, for that they divide the body of the Globe into Two unequal Parts.

- | | | |
|--|-----|--|
| 1. The Meridian | } { | 7. Azimuths, or Vertical Circles |
| 2. The Horizon | | 8. The two Tropicks |
| 3. The Æquinoctial | | 9. Parallels or Circles of Declination |
| 4. The Ecliptick | | 10. Circles or Parallels of Altitude. |
| 5. The Prime Vertical or Circle of East & West | | |
| 6. The Hour-Circles | | |

Of these Circles, all but the three last are great Circles of the Sphere, which divide it into two equal parts; and the two Tropicks, the Circles of Altitude, and Declination, are smaller Circles, and divide the Sphere into two parts unequally.

There

There are no more Circles than these following, *Actually* described on the Sphere viz.

- | | | | | | | | |
|--------------------|---|--------|---|-------------------|---|------------------|---|
| 1. The Meridian | | | | | | | |
| 2. The Horizon | | | | | | | |
| 3. The Equinoctial | | | | | | | |
| 4. The Ecliptick | | | | | | | |
| 5. Equinoctial | } | Colure | } | VI Great Circles. | | | |
| 6. Solstitial | | | | | | | |
| | | | | | | | |
| 7. Tropicks | { | Cancer | | | } | IV Small Circles | |
| 8. Tropicks | | | | | | | { |
| 9. Polar | { | Artick | | | | | |
| 10. Polar | | | { | Antartick | | | |
| | | | | | | | |

Ten Circles in all; Six Greater and Four Lesser as was said before.

As for the Hour-Circles and Vertical Circles, which are mention'd among the Great Circles of the Sphere in the former Analysis, They are not drawn thereon, because there is an infinite Number of them; and must therefore be left for the Imagination to conceive, according to the position of these Places on the Globe which they respect; as well as several other Great Circles, viz. The Circles of Longitude, Position and many others which are only imaginary.

Neither are these Lesser Circles or Parallels of Declination and Altitude fixed thereon for the like Reason.

But being nevertheless of Equal Use in the Art of Dialling, we have therefore Accounted for them among the Rest in the following Definitions.

Besides these great and small Circles, there are several Points of note upon the Globe: as (1.) The Zenith, which is the Point in the Heavens directly over our heads, in what part of the Earth soever we be; (2.) The Nadir, which is the Point directly under our feet; (3.) The Poles of the World, about which the Heavens are moved; (4.) The Poles of the Ecliptick; (5.) the Poles of all other Circles.

1. Of the Meridian.

The Meridian is a great Circle of the Sphere, which passeth through both the Poles of the World, and also through the Zenith and Nadir Points, and crosseth the Horizon in the North and South Points thereof. Unto this Circle (any Day in the year) when the Sun cometh, it is Noon or Mid-day; and when the Moon, Stars or Planets in the Night, come to touch this Circle, they are then said to be upon the Meridian, or at the highest they will be that Night. This Circle in the Scheme of this Projection is noted by the Letters ZHNO.

2. Of the Horizon.

The Horizon also is a great Circle of the Sphere, and it is that Circle which divideth the visible part of the Heavens which we see, from the not visible, that is, it divideth the Sphere into two Hemispheres, the lower, and the higher. To this Circle when either the Sun, Moon, Stars or Planets come to the East part, they are then said to rise; and when they have passed from the Easterly Point by the Meridian, and descended to the Western part of this Circle, they are then said to set. This Circle is represented in the Projection by the right Line HAO.

3. *Of the Equinoctial.*

The *Equinoctial* is a great Circle, and in the *Sphere* it is elevated above the *Horizon* (upon the *Meridian* Circle) so much as is the Complement of the Latitude of the Place. As at *London*, where the Latitude is 51 degr. 32 min. there the *Equinoctial* is elevated 38 degr. 28. min. (which is so much as 51 degr. 32 min. wants of 90 degr.) and it cutteth the *Horizon* in the Points of *East* and *West*. Unto this Circle when the Sun cometh (which is twice every year, namely, about the 10th of *March* and the 12th of *September*) it causeth the Days and Nights to be of equal length all the World over. This Circle is noted in the Scheme with Æ A æ , and cuts the *Horizon* in the point A, which represents both the *East* and *West* points thereof.

4. *Of the Ecliptick.*

This also is a great Circle of the *Sphere*, and (in the *Northern Hemisphere*, where the *North Pole* is visible above the *Horizon*, and the *South Pole* not visible) is elevated above the *Equinoctial* Circle so much as is the Sun's greatest Declination, which is 23 degr. and about 31 min. and is as much depressed below the *Equinoctial* in the *Southern Hemisphere*. This Circle is called by some, *The way of the Sun*, for that the Sun in his motion never swerveth or goeth out thereof; and so his *Longitude* or *Place* is counted in this Line. It cutteth the *Horizon* in the *East* and *West* Point A, as the *Equinoctial* did. It is represented in the Scheme by the Line ⊖ A ⊕ , and hath charactered upon it the 12 Signs of the Zodiack; the Six Northern Signs, $\gamma \delta \epsilon \zeta \eta \theta$ and $\imath$ being on that half which is above the *Horizon*, and the Six Southern Signs $\kappa \lambda \mu \nu \xi \omicron$ and π , on the other half, which is below the *Horizon*.

5. *Of the Prime Vertical.*

The *Prime Vertical*, or Circle of *East* and *West*, (generally called the *Equinoctial Colure*) and then (as the *Sphere* is here projected) the *Meridian* representeth the *Solstitial Colure*, is a great Circle passing through the *Zenith* and *Nadir* Points, and also through the *East* and *West* Points of the *Horizon*. Unto this Circle when the Sun, Moon, Stars or Planets, do (in their Motions) arrive, they are then due *East* or *West*. It is in the Projection signified by the right Line ZAN, passing through Z, the *Zenith*; N, the *Nadir*; and A, the *East* and *West* point of the *Horizon*; and also cutteth the *Equinoctial* in the Points γ and π .

6. *Of the Hour-Circles.*

The *Hour-Circles* are great Circles of the *Sphere*, meeting together in the *Poles* of the World, and crossing the *Equinoctial* at right Angles, dividing it at every 15 degrees; and then every of those Divisions is one Hour of time: but if they pass through other parts of the *Equinoctial*, dividing it unequally, then do those *Hour-Circles* represent unequal Spaces of time, according to the distance they are from the *Meridian*, or one from another. Of these Circles in the Scheme of the Projection there are four, thus noted, P B S, P A S, P C S, and P D S.

7. *Of the Azimuth Circles.*

The *Azimuth* or *Vertical Circles*, are great Circles of the *Sphere*, meeting together in the *Zenith* and *Nadir* Points, as the *Hour-Circles* do in the *Poles* of the World, and divide the *Horizon* at right Angles, either equally, or unequally, as the *Hour-Circles* did the *Equinoctial*. In the Scheme of the Projection there are four of these *Vertical Circles*, thus noted, Z $\odot$ N, Z F N, Z A N, and Z G N.

8. *Of the Tropicks.*

The *Tropicks* are Lesser Circles of the *Sphere*, dividing it unequally, and are drawn parallel to the *Equinoctial*, at 23 degr. 30 min. distance therefrom, equal to the Sun's greatest Declination on either side. That *Tropick* which is on the *North-side* is called the *Tropick of Cancer*, to which when the Sun cometh (which is but once in a year, about the 10th of *June*) it maketh the *Longest Days* to all the *Northern* Inhabitants of the World and the *Shortest Nights*. The other *Tropick*, which is on the *South-side* of the *Equinoctial*, is called *The Tropick of Capricorn*, to which when the Sun cometh (which is about the 11th of *December*) it maketh the *Shortest Dayes* and the *Longest Nights* to all *Northern* Inhabitants, and the contrary to all the *Southern* Inhabitants of the World. In the Projection the *Tropick of Cancer* is signified by $\Im$ I $\Im$, and the *Tropick of Capricorn* by $\wp$ K $\wp$.

9. *Of the Circles or Parallels of Declination.*

These also are Smaller Circles of the *Sphere*, and are drawn parallel to the *Equinoctial*, towards both the *Tropicks*, and up to them. Those that are on the *North-side* of the *Equinoctial* are called *Parallels of North Declination*, and those that are on the *South-side* of the *Equinoctial* are called *Parallels of South Declination*. Of these *Parallels* there are in the Scheme of the Projection two, one towards the *Tropick of Cancer*, the other towards the *Tropick of Capricorn*, and either of them 20 degrees distant from the *Equinoctial*. The *Northern Parallel of Declination* is noted with Π O Ω , and the *Southern* with $\approx$ E $\ddagger$.

10. *Of the Circles or Parallels of Altitude.*

The Circles of *Altitude* are likewise Small Circles of the *Sphere*, and are drawn parallel to the *Horizon*, as the Circles of *Declination* were to the *Equinoctial*. These *Parallels* are drawn from the *Horizon* towards the *Zenith* point, and upon occasion, in many Cases quite up unto it. By these *Parallels* are measured the *Altitude* or *Height* of the Sun, Moon, and Stars. in the Scheme there is only one of them, and that is expressed by the Letters M E L.

Thus have I given you a brief and plain Description of the Circles, both great and small, which we shall have occasion to use in the following Treatise. And here note, that every Circle of the *Sphere* (both Great and Small) hath his proper Poles, which Poles (of all the great Circles) are 90 Degrees, or a Quadrant of a Circle distant from the Circle it self.

By way of Conclusion to this *Introduction*, I have here inserted two *Tables*, useful and pertinent to the following Tractates: the one of the *Latitudes* of divers principal Places in *England*, *Scotland*, and *Ireland*: The other of the *Sun's Declination*, useful for finding the *Sun's Azimuth*, &c.

An Alphabetical Table of the Latitudes of the chief Cities and Towns in England, Wales, Scotland, and Ireland. By Robert Morden.

	D.	M.		D.	M.		D.	M.
<i>In ENGLAND.</i>			Oxford	51	46	Dundee	56	31
Bath	51	23	Peterborough	52	36	Glasgow	56	5
Bedford	52	8	Reading	51	28	Irwin	55	50
Bristol	51	28	Rocheſter	51	25	Larnack	55	51
Buckingham	52	0	Salisbury	51	3	Montroſſe	56	44
Bury in Suff.	52	20	Shrewsbury	52	46	Nairn	57	30
Cambridge	52	3	Southampton	50	54	Perth or St. J.	56	32
Canterbury	51	20	Warwick	52	21	Sterling	56	15
Carlile	54	59	Wincheſter	51	4	Withern	54	57
Cheſter	53	17	Worceſter	52	15	<i>In IRELAND.</i>		
Chicheſter	50	48	York	53	58	Ardmagh	54	23
Colcheſter	51	58	<i>In WALES.</i>			Athlone	53	21
Coventry	52	28	Aſaph	53	20	Bantry	51	30
Derby	52	58	Bangor	53	21	Belfaſt	54	41
Dorcheſter	50	41	Beaumorice	53	24	Caſhel	52	24
Durham	54	50	Brecknock	52	6	Catherlagh	52	46
Ely	52	25	Cardiff	51	30	Clare	52	42
Exeter	50	42	Cardigan	52	12	Cork	51	43
Gloceſter	51	54	Carmarthen	51	56	Craven	54	1
Guilford	51	12	Carnarvan	53	18	Drogheda	53	44
Hertford	51	49	S. Davids	52	0	<i>DUBLIN</i>	53	20
Hereford	51	8	Denbiſh	53	18	Donnegal	54	40
Huntington	52	10	Harlech	52	58	Dundalk	54	2
Ipswich	52	8	Landaaf	51	31	Dungarvan	51	57
Kendale	54	22	Montgomery	52	39	Galloway	53	12
Lancaſter	54	28	Pembrook	51	45	James Town	53	53
Lanceſton	50	49	Radnor	52	30	Kildare	53	8
Leiceſter	52	40	Welchpool	52	43	Kilkenny	52	34
Litchfield	52	50	<i>In SCOTLAND.</i>			Kinſale	51	30
Lincoln	53	15	Aberdeen	57	6	Knockfergus	54	50
<i>LONDON</i>	51	32	St. Andrews	56	24	Limrick	52	33
Monmouth	51	52	Berwick	55	50	Letrim	53	58
Newcaſtle	55	3	<i>EDINGBURGH</i>	56	4	Londonderry	55	4
Northampton	52	14	Dunblain	56	20	Longford	53	42
Norwich	52	42	Dunbritton	56	10	Slego	54	17
Nottingham	52	59	Dunbar	56	3	Waterford	52	9
Okeham	52	41	Dunfries	55	3	Wexford	52	17

Fig. I

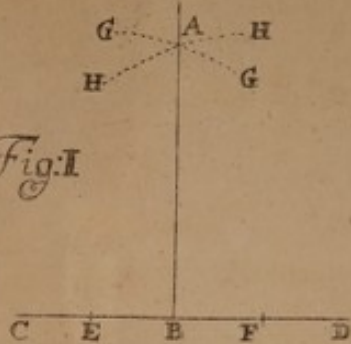


Fig. II

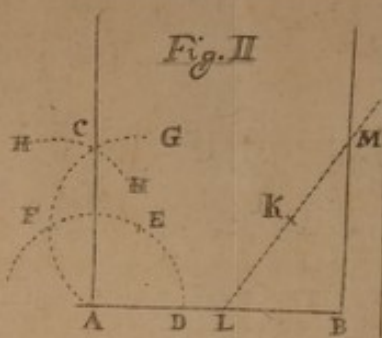


Fig. III

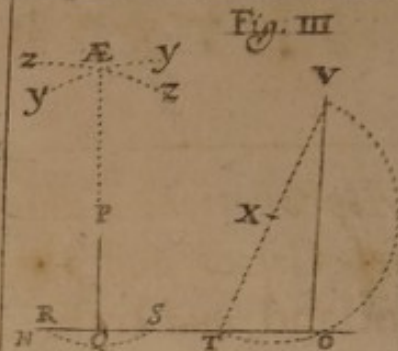


Fig. IV

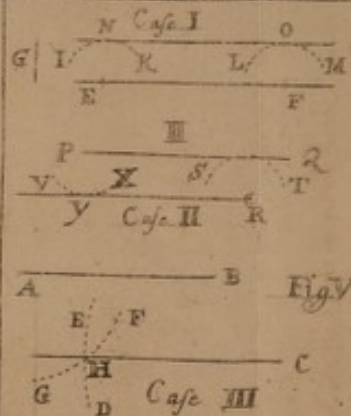
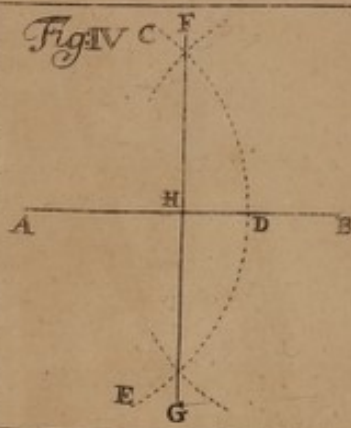


Fig. VI

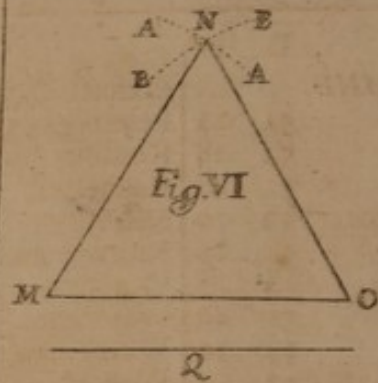


Fig. VII

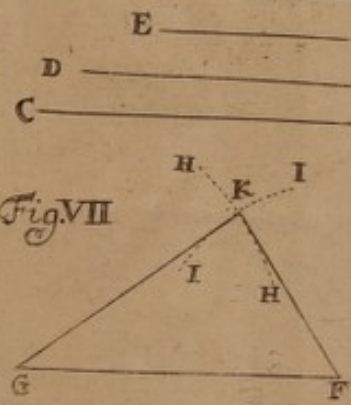


Fig. VIII



Fig. IX

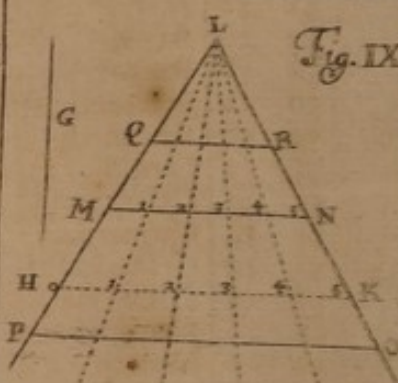


Fig. X

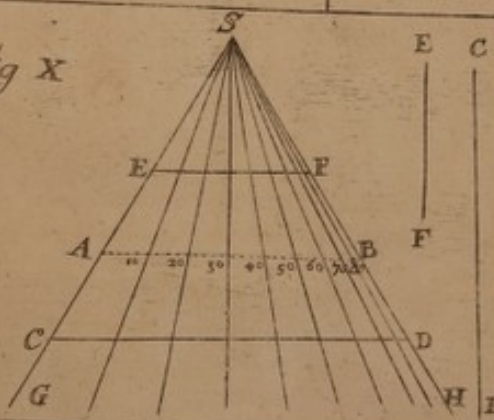


Fig. XI

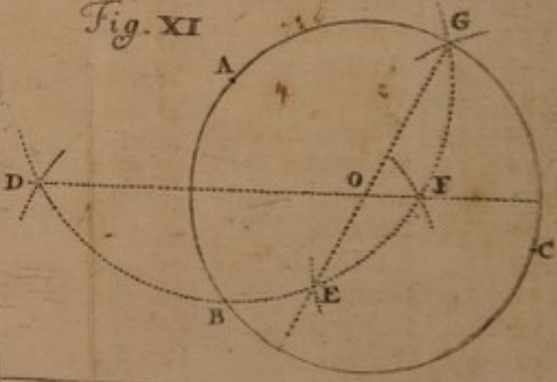


Fig. XIII

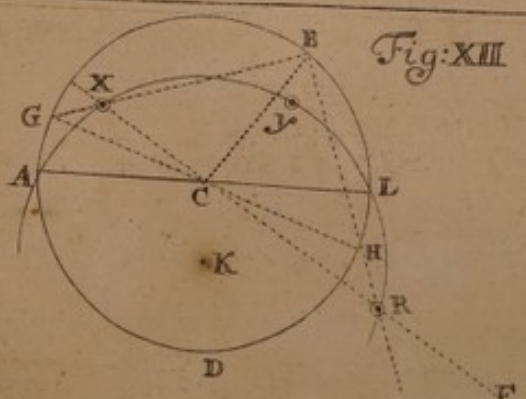
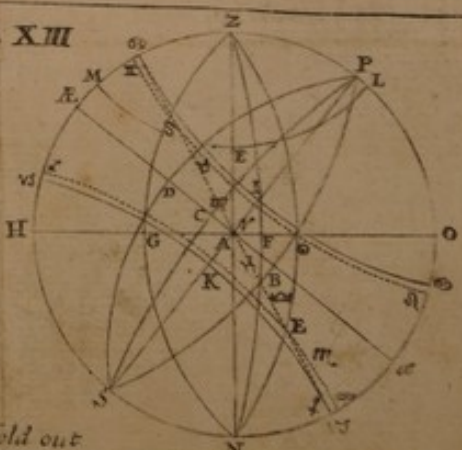


Fig. XIII



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A TABLE shewing the Sun's Declination for every day of the Year, serving for the more ready finding of the Sun's Azimuth.

A Table of the Sun's Declination.

Days.	Janu.		Febr.		March.		April.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.		
	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	
1	21	44	13	46	3	24	8	36	18	5	23	12	22	8	15	12	4	24	7	15	17	40	23	9	
2	21	33	13	26	3	0	8	58	18	20	23	16	22	0	14	54	4	2	7	38	17	56	23	13	
3	21	23	13	5	2	37	9	20	18	35	23	19	21	51	14	36	3	38	8	0	18	12	23	17	
4	21	13	12	45	2	13	9	42	18	50	23	22	21	42	14	17	3	15	8	22	18	28	23	20	
5	21	2	12	25	1	49	10	3	19	4	23	25	21	32	13	58	2	52	8	45	18	43	23	23	
6	20	50	12	4	1	25	10	24	19	18	23	27	21	22	13	39	2	29	9	7	18	58	23	26	
7	20	38	11	43	1	1	10	45	19	31	23	29	21	12	13	20	2	5	9	29	19	13	23	28	
8	20	26	11	21	0	38	11	0	19	44	23	30	21	2	13	1	1	North.	42	9	51	19	27	30	
9	20	13	11	0	0	South.	14	11	27	19	57	23	31	20	51	12	41	1	North.	19	10	13	19	41	31
10	20	0	10	38	0	10	11	47	20	10	23	32	20	40	12	21	0	55	10	35	19	55	23	31	
11	19	46	10	16	0	33	12	7	20	22	23	31	20	28	12	1	0	32	10	56	20	8	23	31	
12	19	32	9	54	0	1	12	28	20	34	23	31	20	16	11	41	0	16	11	18	20	21	23	31	
13	19	18	9	32	1	21	12	48	20	45	23	30	20	4	11	21	0	16	11	39	20	34	23	29	
14	19	3	9	10	1	44	13	7	20	56	23	29	19	51	11	9	0	South.	39	12	0	20	46	23	27
15	18	48	8	48	2	8	13	27	21	7	23	28	19	38	10	39	1	3	12	21	20	58	23	25	
16	18	33	8	25	2	31	13	46	21	17	23	26	19	25	10	18	1	26	12	41	21	9	23	22	
17	18	17	8	3	2	54	14	5	21	27	23	23	19	12	9	57	1	50	13	22	21	20	23	19	
18	18	2	7	40	3	18	14	24	21	37	23	20	18	58	9	36	2	13	13	22	21	31	23	16	
19	17	45	7	17	3	41	14	42	21	46	23	17	18	43	9	15	2	37	13	42	21	41	23	12	
20	17	28	6	54	4	5	15	1	21	55	23	14	18	29	8	53	3	0	14	22	21	50	23	7	
21	17	11	6	31	4	28	15	19	22	4	23	10	18	14	8	31	3	23	14	21	22	0	23	2	
22	16	54	6	8	4	51	15	37	22	12	23	6	17	59	8	9	3	47	14	41	22	9	22	57	
23	16	36	5	45	5	14	15	54	22	20	23	1	17	44	7	47	4	10	15	0	22	17	22	51	
24	16	18	5	21	5	37	16	12	22	27	22	55	17	28	7	25	4	33	15	19	22	25	22	44	
25	16	0	4	58	6	0	16	29	22	34	22	50	17	12	7	3	4	57	15	37	22	33	22	37	
26	15	42	4	34	6	22	16	46	22	41	22	44	16	56	6	41	5	20	15	55	22	40	22	30	
27	15	23	4	11	6	45	17	2	22	47	22	37	16	39	6	18	5	43	16	13	22	46	22	22	
28	15	4	3	47	7	7	17	18	22	53	22	31	16	22	5	56	6	6	16	31	22	52	22	14	
29	14	45	.	.	7	30	17	34	22	58	22	23	16	6	5	33	6	29	16	49	22	58	22	5	
30	14	26	.	.	7	52	17	50	23	3	22	16	15	48	5	10	6	52	17	6	23	4	21	56	
31	14	6	.	.	8	14	.	.	23	8	.	15	30	4	47	.	.	17	23	.	.	21	49		

The End of the Introduction.

PLAIN DIALLING, DEMONSTRATED:

By Projecting the Sphere *in Plano*, upon the Plain of the *Horizon*, suitable to any *Latitude*; and from thence to draw the *Hour-Lines*, *Stile* and *Sub-Stile*, proper to any *Plain*, in their true Places and Positions.

ALSO

Upon the *Projection*, to express the several *Spherical Triangles* from which all the *Requisites* belonging to any *Dial* are to be *Calculated*; And how to *Calculate* the same.

LIKEWISE,

How to Measure the *Sides* and *Angles* of those *Triangles* upon the *Projection* it self.

The First TRACTATE.

CHAP. I.

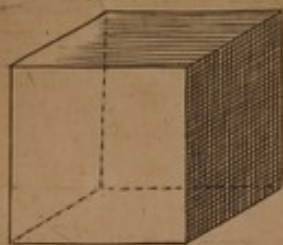
Of the Lines or Scales of Natural Sines, Tangents, Secants, Half Tangents, and Chords, often mention'd, and made use of in this Book; Their construction or making, shewing how they are deduced from a Circle or Semicircle; and from thence transferred unto Streight Lines, and so may properly be termed Circular Scales or Lines.

Definition.] **T**He Circumference of every Circle (be it great or small) is divided into 360 equal Parts, called Degrees; and each of those Degrees is again divided (or supposed so to be) into 60 Minutes So that a Semi, or Half Circle, contains 180 degrees, and a Quadrant, or Fourth part of a Circle, contains 90 degrees.

The Diameter of a Circle is a right Line drawn through the Center of the Circle, dividing the Circle into Two equal Parts.

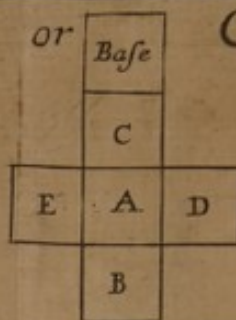
The Semi-Diameter of a Circle, is one half of the Diameter, and is for the most part called the Radius.

Practice.



Hexaedron or Cube

Fig: I.



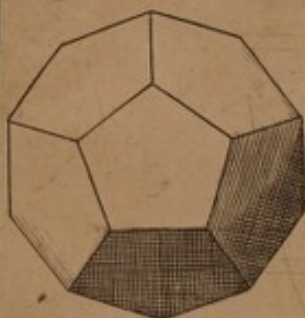
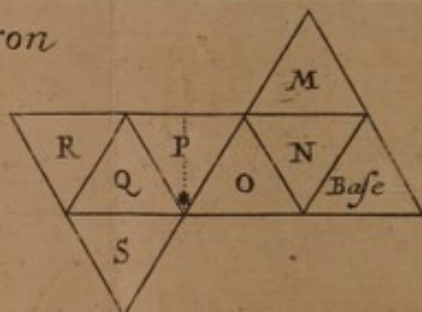
Tetraedron

Fig: II.



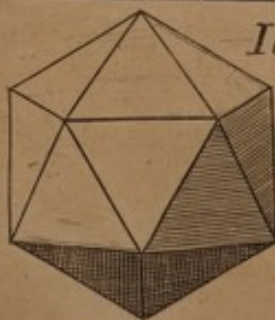
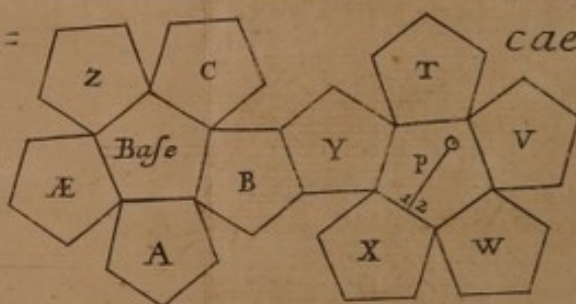
Octaedron

Fig: III.



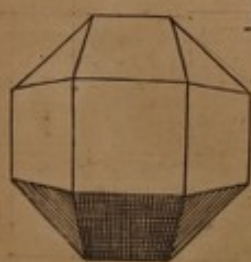
Dodecaedron

Fig: IV.



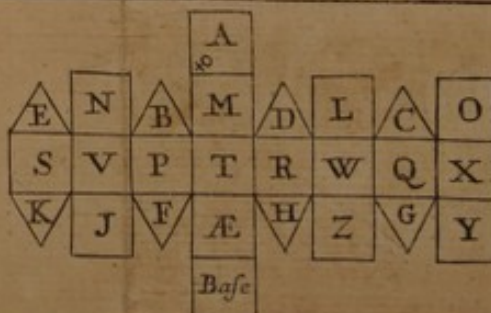
Icosaedron

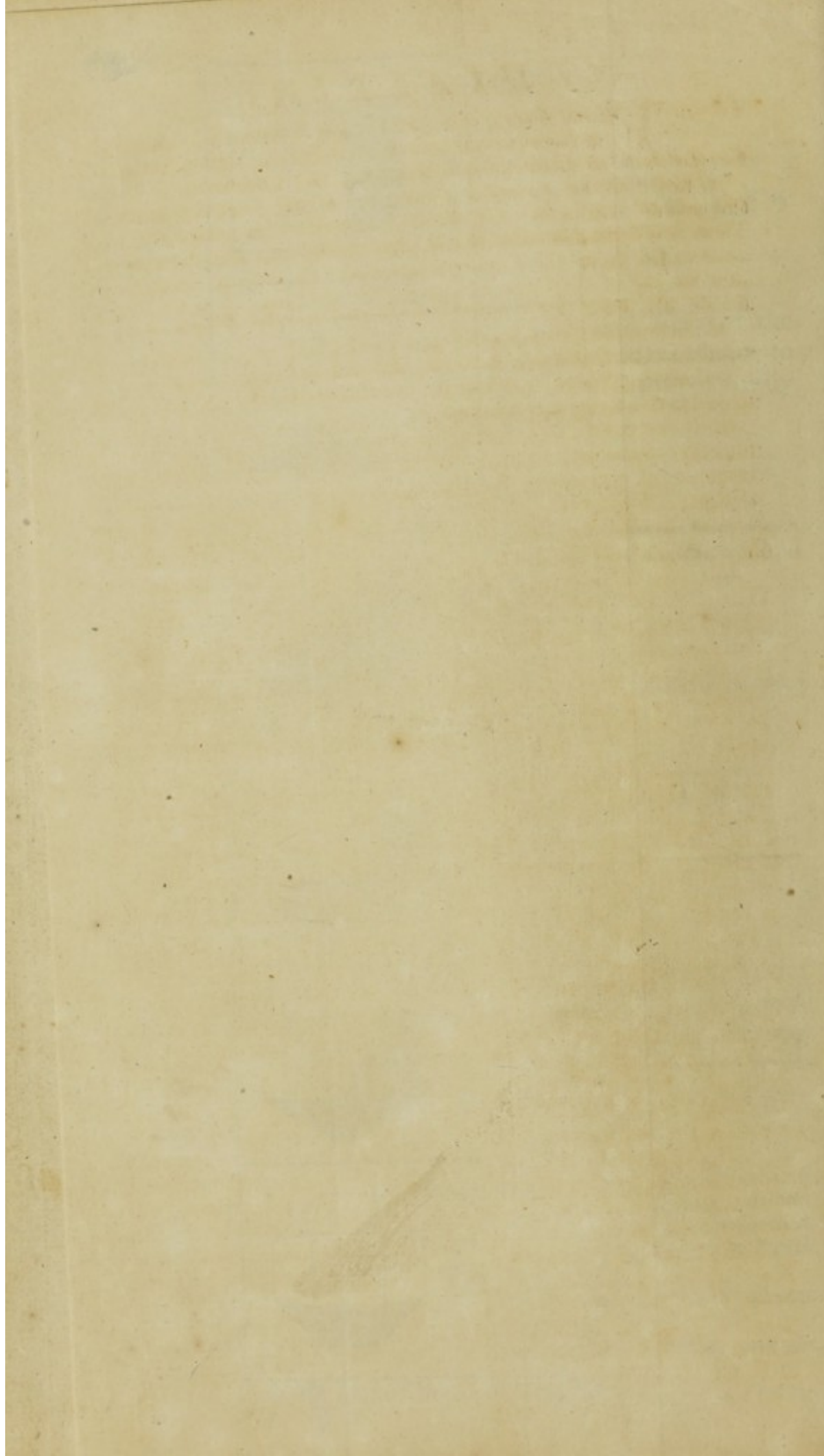
Fig: V.



Poliedron

Fig: VI.





Practice.] F R O M these Definitions of a Circle and its parts, I proceed *Figure I.* to shew the manner of Production of the fore-mention'd Circular Scales or Lines, of Sines, Tangents, &c. there-from.

1. Let there be a Semicircle described of any Radius whatsoever, (suppose of two Inches, as in the Figure) which Semicircle let be VRS, Then is VS the Diameter of the Semicircle VRS, and the Perpendicular raised from the Center or middle of the Diameter $\odot$ R, is the Semidiameter of the Circle, which divides the Semicircle into two Quadrants, viz. $\odot$ RS, and $\odot$ RV.

2. Divide the two Quadrants $\odot$ RS and $\odot$ RV, each of them into 90 equal parts or Degrees, as in the Figure is done, beginning at V and S, and ascending upwards towards R; numbring them by 10, 20, 30, &c. to 90; as there you may see done.

3. If you draw Right Lines from 10 in the one Quadrant, to 10 in the other Quadrant, and from 20 in one, to 20 in the other, and so upwards, till you come to R; those Lines 10. 10, 20. 20, &c. will be all of them Parallel to the Diameter VS; and will cut or divide the Radius, or Semidiameter R $\odot$, into 90 unequal Parts or Divisions; which Line (so unequally divided) is a Line or Scale of S I N E S.

4. Upon the Point S, erect a Perpendicular to VS, namely ST: Then, if from the Center $\odot$, you draw Right Lines through every degree of the Quadrant (as here is through every Tenth) you shall divide the Perpendicular Line ST, into unequal parts, at the points 10, 20, 30, &c. up to T, and farther if you go on: So shall this unequally divided Line S T, be a T A N G E N T Line, or Scale: And from the beginning thereof at S, to 45 degrees thereof, will be equal to the Radius of the Circle, or to the whole Scale of Sines $\odot$ R.

5. If from the Center $\odot$, and from every degree of the Quadrant (or tenth degree thereof) as here is done, you draw Right Lines to the Tangent Line, those Lines so drawn shall be S E C A N T S: As the Line $\odot$ ET, (drawn from the Center $\odot$ through 60 degrees of the Quadrant RS) is the Secant of 60 deg. And the Line drawn from $\odot$, thro' 50 deg. of the Quadrant, to 50 degrees in the Tangent Line; that Line is the Secant of 50 deg. And so of all the Rest.

6. Draw the Line VR, and with one foot of your Compasses placed in V, open the other to 80 deg. in the Quadrant, and transfer that distance of your Compasses, to the Right Line VR, by drawing of the small Arch 80. 80. cutting the Line VR in 80 deg. the like for 70, 60, 50, &c. So shall the Line VR be unequally divided into 90 parts, and so becomes a Line or Scale of C H O R D S. 60 degrees of this Scale of Chords, viz. from V to 60, is equal to the whole Line of Sines; and is called The R A D I U S of the Line, or Scale of Chords; it being equal to the Semidiameter of the Circle $\odot$ R.

7. If 45 degrees of the Tangent Line, viz. from S to 45, be divided as here it is, and 5 deg. be numbered with 10, and 10 with 20, and 20 with 40, then will 45 deg. be 90 deg. and a line so divided is called a Line or Scale of H A L F T A N G E N T S.

These Lines here described may most conveniently, be put upon a Ruler of 8 or 12 Inches long, together with some other Lines, or Scales of Equal Parts, Chords to several Radius's, and such like; which will be a convenient Instrument for any Artift to have about him: a figure of such a Ruler, with such Scales upon them is graduated in Figure II.

Figure.
II.

And Note, That these Scales being put upon a straight Ruler, as in the Figure, they will serve to Project and Work several other Conclusions, however they only suit with the particular Radius to which they are made: But if you put them upon a Sector with a French Joynt, they will be far more convenient for use; for then, they may be applied to any Radius, not exceeding the length of the Sector's Legs.

CHAP. II.

How to Project the Sphere in Plano suitable to any Latitude, upon the Plain of the Horizon.

HAVING already made way for the more orderly proceeding in the matter principally intended in this *First Tractate*, namely *Dialling* deduced from the Sphere it self, which of all others is the most Rational and Demonstrative, the Subject of this second Chapter shall be to shew how to Project the Circles of the Sphere upon a Plain, suitable to any Latitude or Horizon required. This may be performed several ways; Namely, (1) By help of a Line or Scale of equal Parts divided into 10000, of equal length with the Radius or Semidiameter of the Primitive Circle you Project upon. (2) By the help only of a Scale of Chords of the same Radius with the Circle you Project upon. (3) And best of all by the Scales of Sines, Tangents, Secants, Half Tangents, and Chords; all made to the same Radius, or Semidiameter of the Circle you project upon. I shall say nothing of the First of these Three ways, because in this Book there are no Tables of Natural Sines, Tangents, or Secants; nor of the Second, because the Lines in many Cases will extend to almost infinite Excursions, but shall satisfy my self, and the Reader with the Third and Last way namely by the Lines or Scales, of Natural Sines, Tangents, Secants, Half Tangents, and Chords, joyntly used together; the making whereof hath been already taught in the former Chapter. To proceed then, — Let it be required to Project the Sphere suitable to the Horizon of London, whose Latitude is 51 deg. 32 min.

Figure. First, Open your Compasses to the Radius of your Sines, Tangents, III. Secants, Half Tangents, and Chords, which are all of one Radius (*viz.* Two Inches) and with that extent upon the Point Z, as a Center describe a Circle, which I call the *Fundamental* or *Primitive Circle*, and let it represent the *Horizon* of London.

Secondly, Divide this Circle into four equal parts, by help of the two Diameters, drawn at right Angles, namely the line NZS, representing the Meridian, and the Line WZE, representing the *Prime Vertical Circle*, or *Azimuth* of East and West.

Thirdly, Forasmuch as the Latitude of London is 51 deg. 32 min. take 38 deg. 28 min. (the Complement thereof) out of the Scale of Half Tangents, and set them upon the Meridian NZS, from Z to P, so shall P be the Pole of the World, and the Center where all the Hour-Circles must meet and a Circle drawn which shall pass through the three points W, P, E, shall be the Hour-Circle of Six. To find the Center whereof (which

(which will always fall in the Meridian Line NZS, extended if need be) take the Secant of 51 deg. 32 min. out of the Scale of Secants, and set it upon the Meridian from P, it shall give you the Point B: Or the Tangent of 51 deg. 32 min. set upon the Meridian from Z, shall give the same Point B as before; which Point is the Center of the Six a Clock Circle.

Fourthly, In regard that the *Equinoctial Circle* is 90 deg. distant from the *Pole of the World*, and 51 deg. 32 min. distant from the *Zenith*: Take 51 deg. 32 min. out of the Scale of *Half Tangents*, and set them upon the Meridian from Z to Æ, so shall Æ be a Point in the Meridian, through which, and the Points W and E in the *Horizon*, the *Equinoctial Circle* must pass. And to find the Center thereof, the Secant of 38 deg. 28 min. set from Æ, or the Tangent of 38 deg. 28 min. set from Z upon the Meridian, will either of them give the Point C for the Center of the *Equinoctial Circle* W Æ E.

Fifthly, for the describing of the *Hour-Circles*, the Point B (before found) being the Center of the *Hour-Circle of Six*: Through that Point B, draw a Line at length, as K B K, which must be Perpendicular to the Meridian N Z S, and consequently Parallel to the *Prime Vertical Circle* W Z E, and in drawing this Line true (according to these conditions) you must be very careful, for the true drawing of all the other *HOURLY CIRCLES* do wholly depend thereon, the *Centers* of all of them being in this Line. And for the finding of the *Centers* in this Line, you must.

Sixthly, Take 45 deg. out of your *Tangent Scale*, and set it from P to R upon the Meridian Line, and draw an obscure Line through R, Parallel to W E, as the Line R H: Upon this Line, set the Tangent of 15 deg. from R to 5.—Also the Tangent of 30 deg. from R to 4.—Likewise the Tangent of 45 deg. from R to 3.—The Tangent of 60 deg. from R to 2.—And lastly, the Tangent of 75 deg. from R to 1.

Seventhly, Lay a Ruler from P to 5, in the Line R H, and it will cut the Line B K in the Point V, which Point will be the Center, by which to describe the *Hour-Circle of Five*, for one foot of the Compasses placed in V, and extended to P, will describe the Arch 5 P 5, for the *Hour-Circle of Five*. And the distance B V, being set upon the Line B K, on the other side of the Meridian, from B to VII, the same extent of the Compasses as before, one foot being placed in VII, and extended to P, will describe the Circular Arch 7 P 7, for the *Hour-Circle of Seven*.—And in this manner, if you lay a Ruler from P to 4, in the Line R H, it will cut the Line B K in IIII, and the Point IIII will be the Center whereby to draw the *Hour-Circle of Four*, viz. The Arch 4 P 4. And the distance B IIII, being set on the other side of the Meridian, from B to VIII, shall there give you the Center whereby to describe the Circle 8 P 8, for the *Hour-Circle of Eight*.—And in the same manner, must you do for the *Hour Circles* of 3 and 9.—2 and 10.—1 and 11, whose *Centers* will all be in the Line B K, extended both ways:—And in the same manner as the *Whole Hours* were drawn, so may the *Halves*, and *Quarters* be drawn, by allowing 15 deg. of the *Tangent Scale* for *One hour*, 30 deg. for *Two hours*, &c.—7 deg. 30 min. for *half an Hour*, and 3 deg. 45 min. for *One quarter of an Hour*, and setting those distances upon the Line R H, and afterwards transferring them to the Line B K, as you see done in the Figure of the *Projection*; you shall have

Centers for the Halves and Quarters of Hours also.—And because the Centers of those *Hour-Circles* which come near the *Meridian*, as the Hours of 11 and 1, and the *halves* and *quarters* between them and the *Meridian*, falling upon the Line B K will be very remote, and beyond the reach of ordinary Compasses, therefore for the describing of them, Artificers, and other Artists, have an Instrument which they call a *Bow*, by which they draw them with great facility.

A Synopsis of this Projection.

- Figure III.* The Primitive Circle N E S W, represents the *Horizon*,; whose Latitude is 51 deg. 32 min.
 Z is the Zenith.
 N Z S the Meridian.
 W Z E the Prime Vertical Circle, or Azimuth of East and West.
 P the Pole of the World, whose distance from Z is—the half Tangent of 38 deg. 28 min. the Complement of the Latitude.
 W Æ E is the Equinoctial, whose Distance from Z is—the half Tangent of 51 deg. 32 min.
 C the Center of the Equinoctial Circle, whose distance from Æ is — the Secant of 38 deg. 28 min. Or from Z is—the Tangent of 38 deg. 28 min. the Complement of the Latitude.
 B is the Center of the Equinoctial Colure or Hour Circle of Six, W P E, whose distance from P is—the Secant of 51 deg. 32 min. Or from Z is—the Tangent of 51 deg. 32 min. the Latitude.
 The Centers of the Hour-Circles are all found in the Line K B K. extended both ways, as is shewn in the Description.

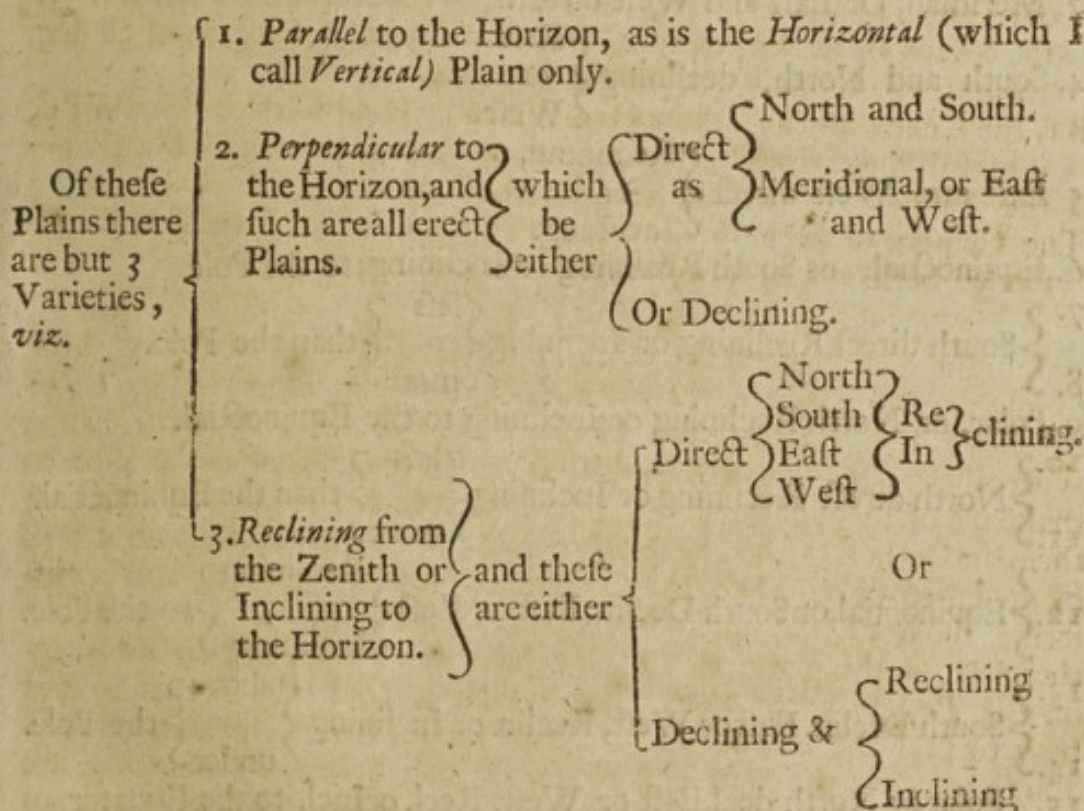
I might have proceeded farther in this *Projection*, by shewing how to inscribe the *Tropicks*, the *Parallels* of the *Signs*, or of the *Sun's Declination*: The *Ecliptick*, the *Circles* of *Altitude*, and *Azimuth* Lines, with others relating to the *Sun's Course*; but there being no occasion to make use of them in this place, I shall reserve the manner of inserting them and others of the like Nature into the *Projection*, because it will be done hereafter, when I shall come to shew the manner how to inscribe those *Circles*, and *others* upon *Dial-Plains*.—Let it suffice therefore, in this place, that I shew how to represent and lay down upon the *Projection* any *Plain* upon which a *Dial* may be made, and how to find the *Centers* and *Poles* of such *Plains* so described: And also to measure the *Sides* and *Angles* of such *Spherical Triangles* as are upon the *Projection*: But first, it will be requisite that I give you an account in a short Analysis

C H A P. III.

Of the Denominations and Situations of the several sorts of plains upon which Dials are usually made.

DI A L S may be made upon any plain Superficies, and all plain Superficies are posited in one or other of these three Positions, *viz.* either *Parallel*, *Perpendicular*, or *Oblique* to the *Horizon* of the Place, wherein the Plain is seated, and all the Hour-Lines drawn upon any Plain, are great Circles of the Sphere, which being projected upon a plain Superficies, become Strait Lines.

Now the Art of Dialling consisteth chiefly in the finding out of these Lines, and their true distances from each other, the which do continually vary, according as the Plains upon which they are described, or projected, are situated in respect of the *HORIZON* of the Place.



Now in the making of particular Dials, which are in number 25, I reduce them to 17, by supplying the *Inclining* Plains from their opposite *Recliners*, as being indeed the same.

And to avoid mistakes, which may possibly arise by comparing my Examples with other Authors, or others with mine; you are to take notice, That I denominate all my Plains from the sight (or the Position) of their Axis in the Heavens, and not from the Circles of the Sphere in which they lie. Therefore.

Those Plains which most Writers call	Horizontal	I call	Vertical	Direct	Because their Poles do lye in the	Vertex or <i>Zenith</i> Point.	
	Vertical		North			North	Points of the <i>Hor.</i>
	Meridian		South	Direct		South	
	Equinoctial		East			East	
	Polar		West	Poles of the World		<i>Equinoctial</i> Circle.	
			Polar				
			<i>Equinoctial</i>				

Again, All leaning Plains whether direct or declining, whose upper faces behold the *Zenith*, I call *Recliners*, and the neather, or under faces of them, which respect, or look down to the *Nadir*, I call *Incliners*.

This Distinction being made, the Plains, of which the Examples following are given, are thus denominated.

1. Vertical or Horizontal.
2. South and North direct.
3. Meridian, Or East and West direct.
4. South and North, declining $\left\{ \begin{array}{l} \text{East} \\ \text{or} \\ \text{West} \end{array} \right.$
5. East and West direct $\left\{ \begin{array}{l} \text{Reclining,} \\ \text{or} \\ \text{Inclining.} \end{array} \right.$
6. Equinoctial, or South Reclining or Inclining, to the Pole.
7. $\left\{ \begin{array}{l} \text{South direct Reclining or Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right. \left\{ \begin{array}{l} \text{than the Pole.} \end{array} \right.$
8. $\left\{ \begin{array}{l} \text{South direct Reclining or Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right. \left\{ \begin{array}{l} \text{than the Pole.} \end{array} \right.$
9. Polar, or North Reclining or Inclining to the Equinoctial.
10. $\left\{ \begin{array}{l} \text{North direct Reclining or Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right. \left\{ \begin{array}{l} \text{than the Equinoctial.} \end{array} \right.$
11. $\left\{ \begin{array}{l} \text{North direct Reclining or Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right. \left\{ \begin{array}{l} \text{than the Equinoctial.} \end{array} \right.$
12. $\left\{ \begin{array}{l} \text{Equinoctial, or South Declin. East or West} \end{array} \right. \left\{ \begin{array}{l} \text{Reclining} \\ \text{Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{to the Pole.} \end{array} \right.$
13. $\left\{ \begin{array}{l} \text{South Declin. East or West, Reclin. or Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right. \left\{ \begin{array}{l} \text{the Pole.} \end{array} \right.$
14. $\left\{ \begin{array}{l} \text{South Declin. East or West, Reclin. or Inclining} \end{array} \right. \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right. \left\{ \begin{array}{l} \text{the Pole.} \end{array} \right.$
15. Polar or North decl. East or West, Recl. or Incl. to the Equator.
16. $\left\{ \begin{array}{l} \text{North declining East or West} \end{array} \right. \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right. \left\{ \begin{array}{l} \text{the intersection of the Meri-} \\ \text{dian and Equator} \end{array} \right.$
17. $\left\{ \begin{array}{l} \text{North declining East or West} \end{array} \right. \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right. \left\{ \begin{array}{l} \text{the intersection of the Meri-} \\ \text{dian and Equator} \end{array} \right.$

C H A P. IV.

How to describe upon the Projection, any Plain mentioned in the former Chapter; and to find the Centers and Poles of all such Plains.

THe Plains that I shall lay down for *Examples* upon the *Projection* in this place, shall be such as are treated of in the following Discourse: I intended to have laid them all down, but finding the *Diagram* to be incumbered with multiplicity of *Circles, Lines, and Letters*, I will content my self, and satisfy the *Reader*, by giving an *Example* of *One* of each *Kind*, and the rather, because (when I come to delineate and draw the Dial from the *Projection*) the same (in effect) will be repeated again: Therefore,

First, The *Horizontal*: This Plain upon the *Projection* is represented by the *Primitive Circle* thereof viz. W N E S. The Center and Poles whereof are in the Point Z the *Zenith*, which Point is 90 deg. distant from the *Plain* in all places thereof, and so must the Poles of all Plains be. Figure III.

2. The *Erect Direct North and South Plains*, are represented by the Line W Z E; for these Plains beholding the direct *North* or *South* Points, the Plain it self must needs lie in the *Azimuth* of *East* and *West*. The Poles of the Plain are N and S, which Points are removed from the Plain 90 deg.

3. The *South Erect Plain, Declining to the West* 35 deg. To describe this Plain upon the *Projection*, Take 35 deg. out of the *Scale of Chords*, and set them from W to *a*, and from E to *a*, (because the Plain declines *Westward*) and draw the Line *a Z a*, for your declining Plain.—Then for the Pole thereof, take 90 deg. out of the *Chord-Line*, and set them from *a* to *b*, and from *a* to *b*, both ways upon the *Primitive Circle*, so shall *b b* be the two Poles of the *Declining Plain*; for a Line drawn from *b* to *b*, would cut the Plain at right Angles in Z, and be every where 90 deg. distant from the Plain.

4. The *Direct West Plain Reclining* 35 deg. Take 35 deg. the *Reclination*, out of your *Scale of Half Tangents*, and set them from Z to *c*, towards W, (because it is a *West Plain*, or towards E, had it been an *East Plain*) so have you three Points, N, *c* and S, through which to draw the Circle N *c* S, representing your *Reclining Plain*.—Now for the Pole of this Plain, Take 55 deg. the Complement of the *Reclination*, out of your *Scale of Half Tangents*, and set it from Z to *d*, upon the Line Z E, so shall *d* be the Pole of the Plain N *c* S. And for the Center of it, take the Secant of 55 deg. the Complement of the *Reclination*, and set them from *c* upon the Line *c E* continued, and that shall give you the Point, upon which to describe the Circle N *c* S, representing your *Reclining Plain*.

5. The *Direct South Plain Reclining* 70 deg. may be thus inserted. The *Half Tangent* of the *Reclination* 70 deg. set from Z to *f*, shall give the intersection of the Plain with the *Meridian*: And the Secant of 20 deg.

deg. (the Complement of the Reclination) set from f to g , shall give the Center, whereby to describe the *Reclining Plain* WfE . also, The *Half Tangent* of 20 deg. (the Complement of the *Reclination*) set from Z to h , shall give h , for the *Pole* of the *Plain*.

This *Plain* passeth between the *Pole* and the *Horizon*.

6. The *North direct Plain*, *Reclining* 70 deg. may be thus inserted: Take the *Half Tangent* of the *Reclination*, 70 deg. and set it from Z to m , also take the *Half Tangent* of the Complement thereof, 20 deg. and set it from Z to n , so shall m be the intersection of the *Plain* with the *Meridian*, and n the *Pole* thereof; and the *Secant* of the *Co-Reclination* 20 deg. set from m , shall give a Point a little above P (the *Pole* of the *World*) for the Center, whereby to describe the *Reclining Plain* WmE .

This *Plain* passeth between the *Equinoctial* and the *Horizon*.

7. We come now to the laying down, or describing, such *Plains* upon the *Projection*, as do both *Decline* and *Recline*; and for our *Example*, Let us take a *South Plain*, *Declining Eastward* 30 deg. and *Reclining* 55 degrees. — To describe this *Plain* upon the *Projection*. — Take the *Declination* of the *Plain* 30 deg. out of a *Scale of Chords*, and set it from E to D , and from W to G ; also set it from N to I , and from S to L ; so shall the Line DG represent the *Base* of the *Reclining Plain* and the pricked Line IL the *Axis* thereof: Now the *Reclination* being 55 deg. the *Half Tangent* thereof set from Z to s , gives the point of the *Plain*, and its Complement 35 deg. set from Z to t , gives the *Pole* of the *Plain* and the *Secant* of 35 deg. (the *Co-Reclination*) gives the point r , for the Center of the *Reclining Plain* GsD : The which *Plain* passeth between the *Pole* and the *Horizon*.

8. The last *Example* shall be of a *North Declining Reclining Plain*, viz *North*, *Declining West* 60 deg. and *Reclining* 54. deg. For the describing of which *Plain* upon the *Projection*; Take 60 deg. the *Plain's Declination* out of a *Scale of Chords*, and set it from E to M , and from W to O and draw the Line MO , for the *Base* of the *Reclining Plain*: Also set 60 deg. from S to Q , and from N to V , and draw the pricked Line VQ for the *Axis* of the *Reclining Plain*. The *Base* and *Axis* being found, Take the *Reclination* 54 deg. out of the *Scale of Half Tangents*, and set it from Z to z , for the *Plain*; and its Complement 36 deg. set from Z to a , will give the *Pole* of the *Plain*, and the *Secant* of the *Co-Reclination* 36 deg. being set from z , upon the Line QV , will give the Center whereon to describe the *Plain* MzO ; the which *Plain* passeth between the *Equator* and *Horizon*.

How the Pole of any Great Circle described upon the Projection may be found.

Figure III. **L** Et the pricked Arch O^*M be the Arch of a great Circle described upon the *Projection*: To find its *Pole*, Draw a Right line from the two points where the Arch toucheth the primitive Circle, as from the Points O and M , which Line OM (if the Arch be the true Arch of a great Circle,) will pass through Z the Center. — From M or O , set 90 deg. to V and Q , and draw the pricked Line VQ cutting the described Arch in the point $*$. — Then lay a Ruler from M to $*$, and it will cut the primitive Circle in x , set 90 deg. from x to z , and a Ruler laid

laid from M to ∞ , will cut the Line V Q in δ , so is δ the Pole of the Arch of the Great Circle O * M: And in this manner may the Pole of the Arch of any Great Circle be found:

Note here, (because hereafter there will be often occasion for it) That, if the Arch of a Great Circle, whose Pole you seek, do pass thro' P the Pole of the World, the Pole of that Circle will be in some part or other of the *Æquinoctial Circle* W $\mathcal{A}$ E.

C H A P. V.

How the Sides and Angles of Spherical Triangles are to be Measured upon the Projection.

BY the Interfection of these Arches of *Great Circles* upon the *Projection* are constituted divers *Spherical Triangles*, some *Right-Angled*, some *Quadrantal*, and others *Oblique-Angular*. The *Sides* and *Angles* of all which, may be measured by help of the Scales of *Chords* and *Half Tangents*: But to avoid confusion of Letters in the Scheme, I will make choice only of one Right-Angled Triangle, namely, M d E Right-Angled at E.

For the Right Angled Triangle M d E,

1. The Side ME, is measured by taking the distance of ME in your Compasses, and applying it to a *Scale of Chords*, so shall you find it to contain 60 deg.
2. The Side d E is measured by laying a Ruler to N (the Pole of the Circle W Z d E) and the point d, which Ruler will cut the *Primitive Circle* in δ , so the distance δ E, measured upon a *Scale of Chords*, will be found to be 32 deg. 10 min. for the Side d E.
3. The Side M d, is measured by laying a Ruler upon ϵ (the Pole of the Circle M d O) and the point d, which Ruler will cut the *Primitive Circle* in λ , the distance λ M, measured upon the *Scale of Chords*, will give 64 deg. 58 min. for the Side d M.
4. For the Measure of the Angle dME, a Ruler laid from M to ∞ (a Quadrant from M) will cut the *Primitive Circle* in P: and the distance P Q measured upon a *Scale of Chords*, shall give 36 deg. for the Angle dME.
5. For the Angle M d E, or its *Alternate Angle* ϵ d O, equal thereunto, lay a Ruler to ϵ , the Pole of the Circle M d O, and upon d (the Angular point) it will cut the *Primitive Circle* in λ , Then set 90 deg. from λ to γ , and lay a Ruler upon ϵ and γ , it will cut the Circle M d O in π ; A Ruler laid from d (the Angular point) to π , will cut the Circle in B, and the distance B W measured upon a *Chord*, will be found to be 72 deg. 54 min. for the quantity of the Angle ϵ d π , equal to the Angle M d E.

C H A P. VI.

Of the Sun's Azimuth, how to find it at any time (the Sun shining) Geometrically, Instrumentally, and Arithmetically

WHat the Sun's Azimuth is, you are shewed in the foregoing Introduction; Our business here is to find it: This work might have been done by the Projection (and that shall be shewed hereafter in its due place) but the Scheme being too much incumbred already, I shall shew other ways for finding it. As,
First, Geometrically, by help of your Scale of Chords, &c.
Secondly, By the Scale of Sines before described: And,
Thirdly, By Trigonometrical Calculation.

Before the Sun's Azimuth can be found, Three things must be given or known, *Viz.*

1. The Latitude of the Place.
2. The Declination of the Sun.
3. The Sun's Altitude: Which is to be observed by a Quadrant or other Instrument, so often as you have occasion to find the Azimuth; But the Latitude is alwayes known (or given) and the Declination is (nearly) fixed to the time of the Year; and for that end, I have in the Introduction inserted two Tables, the one shewing the Latitude of the Cities, Towns, and Principal places in England, Scotland, and Ireland, — The other of the Sun's Declination for every day in the Year: The which Tables are subservient to the Work of this Chapter.

And now, Having the Latitude of the Place, The Declination and Altitude of the Sun, to find the Azimuth.

I. Geometrically by Scale and Compass.

Figure I. **H**AVING the Latitude of your Place, and the Declination of the Sun, and the Sun's Altitude given, you may find the Sun's Azimuth. So the Latitude of the Place being 51 deg. 32 min. the Declination of the Sun 17 deg. 56 min. North, and the Sun's Altitude 35 degrees; the Azimuth may be found Geometrically as followeth.

First, with 60 deg. of your Line of Chords describe the Semicircle ADC, and upon B the Center, erect the Perpendicular BD.

Secondly, Take 51 deg. 32 min. the Latitude of the Place out of your Line of Chords, set it from D to E, and draw the Line EB, representing the Equinoctial Circle.

Thirdly, Out of your Line of Chords take 17 deg. 56 min. the Sun's Declination, and (because it is Northward) set that distance upwards from E to F, (but if the Declination had been Southward, you must have set it downwards from E to R,) and draw the Line FG parallel to BE, which represents the Sun's parallel for that time.

Fourthly,

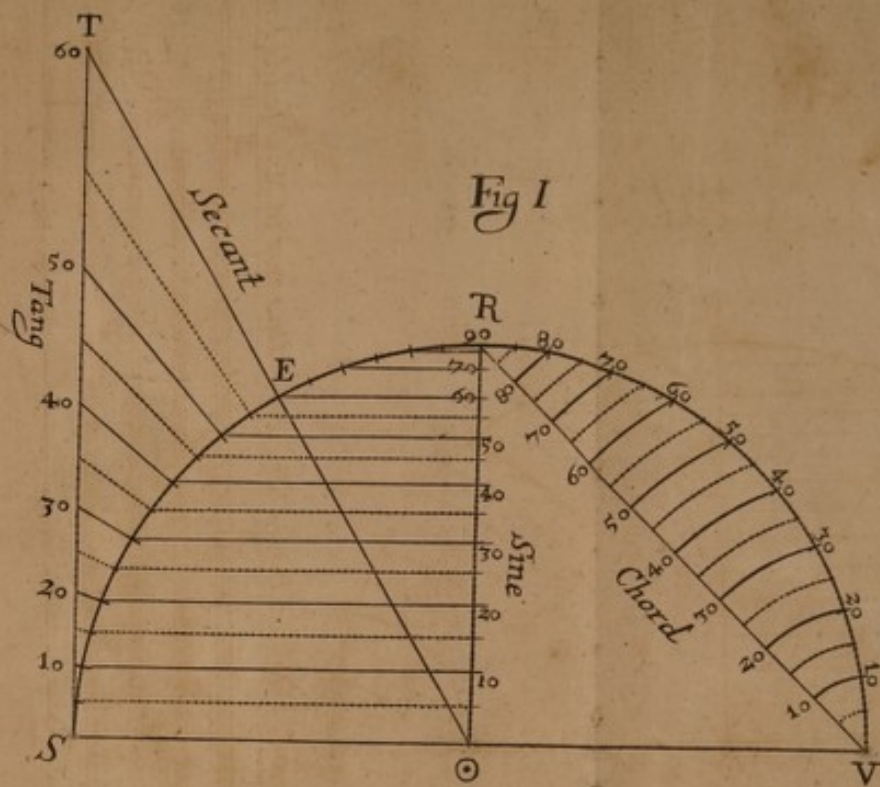


Fig III

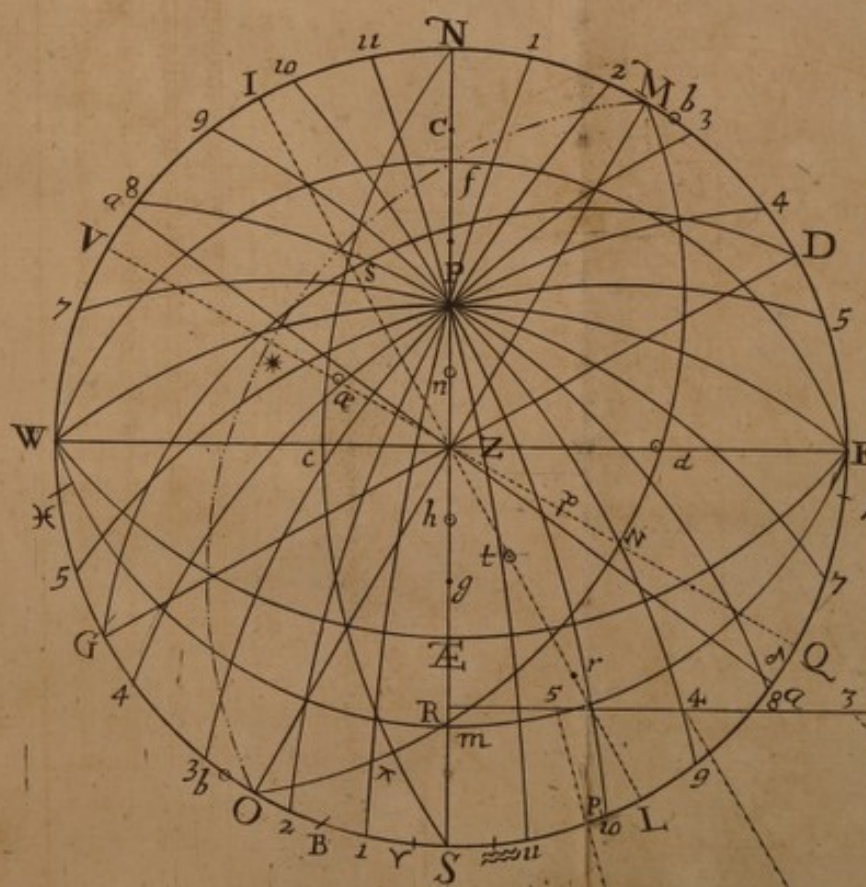
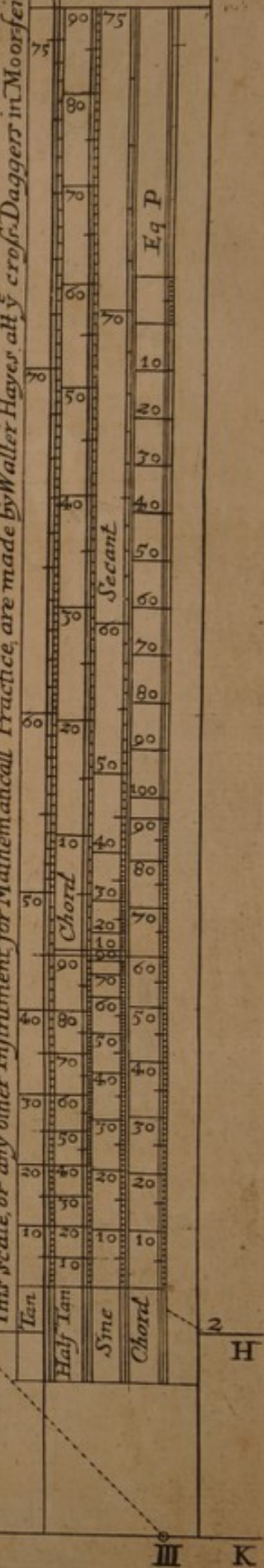


Fig II

This scale, or any other Instrument for Mathematicall Practice, are made by Waller Hayes att y^e cross Daggers in Moorfields, Lond



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Fourthly, From your Line of Chords take 35 deg. the Sun's *Altitude*, and set it from A to H, and from C to L, and draw the Line H K L for the Line of the Sun's *Altitude*.

Fifthly, Take in your Compasses the length of the Line K L, or K H, and with that distance, upon the Center B, describe the Semicircle M P N.

Sixthly, Upon the point O (which is where the parallel of the Sun's *Declination*, and the parallel of the Sun's *Altitude*, intersect each other) erect the Perpendicular O P.

Seventhly, Lay a Ruler from B to P, and it will cut the Circle in Q, and draw the Line P Q.

Lastly, Take the distance from C to Q, and measuring it upon your Line of Chords, you shall find it to contain 73 deg. 56 min. and so much is the Sun's *Azimuth* or his distance from the South part of the Meridian, at the time of Observation.

II. By the Scale of Sines upon the Ruler.

Let the *Latitude*, Sun's *Declination*, and *Altitude*, be the same as *Figure II.* before, viz. *Lat.* 51 deg. 32 min. *Declination* 17 deg. 56 min. *Altitude* 35 deg.

First, With 60 deg. of your Scale of *Chords*, or 90 deg. of the Scale of *Sines*, upon the point $\frac{E}{W}$ describe a Semicircle N B S.

Secondly, Take the Sun's *Declination* 17 deg. 56 min. from your Scale of *Sines*, and set it from the point $\frac{E}{W}$ to $\odot$ (towards N, the *Declination* being *Northward*, or towards S, if it had been *Southward*).

Thirdly, Find the <i>Sum</i> and the <i>Difference</i> between the Complement of the <i>Latitude</i> , and the Complement of the <i>Altitude</i> , the <i>Sum</i> of them is 93 deg. 28 min. and the <i>Difference</i> is 16 deg. 32 min. and the Complement of the <i>Difference</i> is 73 deg. 28 min.	<table border="0"> <tr> <td>Co. Lat.</td> <td>38 d. 28 m.</td> </tr> <tr> <td>Co. Alt.</td> <td>55 00</td> </tr> <tr> <td style="border-top: 1px solid black;">The Sum</td> <td style="border-top: 1px solid black;">93 28</td> </tr> <tr> <td style="border-top: 1px solid black;">Diff.</td> <td style="border-top: 1px solid black;">16 32</td> </tr> <tr> <td style="border-top: 1px solid black;">Co. Diff.</td> <td style="border-top: 1px solid black;">73 28</td> </tr> </table>	Co. Lat.	38 d. 28 m.	Co. Alt.	55 00	The Sum	93 28	Diff.	16 32	Co. Diff.	73 28
Co. Lat.	38 d. 28 m.										
Co. Alt.	55 00										
The Sum	93 28										
Diff.	16 32										
Co. Diff.	73 28										

Fourthly, Take 3 deg. 28 min. (the excess of the *Sum* above 90 deg) from your Scale of *Sines*, and set it from the point $\frac{E}{W}$ towards S, namely at A. — Also take 73 deg. 28 min. from the Scale of *Sines*, and set that distance from the point $\frac{E}{W}$ towards N, at the point D.

Fifthly, Take in your Compasses the distance between A and D, and set it upon the Semicircle from S to B, and draw the Line N B.

Sixthly, Take in your Compasses the distance between D (the *Difference*) and $\odot$ (the point of the Sun's *Declination*) and with that distance, setting one foot of the Compasses upon the Line N S, move it gradually along, till the other foot (being turned about) do only touch the Line N B, and where the foot of the Compasses (upon these conditions) resteth, set Z; so shall the distance E Z, measured upon the Scale of *Sines*, be found to contain 16 deg. 4 min. And such is the Sun's *Azimuth* from the *East* or *West* points of the Horizon. — Which being taken from 90 deg. leaveth 73 deg. 56 min. for the distance ZS, the Sun's *Azimuth* from the *South*. — Or, 90 deg. being added thereto, it

will give the distance ZN, namely, 106 deg. 4 min. and such is the Sun's *Azimuth*, or distance from the *North*.

III. By Trigonometrical Calculation.

Let the *Latitude*, *Declination* and *Altitude* be as before, viz.

	d.	m.		d.	m.
Latitude	51	32	Complement	38	28
Declination	17	56		72	04
Altitude	35	00		55	00
			Their Sum	165	32
			Half Sum	82	46

The difference between the half Sum
and the Complement of the Sun's
Declination. } —10—42

First, You must add the Complement of the Latitude, the Complement of the Declination, and the Complement of the Sun's Altitude, all three into one Sum, and they make 165 deg. 32 min. the half whereof is 82 deg. 46 min. and the difference between this half Sum 82 deg. 46 min. and the Complement of the Sun's Declination 72 deg. 4 min. is 10 deg. 42 min.

Being thus prepared, the Proportion to find the Sun's *Azimuth* by the Table of Sines, will be as followeth.

(1) As the Radius, or Sine of 90 deg.	10—000000
is to the Sine Complement of the Altitude 55 d.	9—913364
So is the Sine Complement of the Latitude 38 d. 28. m.	9—793832
to the Sine of 30 deg. 38 min.	9—707196
(2) As the Sine of 30 deg. 38 min.	9—707196
is to the Sine of the half Sum 82 d. 46 m.	9—996529
So is the Sine of the difference 10 d. 42 m.	9—268733
	19—265262
to this Sine	9—558066
To which add the Radius, or the Sine of 90 deg.	10—000000
The Sum is	19—558066
Half this Sum is	9—779033

Which is the Sine of 36 d. 58 m. the Complement whereof is 53 d. 2 m. the double whereof is 106 d. 4 m. which is the Sun's *Azimuth*, or distance from the North part of the Meridian: And this 106 d. 4 m. being taken from 108 d. leaveth 73 d. 56 m. for the *Azimuth* from the South

South part of the Meridian. And according to either of these ways you may find the Sun's *Azimuth*, at any time of the day, and in any part of the World.

C H A P. VII

Of the Declination and Reclination of Plains, and how to find their quantities.

WHat a *Declining* and *Reclining Plain* is, we have defined in the foregoing Chapter, we now come to shew how to find the quantity of their *Declination* or *Reclination*.—Now, a *Declining Plain* is best represented by the side *Wall* of a *Church*, *House*, or other upright *Edifice* or *Building*, which doth not directly behold the true *East*, *West*, *North* or *South* points of the *Horizon*: And a *Reclining Plain* is best represented by the *Outside* of the *Tiling* of the *Roof* of a *Church*, *House*, *Cooping* of a *Wall*, &c.

Definition 1.] **N**OW, The *Reclination* of a *Plain*, Is the quantity of the *Arch* of that *Vertical Circle*, which passeth through the *Zenith*, and cutteth the *Reclining Plain* at *Right Angles*.

Definition 2.] **T**HE *Declination* of a *Plain*, is the quantity of that *Arch* of the *Horizon*, which is comprehended between the true *North* or *South* points, and a *Line* drawn *Perpendicular* to the *Plain*. Or,

It is the quantity of that *Arch* of the *Horizon*, which is intercepted between the true *East* or *West* points, and the *Plain* it self.

I. How to find the Reclination of a Plain.

Practice. **L**ET *ABCD* being the *Roof* of the *Building* *PLRX*, represent a *Reclining Plain*. First, Draw thereon an *Horizontal Line* as *EF*, which you may do by help of an ordinary *Level*, or by applying a *Ruler* to the *Plain*, and letting One hold the *Ruler* so to the *Plain*, till you find, by the edge of a *Quadrant* applied to the *Ruler*, the *Line* and *Plummet* to fall just upon the edge thereof, as in the *Figure*: Then draw a *Line* by the side of the *Ruler*, as *EF*, and that shall be the *Horizontal Line* of the *Reclining Plain* *ABCD*. Figure III.

To this *Horizontal Line* *EF*, draw another, *Line Square* (or at *Right Angles*) thereunto, as the *Line* *GH*; to which *Line* apply the side of a *Ruler* *MN*, and towards that end which hangeth over the *Plain* as at *N*, apply the side of a *Quadrant*, letting the *Plummet* hang at free liberty, to play by the side of the *Quadrant*, and when it resteth, note what degrees of the *Quadrant* the *Thread* falleth upon, for those degrees are the quantity of the *Plain's Reclination*.

To

II. To find the Declination of a Plain.

Figure
III.

IN taking the Declination of a Plain, Two Observations are to be made by the Sun, both which ought to be done at the same moment of time, or as neer together as may be; The First, is to find the Horizontal distance of the Sun [from the Pole of the Plain: And is called the Horizontal Distance. The other is the Sun's Altitude, thereby to find his Azimuth.

1. For the Horizontal Distance.

Let PQRS be an Upright Plain, whose Declination is required: First, By help of a Level, or by your Quadrant, draw an Horizontal Line upon the Plain, as the Line TV, unto which apply one side of a Quadrant, so that the Limb of the Quadrant may be towards the Sun; Then holding a Thread and Plummet at full liberty by the Limb's side, so that the shadow of the Thread may pass, both through the Center and the Limb of the Quadrant: And observe then what number of Degrees are cut off by the shadow of the Thread, and number them from that side of the Quadrant that standeth square (or Perpendicular) to the Plain; for those Degrees are the Horizontal Distance required.

2. For the Sun's Altitude.

At the same instant of time that you observed the Horizontal Distance, the Sun's Altitude should have been observed also, which could not be done but by two Observers; wherefore, let them be observed as neer together as may be.

To take the Altitude of the Sun, you must take the Quadrant in both your hands, laying your right hand somewhat neer that side that hath the Sights, and your left hand towards the other side, by which means you may let it slip lower, or raise it higher, as occasion requires: Then turning the left side of your body to the Sun, move the Quadrant up or down, till the Sun shining through that Sight which is next the Center of the Quadrant, do cast his Ray or Beam of Light upon the hole of the other Sight, (the Thread and Plummet (all this while) hanging at free liberty) and then look in the Limb of the Quadrant what Degrees and parts of a degree, the Thread cutteth; for those degrees are the degrees of the Sun's Altitude at that time.

¶ By help of the Sun's Altitude, the Sun's Azimuth may be found. — Then by comparing the Sun's Azimuth and the Horizontal Distance (before found) together, the Plain's Declination may be obtained, by the Rules following.

When you make your Observation of the Sun's Horizontal Distance from the Perpendicular of the Plain, Mark whether the Shadow of the Thread

Thread do fall between the *South Point* of the *Horizon*, and that side of the *Quadrant* which is *Perpendicular* to the *Plain*. For,

Rule I. If the *Shadow* fall between them, then the *Horizontal Distance* and *Azimuth* added together, do make the *Declination* of the *Plain*: And (in this *Case*) the *Declination* of the *Plain* is towards the same *Coast* whereon the *Sun's Azimuth* is: That is,

¶ If the *Observation* be made in the *Forenoon*, when the *Sun* is *Eastward* of the *Meridian*, the *Plain* Declineth *Eastward*:—— But if the *Observation* be made in the *Afternoon*, when the *Sun* is *Westward* of the *Meridian*, The *Plain* Declineth *Westerly*.

Rule II. If the *Shadow* fall not between the *South Point*, and that side of the *Quadrant* which is *Perpendicular* to the *Plain*, then the *Difference* between the *Sun's Azimuth* and the *Horizontal Distance* is the *Declination* of the *Plain*: And if the *Azimuth* be the *Greater* of the two, then the *Plain* Declineth to the same *Coast* whereon the *Sun* is. That is,

¶ It Declineth *Eastward* if it be in the *Forenoon*, or *Westward* if in the *Afternoon*.

But if the *Azimuth* be *Lesser* than the *Horizontal Distance*, then the *Plain* declineth to the *Coast* contrary to that the *Sun* is on. That is,

¶ The *Plain* declineth *West*, if the *Observation* be made in the *Forenoon*: But *East* if in the *Afternoon*.

¶ And here it is to be further Noted, That the *Declination* of any *Plain* found by these *Rules*, is always accounted from the *South*; And that all *Declinations* are accounted from the *North* or *South* towards the *East* or *West*, and must never exceed 90 degrees.

Therefore,

1. If the number of degrees of *Declination*, do exceed 90, you must subtract it from 180, and the residue shall be the *Declination* of the *Plain* from the *North*.

2. If the number of degrees of *Declination* do exceed 180, then the number of degrees above 180, gives the *Plain's Declination* from the *North*, and it is towards that *Coast* (either *East* or *West*) which is contrary to the *Coast* upon which the *Sun* was at the time of *Observation*.

For the farther Explanation of these *Rules* (Examples being more satisfactory than bare Precepts) I shall here insert two *Observations* made upon two several *Plains* at the same time, viz.

Upon the 23d of *August* in the *Morning*, I came to the *Plain* PQRS, and applying my *Quadrant* thereto, and holding up a *Thread* and *Plummet* by the side thereof, I found the *Horizontal Distance* to be 61 deg. equal to the Angle *bac* in the *Quadrant*.——At the same time (as near as I could) I went to the other *Plain* KLOX, and thereto I applied my

Figure
III.

my *Quadrant*, as in the Figure, and found the *Horizontal Distance* to be 17 deg. In the mean time that I was taking the two *Horizontal Distances*, an Assistant observed the Sun's *Altitude*, from whence I computed the Sun's *Azimuth*, and found the *Azimuth* to be 68 deg. Easterly of the *South*.

Having these *Notes of Observations*, I compute the *Declinations* as followeth:

Figure IV. First, For the Plain PQRS. Upon a piece of Paper with 60 deg. of a *Scale of Chords*, describe upon the Center *o*, a Semicircle, *acb*, and because the *Horizontal distance* was 61 deg. set 61 deg. upon the Semicircle (the same way you observed the Sun to be) from *c* to *d*, and draw the Line *o d*, for the Line of the Sun's *Azimuth*. Then the Sun's *Azimuth* being 68 deg. Eastward of the *South*, take 68 deg. and set them from *d* Southwards to *S*, and draw the Line *o S*, for the *Meridian Line*. By your *Scheme* you see that the Line of *Shadow*, *o d*, does not fall between *S* (the *South* point) and *o c* (the side of the *Quadrant* which was Perpendicular to the Plain) therefore, by the *Second Rule*, The difference between the Sun's *Azimuth* and the *Horizontal Distance*, must be the *Declination of the Plain*: Wherefore subtract 61 the *Hor. dist.* from 68 the *Azimuth*; the difference is 7 deg. which is the *Plain's Declination*. And by the same *Second Rule*, because the *Azimuth* was greater than the distance; the Plain declines to the same Coast on which the Sun was, namely, Eastward, it being before Noon. And so it doth appear by the *Scheme*, for 22 deg. (the Complement of 68 deg. the *Azimuth* from the *South*) being set Eastward from *d*, will give *E* the *East* Point, and the Line *o E*, will be the *East* and *West* Line: So that by your *Scheme* also you may see that the Plain lies open to the *South* and the *East*, and the Quantity of *Declination* is the Arch *Sc*, or *Eb*, either of which are 7 deg.

Figure V. Secondly, For the Plain KLOX. Upon a piece of Paper with 60 deg. of the *Scale of Chords*, upon *r* as a Center, describe a Semicircle, *mpn*, and because the *Horizontal distance* was 17 deg. set 17 deg. upon the Semicircle as you found it to be by Observation, from *p* to *h*, drawing the Line *r h* for the Line of the Sun's *Azimuth*, then the *Azimuth* being 68 deg. from the *South* Easterly, set 68 deg. Southerly from *h* to *S*, and draw *r S* for the *Meridian Line*, and set 22 deg. (the Complement of the Sun's *Azimuth* to 90) from *h* towards the *East*, at *E*, and draw the Line *r E* for the *Azimuth* of *East*. Now by the *Scheme* you see, that the Line of *Shadow* falls between the *South* point and *r p*, the side of the *Quadrant*, which was Perpendicular to the Plain; therefore, by the *First Rule*, the *Horizontal distance* and *Azimuth* added together, do make the *Declination of the Plain*: Wherefore 68 the *Azimuth* and 17 the *Horizontal distance*, added, do make 85 deg. for the *Declination of the Plain*; and by the same *first Rule*, the *Declination* is Easterly, it being towards the same Coast that the Sun was on: And so it appears to do by your *Scheme* also, the Plain beholding the *South* and the *East*, The *North* and *West* falling behind the Plain. And thus have you several ways to find the Sun's *Azimuth*, and consequently a *Meridian Line*. But before I conclude this Chapter, I will shew you an exact and accurate way.

How to find a true *Meridian Line*, in any *Latitude*, without knowing the *Sun's Declination*, or finding of his *Azimuth*: By help of three *Shadows* cast by a *Gnomon* erected upon an *Horizontal Plain*; and three *Altitudes* of the *Sun* taken at the same times.

In some convenient Place upon an *Horizontal Plain* (unto which the *Sun* may have free access) erect a *Gnomon* (or wyre) of convenient length, Perpendicular (or at Right Angles) to the *Plain*.

The *Plain* thus prepared; At any three times in the same day, mark upon the *Plain* where the *Shadows* of the *Gnomon* casteth; And at the same three times, take three several *Altitudes* of the *Sun*; which set down upon each *Shadow*.

Then through the three *Shadows*, from the foot of the *Gnomon*, draw three Right Lines of sufficient length: And, from your Scale of *Half-Tangents*, take the Complements of the *Sun's Altitudes* (as you found them to be, at the times you observed the *Shadows*) and set them upon their respective lines of *Shadow*, from the foot of the *Gnomon*: So shall you have three Points upon your *Plain*, through which (by the XI *Probl.* of the *Introduction*) describe a Circle.

Lastly, A Right Line drawn through the Center of this Circle, and the foot of the *Gnomon*, shall be a true *Meridian Line*.

Note, It matters not whether these three Observations be made all of them before or after Noon; or some before and others after Noon.

C H A P. VIII.

How to know which of the Poles, whether the North or South is to be Elevated above any Dial-Plain; whether Direct or Reclining, or both Reclining and Declining.

THE *Axis* or *Stile* of every *Dial* lies Parallel to the *Axis* of the *World*, and therefore the two ends of the *Stile* of every *Dial* do directly respect the two *Poles* of the *World*: And therefore if the *South Pole* be elevated upon any *Dial Plain*, a *Dial* made on the backside of that *Plain*, will have the *North Pole* Elevated: And hereafter, that no doubt may arise concerning which *Pole* must be Elevated above any *Plain*; take these few

General Rules.

1. Upon the *Horizontal Plain*, in *North Latitude* the *North Pole*, but in *South Latitude* the *South Pole* is Elevated.
2. Upon all *Erect Plains*, whether *Direct* or *Declining*: If the *Plain* lie open to the *South*, the *South Pole* is Elevated; but if it behold the *North*, the *North Pole* must be Elevated.

3. Upon

3. Upon all Direct East or West Plains, Reclining (how far soever) the North Pole is Elevated; and upon the East and West Incliners, opposite to them, the South Pole.

4. Over all North Reclining Plains, (whether Direct or Declining) the North Pole is Elevated; and over the Inclining Plains, opposite to them, the South Pole.

Lastly, Over all South Reclining Plains, whether Direct or Declining [If the Plain pass between the Zenith and the Pole] the Axis of the Stile must have respect to the South Pole; and on the Inclining Plains, opposite to them, the North Pole.—But, [If the Plain pass between the Horizon and the Pole] the North Pole; and on the Incliners opposite to them, the South Pole.

CHAP. IX.

To Draw the Hour Lines upon a Vertical (commonly called Horizontal) Plain.

I. From the Projection.

Figure
I.

First, Draw a right Line NS, for the Meridian, and Hour-Line of 12, and cross it with another EW, for the Hour-Line of Six, at right Angles in Z; And upon Z, as a Center describe a Circle ENWS, representing the Horizon of London, whose Latitude is 51 d. 32 m. and also this Dial-Plain. Within this Circle Project the Sphere according to your Latitude, as is before taught, then shall the several Hour-Circles touching the Plain of the Horizon, give you Points to draw the Hour-Lines upon your Dial-Plain by: So that a Ruler laid to Z, and every of the Points 1, 2, 3, &c. 11, 10, 9, &c. Where the Hour Circles touch the Horizon, if you draw straight Lines thereby, they shall be the true Hour-Lines for your Vertical (or Horizontal) Dial.

For the making of an Horizontal Dial, there is nothing required to be known, but the Latitude of the Place, equal to which must the height of the Stile be; wherefore take 51 deg. 32 min. out of your Scale of Chords, and set them upon the Horizon from S to A, and draw a Line ZA for the Stile. The Substile (upon which the Stile standeth) in all Horizontal Dials is the Meridian or Hour Line of 12; and so is the Dial finished.

II. By Trigonometrical Calculation.

There is nothing required to be found in this Dial by Calculation, excepting the Hour-Distances from the Meridian; for which this is the Proportion.

As the Sine of 90 deg.

Is to the Sine of the Latitude.

So is the Tangent of each Hour's Equinoctial Distance from the Merid.

To the Tangent of that Hour's Distance upon the Plain.

Where

Fig. I.

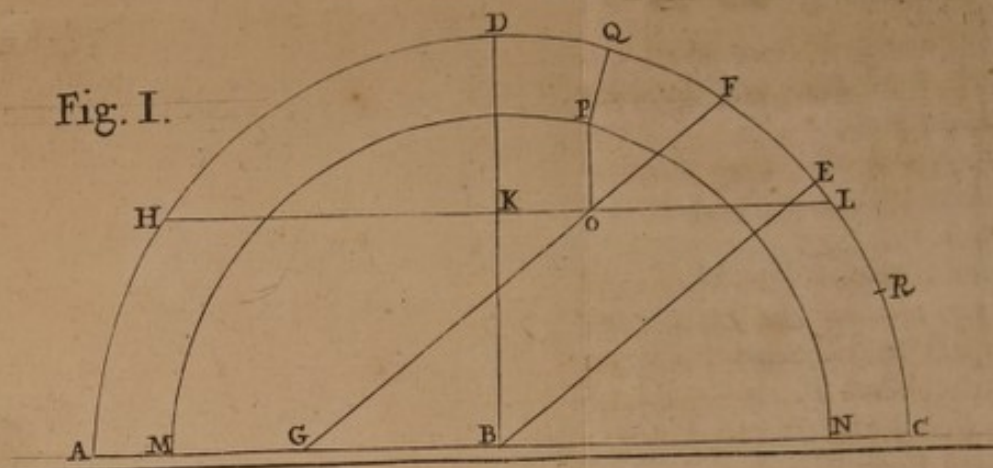


Fig. II.

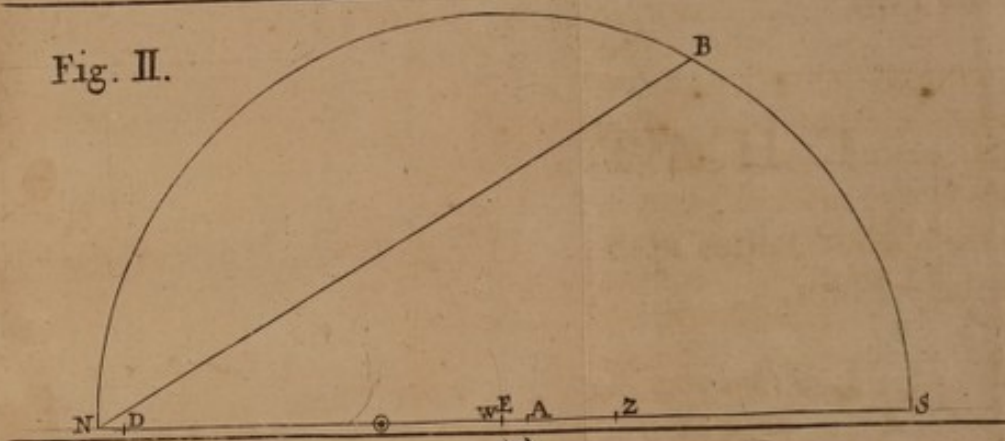


Fig. III.



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Wherefore, having prepared a Table, and placed the Hours from Noon in the *First Column*, and the *Equinoctial Distances* proper to them in the *Second Column* (allowing 15 deg. to one Hour, 30 deg. to 2 Hours, &c.) as you see here done, then work your Proportion as followeth.

As the Radius 90 deg.	10.000000
To Sine of the Latitude 51 deg. 32 min.	9.893544
So the Tang. of 15 deg. the first Hour's Equi. Distance.	9.428052
To Tang. of 11° 51' the first Ho. Dist. on the Plain,	9.321596

Hours from Noon.	Equinoctial Distances.	Hour Distances on the Plain.
	D. M.	D. M.
12	0 0	0 00
11 1	15 0	11 51
10 2	30 0	24 19
9 3	45 0	38 3
8 4	60 0	53 36
7 5	75 0	71 6
6	90 0	90 0

And doing thus for every Hour's Equinoctial Distance, you shall produce such Hour-Distances as you find in the third Column of the Table. Which Distances being taken out of a Line of Chords, and set upon the Plain from S, will give the Points 1, 2, 3, &c. 11, 10, 9, &c. as before; for between S and 11 or 1, you shall find 11 deg. 51 min. from S to 10 or 2, 24 deg. 19 min. &c.

And thus have you two ways, viz. A Geometrical or Projective way, and an Arithmetical or Calculatory way to make your *Dial*, demonstrating one another. And in this order I shall proceed in all other Plains.

C H A P. X.

How to Describe the Hour-Lines upon an Erect Direct South or North Plain.

I. By the Projection.

HAVING drawn a right Line NS for the *Meridian* or Line of 12, Figure II. and another at right Angles thereto, as EW for the *Horizontal* Line of the Plain, crossing each other in the point Z. Upon Z as a Center, describe a Circle NESW, representing the *Horizon* of London, and therein Project the *Sphere*. Which done, your next work will be, to draw a line upon your *Projection*, which shall represent your Plain, [And here Note, That all upright Plains are represented upon the Projection by streight Lines.] Now an Erect Direct Plain, which beholdeth the South, must needs lie in the *Azimuth* Circle of East and West; therefore, a right Line drawn from E to W, shall represent your Plain.

Having drawn your *Plain* upon the *Projection*, your first work will be to find the *Pole* thereof: And here you are to Note, That [The *Pole* of every *Direct Plain*, whether *Erect* or *Reclining*, is removed 90 deg. from the *Plain* it self; and that every *Plain* hath two *Poles*, and a *Line* being drawn from one to the other, will cut the *Plain* at *Right Angles*.] Now this *Plain* E W, lying in the *Azimuth* of East and West, the *Poles* thereof must lie in the *Azimuth* of North and South; so that N is the *Pole* of the North face of this *Plain*, and S of the South Face, either of which *Poles* are removed 90 deg. from the *Plain*; and a *Line* drawn from one *Pole* to the other, will cut the *Plain* at *Right Angles* in Z.

The next thing to be found is the *Elevation* of the *Pole* of the World above the *Plain*. Now [The *Elevation* of the *Pole* above all *direct Plains*, is an *Arch* of the *Meridian* intercepted between the *Pole* and the *Plain*, and never exceedeth 90 deg.] Now P, the *Pole* of the World, is elevated above this *Plain* E W, the quantity of the *Arch* of the *Meridian* ZP. To find the quantity whereof, Take the distance ZP in your *Compasses*, and measure it upon your *Scale* of *Half Tangents*, and you shall find it to contain 38 deg. 28 min. equal to the *Complement* of the *Latitude*, and so it ought to be.—Or, if you have not a *Scale* of *Half Tangents*, you may find it thus: Lay a *Ruler* to E and P, it will cut the *Circle* in a, the distance between W and a, measured upon the *Chords*, will be found 38 deg. 28 min. as before.

The Third thing to be found is the *Hour-distances* upon the *Plain*: To do which,

Lay a *Ruler* to N (the *Pole* of the *Plain*) and to the several Points 1, 2, 3, &c. 11, 10, 9, &c. where the *hour-Circles* of the *Projection* do cut the *Plain*, and where the *Ruler* cuts the *Primitive Circle*, make small marks, or ***, So *Lines* drawn from the Center Z, through those marks or ***, shall be the true *Hour-lines* upon your *Dial Plain*.

The height of the *Pole* above the *Plain* being found to be 38 d. 28 m. take those degrees from a *Scale* of *Chords*, and set them from S to B, and draw a *Line* Z B for the *Stile*, which must stand upon the *Meridian*, and on the South face must point downwards to the *South Pole*, and on the North face upwards to the *North Pole*; as in Fig. II, III.

II. By Trigonometrical Calculation.

There is no more of *Calculation* in this *Dial*, than there was in the *Horizontal*, namely the *Hour-distances* upon the *Plain*: For in these *direct North* and *South Dials*, the *Complement* of the *Latitude* is evermore the height of the *Pole* above the *Plain*, as appears by the *Projection*: Wherefore, prepare a *Table* (as in the former *Dial*) and then the *Analogie* or *Proportion* for the *Hour-distances* will be this, little differing from the former, only instead of *Latitude*, use *Co-Latitude*. So.

Hours from Noon.	Equinoctial Distances.		Hour-Distances on the Plain.	
	D.	M.	D.	M.
12	0	0	0	00
11 1	15	0	9	28
10 2	30	0	19	45
9 3	45	0	31	53
8 4	60	0	47	8
7 5	75	0	66	42
6 6	90	0	90	0

As

As the Radius, 90 deg.	10.00000
To the Co-Sine of the Latitude (or heighth of the Pole above the Plain) 38 deg. 28 min.	9.79383
So is the Tang. of 15 d. the first Hour's Equ. dist.	9.42805
^{tan of} To 9 d. 28 m. the first Hour's distance upon the Plain.	9.22188

For the North Dial.

1. Upon the Dial Plain, draw an obscure down-right Line N S, representing the *Meridian*, or 12 a Clock at Midnight.— About the middle thereof, as at Z, draw a right Line perpendicular thereunto, as the Line E Z W for the Hour-line of VI.

Figure
III.

2. With 60 deg of your Chord describe upon the Center Z, the Circle E N W S, and taking 38 deg. 30 min. out of the Line of Chords, set them from N to A, and draw the Line Z A for the *Stile* of your Dial.

Now because this Dial looketh towards the *North* part of the *Meridian*, to which in these middle Latitudes without the *Tropicks*, the *Sun* never cometh, therefore must the Hours about Midnight be omitted, as 9, 10, 11 and 12 at Night, and 1, 2 and 3 in the Morning; So that this *Dial* is capable only of the Hours of 4, 5, 6, 7, and 8 in the Morning, and of 4, 5, 6, 7, and 8 in the Evening.

3. Lay the former Table made for the *South Dial* before you, and there you shall find the Hour-distances of VIII and IV of the Clock, are distant from the *Meridian* 47 deg. 8 min. Take 47 deg. 8 min. from your Chord, and set them from N to 8, and from N to 4, and also from S to 8, and from S to 4. Also seeing that the Hour-distances of VII and V are different from the *Meridian* 66 deg. 42 min. take them also out of your Line of Chords, and set them from N to 7, and from N to 5, and also from S to 7, and from S to 5.

Lastly, The *Stile* of the Dial must make an Angle of 38 deg. 28 min. equal to the Complement of the Latitude, and must stand upon the obscure Hour-line of 12 at Night, and must point upwards towards the *North Pole*, as the *South Dials* did downwards towards the *South Pole*. And so have you finished your Dial.

C H A P. XI.

To describe Hour Lines, upon an Erect Direct East or West Plain.

AS an Erect Direct *North* or *South Plain*, lies in the Azimuth Circle of *East* and *West*, and is represented upon the *Projection* by the Line E W, Fig. II. the Poles whereof were N and S; So an Erect Direct *East* or *West Plain*, lies in the Azimuth Circle of *North* and *South*; and so the Plain is represented upon the *Projection* by the Line N S; and the *Poles* of those Plains are E and W.

Now

Now the Line NS, representing the Plain, passeth directly through P, the Pole of the World; and therefore the *Pole* hath no Elevation above these *Plains*, and consequently the *Dial* will have no *Center*, but all the Hour-Lines will be *Parallel* one to the other: and these *Dials* may be drawn according to these following Directions.

The Geometrical Construction of these Dials.

Figures Let ABCD be a Dial Plain, upon which you would draw an *East*
IV. V. or *West* Direct Dial.

1. Upon the point C, at one lowermost corner, if it be an *East* Dial; or upon the point D at the other lowermost corner, if it be a *West* Dial, with 60 deg. of your Line of Chords, describe an obscure Arch of a Circle EF: Then from the same Line of Chords, take 38 deg. 28 min. the Complement of the Latitude of the Place (which is also the Elevation of the Equinoctial above the Horizon) and set that distance upon the Arch from E to F, and draw the Line CF quite through the Plain, which Line shall represent the Equinoctial Circle.

2. That you may the better proportion your Stile to your Plain, and that all the Hours may come on, and be at a convenient distance one from another, assume two points in the Equinoctial Line, one towards the end C, for the Hour of 11 in the *East* Dial (or of 1 in the *West* Dial) as the point G, and another towards the other end thereof, for the Hour of 6, as the point H; and through these two points G and H, draw two Lines at right Angles to the Equinoctial Line, for the Hour-Lines of XI and VI a Clock.

3. Upon the point G with 60 deg of the Line of Chords describe an obscure Arch of a Circle (below the Equinoctial Line) as IK, setting thereon 15 deg. of your Line of Chords, from I to K, and draw the obscure Line GK, extending it till it cut the Hour-Line of VI in the point L; so shall the distance LH be the height of the perpendicular Stile, proportioned to this Plain.

4. Open your Compasses to 60 d. of your Line of Chords, and setting one foot in the point L; with the other describe an obscure Arch of a Circle MN; between the Hour-Line of VI and the Line GL.

5. Divide the Arch MN into five equal parts (which 15 d. of your Line of Chords will do) at the points ○○○○○, and lay a Ruler from L, to each of these points ○○○○○, and the Ruler shall cut the Equinoctial Line CH in the points ****, through which points draw right Lines parallel to the Hour-line of VI, as the Lines VII * VII, VIII * VIII, IX * IX, X * X, and they shall be the true Hour-lines of an East Plain, from Six in the Morning to Eleven before Noon.

6. For the Hour-lines before VI, namely of IV and V in the Morning, you may put them on by transferring the same Distances upon the Equinoctial line before VI, as there is between VI, and the Hour-lines of VII and VIII after VI, and through those points draw Lines parallel to the Hour-line of VI, and they shall be the Hour-lines of IV and V in the Morning.

7. For the Stile of these East or West Dials, it may be either a straight Pin or Wire pointed, of the just length of the line HL, fixed in the point H, or some other part of the line of VI, perpendicularly to the Plain, which will shew the true hour only by the shadow of the very
top

top thereof, as in the West Dial, Figure V.——Or, (which is better) it may be a Plate of Brass or Iron, of the same breadth as is the distance between the Hour-lines of VI and IX upon the Equinoctial, as in the East Dial, Figure IV; which Plate must be set perpendicularly upon the Hour-line of VI, which shall shew the Hour by the shadow of the upper edge thereof: and so is your Dial finished.

8. If you would insert the halves and quarters of hours into these Dials, you may easily effect it, by dividing each space between $\odot$ and $\odot$ on the Arch MN, into four equal parts and so transferring them to the Equinoctial Circle, as you did the whole hours. All which may be plainly seen in Figure V.

In the making of this Dial you have made two Dials, namely a West Dial as well as an East, for it is the same in all respects as to the Hour-distances and height of the Stile.——Only whereas the Arch EF in the East Dial (through which the Equinoctial passeth) was described on the Right-hand of the Plain, upon the Center C: In the West Dial it must be described on the Left-hand, upon the Center D: And the Hour-lines of IV, V, VI, VII, VIII, IX, X, and XI in the Forenoon, on the East Dial; must be VIII, VII, VI, V, IV, III, II, and I in the Afternoon, on the West-Dial: as the Figures IV and V do evidence.

C H A P. XII.

How to draw the Hour-Lines upon an Erect North or South Plain declining East or West.

I. By Projection.

OUR Example shall be of an Upright Plain, declining from the South Westward 30 degrees. Figure VI.

First, Draw a Right-line AB, representing your Declining Plain, crossing it with another Right-line CD, at Right Angles in Z, making Z for the *Zenith* of the *Place*, and Center of your Dial; and upon Z describe a Circle ABCD,——Then from C, towards B (because the Plain declineth Westward, or from C towards A, if it had declined Eastward) set 30 deg. the *Declination of your Plain*, from C to N, and draw the Line NZS, for the *Meridian of the Place*, upon which, from Z to P set off the Pole of the World, and finish your *Projection* as is before taught.

Secondly, Your *Projection* being finished, AB being the Line representing the Plain, the points C and D are the Poles thereof, they being 90 deg. distant from A and B.——And now you have three points given, namely, C, P and D, through which three points (by the 11th. Problem of the *Introduction*, draw an Arch of the Circle CPRD, whose Center will always fall in the Line of the Plain AB, it being extended: This Circle is an Arch of a *Meridian* or *Hour-Circle*, passing through P the *Pole of the World*, and C and D the *Poles of the Plain*, and cutteth the Plain AB at Right Angles in R, and is therefore called the *Meridian of the Plain*. The Pole of this Circle must next

be found, and that may be done in this manner. Lay a Ruler from D to R, it will cut the Primitive Circle in *a*, then take always 90 deg. of your Chord (because, the *Poles of all Great Circles of the Sphere are 90 deg. distant from the Circles themselves*) and set them from *a* to *e*, and if you lay a Ruler from D to *e*, it will cut the Line of the Plain in Q, so is Q the Pole of the Circle CRD.

Thirdly, The Sphere being projected, and the Lines and Circles relating to this Plain drawn upon the *Projection*: There are Three things to be found before you can draw the Hour-lines: And those three things are all comprised in the little *Spherical Triangle* PZR: The three things to be found, are

1. *The Height of the Pole above the Plain*, Represented in the Triangle by the side PR, the quantity whereof may thus be found.
— Lay a Ruler upon Q (the Pole of the Circle CRD) and P, the Pole of the World, it will cut the Circle in *b*, and the Arch Bb measured upon a Scale of Chords, will be found to be 32 deg. 36 min. and so much is the Pole of the World elevated above the Plain AB.
2. The second thing to be found, is the *Deflection*, or the *Substile's distance from the Meridian of the Place*, represented in the Triangle by the side ZR, and may thus be found.— Lay a Ruler upon D, the Pole of the Plain AB, and R; it will cut the Circle in *a*; the distance aC measured upon the Chords will give 21 deg. 40 min. for the side ZR, which is the *Substile's distance from the Meridian*: Or, The Line ZR measured upon the Scale of Half Tangents, will give 21 deg 40 min. also.
3. The third thing to be found is, *The Plain's difference of Longitude*: Or, *The Angle between the Meridian of the Place NZS, and the Meridian of the Plain CRD*, and is represented in the Triangle by the Angle ZPR: the quantity whereof may be thus found.— Lay a Ruler upon P, the Pole of the World, and V, the Point where the Circle CRD crosseth the Equinoctial, and it will cut the Primitive Circle in *k*, the distance Sk measured on a Scale of Chords, will give 35 deg. 26 min. for the Plain's Difference of Longitude.

And now for the drawing of the Hour-lines; Lay a Ruler to C, and to the several Points 9, 10, 11, and 1, 2, 3, 4, &c. where the *Hour-Circles* cross the Line of the Plain AB, and where the Ruler crosseth the Primitive Circle, make small marks or ***, and Lines drawn from the Center Z, through those marks or ***, shall be the true *Hour-Lines* belonging to the Declining Plain.

A Ruler laid from C to R, will give the Point L, whereby to draw the *Substilar Line* ZL; and 32 deg. 36 min. set from L to F, will give the Point whereby to draw the *Stile* ZF. And so is your Dial Finished.

From this South Plain declining West, a South Dial is also made declining East 30 deg. turning from the East side to the West side, and the contrary: and by changing the names of the Hours, by calling 11 One, 10 Two, 9 Three, &c. also 1 Eleven, 2 Ten, &c. the Forenoon-Hours in the West Dial, being the Afternoon-Hours in the East, and the contrary: An Example of a North Dial declining Eastward 45 deg. you have in Figure VII.

II. By

II. By Trigonometrical Calculation.

Before you can draw the Dial, you are to find out the three fore-mentioned *Requisites*, viz. (1.) *The height of the Pole above the Plain.* (2.) *The Deflection, or Substile's distance from the Meridian.* (3.) *The Plain's difference of Longitude:* All which are parts of the Spherical Triangle PRZ , right Angled at R :—In which there is given, (1.) The side PZ 38 deg. 28 min. equal to the Complement of the Latitude of the Place. (2.) The Angle PZR , the Complement of the Plain's Declination 60 deg. (3.) The Right Angle at R . And by these *Three* things given, you may find.

I. *The Height of the Pole or Stile above the Plain.*

As the Sine of 90 deg. _____ 10.00000

Is to the Sine Complement of the Lat. 38 deg. 28 min. _____ 9.79383

So is the Sine Complement of the Plain's Declin. 60 deg. _____ 9.93753

To the Sine of 32 deg. 36 min. _____ 9.73136

Which 32 deg. 36 min. is the height of the Pole or Stile, above the Plain.

II. *The Distance of the Substile from the Meridian.*

As the Sine of 90 deg. _____ 10.00000

Is to the Sine of the Plain's Declination 30 deg. _____ 9.69897

So is the Tangent of the Complement of the } _____ 9.90008

Latitude of the Place 38 d. 28 m. _____ }

To the Tangent of 21 deg. 40 min. _____ 9.59905

Which 21 deg. 40 min. is the distance of the Substile from the Meridian.

III. *The Plain's Difference of Longitude.*

As the Sine Complement of the Latitude 38 deg. 28 min. _____ 9.79383

Is to the Sine of 90 deg. _____ 10.00000

So is the Sine of the Substile's distance from } _____ 9.56736

the Meridian 21 deg. 40 min. _____ }

To the Sine of 36 deg. 25 min. _____ 9.77353

Which 36 deg. 25 min. is the Plain's difference of Longitude.

From

From the Plain's difference of Longitude thus found, allowing 15 deg. of the Equinoctial for one Hour, and one Degree for four minutes of time, it will follow, that the Substile of the Dial (which is the Meridian of the Plain) must fall between the Hour-Lines of 2 and 3 of the Clock in the Afternoon, because the Plain declineth Westward: For the Plain's difference of Longitude falling between 30 and 45 deg. (namely between the second and third Hour's Equinoctial distance) there will be two compleat Hours, and 6 deg. 25 min. more. Wherefore, make a Table of the Hours fit for the Plain, as is here represented to the Eye: In which, against the Hour of XII, set the Plain's difference of Longitude 36 deg. 25 min. from which subtract 15 deg. and there will remain 21 deg. 25 min.

which set against the Hour of XI and I, and from 21 deg. 25 min. subtract 15 deg. and there will remain 6 deg. 25 min. which set against the Hour of X and II; and (because it is less than 15 deg.) write the word *Substile*, and subtract 6 deg. 25 min. from 15 deg. then will there remain 8 deg. 35 min. which set above the word *Substile*, against the hours of IX and III, which, by the continual addition of 15 deg. will give you the Equinoctial Hour-distances of each Hour, as in the Table. Which Table being made, the next thing will be

A Table of the Hour-distances of a South Dial declining either to the East or West, 30 deg. 00 min.

Latitude of the Place	51 d.	32 m.
Dist. of Substile and Merid.	21	40
Height of the Stile	32	36
Plain's differ. of Longitude	36	25

Hours for the East West	Hour-di- stances at the Equi- noctial.	True Hour-di- stances on the Plain	
		D.	M.
V VII	68 35	53	57
VI	53 35	36	08
VII V	38 35	23	16
VIII IV	23 35	13	14
IX III	8 35	4	36
	Substile.		
X II	6 25	3	28
XI I	21 25	11	56
XII	36 25	21	41
I XI	51 25	34	03
II X	66 25	51	00
III IX	81 25	74	21

IV. To find the Angle that each Hour maketh with the Substile.

And for the finding of those Angles, this is the Proportion.

As the Sine of 90 deg.	10—00000
Is to the Sine of the height of the Pole above the Plain 32 deg. 36 min.	9—73140
So is the Tangent of the Equinoctial distance of the next hour to the Substile, viz. 6 d. 25 m.	9—05101
To the Tangent of 3 deg. 28 min.	8—78241

Which 3 deg. 28 min. is the distance of the Ten or Two a Clock Hour-lines from the Substile. So again.

As

Figure I.

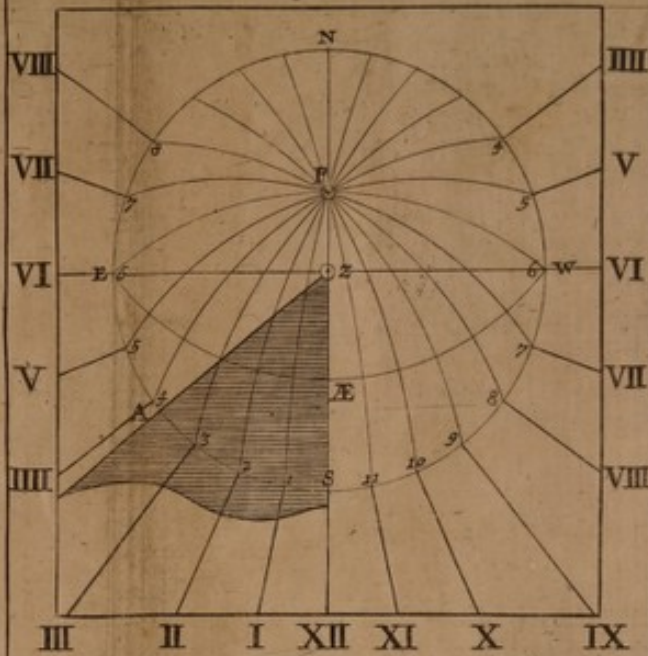


Figure II.

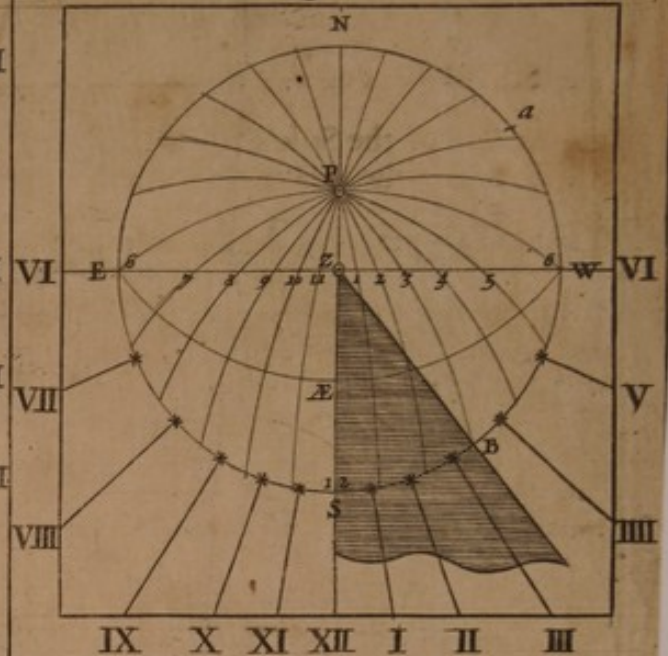


Figure III.

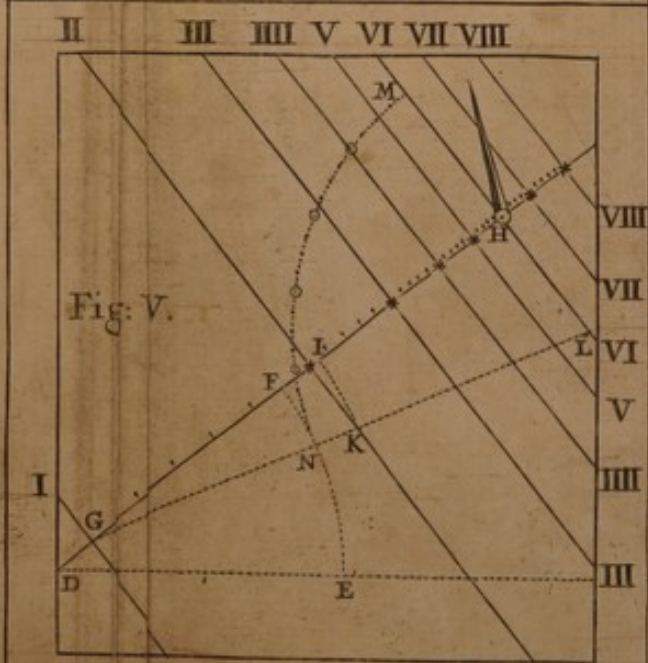
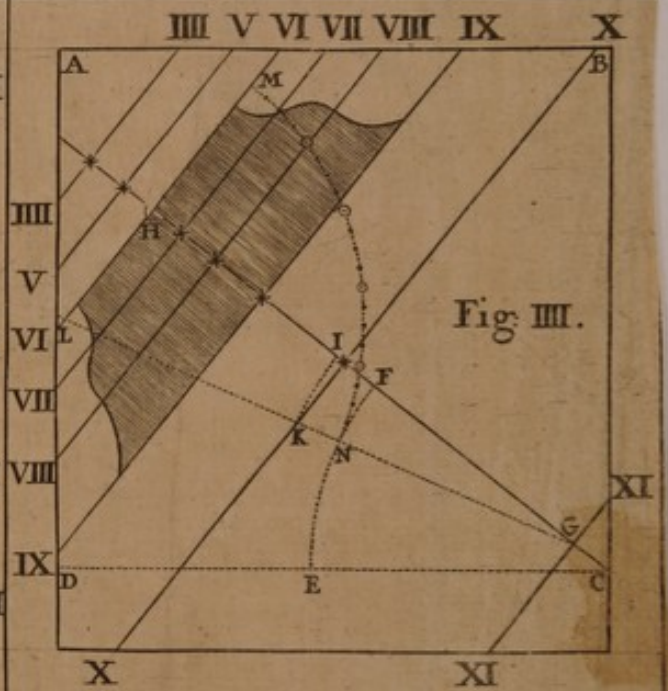
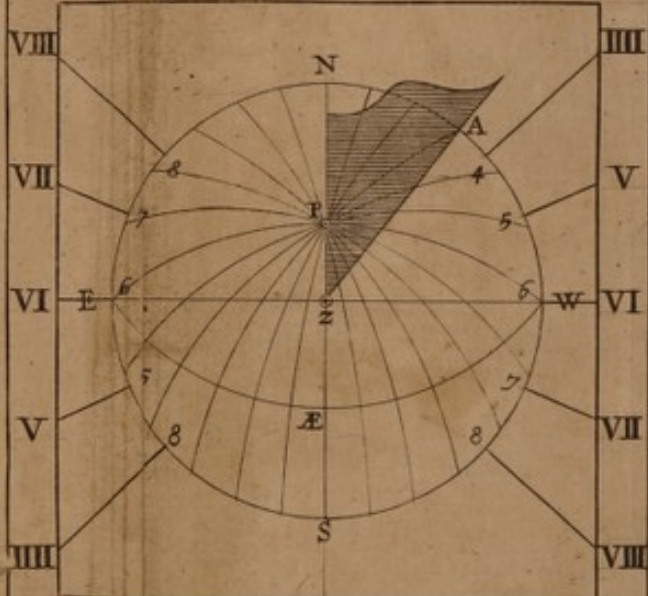
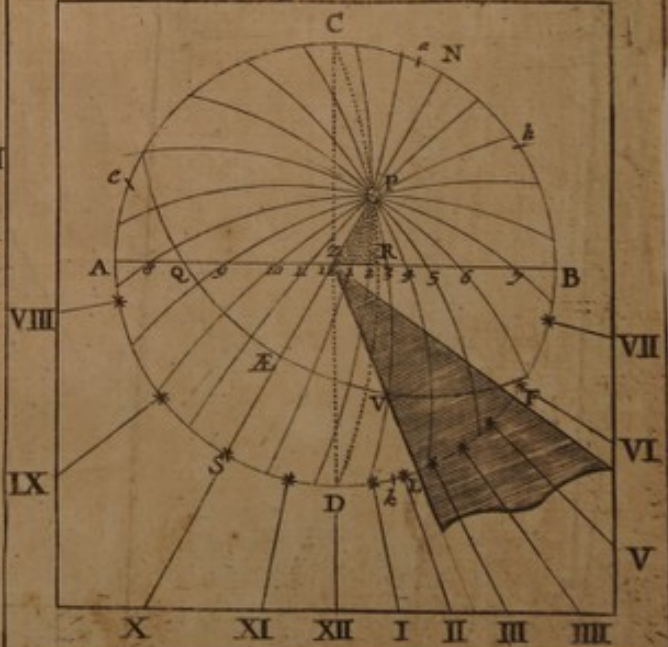


Figure VI.



As the Sine of 90 deg.	10—00000
To the Sine of the Stile's height 32 deg. 36 min.	9—73140
So the Tang. of the next Equin. dist. 21 deg. 25 min.	9—59354
To the Tangent of 11 deg. 56 min.	9—32494

Which 11 deg. 56 min. is the Distance of the Hour-Lines of Eleven or One of the Clock from the Substile. And so of all the rest, as in the Table: Which being measured upon the Primitive Circle by help of a Scale of Chords, will be found the same as where the Hour-Circles of the Projection did cut the Primitive Circle.

C H A P. XIII.

How to draw Hour-Lines upon a South or North-Plain, which declines many Degrees towards the East or West.

IF a Plain shall be found to decline many Degrees from the North or South towards either East or West; as, above 60 deg. Although the *Requisites* may be found, and the *Dial* made in all respects as the former *Dial* was in the last Chapter, yet by reason that the *Pole* of the *World*, will have but small Elevation above such a *Plain*, the *Hour-Lines* will fall so close one to another, that there will be no competent distance between them, till they be extended very far from the *Center*: And therefore, it was the way of the Ancients, to draw the *Dial* upon a large Floor, and extend the *Hour-lines*, *Stile* and *Substile*, to a great length, that so the *Hour-lines* might be of a convenient distance; and then to cut the *Dial* off, *Stile* and all, and so transfer it to the *Plain*. But this being too *Mechanical*, I will here shew a more artificial way how to draw such a *Dial Geometrically*, by help of a *Line of Chords* only, having no regard to the *Center* of the *Dial*. And,

I. By Trigonometrical Calculation.

You must find the *Requisites*: Namely, (1.) The height of the Pole, or Stile, above the Plain. (2.) The distance of the Substile from the Meridian. (3.) The Plain's difference of Longitude. All which may be found by the foregoing Analogies, or Proportions.

Suppose therefore, An Upright Plain, in the Latitude of 51 deg. 32 min. should decline from the South, Eastward 85 deg.

I. For the Stile's height.

As the Radius 90 deg.	10—00000
To the Co-Sine of the Latitude 38 deg. 28 min.	9—79384
So is the Co-Sine of the Plain's declination 5 deg.	8—94029
To the Sine of 3 deg. 6 min. the height of the Pole or Stile	8—73413

II. For the Substile's Distance from the Meridian.

As the Radius 90 deg. ————— 10—00000

To the Sine of the Declination 85 deg. ————— 9—99834
 So is the Co-Tangent of the Latitude 38 deg. 28 min. — 9—90008

To the Tangent of 38 deg. 22 min. ————— 9—89842
 For the Deflection, or the Substile's distance from the Meridian.

III. For the Plain's Difference of Longitude.

As the Sine of the Latitude 51 deg. 32 min. ————— 9—89374

Is to the Radius 90 deg. ————— 10—00000
 So is the Tangent of the Declination 85 deg. ————— 11—5804

To the Tangent of 86 deg. 5 min. ————— 11—16430

Which is the Plain's Difference of Longitude.

These *Requisites* being thus found, you may proceed to the making of a Table for the Hour-Distances, in all respects as in the last Chapter: By first setting down the Hours proper for the Plain in Order, as in this Table: And against XII, set the Difference of Longitude 86 deg. 5 min. from which subtract 15 deg. and there will remain 71 deg. 5 min. which set against XI and I. Also from 71 deg. 5 min. subtract 15 deg. the remainder will be 56 deg. 5 min. which set against X and II; and so by the continual Subtraction of 15 deg. you shall find 11 deg. 9 min. to stand against VII and V, under which write *The Substile's Place*, and then 11 deg. 5 min. being subtracted from 15 deg. there will remain 3 deg. 55 min. which set under *The Substile's Place*, against VI; and then by the continual addition of 15 deg. thereto, you shall have such Equinoctial Distances, as the second Column of the Table affordeth: And then for the true Hour-distances upon the Plain, say

As the Radius 90 deg. ————— 10—00000

To the Sine of the Stile's height 3 deg. 6 min. ————— 8—73302
 So is the Tangent of 86 deg. 5 min. the Equi- }
 noctial distance of XII ————— 11—16453

To the Tangent of 33 deg. 23 min. ————— 9—89755

Which is the distance of XII a Clock from the Substile, upon the Plain; And so proceeding with the rest of the Equinoctial Distances, you shall exhibit such Numbers as the Third Column affordeth.

	D.	M.
South Declin. West	85	00
Distance Substile and Meridian	39	22
Height of the Stile	3	06
Plain's difference of Longitude	86	05

By

Hours		Equinoctial Distances		Hour-dist. on the Plain	
East	West	D.	M.	D.	M.
XII		86	5	38	23
XI	I	71	5	8	58
X	II	56	5	4	36
IX	III	41	5	2	42
VIII	IV	26	5	1	31
VII	V	11	5	0	36
The Substiles Place					
	VI	3	55	0	13
V	VII	18	55	1	4
IV	VIII	33	55	2	6

By this Table you may see that the Hour-distances about the Substile (and indeed all the rest except the extreme Hour of XII) do fall so near together, that without an infinite extension of them, there will be no competent Distance between Hour-line and Hour-line; wherefore, laying aside your Table, proceed to make your Dial Geometrically, according to these following Directions.

The Geometrical Projection of this (or the like) Dial.

1. Draw a right-line A B perpendicular to one side of your Plain, and towards the Right-hand, because the Plain declineth *Eastward*; and with 60 deg. of your Line of Chords, describe an obscure Arch of a Circle C D E, and upon it (from C to D) set off 38 deg. 23 min. the *Substile's distance* from the *Meridian*, and draw the Line A D for the *Substile*, quite through the Plain. Figure VIII.

2. Out of your Line of Chords take 3 deg. 6 min. the height of the *Stile*, and set them upon the former Arch from D to E, and draw the Line A E for the *Stile*.

3. Now (because the *Stile* is but of small *Elevation*, viz. but 3 deg. 6 min.) draw another Line (as G H) parallel to the Line of the *Stile* A E, at such convenient distance as you shall think fit; which shall be your *Augmented Stile*.

4. Assume any two Points in the *Substilar Line* A D, at some convenient distance each from other, as R and S, and through those two Points draw two infinite Right-lines, both of them at Right Angles to the *Substilar Line* A D, as the Lines Z Z, and X X.

5. From the Point R, with your Compasses take the nearest distance to the new *Augmented Stile* G H, and set that distance upon the *Substilar Line* from R to K. — Also, from the Point S, take the nearest distance to the new *Augmented Stile* G H, and set that distance also upon the *Substilar Line* from S to L.

6. Upon these two Points K and L, with 60 deg. of the Line of Chords, describe two *Semicircles*, and in either of them set off 86 deg. 5 min. the Plain's difference of Longitude; as from R to M, and also from S to M; both of them on the same side of the *Substilar Line*, on which the first perpendicular Line A B was drawn.

7. Divide either of the *Semicircles* last drawn into 12 equal Parts, beginning at the point M, as the Points ○○○, &c. which 15 deg of the Line of Chords will effect.

8. Lay a Ruler to the Point L, and the respective Points ○○○, &c. in the *Semicircle*, and the Ruler will cut the Line X X in the Points *** &c. — Also lay a Ruler to K, and the several Points ○○○, &c. and the Ruler will cut the Line Z Z in the several Points *** &c.

Lastly, Lines drawn from the first Point * in the Line Z Z, to the first Point * in the other Line X X, (which the *Substilar Line* will direct

rect you how to do) those Lines so drawn shall be the true Hour-lines proper for the Plain, and will appear as in the Figure, and be at a competent distance one from another, without having any relation at all to the Center.

Now in the making of this Dial you have made four Dials, *viz.*

$$\begin{array}{l}
 \left. \begin{array}{l} \text{South declining West} \\ \text{South declining East} \\ \text{North declining West} \\ \text{North declining East} \end{array} \right\} 85 \text{ degrees}
 \end{array}$$

only by changing of the names of the Hours, and placing the *Stile* on the contrary side of the Line AB, for the South declining East. And by turning of the Dial upside downwards, for the two North Decliners; so that the Stiles may point upwards to the North-Pole, and the Hours about Midnight be omitted, as in the former North Dial, Figure VII.

C H A P. XIV.

How to draw the Hour-lines upon a Direct East or West Reclining Plain.

I. By the Projection.

Suppose a direct *West Plain* should Recline from the *Zenith* 35 deg. in the *Latitude* of 51 deg. 32 min. As in all Upright Plains, whether *Direct* or *Declining*, the *Meridian of the Place* and Hour-line of 12, is always *Perpendicular* to the *Horizon*: So in all *Direct East* and *West Reclining*, or *Inclining Plains*, the *Meridian of the Place* and Hour-line of 12, is parallel to the *Horizon*. To make these Dials.

Figure
IX.

First, Draw a Right-line NZS, representing the *Base* of your *Reclining Plain*, and Hour-line of 12: Upon Z, describe a Circle, and draw the Diameter WE, to cut the Line NS at Right Angles in Z. Upon Z describe a Circle, and upon the *Meridian Line* NS, set off the Pole of the World from Z to P, answerable to the Complement of the Latitude of the Place, and finish your *Projection* as hath been already taught.

Secondly, Because the Plain Reclines 35 deg. take 35 deg. out of a Scale of *Chords*, and set it from S to a, a Ruler laid from N to a, will cut the *Vertical Line* of the Plain in O, and now have you three Points, N, O, and S, whereby to draw your *Reclining Plain*, whose Center will always be in the Line EW extended; Or, 35 deg. the *Reclination*, being taken out of a Scale of *Half Tangents*, will give the point O as before. The Circle NOS representing the *Reclining Plain*, being drawn, you must find its *Pole*, which may be done in this manner: Take 90 deg. out of the Line of *Chords*, and set them from a to b, a Ruler laid from N to b, will cut the *Vertical Line* of the Plain EW, in Q, for the Pole of the *Reclining Plain* (or the complement of the *Reclination* 55 deg. being taken out of a Scale of *Half Tangents* and set

set from Z, will find the point Q for the Pole of the Plain also). Now having found the Pole of the Plain at Q, and the Pole of the World at P, you have two Points, viz. P, and Q, through which you must (by the 12th Problem of the Introduction) draw an Arch of a Great-Circle, which will cut the Reclining Plain at Right-Angles in R: Now part of the Arch of this Circle: Part of the Meridian NP: And part of the Reclining Plain NR, do constitute a Spherical Triangle N R P, Right Angled at R. And out of this Triangle may all the Requisites belonging to this Plain be found, which are Three, viz.

- I. The Height of the Pole above the Plain, represented by the Arch P R.
- II. The Distance of the Substile and Meridian, represented by N R.
- III. The Plain's difference of Longitude, or the Angle between the Meridian of the Place, and the Meridian of the Plain, represented by the Angle N P R.

First, you must find the Pole of the Meridian of the Plain, Which will always be where the Circle NOS, representing the Plain, doth cross the Equinoctial Circle, as here it doth at A; so is A the Pole of the Meridian of the Plain. And now,

1. To find the Height of the Pole or Stile above the Plain,] A Ruler laid from A to P, will cut the Circle in e, and laid from A to R, it will cut the Circle in c, the distance e c measured upon a Scale of Chords will give 26 deg. 41 min. for the Stile's Height.

2. A Ruler laid from Q to R, will cut the Circle in L, the distance N L 45 deg. 52 min. Is the distance of the Substile from the Meridian.

3. A Ruler laid from P to B, where the Meridian of the Plain cuts the Equinoctial Circle E Æ W, will cut the Circle in g, (or where the Meridian of the Plain cuts the Primitive Circle, which is in g also,) the distance S g 66 deg. 27 min. is the Plain's difference of Longitude, or the Angle between the Meridian of the Plain, and the Meridian of the Place.

The Requisites being thus found, the Hour-lines are easily drawn. For lay a Ruler from Q, the Pole of the Plain, to the several Points where the Hour-Circles cross the Reclining Plain, as at 1, 2, 3, &c. and where the Ruler cuts the Primitive Circle make marks, or ***, thro' which marks if you draw Lines from Z, they shall be the true Hour-Lines proper for your Reclining Plain. And a Ruler laid from Q to R gives the Point L for the Substile. The height of the Stile being 26 deg. 41 min. set 26 deg. 41 min. from L to F, and draw the Line Z F for the Stile. And so is the Dial Finished: And in making of this Dial you have made an East Reclining also, by only turning the Dial about, and numbering the Hours contrary, as in the Upright Decliners.

II. By Trigonometrical Calculation.

You must first find all the Requisites belonging to the Plain, all which may be obtained by resolving the Right angled Spherical Triangle N R P Right angled at R.

I. *For the Height of the Pole or Stile above the Plain.*

As the Radius, the Sine of 90 deg.	10.00000
Is to the Sine of the Latitude P N 51 deg. 32 min.	9.89374
So is the Sine of the Plain's Reclination R N P 35 deg.	9.75859
To the Sine of 26 d. 41 m. the side P R, the Stile's height above the Plain.	9.65233

II. *For the Substile's distance from the Meridian.*

As Radius	10.00000
To the Tangent of the Latitude 51 deg. 32 min. N P	10.09991
So is the Co-sine of the Reclination 55 deg.	9.91336
To the Tangent of 45 deg. 52 min. N R, the distance of the Substile and Meridian.	20.01327

III. *For the Plain's Difference of Longitude.*

As the Sine of the Latitude 51 deg. 32 min. P N	9.89374
Is to the Radius 90 deg.	10.00000
So is the Sine of the Substile's distance from the Meridian 45 deg. 52 min. N R	19.85595
To the Sine of 66 deg. 27 min. The Plain's difference of Longitude R P N.	9.96221

The *Requisites* being found, you are next to prepare a *Table* as followeth, wherein set the Hours proper for the Plain, namely, from 4 in the Morning till 2 in the Afternoon, for the *East Recliner*, and from 10 in the Forenoon till 8 at Night, for the *West Recliner*.

Then, considering the Plain's *Difference of Longitude* to be 66 deg. 27 min. consider how many *Equinoctial Hours* are therein (allowing 15 deg. for an Hour) and you shall find 4 Hours, and 6 deg. 27 min. remaining, wherefore the Substile must stand between the Hours of 4 and 5 in the *East Dial*, and between 7 and 8 in the *West Dial*, between which Hours write the word *The Substile*: Then, because there is 6 deg. 27 min. remaining above 4 hours, write 6 deg. 27 min. in the second Column over *Sub-* against the Hours of 4 and 8. Also subtract 6 deg. 27 min. from 15 deg. the Remainder will be 8 deg. 33 min. which write under *The Substile* against the Hours of 5 and 7. Then by the continual addition of 15 deg. to either of these Numbers, you shall have the *Equinoctial distances* belonging to each Hour, as in the second Column of the *Table*, namely, 21 deg. 27 min. for 9 and 3; And 23 deg. 33 min. for 6 and 6, &c.

West Reclining	35	0
Latitude	51	32
Stile's height	26	41
Deflection	45	52
Difference of Long.	66	27

Hours from the Substile		Equino- ctial Di- stances.		Hour- di- stances from the Substile.	
		D.	M.	D.	M.
11	1	81	27	71	29
	12	66	27	45	52
1	11	51	27	29	24
2	10	36	27	18	20
3	9	21	27	10	0
4	8	6	27	2	54
The		Sub-		stile.	
5	7	8	33	3	52
6	6	23	33	11	4
7	5	38	33	19	41
8	4	53	33	31	18
9	3	68	33	48	49
10	2	83	33	75	50

The *Table* being thus Prepared, you have nothing now to do, but to Calculate the Hour-distances upon the Plain from the *Substile*; which is easily done by this general *Analogy* or *Proportion*.

As the Radius 10.00000

Is to the Tangent of
6 d. 27 m. the Equi-
noctial dist. for the
hours of 4 and 8 9.05328

So is the Sine of the Stile's
height P R 26 deg. 41
min. 9.65233

To the Tangent of 2 deg.
45 min. the dist. of the
Hours of 4 and 8 upon
the Plain from the Subst. 8.70561

And by continual working of
this *Proportion*, you shall find
such numbers as this Table af-
fordeth in the Third Column
thereof, which being set off by
help of a Scale of Chords upon

a Circle from the *Substile* of the Dial, they shall be the true *Hour-
lines* proper for your *Reclining Plain*.

C H A P. XV.

How to draw Hour-Lines upon direct South Reclining Plains.

The First Variety, Reclining Equal to the Pole.

OF these Plains, there are *Three Varieties*: For, First, the *South Figure*
Plain may so Recline, that it may fall just into the Pole, and X.
that is when the *Reclination* of the Plain is equal to the *Comple-*
ment of the Latitude of the Place, Over such a Plain the *Pole* hath no
Elevation, and therefore the *Dial* no *Center*, and all the *Hour-Lines*
must be *parallel*; and the making of this Dial is the same as the *East*
or *West Erect-direct Dials* where, only, as the *Stile* of those Dials stood
upon the Hour-Line of *Six*, in these it must stand upon the Hour-Line
of *Twelve*, and the *Equinoctial Line* in that, must be an *Horizontal*
Line in this. An Example of such a Plain you have in Figure X.

II. *The Second Variety, South Reclining Less than to the Pole.*

Having drawn a Circle W S E N, and crossed it with two Diameters Figure
S N, for the *Meridian* of the Place and the Hour-Line of 12, and W E XI.
for

for the *Prime Vertical* Circle, and Hour-Line of Six, and within this Circle Projected the *Sphere* according to the former Directions, you may now proceed to the making of the Dial; Which, Let be a *South Plain*, *Reclining* from the *Zenith* 25 Degrees.

I. By the Projection.

The *Reclination* of the Plain being 25 deg. take 25 deg. from a Chord, and set them from E to *a*, a Ruler laid from W to *a*, will cut the Meridian of the Place in R: Or, the half Tangent of 25 deg. will reach from Z to R also: And now you have three Points W, R, and E, whereby to draw your *Reclining Plain*, whose Center will always be in the Meridian Line S Z N extended, and from its Center to R, will be equal to the *Secant* of 70 deg. the Complement of the Reclination.

The Circle W R E representing the Plain, being drawn, you see that it passeth between the *Pole of the World* and the *Zenith*, and therefore the *South Pole* is Elevated above it; and how much, you may thus find; Lay a Ruler from W to P, it will cut the Circle in *c*, the distance from *c* to *a* measured upon a Chord, will be found to be 13 deg. 28 min. for the height of the *South Pole* or *Stile* above the Plain.

For finding the *Pole* of the Plain, take 90 deg. of the Chords, and set them from *a* to *b*, a Ruler laid from W to *b*, will cut the Meridian Line S N in Q, so is Q the *Pole* of the Plain.

Now for the *Hour-Lines*, Lay a Ruler to Q, and to the several Points 1, 2, 3, &c. where the Hour-Circles of the Projection intersect with the Plain W R E, and on the Circle, where the Ruler crosseth it, make marks ***, and from Z the Center, through those marks, draw Lines, and they shall be the true Hour-Lines proper to the Reclining Plain; and 13 deg. 28 min. set from N to L shall give the Point L, whereby to draw the Line Z L for the *Stile* of the Dial.

II. By Trigonometrical Calculation.

In these Plains there is nothing (besides the Hour-Distances) to be found, but *The height of the Pole or Stile above the Plain*, and that is easily done: For, The Plain falling between the *Pole* and the *Zenith*, if you subtract the *Reclination* Z R 25 deg. from Z P 38 deg. 28 min. the *Complement of the Latitude*, the Remainder 13 deg. 28 min. is the *Height of the Pole above the Plain*.

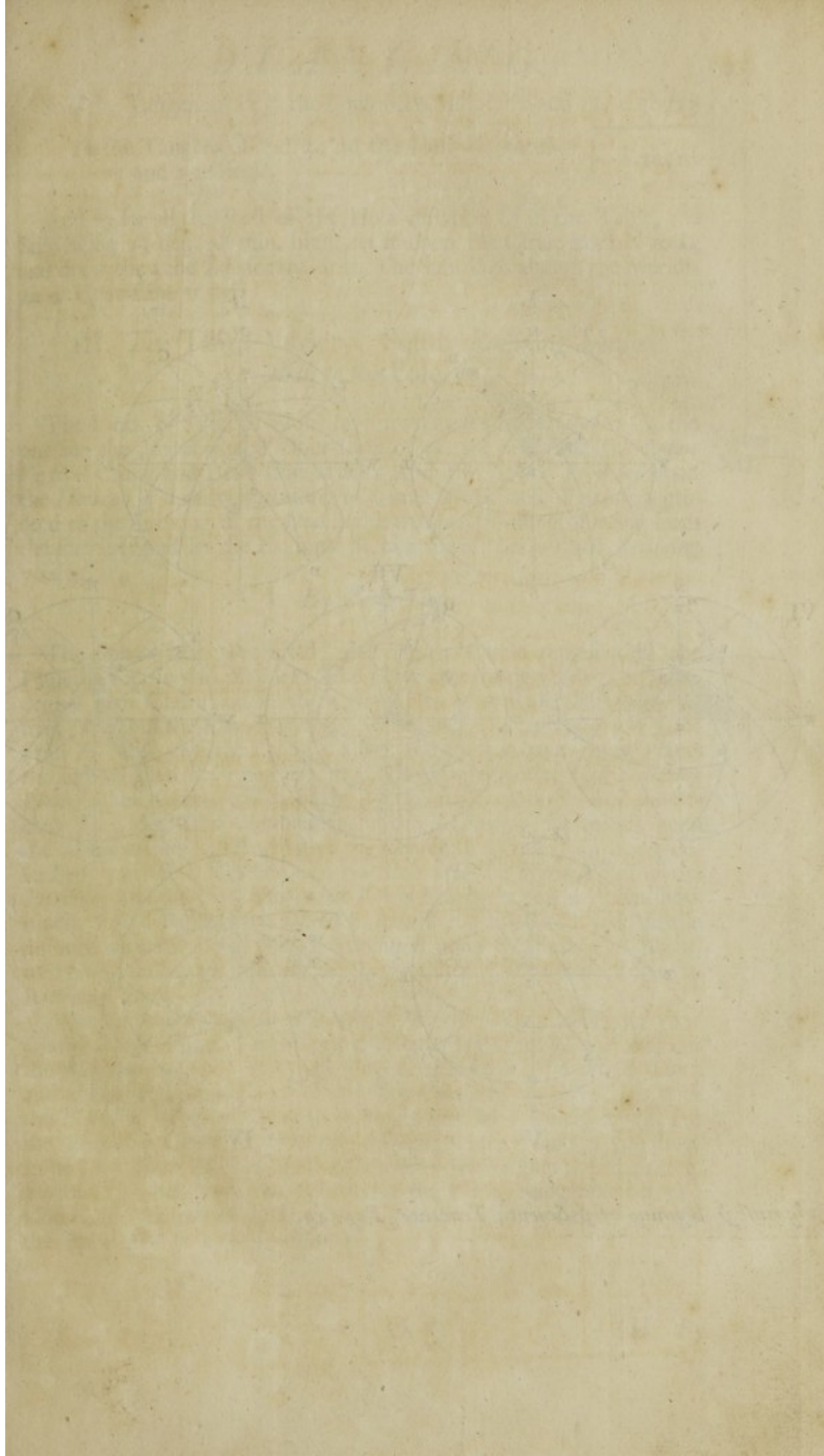
Stile's height 13 d. 28 m.				
Hours from Noon.		Equinoctial Distances.		Hour-Distances on the Plain.
		D.	M.	
12		0	0	0 00
11	1	15	0	3 34
10	2	30	0	7 39
9	3	45	0	13 7
8	4	60	0	21 58
7	5	75	0	41 0
6		90	0	90 0

Now for the *Hour-Lines*, the height of the Pole above the Plain being found, the general *Canon* for Hour-distances will effect that; for having framed a *Table* with *Hours* and *Equinoctial distances* answerable to them, you may by the general Canon work as followeth.

As the Radius 90 deg. 10.00000

To the Sine of R P 13 d. 28 m. the height of the Pole above the Plain. 9.42805

So



So is the Tangent of 15 d. the Equinoctial dist. for 1 and 11, 9.36713

To the Tangent of 3 d. 34 m. the Hour-distances of } 8.79518
 11 and 1 a Clock

And so for all the Rest of the Hour-distances as in the Table, the Stile being 13 deg. 28 min. high, set it upon the Circle from N to L, and draw the Line ZL for the Stile, The Substile is always the Meridian or Hour-Line at 12.

III. The Third Variety, South Reclining More than to the Pole.

The Lines N S and E W being drawn at Right Angles in Z, the one for the *Meridian* and Hour-Line of 12, the other for the *Prime Vertical Circle* and Hour Line of Six: And the *Sphere Projected* upon the *Horizon of London* according to former Directions, You may proceed to the drawing of the *Dial* in this manner, nothing differing from the former: And let the Example be of a direct *South Plain Reclining* 70 deg.

Figure
XII.

I. By Projection.

The Sphere being Projected, describe the Circle representing the Plain upon it, in this manner: The *Reclination* being 70 deg, take 70 deg. of your Chord and set them from E to *a*, A Ruler laid from W to *a*, Will cut the Meridian in R, (or the half Tangent of 70 deg. set from Z, will give the Point R also) and so you have three Points through which to describe the Circle E R W representing your *Reclining Plain*, whose Center will be in the Meridional Line N S: And the Secant of 20 deg. (the Complement of the *Reclination*) set from R upon the *Meridian Line* to B, will give the Center: And the Plain being described, you see it falls between the *Pole* and the *North Point* of the *Horizon*, and therefore the *North Pole* is Elevated, and to know how much, Lay a Ruler from W to P, it will cut the Circle in *b*, so the distance between *a* and *b* being measured upon the Scale of Chords, will give 31 deg. 32 min. for the height of the *Pole* or *Stile* above the *Reclining Plain*.

Next find the *Pole* of the *Plain* E R W, by taking 90 deg. of your Chords, and setting it from *a* to *c*, a Ruler laid from W to *c* will cut the *Meridian* in Q, so is Q the *Pole* of the *Plain*; To which Point and the several intersections of the *Hour-Circles* of the *Projection* with the *Plain*, 1, 2, 3, &c. If to these Points you lay a Ruler, it will cut the *Primitive Circle* in ***, &c. through which Points if you draw right Lines from Z, they shall be the true Hour-Lines: And 31 deg. 32 min. the height of the *Pole* above the *Plain*, being taken from a Chord, and set from N to L, it shall give the Point whereby to draw the *Stile*: And so is the *Dial* finished.

II. By Trigonometrical Calculation.

There is nothing in this Dial to be Calculated but the *Hour-Distances*, and before you can Calculate them, you must first obtain *The height of the Pole or Stile above the Plain*, in this manner: The Plain falling between the *Horizon* and the *North Pole*, the Arch of the *Meridian* P R, must be the height thereof: Now from Z to R is 70 d. the *Reclination* of the Plain, and from Z to P is 38 deg. 28 min. the *Complement* of the *Latitude*: Subtract P Z 38 deg. 28 min. from

Z R 70 deg. the remainder 32 deg. 31 min. is the *Arch* P R, the height of the *Pole* above the *Plain*: Which known, prepare a *Table* and Calculate the *Hour-distances* by the general Analogue or Proportion.

Stile's height 31 d. 32 m.					
Hours from Noon.		Equinoctial Distances.		Hour-Distances on the Plain.	
		D.	M.	D.	M.
12		0	0	0	00
11	1	15	0	7	59
10	2	30	0	16	48
9	3	45	0	27	36
8	4	60	0	42	10
7	5	75	0	62	52
6		90	0	90	0

As Radius

10.00000

To the Sine of the height of the Pole above the Plain P R 31 deg. 32 min.

9.71850

So is the Tangent of 15 deg. the Equinoctial distance

9.42805

To the Tangent of 7 d. 59 m. the Hour-dist. of 11 or 1.

9.14655

And so for all the rest of the Hour-Distances as in the Table, The Stile must be Elevated above the *Meridian* or Substile equal to the Angle N Z L 31 deg. 32 min. And so is the Dial finished.

C H A P. XVI.

How to draw Hour-lines upon direct North Reclining Plains.

OF these kind of Plains there are Three Varieties, as there were of South Recliners: For (1.) The *Reclination* may be such that the Plain may just lie to the *Equinoctial Circle*.—Or, (2.) It may *Recline* so, that the Plain may fall between the *Zenith* and the *Equinoctial Circle*. Or, (3.) The Plain may *Recline* so, as to fall between the *Equinoctial* and the *Horizon*. Examples of all which do here follow.

I. The

Figure VII III V VI

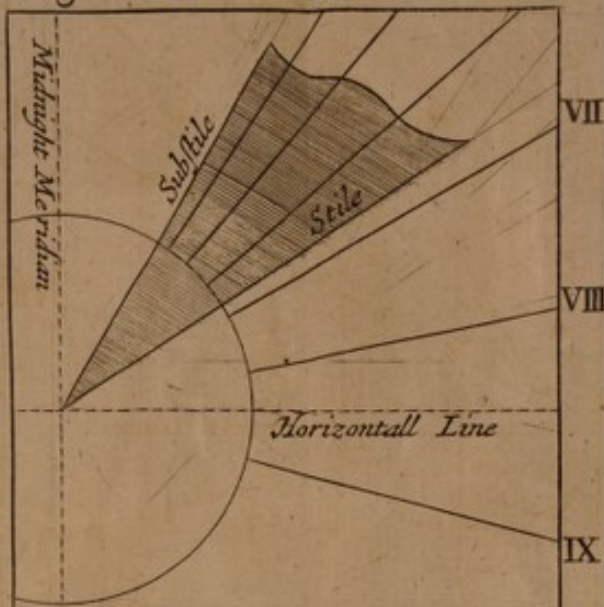


Figure VIII

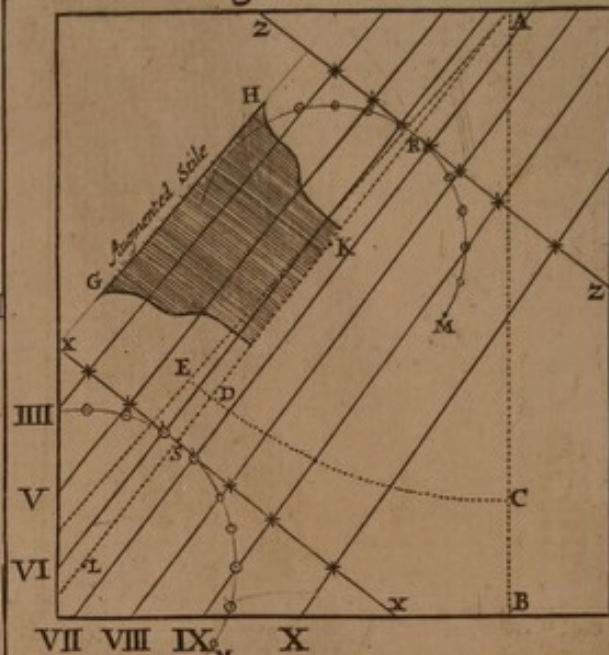


Figure IX V VI VII VIII

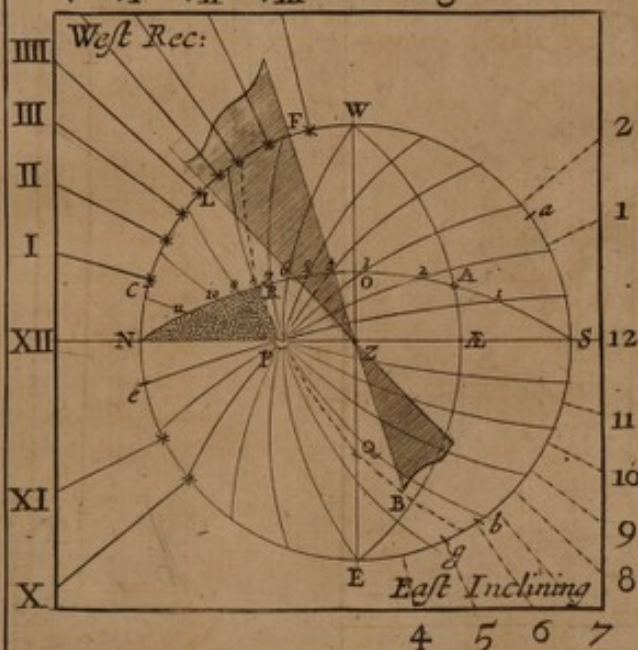


Figure X

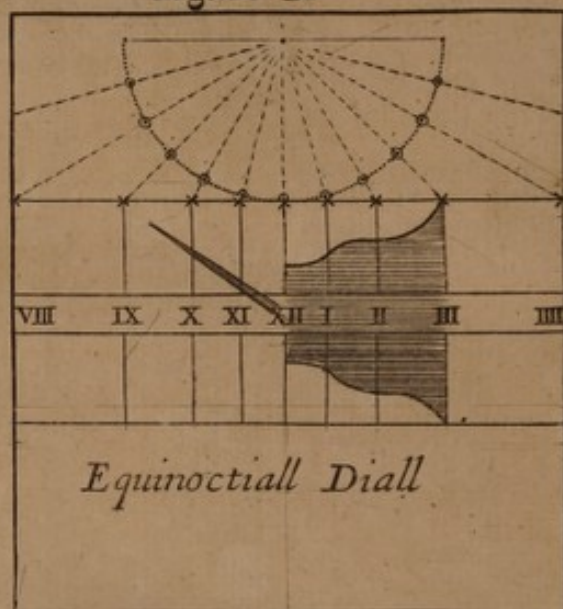


Figure XI 4 8

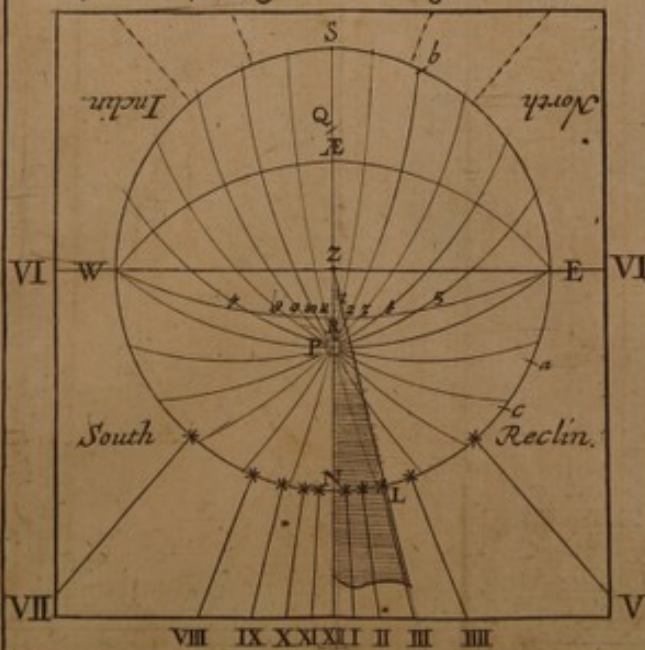


Figure XII IX X XI XII I II III

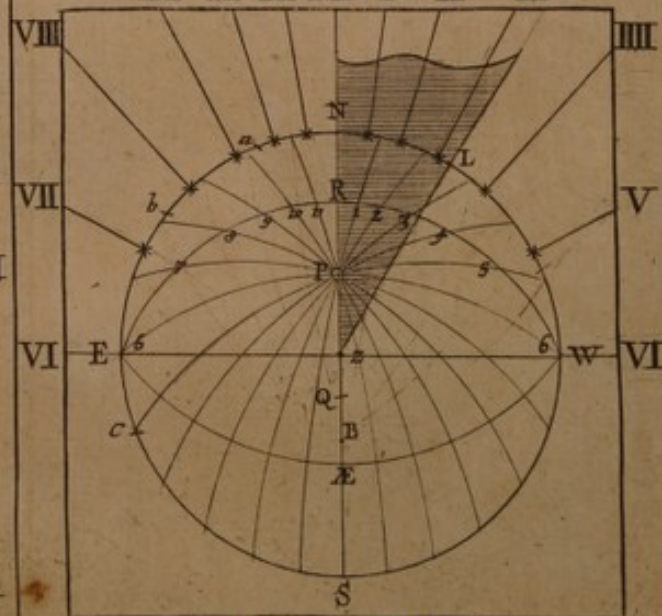


Figure XII

I. *The First Variety ; North Reclining, Equal to the Equinoctial.*

I. *By Projection.*

Our first Example shall be of a *North Plain, Reclining* from the *Zenith*, 51 deg. 32 min.

First, Having drawn N S for the *Meridian* and Hour-Line of 12, *Figure XIII.* and E W for the *Prime Vertical Circle*, and Hour-Line of 6, crossing each other at Right Angles in Z, and upon Z described a Circle, and therein *Projected* the *Sphere*: The next thing to be done is to project the *Circle* representing your *Reclining Plain*: And the *Reclination* being 51 deg. 32 min. take those Degrees from your Line of Chords and set them from W to *a*: A Ruler laid from E to *a*, will cut the *Meridian* in *B*, which is the very intersection of the *Equinoctial Circle* with the *Meridian* N S; and so the *Equinoctial Circle* represents your *Plain*: To find the *Pole* whereof, Take 90 deg. of your Chords and set them from *a* to *b*, and laying Ruler from E to *b*, it will cross the *Meridian* N S in P the *Pole* of the *World*, so that the *Pole* of the *World* is the *Pole* of this *Plain*; and the distance *a b* being 90 deg. shews the *North Pole* to be elevated above the *Plain* 90 deg.

Now for the Hour-Lines, P being the *Pole* of the *Plain*, lay a Ruler thereto, and to every of the Hour-points 1, 2, 3, &c. 11, 10, 9, &c. where the *Hour-Circles* cross the *Plain*, and where the Ruler crosseth the *Primitive Circle*, make marks * * *, through which, and the Center Z, Lines being drawn shall be the true Hour-Distances proper for this *Reclining Plain*: And indeed they are no other than if the *Circle* were divided into 24 equal parts, for the Hours are all of an equal distance one from another, namely 15 deg. Now the *Stile* having 90 deg of *Elevation*, A straight *Pin* or *Wyre* of any length, set upright, (i. e.) *Perpendicular to the Plain*, in the point Z, shall point directly to the *North Pole*, and so shew the Hour by the shadow thereof.

There needs no *Trigonometrical Calculation* for this *Dial*, the Hour-Distances being all Equal, viz. 15 Degrees from each other, and the *Stile* only a *straight Wyre*, set perpendicular to the *Plain*.

II. *The Second Variety ; North Reclining Less than the Equinoctial.*

I. *By Projection.*

Let this Second Example be of a *North Plain, Reclining* from the *Zenith* 25 deg. Having drawn N S for the *Meridian*, and E W for *Prime-Vertical*, intersecting at Right Angles in Z, and upon Z described a Circle E N W S, and in it *Projected* the *Sphere*; Your next work will be to Draw the *Circle* representing the *Plain* upon the *Projection*, in this manner: *Figure XIV.*

The *Plain Reclining* 25 deg. take 25 deg. out of your Line of Chords, and set it from W to *a*: A Ruler laid from E to *a* shall cut the *Meridian*

Meridian in R, (or the half Tangent of 25 deg. set from Z, shall give the Point R also). And now you have Three points to draw your plain by, viz. E R W, whose Center will be in the Meridian Line N S, and the Secant of 25 deg. set from R will give the same.

The Plain being thus described, you see it passeth between the Zenith and the Equinoctial, and the North Pole is Elevated above it the Quantity of the Arch of the Meridian R P; and to know how much that is, you must first find the Pole of the Plain thus: Set 90 deg. from *a* to *b*, then lay a Ruler upon E and *b*, it will cut the Circle in Q, so is Q the pole of the Plain; and a Ruler laid from E to P will cut the Circle in *c*, the distance *ac* measured upon a Scale of Chords will give 63 deg. 28 min. for the Arch P R, equal to the height of the Pole above the Plain.

To draw the Hour-Lines; Lay a Ruler upon Q, and to the several points where the Hour-Circles cross the Plain, and where the Ruler cutteth the Primitive Circle make marks or * * *, through which points, from the point Z, draw Lines, and they shall be the true Hour-Lines. For the Stile take 63 deg. 28 min. from your Scale of Chords and set them from N to L, and draw the Line Z L for the Stile; The Substile is the Line N Z, or the Meridian of the place, as in *South Recliners*; but in these *North Recliners* the North Pole is always Elevated, and the Hours about Midnight left out: As in Figure XIV.

II. By Trigonometrical Calculation.

All the Calculation that is required in these Direct Reclining Plains, is only the Height of the Pole above the Plain, and the Hour-distances from the Meridian. For the First, it is the Quantity of the Arch P R, Now from Z to R is 38 deg. 28 min. equal to the Complement of the Latitude, and Z R is 25 deg. equal to the Reclination, which added together make 63 deg. 28 min. And so much is the height of the Pole or Stile above the Reclining Plain E R W.

Stile's height 63 d. 28 m.				
Hours from Noon.	Equinoctial Distances.		Hour-Distances on the Plain.	
	D.	M.	D.	M.
12	0	0	0	00
11 1	15	0	13	29
10 2	30	0	27	19
9 3	45	0	41	49
8 4	60	0	57	10
7 5	75	0	73	20
6	90	0	90	00

For the Hour-Distances from the Meridian, they are to be found by the general Analogie or Proportion.

As Radius 90 deg. 10.00000

To the Sine of 63 deg. 28 min. the Stile's Height; } 9.95166

So is the Tangent of the first Equin. distance } 9.42805
15 deg.

To the Tangent of 13 deg. 29 m. for the distance of 11 and 1 } 9.37971

The like must be done for all the rest, and so shall you produce such Numbers as are in the third Column of the Table.

The Stile must stand upon the *Meridian-Line* N Z, making an Angle of 63 deg. 28 min. therewith.

III. *The Third Variety: North Reclining more than the Equinoctial.*

I. By Projection.

Suppose a *North Plain* in the Latitude of 51 deg. 32 min. should *Recline* from the *Zenith* 70 deg.

First, Draw N S and E W at Right Angles in Z, and upon Z describe a Circle, and therein project the Sphere. Which done, Take the *Plain's Reclination* 70 deg. out of your *Scale of Chords*, and set it upon the Circle from W to *a*, a Ruler laid from E to *a*, will cut the *Meridian* in R, (or 70 deg. taken out of the *Scale of Half Tangents*, will reach from Z to R also). Now having Three points E, R, and W, describe it upon your Projection, the Center thereof will be in the *Meridian Line* N S, and will be distant from R, equal to the *Secant* of 20 deg: The *Plain* being drawn, find the *Pole* thereof, by taking 90 deg. of your *Chords*, and setting them from *a* to *b*, so a Ruler laid from E to *b*, shall cut the *Meridian* N S in Q the *Pole of the Reclining Plain*. But now to find the *Height* of P the *Pole of the World*, above the *Reclining Plain* E R W, Lay a Ruler upon E and P, it will cut the Circle in *d*, so should *a d* be the height of the Pole above the Plain; which being above 90 deg, viz. 108 deg. 28 min. the Complement thereof to 180 deg. namely 71 deg. 32 min. is the *Stile's* height; which set from S to L, shall give you the point L, whereby to draw the Line of the *Stile*.

Figure
XV.

Next for the *Hour-Lines*. A Ruler laid to Q, the *Pole* of the Plain, and the respective points 1, 2, 3, &c. (where the *Hour-Circles* cross the Plain) mark where the Ruler cuts the *Primitive Circle*, and there make marks or * * * ; and from Z, if you draw Lines through those * * *, they shall be the true *Hour-Lines* belonging to your *Reclining Plain*.

II. By Trigonometrical Calculation.

As in the other *Reclining Plains* which are direct North or South, there was no *Arithmetical Calculation* but only to find the *Height of the Pole above the Plain*, and the *Hour-Distances* from the *Meridian* of the Place, neither is there more in this.

For the first, (namely the *Height of the Pole or Stile* above the Plain) which is Represented by the Arch of the *Meridian* in the Projection by P R. Now from Z to P is 38 deg. 28 min. equal to the Complement of the Latitude, and Z R is 70 deg. equal to the Reclination, these two being added together make 108 deg. 28 min. but this cannot be the true height of the Pole above the Plain, for that can never exceed 90 degrees, but this Plain falling between the *Equator* and the *Horizon*, must needs have so much less than 90 deg. of Elevation, as the *Reclination* is more than the *Latitude*; therefore,

Stile's height 71 d. 32 m.		Equinoctial Distances.		Hour-Distances on the Plain.	
Hours from Noon.		D.	M.	D.	M.
12		0	0	0	00
11	1	15	0	14	16
10	2	30	0	28	43
9	3	45	0	43	30
8	4	60	0	58	41
7	5	75	0	74	14
6		90	0	90	00

If you add 38 deg. 28 min. the Complement of the Latitude, and 70 deg. the *Reclination*, together, the Sum will be 108 deg. 28 min. as before, whose *Complement* to 180 deg. is 71 deg. 32 min. and that is the true height of the Pole above the Plain: Or if you add Z A, 51 deg. 32 min. the Latitude, to R S 20 deg. (the Complement of the Plain's *Reclination*) the Sum of them will be 71 deg. 32 min. for the Height of the Pole or Stile above the Plain.

The Hour-Distances (now the height of the Stile is known) may be found by the *Common Analogy*.

As the Radius 90 deg. ————— 10.00000

To the Sine of the Stile's height 71 deg. 32 min. ——— 8.97704
So is the Tangent of 15 deg. to the first Equin. distance — 9.42805

To 14 d. 16 m. the first Hour's distance from the Merid. 19.40805

And repeating this Work for all the Hours, you shall have such Distances as in the Third Column of the Table are set down.

The Stile must be erected upon the Meridian, and raised to an Angle of 71 d. 32 m. equal to the height of the Pole above the Plain.

C H A P. XVII.

How to draw the Hour-Lines upon South Declining Reclining Plains.

OF South direct *Reclining Plains*, there were *Three Varieties*, so are there as many of *South Recliners* which *Decline* also; For to any *Declination*, the *Plain* may *Recline* so, that it may pass through the Pole of the *World*. Or, *Secondly*, It may *Recline* so, that the *Plain* shall fall below the *Pole*, and so fall between the *Zenith* and the *Pole*. Also, *Thirdly*, It may so *Recline*, that the *Plain* shall pass between the *Pole* and the *Horizon*: Of all which *Varieties* I shall give particular *Examples*.

I. *The First Variety: Of South Declining Reclining Plains, The Plains passing through the Pole.*

I. *By Projection.*

Figure XVI. This Example shall be of a *South Plain*, *Declining* from the *South Eastward* 30 deg. and *Reclining* from the *Zenith* 34 deg. 32 min.

First,

First, Draw a Right Line A B, representing the Basis of your *Reclining Plain*, and cross it with another Line C D, at Right Angles in the point Z.

Secondly, Upon Z, describe a Circle and in it from C towards E, (because the Plain declines Eastward) set 30 deg. the *Declination* of the *Plain*, to N, and draw the Line N Z S for the *Meridian* of the *Place*, upon which, from Z to P, set the Half Tangent of the Complement of the *Latitude* 38 deg. 28 min. and finish the *Projection*: Which done,

Thirdly, Take the Half Tangent of the *Reclination* of the *Plain* 34 d. 32 m. and set it from Z to R, upon the Line C D, so have you three Points A, R, and B, by which to draw your Plain, whose Center will be in the Line C D extended, and the *Secant* of 55 deg. 28 min. set from R, will give the Center point: Also the Half Tangent of 55 deg. 28 min. being set from Z will give you the point Q, for the Pole of the *Plain*; through which point Q, and P the Pole of the *World*, you must (by the 12th Problem in the *Introduction*) draw the Arch of a *Great Circle*: And now seeing the Plain passeth just through the Pole of the *World*, the Pole hath no Elevation above it, and therefore the *Hour-Lines* must be parallel one to the other. But before you can draw them, two things must be found,

1. The *Distance of the Meridian from the Horizon* P B.
2. The *Plain's Difference of Longitude*, the Angle Z P Q.

Both which by the *Projection* are thus found:

A Ruler laid from Q to P, will cut the Circle in a, and the distance a B measured upon the *Chords* will give 71 deg. 53 min. for the *Distance of the Meridian from the Horizon*: And the Arch S b, measured upon the *Chords*, will be 24 deg. 19 min. for the *Plain's Difference of Longitude*.

These things found, the *Dial* must be drawn Geometrically, not much differing from the direct *East, West, and Equinoctial Dials*, as shall be presently shewed. But First,

II. By Trigonometrical Calculation.

1. To find the *Distance of the Meridian from the Horizon* P B.

By the intersection of the *Circles* of the *Sphere* with the *Plain*, you have constituted a *Right Angled Spherical Triangle* P R Z, Right Angled at R, in which there is given, (1.) The *Hypotenuse* Z P 38 deg. 28 min. the *Complement of the Latitude*. (2.) The *Angle* R Z P 30 deg. the *Plain's Declination*, and if you will, (3.) the side R Z 34 deg. 32 min. the *Plain's Reclination*. To find the side R P, the *Complement of the Meridian's distance from the Horizon*: For doing whereof this is the Proportion.

As Radius 90 deg.

10.00000

To the Sine of P Z the Co-Latitude 38 deg. 28 min.

9.79383

So is the Sine of R Z P the *Plain's Declination* 30 deg.

9.69897

To the Sine of R P 18 deg. 7 min.

9.49280

The Complement whereof 71 deg. 53 min. is the Arch P B, the *Distance of the Meridian from the Horizon*:

2. For

2. For the Plain's Difference of Longitude Z P Q.

As the Sine of P Z the Co-Latitude 38 deg. 28 min. 9.79383

Is to the Radius 90 deg. 10.00000

So is the Sine of Z R the Plain's Reclination 34 deg. 32 min. 9.75349

To the Sine of Z P R 65 deg. 41 min. 9.95966

Whose Complement 24 deg. 19 min. is the Angle Z P Q, the *Plain's Difference of Longitude*.

The Geometrical Projection of this Dial.

Figure
XVII.

First, Draw a Line at pleasure, as A Z B, representing the Horizontal Line of the Plain; Then, considering of what length you would have your *Stile* to be, answerable to the bigness of your *Plain*; suppose Z D, take that distance in your Compasses, and setting one foot in Z, with the other describe a Semicircle A C D B, upon which (by help of a Scale of Chords) set 71 deg. 53 min. the *distance of the Meridian from the Horizon*, from A to C, and draw the Line Z C E, for the *Substile*.

Secondly, Take 24 deg. 19 min. the *Plain's Difference of Longitude* and set it from C to D.

Thirdly, Through the point C, draw a Line F G, perpendicular to the *Substile* Z E; and another Line H I, at any distance parallel to F G.

Fourthly, Lay a Ruler from Z to D, it will cut the Tangent Line F G, in 12, through which point, draw the Line 12, 12 Parallel to the *Substile* Z E, for the *Hour-Line* of 12.

Fifthly, Divide the Semicircle A D B into 12 equal parts, at the points * * *, &c. beginning at D.

Lastly, Lay a Ruler unto Z, and upon every of the marks * * *, &c. and the Ruler will cut the Line F G, in the points 7, 8, 9, 10, 11, 12, 1, 2, through which points, draw Lines parallel to the *Substile* Z E, so is your *Dial* finished.

As for the *Stile*, it may be a straight *Pin* or *Wyre*, of the just length of the Line C Z, as K L, set perpendicular to the *Plain* upon any part of the *Substile*; whose point will give the Shadow.— Or, it may be a *Plate* of *Brass* or *Iron*, of the same breadth with the Line Z C, which will shew the Hour by the Shadow of the side thereof.

II. The Second Variety: Of South Declining Reclining Plains; The Plain passing between the Pole and the Zenith.

I. By the Projection.

Figure XVIII. Our Second Example shall be of a *Plain Declining* from the South Eastward 30 deg. and *Reclining* from the Zenith 20 deg.

First, draw a Right Line A B, for the Base of the *Reclining Plain*, and another C D, perpendicular thereunto, for the *Vertical Line* of the *Plain*, crossing one another at Right Angles in Z.

Secondly

Secondly, upon Z describe a Circle, and thereon set 30 deg. the *Declination* from A to E, and draw the Line E W for the *Prime Vertical Circle*, and at Right Angles to it the Line S P N for the *Meridian* of the Place, and now *Project* the *Sphere*, as hath been before taught.

Thirdly, Out of your Scale of Half Tangents, take 20 deg. the *Reclination* of the *Plain*, and set it from Z to H upon the Line C D; for the *Plain*: Also take 70 deg. and set them from Z to Q, for the *Pole* of the *Plain*; and having three Points A, H, and B, whereby to describe your *Plain*, if you take the Secant of 70 deg. and set it from H, upon the Line C D extended, it shall give the Center whereby to describe the *Reclining Plain* A H B. — And now having found Q, the *Pole* of the *Plain*, you must through it, and P the *Pole* of the *World* (by the 12th Problem of the Introduction) describe the *Arch* of a *Great Circle* Q R P.

Having proceeded thus far, the next thing to be done is to find the *Requisites* belonging to this *Plain*, which in all *Declining Reclining Plains* (excepting such as pass through the *Pole* of the *World*, or by the intersection of the *Meridian* and *Equinoctial*) are Four, viz.

- | | | |
|--|-----------------------|------------------------------|
| 1. The distance of the Meridian and Horizon | } represen-
ted by | } O B
P R
O R
O P R |
| 2. The height of the Pole or Stile above the Plain | | |
| 3. The distance of the Substile from the Meridian | | |
| 4. The Plain's difference of Longitude | | |

And all these may be found by the *Projection*:

1. For O B: Lay a Ruler from Q to O, it will cut the *Primitive Circle* in *a*, the Distance from B to *a*, measured on a Scale of Chords, will be found to be 78 deg. 50 min. for the *Distance of the Meridian from the Horizon*.

2. For P R: You must first find the *Pole* of the *Great Circle* P R Q (as hath been taught already at the end of the Fourth Chapter hereof) which will be at *q* (always in some part of the *Equinoctial Circle*, namely, at the Intersection of the *Equinoctial* and the *Plain*): which found, Lay a Ruler from *q* to P, it will cut the Circle in *b*, and laid to R, it will cut the Circle in *c*, the distance *b c* measured on the Chords, will be found to be 13 deg. 49 min. for *The height of the Stile*.

3. For O R: A Ruler laid from Q to O, did cut the Circle in *a*; and laid from Q to R, it will cut the Circle in *d*; the distance *a d* will be found by the Scale of Chords to be 7 deg. 30 min. for the *Deflexion*, or *Substile's distance from the Meridian*.

4. For O P R: (The measure whereof upon the *Equinoctial* is *Æ L*.) Lay a Ruler from P to L, it will cut the Circle in *e*, the distance N e measured, will be found 28 deg. 52 min. for *The Plain's difference of Longitude*.

The *Requisites* being found, the next work will be to draw the *Hour-Lines*, which differs nothing from what is done in other *Plains*: Wherefore, Lay a Ruler upon Q (the *Pole* of the *Plain*) and upon the several points where the *Hour-Circles* of the *Projection* cut the *Plain* A H B, and where the Ruler cuts the *Primitive Circle* make marks or * * *: And from the Center R, Lines drawn through those marks or * * * shall be the true *Hour-Lines*. — The *Stile* must be Elevated above the *Substile* the quantity of the side P R, namely 13 deg. 49 min.

II. By Trigonometrical Calculation.

By the Interfection of the *Circles* of the *Sphere*, with the *Great Circles* belonging to this *Reclining Plain*, there are Constituted several *Spherical Triangles*; but especially *Two*: By the resolving of which, all the fore-mentioned *Requisites* may be attained: The two *Triangles* are *H O Z*, Right Angled at *H*, and *O P R* Right Angled at *R*.

I. For the distance of the Meridian from the Horizon *B O*.

This will be found in the Right Angled *Spherical Triangle H O Z*, in which is given, (1.) The Side *H Z* 20 deg. the *Plain's Reclination*. (2.) The Angle *H Z O* 30 deg. the *Plain's Declination*: To find the Side *H O*,

As Radius 90 deg. 10.00000

To the Sine of *Z H* 20 deg. the *Reclination* 9.53405
So is the Tangent of *H Z O* 30 deg. the *Declination* 9.76144

To the Tangent of *H O* 11 deg. 10 min. 9.29549
Whose Complement 78 deg. 50 min. is the Arch *B O*, the
Distance of the Meridian from the Horizon.

2. For the height of the Pole or Stile above the Plain *P R*

This must be found in the Triangle *P O R*, but in it there is not yet enough given; wherefore *P O* must be first found in the former Triangle *H O Z*. Thus,

As the Sine of *H Z O* 30 deg. the *Declination* 9.69897

To the Sine of *H O* 11 deg. 10 min. 9.28705
So is *Z H O* the Sine of 90 deg. 10.00000

To the Sine of *O Z* 22 deg. 47 min. 9.58808

Which subtracted from *Z P* 38 deg. 38 min. there remains 15 deg. 41 min. for the side *O P* in the other Triangle *O P R*: And now seeing the two Triangle *H O Z* and *P R O* are alike, and the *Sines* of their *Hypotenususes* and *Perpendiculars* are proportional, you may work with both *Triangles* together to find *P R*. For,

As the Sine of <i>Z O</i> 22 d. 47 m. <i>Hypot.</i>	}	in Trian. <i>HOZ</i>	{ 9.58799
To the Sine of <i>Z H</i> 20 d. <i>Perpend.</i>	}		{ 9.53405
So is the Sine of <i>P O</i> 15 d. 41 m. <i>Hypot.</i>	}	in Trian <i>POR</i>	{ 9.43188
To the Sine of <i>P R</i> 13 d. 49 min. <i>Perpend.</i>	}		{ 18.96593
			9.37794

3. For the Distance of the Substile from the Meridian *O R*.

In the Triangle *P O R*, where there is given the side *P O* 15 deg. 41 min. the side *P R* 13 deg. 49 min, And the *Right Angle* at *R*: To find *O R*.

As

Figure XIII.

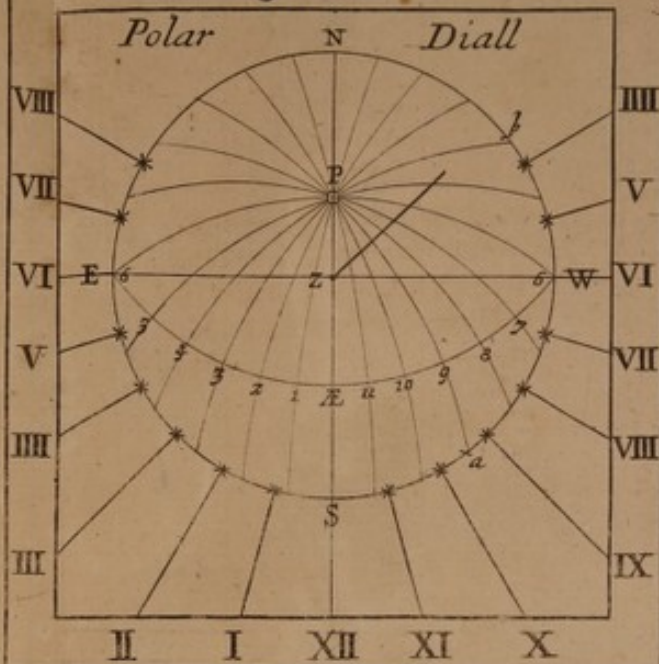


Figure XIII.

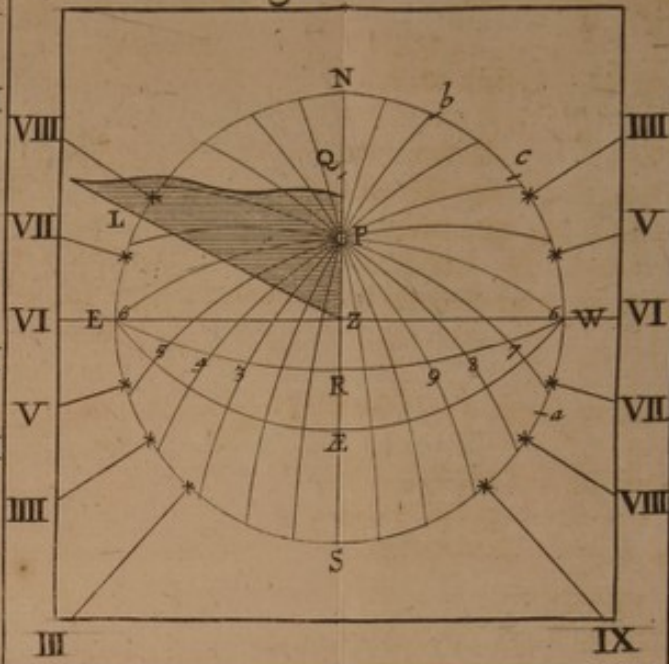


Figure XV.

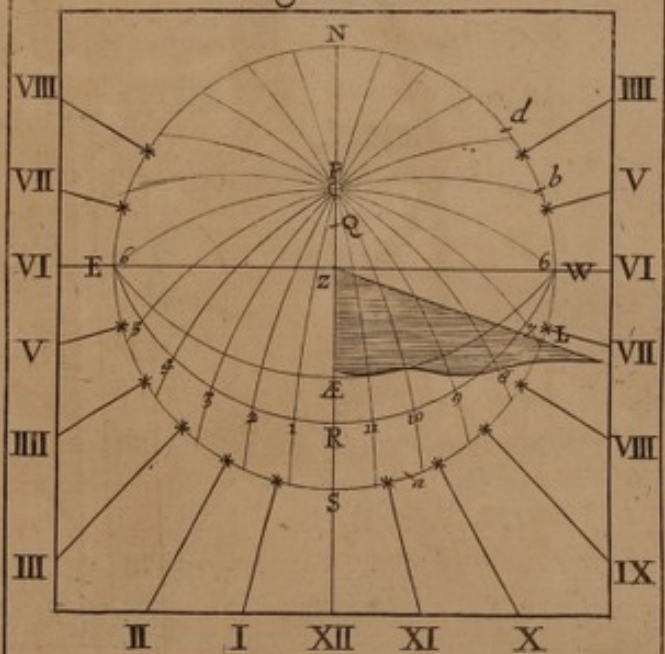


Figure XVI.

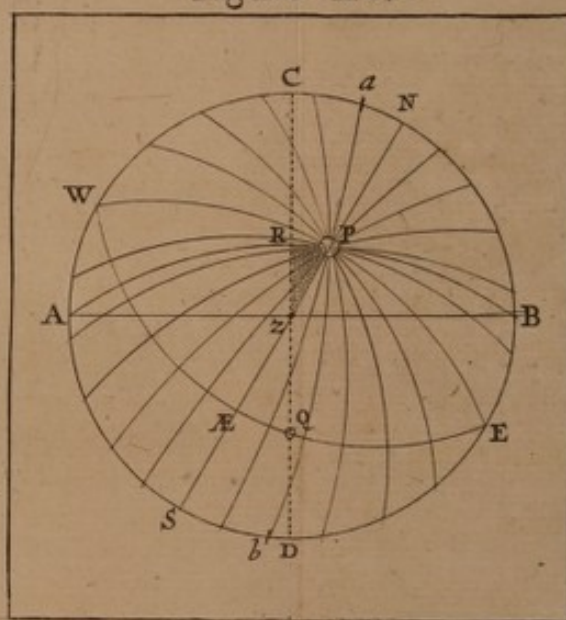


Figure XVII.

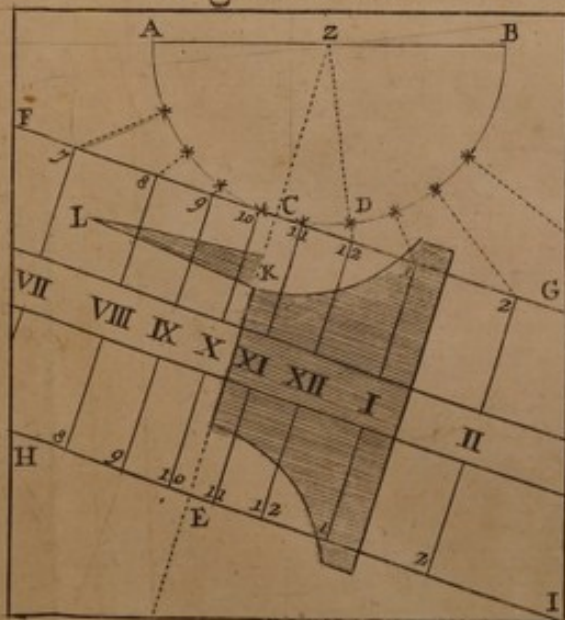
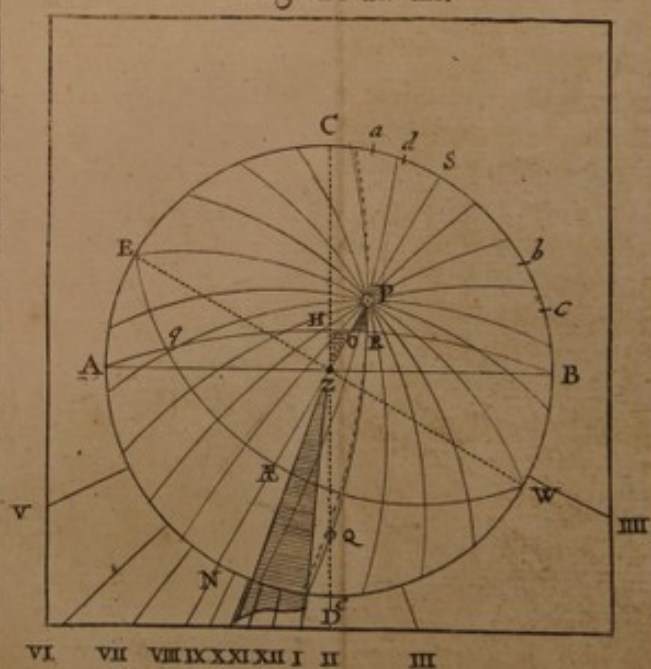
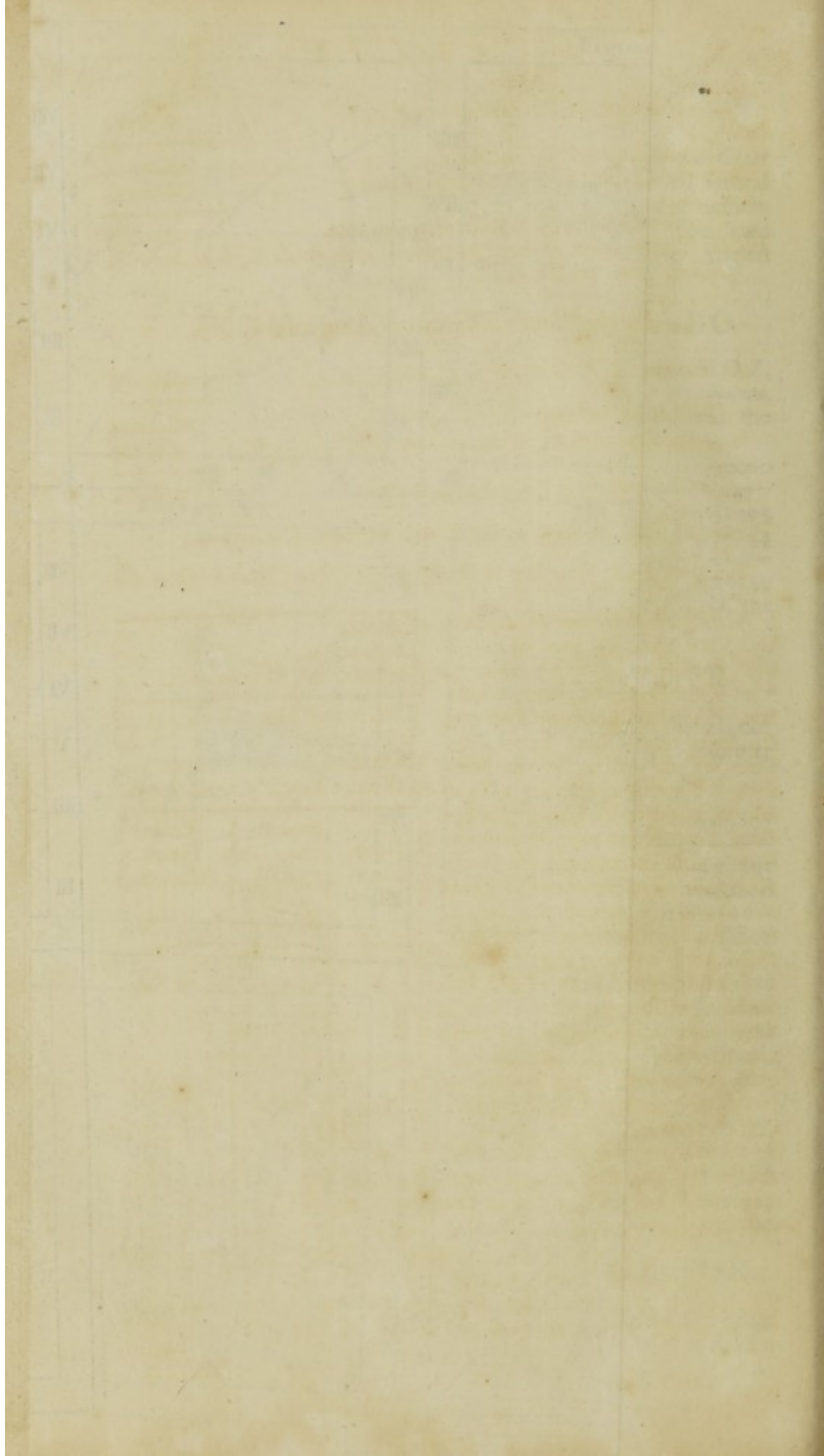


Figure XVIII.





As the Co-Sine of P R 76 deg. 11 min.

9.98725

To the Radius P R O 90 deg.

10.00000

So is the Co-Sine of P O 74 deg. 19 min.

9.98352

To the Co-Sine of O R 82 deg. 30 min.

9.99627

Whose Complement 7 deg. 30 min. is the side O R, *The Substile's distance from the Meridian.*

4. For the Plain's difference of Longitude O P R.

As the Sine of P O 15 deg. 41 min.

9.43188

To P R O 90 deg.

10.00000

So is the Sine of R O 7 deg. 30 min.

9.11569

To the Sine of O P R 28 deg. 52 min.

9.68381

Which 28 deg. 51 min. is the *Plain's difference of Longitude.*

The next thing you are to seek, is the *Hour-Distances* upon the *Plain.*

The *Plain's Difference of Longitude* being 28 deg. 52 min. which is but *One Hour*, and 13 deg. 52 min. of the *Equinoctial* over; wherefore, *The Plain Declining Eastward*, the *Stile* must stand between the Hours of 10 and 11 in the Forenoon: Therefore, Prepare a *Table* and write down the Hours that the *Plain* is capable to receive, namely, from 5 in the Morning, till 4 in the Afternoon; and between the Hours of 10 and 11, where the *Substile* must stand, write the word *Substile*, and under it write 13 deg. 52 min. which subtracted from 15 deg. the remainder will be 1 deg. 8 min. which write over *Substile*. Then to these two Numbers, by the continual addition of 15 deg. (one *Equinoctial Hour's* distance) you shall produce such Numbers as are set down in the *second Column* of the *Table*. And now to find the *true Hour-distances* upon the *Plain*: Make use of the accustomed *Analogy*.

Latitude	51	32			
Declination	30	00			
Reclination	20	00			
Dist. Mer. & Hor.	78	50			
Stile's height	13	49			
Deflection	7	30			
Differ. of Long.	28	52			
Hours from Noon	Equino- ctial Di- stances.		True Hour distances		
	D.	M.	D.	M.	
5	7	76	8	44	3
6		61	8	23	25
7	5	46	8	13	57
8	4	31	8	8	12
9	3	16	8	3	57
10	2	1	8	0	16
The		Sub-		stile.	
11	1	13	52	3	22
12		28	52	7	30
1	11	43	52	12	55
2	10	58	52	21	34
3	9	73	52	39	32
4	8	88	52	85	16

As the Radius 90 deg.

10.00000

To the Sine of the Stile's height 13 deg. 49 min.
So is the Tangent of 76 d. 8 m. the Equinoctial di- } 9.37806
stance of 5 or 7 a Clock. } 10.60755

To the Tang. of 44 d. 3 m. the true dist. of the }
Hours of 5 or 7 upon the Plain from the Subst. } 9.98561

And thus working for every *Hour*, you shall produce such numbers as are in the third Column of the *Table*, which with the *Meridian*, *Substile*, *Stile*, or *Deflexion*, being set upon your *Plain*, your *Dial* is Finished.

III. The Third Variety, of South Declining Reclining Plains: The Plain passing between the Pole and the Horizon.

I. By Projection.

Figure Let this Third Example be of a South Plain Declining Eastward
XIX. 30 deg. and Reclining from the Zenith 55 deg.

First, Draw a Right Line A B for the *Base* of your *Plain*, and cross it with another Line C D, at right angles in Z, for the *Vertical Line* of the Plain.

Secondly, Upon Z describe a Circle, and upon the Periphery thereof, set 30 deg. the *Plain's Declination*, from C to N, and draw the Line N Z S for the *Meridian* of the Place, Projecting the *Sphere* within the Circle.

Thirdly, Take 55 deg. the *Reclination*, from your *Scale of Half Tangents*, and set them from Z to F, for the point of your Plain, and set the Complement thereof 35 deg. from Z to Q, for the Pole of the Plain: And having three points A, F, and B, whereby to draw your *Reclining Plain*, the *Secant Complement* of the *Reclination* 35 deg. set from F upon the Line F D, will give you the *Center* whereby to describe it.

Fourthly, Through P the *Pole* of the *World*, and Q the *Pole* of the *Plain*, draw the Arch of a *Great Circle* R P Q (by the 13 Prob. of the Introduction) and find the *Pole* thereof at q in the *Equinoctial Circle*.

Fifthly, You must find these *Requisites*,

- | | | |
|--|----------------------------|-------------------------------|
| 1. The Distance of the Meridian from the Horizon | } repre-
sent-
ed by | { O B
P R
R O
A P Q. |
| 2. The Height of the Pole or Stile above the Plain | | |
| 3. The Distance of the Substile from the Meridian | | |
| 4. The Plain's Difference of Longit. RPO or | | |

All which may be found by the *Projection*, in this manner:

1. For O B: Lay a Ruler from Q to O, it will cut the Circle in a, and B a measured upon the *Chord*, will give 64 deg. 41 min. for the *Distance of the Meridian from the Horizon*.

2. For P R: Lay a Ruler from q to P, it will cut the Circle in b: also, a Ruler laid from q to R, will cut the Circle in c, the distance b c being 19 deg. 25 min. is the *Height of the Pole or Stile above the Plain*.

3. For

3. For R O : A Ruler laid from Q to O, did cut the Circle in a , and Laid from Q to R, it will cut it in d , the distance $a d$, 6 deg. 2 min. is the *Deflexion*, or *The Substile's distance from the Meridian*.

4. For R P O, (or rather Æ P Q) whose measure upon the Equinoctial is Æ L , a Ruler laid from P to L, will cut the Circle in e , and $S e$ measured upon the *Chord*, will be 17 deg. 38 min. for the *Angle between the Meridian of the Place, and the Meridian of the Plain*, which is the *Plain's Difference of Longitude*.

The *Requisites* thus obtained, The *Hour-lines* are to be drawn as in other *Plains*, by laying a Ruler to Q, and to the several Points where the *Hour-Circles* cross the *Plain*; and where the Ruler cuts the *Primitive Circle*, make marks or $***$, through which Points, or $***$, from the Center Z, draw Lines, and they shall be the true *Hour-lines* proper for your *Plain*.

II. By Trigonometrical Calculation.

The *Triangles*, by the resolution whereof the *Requisites* may be found, are the *Triangles* O F Z, R O P, and O N B.

1. For the Distance of the Meridian from the Horizon B O.

In the Triangle O F Z, you have given (1) The Side F Z, the *Plain's Reclination* 55 deg. (2) The Angle F Z O, the *Plain's Declination*; and (3) The Right Angle at F.

As The Radius O F Z 90 deg.	10.00000
-----------------------------	----------

Is to the Sine of F Z, the <i>Plain's Reclination</i> , 55 deg.	9.91336
So is the Tangent of C N, the <i>Plain's Declination</i> , 30 deg.	9.76144

To the Tangent of F O 25 deg. 19 min.	9.67480
Whose Complement is O B 64 deg. 41 min. the <i>Distance of the Meridian from the Horizon</i> .	

2. For the Height of the Pole or Stile above the Plain P R.

This should be found in the Triangle R O P, but there is not enough given; wherefore, in the Triangle O N B, you must seek the Side N O, thereby to come to the Side O P, thus,

As the Sine of O B N 90 deg.	10.00000
------------------------------	----------

Is to the Sine of B O 64 deg. 41 min.	9.95615
So is the Sine of N B O 35 deg.	9.75859

To the Sine of N O 31 deg. 14 min.	9.71474
------------------------------------	---------

This N O 31 deg. 14 min. taken out of N P, 51 deg. 32 min. leaves 20 deg. 18 min. for P O.

And now because the *Hypotenuses* and *Bases* of the *Triangles* O N B and R P O are proportional, you may deal with them *both* joyntly to find P R : For,

R

As

As the Sine of B O 64 d. 41 m. Hypot. } in Triang. NOB 9.95615
 To the Sine of N O 60 deg. Perpen. } 9.93753
 So is the Sine of P O 20 d. 18 m. Hypot. } in Triang. ROP 9.54025
 To the Sine of R P 19 d. 25 m. Perpen. } 19.47778
 9.52163

3. For the distance of the Substile from the Meridian R O.

As the Co-Sine of R P 19 deg. 25 min. 9.97457
 To the Sine of P R O Radius 90 deg. 10.00000
 So is the Co-Sine of P O 20 deg. 18 min. 9.97215
 To the Co-Sine of R O 6 deg. 2 min. 9.99758
 Which 6 deg. 2 min. is the Deflexion, or Substile's distance from the Meridian.

4. For the Plain's Difference of Longitude P R O.

As the Sine of P O 20 deg. 18 min. 9.54025
 To P R O Radius 10.00000
 So is the Sine of R O 6 deg. 2 min. 9.02163
 To the Sine of R P O 17 deg. 38 min. 9.48138
 Which 17 deg. 38 min. is the Plain's difference of Longitude.

Latitude	51	32
Declination	30	00
Reclination	55	00
Dist. Mer. & Hor.	64	41
Stile's height	19	25
Deflection	6	2
Differ. of Long.	17	38

Hours from Noon	Equinoctial Distances.		True Hour distances	
	D.	M.	D.	M.
5 7	87	22	82	7
6	72	22	46	17
7 5	57	22	27	26
8 4	42	22	16	52
9 3	27	22	9	46
10 2	12	22	4	10
	Sub-		stile.	
11 1	2	38	0	53
12	17	38	6	2
1 11	32	38	12	1
2 10	47	38	20	1
3 9	62	38	32	42
4 8	77	38	56	35

This 17 deg. 38 min. is but one Hour, and 2 deg. 38 min. of the Equinoctial over, it denotes (the Plain declining Eastward) that the Stile must stand between the Hours of 10 and 11, a small distance beyond 10 : Wherefore, prepare your Table, and set down all the Hours the Plain is capable to receive, as from 5 in the morning till 4 in the Afternoon ; and between the Hours of 10 and 11 write Sub-stile, and under it, the 2 deg. 38 min. remaining, which subtract from 15 deg. and the remainder 12 deg. 22 min. set over Sub-stile, and by the continual addition of 15 deg. to these numbers above and below the word Sub-stile ; you shall produce such Numbers as those in the Second Column of this Table are.

Now for the Hour-Distances upon the Plain, they are found by the usual Canon, viz.

As the Radius 90 deg.

10.00000

To the Sine of the <i>Stile's</i> height 19 deg. 25 min.	9.52171
So is the Tan. of 42 d. 22 m. Eq. dist. for 8 and 4 a Clock	9.95002

To the Tangent of 16 d. 25 m. the true dist. of those } Hours upon the <i>Plain</i> from the <i>Substile</i>	9.48173
---	---------

And so for all the rest of the Numbers in the *Table*: And having found all the *Requisites*, you may by a *Scale of Chords* transfer them and the *Hour-distances* also from this *Table* to your *Plain*.

C H A P. XVIII.

How to draw the Hour-Lines upon North Declining Reclining Plains.

AS there were Three *Varieties* in *South Reclining Plains* which *Decline*, so are there as many in *North Decliners Reclining*; for to any *Declination* a *Reclination* may be fitted, that the *Plain* shall pass by the Intersection of the *Meridian* with the *Equinoctial Circle*. — Or the *Reclination* may be such, that the *Plain* shall pass between the *Zenith* and the *Equator*. — Or, it may recline so, that the *Plain* shall pass between the *Equator* and the *Horizon*: *Examples* of all these *Varieties* follow in order.

I. *The First Variety*: Of *North Declining Reclining Plains*, *The Plain passing through the Intersection of the Meridian with the Equinoctial*.

I. *By the Projection.*

Our First *Example* shall be of a *North Plain declining Westward* Figure 60 deg, and *Reclining* from the *Zenith* 32 deg. 11 min XX.

First, Draw a Line A B, representing the *Base* of your *Reclining Plain*, and another at right angles thereto, as C D, for the *Vertical Line* of the *Plain*, crossing each other in Z. — Upon Z, describe a *Circle*, and upon the *Periferie* thereof, set 60 deg. (the *Plain's Declination*) from C towards B, at N; and from D towards W, at S, because the *Plain Declines Westerly*; and draw the Line N S for the *Meridian* of the *Place*, and so finish your *Projection*.

Secondly, Take 32 deg. 11 min. from your *Scale of Half Tangents*, and set it from Z to G, upon the Line C D; so shall G be the point in the *Vertical Line*, through which the *Plain* must pass. Also, take the *Half Tangent* of 57 deg. 49 min. the *Co-Reclination*, and set it from Z to Q, upon the Line C D also; so shall Q be the *Pole* of the *Plain*: And the *Secant* of 57 deg. 49 min. the *Complement* of the *Reclination*, being set from G, upon the Line D C extended, will give the *Center* whereby to describe the *Plain* A G B.

Thirdly,

Thirdly, Through P, the Pole of the World, and Q the Pole of the Plain, describe an Arch of a Great Circle (by the 13th Problem of the Introduction) which you shall find to be the same with the Hour-Circle of Six, and therefore the Hour-Line of Six will be the Substile line of the Dial, and the Pole of this Circle (by the latter part of the Fourth Chapter hereof) will be found at Æ , the very point of the Intersection of the Meridian with the Equinoctial.

Fourthly, The Requisites belonging to this Plain are Four; as in South Decliners Reclining; viz.

- | | | | |
|---|------------------|---|------------------|
| 1. The Distance of the Meridian from the Horizon, | } represented by | { | A Æ . |
| 2. The Height of the Pole or Stile above the Plain, | | | P R. |
| 3. The Substile's Distance from the Meridian, | | | Æ R. |
| 4. The Plain's Difference of Longitude, | | | Q P Æ . |

All which by the Projection may be thus easily found.

1. For A Æ , Lay a Ruler from Q to Æ , it shall cut the Plain in a , the Distance from A to a , measured upon a Scale of Chords, will be 47 deg. 18 min. for the Distance of the Meridian from the Horizon.

2. For P R, Lay a Ruler from q to R, it will cut the Circle in b , the Distance N b , measured upon a Scale of Chords, will give 42 deg. 52 m. for the Height of the Pole or Stile above the Plain.

3. For Æ R, A Ruler laid from Æ to R, did cut the Circle in b , and laid from Æ to Q, it will cut the Circle in c , the Distance from b to c will be found to be just 90 deg. for the Substile's Distance from the Meridian.

4. For Q P Æ , or Æ P R, that is also 90 deg. for the Plain's Difference of Longitude. For it is obvious from the Projection, that all the Sides of the Triangle Q Æ R, are all Quadrants, and all the Angles by consequence Right Angles.

The Requisites being thus found, the Hour-Distances may be found as in other Plains, by laying a Ruler to Q, and the several Points where the Hour-Circles cross the Plain, and where the Ruler cuts the Primitive Circle, make marks or * * *, and through them, from Z, draw right Lines for the Hours.

In this Dial the Hour-Line of 6 is the Substile, and the Hour-Line of 12 is 90 deg. distant from it, so that they cross each other at Right Angles, as in all Direct Plains they do. And this Dial is no other than an Horizontal Dial for the Latitude of 42 d. 52 m. if you change the naming of the Hours, calling 6-12 and 5-11, &c.

II. By Trigonometrical Calculation.

To find the Requisites.

1. For A Æ , the Distance of the Meridian from the Horizon.

In the Triangle Z G Æ , right-Angled at G, there is given (1) Z G the Plain's Reclination 32 d. 11 m. (2) the Angle Æ Z G the Plain's Declination 60 d. (3) the right Angle Z G Æ , by which you may find Æ G. Thus,

As

Fig. I.

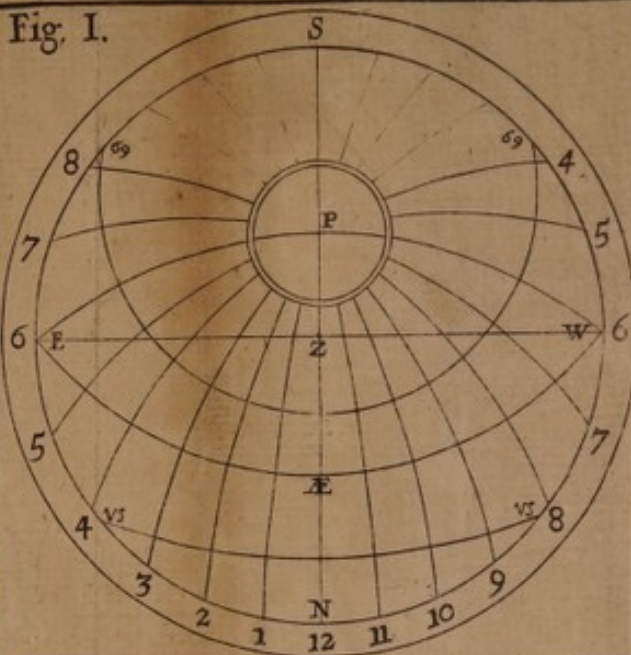


Fig. II.

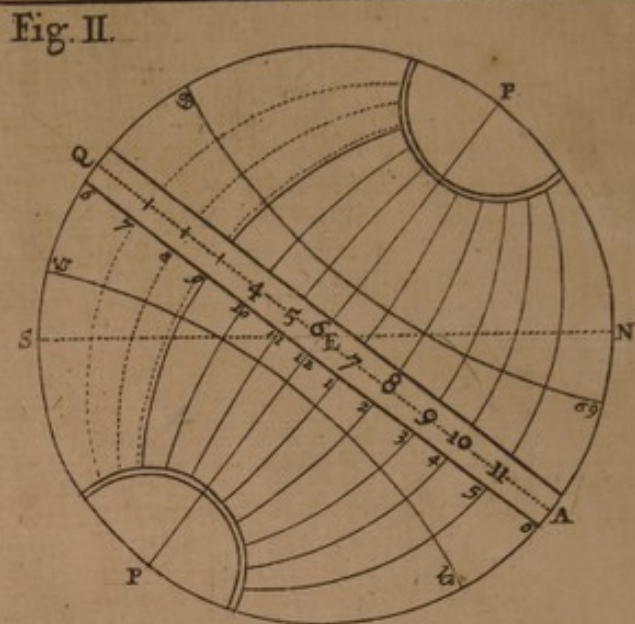


Fig. III.

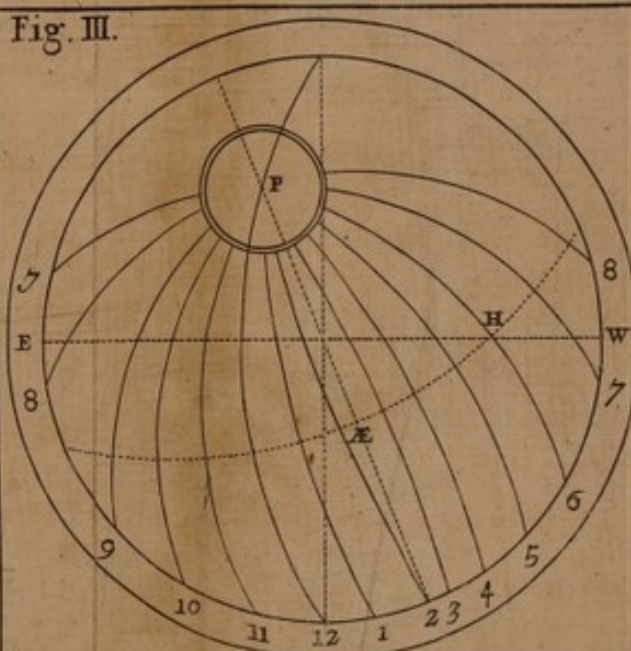


Fig. IV.

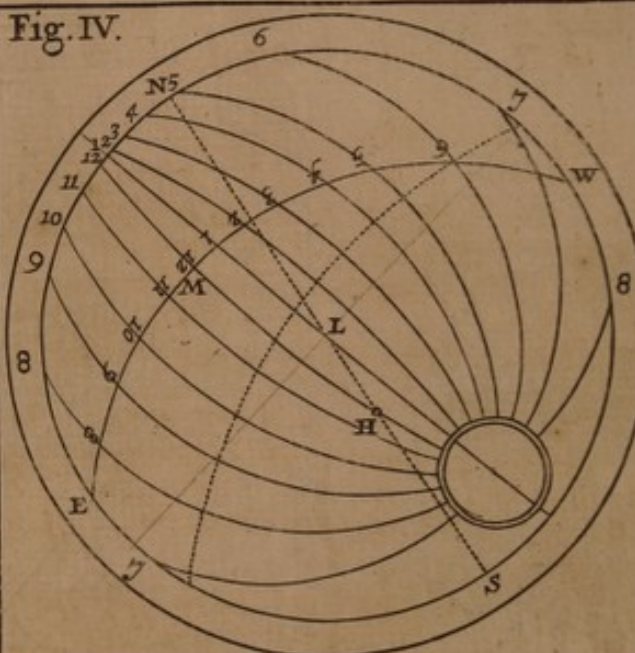


Fig. V.

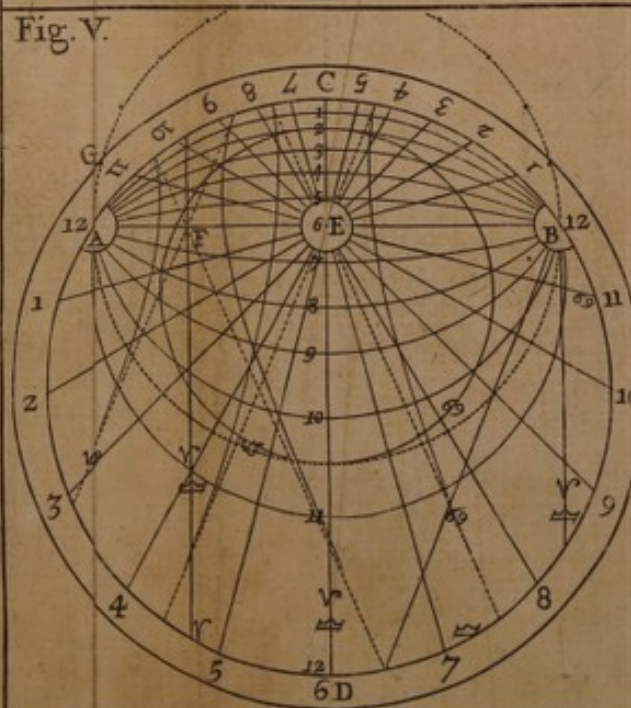
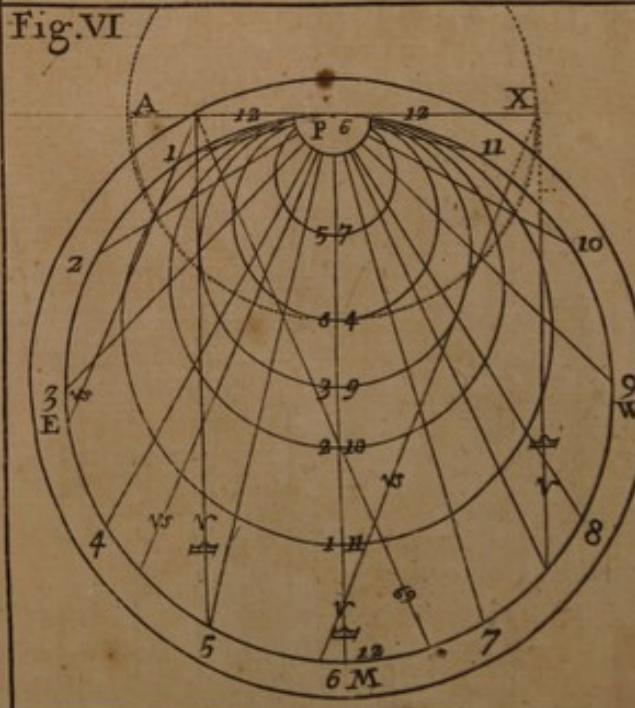


Fig. VI.



Wash

As Radius 90 deg.

10.00000

To the Tangent of Æ Z G 60 d. the Declination
So is the Sine of Z G 32 d. 11 m. the Reclination

10.23856

9.72642

To the Tangent of Æ G 42 d. 42 m.

9.96498

Whose Complement 47 d. 18 m. is the Distance of the Meridian from the Horizon.

2. For P R the height of the Pole above the Plain.

In the Quadrantal Triangle P Æ R ,

As the Sine of Æ G 42 d. 42 m.

9.83133

To Radius Æ R 90 deg:

10.00000

So is the Tangent of Z G 32 deg. 11 min.

9.79887

To the Tangent of P R 42 d. 52 m.

9.96754

Which is the height of the Pole or Stile above the Plain

3. and 4. For the other two *Requisites*, the Distance of the Substile from the Meridian R Æ , and the Plain's Difference of Longitude Q P Æ or Æ P R , they are either of them 90 deg. as is evident in the Projection.

And for the *Hour-Distances* they are calculated as the Hour-Distances for an *Horizontal Dial*, wherefore prepare a Table as is here done, setting the *Equinoctial Distances* against their proper Hours; And then by the general *Analogy* or *Proportion* say,

As Radius 90 deg.

10.00000

To the Sine of 42 d. }
52 min. the Stile's height } 9.83270

So is the Tang. of 15 d. &c. 9.42805

To the Tangent of }
10 d. 20 m. } 9.26075

For the two first Hours from Six, the Substile of 5 and 7 on either side; and so for all the rest, as in the Table.

Latitude	51	32		
Declination N.	60	00		
Reclination	32	11		
Dist. Mer. & Hor.	47	18		
Stile's height	42	52		
Deflection	90	00		
Differ. of Long.	90	00		
Hours from Noon.	Equinoctial Distances.		True Hour-Di- stances	
	D.	M.	D.	M.
6	0	00	0	00
7 5	15	00	10	20
8 4	30	00	21	27
9 3	45	00	34	14
10 2	60	00	49	41
11 1	75	00	68	30
12	90	00	90	0

II. *The Second Variety: of North Declining Reclining Plains, where the Plain passeth between the Zenith and the Equator.*

I. *By the Projection.*

Figure
XXI.

L Et this Second Example be of a North Plain, declining Westward 60 deg. and Reclinign from the Zenith 16 degrees. First, draw a right Line A B, for the Base or Horizontal Line of your Reclining Plain, and at right Angles thereunto another C D, for the Vertical Line of the Plain, crossing in Z: — Upon Z describe a Circle, and upon it from C to N, and from D to S, set the Plain's Declination 60 d. drawing the Line N S for the Meridian of the Place: — Upon which set off the Pole of the World at P, and in the Circle project the Sphere.

Secondly, Take the half Tangent of 16 deg. the Plain's Reclination, and set it from Z to H, so shall H be the Point in the Vertical Line C D, through which the Reclining Plain must pass: — Also the half Tangent of 74, the Complement of the Plain's Reclination, being set from Z upon the Line C D, shall give the Point Q, for the Pole of the Plain — And so have your three Points, namely, A, H, and B, through which the Reclining Plain must pass. The Secant of the Co-Reclination, being set from H, upon the Line C D extended, will give you the Center whereby to describe it.

Thirdly, Through P the Pole of the World, and Q the Pole of the Plain, draw the Arch of a Great Circle (by the 13th Prob. of the Introduction) and find the Pole thereof, which will be at q, where the Plain crosseth the Equinoctial Circle.

Fourthly, Find the Four Requisites relating to this Plain, viz.

- | | | | |
|--|------------------|---|--------|
| 1. The Distance of the Meridian from the Horizon, | } represented by | { | A O. |
| 2. The height of the Pole or Stile above the Plain, | | | P R. |
| 3. The Deflexion or Substile's Distance from the Merid | | | R O. |
| 4. The Plain's Difference of Longitude, | | | O P R. |

All which by the Projection may be thus found.

1. For A O, A Ruler laid from Q to O, will cut the Primitive Circle in *a*, and the Distance A *a*, 64 deg. 29 min. is the Meridian's Distance from the Horizon.

2. For P R, a Ruler laid from *q* to R, will cut the Circle in *b*, and laid from *q* to P, it will cut the Circle in *c*, the distance between *c* and *b*, 30 d. 59 m. is the Height of the Pole or Stile above the Plain.

3. For R O, A Ruler laid from Q to O, did cut the Circle in *a*, and now laid from Q to R, it will cut the Circle in *d*, the distance *a d*, 64 deg. 26 min. is the Deflexion or Substile's Distance from the Meridian.

4. For O P R, A Ruler laid from P to *c* (where the Arch of the Great Circle Q P R crosseth the Equinoctial Circle) shall cut the Circle in *b*, the Distance S *b* 76 deg. 10 min. is the Plain's Difference of Longitude.

Fifthly

Fifthly, For the *Hour-Distances*, they are found in all respects as in other *Plains*, by laying a Ruler to Q, and the several Points where the *Hour-Circles* cross the *Plain* B H A, and where the Ruler cuts the *Primitive Circle* make marks or * * *, and from Z, through those marks, Lines drawn shall be the *Hour-Lines*.

II. By Trigonometrical Calculation.

The first thing to be done is to find the Requisites.

1. For A O, the Distance of the Meridian and Horizon.

In the Right Angled *Spherical Triangle* Z H O, Right Angled at H, there is given. (1) The Side Z H 16 deg. the *Reclination*. (2) The Angle H Z O 60 deg. the *Declination*, (3) The *Right Angle* at R. — To find the Side A O.

As Radius R 90 deg.	10.00000
To the Sine of Z H 16 deg.	9.44034
So is the Tangent of H Z O 60 deg.	10.23856
To the Tangent of H O 25 deg. 31 min.	9.67890
Whose Complement A O 64 deg. 29 min. is the <i>Distance</i> of the <i>Meridian</i> from the <i>Horizon</i> .	

2 For P R, which must be found in the Triangle P R O.

In which there is not yet enough given, wherefore you must get the Side P O, by resolving the Triangle H O Z. Thus,

As the Sine of H Z O the Declination 60 deg.	9.93753
Is to the Radius 90 deg. H	10.00000
So is the Sine of H O (the Arch before found) 25 d. 31 m.	9.63425
To the Sine of Z O 29 deg. 50 min.	9.69672
Unto which 29 deg. 50 min. if you add Z P 38 deg. 28 min. the sum will be 68 d. 18 m. and so have you the whole side P O.	

Now the two Triangles, O Z H, and R O P, being proportional, the Side P R may be thus found,

As the Sine of O Z 29 d. 50 m. <i>Hyp.</i>	9.69672
To Sine of H Z 16 deg. <i>Per.</i>	9.44034
So is Sine of O P 68 d. 18 m. <i>Hyp.</i>	9.96807
To Sine of P R 30 d. 59 m. <i>Per.</i>	9.71164
Which 30 deg. 59 min. is the <i>Height</i> of the <i>Pole</i> or <i>Stile</i> above the <i>Plain</i> .	

3. For O R the Deflection or Substile's Distance from the Meridian.

In the two former Triangles the *Sines* of the *Bases*, and the *Tangents* of the *Perpendiculars* being *Proportional*, work thus,

As the Tangent of Z H 16 deg. Perpend. } in Trian. Z H O	9.45749
Is to the Sine of H O 25 d. 31 m. Base }	9.63425
So is the Tang. of P R 30 d. 59 m. Perp. } in the Tri. Z R O	9.77849
To the Sine of R O 64 d. 26 m. Base }	19.41274
	9.95525

Which 64 deg. 26 min. is the *Deflection*, or *Substile's* Distance from the *Meridian*.

4. For O P R, the Plain's Difference of Longitude.

As the Sine of P R 30 deg. 59 m. the Stile's Height 9.71163

To the Sine of 90 deg. the Radius 10.00000
So is the Tangent of R O 64 deg. 26 min. the Deflexion 10.32020

To the Tangent of R P O 76 deg. 10 min. 20.32020
10.60857

Which 76 deg. 10 min. is the *Plain's* Difference of *Longitude*.

5. For the Hour-Distances, the Plain's Difference of Longitude being 76 deg. 10 min.

Latitude	51	32
Declination	60	00
Reclination	16	00
Dist. Mer. & Hor.	64	29
Stile's height	30	59
Deflection	64	26
Differ. of Long.	76	10

Hours from the Substile.	Equinoctial Distances.		Hour distances from the Substile.	
	D.	M.	D.	M.
1 11	88	50	87	44
2 10	73	50	60	37
3 9	58	50	40	24
4 8	43	50	26	18
5 7	28	50	15	49
6 6	13	50	7	13
The Sub-			file.	
7 5	1	10	0	36
8 4	16	10	8	29
9 3	31	10	17	18
10 2	46	10	28	12
11 1	61	10	43	5
12 12	76	10	64	26

In this Distance is contained five compleat Hours, and 1 deg. 10 min. more, wherefore the Stile must stand between the fifth and sixth Hours from the *Meridian*. Prepare therefore a *Table* as here is done, and write down all the *Hours*, and between the Hours of 5 and 6, or 6 and 7 (which are all one, according as the Plain declines Eastward or Westward) write *Substile*; and under it, the remainder 1 d. 10 m. against 7 and 5, which subtract from 15 deg. and there will remain 13 deg. 50 min. which write over *Substile* against the hours of 6 and 6. And so, by the continual addition of 15 deg. to the numbers next above and below *Substile*, you shall produce such numbers as this *Table* affords in the second Column thereof: from which numbers, which are *Equinoctial distances*, the *True hour-distances* upon the *Plain* may be collected by this *Proportion*.

As Radius 90 deg.

10.00000

To the Sine of 30 deg. 59 min. the Stile's height	9.71163
So is the Tangent of 88 deg. 50 min. the first Equi. Dist.	11.69112

To the Tangent of 87 deg. 44 min.	11.40275
-----------------------------------	----------

Which is the true Hour-Distance of the Hours of One and Eleven upon the Plain from the *Substile*: and so doing for all the rest, you shall produce such numbers as the third *Column* of the *Table* affordeth, which may be transferred from this *Table* by help of a *Scale of Chords*; and so is your *Dial* finished.

III. The Third Variety of North Declining Reclining Plains, where the Plain passeth between the Equator and the Horizon.

I. By the Projection.

Figure
XXII

Our Third and Last *Example* shall be of a *North Plain*, Declining Eastward 60 deg. and Reclining from the *Zenith* 54 deg.

First, Draw a right Line *A B* for the *Horizontal Line*, or *Base* of the *Reclining Reclining Plain*, and cross it at Right Angles in *Z*, with another Right Line *C D*, for the *Vertical Line* of the *Plain*.— Upon *Z*, describe a Circle, and upon it, from *C* to *N*, and from *D* to *S*, set 60. deg the *Declination* of the *Plain*, and draw the Line *S N* for the *Meridian* of the *Place*, upon which set off *P* the *Pole*, and *Æ* the *Equinoctial's* intersection therewith; and Project the *Sphere* within the Circle *W N E S*, as formerly.

Secondly, Take the *half Tangent* of 54 deg. the *Plain's Reclination*, and set it from *Z* to *F*, so shall *F* be the Point in the *Vertical Line C D*, through which the *Reclining Plain* must pass. — Also the *Half Tangent* of 35, the *Co-Reclination* of the *Plain*, set from *Z* upon the *Vertical Line C D*, shall give *Q* for the *Pole* of the *Plain*. — And now you have three Points, *A*, *B*, and *F*, whereby to draw the *Reclining Plain*, and the *Secant* of 36 deg. set from *F* upon the Line *C D*, will give the *Center* whereby to describe it.

Thirdly, Through *P* and *Q*, the *Pole* of the *World*, and the *Pole* of the *Plain* (by the 12 *Problem* of the *Introduction*) draw the Arch of a *Great Circle Q P R*, and find the *Pole* thereof, which will be at *q* the intersection of the *Plain* with the *Equinoctial Circle*.

Fourthly, You must next find the Four *Requisites* belonging to this *Plain*, viz.

- | | | | | |
|--|---|------------------------|---|--|
| <ol style="list-style-type: none"> 1. The Distance of the Meridian from the Horizon, 2. The Height of the Pole or Stile above the Plain, 3. The Deflection or Substile's Dist. from the Merid. 4. The Plain's Difference of Longitude, | } | repre-
sented
by | { | <ol style="list-style-type: none"> <i>A O.</i> <i>P R.</i> <i>O R.</i> <i>O P R.</i> |
|--|---|------------------------|---|--|

1. For A O, A Rule laid from Q to O, will cut the Circle in *a*, and the Distance *A a* measured upon the *Scale of Chords*, will be 35 deg. 31 min. for the *Distance* of the *Meridian* from the *Horizon*.

2. For P R, A Ruler laid from *q* to P will cut the Circle in *b*, and laid from *q* to R it will cut it in *c*, and the Distance *b c* measured upon the *Chords* will be 54 deg. 43 min. for the *Height* of the *Pole* or *Stile* above the *Plain*.

3. For O R, A Ruler laid from Q to O, did cut the Circle in *a*, and laid from Q to R, it will cut it in *e*, so the Distance *a e* is 123 deg. 19 min. for O R, whose *Complement* to 180 deg. is 56 deg. 41 min. for R X; the *Distance* of the *Substile* from the *Meridian*.

4. For O P R (or rather its *Complement* O P Q, equal to X P R) A Ruler laid from P to L (where the *Great Circle* Q P R cuts the *Equinoctial Circle*) will cut the Circle in *h*, so the distance *S h* 61 deg. 17 min. is the *Plain's Difference* of *Longitude*.

5. For the *Hour-Distances*, they are found by laying a Ruler from Q to the several intersections of the *Hour-Circles* of the *Projection* with the *Reclining Plain*, and where the Ruler cuts the *Primitive Circle*, make marks or * * *, through which *Points* or marks, if you draw Lines from the Centre Z, they shall be the true *Hour-Lines* for this *Declining Reclining Plain*.

II. By Trigonometrical Calculation.

The first thing to be done is to find the *Requisites*, and they will be all found in the three Spherical Triangles Z F O, O P R, and B N X.

1. For A O, In the Triangle Z F O, there is given (1) Z F the *Plain's Reclination*. (2) O Z F the *Plain's Declination*, and (3) The *Right Angle* at F. To find O A, or its *Complement* O F,

As the Radius 90 deg.	10.00000
To the Sine of Z F the Reclination 54 deg.	9.90795
So is the Tangent of O Z F, the Declination, 60 deg.	10.23856
To the Tangent of F O 54 deg. 29 min.	10.14651

Whose *Complement* is A O 35 deg. 31 min. for the *Substile's Distance* from the *Meridian*.

2. For R O, In the Triangle O P R there is not yet enough given; therefore, First find the side Z O in the Triangle Q Z F.

As the Sine of the Plain's Declination O Z F 60 deg.	9.93753
To the Radius 90 deg.	10.00000
So is Sine of Dist. of Mer. and Hor. O F 54 d. 29 m.	9.91059
To the Sine of Z O 70 deg. 2 min.	9.97306
Unto this 70 deg. 2 min. add Z P 38 deg. 28 min. the sum is 108 deg. 30 min.	

Then

Then by the two Proportional Triangles O Z F and O P R.

As the Sine of O Z 70 d. 1 m. Hypotenuse	2	in the Tri.	9.97307
To the Sine of Z F 54 d. Perpendicular	3	OF Z	
So Co-sine of P O to 180-71 d. 30 m. Hyp.	2	in the Tri.	9.90796
To the Sine of P R 54 d. 43 m. Perpendicular	3	O P R	9.97696
			19.88492
			9.91185

Which is the *Height* of the *Pole* or *Stile* above the *Plain*.

3. For R O, or its Complement R X, Continue the sides O P and O R of the *Triangle* O P R, and you shall constitute another *Triangle* N X B, and then the Proportion for finding R O will be;

As the Tangent of Z F the Reclination 54 deg.	10.13874
To Sine of F O, Co-dist. of Mer. and Hor. 54 d. 29 m.	9.91059
So is the Tangent of P R, the Stile's Height 54 d. 43 m.	10.15021
To the Sine of R X 56 deg. 42 min.	20.06080
	9.92207

Which 56 deg. 42 min. is the *Substile's Distance* from the *North* part of the *Meridian*, whose Complement to 180 deg. is 123 d. 19 m. its *distance* from the *South* part thereof.

4. For the Angle O P R, or its Complement R P X;

As the Sine of P R, Stile's Height 54 deg. 43 min.	9.91184
To Tan. of R X, Substile's dist. from Mer. 56 d. 42 m.	10.13851
So is the sine of P R X, Radius 90 deg.	10.00000
To the Tangent of R P X 61 deg. 48 min.	10.27067

R P X being 61 deg. 48 min. is the *Angle* counted from the *North*, therefore the *Angle* O P R, the Complement to 180 deg. is 118 deg. 13 min. the *Plain's Difference* of *Longitude* reckoned from the *South*.

These things prepared, I proceed to make the *Table* for the *Hour-Distances* from the *Substile*, wherein considering that the Angle P, the *Plain's Difference* of *Longitude* is 118 deg. 12 min. reckoned from the *South*, whereof 90 deg. is answerable to 6 Hours, and 105 to 7 Hours, and there is yet remaining 13 deg. 13 min. it is evident, for the *Substile* must be drawn between the Seventh and Eighth Hour from the *South* part of the *Meridian*, or between the Fourth or Fifth Hour reckoned from the *North* part.

Wherefore set the *Hours* down as in the *Table*, and between the Hours of 4 or 8, and 5 or 7, write *Substile*, setting the remainder 31 deg. 13 min. under *Substile*, and the Complement thereof to 15 deg. viz. 1 deg. 47 min. over *Substile*, and by the continual addition of 15 deg. to both these numbers, you shall produce the *Equinoctial Distances*

Latitude	51	32
Declination	60	00
Reclination	54	00
Dist. Mer. & Hor.	35	31
Stile's height	54	43
Deflection	{ 123	19
	{ 56	41
Differ. of Long.	{ 118	13
	{ 61	74

Hours from the Substile.	Equino- ctial Di- stances.		Hour- distances from the Substile.	
	D.	M.	D.	M.
11	1	76	47	73
12		61	47	56
1	11	46	47	40
2	10	32	47	26
3	9	16	47	13
4	8	1	47	1
The		Sub-		stile.
5	7	13	13	10
6	6	28	13	23
7	5	43	13	37
8	4	58	13	52
9	3	73	13	69
10	2	88	13	87

stances as in the *Second Column* of the *Table*: And those by the general *Canon*, will help you to the true *Hour-Distances* upon your *Plain*.

For,

As Radius 90 deg. 10.00000

To the Sine of 54 d. }
43 m. the Stile's Height } 9.91185

So is the Tang. of 28 d. }
13 m. the Equi. Dist. for 6 a Clock } 9.72963

To the Tang. of 23 d. }
39 m. } 9.64148

Which is the true Distance of the Six a Clock Hour from the *Substile* of the *Dial*.

And thus continuing this *Proportion* through all the *Equinoctial Distances*, you will in the end have such numbers to every *Hour* as the third *Column* of the *Table* sheweth, which are the true *Hour-Distances*, counted from the *Substile* upon your *Plain*.

The *Meridian*, *Horizon*, *Substile* and *Hour-Distances* may be transferred from this *Table* to the *Dial-Plain* at pleasure, by help of a large *Chord* and *Beam-Compasses*.

C H A P. XIX.

Of *Dial Plains*, and how one *Plain* may be deduced from another, a *North* from a *South*, an *East* from a *West*, a *North Decliner* from a *South Decliner*; and all *Inclining Plains* from *Recliners* opposite to them.

AS there were Six Varieties of *Direct Reclining Plains*, and as many of *Recliners* which do also decline; so there are as many of both sorts which do *Incline*, and *Incline* and *Decline* also; of all which it may be expected I should give particular Examples, as of *North* and *South Direct Recliners*, and *North* and *South Recliners* which do also decline. — But for as much as a *Direct North Dial* may be deduced from a *Direct South Dial*, and a *Direct West Dial* from a *Direct East Dial*; as by *Chap. VIII. Fig. II* and *III*, and

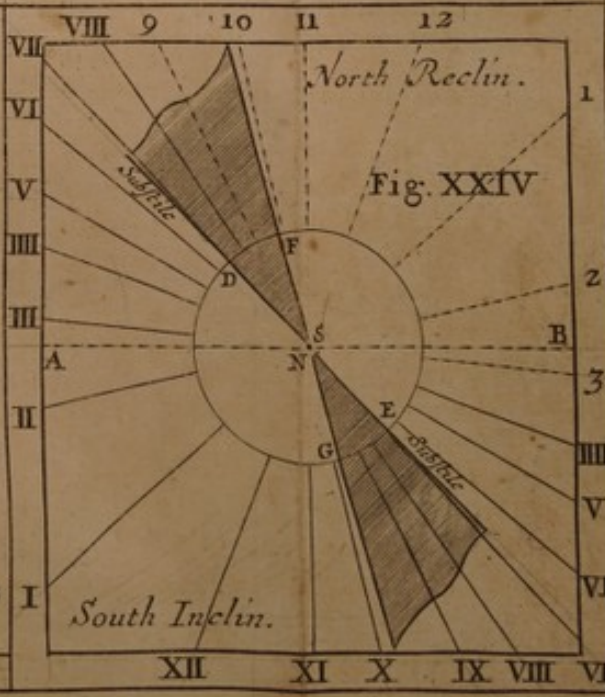
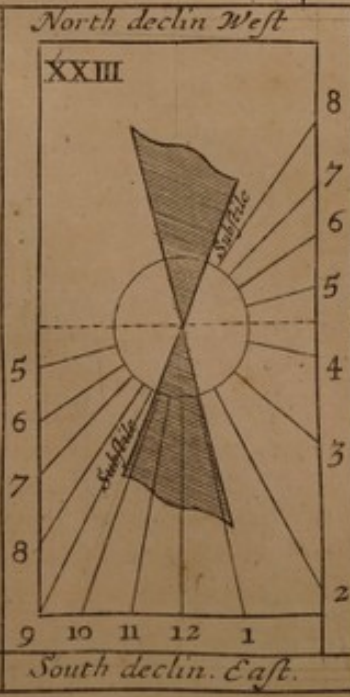
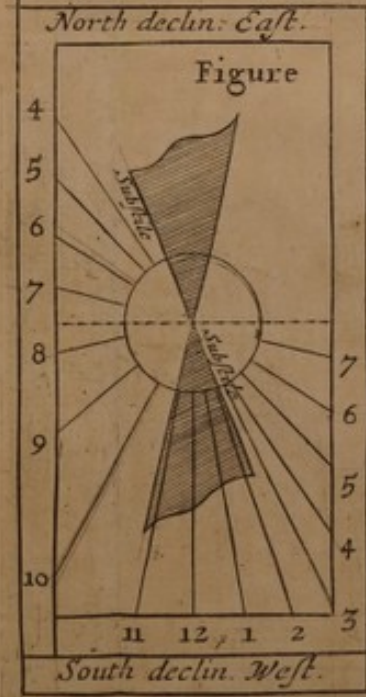
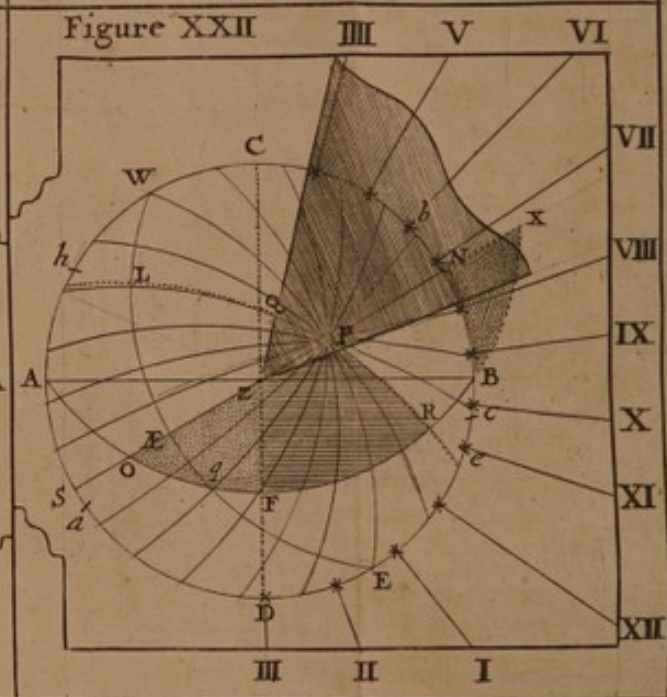
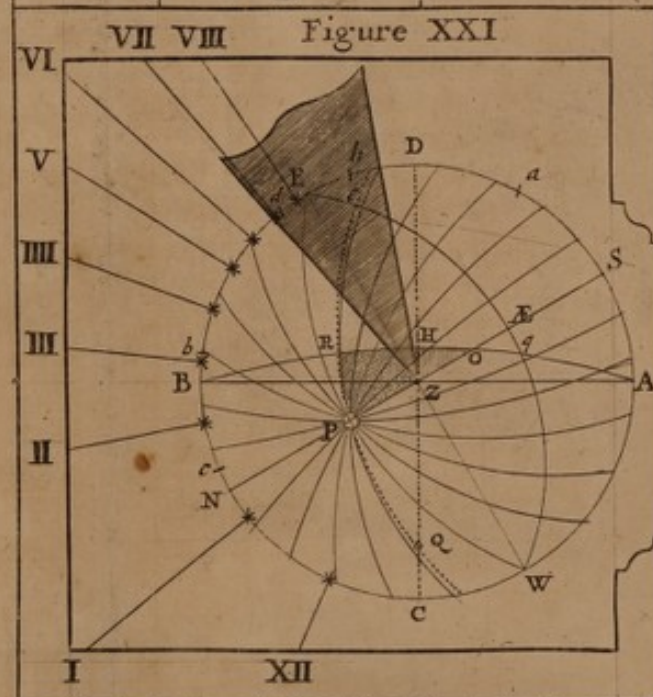
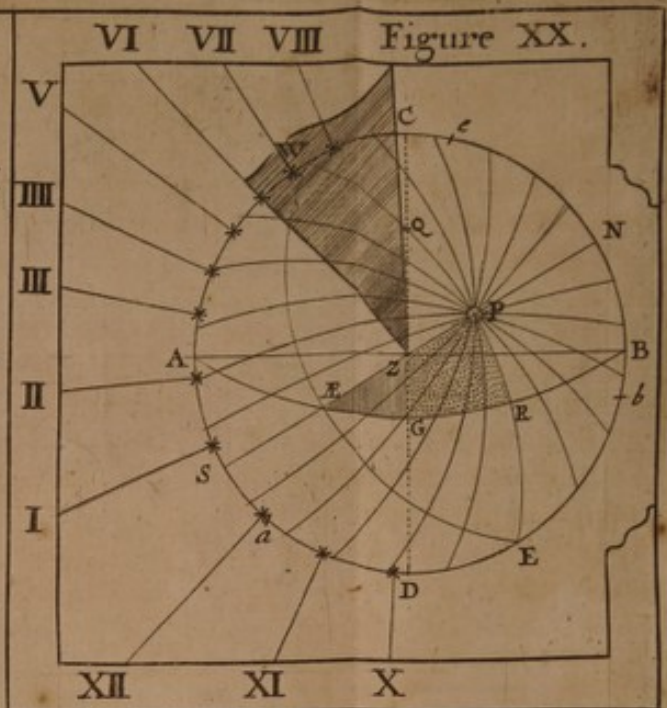
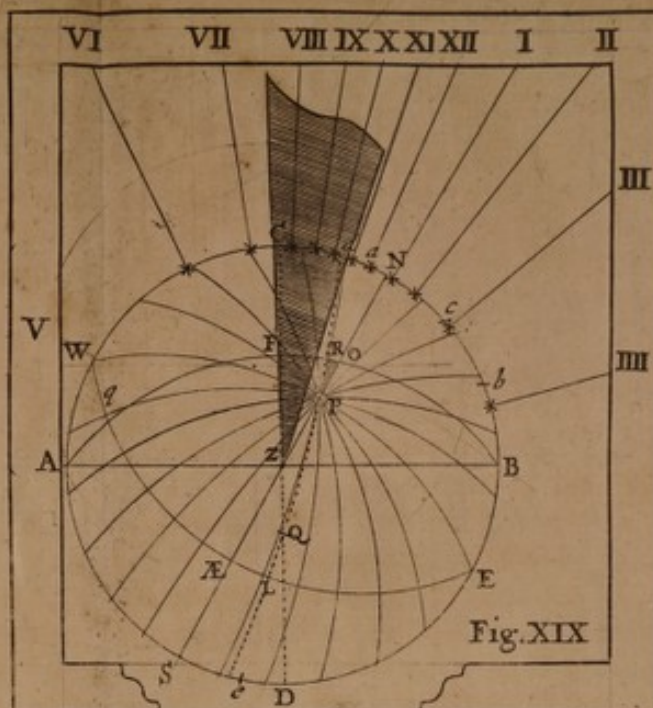
Chap.

Chap. IX. Fig. IV, and V. of this Tractate do plainly demonstrate: So from a South Declining Plain, may a North Declining Plain also; be deduced; and this is also demonstrated in Chap. XII, Figure VI and VII; at the end of which 12th Chapter I use these words, [“From this South Plain declining West, a South Dial is also Declining East 30 deg. turning of the East side to the West side, and the contrary; and by changing the names of the Hours, by calling 11 One, 10 Two, 9 Three, &c. Also 1 Eleven, 2 Ten, 3 Nine, &c. The Forenoon Hours in the West Declining Dial being the Afternoon Hours in the East Declining Dial, and the contrary]—— Now because these kind of Dials, are of all other most common in use, and to make them the more conspicuous to every Mans Eye, I have in this Chapter, Figure XXIII, made Four Dials together, all of them deduced from one Dial, namely, A South Declining East and West 30 deg. and a North Declining East and West as much, only placing the numbers of the Hours and Stile respectively upon each Plain. In which XXIII Figure, you may plainly see, that there is no difference at all between the South declining East, and the South declining West, but that the Forenoon Hours on the Left Hand of the Meridian in the East Dial, are become the Afternoon Hours, and on the Right Hand of the Meridian in the West Dial, and the contrary. The Stiles of the Dials also, must of necessity change their places, for the Stile which in the East declining Dial stands between the Hour Lines of 9 and 10 in the Fore-noon, stands between the Hour Lines of 2 and 3 in the Afternoon—— And in this XXIII Figure you may also observe that each North Dial is formed out of its correspondent South, by only drawing of the Hour Lines, Stile and Substile, of the South Dial through the Center. And so is the North declining West Dial 30 deg. deduced from the South declining East Dial 30 deg. And the North declining East Dial, out of the South declining West—— And from hence it followeth of necessity, that the South side of the Plain declining West, the North side thereof declineth as much towards the East, and the contrary. And this also holdeth in all other Dials, as shall be made appear. For,

In the 14th Chapter of this Tractate, Figure IX, you have an East Incliner, deduced from a West Incliner—— In Chapter XV Section 2, Figure XI, You have a North Inclining Dial 25 deg. deduced from a South Dial Reclining as much, namely, 25 deg.—— Also Chap. XVI, Sect. 2 and 3, Fig. XIV and XV; by the former Artifice may two South Incliners be deduced from the two North Recliners, although Lines are not drawn (because the Hour Lines, proper for the Recliners, do occupy both parts of the Plain, above and under the Hours of Six) yet the reason of effecting what is here intended, may be easily conceived.

Again, In this Chapter Figure XXIV, You have a North Reclining Plain declining Westward 60 deg. And if from thence you would make a South Inclining Plain declining 30 deg. the very sight of the Figure is enough to inform you. But least any doubt should arise, Let A 3, 4, 5, 6, 7, 8, be the Hours of the Recliner, and D S the Stile thereof, which drawn through the Center to E, take the distances of each Hour from D, and set them from E, the Hours under D above E, and the contrary; or else draw them all through the Center, Stile
U and

and all, to the opposite side of the Plain, as you did the Substile, and set the same Numbers to the Hour-Lines continued that were in the Recliner, so have you made the Inclining Dial to the same Plain, which, notwithstanding, must be prickt through the Paper, and taken on the other side thereof. — And here you may observe how the two Dials are divided one from the other. The Center of the Recliner downwards, and the Axis S F, with the Hours pointing upwards to the North Pole, and the Axis N G, with the Hours thereof, pointing downwards towards the South Pole, and the whole Diurnal Arch of 16 Hours supplied by the two Plains; the Incliner receiving the Sun at Four in the Morning, and the Recliner continuing the same till Eight at Night, and when the Sun forsakes the Inclining Face, it illuminates the Reclining or upper Face — And for further Satisfaction and Explanation of what in this Chapter hath been delivered, Let the upper Face, or the Recliner A S F, be turned about till it become the neather part, or the Incliner B N G, and after this conversion, let the Hour-Lines on the right hand of the Substile near D in the Recliner, be made the Hours on the left hand of the Substile, near E, in the Incliner; and the contrary, which may easily be done, by supposing A F S to be carried about the Center S Horizontally (with the rest of the Dial) till F become placed in G, and A in B, and then you shall see the Incliner is the very same as the Recliner was, and so by consequence the one formed out of the other.



VII

VII

A
SUPPLEMENT
 TO THE
FIRST TRACTATE:

SHEWING

A General and Easie Way to Project Hour-Lines upon all Sorts of Plains, according to the Rules of Stereographick or Circular Projection of the Sphere in Plano.

HAVING in the foregoing *Tractate* shewed how to describe *Hour-Lines* upon all sorts of *Plains*, how much and in what *Latitude* soever situate, by *Projecting* of the *Sphere* suitable to the *Latitude* of the *Place* where any such *Dial* is to be made; and discovered thereupon the *Spherical Triangles*, whereby the *Requisites* belonging to every *Plain* may be *Calculated* by the *Cannons* of *Artificial Sines* and *Tangents*, (which of all others, is the most exact and absolute way of *Performance*) it may seem unnecessary to say any thing more concerning that matter in this place.

But, forasmuch, as it is there required first to *Project* the *Sphere* upon the *Horizon* of the *Place*, and describe the *Meridians* and *Hour-Circles* thereupon; and then the *Great Circle* which is to represent the *Plain*: I shall here (to express the more variety in *Projection*, and) for the satisfaction of the more inquisitive *Reader* in this matter; briefly discover unto him, how to describe *Hour-Lines* upon all sorts of *Plains* (according to the *Rules of Stereographick Projection*) without the drawing of the *Meridians* or *Hour-Circles* upon the *Projection*: but by making the *Fundamental* or *Primitive Circle* to represent the *Dial-Plain* it self, what ever it be; whether *Horizontal*, *Vertical*, *Direct*, *Declining*, *Reclining* or both; giving *Examples* in all the *Varieties* of *Plains* mentioned in the foregoing *Tractate*.

And to pass by the *Eight first Chapters* of the said *Tractate* as consisting of such things as are common to all sorts of *Projections* of the *Sphere*, and to all kinds of *Dialling*, whether, *Arithmetical*, *Geometrical* or *Instrumental*; I shall begin with the *Example* in CHAP. IX. which is,

SECT.

S E C T. I.

How to draw an Horizontal Dial in any Latitude: viz. London, whose Latitude is 51 d. 32 m.

Figure I. **U**Pon Q, as a Center, describe a Circle to represent your *Horizontal Dial Plain*: And cross it with the Diameters N S, for the *Meridian* and *Hour Line* of 12, and W E for the *Hour Line* of 6, crossing each other in Q, the Center of the *Dial Plain*.

Then, the *Latitude* being 51 d. 32 m. take 51 d. 32 m. out of your *Scale of Chords*, and set them from S to *a*, and from W to *b*, a Ruler laid from W to *a*, will cut the *Meridian* in P, the *Pole of the World* [or, *The half Tangent* of 38 d. 28 m. [the *Complement* of the *Latitude* being set from Q, will give the same Point P, for the *Pole of the World*] Also, a Ruler laid from E to *b*, will cut the *Meridian* N S in *Æ*, the point of the intersection of the *Meridian* and *Equinoctial* [or, *The half Tangent* of the *Latitude* 51 d. 32 m. set from Q, will give the same Point] And now you have three Points, viz. W *Æ* E, through which you may draw the *Equinoctial Circle* W *Æ* E, whose Center is at C, and the *Semidiameter* thereof *Æ* C, equal to the *Secant* of 38 d. 28 m. the *Complement* of the *Latitude*.

This done, Divide the Semicircle W N E, into 12 Equal Parts, at the Points $\odot \odot \odot$, &c. Then lay a Ruler to Q, and every one of those Points $\odot \odot \odot$, and the Ruler will cross the *Equinoctial Circle* W *Æ* E, in the points *x x x*, &c. dividing it into 12 unequal parts. Again, Lay a Ruler to P, the *Pole of the World*, and to every of the Points *x x x*, &c. and it will cut the Circle W N E (representing the *Horizontal Plain*) in the Points 1, 2, 3, &c. on one side of N, and in 11, 10, 9, &c. the other side.

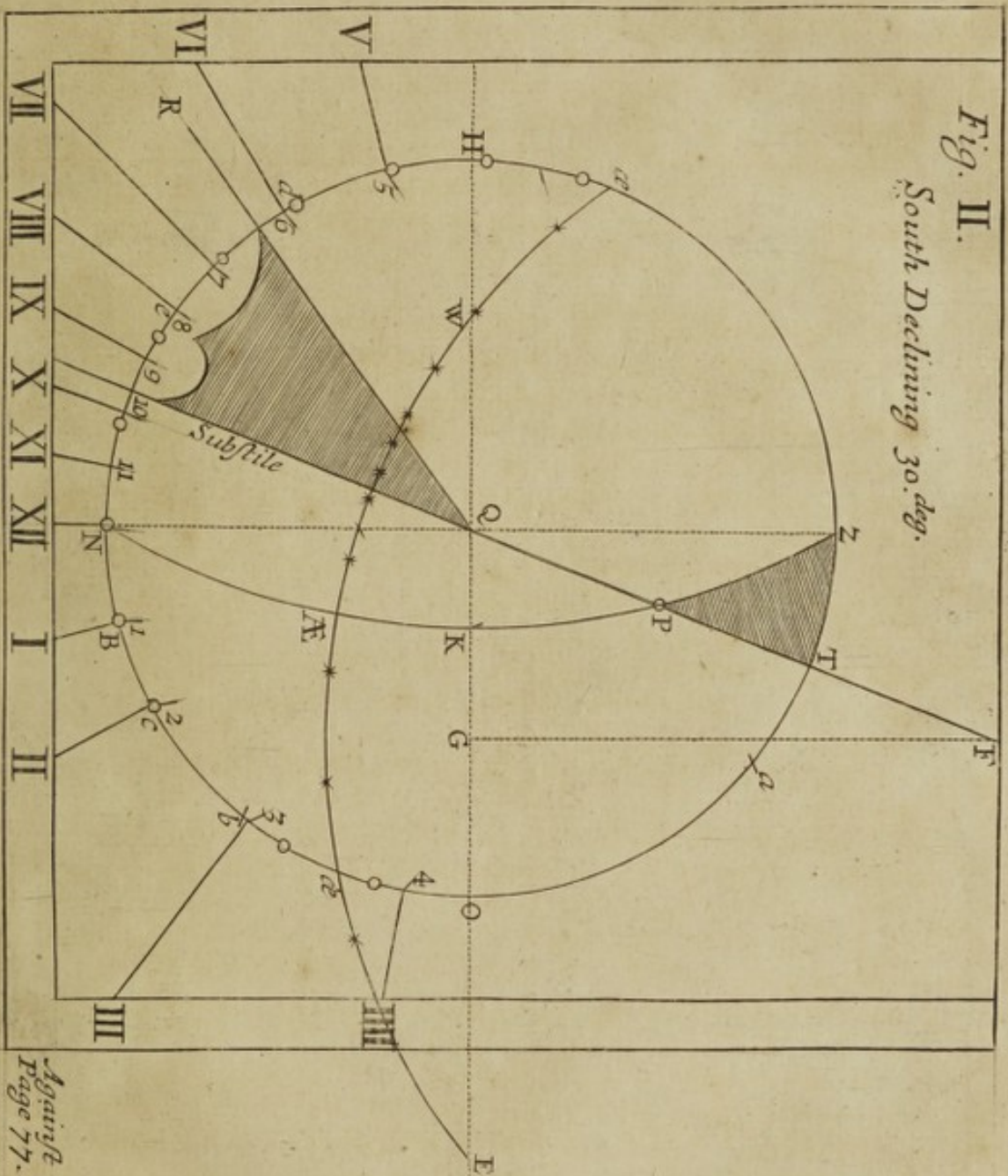
Lastly, From the Center Q, and through those Points 1, 2, 3 : 9, 10, 11, &c. draw Right Lines, and they shall be the true *Hour Lines* proper for an *Horizontal Dial* for the *Latitude* of 51 d. 32 m.

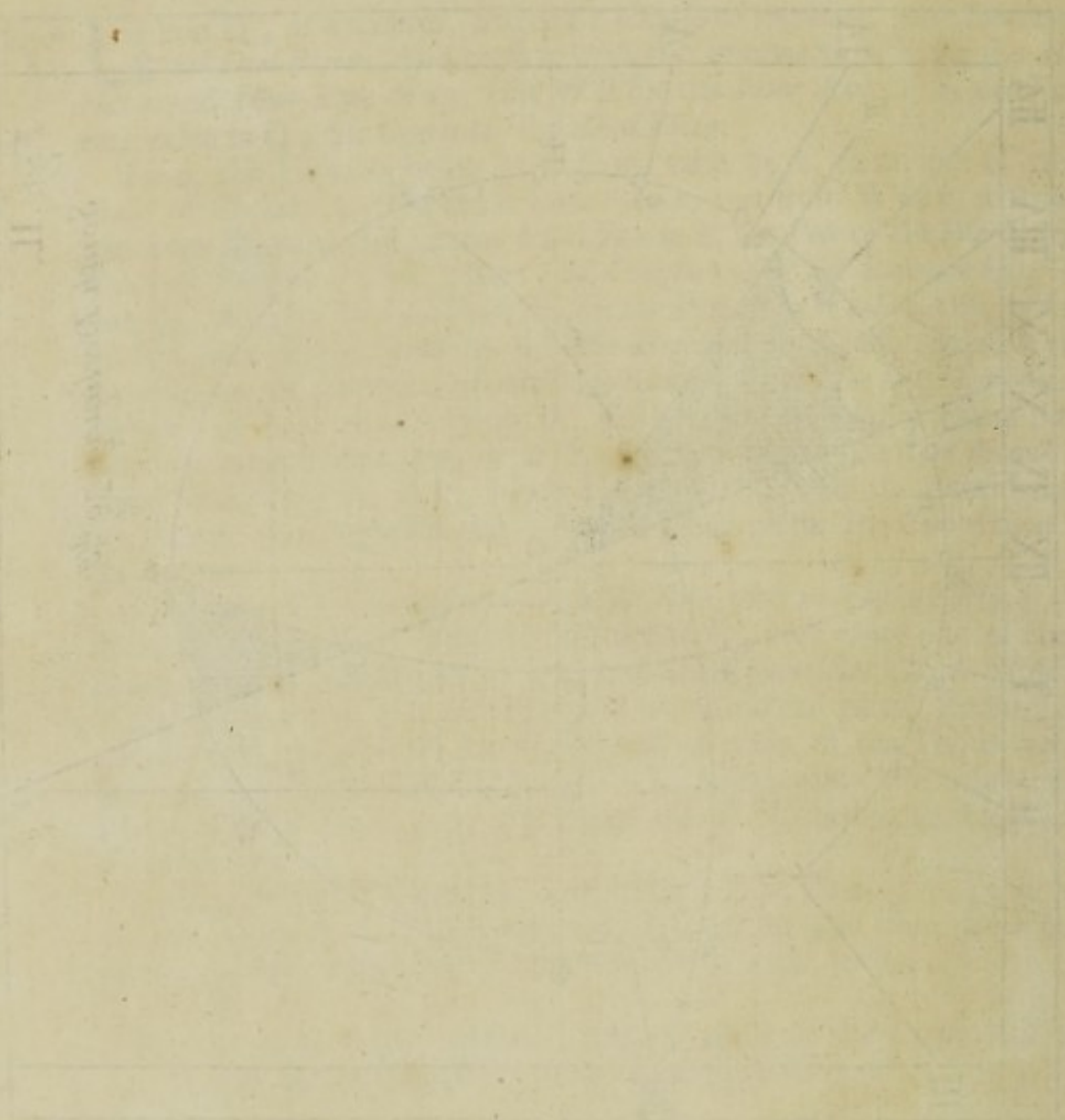
For the *Stiles height* (which is always equal to the *Latitude* of the Place) and for the placing of it, see the 9th Chapter.

The Xth Chapter is, *To make an Erect Direct South or North Dial*: — Now a *South* or *North Dial* in any *Latitude*, is no other than an *Horizontal Dial* in that *Latitude* which is equal to the *Complement* of the other *Latitude*, so an *Erect Direct South Dial* for the *Latitude* of London 51 deg. 32 m. is no other then an *Horizontal Dial* made for the *Latitude* of 38 deg. 28 min. And may be made by the Artifice deliver'd in this Section.

The XIth Chapter is, *To describe Hour Lines upon an Erect Direct East or West Plain* — East and West Dials in all *Latitudes* are the same, and may be made by the Rules delivered in the 11th Chapter with this Caution only : That the *Equinoctial Line* G H in those Figures, must make an Angle with the *Horizontal Line* of the Plain D C, equal to the *Complement* of the *Latitude* of the Place for which the *Dial* is to be made.

Fig. II.
South Declining 30. deg.





II

III

IV

V

VI

VII

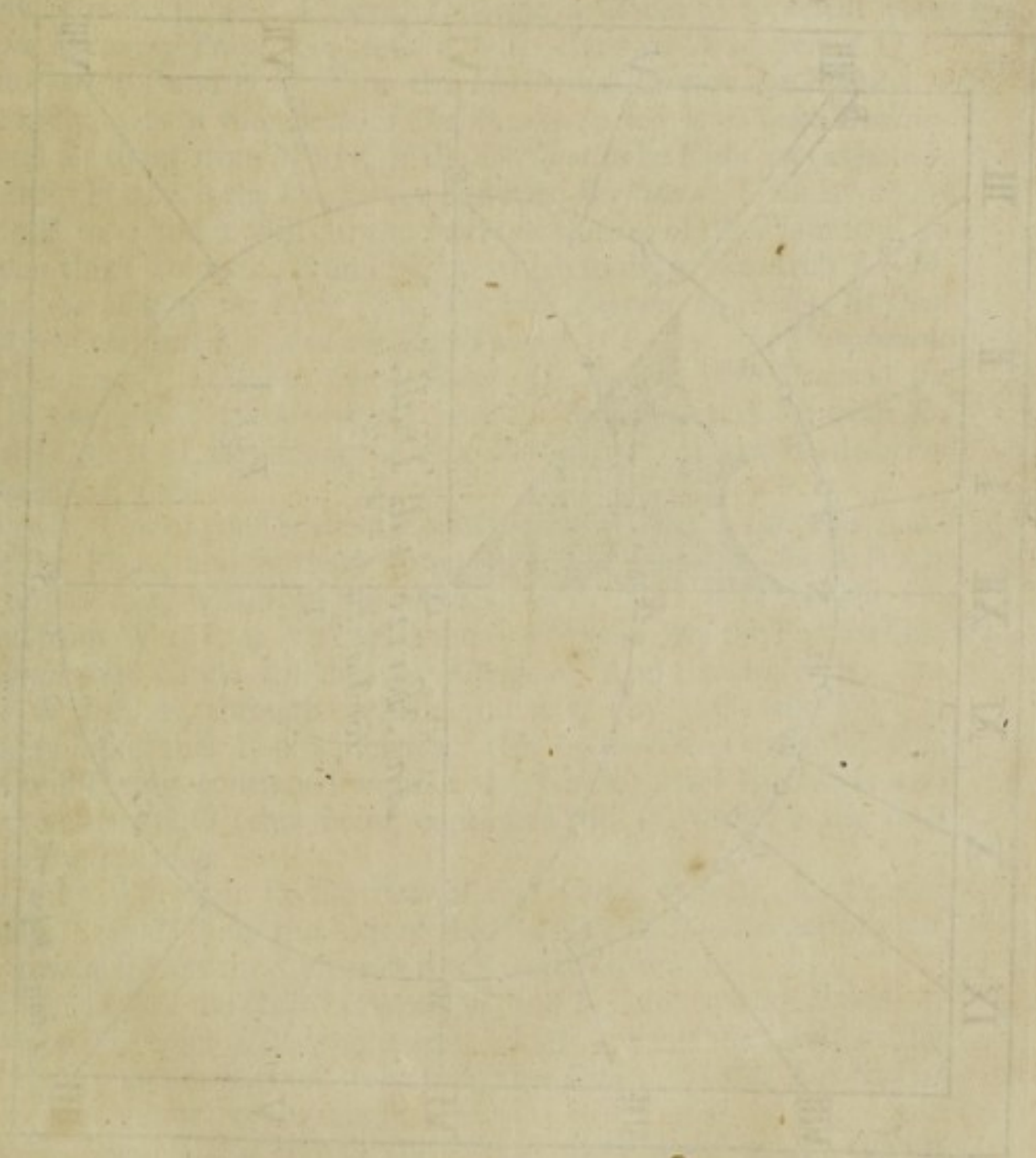
VIII

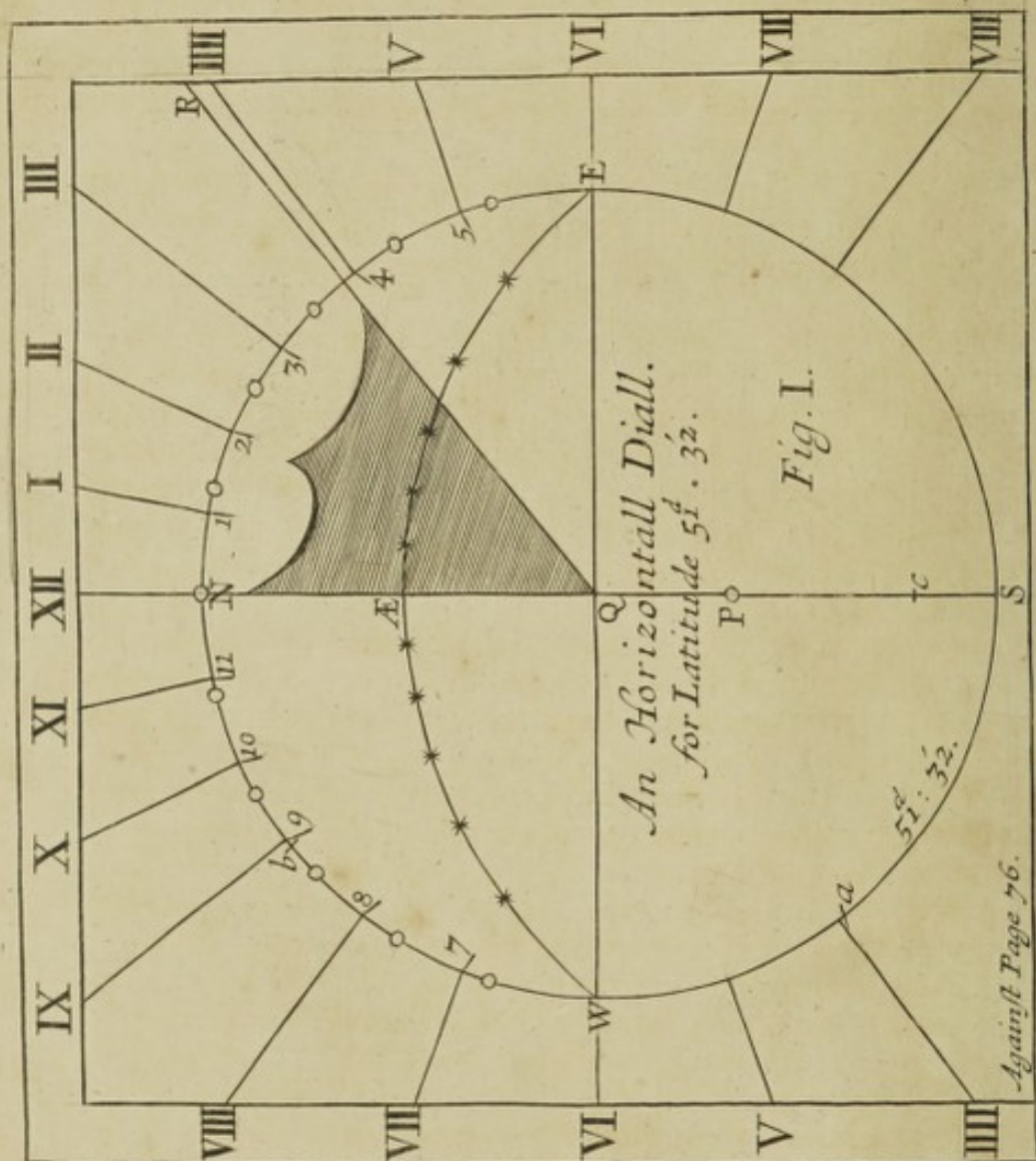
IX

X

XI

XII





S E C T. II.

How to describe Hour Lines, upon an Erect South or North Plain, Declining East or West.

IN the Latitude of *London*, which is 51 deg. 32 min. Let it be required to make a *South Erect Dial, Declining East or West 30 degrees.*

This is the Work of *C H A P. XII.* And such a Dial may be made by this way of *Projection*, by these *Rules* following.

First, Upon *Q*, as a Centre, Describe a Circle to represent your *Upright Declining Plain, G*; cross it with the two Diameters *Z Q N* for the *Vertical*; and *H Q O* for the *Horizontal Line* of the *Plain*. Figure II.

Secondly, Out of your Scale of *Chords* take 30 deg. the *Plains Declination* and set them from *N* to *c*, if the *Declination* be *Eastward* (as here it is) or from *N* to *e*, if the *Declination* had been *Westward*; Then lay a Ruler from *Z* to *c*, and it will cut the *Horizontal Line* of the *Plain* in *K*, so have you three Points *Z, K* and *N*, by which to draw the Arch *Z K N*, for the *Meridian of the Place* [Or, The half *Tangent* of 30 deg. set from *Q* will give the same *K*: And the half *Tangent* of 60 deg. the Complement thereof, set from *Q*, will give you the Point *W*, for the *West Point* of the *Horizon* and *Pole of the Meridian*.] And the *Secant* of 60d. set from *K*, upon the Line *K H*, extended, will give the Centre, whereon to describe the *Meridian Circle*.

Thirdly, Out of your Scale of *Chords*, take 51 deg. 32m. the *Latitude* of the *Place*, and set them from *O* to *a*, and from *N* to *b*; A Ruler laid from *W* to *a*, will cross the *Meridian* in *P*, the *Pole of the World*: and laid from *W* to *b*, it will cross the *Meridian* in *Æ*, the Point where the *Equinoctial Circle* will cut the *Meridian*: And thus have you two Points *W* and *Æ*, through which you may (by the 12th. *Prop.* at the beginning of this Book) describe the *Equinoctial Circle W Æ E* which will (being continued without the Circle) cross the *Horizontal Line* of the *Plain H O* (that being continued) in *E*, which is the *East Point* of the *Horizon*.

Fourthly, Through *P*, the *Pole of the World*, and *Q*, the *Pole of the Plain*, draw *P Q* for the *Axis of the World*, and *Substilar line* of your *Dial*, in which Line the Centre of the *Equinoctial* will be.

Fifthly, Divide the space between *W* and *E*, into two equal parts in *G*, and on *G*, erect a *Perpendicular*, which will cut the *Axis* of the *World Q P*, extended, in *F*, which is the *Centre* of the *Equinoctial Circle*: (if you have truly wrought.)

Sixthly, From *P* the *Pole of the World*, lay a Ruler to *Æ*, the intersection of the *Meridian* with the *Equinoctial*, and it will cut the Circle in *B*; At this point *B*, begin to divide the Semicircle *H N O*, into 12 equal parts, at the points $\odot \odot \odot \&c.$

Seventhly, From *Q* (the *Pole of the Plain*) lay a Ruler to every of the Points $\odot \odot \odot, \&c.$ and it will cross the *Equinoctial Circle a Æ a*, in the Points *x x x, \&c.*

Eighthly, lay a Ruler to *P*, (the *Pole of the World*) and every of the Points $***, \&c.$ and it will cut the *Primitive Circle* representing the *Plain* in the Points *N, 9, 10, 11, N, 1, 2, 3, \&c.* Through which
X Points;

Points; Lines drawn from the Centre Q, shall be the true *Hour Lines* of an *Erect South Plain, Declining Eastward 30 deg.* in the *Latitude of 51 deg. 32 min.*

Concerning the *Requisites* belonging to any *Upright Declining Plain* they are all of them represented to the eye, in the *Spherical Triangle* Z T P, Right angled at T, In which

The Side	{	Z T, is the Distance of the <i>Substile</i> from the <i>Meridian</i>	21 49
		Z P, the Complement of the <i>Latitude</i> of the Place	38 28
		T P, the height of the <i>Pole</i> above the <i>Plain</i>	32 36
The Angle	{	P Z T, the Complement of the <i>Plains Declination</i>	60 00
		Z P T, the <i>Plains Difference of Longitude</i>	36 25
		Z T P, is a Right Angle.	90 00

And all these may be found by *Trigonometrical Calculation*, as is shewed at large in the foresaid 12th. Chapter, As also, the manner how to place the *Stile*, and from one *Declining Dial* to make *Four* of the same *Declination, &c.*

The XIIIth. Chapter Is, To draw *Hour Lines*, upon a *South or North Plain*, which *Declines many Degrees toward the East or West.*

For the making of such *Dials*, no better ways can be prescribed than are there delivered in the said Chapter and so I say no more of them in this place.

The XIVth Chapter Is, How to describe *Hour Lines* upon *Direct East or West Reclining Plains.*

Hour Lines may be described upon such *Plains* by the Precepts delivered in this Section; if first you reduce them to a *New Latitude*, and a *New Declination*, wherein they may become *Upright Declining Plains* in that *New Latitude*: Which is very easie to be done — For a *Direct East or West Dial Reclining 35 deg.* in the *Latitude of 51 deg. 32 min.* (and such a *Plain* is the Example in Chap. 14) may be Reduced to a *New Latitude*, and *New Declination*. For, The *New Latitude* will be the Complement of the *Old Latitude*: And the *New Declination* the Complement of the *Reclination*: So, the above-mentioned *Plain*, will be a *South Plain Declining 55 deg.* in the *Latitude of 38 deg. 28 m.* And a *Dial* made to such *Latitude* and *Declination* shall be an *East or West Dial Reclining 35 deg.* in the *Latitude of 51 deg. 32 m.* But, whereas in the *Upright Declining Plain* the *Hour Line* of 12 is, always, *Perpendicular*; so the *Line* of 12 in the *Reclining Plain*, must be, always, *Parallel* to the *Horizon*. For finding the *Requisites* belonging to these *Plains*; &c. See the *Rules and Cautions* in Chap. 14.

The XVth. Chapter sheweth, How to draw *Hour Lines* upon *Direct South Dial Plains Reclining from the Zenith.*

Of these there are *Three Varieties*, and all of them are Reducible to *New Latitudes* where they will be *Horizontal Plains*; for, the height of the *Stile* or *Pole* above any *South Direct Reclining Plain*, is the *New Latitude* wherein that *Reclining Plain* would be an *Horizontal Plain*: Now the *three Varieties* of the *Plains* there mentioned have

In the	{	First	Variety	{	00 ^d 00 ^m	}	For the height of the	
		Second						13 28
		Third						31 32

Pole above the Plain.

And so, *Horizontal Dials* for those *Latitudes*, being made according to the Directions in the *First Section* hereof will be such *Reclining Dials* as are taken for *Examples* of the *Three Varieties* in that Chapter, where
how

Figure 1. A. (a) and (b)

Figure 1. A. (a) and (b) are two diagrams illustrating the geometry of a sphere. (a) shows a sphere with a horizontal line passing through its center, and a vertical line passing through its center. (b) shows a sphere with a horizontal line passing through its center, and a vertical line passing through its center. The diagrams are labeled with letters A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z.

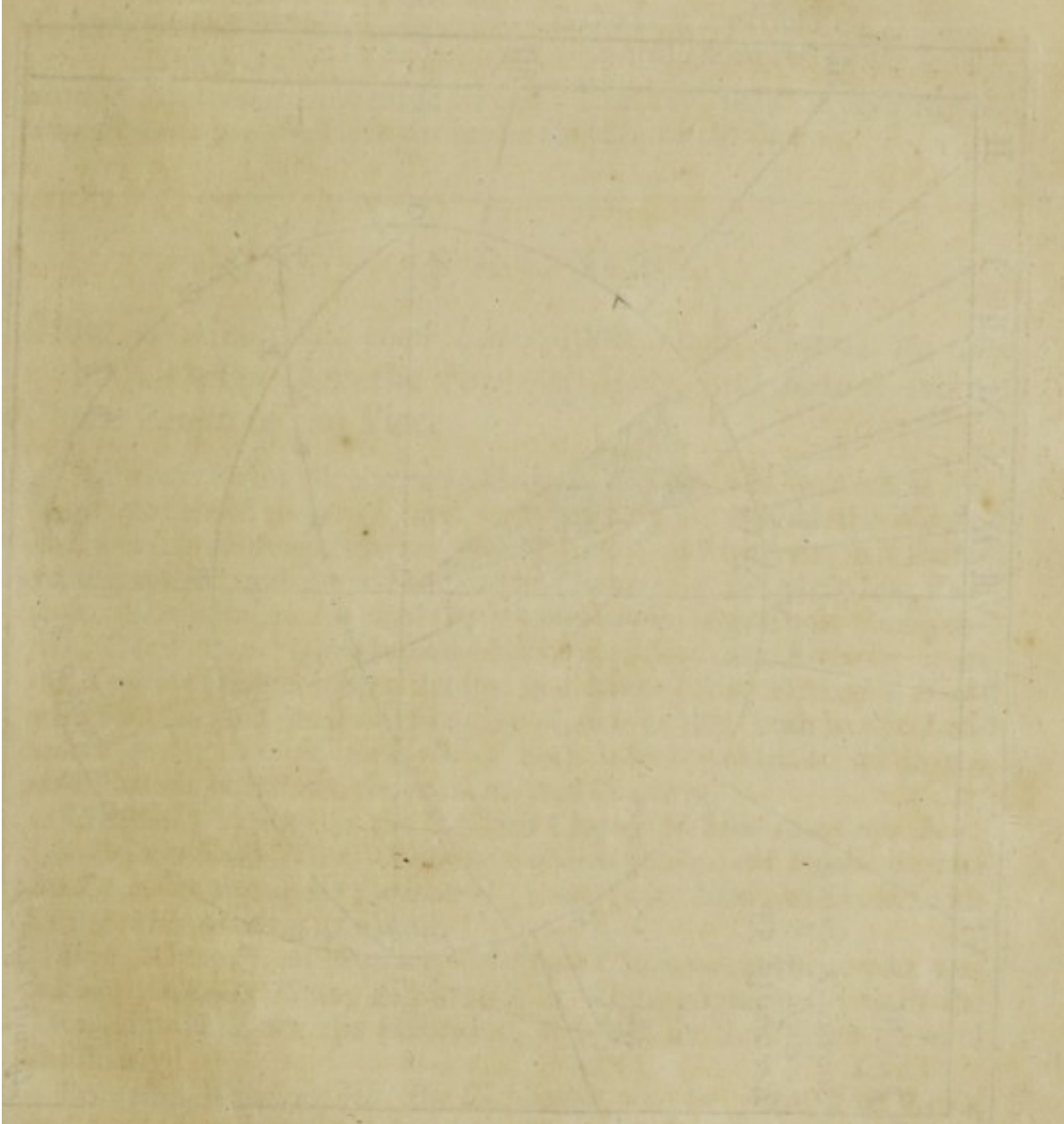
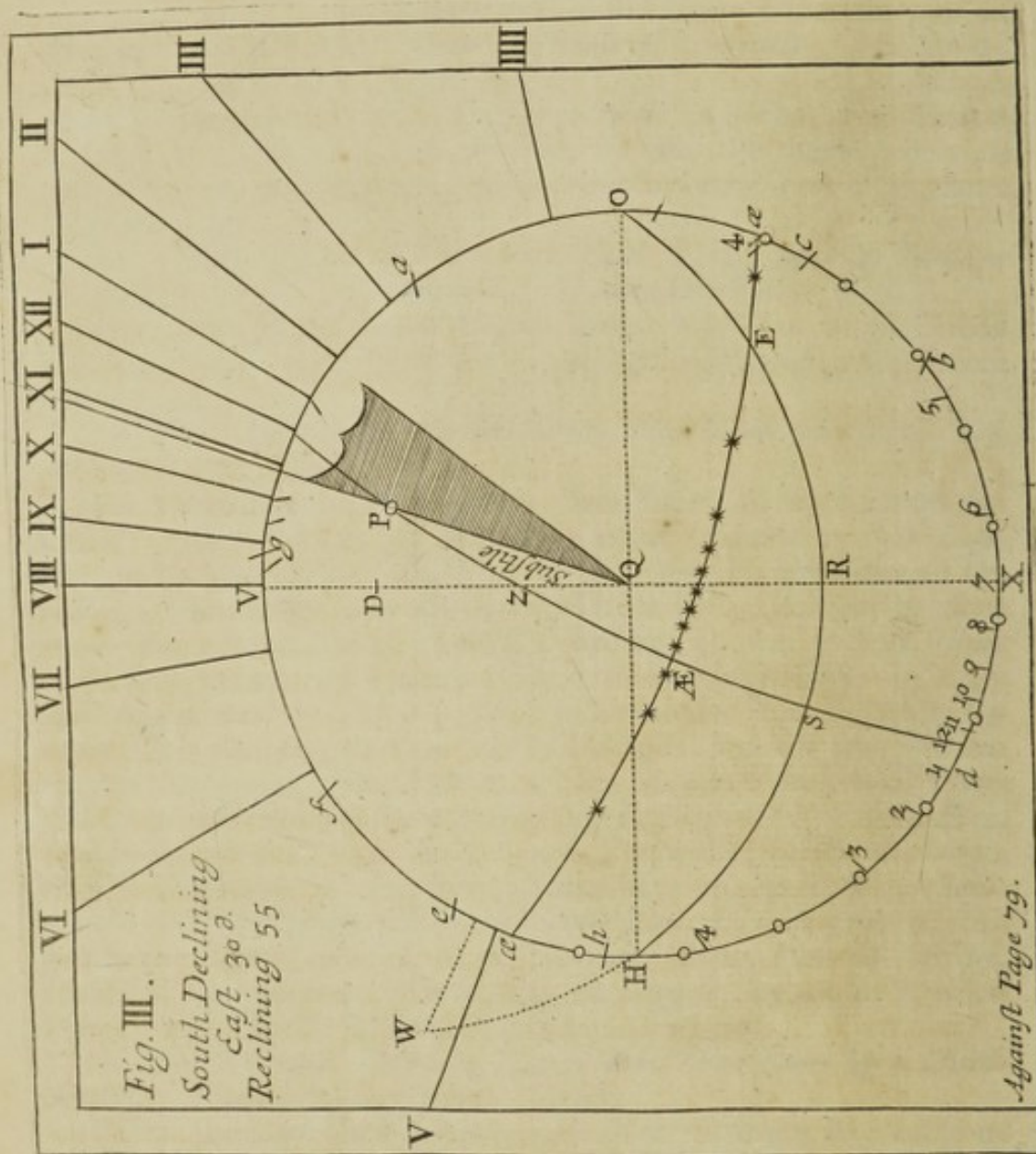


Figure 1. A. (a) and (b) are two diagrams illustrating the geometry of a sphere. (a) shows a sphere with a horizontal line passing through its center, and a vertical line passing through its center. (b) shows a sphere with a horizontal line passing through its center, and a vertical line passing through its center. The diagrams are labeled with letters A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z.



Against Page 79.

how to find the *Height of the Pole* above any *South Reclining Plain* is plainly taught, as also how to place the *Stile* and *Dial*, &c.

The *XVIth Chapter* sheweth; *How to draw Hour Lines upon Direct North Dial Plains Reclining from the Zenith.*

Of these also there are *Three Varieties*; Reducible also to *New Latitudes* wherein they will become *Horizontal Plains*: And how to find these *New Latitudes*, which is the height of the *Pole* or *Stile* above the *Plains*, is there shewed and

In the	{ First	{ Variety	{ 90 ^d 00 ^m	{ Is the height of the <i>Pole</i>		
	{ Second				{ 63 28	{ or <i>Stile</i> above the <i>Plain</i> .
	{ Third					

And so *Horizontal Dials* made for those *Latitudes*, shall be such *Reclining Plains* as are the *Examples* in the above said 15th Chapter.

S E C T. III.

How to describe *Hour Lines* upon such *Plains*, as do both *Decline* from the *North* or *South*, and *Recline* from the *Zenith* of the *Place*.

OF these *Plains* there are two kinds principally, viz. such whose *Faces* behold the *South*, and such whose *Faces* behold the *North*: and in either of these there are *Three Varieties*, of which you may see several *Examples* in the 17th and 18th Chapters of the preceding *Treatate*. It shall suffice therefore (in this *Supplement*) to give only two *Examples*, One a *South Plain Declining Eastward 30 deg.* and *Reclining from the Zenith 55 degrees*. And another of a *North Plain, Declining Westward 60 deg.* and *Reclining from the Zenith 54 deg.* both in the *Latitude* of 51 deg. 32 m. *Examples* of both which you shall find in the *three Varieties* of the two above-mentioned Chapters.

The third Variety in the *XVIIth Chapter* Is *How to describe Hour Lines upon a South Plain, Declining Eastward 30 deg. and Reclining from the Zenith 55 deg. in the Latitude of 51 deg. 32 m.* Now, to make such a *Dial* by this Artifice, you must,

First, Upon *Q*, as a Centre, describe a Circle to represent your *Declining, Reclining Plain*; and cross it at Right angles in *Q*, with the Diameters *H O*, for the *Horizontal*, and *V X* for the *Vertical Lines* of the *Plain*. Figure III.

Secondly, Take 55 deg. the *Reclination*, and set them from *V* to *a*, and from *O* to *b*, a Ruler laid from *H* to *a*, will give the Point *Z*, for the *Zenith* of the *Place*, and from *H* to *b*, it will give the point *R*, for the intersection of the *Vertical Line* of the *Plain*, with the *Horizon* of the *Place*: [Or, The half Tangent of 35, the Complement of the *Reclination* set from *Q*, will give the point *Z*, and the half Tangent of 55, the *Reclination* will give the point *R*].

Thirdly, Through the three Points *H R O*, you may draw the *Horizon* of the *Place*, whose Centre will be at *D*, the Semidiameter whereof *D R* is equal to the *Secant* of 35 deg. the complement of the *Plains Reclination*.

Fourthly, Take 30 deg. the *Plains Declination*, out of your Scale of Chords,

Chords, and set them from O to *c*, from X to *d*, and H to *e*, and a Ruler laid from Z to *c*, will give the point E, and laid from Z to *d*, will give the point S, and laid from Z to *e*, will give the Point W, all in the *Horizontal Circle*, for the true *East, South, and West* Points thereof.

Fifthly, Through the Points Z, the Zenith, and S, the South point of the *Horizon*, you may (by the 12th Problem at the beginning of this Book) Draw the *Meridian* of the Place S Z P,

Sixthly, Lay a Ruler to the Points E and Z, and it will cut the *Primitive Circle* in *f*, from *f*, set 38 de. 28 m. of your Scale of *Chords*, and they will reach from *f* to *g*, and a Ruler laid from E to *g*, will cross the *Meridian Circle* in P, the *Pole* of the *World*: and 90 de. of your *Chords*, set from *g*, will reach to *h*, and a Ruler laid from E to *h*, will cross the *Meridian* in *Æ*, and so you have three Points W, *Æ* and E, through which to draw the *Equinoctial Circle* *a* *Æ* *a*.

Seventhly, Through Q the *Pole* of the *Plain*, and P the *Pole* of the *World*; draw the right line Q P for the *Axis* of the *World*, and the *Substilar* line of your *Dial*: it must be drawn upwards towards the *North*; because the *North Pole* is elevated above this *Plain*, as is manifest by the *Scheme*.

Eighthly, Lay a Ruler upon P, the *Pole* of the *World*, and *Æ*, where the *Meridian* and *Equinoctial* intersect, and it will cut the *Primitive Circle* in B.

Ninthly, At the Point B, begin to divide the *Primitive Circle* into 24, (or the half of it *a* B *a* into 12) equal parts, at the Points $\odot \odot \odot$, &c.

Tenthly, Lay a Ruler to Q, and every of those Points, and it will cross the *Equinoctial Circle* *a* *Æ* *a*, in the Points $\times \times \times$ &c. And a Ruler laid from P, the *Pole* of the *World*, to every of these Points; $\times \times \times$, &c. will cut the *Primitive Circle* representing the *Dial Plain*, in the Points 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, from which Points, Right Lines being drawn through the Centre Q, (upwards, because the *North Pole* is elevated above the *Plain*) they shall be the *Hour Lines* belonging to such a *Declining Reclining Dial* as was required to be drawn.

As concerning the *Requisites* belonging to this *Declining Reclining Dial*, they are all visible in the *Projection*, and three of them in the Triangle L P C. For,

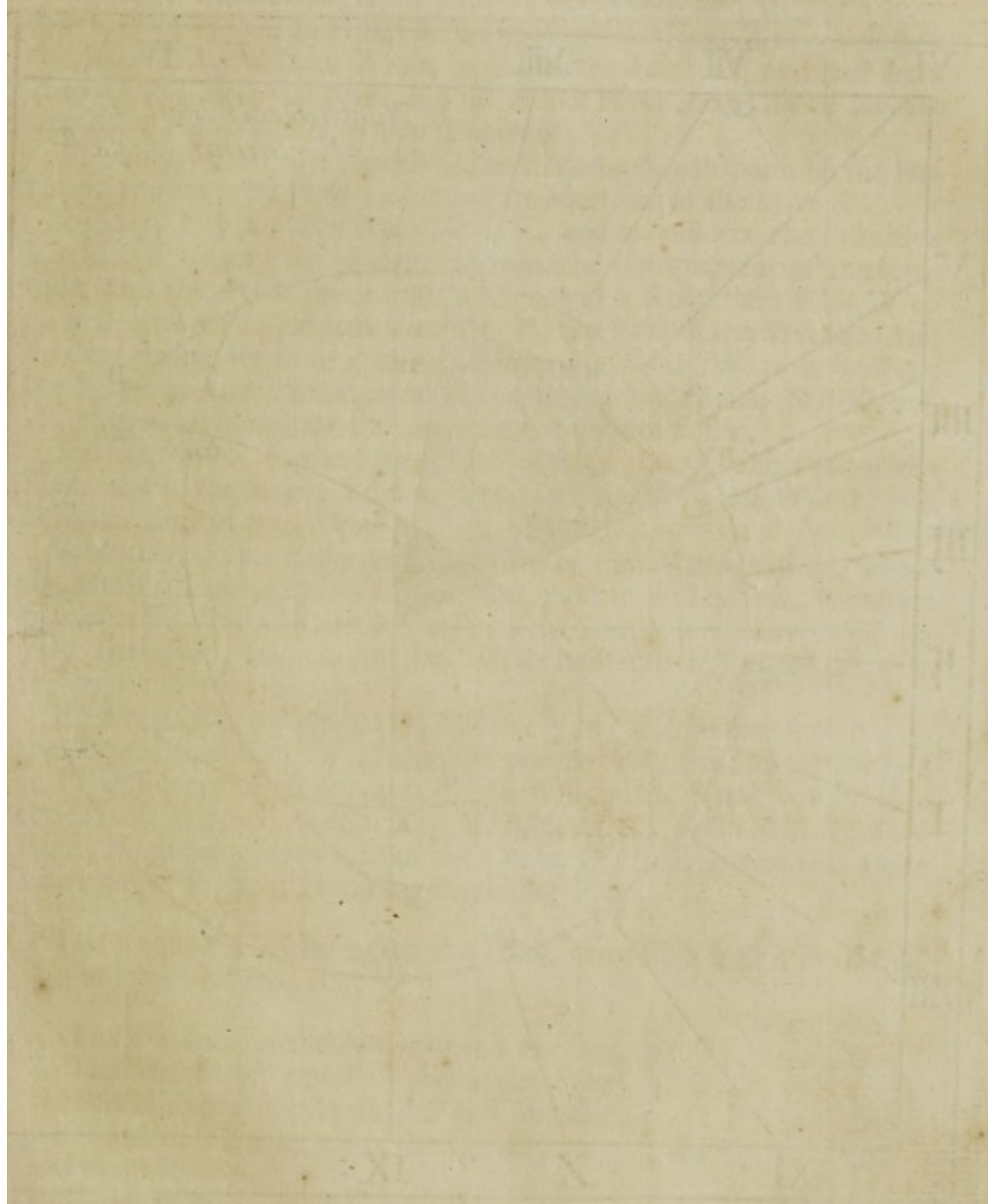
	de	m
The height of the <i>Pole</i> above the <i>Plain</i> is C P,	19	25
The Distance of the <i>Substile</i> and <i>Meridian</i> C L,	06	02
The Plains <i>Difference</i> of <i>Longitude</i> L P C,	17	38
The Distance of the <i>Meridian</i> and <i>Horizon</i> , is the <i>Arch</i> O C	64	41

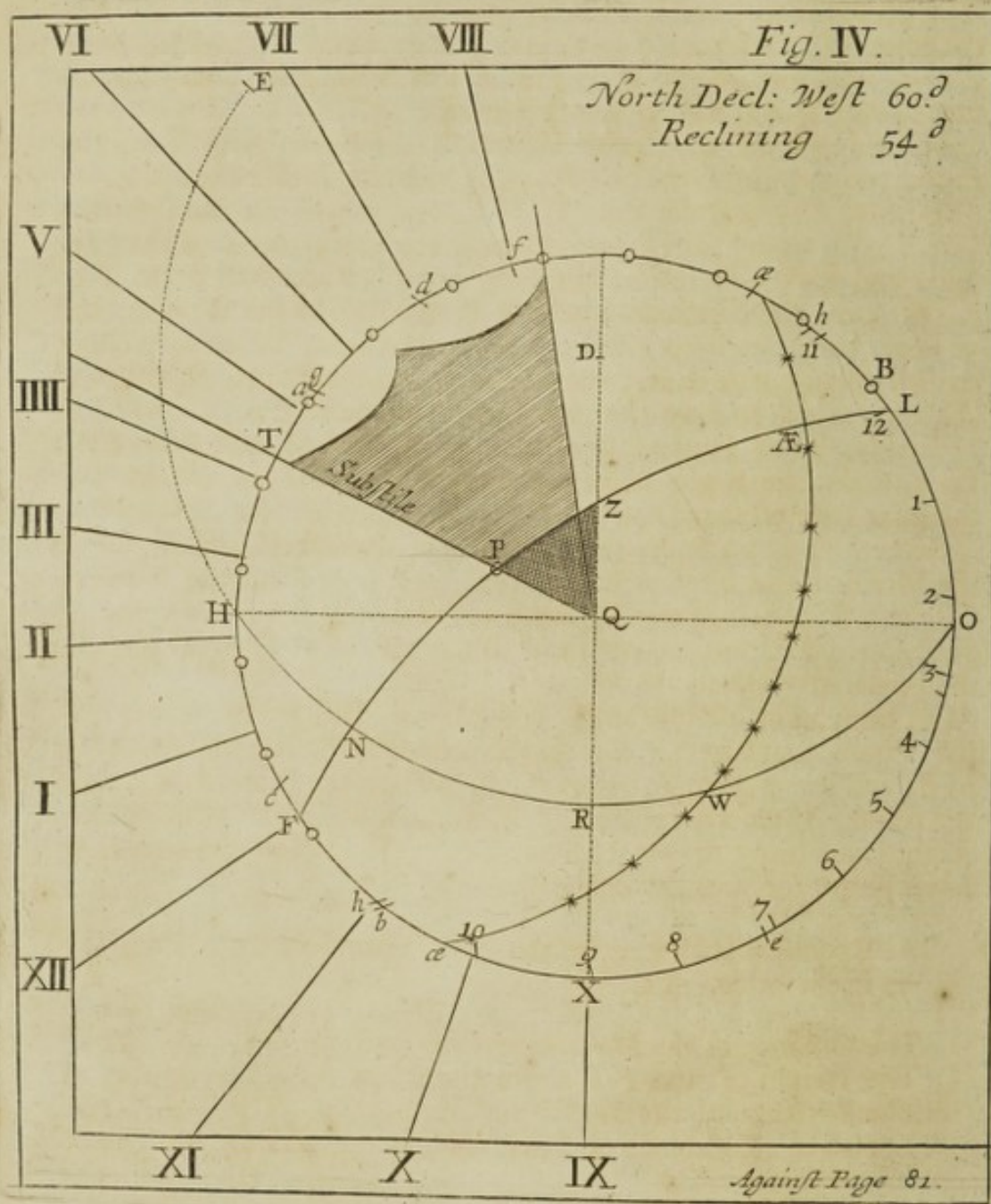
As by the Trig. Calculation doth appear.

The Third Variety in the XVIIIth. Chapter Is how to describe *Hour Lines*, upon a *North Plain*, *Declining West* 60 deg. and *Reclining from the Zenith* 54 deg. in the *Latitude* of 51 deg. 32 m. and to make such a *Dial* according to this way of *Projection*: you must,

Figure IV. First, Upon the Centre Q, with 60 deg. of your Scale of *Chords*; describe a Circle representing the *Dial Plain*; and cross it with the two *Diameters* V X for the *Vertical*, and H O, for the *Horizontal Lines* of your *Plain*.

Secondly, Take 54 deg, the Plains *Reclination*, out of your Scale of *Chords*,





Chords, and set them from U to *a*, and from H to *b*, a Ruler laid from H to *a, b* will cut the Vertical Line of the Plain U X, in the Points Z, for the Zenith of the Place; and in R, for the Point of Intersection of the Horizon of the Place, with the Vertical Line of the Plain; and now you have three points, thro' which to draw the Horizontal Circle H R O, whose Center will be at D.

Thirdly, Take 60 degr. the Plain's Declination, and set them from O to *e*, from H to *d*, and from X to *f*, a Ruler laid from Z to *e*, will give the point W; and from Z to *c*, will give the Point N; and laid from Z to *d*, will give the point E; all in the Horizontal Circle, for the true East, North and West points thereof.

Fourthly, Thro' the Zenith Z, and N, the North-point of the Horizon, you may (by *Probl. 12.*) draw the Meridian of the Place N Z.

Fifthly, Lay a Ruler from W to Z, and it will cut the Primitive Circle in *f*; from *f* set 38 degr. 28 min. the Complement of the Latitude, and they will reach from *f* to *g*; and a Ruler laid from W to *g*, will cross the Meridian-Circle in P, the Pole of the World: And 90 degr. being set from *g* to *h*, a Ruler laid from W to *h*, will cut the Meridian-Circle in *Æ*; and so you have three Points, N, W, and *Æ*, thro' which to draw the *Æ*quinoctial-Circle $\propto \text{Æ} \propto$.

Sixthly, Thro' P, the Pole of the World, and Q, the Pole of the Plain, draw the Right Line Q P L, for the *Axis* of the World, and Substilar Line of your Dial.

Seventhly, Lay a Ruler to P, the Pole of the World, and *Æ*, where the Meridian and *Æ*quinoctial intersect, and it will cut the Primitive Circle in B: At this Point B, begin to divide the Circle representing your Dial-plain, into 24 (or the half thereof into 12) equal parts, in the points $\odot \odot \odot$, &c.

Eighthly, Lay a Ruler to Q, and every of those points, it will cross the *Æ*quinoctial Circle $\propto \text{Æ} \propto$, in the points ***, &c. and a Ruler laid to P, and every of those points ***, will cut the Primitive Circle in the points, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 7, 8. From which points, Right Lines being drawn from the Center Q, shall be the true Hour Lines proper for your Declining Reclining Plain.

The Requisites belonging to the Plain, are visible in this *Projection*, as in the other. For,

		degr.	min.
The Distance of the Meridian and Horizon, is	OL	35	31
The Height of the Pole above the Plain, is	PT	53	43
The Distance of the Substile and Meridian, is	TF	56	41
The Plain's Difference of Longitude, is	ZPQ	61	47

A
SYNOPSIS,
 OR
ABSTRACT,
 OF

What hath been delivered more at large, in the fore-going Chapters of this Tractate.

IN this *Abstract* I shall only give you an account of what things are *Given* and what are *Required* in every *Plain*, and *Proportions* by which those *Requisites* are to be *found*, and not particular *Examples* in Numbers, as is already largely done, yet so, that the whole substance, in the general, may be seen in this at one view, and so I shall take them in order, beginning with

I. Vertical or Horizontal Plains, *Chap. IX. Fig. I.*

In these Plains there is nothing required but the Arch of the *Meridian* comprehended between the Pole of the World and the Plain, which is the *Latitude of the Place*, and is always given.

II. The Erect Direct South and North Plains, *Ch. X. Fig. II and III.*

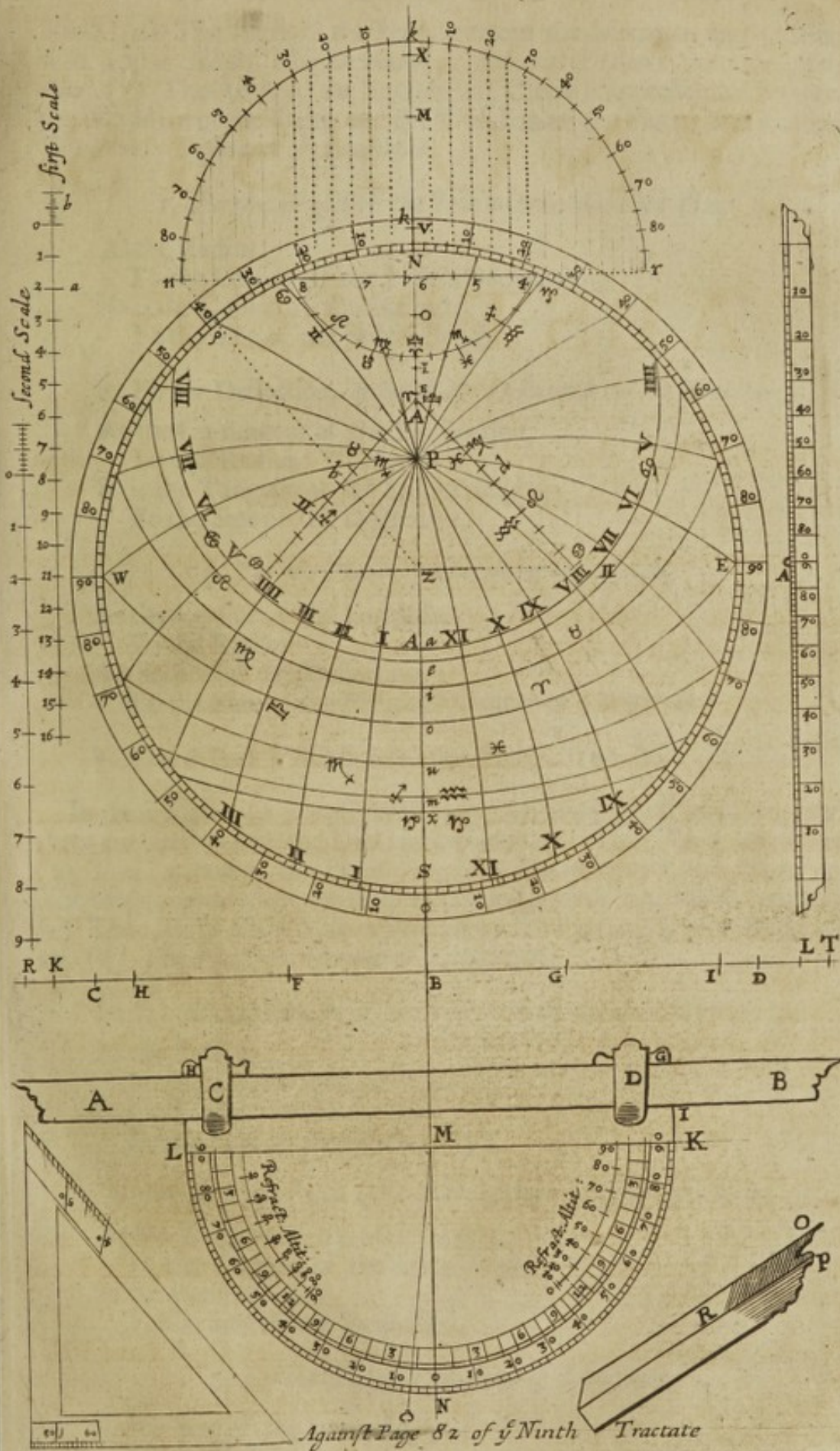
In these Plains also there is nothing required but the Arch of the *Meridian*, comprehended between the Pole of the World and the Plain, and this is always equal to the *Complement of the Latitude*, and so is also given.

III. Erect Direct East and West Plains, *Chap. XI. Fig. IV and V.*

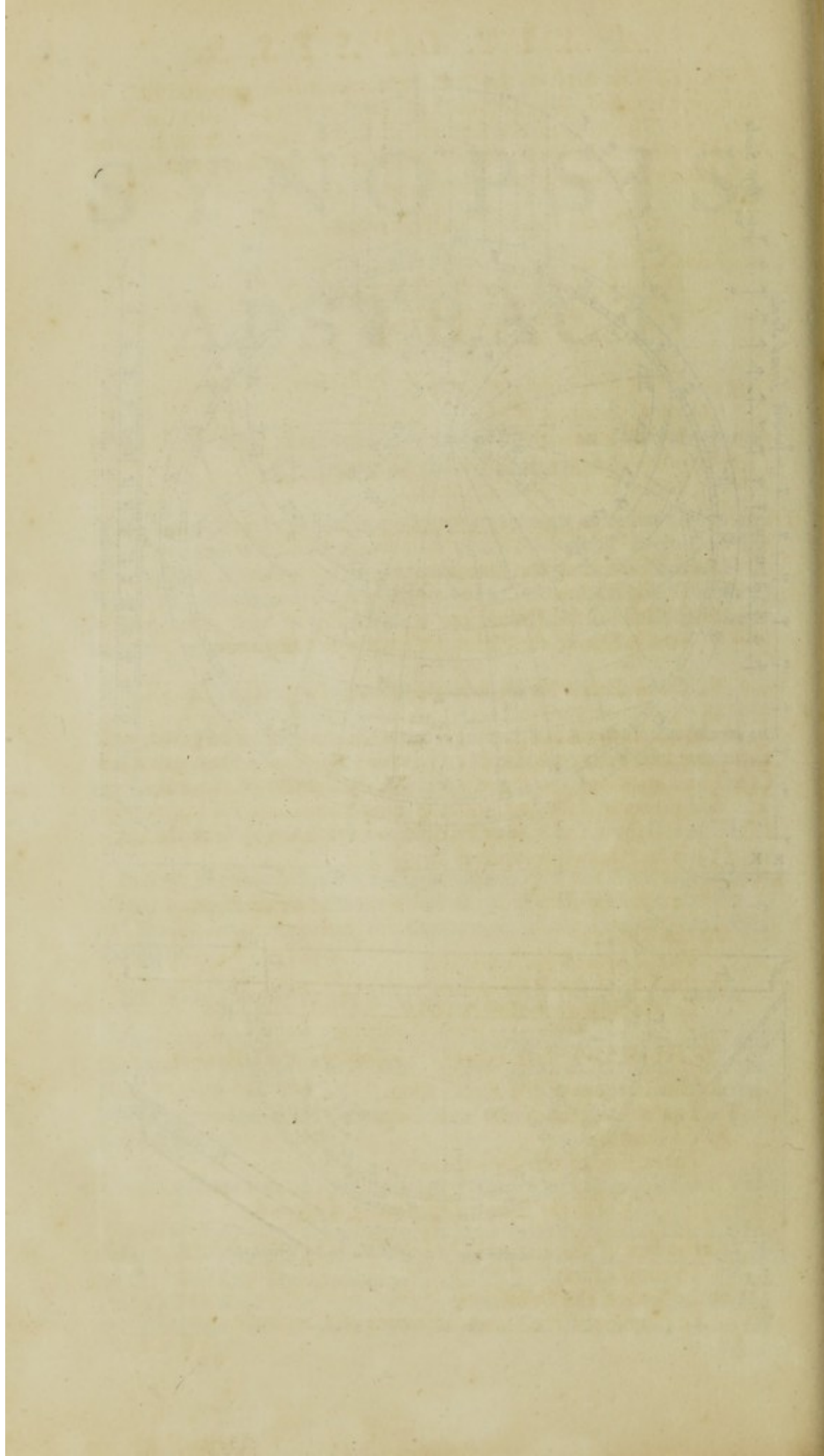
Over these Plains, neither of the *Poles* of the World is elevated, and therefore no Arch of the *Meridian* either given or required; but the Hour Lines being all Parallel, their distance may be contracted or enlarged answerable to the bigness of the Plain, and length of the Perpendicular *Stile*.

IV. North and South Erect Declining Plains, *Ch. XII. Fig. VI and VII.*

In these Plains two things are given, and three things must be sought, before the Dial can be made — The things given are (1) The *Latitude* of the Place (2) The *Declination* of the Plain, — The things required are (1) The Arch of an *Azimuth Circle* between the Pole of the World and the Plain, and is called *The Height of the Pole or Stile above the Plain.*



Against Page 82 of y^e Ninth Tractate



Plain. (2) The Arch of the Plain between the Meridian and the Substile, and is called, The *Deflection* or *Substiles Distance* from the *Meridian*. (3) The Arch of the Equinoctial Circle comprehended between the Meridian of the Plain, and the Meridian of the Place ; and is called, *The Plain's Difference of Longitude*.

1. *For the Height of the Pole or Stile above the Plain,*

As the Radius,

To the Co-sine of the Plain's Declination :

So is the Co-sine of the Latitude,

To the Sine of the Stile's Height.

2. *For the Deflection, or Substile's Distance from the Meridian,*

As the Co-tangent of the Declination,

To the Radius :

So is the Tangent of the Stile's Height,

To the Sine of the Deflection.

3. *For the Plain's Difference of Longitude,*

As the Co-sine of the Latitude,

To the Radius :

So the Sine of the Deflection,

To the Sine of the Plain's Difference of Longitude.

V. *Direct East or West Reclining Plains, Chap. XIV. Fig. IX.*

In these Plains (as in upright Plains) two things must be given, and three required before the Dial can be made. — The Things given are (1) The *Latitude* of the Place. (2) The *Reclination* of the Plain. — The things required are the same as in upright declining Plains, namely (1) The Height of the Stile or Pole above the Plain. (2) The *Deflection*. (3) The Plain's difference of Longitude.

1. *For the Height of the Pole or Stile above the Plain,*

As the Radius,

To the Sine of the Latitude :

So the Sine of the Reclination,

To the Sine of the Stile's Height.

2. *For the Deflection or Substile's distance from the Meridian,*

As the Tangent of the Reclination,

To the Tangent of the Stiles Height :

So the Radius,

To the Sine of the Deflection.

3. *For the Plain's Difference of Longitude,*

As the Sine of the Latitude,

To the Radius :

So the Sine of the Deflection,

To the Sine of the Plain's difference of Longitude.

VI. *Direct*

VI. *Direct South Reclining Plains, Chap. XV. Fig. X, XI, XII.*

In these Plains, the Latitude of the Place and the Reclination of the Plain being given, there is nothing required but the Arch of the Meridian comprehended between the Pole of the World and the Plain, which is, *The Height of the Pole, or Stile above the Plain*; and in these South Recliners it is thus found — Subtract the Reclination from the Complement of the Latitude, or the Complement of the Latitude from the Reclination, and the difference is the *Height of the Pole or Stile above the Plain*: And note,

If the Reclination be $\left\{ \begin{array}{l} \text{Equal to} \\ \text{Lesser than} \\ \text{Greater than} \end{array} \right\}$ the Comp. of the Latitude, the Plain is Equinoctial, as Fig. XV. $\left\{ \begin{array}{l} \text{South} \\ \text{North} \end{array} \right\}$ Pole is elevated.

VII. *Direct North Reclining Plains, Chap. XVI. Fig. XIII, XIV, XV.*

The Latitude of the Place, and the Reclination being known, there is nothing required in these Plains to be found, but the Arch of the Meridian between the Pole and the Plain, which is the *Stile's Height*. And in North Recliners it is thus found — Add the Complement of the Latitude of the Place, and the Reclination of the Plain together, the sum of them (if under 90 deg. or the Remainder to 180 deg. if above 90 deg.) is the *Height of the Pole or Stile above the Plain*. But if the Sum or Aggregate be just 90 deg. it is a *Polar Plain*, as Fig. XIII and XIV.

VIII. *South Declining Reclining Plains, Chap. XVII. Fig. XVI, XVII, XVIII, and XIX.*

In these Plains three things must be given, and four things sought before the Dial can be drawn — The things given are (1) The Latitude of the Place. (2) The Declination. And (3) The Reclination of the Plain. — The things required are (1) The Distance of the Meridian and the Horizon, (2) The Height of the Pole above the Plain, (3) The Deflection, or Substile's Distance from the Meridian, (4) The Plain's difference of Longitude.

1. *For the Distance of the Meridian from the Horizon,*

As the Radius,

To the Sine of the Reclination:

So the Tangent of the Declination,

To the Co-Tangent of the Dist. Meri. and Horizon.

2. *For the Height of the Pole or Stile above the Plain,*

As the Sine of the Declination,

Is to the Co-sine of the dist. of Mer. and Horizon:

So is the Radius,

To a Fourth Sine.

If this Fourth Sine be equal to the Co-Latitude, the Plain is an Equinoctial Decliner; but if it be lesser than the Co-Latitude, subtract it from the Co-Latitude, noting the Remainder. Then say,

As the Sine of the Arch last found,

To the Sine of the Reclination:

So is the Sine of the Remainder before found,

To the Sine of the Height of the Pole above the Plain.

3. *For*

3. *For the Deflection, or Substile's Distance from the Meridian,*
As the Co-Sine of the Stile's Height,
To the Radius:
So the Sine of the first Remainder,
To the Co-sine of the Deflection.

4. *For the Plain's Difference of Longitude,*
As the Sine of the first Remainder
To the Sine of the Deflection:
So is the Radius,
To the Sine of the Plain's difference of Longitude.

IX. *North Declining Reclining Plains, Chap. XVIII. Fig. XX, XXI, XXII.*

In these North Recliners Declining Plains, the same three things must be given, and the same four things sought, as were in South Recliners Declining. And they are thus found:

1. *For the Distance of the Meridian and Horizon,*
As the Radius,
To the Tangent of the Declination:
So is the Sine of the Reclination,
To the Co-Tangent of the Meridian and Horizon.

2. *For the Height of the Pole above the Plain,*
As the Sine of the Declination,
To the Radius:
So Co-sine Dist. Meri. and Horizon,
To a Fourth Sine.

Unto this Fourth Sine add the Complement of the Latitude, and reserve the Sum: And say,

As the Sine of the Fourth Sine,
To the Sine of the Reclination:
So the Sine of the Sum last found,
To the Sine of the Poles Height above the Plain.

3. *For the Deflection, or Substile's Distance from the Meridian,*
As the Tangent of the Reclination,
To the Sine of the Fourth Arch before found:
So Tangent Pole's Height above the Plain,
To the Sine of the Deflection.

4. *For the Plain's Difference of Longitude,*
As the Sine of the Stile's Height,
To the Tangent of the Deflection:
So is Radius,
To the Tangent of the Difference of Longitude.

And thus have you in this one Chapter an *Epitome* of the whole Art of *Dialling*, performed by *Trigonometrical* Calculation.

The End of the First Tractate.

GEOMETRICAL DIALLING DEMONSTRATED.

SHEWING,

*Several Ways, how to find the true Places of the
Stile, Substile and Meridian; As also how to
draw the Hour-Lines, upon all Plain Superfi-
cies in their due Positions.*

The Second TRACTATE.

P R O E M E.

IN the fore-going *Tractate*, having largely insisted upon all sorts of *Plains*, upon which *Dials* are usually made, and shewed the Reason of each *Plain* deduced from the *Sphere*; I shall in this *Second Tractate* be more brief, shewing only how the Places of the *Stile*, *Substile* and *Meridian*, may be found upon all sorts of *Plains*, seated in their true Places and Positions, and from them to draw the *Hour-Lines*. And therefore to say nothing of the *Horizontal*, Full North, South, East, or West *Plains*, whether *Erect* or *Reclining*, I shall immediately begin with *Upright Declining Plains*, and from them proceed to *South* and *North Declining Reclining Plains*, giving but one *Example* of each kind.

C H A P. I.

*How to find the Place of the Substile, Stile and Meridian,
and how to draw the Hour-Lines upon an Erect Declining
Plain.*

Figure
I.

OUr First Example shall be of an upright Plain declining from the South Eastward 30 deg. in the Latitude of 51 deg. 32 min.

Upon C, as a Center, describe the Quadrant CAQ, and with the same distance of the Compasses, upon A, (which shall be the Center of the Dial) describe an obscure Arch of a Circle, and herein set off 38 deg.

deg. 28 min. the *Complement* of the *Latitude* of the *Place*, from C to L, and draw the Line AL, prolonging it to D: Also, set 30 deg. the *Declination* of the *Plain*, from Q to X, and draw the Line XC, prolonging it, if occasion be. Then upon C, with the distance CD, describe an occult Arch of a Circle, continuing it, till it concur with the Line XC extended in S: And from S let fall a Perpendicular upon the Line QC extended in R.

Then make CY equal to RS, and draw AY for the *Substilar Line* of your Dial: Then upon Y, erect a Perpendicular YG, making YG equal to CR, and through G, draw AG for the *Stile* of your Dial.

Then setting one foot of your Compasses in Y, with the other take the nearest distance to the *Stile* AG, and set that distance upon the *Substile* from Y to @, So shall @ be the Center of the *Equinoctial Circle*, and the Line GY extended both ways, shall be a *Tangent Line* thereto.

Upon @ as Center describe the Semicircle D * F representing one half of the *Equinoctial Circle*, which done, lay a Ruler from @ to P, where the *Tangent Line* crosseth the *Meridian* or Line of 12. And where the Ruler crosseth the *Equinoctial Circle*, which is at *, there begin to divide the Semicircle into 12 equal parts. A Ruler laid from @ at the Points @ @ @, &c. to every of those Divisions @ @ @, &c. the Center of the *Equinoctial Circle*, I shall cut the *Tangent Line* in the Points 5, 6, 7, 8, 9, 10, 11 on the one side, and at 1, 2, 3, 4 on the other side of the *Meridian*. Lastly, Lines drawn from the Center A, through these Points in the *Tangent Line*, shall be the true *Hour-lines* belonging to the *Plain*: And that the *Stile* and *Substile* are rightly placed, shall be thus *Demonstrated*.

D E M O N S T R A T I O N.

The *Trigonometrical Canon* or Proportion for finding the *Substile's distance* from the *Meridian* being, As the *Radius*, Is to the *Tangent Complement* of the *Latitude*; So is the *Sine* in the *Plain's Declination*; To the *Tangent* of the *Substile's distance* from the *Meridian*.

Now AC being the *Radius*, CD is the *Co-tangent* of the *Latitude*, the Angle CAD being 38 deg. 28 min. by Construction. And if the *Co-tangent* CD be made the *Radius*, it is manifest that the *Sine* of the Angle XCQ, the *Declination* shall be made thereby the *Tangent* of the *Substile's distance* from the *Meridian*, YC.

In like manner it may be proved, that as the *Radius* CD, is to CD the *Co-sine* of the *Latitude* ADC: So is RC, the *Co-sine* of the *Declination*, to RC, the *Sine* of GAY, which was to be *Demonstrated*.

C H A P. II.

How to find the place of the Meridian, Stile and Substile, in Declining, Reclining Plains.

Example I. of a South Plain { *Declining East* 30 deg. 0 min. } *Lat.* 51 d. 32 m.
 { *Reclining* ——— 55 deg. 0 min. }

Draw a right Line LG, representing the Base of the Declining Re-
clining Plain; In any part thereof, as at X erect a Perpendicular, as
XW for the *Vertical Meridian*, extending it to a sufficient Length: Also
draw another Line as QS, parallel to LG, at any convenient distance.

Upon

Figure
II.

Upon X as a Center describe the Arch of a Circle, and thereon set 55 deg. (the *Plains Reclination*) from *a* to *b*, and draw the Line X*b*, extending it till it meet with the Line Q*S* in N.

Then upon A (as a Center) describe a small Arch *cd*, and upon it set off 30 deg. equal to the *Declination* of the Plain, and draw the Line A*B*, between the two Parallel Lines.

Then making X*C* equal to X*N*, draw the Line C*B*, so shall B be the Center of the Dial, and the Line B*C* the *Meridian of the Place*, or Home Line of 12.

Also, make A*M* equal to A*B*, and upon M (as a Center) describe an Arch of a Circle *ef*, and upon it set 51 deg. 32 min. the Latitude of the Place from *f* to *e*, and draw the Line M*e*, extending it till it cut the Perpendicular Line X*W* in Z.

Likewise, make A*K* equal to A*X*, and A*D* equal to A*N*, and draw the Line K*D*, till it cut the Line X*W*, and prolonging it farther if need require.

From Z, let fall a Perpendicular to K*D*, in H, and taking the length K*H* in your Compasses, apply that distance from B (the Center of the Dial) to R in the *Vertical Meridian*; and draw the Line B*R* for the *Substile*.

Lastly, from the Point R, upon the Line B*R*, erect a Perpendicular, as R*E*, making R*E* equal to Z*H*, and from B to E, draw B*E* for the *Stile* of the Dial.

Now this Line R*E* being produced both ways shall be a *Tangent* to the *Equator*, whose Semidiameter must be equal to a Line let fall perpendicularly from R to the *Stile*, and that distance taken and set upon the *Substile* from R, shall be the Centre of the *Equator*, which being divided, and Points found in the *Tangent* Line, the rest of the *Dial* may be finished according to the usual manner.

Note I. If the Point D fall just into the Point Z, the *Plain* passeth through the *Pole*, and the *Plain* is a *Polar Plain*, and so it will do in a *South Plain Declining* 30 deg. and *Reclining* 34 deg. 32 min. in the Latitude of 51 deg. 32 min.

Note II. If the Point D, fall above Z, the *Plain* passeth between the *Zenith* and the *Pole*, and the *South Pole* is Elevated, and so it will do in a *South Plain Declining* 30 deg. and *Reclining* 20 deg. in the Latitude of 51 deg. 32 min.

Note III. If the Point D fall below Z, the *Plain* passeth between the *Pole* and the *Horizon*, (as in this Example) and the *North Pole* is Elevated.

Note IV. That although there will be considerable variation in the *Schemes*, by which these several *Varieties* of *Declining*, *Reclining Plains* are drawn; yet the construction will be the same, for sometimes the Point H, which here falls on that side of the *Vertical Meridian* which is next to S, in a *South Plain Declining* 30 deg. and *Reclining* 20 deg. will fall on the other side thereof towards Q. Likewise the home of 12, that is B*C*, which falls here between the *Substile* and the *Horizontal Meridian*, B*A*, would in such a *Plain* as I last mentioned fall between the *Axis* and the *Substile*.

Note V. As the *Reclination* of any *Plain* increases, the Points N, C and R all approach nearer to A, and when the *Reclination* is 90 deg. they are all Co-incident, and so vanisheth into an *Horizontal Dial*, whose *Substile* will be B*A*. And if the *Declination* be increased, at length the Points B and M, will be Co-incident, and the *Dial Plain* will be parallel to the *Prime Vertical*, and the *Dial* a *South Dial* whose *Substile* may be Z*A*.

DEMONSTRATION.

The Center B is taken at pleasure, in any part of the *Horizontal Meridian*: For the Parallels Q S, and L G, might be nearer or farther off, only the *Diagram* would be *greater* or *lesser* accordingly.

Now because X C is equal to X N, the Face of the Reclining Plain X N shall cut the *Vertical Meridian* X W, and let it cut in the Point C.

And because the Line B C subtends both the *Meridians* B A and A C, and is drawn upon the Plain from the Center, it shall represent the *Meridian of the Place*: For the Sun enlightning the Point C, at 12 a Clock in the *Vertical* X W, and at the same time the Point B, in the *Horizontal Meridian* A B, it shall at the same time illuminate the whole Line B C, so as the *Stile* of the Dial shall shadow the same just at the same time.

Again, because the Triangles A N X and A K D are equiangular and equal: If the point W be the *Zenith*, (the point X supposed to be laid upon the point K) the Lines K D and X N will be equal, and the Angle A K D, equal to the *Reclination*: K D shall then truly represent the *Reclining Plain*.

Moreover, A M, being equal to A B by construction, and the Angle A M Z, equal to the Latitude, the point Z represents a *Pole* of the *Equator*, because the *Axis* M Z, and the *Meridian* A Z, meet there.

If therefore from the *Pole* Z, a *Meridian* Z H, do fall upon the *Plain* K D (or the back side thereof) at right Angles; it shall fall upon a point of the *Substile* in H, which point H, doth therefore limit the *Substile* on that part.

But the *Horizontal Line* in which B, the Center of the Dial is taken, must limit it on the other part also, to wit, in the point X, or K, so that H K is the just length of the *Substile* upon the *Plain*.

And because the *Substile* must both pass through the Center B, and incline to the *Vertical* X W (to which the Plain it self inclines) the Line B R, equal to K H, being so placed, is the *Substile*.

Lastly, Because Z H is the nearest distance between the *Pole* and the *Plain*, E R being equal thereunto, and perpendicular to the *Substile*, it shall be the length of the *Stile*, that is (where the *Substile* B R is *Radius*) the *Tangent* of the height of the *Pole* above the *Plain*, which is all which was to be proved.

C H A P. III.

Example II. Of the North Plain $\left\{ \begin{array}{l} \text{Declining--}60 \\ \text{Reclining--}16 \end{array} \right\} \text{Latit. } 51^{\circ} 32' m.$

AS in the former Example, so in this; First, draw a right Line at pleasure as F Q, which shall represent the *Base* of the Plain.

Assume any Point therein as B, from which Point erect a Perpendicular B Y, extending it both above and below the *Base Line* F Q.

Unto F Q, draw another right Line Parallel thereunto, at any convenient distance, as P M.

Then upon B, as a Center, describe an Arch of a Circle C b, and upon it set

A a

60 deg.

Figure
III.

60 deg. (the *Plain's Declination*) from C to *b*, and draw the Line B *b*, extending it till it meet with the Parallel P M in A.

Again, upon C, a Center describe another little Arch, as *a c*, and upon it set 16 deg. (the *Plain's Reclination*) from *a* to *c*, and draw the Line C *c*, extending it, till it concur with the Base Line F Q in D.

Take in your Compasses the Distance between C and D, and set that distance upon the Perpendicular Line B Y, from C to E, so that E be the *Center* of your Dial, and a Line drawn from E to A, shall be the *Meridian of the Place*, and Hour-line of 12.

Upon D, as a Center, describe an Arch of a Circle *d e*, and upon it set off 38 deg. 28 min. the *Complement* of the *Latitude*, from *d* to *e*, and draw the Line D *e*, extending it, till it meet with the perpendicular Line B Y extended downwards in Z. Then,

Prolong the Line A B, and make B K equal to B Z. and, through the Point K, draw the Line K U parallel to Z Y, cutting the Base Line F Q in S. And make B L equal to S K.

From L, let fall a Perpendicular to D C, *viz.* L O, and make H G equal to C O.

Then from E, the *Center* of the Dial, through G, draw the right Line E G for the *Substilar Line* of the Dial.

Also, upon the Line E G, from the point G, erect a Perpendicular, and make it equal in length to the Line L O, as the Perpendicular G N: Then a Line drawn from the Center E, through N, shall be the *Stile* of the Dial.

And thus have you all the Requisites belonging to this *Reclining Plain*; and if you take the least distance from the point G, to the *Stile* N E, and set that distance upon the *Substilar Line* from G to $\odot$; the point $\odot$ shall be the *Center* of the *Equinoctial Circle*, and the Line N G extended both ways shall be a *Tangent* thereto, by which the Dial may be finished according to the usual way.

D E M O N S T R A T I O N.

Because the Angle A B C, (to which the Angle K B Z is equal) is equal to the *Plain's Declination*: Therefore the Line K B A is the *Horizontal Meridian* upon the Bases P M and F Q. And B K is equal to B Z by construction, and the Triangles D B K and D B Z are equi-angled and equal, having one common Side D B, and a common Angle B D Z, and B K is equal to B Z: Therefore a right Line passing from K in the *Horizontal Meridian* to D, or E in the *Vertical Meridian* Z Y, shall represent the Axis of the Equator; for the Angle B D K equal to B D Z is the *Complement* of the *Latitude*, by construction, and D B Z a right Angle.

And therefore, whensoever the point K, is either shaddowed or enlightened, the point A is the same, and the point E also, because it is in the same *Axis* with K, is at the same time so affected; wherefore, the *Center* of the Dial being at E, a Line drawn from thence upon the *Plain* to A, shall be the *hour* of 12.

And because the *Hypotenusa* D K, or E K, is the *Axis* passing from E, in the *Reclining Plain* by K in the *Horizontal Meridian*, and the point K being in the Line K S H G, a Perpendicular let fall from thence to the *Plain*, shall fall in the same Line K S H G.

Make CY equal to HG , which is also equal to CO : then a Perpendicular from L to X , is the same with that from L to O , namely the Line LO .

And because BL is equal to SK , and CX to HG , therefore a Perpendicular let fall from K to G , shall be equal to LX , or LO .

And because K (as hath been shewed) is a *Point* in the *Axis*, and G a *Point* in the *Dial Plain*, the Perpendicular KG , or LO shall be the *height* or *length* of the *perpendicular Stile* NG : or more properly the *Tangent* thereof, EG being made *Radius*. And the point G , where it cuts the *Dial Plain* at right Angles, shall be a point in the *Substile*.

But E or D is the *Center* of the *Dial*, as hath been already proved; Therefore, a Line drawn from E to G , that is, the Line EG , is the *Substile*.

And because GN , being equal to LO , and the Angle EGN is a right Angle; therefore, the Line EN , drawn by the points E and N is the *Stile*.

Enough is here written to shew how to find the *Meridian*, *Stile* and *Substile*, in all *Declining* and *Reclining Plains*; In which this is worth the observing, that by the *Precepts* here delivered, not only the *Requisites* and their *Magnitudes* or *Quantities* are found; but their true *Places* and *Situations* upon the *Plains* also, all which are obvious together in the very working, or with a very little transposition made so. And for that reason, I have here made choice of *Two* such *Examples* as are before in the first *Tractate* made use of, and the work of them performed by other means, that so the coherence may be the more obvious, both which *Examples* you will find in the 18th and 19th *Chapters* of the preceding *Tractate*.

From the *Precepts* before delivered, it may be *Noted*, That as the *Reclination* may increase, the Points N , E and R , all approach still nearer to A ; and when the *Reclination* is 90 deg. they are all Co-incident. and Vanish into an *Horizontal Dial*, whose *Substile* is BA .

In like manner, if the *Declination* be still increased, at length the Points B and M , will be Co-incident, and the *Dial Plain* will be parallel to the *Prime Vertical Circle*, and the *Dial* a *South Dial*, whose *Substile* may be ZA .

But whether the *Declination* increase or not, if the *Reclination* amount to 70, or above 70 degrees: Then the *Substilar Line* applied (as before) from B to the *Vertical* ZX , it shall fall between the points A and X , upon the *Base* of the *Plain*. And by this means the former *Precepts* may be rendred insufficient, or (at least) inconvenient in such Cases.

And for these Reasons I have added what follows in the next Chapter.

CHAP. IV.

A Second Geometrical Way to find the Requisites belonging to Declining Reclining Plains, agreeable to the Calculatory way before delivered in the First Tractate: and thereby Demonstrated.

Our Example here shall be of a *South Plain, Declining Eastward 30 deg. and Reclining from the Zenith 55 deg.* which is the *Example of the Third Variety of South Declining Reclining Plains* in the *First Tractate, Chap. XVII.*

Wherein let it be required to find	deg.	min.
1. The distance of the Meridian and Horizon	64.	41
2. The height of the Pole or Stile above the Plain	19.	25
3. The distance of the Substile from the Meridian	6.	02
4. The Plain's difference of Longitude	17.	38

I. *For the Distance of the Meridian and Horizon.*

Figure IV With 60 deg. of a Scale of Chords describe the Quadrant ABD: and upon A, erect the Perpendicular AR, which shall be a Tangent Line thereto. Then,

1. Take 30 deg. the Plain's Declination, and set it from A to E; Also take 55 deg. the Reclination and set it from D to G, and from E to G, let fall the Perpendiculars EM and GH; and through E and G draw two right Lines from B, extending them till they cut the Tangent Line in the Points F and R: — So shall GH be the Sine, and AR the Tangent of 35 deg. equal to the Complement of the Plain's Reclination: — Also EM shall be the Sine, and FA the Tangent of 30 deg. equal to the Plain's Reclination.

2. Make AI equal to HL, A Ruler laid from B to I, will cut the Quadrant in K: So is KD the distance of the Meridian from the Horizon, namely 64 deg. 41 min.

Demonstration from Trigonometrical Calculation.

As the whole Sine (or Radius) AB 90 deg.

Is to BH, the Sine of the Reclination 55 deg.

So is AF the Tangent of the Declination 30 deg.

To AI, the Tangent of the Arch AK 25 deg. 9 min.

Whose Complement is the Arch DK 64 deg. 41 min. the distance of the Meridian and Horizon.

II. *For the height of the Pole or Stile above the Plain.*

1. Extend the Line ME, till it cut the Line BR in P, and make AN equal to MP: So is AN the Tangent of the Arch A*, which measured upon the Chords will be 31 deg. 14 min. Which Arch being less than the Latitude of the Place 51 deg. 32 min. Subtract it therefrom; so will the remainder be 20 deg. 18 min.

2. Set

2. Set 20 deg. 18 min. the Arch last found from A to Q, and draw the Line Q C perpendicular to A B — Also make B S equal to Q C — B O equal to B R — And B W equal to B M — So shall B S be the Sine of 20 deg. 18 min. the Arch last found — B W the Sine of 60 deg. the Complement of the Declination — and B O the Sine of 64 deg. 41 min. the distance of the Meridian from the Horizon.

3. Take in your Compasses the distance B S, and setting one foot in O, with the other describe an obscure Arch of a Circle *a a*, and from B, draw a Line B *m*, which may only touch the top of the same Arch, which done, set one foot of the Compasses in W, and with the other take the nearest distance to the Line B *m*, which distance set from B to V; and draw the Line V T parallel to A B, so shall T A measured upon the Scale of Chords be 19 deg. 25 min. for the height of the Pole or Stile above the Plain.

Demonstration from Trigonometrical Calculation.

(1.) As the whole Sine (or *Radius*) A B 90 deg.

Is to B M (the Sine of the Complement of the Plain's Declination) 60 deg.
So is A R (the Tangent Complement of the Reclination) 35 deg.

To A N (the Tangent of the Arch A *) 31 deg. 14 min.

Which Arch being taken out of the Latitude 51 deg. 32 min. leaves
20 deg. 18 min. which is an Arch of the Meridian of the Place intercepted between the Plain, and the Pole of the world.

(2.) As the Sine B O (the distance of the Meridian and Horizon,) 64 deg. 41 min.

Is to the Sine B S (the Arch last found) 20 deg. 18 min.

So is the Sine B W (the Complement of the Plain's Declination) 60 deg.

To the Sine B V (whose Arch A T is the height of the Pole or Stile above the Plain.)

III. *For the Substile's Distance from the Meridian.*

Take B V the Sine of the Stile's height 19 deg. 25 min. and setting one foot in D, with the other describe the Arch *cc*, and from B, draw the right Line B *o* only to touch the top of the Arch *cc* — Then setting one foot of your Compasses in S, with the other take the least distance to the Line B *o*, this least distance set from B to Y and through Y draw Y X parallel to A B, so shall B Y be the Sine, and A X the Arch or Chord of 6 deg. 2 min. and is the distance of the Substile from the Meridian.

Demonstration from Trigonometrical Calculation.

As the Sine of B V (the height of the Pole above the Plain) 19 deg. 25 min.

Is to the *Radius* B D (90 deg.)

So is the Sine of B S (the Arch of the Meridian between the Pole and the Plain) 20 deg. 18 min.

To B Y (the Sine of A X) 6 deg. 2 min.

Which is the Substile's distance from the Meridian.

IV. *For*

IV. For the Plain's Difference of Longitude.

Take B S and set it from B to Z, so is B Z the Sine of 20 deg. 18 min. (the Arch of the Meridian between the Pole and the Plain.) ----- Also take B Y, the Sine of 6 deg. 2 min. (the height of the Pole above the Plain.) And setting one foot in Z, with the other describe the Arch *nn*: Lay a Ruler to B, and this Arch *nn*, and draw an obscure Line thereby, till it cut the Quadrant in *Æ*: So shall A *Æ* be 17 deg. 38 min. for the Plain's Difference of Longitude.

Demonstration from Trigonometrical Calculation: For,

As the Sine of Z B (the Arch of the Meridian between the Pole and the Plain) 20 deg. 18 min.

Is to the whole Sine (or Radius) A B 90 deg.

So is the Sine Y B (the Substile's distance from the Meridian) 6 deg. 2 min.

To the Sine of the Arch A *Æ*, 17 deg. 38 min.

Which is the Plain's Difference of Longitude.

CHAP. V.

How by the Help of an Horizontal Dial in any Latitude, to draw the Hour-Lines, find the Place of the Stile and Substile for any Upright Declining Plain in the same Latitude.

Figure V. **O**ur Example shall be of an Upright Plain Declining from the South towards the West 30 deg. in the Latitude of 51 deg. 32 min.

First, draw a right Line R T, representing the Base or Horizontal Line of the Declining Plain.

Secondly, In this Line, assume any Point, as A, and from it draw another right Line A S, making the Angle S A T, equal to 30 deg. the Plain's Declination: Which Angle must be made towards the Right hand of A, if the Plain decline Westward (as here it doth) or towards the Left hand if the Plain decline Eastward.

Thirdly, Upon this Point A, erect a Perpendicular to the Line R T, for the Meridian Line of the Declining Plain; ----- And (from the same point A) another perpendicular to the Line A S, for the Meridian of the Horizontal Dial.

Fourthly, In any part of this last Perpendicular, assume any Point at pleasure, (as X,) and make that the Center of an Horizontal Dial, and upon it describing a Circle, set thereon the Hour-arches proper for an Horizontal Dial for your Latitude (namely of 51 deg. 32 min.) at the marks * * *, &c.

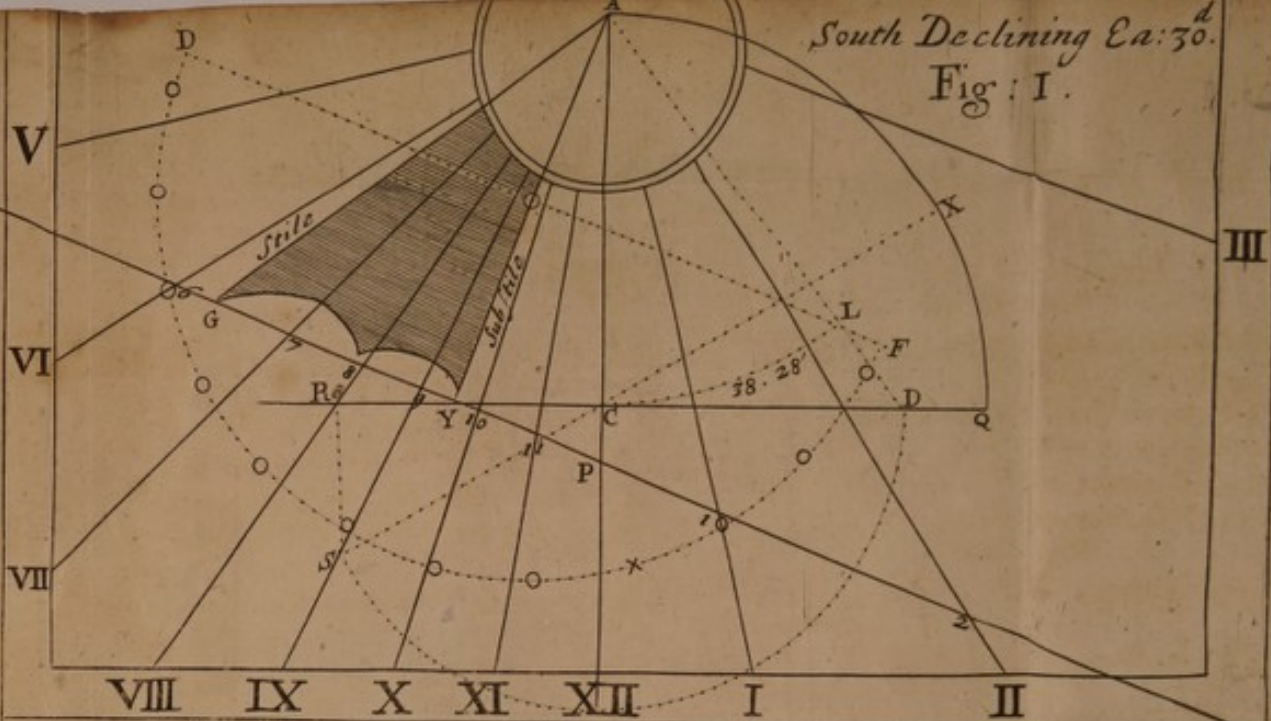
Fifthly, From the Center X, which is the Center, and the several Points * * *, &c. draw right Lines, extending them till they concur or meet with the Horizontal Line of the Declining Plain R T first drawn, at the Points 9, 10, 11 and 1, 2, 3, 4, 5, &c.

Sixthly, Upon the Center X, make the Angle A X P, equal to the Latitude, 51 deg. 32 min. and draw the Line X P, cutting the Line A S in P.

Seventhly, Make A Z equal to A P, so shall Z be the Center of the Declining Dial.

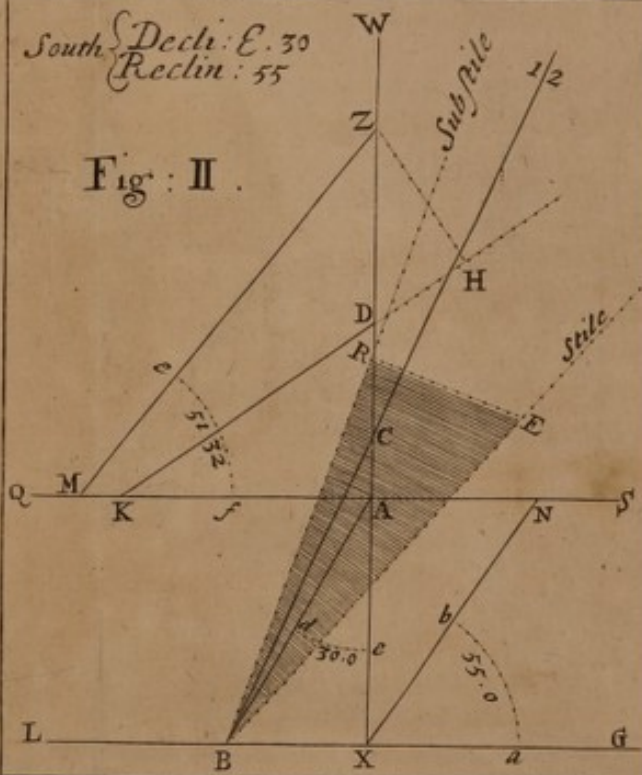
Eighthly,

South Declining Ea: 30.
Fig: I.



South Decl: E. 30
Reclin: 55

Fig: II.



North Declining West. 60.
Reclining — 16.

Fig: III.

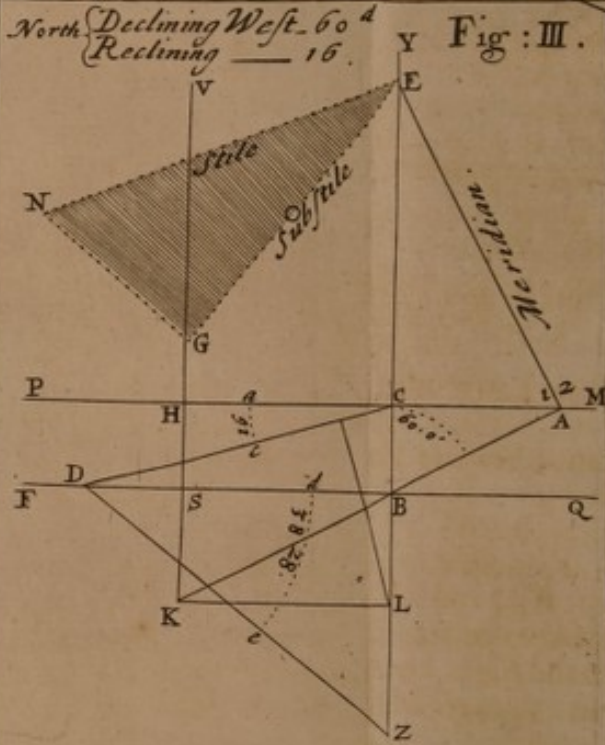


Fig: IV.

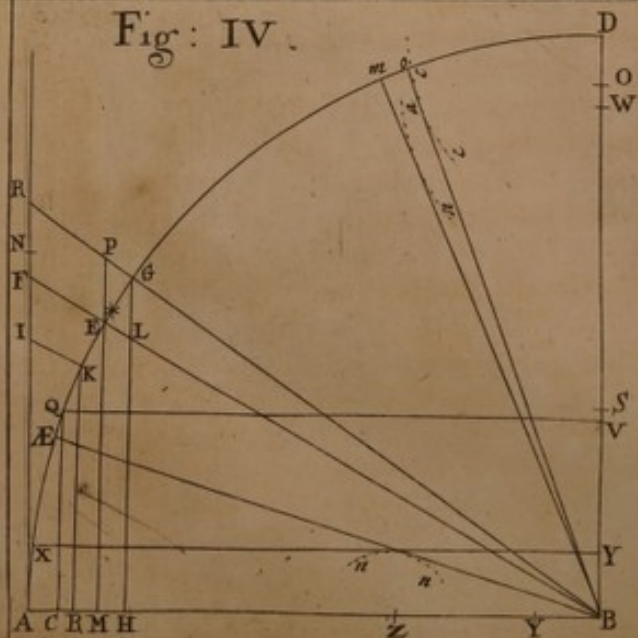
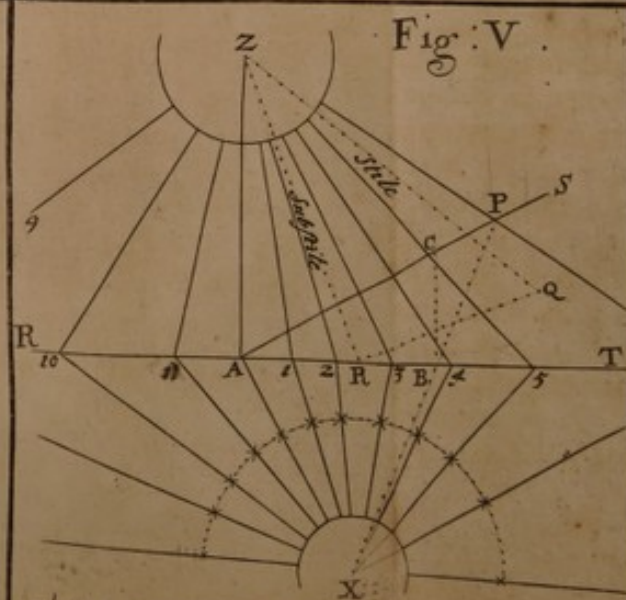
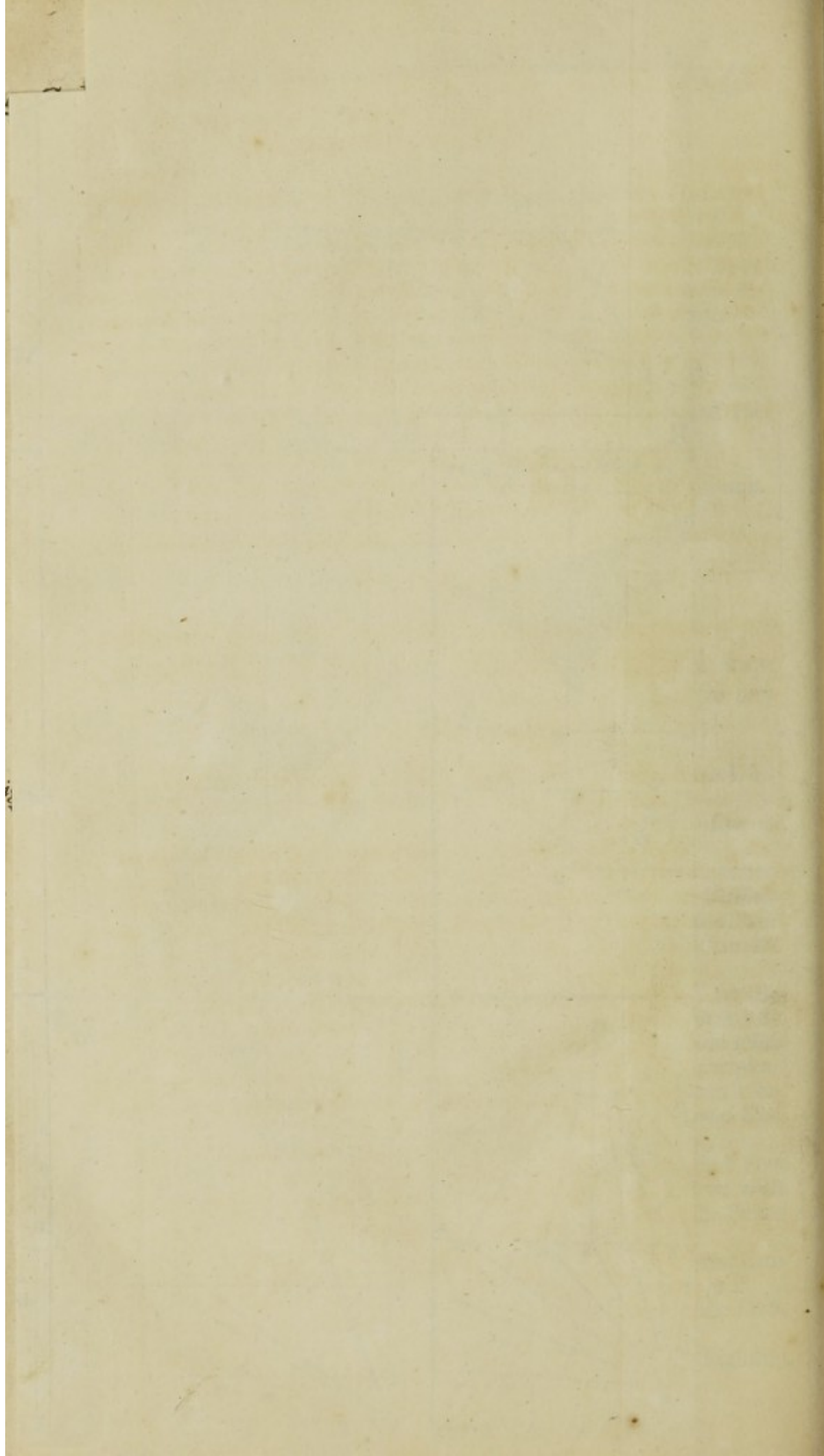
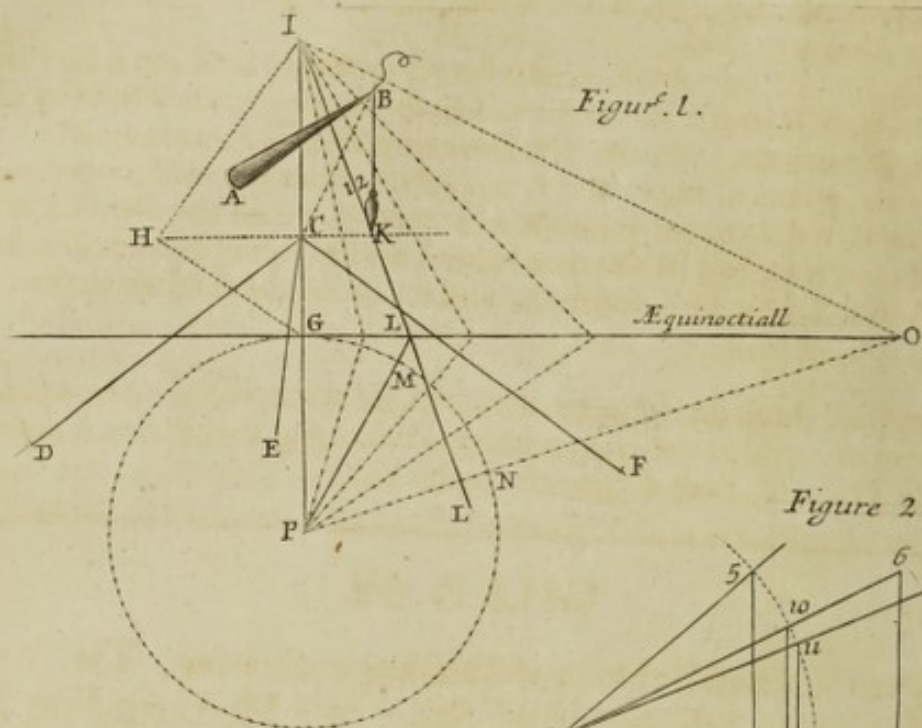


Fig: V.



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Figur. 1.

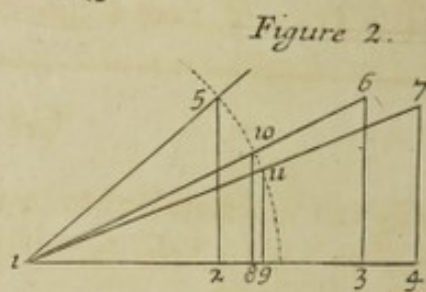
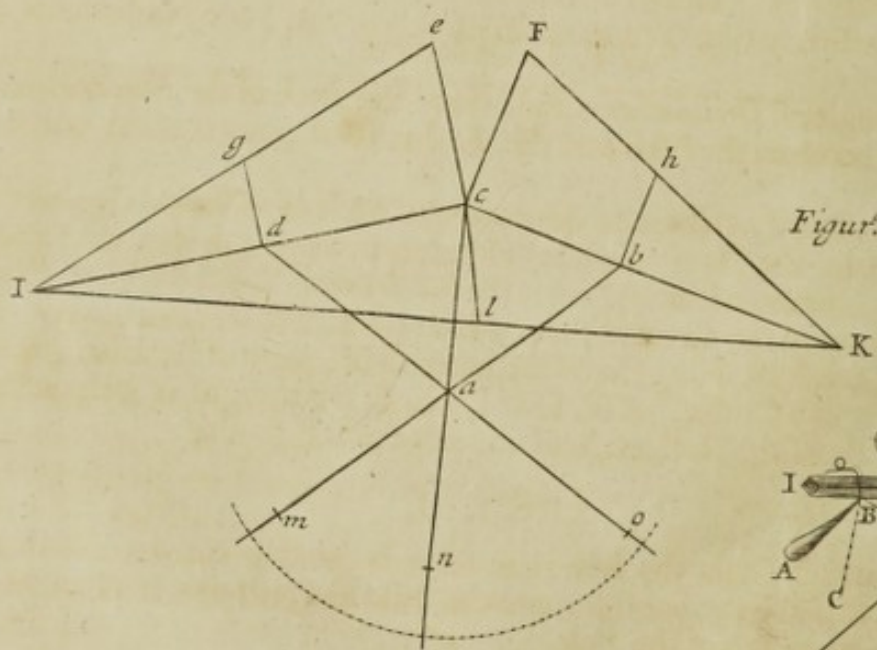


Figure 2.



Figur. 3.

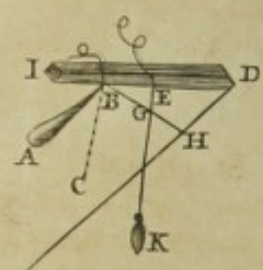


Figure 4.

Against Page 95. Chap. XI of 9 ninth Tractate

Eighthly, Upon the point B, (where the Line X P cutteth the Horizontal Line of the Declining Plain, R T) erect a Perpendicular, cutting the Line A S in C.

Ninthly, Make A R, equal to B C and draw the Line Z R, for the *Substile* of the *Declining Dial*.

Tenthly, From the point R, erect a Perpendicular to the Line Z R, making R Q equal to A B, and draw the Line Z Q for the *Stile* of the *Declining Dial*.

Lastly, If from the Center of the Declining Plain Z, you draw right Lines to the several points 9, 10, 11 and 1, 2, 3, &c. (where those *Hour-lines* of the *Horizontal Dial* did concur with the *Horizontal Line* of the *Declining Plain* R T,) those Lines shall be the true *Hour-lines* belonging to your Declining Plain: And so is your Dial finished; and the *Stile* and *Substile* in their due Places.

If Any shall think this Chapter deficient for want of Demonstration, let them know, that the Demonstration belonging to the First Chapter of this Tractate, doth Demonstrate this also.

CHAP. VI.

A Third Geometrical Way of Dialling: Shewing, The Manner how to inscribe the Substile, Stile, and Meridian-line in all Plains.

SECT. I. Definitions.

BY the Angle of *Declination* is understood the Arch of the *Horizon* intercepted between the *Plain* and the *East* or *West* point toward which it declineth.

By the Angle of *Erection* is understood the Arch of a *Vertical Circle* intercepted between the *Plain* and the *Horizon* toward the depressed Pole; which in our Northern Hemisphere is the *South Pole*. Wherefore the *Plains* which lean toward the elevated Pole (which by others are called *North* inclining, and *South* reclining) have evermore their Angle of *Erection* greater then a quarter of a Circle. And such *Plains* as are upright or perpendicular on the *Plain* of the *Horizon*, are said to be erected 90 deg.

SECT. II.

In *Horizontal Dials* the *Meridian-Line* is directly drawn *North* and *South*: and it is also the *Substile*, and the *Stile* hangeth over it at an Angle equal to the *Elevation* of the *Pole*.

SECT. III.

In *North* and *South* upright *Plains* the *Six-a-Clock-Line* is drawn parallel to the *Horizon*, and the *Meridian-Line* is to be drawn perpendicular to it; and the *Meridian-Line* is also the *Substile*: over which the *Stile* is to hang a an Angle equal to the *Complement* of the *Elevation* of the *Pole*.

SECT. IV.

S E C T. IV.

In *North* and *South* Plains which stand not upright but bowing, the Six-a-Clock-Line also is parallel to the Horizon. And the Meridian-Line is perpendicular thereto; being also the Substile. But the Angle which the Stile maketh with it is thus found out. Add the Angle of Erection to the Height of the Pole, and the Aggregate thereof shall be the Angle of the Stile's Altitude to be accounted from the upper end of the Meridian in *South* Plains, but from the lower end in *North* Plains.

If the Aggregate be just 90 deg. the Plain is parallel to the *Æquinoctial*. If it be just 180 deg. the Plain is parallel to the Sixth Horary Circle, and consequently to the *Axis* of the World: and hath therefore no Center. If it exceed 180 deg. subduct 180, and the Arch remaining shall be the Altitude of the contrary Pole.

For it is to be noted that in our *Northern* Hemisphere in all kind of *North* Dials the *North* Pole is elevated, and the Stile pointeth upwards from the Center: and in all kind of *South* Dials the *South* Pole is elevated, and the Stile pointeth downwards; except in such cases wherein it is required otherwise.

S E C T. V.

East and *West* Plains are parallel to the Meridian or Twelfth Horary Circle; and consequently to the *Axis* of the World: and have therefore neither Center nor Meridian-Line. And in them the Substile is a Line drawn up toward the *North* from a Line parallel to the Horizon, at an Angle equal to the Elevation of the Pole: and is therefore parallel to the *Axis* of the World.

C H A P. VII.

A general way for the Inscription of the Substile, Stile and Meridian, in all Declining Dials.

Figure
I.

DRraw a long line parallel to the Horizon, and note the *East* and *West* ends thereof: cross it with a perpendicular line, being the Diameter, describe a Semicircle that way toward which the Declination is either *East* or *West*. Then beginning at the upper end of the Diameter if the Plain stand *Southward*, or else at the lower end, if it stand *Northward* (but contrarily in the *Southern* Hemisphere) reckon upon the Semicircle these three Arches, namely the Elevation of the Pole, the Declination of the Plain, and the Erection thereof. To the end of each of these Arches draw a Line out of the Center *A*, But the Line of the Declination must be extended beyond the Center. Take also on the first line the point *B* toward the Semicircle where you shall see convenient: and through the point *B* draw a Line parallel to the Diameter, cutting the Line of erection in *E*, and the Line of the Pole's Altitude in *C*. Then on the Line of Declination beyond the Center measure *AP* equal to *BC*, and through the point *P* draw a long line parallel also to the Diameter called therefore the second parallel. Also from the point *E* draw a long line for the Horizon parallel to *AB*, cutting the line of Declination in *D*, the Diameter in *G*, and the second parallel in *F*.

Again

Again from the Center A upon the Diameter toward the contrary end to that where you began to reckon the three Arches, measure A L equal to A E, and through L draw the Prohorizon parallel also to A B, cutting the second parallel in H, and thereon measure L M equal to D G directly under it: Draw A M for the Meridian-line.

Lastly, on the Line of Erection measure A N equal to P F, and from the point N draw the Line N O parallel to the Diameter: and on the second parallel from the point H measure H S toward the Horizon equal to N O, And from the Center draw A S for the Substile, over which the Stile must stand perpendicularly having at S the height of the line A O, wherefore upon the point S erect the Line S Z perpendicular to the Substile and equal to the Line A O, and from the Center draw A Z for the Stile, so that the angle Z A S shall be the height of the Stile above the Substile.

Note that if the point P fall not between the Horizon and the Prohorizon, the contrary Pole shall be elevated, and therefore the Substile and Stile shall be drawn forth on the other side of the Center, as it is done in the second Figure.

And if the point P fall on the Horizon, the Plain is parallel to some one Meridian Circle, and consequently to the *Axis* of the World, and hath therefore no Center. An example of this kind (because it is mistaken by many Writers of the Art of Dialling) is here after set down.

And if the Declining Plain be upright or erected 90 deg. the Horizon shall be the Line A B, and the Prohorizon shall be drawn parallel to it at the distance of the Line A B, and the point S shall fall upon the point H, upon which the Stile shall have height equal also to P F. And the Line or Diameter A L shall be the Meridian.

If the Arch of Declination chance to be so great, that the point D, being the concurrence of the Line of Declination with the Horizon, will not fall with your Paper, you may find out the Angle L A M for the drawing of the Meridian Line, thus.

Draw a Line $\alpha \epsilon$ as in Fig. I. touching the Semicircle in the Diameter: and thereon measure $\alpha \lambda$ equal to the sine $\gamma \theta$: then draw the Line $\lambda \mu$ parallel to the Line of Declination. Lastly, out of the Center draw A μ : So have you the Angle $\lambda A \mu$ sought for.

C H A P. VIII.

II. The manner how to inscribe the rest of the Hour-lines.

TAKE the point R any where upon the Substile formerly inscribed; and through it draw a long line perpendicularly T R V for the Contingent line: and where the Contingent line crosseth the Meridian line, note that point with the letter K. Then measure the nearest distance of the Stile from the point R, and set R Q upon the Substile equal to it: Q shall be the Center of the *Æquinoctial* Circle: describe therefore the *Æquinoctial* Circle of what bigness you will upon the Center Q. And laying your Ruler upon the Center Q and the point K, the Intersection of the Meridian and Contingent lines, draw the Line Q K X cutting the *Æquinoctial* Circle in X. This Line Q K X is the Meridian line of the *Æquinoctial*, at which you must begin to divide that Circle. Divide it therefore (beginning at X) into 24 parts.

Figure
III.

C c.

Then

Then applying your Ruler unto the Center Q and each of those Divisions which are in the two Quadrants of the *Æquinoctial* next to the Contingent line, where in every place your Ruler cutteth the Contingent, make there obscure Pricks. And out of A the Center of the Dial through each of those obscure Pricks draw fair long lines for the Hour-lines. And by continuing those Hour-lines through the Center you may fill up the whole 24 Hours.

But if the Dial have no Center, the Hour-lines must be drawn parallel to the Substile: and the height at which the Stile shall hang parallel above the Substile, shall be equal to the space between the Contingent line, and the Center of the *Æquinoctial*, that is equal to Q S.

The Hour-lines being drawn must be noted with their proper figures beginning at the Meridian, or Noon, or 12 a-clock-line: and from thence setting down the morning Hours on the *West* side; and the afternoon Hours in order on the *East* side. And the Dial will be more artificial and seemly if you omit all those Hours which serve not for use at some time of the year.

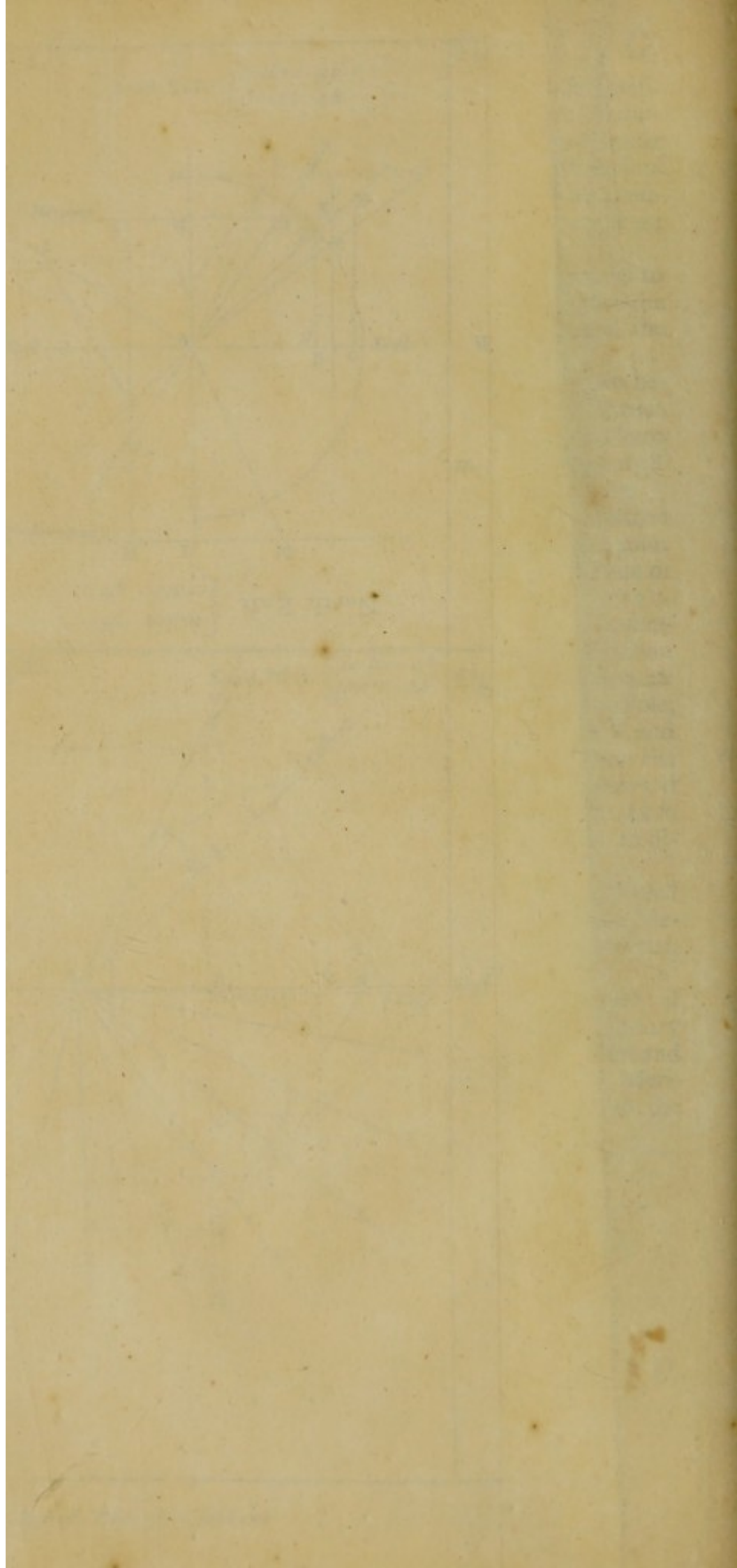
Figure IV. Now concerning such Dials in which the point P falleth on the Horizon (an example whereof is in the second figure following) although the point M falleth upon S, yet the Substile (by reason of the obliquity of the Plain of the Meridian unto the Plain of the Dial) shall be distracted from the 12 a-clock-line: In which case you shall find out the Meridian of the *Æquinoctial* thus, Through the point γ , in which the Line of the Erection cutteth the Semicircle, draw $\gamma \delta$ parallel to the Diameter, then with your Compasses take $\zeta \eta$ the Sine of the Complement of the Elevation of the Pole, and setting one foot in γ with the other foot describe x in the Line A B, and thereunto draw the Line γx . Then upon the *Æquinoctial* Circle from the Substile measure out the Angle A Q X equal to the Angle $x \gamma \delta$, downward if the Plain be *South*, but upward if it be *North*. And so shall you have Q K X the Meridian of the *Æquinoctial*, whereat you must begin to divide that Circle.

The example in *Fig. III.* may serve for all Dials having Centers: if withal you remember that in such Dials which have the same Line both for the Meridian and Substile, the same Line also is the Meridian of the *Æquinoctial*, which you must begin to divide.

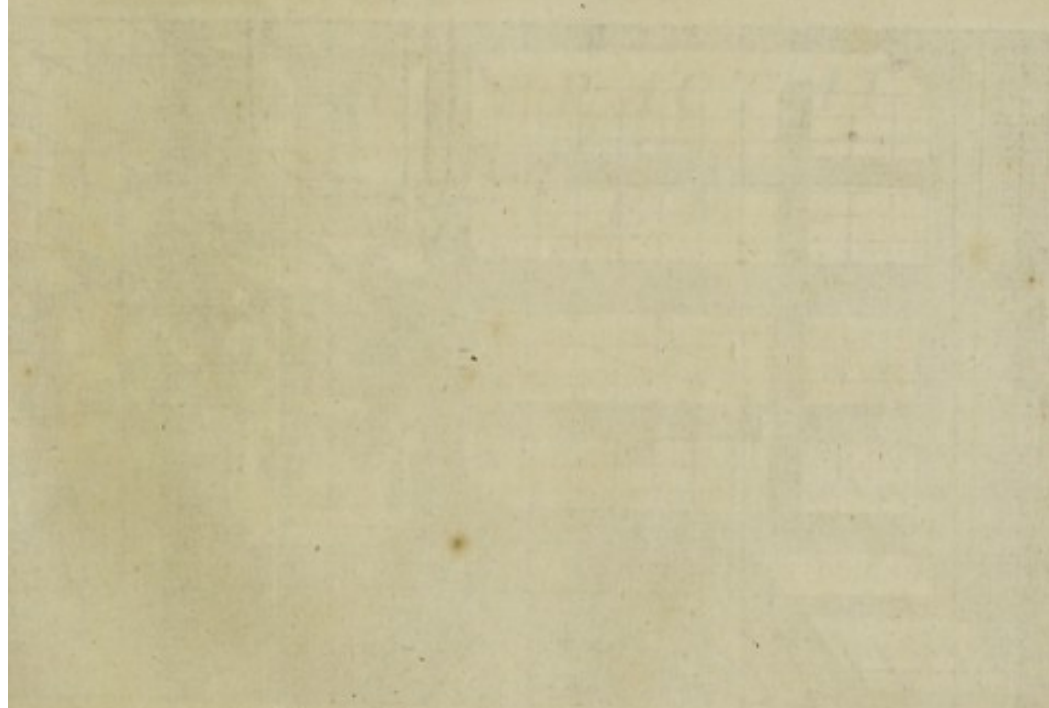
The example in *Fig. IV.* may serve for all Dials having no Centers: if withal you remember that in Dials parallel to the Plain of the Sixth Horary circle, the same Line is the Substile, and the Meridian both of the Dial and of the *Æquinoctial*. And that in *East* and *West* upright Dials the Meridian of the *Æquinoctial* is that Diameter thereof, which is parallel to the Contingent line.

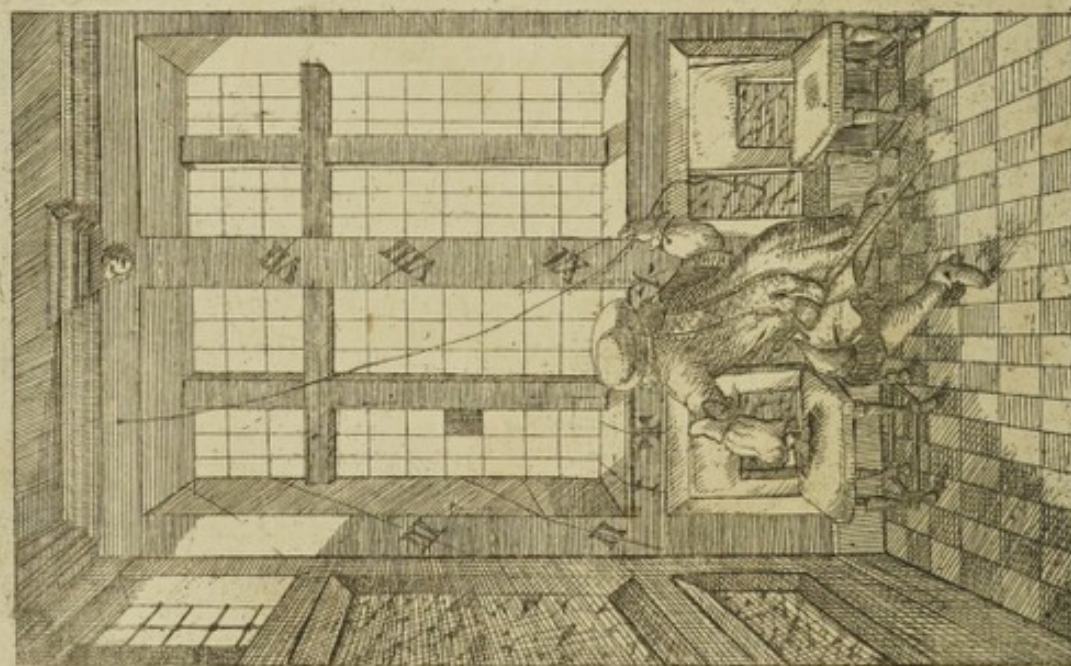
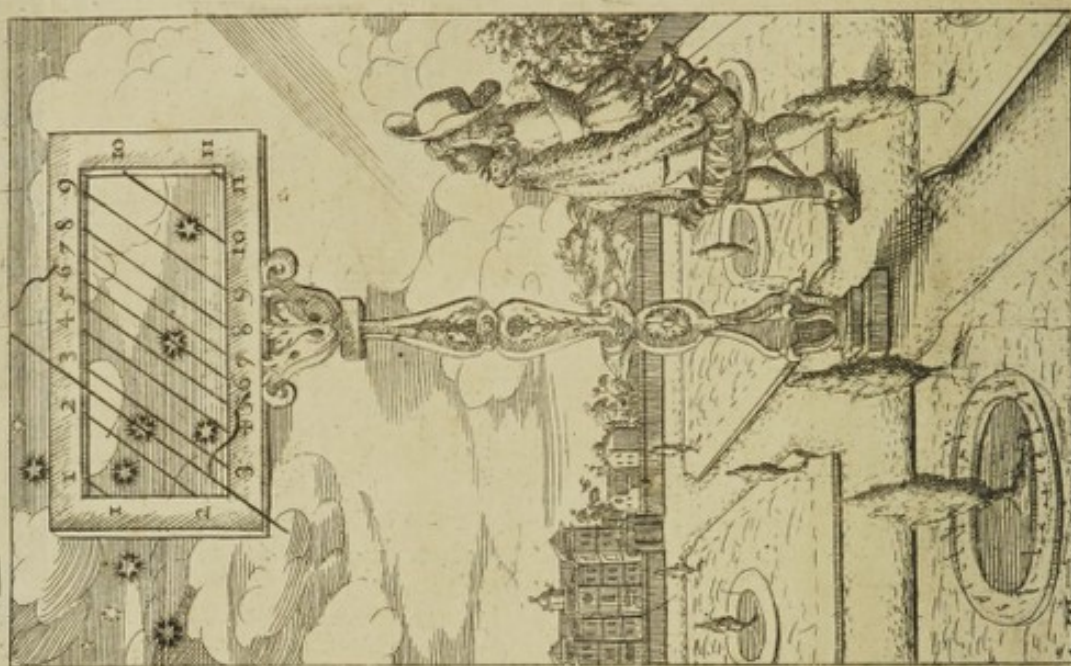
The End of the Second Tractate.

INSTRU-



INSTRUMENTAL DIALLIN





INSTRUMENTAL DIALLING

Performed by

SCALES of *Natural SINES & TANGENTS.*

Shewing (by an easie *Artifice*) in any *Latitude*, how *Hour-Lines* may be described upon all kind of *Plain Superficies*; by Referring all *Declining Reclining Plains*, to *New Latitudes* and *New Declinations*; where they shall become only *Upright Decliners*.

A N D

How the same *Work* may be performed, by *Trigonometrical Calculation*, by the CANONS of *Artificial SINES & TANGENTS.*

The Third T R A C T A T E.

P R O E M E.

IN this *Traēctate* I shall be very brief, the manner of making of *Sun-Dials* by help of these *Scales* being very easie to perform, and no less delightful to put in Practice: And, the manner of working being (almost) the same in all *Cases*, I shall not need to give *Examples* in all Varieties of *Plains* but in *One* or *Two*, which will be sufficient for all *Cases*. For one *Example* may very well serve for all *Vertical* or *Horizontal*, all *Direct North* and *South Plains*, whether *Erect*, *Reclining* or *Inclining*: And another *Example* of an *Upright Plain*, *Declining* from the *North* or *South*, towards the *East* or *West*: For all other *Plains*, as *Direct East* or *West Recliners* or *Incliners*; as also of all *North* and *South Recliners* or *Incliners*, which *Decline* also; Those (by the *Artifice* delivered in this *Traēctate*) may be Reduced to a *New Latitude*, and a *New Declination* in that *Latitude*, where they shall stand as *Upright Declining Plains*. And, forasmuch, as all *Instrumental* ways (at the best) are subject to some inconveniencies in many *Cases*, I have therefore also framed *Canons*, whereby this *Artificial* way of Referring *Declining Reclining Plains* to *New Latitudes* and *New Declinations*, where they may stand as *Upright Plains*, may be performed by *Trigonometrical Calculation*, by the *Canons* or *Tables* of *Artificial Sines* and *Tangents*.

C H A P.

C H A P. I.

Of *Vertical or Horizontal, as also of Direct North or South Erect, or Reclining and Inclining Plains, how to describe Hour-Lines upon them.*

What these several *Plains* are, hath been already shewed in *Chap 3. Tractate I*, And that there is nothing in all these *Plains* required to be known before *Hour-lines* can be drawn upon them, but the *Latitude* of the Place and *Reclination* or *Inclination* of the *Plain*: And how that may be attained is also shewed at large in the 14th and 16th Chapters of the First *Tractate*. And therefore to pass by the finding of those things I will immediately proceed to *Examples*.

Suppose therefore, that a *Direct South Plain*, in the *Latitude* of 32 deg. should *Recline* from the *Zenith* 28 deg.

By the forementioned *Chapters*, the Height of the Pole above such a *Plain*, would be found to be 30 deg. For 28 deg. the *Reclination* of the *Plain* being Subtracted from 58 deg. the Complement of the *Latitude*, the Remainder will be 30 deg. and so much is the Pole Elevated above the *Reclining Plain*. Which known; the Dial may be made as followeth.

Figure
I.

1. Draw two right Lines, one for the *Meridian*, and *Hour-line* of 12; the other for the *Horizon*, and *Hour-line* of 6; crossing at right Angles in O, the Center of the Dial.

2. In all these *Horizons*, *Direct North* or *South Plains*, whether *Erect*, *Reclining* or *Inclining*, Take [always] 90 deg. out of the Scale of *Sines*, (or 45 deg. out of the Scale of *Tangents*, which is equal thereto) and set that distance upon the *Meridian Line*, from O, the Center of the Dial, to X.

3. Out of the Scale of *Sines* also, take the height of the Pole above the *Plain* (in this *Example* 30 deg.) and set them from O to A, and from O to B, and draw the Lines AX and BX.

Figure
II.

4. For the finding of the *Hour-points*, you must draw a right Line as CED, and taking 45 deg. from your *Tangent Scale*, with that distance, upon E as a Center, describe the Semicircle CFD: Also, from your Scale of *Tangents* take 15. deg. (or one hours Equinoctial Distance,) and set them from E to II, likewise, take 30 deg. and set them from E to I. And at E set E III. — In like manner, the whole *Hour-spaces* E III: E II: E I, being thus pricked down upon the Line ED, you may insert between them the Equinoctial Distances for the Halves, and Quarters of Hours, by taking 3 deg. 45 min. for one Quarter, 7 deg. 30 min. for half, and 11 deg. 15 min. for 3 quarters of an Hour, out of your *Tangent Scale*, and setting them from E to 1 2 3 for the quarters of that Hour — Also 18 deg. 45 min. — 22 deg. 30 min. and 26 deg. 15 min. will divide the Space between the *Hour-points* of I and II into Quarters also — And Lastly, 33 deg. 45 min. — 37 deg. 30 min. and 41 deg. 15 min. will divide the Space between the *Hour-points* of I and D into Quarters likewise: And so is your *Semicircle*, or *Hour-Scale* ED, rather, divided.

And

And here Note, That this *Semicircle*, or *Hour-Scale* being thus prepared, it is ready to find the Hour-points, not only in these *Direct Plains*, but in all upright *Declining Plains* also — And now let us proceed to finish the Dial.

5. Take in your Compasses the length of the Line A X or B X, and set that distance upon the Semicircle from D to *a*, and draw the Line C *a*.

6. Set one foot of the Compasses in the Hour-point of I, in the Line E D of the Semicircle, and with the other take the least distance to the Line C *a*, which set upon the Lines A X and B X, from X to 5 and from X to 7, and also from A to 11, and from B to 1. — Again, Set one foot of your Compasses in the Hour-point of II, in the Line E D of the Semicircle, and with the other take the nearest distance to the Line C *a*, and set that distance upon the Lines A X and B X of the Dial, from X to 4, and from X to 8: and also from A to 2 and from B to 10. — Lastly, the least distance taken from E (or III the third Hour-point in the Semicircle) to the Line C *a*, must be set upon the Lines A X and B X from X to 9, and from X to 3.

7. Lines being drawn from O, the Center of the Dial, through the respective Points 1, 2, 3, &c. 11, 10, 9, &c. they shall be the true Hour-lines belonging to the Reclining Plain.

8. Lastly, The Stile must stand upon the Meridian Line O X (which is also the Substile) making therewith an Angle of 30 deg. and so is the Dial finished.

Note, In the same manner as you found the Points for the whole hours, by taking the least distances from the hour-points of I. II and III, to the Line C *a*; So may Points for the Halves and Quarters of Hours be found by taking of the least distances from the Points 1, 2, 3 to the same Line C *a*.

C H A P. II.

Of Upright (or Erect) Declining Plains, and how to find the Place of the Stile and Substile; and to describe Hour-Lines upon such Declining Plains in any Latitude.

Let it be required to describe *Hour-Lines*, and to find the place of the *Stile* and *Substile* upon an *Upright Plain*, *Declining* from the *South* towards the *East* 20 degrees, in the *Latitude* of 46 deg.

1. Draw a right Line perpendicular to the *Horizon* for the Meridian of the Place, and Hour-line of 12. Towards the upper part thereof, if the Plain behold the South, as here it doth (or towards the lower part thereof if the Plain had beheld the North) assume any point, as G, for the Center of the Dial. Figure III.

2. Out of your Scale of *Tangents* take 46 deg. the Latitude of the Place, and set them from G to H. Also, from the same Scale take 44 deg. the Complement of the Latitude, and set them from G to Q and from H to K, making G Q and H K perpendicular to G H, and then draw Q K which will be parallel and also equal to G H.

3. From the Scale of *Sines* take 20 deg. the Plain's Declination, and set them
D d them

them from H to L, and from Q to R, through which points, draw GL for the *Substile* of the Dial, and GR for the *Hour-line* of Six, which Hour-line of Six you must draw quite through the Center of the Dial.

4. Take 70 deg. the Complement of the Plain's Declination, out of the Scale of Sines, and set them from G to 12, upon the Line GH, and from L to M, making ML perpendicular to GL; and, through M, draw GM for the *Stile* of the Dial.

5. Out of the Scale of Sines take 44 deg. the Complement of the Latitude, and set them upon the Line GQ, from G to P, and through P, draw a Line P6 Parallel to GH, cutting the Hour-line of Six in 6.

Figure

II.

7. Take in your Compasses out of your Dial-plain the shorter Line 12. 6, and repairing to your Semicircle, set it from D to *b*, and draw the Line C*b*. — Also take the longer Line 12. 6, and set it upon the Semicircle from D to *c*, and draw the Line C*c*,

8. From the Hour-point of I. in the Hour-scale, or the Semicircle, take the least distance to the Line C*b*, and set that distance upon your Dial from 12 to 7, and from 6 to 11 — Also take from the point II, the least distance to the Line C*b*, and set that distance upon your Dial from 12 to 8, and from 6 to 10 — And the least distance taken from III or E, to the Line C*b*, must be set upon the Dial from 12, or 6, to 9. And thus are Points for Six of the Hour-lines found. — In like manner, take the least distance from the Hour-point of I, to the Line C*c*, and set that distance upon the Dial from 12 to 5, and from 6 to 1. — Also the least distance from II to C*c*, must be set from 12 to 4, and from 6 to 2. — And Lastly, the distance from III or E, to C*c*, must be set from 12, or 6, to 3. And so have you points for all the hours. — Through which right Lines drawn from the Center, shall be the true Hour-lines required to be drawn.

In the same manner may the Halves and Quarters of Hours be inserted; And for the *Stile* of the Dial it must stand Perpendicular upon the Substilar Line GL, making an Angle therewith equal to the Angle MGL. And so will your Dial be finished.

C H A P. III.

Of East and West Reclining or Inclining Plains.

THESE East and West Reclining and Inclining Plains may be described and drawn by the directions of the last Chapter; If first, you find out in what *Latitude* such an East or West Reclining Plain, will be an *Erect* or Upright Plain; And also, what *Declination* that Upright Plain shall have in that *New Latitude*: And in East or West Reclining or Inclining Plains this *New Latitude* and *New Declination* may be easily found: For;

1. The *New Latitude* will be (always) the Complement of the *Old Latitude*. And;
2. The *New Declination* will be (always) equal to the Complement of the *Reclination* in the *Old Latitude*.

Example: Suppose, that a Direct East or West Plain in the *Latitude* of 35 deg. should Recline from the *Zenith* 26 deg. 30 min. In what *Latitude* will

this

this *East Reclining Plain* be an *Upright Plain*? And what *Declination* shall it have in that *New Latitude*?

1. The *Old Latitude* is 35 deg. the *Complement* whereof 55 deg. is the *New Latitude*.

2. The *Old Reclination* is 26 deg. 30 min. and the *Complement* thereof 63 deg. 30 min. is the *New Declination*. Wherefore;

If you make (by the directions of the last Chapter) an *Upright Dial*, Declining 63 deg. 30 min. in the *Latitude* of 55 deg. That *Dial* shall be the same with a *Direct East Dial Reclining* 26 deg. 30 min. in the *Latitude* of 35 deg.

Only this is to be remembred, That in all *Upright Plains* the *Hour-line* of 12 stands *Perpendicular* to the *Horizon*, and in all *East or West Recliners* the *Hour-line* of 12 must lie *Parallel* to the *Horizon*.

An *Example* of an *East or West Reclining Dial*, you have in the 14th Chapter of the *First Treatise*, Fig. IX.

Note moreover, that when the *New Latitude* and *New Declination* are found as before, the *Upright Dial* must be drawn to the *New Latitude* and *New Declination*, and not to the *Old*.

C H A P. IV.

Concerning North and South Plains, which do both Decline and Recline.

THE best way to describe *Hour-lines* upon these kind of *Plains*, will be:

1. To refer them to a *New Latitude* where they may be *Upright Plains*: And;
2. To find what *Declination* they shall have in that *New Latitude*: And;
3. To know how much the *Meridian* (or *Hour-line* of 12) must *ascend above*, or *descend below* the *Horizontal Line* of the *Reclining Plain*: And;
4. *Which way* (or to what *Coast*) that *Ascension* or *Descension* must be: And;
5. How the *Dial* (being drawn upon Paper, according to its *New Latitude* and *New Declination*) is to be transferred from the Paper Draught upon the Plain.

And to find these *Five Requisites*, and to transfer the *Dial* to the Plain, shall be the work of this Chapter.

Let it be required to find the *Five* forementioned *Requisites*, in a *South Plain* which *Declineth* from the *South Westward* 24 deg. 20 min. And *Reclineth* from the *Zenith* 54 deg.

I. To find the New Latitude.

1. Describe a Semicircle B D A, whose Diameter B A, let be made equal to 90 deg. of your *Scale of Sines*, or to 45 deg. of your *Scale of Tangents*, which is all one: Then: Figure IV.
2. Take

2. Take 36 deg. the Complement of the Plain's Reclination, out of your Scale of *Tangents*, and set them upon the Semicircle from B to D, drawing the Lines A D, and B D.

3. Take 65 deg. 40. min. the Complement of the Plain's Declination out of the Scale of *Sines*, and set them from A to C.

4. Set one foot of the Compasses in C, and take the nearest distance to A D, which distance set from A to E; so shall A E measured upon the Scale of *Tangents*, contain 33 deg. 30 min.

Note 1. In *South Reclining* Plains, (as this our Example is) this Tangent last found (*viz.* 33 deg. 30 min.) must be compared with the *Latitude* of the Place, 51 deg. 30 min. and their difference is 18 deg. whose Complement 72 deg. is the *New Latitude sought*.

Note 2. If the fourth Tangent last found had proved to be equal to your Latitude, the Plain would have been an *Equinoctial Plain*: If less than the Latitude (as here it is,) the contrary Pole (*viz.* the *North Pole*) is Elevated.

This Rule for *South Recliners*. But for *North Recliners*,

Note, That the Fourth Tangent last found, must be compared with the Complement of the Latitude of the Place; And if it prove to be equal thereunto, the Plain is a *Polar Declining Plain*. — But if it be greater or less than the Complement of the Latitude, the difference between them is the *New Latitude*.

II. To find the New Declination.

Figure
IV.

1. Take 36 deg. the Complement of the Plain's Reclination, out of the Scale of *Sines*, and set them from B to F, and draw the Lines B F and A F.

2. Take 24 deg. 20 min. the Plain's Declination, out of the Scale of *Sines*, and set them from A to G.

3. From the Point G, take the least distance to the Line F A, and set that distance from A to H; So shall the distance A H measured upon the Scale of *Sines*, contain 14 deg. 1 min. And so much is the *New Declination*, in the fore-found *New Latitude*.

Note, That the *New Declination* thus found, is [always] less in Quantity than the *Old Declination* was: But it is [always] to the same Coast, that is to say, from the *North* or *South*, towards either *East* or *West*, as the *Old Declination* was.

III. To find the Meridian Ascension or Descension.

Figure
IV.

1. Take 24 deg. 20 min. The Plain's *Old Declination*, out of the Scale of *Tangents*, and set them from B to K, and draw the Lines B K and A K.

2. Take 54 deg. the Plain's Reclination, out of the Scale of *Sines*, and set them from A to L.

3. Take the least distance from L, to the Line A K, which distance set from A to M, and A M, measured upon the Scale of *Tangents* will give 20 deg. 6 min. for the distance of the Meridian from the Horizon.

IV. To

IV. To find which way (or to what Coast) the Meridian Line, Ascending or Descending above or under the Horizontal Line of the Plain, is to be drawn.

The last Section of this Chapter taught how to find the quantity of the Angle which the *Meridian* makes with the *Horizontal* Line of the Plain: Now it resteth to let you know, to what *Coast*, it must be drawn, and also whether it must be drawn to ascend above, or descend below the Horizontal Line of the Plain: For which take these

General Rules.

In { North Incliners. South Recliners.	{ Less than Equinoctial, the Meridian must be drawn,	{ above { That end of the Horizontal Line, which lies contrary to the Coast of the Plain's Declination.
		{ below {
	{ More than Equinoctial, the Meridian must be drawn,	{ below { That end of the Horizontal Line, which lies the same way with the Coast of the Plain's Declination.
		{ above {
	{ Less than a Polar, the Meridian must be drawn,	{ above { That end of the Horizontal Line that looks the same way with the Coast of the Plain's Declination -- And this Meridian thus drawn in North Recliners, represents 12 at Midnight.
		{ below {
In { North Recliners. South Incliners.	{ Equal to a Polar, the Meridian must be drawn below the Horizontal Line at that end which is contrary to the Coast of Declination, and the Six of Clock Hour-Line is always the Substile.	
	{ More than a Polar, the Meridian must be drawn,	{ below { And from that end of the Horizontal Line, which lies contrary to the Coast of the Plain's Declination --- And in South Incliners it is only serviceable to help to draw the rest of the Dial.
		{ above {

V. *How the Dial (being made according to the New Latitude and New Declination) is to be transferred from the Paper-Draught, upon the Plain.*

Having drawn an *Horizontal Line* upon your Dial Plain, in the most convenient part thereof, and made choice of a Point therein for the Center of your Dial, apply the Center of your Paper Draught to this Center, moving the Paper Draught about, till the *Meridian Line* of the Paper Draught do make an Angle with the *Horizontal Line* drawn upon the Plain, equal to what you found it to be by the Third Section of this Chapter, and to its proper *Coast* as you found it should, by the Fourth Section hereof, then (if you have not erred in any of your former workings) will the *Stile* of your Paper Draught, (or rather a pattern thereof cut out in Past-board) being placed upon the *Substile* of your Paper Draught, have direct respect to the *Elevated Pole*, And thus, due respect being had to what is here delivered, you may easily transfer the *Substile* and the rest of the Hour-lines to the Plain, putting thereon so many as the Plain is capable to receive at any time of the year: And leaving out such as may be superfluous.

¶ From this way of making of *Declining Reclining Dials* by transferring them to a *New Latitude* and a *New Declination* where they may be *Upright Declining Plains* only, it will sometimes so fall out, that this *New Declination* may be very great, and then, the best way to draw such Dials will be by the Directions given in the 13th Chapter of the First Tractate. — Also, sometimes the *New Latitude* will be very great, and sometimes very small, and then the Precepts for finding of the Place of the *Substile*, *Stile* and *Hour-line of Six* in the Second Chapter of this Tractate, will, in such Cases, be thought insufficient, or (at least) inconvenient; To remedy which the following Chapter is added.

CHAP. V.

How to find the Place of the Substile, Stile, Hour-line of Six, &c. in all Upright Declining Plains, in such Latitudes where the Pole hath either very Small or very Great Elevation.

WHEREAS the Precept delivered in the Second Chapter hereof, will be only convenient in these Middle Latitudes; namely, between 30 and 60 deg. Yet by the referring *Declining Reclining Plains* in One Latitude to *Upright Decliners* only, in another Latitude, that *New Latitude* will sometimes fall out to be either very Great or very Small, and how to deal with upright *Declining Plains* in such Latitudes shall be here taught.

I. Where the Latitude is but Small.

Suppose that a *Declining Reclining Plain*, in some one Latitude, being referred to a *New Latitude* and *New Declination*, the *New Latitude* should be found to be 20 deg. and the *New Declination* 30 deg. To find the Place of the *Substile*, *Stile*, &c. (the Latitude being but Small, viz. 20 deg.) proceed in manner following.

1. Draw

1. Draw a right Line A B 12, for the Meridian and Hour-line of 12, in which Line make choice of a Point convenient for the Center of your Dial, as A.

2. Out of your *Scale of Tangents* take 45 deg. (for the *Radius*) and set them from A to C, drawing the Line A C at right Angles to the Meridian Line A B 12, — Also, Take 20 deg. (the Latitude) out of your *Scale of Tangents*, and set them from A to B, — Then make CD equal to AB, and B D equal to AC, constituting the right angled Parallelogram A B C D, and drawing the Diagonal Line C B.

3. Out of your *Scale of Sines*, take 30 deg. (the Plain's *Declination*) and set them from B to E, and draw the Line A E for the *Substile* of the Dial.

4. Through the Point E, draw the Line E K parallel to C B, cutting the Line C D in K, and through the Point K, draw the Line A K for the Hour-line of Six, extending it through the Center of the Dial on the opposite Side of the Plain.

5. Upon the Point E, erect a Perpendicular to the Line A E, and out of your *Scale of Sines*, take 60 deg. (the Complement of the Plain's *Declination*) and set them from A to 12, and from E to F, drawing the Line A F for the *Stile* of the Dial.

6. Take 70 deg. (the Complement of the Latitude) out of your *Scale of Sines*, and set them from A to H, and draw the H m, parallel to A B, cutting the Hour-line of Six in 6; And make A 6, above the Center of the Dial, equal to A 6 below the Center; and draw the Lines 12.6 and 12.6.

7. Lastly, if you take these two Lines 12.6 and 12.6 in your Compasses, and put them into your Semicircle (or Hour-Scale, Figure III) you may divide them therefrom as before in Chapter 2, at the Points 5, 6, 7, 8, 9, 10 and 11. And also at 1, 2, 3, 4 and 5. Through which Points Lines being drawn they shall be the true Hour-lines.

II. Where the Latitude is Great.

If a Declining Reclining Plain being referred to a New Latitude, that New Latitude should be found to be 70 deg. in such Great Elevations of the Pole, work as followeth.

1. Draw a right Line for the Meridian, and Hour-line of 12, as ART, assuming the Point A for the Center of the *Declining Dial*. Figure
VI.

2. Out of your *Scale of Tangents* take 45 deg. (or the *Radius*) and set them from A to B.

3. Take 20 deg. the Complement of the Latitude, out of the *Scale of Tangents*, and set them from A to C, and from B to D, and draw the Line CD, constituting the Right-angled Parallelogram A B C D.

4. Out of your *Scale of Sines*, take 30 deg. (the Plain's *Declination*), and set them from B to R, and from C to G; and draw the right Line G R, cutting the Line B D in E — Then draw the Line A E for the *Substilar* Line of your Dial, and A G for the *Hour-line* of Six; which continue thro' the Center of the Dial A.

5. Take 60 deg. (the Complement of the Plain's *Declination*) out of the *Scale of Sines*, and set them from G to P (upon the Line C D continued) and from R to T, and from A to 12.

6. Draw a right Line, through the Points T and P, extending it till it cut the Line B D (that being also extended) in the Point O.

7. Upon the Point E, erect a Perpendicular to the Line A E, making EF equal to E O, and draw A F for the *Stile* of your Dial.

8. Take

8. Take 20 deg. (the Complement of your Latitude) out of the *Scale of Sines*, and set them from A to H, and draw the Line H 6 parallel to A B, cutting the Hour-line of Six in 6.

9. Make A 6 above the Center, equal to A 6 below the Center, and draw the Lines 12.6 and 12.6.

Lastly, These two Lines 12.6 and 12.6 being put into the Semicircle (or Hour-Scale *Fig. II.* you may divide them in the Points 5.6.7.8.9.10.11 and 1.2.3.4 and 5. So Lines being drawn from A, through those Points, shall be the true *Hour-lines* for the *Declining Reclining Plains*, it being referred to this *New Latitude* and *New Declination*.

C H A P. VI.

How the Work of the Fourth Chapter is to be performed by Trigonometrical Calculation, by the Tables of Artificial Sines and Tangents.

THE best of *Instrumental* Operations are subject to inconveniencies in some Cases; and therefore I have added this *Chapter*, shewing how the Work of the Fourth *Chapter* may be performed by *Calculation*, which of all other ways must have the preheminance: And that the harmony there is between *Instrumental Operation* and *Arithmetical Calculation* may the plain-er appear, I will take for an Example, the same Example of a *Declining Reclining Plain*, that is in the forementioned Fourth *Chapter*, viz.

$$\text{South} \left\{ \begin{array}{l} \text{Declining West } 24 \text{ deg. } 20 \text{ min.} \\ \text{Reclining } \text{---} 54 \text{ deg. } 00 \text{ min.} \end{array} \right\} \text{Latitude } 51 \text{ deg. } 30 \text{ min.}$$

I. To find the New Latitude.

As the Radius, 90 deg.	10.000000
Is to the Co-sine of the Old Declination 65 deg. 40 min.	9.959596
So is the Co-tangent of the Reclination 36 deg.	9.361261
To the Tangent of 33 deg. 30 min.	9.820857

Note 1. In *South Recliners* (as this Example is) this Fourth Tangent found, viz. 33 deg. 30 min. must be compared with your *Latitude*, and the Complement of their *Difference* in the *New Latitude* sought for: So this 33 deg. 30 min. being Subtracted from the Latitude 51 deg. 30 min. the Remainer 18 deg. is the *NEW LATITUDE*.

Note 2. If this Fourth Tangent prove to be *Equal* to your *Old Latitude*, the Declining Reclining Plain will be an *EQUINOCTIAL PLAIN*.

Note 3. If the Fourth Tangent prove to be

More } than the Old { North } Pole is Elevated in { South } Decliners.
 Less } Latitude the { South }

In North Recliners.

Note 1. The Fourth Tangent is to be compared with the *Complement* of the *Old Latitude*, and their *Difference* is the *NEW LATITUDE*.

Note 2. If the Fourth Tangent prove to be *Equal* to your *Old Latitude*, the Declining Reclining Plain will be an *EQUINOCTIAL PLAIN*, *DECLINING*.

II. To find the New Declination.

As the <i>Radius</i> , 90 deg.	10.000000
To the Co-sine of the Reclination 36 deg.	9.769213
So is the Sine of the Old Declination 24 deg. 20 min.	9.614944
To the Sine of 14 deg. 1 min.	19.384162
Which 14 deg. 1 min. is the <i>New Declination</i>	

III. To find the Angle made between the Meridian and the Horizon.

As the <i>Radius</i> , 90 deg.	10.000000
To the Tangent of the Old Declination 24 deg. 20 min.	9.655347
So is the Sine of the Reclination 54 deg.	9.907957
To the Tangent of 20 deg. 6 min.	19.563304
Whose Complement 60 deg. 54 min. is the <i>Angle that the Meridian must make with the Horizontal Line of the Reclining Plain.</i>	

For the manner how the *Meridian* is to be drawn, whether to *ascend above*, or to *descend below* the *Horizontal Line*, the Fourth Section of the Fourth Chapter hereof, will direct.

C H A P. VII.

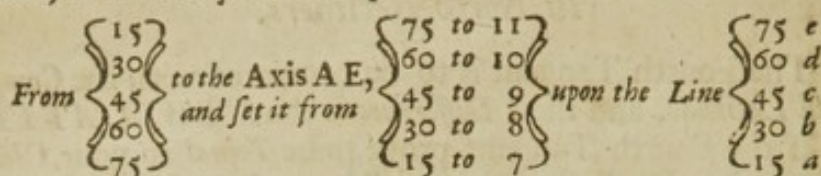
Another Way, by the Scale of Sines only, To describe Hour-Lines upon Direct and Declining Plains.

I. For *Horizontal North or South Plains either Upright or Reclining.*

WITH the *Radius* of your *Scale of Sines* upon A as a *Center*, describe the *Quadrant* A B C. Also take out of the same *Scale* the respective *Sines* of the *Equinoctial* hour distances, as of 15, 30, 45, 60, and 75, and prick them down upon the *Semidiameter* of the *Quadrant* A C from A at the points 15, 30, 45, 60 and 75, and through them draw right *Lines* parallel to the Side A B of the *Quadrant*, as the *Lines* 15 a, 30 b, 45 c, 60 d, and 75 e, which will divide the *Quadrant's Limb* B C into six equal parts, for B a, a b, b c, c d, d e and e C, are each of them 15 deg. of your *Scale of Chords*:—Also take the *Sine* of the *Latitude* (suppose 40 deg.) out of the *Scale of Sines*, and set them from A to D, and drawing the *Line* D E parallel to A B, and the *Line* A E for the *Axis* or *Stile* of the *Dial*.

Figure
VII.

This done, take with your Compasses the least Distance



Make A 6 equal to the Line D E, or set the Sine of the Latitude (40 deg.) from A to 6.—Now if with an even hand a Line be drawn thro' the several Points C, 11, 10, 9, 8, 7, 6, it shall be one quarter of an *Ellipsis*: And right Lines drawn thro' those Points from the Center A, shall be the true Hour-lines of an Horizontal Dial for the Latitude of 40 deg. or of a South or North Dial in the Latitude of 50 deg. or of any Reclining or Inclining Plain in any Latitude where the Height of the Stile above the Plain is found to be equal to 40 deg.

II. For Upright Declining Plains.

If an Upright Plain in the Latitude of 40 deg. should decline from the South Eastward 14 deg. by several ways before taught (in the 1st, 2^d, 3^d, Tractate) the Height of the Pole or Stile above such a Plain would be found to be 48 deg. 1 min.—The Distance of the Substile from the Meridian 13 deg. 42 min.—And the Plain's Difference of Longitude 13 deg.

The Plain's difference of Longitude being known make a Table of the Equinoctial distances as is before taught in the 12th and 13th Chapters of the First Tractate, as is here done in this Table. You may proceed to the description of the Dial in this manner.

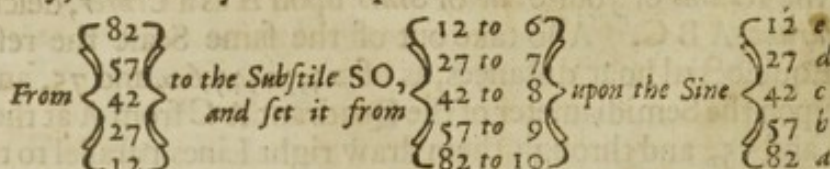
Figure
VIII.

First, Draw a right Line O 12 for the Meridian and Hour-line of 12; and upon O with the Radius of your Scale of Chords describe a Quadrant of a Circle and upon it from 12 to P, set 13 deg. 42 min. the Distance of the Substile from the Meridian, and draw the Line O P for the Stile.

Secondly, Take 43 deg. 1 min. and set them from P to S, and draw O S for the Stile.

Thirdly, out of the former Table, take the Respective Sines of 82, 57, 42, 27 and 12, and set them from O to the several Points 82, 57, 42, 27 and 12 upon the Substile, and through them on the left hand Side of O P, draw Lines Perpendicular to the Substile: as the Lines 82 a, 57 b, 42 c, 27 d and 12 e.—Also, set the Sine of 3, 18, 33, 48, 63 and 78 upon the Substile O P, and thro' them draw Lines perpendicular to O P towards the Right-hand.

Fourthly, Take in your Compasses the least distance



So shall the several Points 6, 7, 8, 9, 10 and P constitute almost one quarter of an *Ellipsis*, and Lines drawn from O thro' every of them shall be the true Hour-lines for the Plain on the West Side of the Substile: For those on the East Side they must be found by taking the least Distances from the Points 78, 63, 48, 33, 18, and 3 to the Substile, and setting them upon their contrary parallel Lines; so shall Lines drawn from O thro' each of them be the Afternoon-Lines on the East Side of the Plain.

The End of the Third TRACTATE.

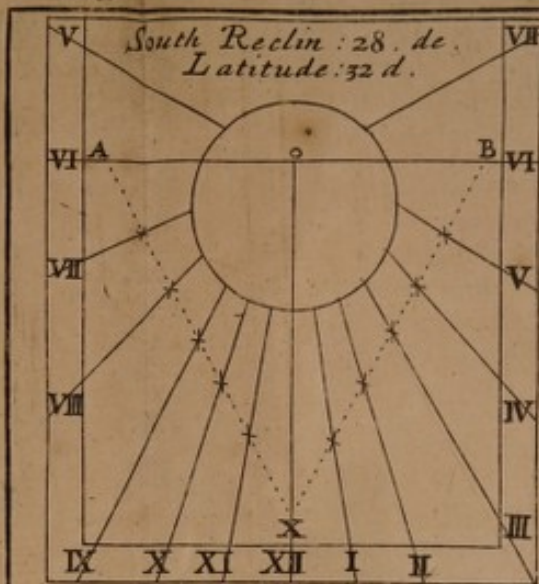


Fig. II

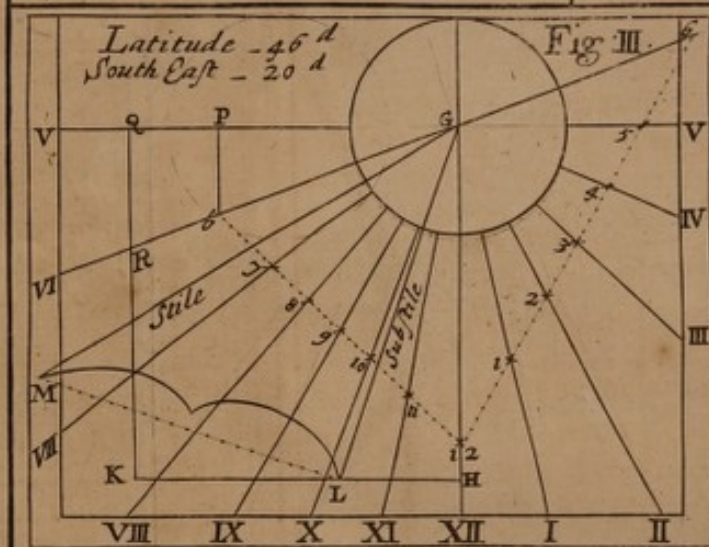
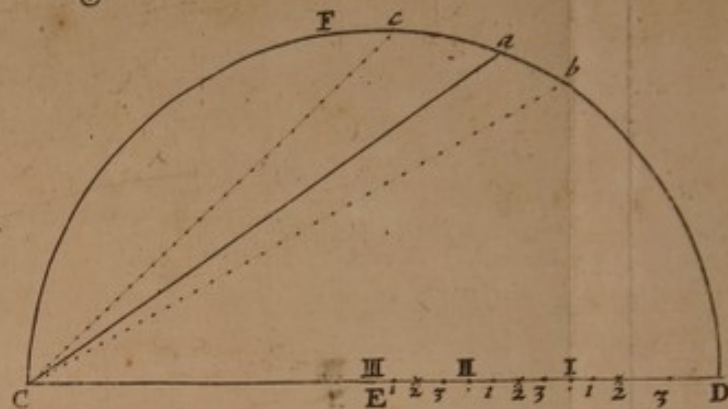
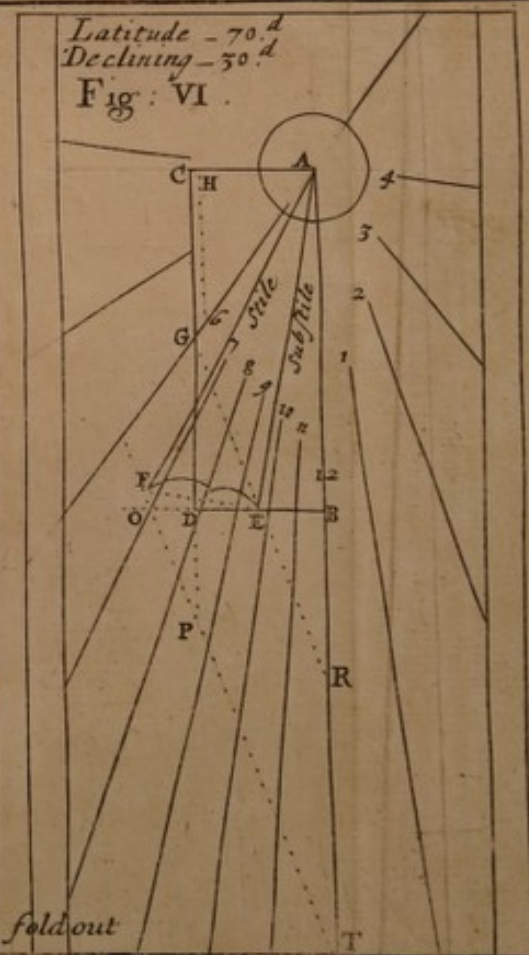
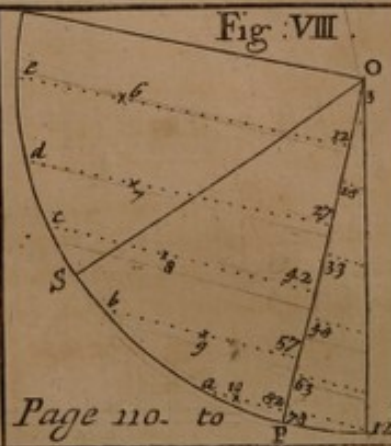
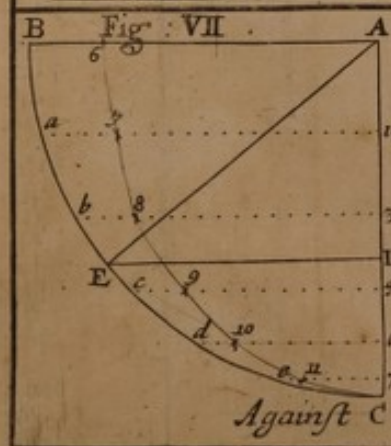
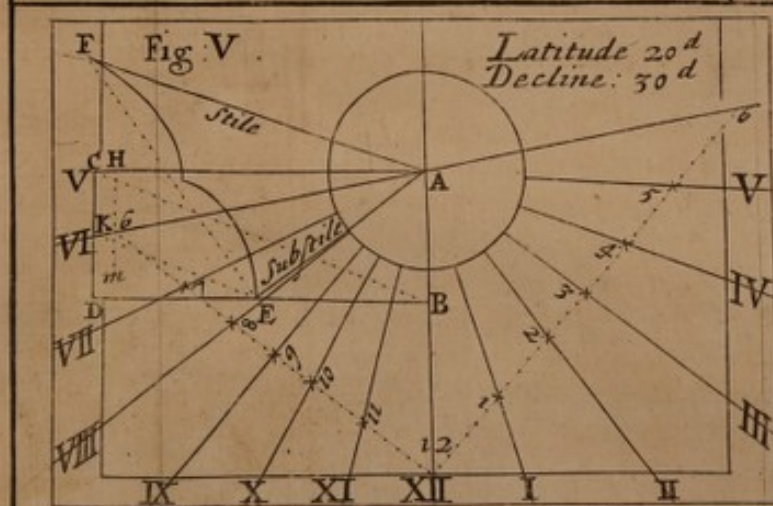
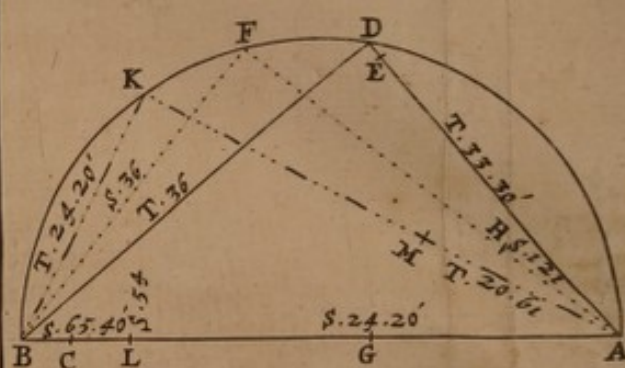
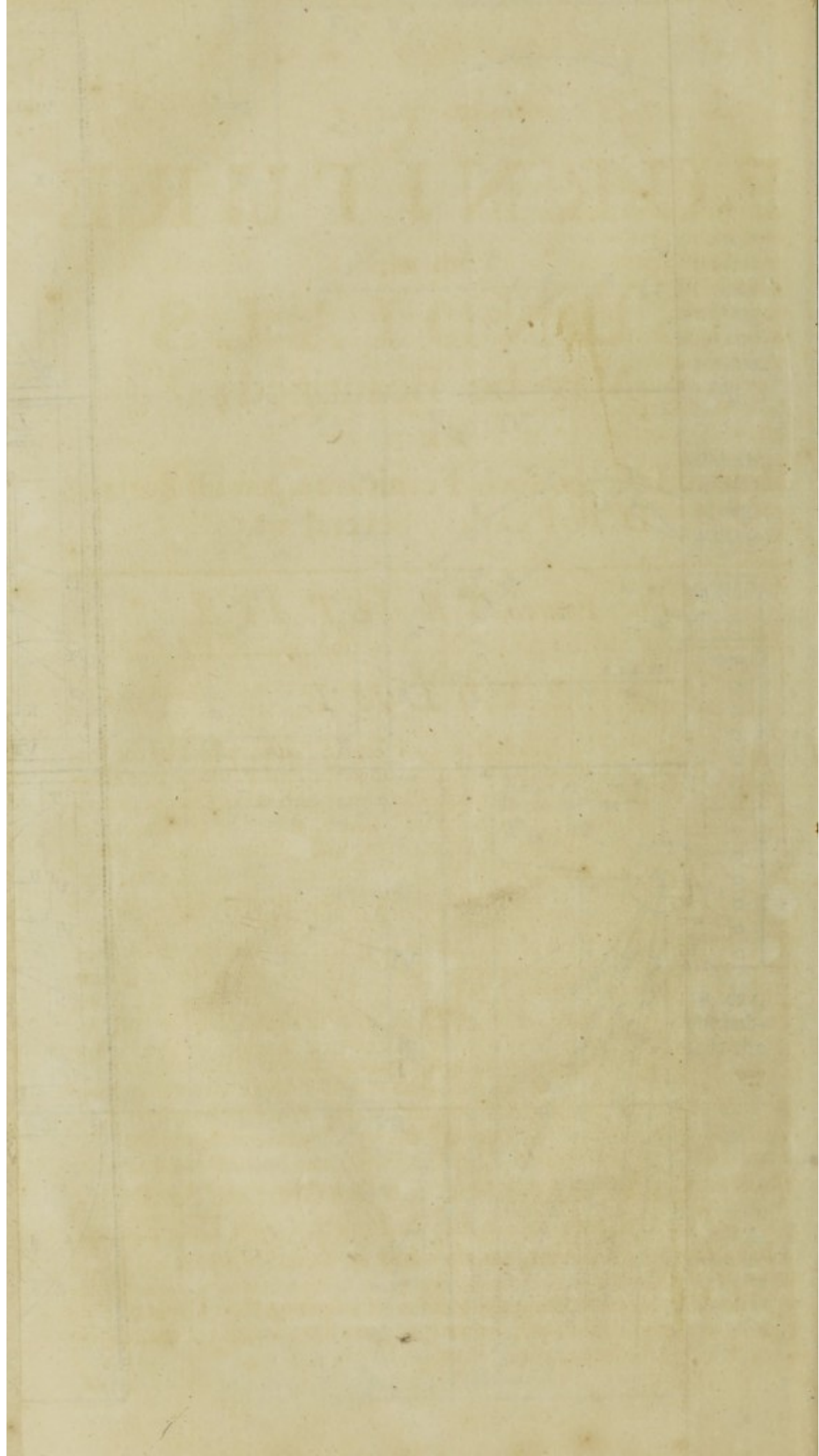


Fig. IV





OF THE FURNITURE

With which

SUNDIALS

May be Beautified;

AND

How to Inscribe such Furniture upon all Sorts of
DIAL-PLAINS; Several ways.

The Fourth T R A C T A T E.

P R O E M E.

AS *Lines* may be described upon all sorts of *Plains*, which by the shadow of a *Stile* or *Axis* will shew upon the *Dial-Plain* the true *Hour* of the Day: So also upon such *Plains* may such other *Lines* be described that have relation to the *Sun's Course*, which by the Shadow of an *Apex* (or *Point* in that *Axis*) shall trace out, and discover upon the *Plain*, many useful and necessary *Astronomical* Conclusions——As to shew the *Time* of the Year——The *Rising* and *Setting* of the *Sun*——The *Length* of the *Day* and *Night*——The *Azimuth*, or *Point* of the *Mariner's Compass* upon which the *Sun* at any time of the *Day* is——The *Almicanthar*, or *Circle* of the *Sun's Altitude*; whereby the proportion that any *Object* bears to its *Shadow* is discovered——The *Babylonish*, *Italian* and *Jewish* (or *Unequal*) *hours*——The *Sign* of the *Zodiack* in the *Meridian*, with those *Ascending* and *Descending*——And the *Circles* of *Position*, discovering in which of the *Twelve Celestial Houses* the *Sun* at any time of the *Day* is, &c.

C H A P. I.

Of the Habitudes, or Affections, that such Great and Small Circles of the Sphere, which may be Projected upon Dial-Plains, have to all such Plains, as they may be described upon.

BEfore I proceed to shew the manner of inscribing these *Circles* of the *Sphere* upon *Dial-Plains*, let me give you a short account of their *Affections*, which I Reduce to these following Heads.

I. *All*

- I. *All Great Circles of the Sphere, (such are all Meridians or Hour-Circles, all Azimuths or Vertical Circles, all Circles of Position, &c.) being Projected upon any Dial-Plains, do become thereon Streight Lines. And,*
- II. (1.) *If the Plains on which such Great Circles are Projected, do lie, or stand, Parallel, to those Great Circles in the Heavens, then are those Streight Lines all Parallel one to the other. But, (2.) If the Plain upon which they are Projected, lie, or stand, Perpendicular to the corresponding Circles in the Heavens, then the streight Lines so projected on the Dial-Plain, shall all meet in a Center at Equal Angles; And, (3.) If the Dial-Plain upon which these Great Circles of the Sphere be Projected to lie at Oblique Angles to the same correspondent Circles in the Heavens, then shall all the Projected Lines representing those Circles in the Heavens, meet in one Center upon the Plain, but, at Unequal Angles.*
- III. *All Smaller Circles of the Sphere, (such are all Parallels of the Sun's Course or Declination, Almicanthars or Circles of Altitude) being Projected upon any Dial-Plain, become Conick Sections, viz. either Sections of Ellipses, Parabola's or Hyperbola's; Except, those smaller Circles be projected upon such Plains as do lie parallel to those smaller Circles in the Heavens: And therefore,*
- IV. *All Parallels of the Sun's Course, or Declination (which are smaller Circles) drawn upon a Plain, which lies parallel to the Equinoctial in the Heavens, which Equinoctial is that Great Circle of the Sphere to which these smaller Circles of the Sun's Course or Declination are parallel; those Parallels upon such a Plain, become perfect Circles. And,*
- V. *All Almicanthars or Parallels of Altitude, being described upon a Plain, lying parallel to the Horizon, to which Great Circle all Almicanthars are parallel, those Circles of Altitude being described upon such a Plain, shall also become perfect Circles, by the same reason as the last foregoing: For, the Almicanthars have the same Affection or Habitude to the Horizon, as the Parallels of Declination have to the Equinoctial.*
- VI. *All Dial-Plains in any Latitude, and howsoever situate in that Latitude, whether they be Direct, Declining, Reclining, Inclining, or do both Decline and Recline; are in some one part of the World or other, Horizontal Plains, And look what Altitude or Elevation the Stile of any such Oblique Dial hath in any Latitude, in that Latitude will that Plain be an Horizontal Plain, but under another Meridian.*
- VII. *When the Hour-Lines proper to any Dial-Plain be drawn thereupon with their Halves and Quarters. If upon the same Plain (afterwards) you draw an Horizontal Dial (in occult or obscure Lines) proper to that Latitude in which the Plain will be Horizontal, and find upon those Occult Horizontal Hour-Lines, points through with such Hours, Azimuths, Parallels of the Sun's Course or Declination, Almicanthars, &c. shall pass, and draw the Section (whatever it happens to be) through those points, and afterwards expunge the Horizontal Hour-Lines, the Parallels, so drawn, shall be the true Parallels of the Sun's Course upon the other Plain, whether it be Direct, Declining, Reclining, or both.*
- VIII. *The whole Stile or Axis of the Dial which shews the common Hour of the Day, doth not shew the Parallels of the Sun's Course, &c. but the Shadow of some one Point in that Stile or Axis; the Shadow whereof, as it creepeth along those Lines or Sections, will shew you what the Time, or Quantiry is.*

Having premised these few *Affections*: I shall shew you first *Geometrically*, and then *Arithmetically* and *Instrumentally*, or by Tables ready calculated, how to find *Points* upon any *Plain*, through which such *Lines*, *Circles*, or *Conick Sections* are to pass; and the *Points* being found, I shall discover unto you whether they be *Streight Lines*, *Arches of Circles*, or other *Sections Elliptical*, *Parabolical* or *Hyperbolical*.

Now (because the Sun in his Course moveth Continually between the two *Tropicks*, and never exceedeth those Limits) all Astronomical Conclusions that are drawn or described upon any *Dial-Plain*, are limited between these two *Tropical Circles*, or (at least,) between the *Equinoctial* and one of them, or the *Horizon*: And therefore it will be requisite to shew, first how these *Circles* (namely the *Equinoctial*, and the two *Tropicks*) and the *Horizon* may be described upon all sorts of *Plains*, they being the Bounds and Confines of all other *Circles* whether of the Sun's entrance into the 12 *Signs*; or *Diurnal Arches*: or of any other intermediate *Parallels* of the *Sun's Declination*: And to shew how they may be inscribed upon all *Plains*, shall be the work of this following Chapter.

CHAP. II.

How to describe the Equinoctial, the two Tropicks, and other Circles or Parallels of Declination, together with the Horizon, upon all sorts of Plains.

THESE *Circles* (as I have said already) become various *Sections* according as the *Plains* upon which they are projected are situate in respect to those *Circles* in the Heavens: And therefore I will begin to shew their Inscription upon such *Plains*,

First, As lie Perpendicular }
Secondly, As lie Parallel } to the *Axis* of the *World*.
Thirdly, As lie Obliquely }

SECT. I. Upon such *Plains* as are Perpendicular to the *Axis* of the *World*: As, upon the Direct Polar Plain.

A *Polar Plain* is such a *Plain* as cutteth the *Axis* of the *World* at right Angles, as is described in the 16 Chapter of the First *Treatise*. And is no other than a *Circle* divided into 24 equal parts: And this *Plain* cutting the *Axis* of the *World* at right Angles is perpendicular thereunto, and therefore must needs lie in (or parallel to) the very *Plain* of the *Equinoctial Circle* in the Heavens: And therefore the *Equinoctial* it self, and all other *Parallels* of *Declination* being described upon this *Plain*, will be perfect *Circles*: The *Stile* of this *Dial* (as in the making of it is shewed) may be a streight *Pin* or *Wyre* perpendicularly erected upon the *Plain*, and issuing from the Center, where all the *Hour-lines* meet with equal Angles: The length of this *Stile* or *Wyre* is arbitrary, in respect of the *Hour-lines*: but the *Apex* or Top thereof, which must give shadow to the *Parallels* of *Declination* (or other *Astronomical Circles*

described upon this Plain) will require a Proportionable limitation between the length of the *Stile*, and the largeness of the *Plain*: and therefore I will shew,

I. How to proportion the *Stile* to the *Plain*.

Upon this *Plain*, the *Equinoctial Circle* it self cannot be described, which is evident, for the Sun being in this Circle, it will cast the Shadow of the *Apex* of the *Stile* (be it made never so short) to an infinite extension, and for some few days before and after the two *Equinoxes*, the *Furniture* inscribed upon these *Dials* will be of little use; And the *Reclining* or upper face of this *Dial* the Sun will shine upon from the Tenth of *March* to the Twelfth of *September*, and from thence to the Tenth of *March* again, the *Inclining* or under face thereof will be wholly in use.

Consider therefore what *Parallels of Declination* you intend to describe upon your *Plain*; And let the outermost Verge or Circle of your *Plain* represent that *Parallel* which hath least *Declination* from the *Equinoctial Circle*.

Figure I. In this *Example*, I have made choice (for a Reason which will hereafter appear) of these *Parallels*, viz. of 11 deg. 37 min. of 16 deg. 55 min. of 21 deg. 40 min. and of 23 deg. 31 min. which is the *Declination* that the Sun hath when he is in either *Tropick*.

Let E S W N represent a *Polar Plain*, cross it with the two *Diameters* S N for the *Meridian*, and Hour-line of XII, and E W for the Hour-line of VI, crossing each other at right Angles in A. So is A the *Center* of the *Dial*, and the outer Circle thereof the *Parallel* of the Sun's Course when he hath 11 deg. 37 min. of *Declination*.

Now to Proportion the *Stile* to the *Plain*, upon a piece of fine Past-board or other like matter, draw a Line at length as B C, and out of your *Dial-Plain* take the distance from A to N, and set it upon this Line from C to D, and through D, draw the Line F D perpendicular to B C — Then upon C, with 60 deg. of a *Scale of Chords* describe an obscure Arch of a Circle G H, and out of your *Scale* take 11 deg. 37 min. (the *Declination* of the remotest Circle E S W N from the *Center*) and set them from H to a, and draw the Line C a K, so shall K D be the length of the *Perpendicular Stile*: — The *Stile* being thus proportioned to the *Plain*, the next thing necessary will be,

II. To draw the Horizontal Line proper to this *Plain*.

Many *Horizontal Lines* may be drawn upon any *Plain*, but the *Horizontal Line* Proper to this *Plain*, must be drawn upon the *Plain*, so, as to lie in the same *Plain* with the *Apex* or *Top* of the *Perpendicular Stile*, and to find the Point upon the *Meridian* S N, through which this Line must pass, do thus:

Upon the Point K, describe an obscure Arch of a Circle, and upon it set 51 deg. 52 min. the *Latitude of the Place* from D to L, and draw the Line K L, cutting the Line B C in M; So the distance D M taken in the *Compasses*, and set upon the *Dial-Plain* upon the *Meridian* from the *Center* A upwards to S in the *Reclining Plain*, (but downwards in the *Inclining Plain*) so a Line drawn through S, parallel to E W, as P S Q, it shall be the *Horizontal Line* proper for this *Plain*: and beyond this Line the *Tropicks* nor *Parallels of Declination*, or any other *Furniture* need to be extended. And now,

III. To

III. To draw the Tropick of Cancer, and the other Parallels of Declination upon the Plain.

The other Parallels of Declination being 16 deg. 55 min. — 21 deg. 40 min. — 23 deg. 31 min. Set them upon the Arch GH of the *Trigon* from H to *b*, *c* and *d*; and draw the Lines C*b*, C*c*, C*d*.

This done, through the Point K, draw the Line KR Parallel to DC, and where that Line crosseth the Lines of the *Trigon* drawn from C (as it doth at the Points K, *e*, *f* and *g*) through those Points Lines being drawn Parallel to KD, as *e* 15, *f* 16, *g* 5, shall give CD for the Semidiameter of the Circle PNQ upon the Plain — The distance C 15, shall be the Semidiameter of the Circle 15. 15. 15 — The distance C 16, shall be the Semidiameter of the Circle 16. 16. 16 — And the distance C 5, shall be the Semidiameter of the Tropick of 5. 5. 5. — With which Semidiameters if Circles be described upon the Center A, of the Dial-Plain, they shall be the true Circles for the Sun's Course when he hath such Declinations as are inserted into the *Trigon*. — And in the same manner may you insert what Parallel of Declination you please; Whether of the Sun's Entrance into any Sign of the *Zodiack* — Any Anniversary or Festival Day, or what other Remarkable Time or Day you please, only having regard to what Declination the Sun hath at that time.

Note, That a Dial thus made, being elevated to the Complement of any Latitude, and moved above upon a Semicircle as a Declinatory, till the Shadow of the Apex of the Stile do cut the Parallel of Declination for the Day, you shall, at one view, have the Hour of the Day, a Meridian Line, and the Declination of a Plain; without taking the Sun's Altitude, or finding his Azimuth.

SECT. II. Upon such Plains as are Parallel to the Axis of the World; As upon the East, West and Polar Plains.

How to make an East or West Dial you are taught before, therefore let the Square ABCD be a Plain, on which there is an East Dial drawn, the height of the Stile being equal to the distance between the hours of 9 and 6, noted there with the Letters EG, and let it be required to draw upon the same Plain the Equinoctial and the two Tropicks. Now the Equinoctial being a Great Circle of the Sphere, it is therefore a Streight Line, and is represented in the Dial by the Line HS. The Hour-lines and the Equinoctial being thus drawn, we may proceed to the rest of the Work in manner following.

Figure II.

But first, it will be necessary to draw the Horizontal Line proper for the Plain: which is done in this manner; for in all Upright Plains, whether Direct or Declining, this is for drawing the Horizontal Line,

A General Rule.

In all Upright Plains, the Horizontal Line must be drawn through the Foot of the Perpendicular Stile, and also through the intersection of the Equinoctial Circle with the Hour-line of Six: In these East or West Dials these two Points are co-incident, and is here the Point E, wherefore through the Point E, draw the Line MEN parallel to the Horizon,

Horizon, or making the Angle MEG equal to the Latitude of the Place 51 deg. 32 min. the Line MEN so drawn shall be the proper *Horizontal Line* for this Plain.

The *Equinoctial Circle* ES and the *Horizontal Line* MEN, being drawn upon your *Plain*; proceed as followeth.

Figure III. Upon a piece of fine Past-board, or other convenient matter, draw a Line as OR, and upon O, as a Center, describe the Arch of a Circle RS, and because the Declination of the Tropick of *Cancer* or *Capricorn* is 23 deg. 31 min. distant from the Equinoctial, on either Side thereof, therefore on the Arch RS set 23 deg. 31 min. from R to S, and draw the Line OS, then shall the Line OR represent the *Equinoctial*, and the other Line OS either of the *Tropicks*, and this Triangular Figure ORS, we shall hereafter call the *Trigon*.

Having fitted your *Trigon*, you must have recourse to your *Dial*, and from thence with your Compasses you must first take out the distance EG (equal to the height of the Stile of the same Dial) and prick it down in the *Trigon* from O to P, and draw the Line P6 perpendicular to OR.

Secondly, Going to your *Plain* again, take the distance from G (the Top of the Stile) to 7 the *Equinoctial* of your *Plain*; and place that distance in the *Trigon* from O to q, and draw the Line q7, perpendicular to OR. Thirdly, take out of your *Plain* the distance G8, and prick it down in your *Trigon* from O to r, and draw the Line r8, perpendicular to OR. Fourthly, take out of your *Plain* the distance G9, and prick it down in your *Trigon* from O to s, and draw s9 perpendicular to OR. Fifthly, take out of your *Plain* the distance G10; and prick it down in your *Trigon* from O to t, and draw t10 perpendicular to OR. Lastly, take the distance G11, and prick it down in your *Trigon* from O to v, and draw v11 perpendicular to OR, as is done in Figure III.

These distances being, all of them, taken out of your *Plain*, and placed on your *Trigon*, it resteth now to shew you how they must be again transferred from the *Trigon* to the *Plain*. Therefore, to find upon the Hour-lines of your Dial, the Points through which the Tropick of *Cancer* must pass, you have no more to do but thus. First, out of your *Trigon*, take the distance P6, and set that same distance upon your *Plain* from E to c, upon the Hour-line of Six. Secondly, take out of your *Trigon* the distance q7, and place that distance upon the *Plain* from V to b, and from VII to d: upon the Hour-lines of 5 and 7. Thirdly, take out of your *Trigon* the distance r8, and set that distance on your *Plain* from IV to a, and from VII to e upon the Hour-lines of 4 and 8. Fourthly, take out of your *Trigon* the distance s9, and set it on your *Plain* from IX to f. Fifthly, take from your *Trigon* the distance t10, and set it on your *Plain* from X to g. Lastly, take out of your *Trigon* the distance v11, and set it on your *Plain* from XI to h.

These Points a b c d e f g h, being found upon the several and respective Hour-lines, shall be the Points through which the Tropick of *Cancer*, shall pass, therefore draw the Line a b c d e f g h, with an even hand that it make no Angles and that shall be the Tropick of *Cancer*; so that when the Sun is in *Cancer*, (which is about the 11 of June) the Apex or Top of the Shadow of the Stile of your Dial will run directly along that Line a b c d e f g h, and when the Sun is in the *Equinoctial*, that is, in the beginning of *Aries* or *Libra*, (which is on the 10 of March, or the 12 of September) the Top of the Shadow of the Stile will run along the *Equinoctial Line* ES.

The *Tropick* of *Cancer* being drawn, I will now shew you how to draw the *Tropick* of *Capricorn*, which differeth nothing from that of *Cancer*, because they have both of them like *Declination* from the *Equinoctial*, therefore the distance *VIII k* being made equal to the distance *VIII e*, and the distance *IX l* equal to *IX f*; and the distance *X m* equal to *X g*, you shall have the Points *k l m* and *n* upon the hours of 8, 9, 10 and 11, through which Points *k l m n* draw the Line *k l m n*, &c. which Line shall represent the *Tropick* of *Capricorn*, along which Line the Top of the Shadow of the Stile shall run about the 11th of *December*, when the Sun is in *Capricorn*.

Having thus plainly shewn you how to insert the *Equinoctial* and *Tropicks* into your Plain, I will now give you one Rule by which you may put on any other intermediate *Parallels* of the *Sun's Course*, differing nothing at all from the directions formerly given you to insert the *Tropicks*.

Consider therefore what *Parallels* you would put on your Plain, and find what *Declination* the Sun hath when he is in such a Parallel, and accordingly insert those degrees of *Declination* into your *Trigon*, as before you did the *Tropicks*.

Example, Let it be required to put upon your Plain, the *Parallels* of the *Sun's Course* at his Entrance into the 12 *Signs* of the *Zodiack*: You must, first, find what *Declination* the Sun hath when he enters any of those *Signs*, which this little Table doth plainly shew: For at the *Sun's Entrance* into *Aries* or *Libra*, it hath no degrees of *Declination*. And when he enters into *Cancer* or *Capricorn* he hath 23 deg. 31 min. of *Declination*; And when he enters into *Taurus*, *Virgo*, *Scorpio*, or *Pisces*, his *Declination* is 11 deg. 30 min. and when he is in the beginning of *Gemini*, *Leo*, *Sagittarius* or *Aquarius*, his *Declination* is 20 deg. 12 min.

A Table shewing what Declination the Sun hath at his Entrance into the Twelve Signs.

North Decl.							South Decl.
	<i>Aries</i>		D	M	<i>Libra</i>		
	<i>Taurus</i>	<i>Virgo</i>	11	30	<i>Scorpio</i>	<i>Pisces</i>	
	<i>Gemini</i>	<i>Leo</i>	20	12	<i>Sagittarius</i>	<i>Aquarius</i>	
	<i>Cancer</i>		23	31	<i>Capricorn</i>		

Therefore take 11 deg. 30 min. in your *Compasses*, and place it in your *Trigon* from R unto V, and draw the Line O V, which shall represent the Parallel of *Taurus*, *Virgo*, *Scorpio* and *Pisces*. Also take 20 deg. 12 min. in your *Compasses* and place it in your *Trigon* from R unto X, and draw O X, which shall represent the parallel of *Gemini*, *Leo*, *Sagittarius* and *Aquarius*.

These *Parallels* being placed in your *Trigon* according to their true *Declination* from the *Equinoctial*, they are to be transferred into your *Dial-Plain* in all respects as the *Tropicks* were, by taking out of your *Trigon* the distances from the Line O R, to the several Points where the hours cross the Parallel, and place the same distances upon your Plain from the *Equinoctial* upon the respective Hour-lines, from which they were taken out of the *Trigon*, and through these Points draw with an even hand the Lines on your Plain, which

shall be the true *Parallels* of the Sun's Course at his Entrance into all the 12 Signs of the Zodiack, to which you may set the Characters of the Signs, as you see done in Figure II.

¶ And here note, That if you draw upon your Plain the halves and quarters of hours, and put them into your *Trigon* and transfer them to your Plain again, you shall then have more points, through which your *Parallels* must pass, which will much help you in the drawing thereof, (especially in large Plains) for there is no better way to draw these kind of lines, but by finding a great number of points, and so draw them with an even hand, so that they make no Angles.

¶ Note also, That whatsoever is here spoken of the *East* and *West* Dials, the same in all respects is to be observed in putting on the *Parallels* of the Sun's Course in all Plains that lie parallel to the *Axis* of the World, as all *Equinoctial* Plains whether *Direct* or *Declining*, do: An Example of such a Plain you have in Figure IV.

Figure
IV.

In all these Plains, I mean *East*, *West*, and *Equinoctial*, the *Stile* were best to be made of a straight piece of *Wyer*, equal in length to the Line *E G*, fixed in the Point *E*, standing perpendicular unto the Plain, the end thereof at *G* being filed very fine and sharp, proportionable to the greatness of the Plain, for all these *Astronomical Conclusions* are shewed (not by the shadow of the whole length of the *Stile*, but) by the very *Apex* or Top thereof, and therefore the more care ought to be had in the forming and making of it.

Figure
II.

¶ The Line *M E N* in the *East Dial* is called the *Horizontal Line*, because it lieth parallel to the *Horizon*, and by the meeting of the *Parallels* of the Sun's Course with this Line, the Rising of the Sun may be nearly estimated; for there you see that the *Tropick of Cancer* cutteth this Line near the Point *M*, which is a little before the four-a-clock Hour-line, which sheweth, that when the Sun is in the *Tropick of Cancer*, he riseth somewhat before four in the Morning, in like manner the *Tropick of Capricorn* cutteth the *Horizontal Line* something after 8, at which time the Sun riseth being in *Capricorn*, but this by the way; the farther use of this Line shall be shewed hereafter.

I have been the larger in the work of this *Section*, because I intend to be more brief in those which follow, and this being well and truly understood, those which follow will need very few Precepts or Examples; Having thus finished the *East* or *West* Plains, I will now shew you how to do the like in the *Vertical* or *Horizontal* Plains; As also in *South* or *North* Plains, that do not decline; which are the next in order: But first I shall give you the Sight of an *Equinoctial* Plain with its Furniture in Figure IV.

SECT. III. Upon such Plains as cut the *Axis* of the World at Oblique Angles; As upon the *Vertical* or *Horizontal*, the *North* and *South Erect Direct*, and the *North* and *South Reclining*.

I N all these Plains the *Substilar* and the *Meridian* are all one, and the height of the *Stile*, in the *Vertical* or *Horizontal Dial* is always equal to the *Latitude* of the place, and you are to take notice, that whatsoever

ever is said of the full *North* and *South* Upright Plains, the same is to be understood of the *Vertical* or *Horizontal* Plain, the full *North* and *South* *Reclining* or *Inclining* Plains, all which in those *Latitudes*, whose Complement is equal to the height of the *Stile*, they are *Erect Direct North* or *South Plains*, and in those *Latitudes* which are equal to the height of the *Stile* above such *Reclining Plains*, they are *Horizontal Plains*. One Example therefore in one Plain will be sufficient for the rest. Therefore, in *Latitude* of 51 deg. 32 min. Let it be required to describe the *Equinoctial*, and the two *Tropicks* in a full *South* erect Plain.

Having drawn your *Dial* with the *hours*, *halves* and *quarters*, as also the Line C Q for the *Stile*, you must assume some point in the Meridian or Substilar Line through which to draw the *Equinoctial Circle*, which is a straight Line, and through what point soever you draw it, it must be *Parallel* to the Hour-line of *Six*, and consequently perpendicular to *Twelve*: but let it be such a point as the *Equinoctial Line* (with these conditions) may cross most of the *Hour-lines*. — Let the point assumed be *a*, upon which point describe an Arch of a Circle, and make an Angle equal to the *Latitude* of the place, viz. 51 deg. 32 min. as the Angle L a S, drawing the Line a S, till it cut the Line of the *Stile* C Q in S, so shall the point S be the point in the *Stile*; for the *Nodus* or *Knot* which must give the *Shadow* to the *Tropicks* and other *Parallels* of *Declination*. For all these *Astronomical Conclusions* are not shewed by the *Shadow* of the whole length of the *Stile* or *Axis*, as the hour is, but by some point therein which representeth the Center of the Earth, which in the *Dial* following is the point S, and the *Triangular Stile* in that *Dial* is represented by the Triangle C S L, whereof G L is called the *Substilar*, C S the *Axis* of the *Stile*, and S L the *Perpendicular Stile*, the Top of which, viz. S, is the point we are in this place to respect, and thus is your *Stile* proportioned to your Plain.

Figure V.

The *Dial* being drawn, and the Triangle C S L made equal to the *Cock* of the *Dial*, you must upon a piece of pastboard draw the Triangle O P R equal to the *Stile* in your *Dial* C S L, making R O equal to C L the *Substilar*, P O equal to C S the *Axis* of the *Stile*, and P R equal to S L the length of the perpendicular *Stile*.

Figure VI.

Then from the point P, raise a perpendicular as P B, representing the *Equinoctial*, and on P as a Center, describe the Arch A B C, now because the *Tropicks* of *Cancer* and *Capricorn* do decline 23 deg. 31 min. from the *Equinoctial*, therefore take 23 deg. 31 min. from your *Scale of Chords*, and set it off upon the Arch A B C from B to A, and from B to C, and draw the Lines P A and P C representing the two *Tropicks* of *Cancer* and *Capricorn*. This done, extend the Line of the *Substilar* R O (which in *North* or *South* erect direct Plains, and also in the *Vertical* or *Horizontal* Plain I told you, was always the same with the *Twelve-a-clock* Line) from O to 12, cutting the *Equinoctial Line* P B in the point *a*, then with your *Compasses* take the distance O a out of the *Trigon*, and place it in your Plain from the Center C unto *a*, and draw the Line C a perpendicular to the *Substile* or Line of 12; which *Equinoctial* being drawn: First, take out of your Plain the distance C b, and place that distance in your *Trigon* from O unto *b*, and draw the Line O b 1; representing the hour of 1 or 11 in your *Dial*: Secondly, take out of your Plain the distance C c, and place that in your *Trigon* from O unto *c*, and draw the Line O c 2, representing the Hour-lines of 2 or 10. Thirdly, take out of your Plain the distance C d, and place it in your *Trigon* from O unto *d*, and draw the Line O d 3, for the hours of 9 and 3. Fourthly, from your Plain take the distance

distance Ce , which set in your *Trigon* from O unto e , and draw the Line Oe representing the hours of 4 and 8. And thus must you do with the rest of the hours in your Plain if occasion require.

These Lines Oa , Ob , Oc , Od , and Oe , in your *Trigon*, being extended, do cut the *Tropick* of *Cancer* PA in the points 12, 1, 2, and 3, and the Line PC representing the *Tropick* of *Capricorn* in the point, 12, 11, 10, 9 and 8; therefore out of your *Trigon* take the distances $O12$, $O1$, $O2$, $O3$, $O4$, and set them upon their correspondent *Hour-lines* of your Plain, from the Center C unto $ghik$ and l , so shall the points $ghik$ and l be the points upon the *Hour-lines*, through which the *Tropick* of *Cancer* must pass, and is therefore noted with the Character of *Cancer* ♋ at both ends.

¶ Now before you draw the *Tropick* of *Capricorn*, it is necessary to draw the Horizontal Line of your Plain AB , which Line in all Upright Plains, not declining, must be drawn through the point L , the foot of the *Perpendicular* *Stile*, and perpendicular to the *Meridian* or Line of 12: And in all Plains whatsoever, this Line must be drawn through the Intersection of the *Equinoctial* with the hour of Six. This Line ought first to be drawn, because it is very improper to extend the *Tropicks* or other *Parallels* of *Declination*, above the *Horizontal Line*, because at what hour any *Parallel* of *Declination* cutteth this Line, on either side of the *Meridian*, at that time doth the Sun Rise or Set, as was instanced in the last.

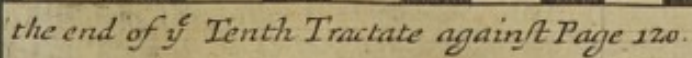
Now the *Tropick* of *Capricorn* must be put upon your Plain in the same manner as that of *Cancer*, by taking out of your *Trigon* the distance from O , to the points 11, 10, 9 and 8, where the several *Hour-lines* $abcde$ do cut the *Tropick* of *Capricorn* PC , and place them on your Plain from the Center C upon the respective *Hour-lines*, and through those points so found, draw the curved Line wv , representing the *Tropick* of *Capricorn*.

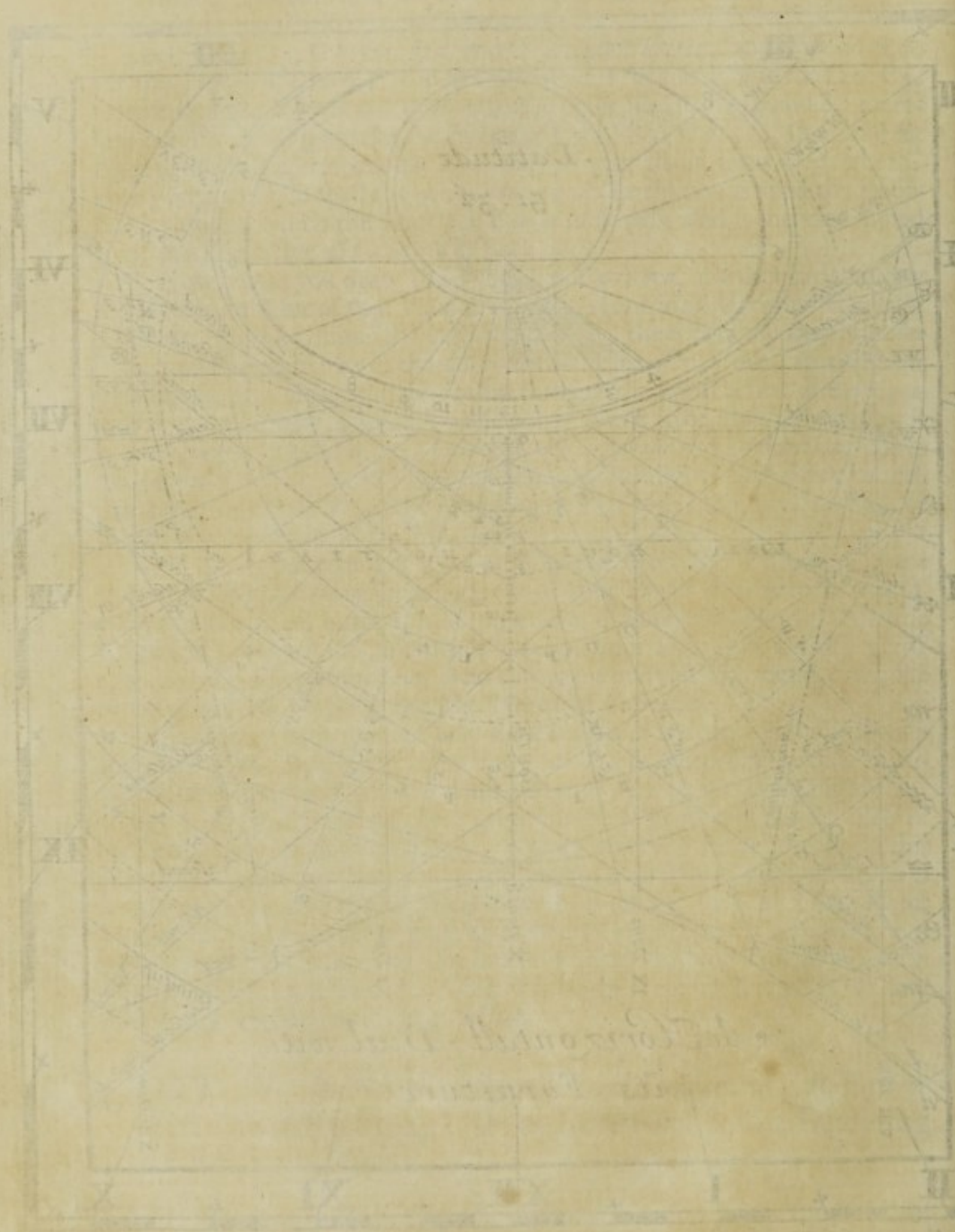
¶ And in the same manner may the *Parallels* of the other Signs be drawn upon your Plain, by placing them into your *Trigon*, according to their *Declinations*, and afterwards transfer them into your Plain, as you see in Figure V.

The Rules that have been here given for the describing of the *Parallels* of the Signs in this Erect Direct Plain, is Universal in all Plains, observing this one Exception; that whereas in all Erect Direct Plains the *Equinoctial* is drawn perpendicular to the *Meridian* or Line of 12, so in all other Plains whatsoever, the *Equinoctial* must be drawn Perpendicular to the *Substile*, and the Horizontal Line through the Intersection of the *Hour-line* of Six with the *Equinoctial*, and then the Work will be the same in all respects, as may appear more largely in this next Section.

SECT. IV. In North or South Erect Declining; In East or West Direct Reclining: Or on North and South Declining and Reclining Plains.

THE *Caution* preceding is sufficient for the performing of the Work of this Section, and therefore needeth no Example: For every one of these last mentioned Plains is an *Horizontal Plain* to that place in the World which agrees in *Longitude* with the Plain's difference of *Longitude*, and in *Latitude* equal to the height of the Pole or *Stile* above the Plain: I might here give you Rules and particular Examples in every one of these Plains, but I shall give you but one for all, and that shall be both easie and general, and come nearest to the Work before taught in the last Section; And this way I prefer for





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SUNDIAL

for these Reasons, — (1.) Because you shall have Two *Dials* contrived in One. — (2.) Because the Work will be still the same in all Plains, without any Variation. — And (3.) Because one half of the labour is saved, there being but 5 or 6 Hour-lines to work upon at the most, whereas in most of these sorts of *Dials* here mention'd 9, 10, or 12 Hour-lines must sometimes be made use of.

One Example I say shall serve for all, and let it be of a *South Plain Declining Eastward* 30 deg. and *Reclining* from the *Zenith* 55 deg. which is one of the *Dials* of the 17th Chapter of the First *Traçtate*; Whose *difference of Longitude* was there found to be 17 deg. 38 min. And the *Stile's height* 19 deg. 25 min. — This *Dial* being made, if you would describe the *Equinoctial*, the *Tropicks* (and other *Parallels* of the Sun's Course) you must consider that this *Dial* is an *Horizontal Dial* in that part of the World which lies *Eastward* from *London* 17 deg. and 38 min. And in the *Latitude* of 19 deg. 25 min. Wherefore, the true Hour-lines proper for this Plain, together with the *Stile* and *Substile* being drawn in their proper places; If you make the *Substilar Line* of this *Dial* to be the *Twelve-a-clock Hour-line* of an *Horizontal Dial* for the *Latitude* of 19 deg. 25 min. draw such a *Dial* obscurely upon this *Dial-Plain* (as the small pricked Lines in *Figure VII* are :) then proceed to the drawing of the *Equinoctial* and *Tropicks* in this manner.

Let A be the Center of the *Dial*, and let the Distance of the *Meridian* and *Figure VII.*
Horizon, the *Substile*, *Stile* and *Meridian* be set off upon the Semicircle EGF according to their true distances: as also the Hour-lines proper for the Plain by help of the *Table* in the forementioned 17th Chapter of *Traçtate I.* — Secondly, let an *Horizontal Dial* be made or calculated for the *Latitude* of 19 deg. 25 min. the *Stiles height* of the *Reclining Declining Plain*, which will be such as this *Table* affordeth. Which distances being set upon the Semicircle EGF, from G the *Substile* both ways, they shall be the *Horizontal Hour-lines*, and they will give the true hour of the Day in that *Latitude* wherein the *Plain* would be *Horizontal*.

	hours	deg.	min.
For	12	00	00
	11	1	5
	10	2	10
	9	3	18
	8	4	29
	7	5	51
	6		90

This done, Assume any point in the *Substile* as D, through which to draw the *Equinoctial Line* at right Angles thereto; And upon the point D, make an Angle BDC equal to the Complement of the new *Latitude* 29 deg. 25 min. viz. 70 deg. 35 min. drawing the Line DC, till it cut the *Axis* of the *Stile* AC, in C, so shall C be the *Nodus*, *Apex* or *Point* in the *Stile* which must give the *Shadow* to the *Tropicks* and other *Furniture* upon the *Dial*.

Again, Observe where the *Hour-line* of Six doth cross the *Equinoctial Circle*, for through that point (always) must you draw the *Horizontal Line* of the *Plain* HO, and parallel to the *Horizontal Base* of the *Figure VIII.*
Plain EAF.

Now make a *Trigon*, wherein let CA be equal to the *Stile*, AB to the *Substile*, and CB to the *Axis* of the *Stile* of your *Dial*, and draw the Line Cγ perpendicular to the *Stile* CA, — Upon C, with 60 deg. of your *Chords*, describe an Arch of a Circle and thereon set 23 deg. 31 min. the *Declination* of the *Tropicks* from L, both ways, to K and M, and draw CK and CM: — This done, Out of your *Dial-Plain*, from the Center A, take the distances of every of the *Horizontal Hour-lines*, where they cross the *Equinoctial*, (beginning with the

the Substile) and set those distances upon the *Equinoctial* in the *Trigon* from the Center A, to the Points *a, b, c, d, e, and f*, — Which done draw Lines from A through those Points, as the Line *a A, b A, c A, d A, e A, and f A*, which distances being taken in the Compasses from A in the *Trigon*, and set upon the *Horizontal Hour-lines* on the *Dial-Plain* from the Center, shall there give the Points 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, through which a Line drawn with an even hand from one to another without making any Angles, it shall be the *Tropick* next the Center, namely that of *Cancer*, — The Points for the other *Tropick* of *Capricorn* may be found by taking the Distances from A, out of the *Trigon*, to the Intersections of the *Horizontal Hour-lines* with the Line *CK*, which transferred to the Plain, will give the Points 9, 10, 11, 12, 1, 2, by which the *Tropick* of *Capricorn* may be drawn: And thus have you upon this *Declining Reclining Plain*, described the *Equinoctial* and the two *Tropicks*, and by the same reason also you may insert any other intermediate Parallels of the Sun's Declination.

I have been very large in the Work of this *Chapter*, but before I conclude it, I will give you notice. That,

Whereas you are directed to take out of your *Trigon* from its Center to the *Tropick* or other *Parallel* that you are to set upon your Plain, and apply that distance to the correspondent *Hour-line* from the Center of the *Dial*: You are to Note — That if you take the distance upon the *Trigon* from the Intersection of any *Hour-line* with the *Equinoctial*, to the *Tropick* or *Parallel* you would put upon your Plain; and apply that distance from the Intersection of the same *Hour-line* with the *Equinoctial* on the Plain, you shall have the same point upon the *Hour-line* as before: — And this way is the better of the two. (1.) Because in often applying the Compasses both to the Center of the *Trigon* and of the *Dial-Plain*, the Centers will be apt to rend with often applying the Compasses to them. 2. Because this way you have several points to which you may apply the Compasses. And (3.) many times the Center may be very remote from the point whose distance you are to take, whereas the *Equinoctial* may be near at hand. And for these Reasons I give you this *Advertisement*.

C H A P. III.

Shewing how to inscribe the Diurnal Arches, or Parallels of the length of the Day on any Plain.

THE Parallels of the *Length* of the *Day*, and those of the Sun's entrance into the 12 *Signs*, are inscribed upon all kind of Plains by one and the same Rules, they being in the *Sphere* the same *Circles*, so that as when you put on the *Parallels* of the Sun's entrance into the 12 *Signs*, you seek what Declination the Sun hath, and accordingly proceed as before is directed: So now for the *Parallels* of the *Length of the Day* you must seek what Declination the Sun hath at such a length of the day,

as you would put into your Dial-Plain, which that you may do, I have here added the Rule following.

¶ Consider how much longer or shorter your day proposed is than 12 hours, and take the difference, then the proportion will be,

As the Sine of 90 deg.

Is to the Sine of half the difference.

So is the Tangent Complement of the Latitude of the place,

To the Tangent of the Declination that the Sun shall have when the day is at such a length as you require.

As for Example, Let it be required to know what Declination the Sun shall have when the day is 16 hours long in the Latitude of 51 deg. 32 min. The difference betwixt 16 hours and 12 hours is 4 hours, (or 60 deg.) the half of which is 30 deg. Therefore say,

As the Sine of 90 deg.

10.000000

Is to the Sine of 30 deg. which is half the difference,

9.698970

So the Tangent Complement of the Latitude 38 deg. 28 min.

9.900086

To the Tangent of the Declination of the Sun, 21 deg. 40 min. 29.599056

And such Declination shall the Sun have when the day is either 16 hours, or 8 hours long in the Latitude of 51 deg. 32 min.

Now if the Day be above 12 hours long, the Sun hath North Declination, but if less than 12 hours long, he hath South Declination. I have here added a Table shewing what Declination the Sun hath at such time that the day is either 8, 9, 10, 11, 12, 13, 14, 15, or 16 hours long, in the Latitude of 51 deg. 32 min. which Table was made by the preceding Proportion, and the like may be done for any other days and in any other Latitude.

By which Table you may see that when the day is 12 hours long, the Sun hath then no Declination, but is in the Equinoctial; but when the day is either 11 or 13 hours long the Declination is then 5 deg. 55 min. and when the day is either 9 or 15 hours long, the Sun hath 16 deg. 55 min. of Declination, and so for the rest, as in the Table.

For the placing of these Parallels of the length of the day upon any of the fore-mentioned Plains, you must insert these Angles of Declination into your Trigon between the Tropicks; and proceed in all respects as before. I will therefore give you but one Example, which shall be in a South Plain, Declining Eastward 15 deg. in the Latitude of 51 deg. 32 min.

Having drawn your Dial with hours, halves and quarters, or made an Horizontal Dial proper for this Declining Plain, and put in the Equinoctial, proportioned your Stile to the Plain and described the two Tropicks as hath been already taught.

Length of the day.	The Sun's Declinati- on.	
	D	M
8	23	31
9	21	40
10	16	55
11	11	37
12	5	55
13	0	00
14	5	55
15	11	37
16	16	55
17	21	40
18	23	31

You

You must then, for the drawing of the *Parallels of the length of the day*, have recourse to the little Table before-going, and insert those Degrees of Declination into your Trigon, and from thence transfer them to your Plain.

It is to be performed in all respects as in the former Chapter for the inserting of the Signs, not at all differing therefrom; and therefore I shall forbear to give any farther instructions for the performance thereof, but shew you the Figure of a South Plain Declining Eastward 15 deg. with these *Parallels* drawn thereon, which will instruct more than a whole Chapter of Information. See *Figure IX*.

Note, In Chapter I. of this Tractate, where I shewed how to describe the Tropicks and other *Parallels of Declination* upon a Polar Plain, where they are Perfect Circles, I told you that I made choice of such and such *Parallels of Declination*, as of 11 deg. 37 min. 16 deg. 55 min. &c. for a reason hereafter to be given; that is, because those were the *Parallels of Declination* proper for those Circles when the day shall be 10 or 14: 11 or 9 hours long, and therefore, the Circles drawn through those Points of Declination are the *Parallels of the Sun's Course* or *Diurnal Arches* when the day is 13, 14, 15 or 16 hours long, as they are noted in *Figure I*.

And thus much for the drawing of the *Parallels of the Signs* and *Diurnal Arches* in all kinds of Plains. I will now proceed to shew you how some other *Astronomical Conclusions* (which are very pleasing and delightful) may be inscribed upon all sorts of Dial-Plains.

C H A P. IV.

Shewing how the Italian and Babylonish hours may be Described upon all kinds of Dial-Plains.

THE *Italians* account their hours from the *Sun's Setting*; and the *Babylonians* from his Rising, so that these kind of Hour-lines being drawn upon any Plain, you know how many hours are past since the last Setting or Rising of the Sun. The Inscription of these *Hour-lines* into any of the former Plains is very easie, the Work of the last Chapter being well understood.

Because that upon a full South or an Horizontal Plain, these Hour-lines shew themselves most uniform, I have therefore for Example sake, made choice of a full South Dial, upon which it shall be shewn how to draw both the *Italian* and *Babylonish* hours.

Your Dial being drawn and the two Tropicks and the Equinoctial thereon inscribed, and also the Horizontal Line as in *Figure X*. you must draw in your Dial two obscure *Parallels of the length of the day*, one when the day is 8 hours, and the other when the day is 16 hours long: expressed in the Dial by the two pricked Arches near the two Tropicks, the uppermost of which is the Parallel of the Sun's Course when the day is 8 hours long, and the undermost is the Parallel of his Course when the day is 16 hours long, and the Equinoctial is the Parallel of the Sun's Course when the day is 12 hours long.

Your

Your Dial being thus prepared, and these Parallels thus inserted, the Inscription of these Hour-lines is very easie and plain to be understood. To begin then with the Inscription of the *Babylonish* hours (which are the hours from the Sun's rising.) First, It is apparent that when the day is 8 hours long, that the Sun riseth at 8 in the Morning, so that at that time, the first hour after the Sun's rising is 9 in the Morning. Secondly, When the day is 12 hours long, the Sun riseth at 6 in the Morning, so that at that time, the first hour after the Sun's rising is 7 in the Morning. Thirdly, When the day is 16 hours long, the Sun riseth at 4 in the

		Length of the Day.		
		8	12	16
Hours from Sun-rising.	1	9	7	5
	2	10	8	6
	3	11	9	7
	4	12	10	8
	5	1	11	9
	6	2	12	10
	7	3	1	11
	8	4	2	12
	9	5	3	1
	10	6	4	2
	11	7	5	3

Morning, so that the first hour after his rising is 5 in the Morning, as plainly appeareth by this Table: by which you may perceive that when the day is 8 hours long, the seventh hour from Sun rising is 3 in the Afternoon. When the day is 12 hours long, the seventh hour from the Sun's rising is 1 in the Afternoon. And when the day is 16 hours long, the seventh hour from the Sun's rising is 11 before Noon, as by this Table doth evidently appear. And therefore a streight Line drawn in your Dial through those Points where the common Hour-lines of your Dial cross the respective Parallels of the days length, shall shew the true quantity of hours since the Sun's rising at all times of the Year, which is the *Babylonish* hour.

For *Example*, Let it be required to draw the seventh hour from the Sun's rising in your Dial. First, By the Table you see, that in the Parallel of 8 hours for the length of the day, the seventh hour from the Sun's rising is 3 in the Afternoon, therefore observe where the Hour-line of three crosseth the Parallel of 8 hours, which is at *a*. Secondly, By the Table you see that in the Parallel of 12 hours for the length of the day, the seventh hour from Sun rising is then 1 in the Afternoon, wherefore observe where the Hour-line of 1 crosseth the Equinoctial, which is at *b*. Thirdly, By the Table you see that in the Parallel of 16 hours, for the length of the day, the seventh hour from the Sun's rising is 11 before Noon, therefore observe where the Hour-line of 11 crosseth the Parallel of 16 hours, which is at *c*: then draw the streight Line *abc*, which shall be the seventh *Babylonish* hour, or the seventh hour from the Sun's rising all the Year long.

And by this Rule, and the help of the Table, you may draw all the other hours from Sun rising, as you see them drawn in the Figure, and put Numbers to them, as you see there done; But to remove all doubts that may arise in the performance thereof, observe the following Notes.

Note 1. That if any of the Points you are to make use of for the drawing of any of these hours fall without your Plain, you must in this case extend your Hour-line, Parallel and Equinoctial, beyond the limits of your Dial-plain, and there make use of the Points, but you need extend the Line you draw no farther than the bounds of the Plain, as here in the Figure you see the first hour from Sun rising crosseth not the Equinoctial and the Hour-line of 7 within the Plain, but if the Equinoctial and the Hour-line of 7 were extended, it would cross.

Note 2. That if any of the three Points you are to make use of do so far exceed the limits of your Plain, that it will be either impossible (or at least very troublesome) to extend the Hour-lines so far, then in that case any two of the three Points will sufficiently serve the turn.

Note 3. That as the hours from Sunr-ising were put into the Plain, by the same Rule may the hours from Sun-setting (or *Italian* hours) be inserted, the difference being only in the numbring of them; the hours from the Sun's rising being numbred from the West side to the Horizontal Line by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11, and the hours from the Sun's setting are denominated from the East side of the Horizon, and numbred backwards by 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, and 13, as in Figure X. doth evidently appear.

Note 4. That these *Italian* and *Babylonish* hours inscribed on all Plains by help of this little Table, and the Rules and Cautions delivered in this Chapter, and therefore more Examples were superfluous: Only for your further satisfaction have recourse to Figure IV, and Figure I, where these Hour-lines are inscribed upon Direct *Polar* and Direct *Equinoctial* Plains.

A Corollary arising from the Work of this Chapter.

The Parallels or Hour-lines from the Sun's *Rising* or *Setting* being inscribed upon any Plain, there will, by their Correspondent Intersections one with another, be Points produced, through which, if Lines be drawn with an even hand, the same shall be Parallels of the Length of the day: So the Pricked Line 5 c 19, in Figure X, is the Parallel of the Sun's Course when the day is 16 hours Long; and the Pricked Line o a o in the same Figure X, is the Parallel when the day is 8 hours Long. So the Pricked Curved Lines in the Equinoctial Dial, Figure IV, are the Parallels of the Sun's Course when the day is 8. 9. 10. 11. 12. 13. 14. 15 and 16 hours Long. Also, the Circular Line noted with 15. 15. 15. in the Polar Dial, Figure I. is the Parallel of the Sun's Course when the day is 15 hours Long: and thus may Points be found whereby to draw the *Diurnal Arches* upon all Plains whatsoever.

C H A P. V.

Shewing how the Jewish or Old Unequal Hours may be drawn upon any Plain.

IT was the Custom of the Ancients to divide their Day and also their Night (whether long or short) into 12 equal parts, beginning their Day at the Sun's rising, and their Night at the Sun's setting: So that 12 of the Clock at Noon was always the *Sixth* hour of their day, and 12 at night was always the *Sixth* hour of their Night, and according to this Division were their Dials drawn; so that all the Summer the hours of their day were longer than the hours of their night; and all the Winter, the hours of their night were longer than those of their day, and when the Sun is in the Equinoctial, then the hours of their day and night were equal, and the same with those of our Account, but at all other times of the Year different.

The

The inscribing of these hours into all kind of Plains is very easie, being much like the drawing of the *Babylonish* and *Italian hours* before taught.

Having therefore drawn your Dial with the Hours, Halves, and Quarters, and also drawn the two Tropicks and the Parallels of the length of the day thereupon, as you see done in Figure IX, which is a South Plain declining Eastward 15 deg. Then make choice of two Parallels of the length of the day, which must be both of them equidistant from the *Equinoctial*, which let be the Parallels of 9 hours and 15 hours, both which are three hours distant from the *Equinoctial* on either side thereof, and these two Parallels are the most convenient for this purpose, because the *Jewish hours*, will fall (in these two Parallels,) justly upon the *Hours, Halves and Quarters* of the *Common Hour-lines*: and so be the easier drawn. Now the Points through which every one of the *Jewish hours* must pass is shewed by this little Table, wherein you may see that the First *Jewish hour* must be drawn through 5 hours 45 minutes (or 5 hours three quarters) in the Parallel of 15, through 7 hours in the *Equinoctial*, and through 8 hours and a quarter in the Parallel of 9 hours.

Jewish hours.	The Parallel of 15 hours.		Equinoctial.	The Parallel of 9 hours.	
	H	M		H	M
1	5	45	7	8	15
2	7	0	8	9	0
3	8	15	9	9	45
4	9	30	10	10	30
5	10	45	11	11	15
6	12	0	12	12	0
7	1	15	1	0	45
8	2	30	2	1	30
9	3	45	3	2	15
10	5	0	4	3	0
11	6	15	5	3	45
12	7	30	6	4	30

In like manner, the Second *Jewish hour* must be drawn in your Plain through 7 of the Clock in the Parallel of 15: through 8 a Clock in the *Equinoctial*: and through 9 of the Clock in the Parallel of 9 hours, and so of all the rest, according as you see in this Table, and as you may perceive them drawn in the South declining Plain before mentioned Figure IX. And through those hours and quarters of hours which this Table expresth, must the Old unequal or *Jewish hours* be drawn, in all Plains whatsoever; whether Direct, Declining, or Reclining and Declining, of which you have another Example of these hours drawn upon the Polar, or South Reclining Plain, Figure IV. These things are called by some the *Planetary Hours*, but they are very different from them, for these respect the equal Division of the *Equinoctial*, as the other do of the *Ecliptick*.

C H A P. VI.

Shewing how to draw the Azimuths, or Vertical Circles on all sorts of Plains.

THE Azimuths are great Circles of the Sphere, meeting together in the *Zenith* and *Nadir* of the Place: They have the same Relation or Habitude to the *Horizon*, as the *Meridians* or *Hour-circles* have to the *Equinoctial*. They are variously inscribed on all Plains according to their Situation. In the *Horizontal* Plain they meet in a Center with equal Angles: As the *Hour-lines* did in the *Equinoctial* Plain. In all *Upright* Plains, whether

whether *Direct* or *Declining*, they are Parallel to the *Meridian* or Line of 12. And in all *Reclining Plains* they meet together in a Point which is the Zenith of the Place, but with unequal Angles. These Azimuths being great Circles in the Sphere; are therefore straight Lines, and may be described upon all sorts of Plains as followeth.

SECT. I. On the Horizontal Plain.

IN the Horizontal Plain these Azimuths are most easily inserted, for your Dial being drawn, with the Tropicks thereon, you have no more to do, but upon the foot of the Perpendicular Stile to describe a Circle, which you may divide into 32 equal parts (beginning at the Meridian) answering to the 32 Points of the *Mariner's Compass*; Or else you may divide the same Circle into 90 equal parts, according to the *Astronomical Division*, and through each of those Points draw straight Lines from the foot of the Stile, and set Numbers or Letters to them, either by 10, 20, 30, 40, &c. if you divide the Quadrant into 90, or else by South, S by W, SSW, SW by S, &c. if you divide the Circle according to the *Mariner's Compass*; An Example of these Lines drawn upon an Horizontal Dial, you shall find at the end of the Tenth Tractate, *Of Projective Dialling*.

SECT. II. On East or West Erect Direct Plains.

Figure
II.

YOUR Dial being finished, Upon the Point E, of the Horizontal Line MEN in your Dial, raise the Perpendicular EQ equal to the Line EG in your Dial, and on Q as a Center, describe the Quadrant QEL, and divide it into eight equal parts, representing one quarter of the *Mariner's Compass*, and from the Center Q draw Lines through each of those Divisions, extending them till they cut the Horizontal Line MEN in the Points ○ ○ ○ ○ ○ ○, from which Points draw Lines perpendicular to the Horizontal Line MEN, and they shall be the *Azimuths* or *Points* of the *Compass* between the *East* and the *South*. — Now for those *Azimuths* which fall between the *East* and the *North*, namely, E by N. — ENE — NE by N — the same distances being set upon the Horizontal Line from E, towards the left hand, as the three first Azimuths E by S — ESE — SE by E were toward the right hand, shall give the 3 Points ○ ○ ○ on the left hand of E, through which Points also Lines drawn perpendicular to the Horizon, shall be the *Azimuths* between the *East* and the *North*, viz. so many of them as your Plain is capable to receive, as in Figure II.

¶ Here note, That as the *East Dial* sheweth all the *Morning* hours from Sun Rising to the *Meridian*: and the *West Dial* sheweth all the *Afternoon* hours from the *Meridian* to his *Setting*: so doth the *East Dial* shew all the *Azimuths* from the Sun's Rising till Noon, and the *West Dial* all the *Azimuths* from Noon till his *Setting*.

SECT. III. In the full North and South Erect Plains.

THE drawing of the *Azimuths* upon the full North or South erect Plains is very little different from the drawing of the same Circles upon the East or West Plains. But for Example, Let it be required to draw the Azimuths

muths upon a full South Dial. The Tropicks and the Equinoctial being drawn together with the Horizontal Line A L B. Take in your Compasses the length of the Perpendicular Stile of your Dial L S, and set it upon the Meridian Line of your Dial, from L to $\odot$, and upon the Point $\odot$ as a Center, describe the Semicircle E L F, and divide each Quadrant thereof, namely E L and L F into 9 equal parts (each Quadrant representing one quarter of a Great Circle, which is 90 degrees) For in this *Example* I have put in the *Azimuths* according to the *Astronomical Account* of them, as 10, 20, 30, &c. from the Meridian, and not according to the *Mariner's Account* by *Points* of the *Compass* and through each of those Divisions draw Lines from the Center $\odot$ till they cut the Line A L B in the Points *m, n, o, p, q* and *r*, through which Points draw Lines parallel to the Meridian or Line of 12, they shall be the true *Azimuths* upon your Plain, and so these *Azimuths* are according to the *Astronomical Account* by 10, 20, 30, 40, &c. and not by the *Mariner's Account* by *Points* of *Compass*, as in the East Dial they were.

Figure
V.

SECT. IV. On Erect Declining Plains.

IN upright Declining Plains the *Azimuths* are easily inscribed, little differing from the former. Draw therefore your Dial, which we will suppose to be the South Declining Plain before used, Declining from the South Eastward 15 degrees. As Figure IX.

Figure
IX.

Your Dial being drawn with the Equinoctial, Tropicks, and Horizontal Line thereon inscribed; Upon the Horizontal Line D B E in your Dial, on the Point B raise the Perpendicular B C, making B C equal to B O the perpendicular Stile in your Dial: then on the Point C as a Center, describe the Semicircle R B S; This done, Lay a Ruler upon C, unto $\odot$, where the Hour-line of 12 and the Horizontal Line do cross each other, and where it cuts the Semicircle R B S, begin to divide it into sixteen equal parts at the Points *****, &c. then from the Center C draw Lines through each of those Divisions till they cut the Horizontal Line D E in the Points *a b c d e f g h i k* and *l*. — Lastly, Through these Points *a b c d e f g h i k* and *l* draw Lines parallel to the Meridian, which Lines shall be the *Azimuths* required, which you must number according to the Situation of the Plain, viz. the *Western Azimuths* on the East side of the Meridian, and the *Eastern Azimuths* on the West side thereof, as you see them numbred in Figure IX.

SECT. V. Upon Direct North, and South Recliners.

IN all these Plains, because the Zenith of the Place cutteth these Plains obliquely, making oblique Angles therewith, there is in all these Plains two Points to be found, before the *Azimuths* can be drawn: The one is the Zenith of the Plain, (which is the foot of the Perpendicular Stile;) The other is the Zenith of the Place, (which is the Point upon the Plain where all the *Azimuths* must meet, with unequal Angles, as the Hour-lines upon all Dial-plains do in the Poles, except in the Polar Plain, where they meet with equal Angles.) And here note, That the Zenith Point of the Place, always falleth upon the Meridian, or 12 a Clock Hour-line of the Dial.

I. Upon Direct Polar or Equinoctial Plains.

To find these two Points upon a *North Plain* Reclining from the *Zenith* 51 deg. 32 min. equal to the Latitude of the Place, the Complement thereof is 38 deg. 28 min. and such a Plain is the forementioned *Polar Dial*, Figure I.

Figure

I.

In the *Trigon* belonging to this *Polar Dial*, the Line *K D* is made equal to the height of the Perpendicular Stile in the Dial *A X*, Wherefore, Let *K D* be made *Radius*, then *M C* (being Perpendicular to it) is a Tangent Line thereto. Wherefore, upon *K*, as a Center, describe an Arch of a Circle *L D V*, upon which set 51 deg. 32 min. the Reclination of the Plain from *D* to *L*, and set 38 deg. 28 min. the Complement of the Plain's Reclination from *D* to *V*, and through the Points *L* and *V*, draw the Lines *K L M*, and *K V T*.

So, *K D* being equal to the length of the Perpendicular Stile, *D M* shall be the *Tangent*, and *K M* the *Secant* of the Plain's Reclination: And *D T* shall be the *Tangent*, and *K T* the *Secant* of the Complement of the Plain's Reclination.

These Lines being drawn upon your *Trigon*, take *D M* the Tangent of the Plain's Reclination, and set it upon the Meridian Line of your Dial-plain from *A* the foot of the Perpendicular Stile, to *S*, so shall *S* be the Point through which the proper Horizontal Line of the Plain *P S Q* must be drawn. — Also, out of your *Trigon* take *D T*, the Tangent Complement of the Plain's Reclination, and set that distance upon the Meridian Line of your Dial-plain, from *A* the foot of the Perpendicular Stile, to $\odot$, so shall $\odot$ be the *Zenith* of the Place, and the Center where all the *Azimuths* must meet.

Again, Take *K M*, (the Secant of the Plain's Reclination) out of your *Trigon*, and making that *Radius*, set one foot of your Compasses in *A*, the Center of the Dial, and describe the Semicircle *m S n*, which divide into 16 equal parts, for one half of the *Mariner's Compass* if you will put in the *Azimuths* according to that Account (as here they are) Or into 90 deg. each *Quadrant* (if you will) according to the Astronomical Account. Then lay a Ruler upon *A*, and the several Divisions of the Semicircle *m S n*, and it will cut the Horizontal Line *P S Q* (which is also a Tangent Line to the Semicircle *m S n*) in the Points * * * *.

Lastly, Lay a Ruler to $\odot$, which is the *Zenith* of the Place, and to every of these Points * * *, So shall Lines drawn by the Side of the Ruler (as the Pricked Lines in Figure I. are) be the *Azimuth* Lines desired. Which must be numbred from the Meridian towards their proper Coast, as in Figure I. Upon all other Plains the Rule following is General.

II. Upon North and South Reclining Plains.

The Perpendicular Stile being made the *Radius*, the Meridian Line is a Tangent Line thereunto; and the *Vertical* or *Zenith* Point, in which all the *Azimuths* must meet, must always be the *Tangent of the Complement of the Plain's Reclination*, and must be set upon the Meridian Line, from the foot of the Perpendicular Stile downwards in *Recliners*, but upwards (or above the foot of the Perpendicular Stile) in the opposite *Incliners* — Also, The *Horizontal Point* in these Reclining Plains, must be the *Tangent of the Plain's Reclination*, set from the foot of the

Perpen-

Perpendicular Stile upon the Meridian upwards in *Reclining Plains*, but downwards in the *Incliners*. And the *Horizontal Point* being found, the *Horizontal Line* drawn through the same must be always *Parallel* to the *Hour-line* of Six.

In *Equinoctial Plains*, whether *Direct* or *Declining*, the *Azimuth Circles* meet at the *Vertical Point*, with *Un-equal Angles*, and therefore, one other Point must be found to draw each *Azimuth* by :

And that other Point may be most conveniently had, either in the *Horizontal Line* of the *Plain*, or in the *Equinoctial* : And those Points of *Inter-section* with the *Equinoctial*, may be found by this Proportion,

As the Sine of 90 deg.

Is to the Sine of the Latitude,

So is the Tangent of the *Azimuth* from the Meridian,

To the Tangent of the *Equator's Distance* from the Meridian.

So the *Latitude* being 51 deg. 32 min. The 10th *Azimuth* from the Meridian will be found to be 7 deg. 50 min. from the Meridian upon the *Equator* : Or, the *Azimuth* of 11 deg. 15 min. one Point of the *Compass* will be found to be 8 deg. 51 min. from the Meridian upon the *Equator*, and the rest as in these Tables.

Azimuth.		Equinoct. Distance.		Points.			Equinoct. Distance.		Points Names.
D	M	D	M		D	M	D	M	
10	0	7	50	1	11	15	8	51	S by E
20	9	15	54	2	22	30	18	58	S S E
30	0	24	20	3	33	45	27	36	S E by S
40	9	33	18	4	45	0	38	2	So. East
50	9	43	0	5	56	15	49	30	S E by E
60	9	53	35	6	67	30	62	6	E S E
70	9	65	3	7	78	45	75	44	E by S
80	0	77	18	8	90		90	0	East.
90	0	90	0						

I intended to have inserted the *Azimuths* (by this Rule) into Figure IV. but it being incumbred with *Furniture* enough already, I omitted them : These *Directions* being sufficient to supply that Defect.

S E C T. VI. Upon East or West Recliners.

IN all those Plains, the *Hour-line* of XII. (which is the *Meridian* of the Place) and the *Substilar Line* (which is the *Meridian* of the Plain) are not both one Line, (as in all the other Examples they were) but two several Lines: You must therefore (to instance in a *West Dial* Reclining 40 deg. as in Figure XII.) First, Find the *Vertical* or *Zenith Point*, where the *Azimuths* are to meet, and Secondly, the *Horizontal Point*; through which the *Horizontal Line* must pass:

Figure
XII.

First,

First, From the foot of the Perpendicular Stile, as at A, let fall a Perpendicular to the Meridian of the Place or Hour-line of XII. [which Line in all East and West Recliners is Parallel to the Horizon, as in North and South Upright Plains it is Perpendicular thereunto] Let this Perpendicular Line be V A O, so V shall be the *Vertical* or *Zenith Point*, where all the *Azimuths* must meet, and O shall be the *Point* through which the *Horizontal Line* must be drawn, parallel to the Hour-line of 12, as the Line D O E, and (if there be no former Errour in your Work) this *Horizontal Line* will also pass through the Intersection of the *Equinoctial Line* with the *Hour-line* of Six. These Points you see are easily found in these Plains, by drawing of one Line only, namely V A O; But more artificially thus: The Line V A O being drawn at full length, Upon the Point A Erect a Perpendicular A H, making A H equal to A B the length of the Perpendicular Stile. Then making A H the *Radius*, V A O shall be a Tangent Line thereto: Upon H describe the Arch of a Circle L A K, and upon it, set off 40 deg. the Plain's Reclination from A to K, and 50 deg. the Complement thereof from A to L: and draw the Lines H K and H L, till they cut the Perpendicular Line V A O, which they will do in the Points V and O, and so is A O the Tangent of the Plain's Reclination 40 deg. and A V the Tangent Complement of the Reclination 50 deg. and by this means also you have found the *Vertical* and *Horizontal* Points O and V.

This done, take H O (which is the Secant of the Plain's Reclination 40 deg.) and with that distance, upon A, the foot of the Perpendicular Stile, describe a Semicircle P Q S, which divide (each quarter thereof) into Eight equal parts, beginning at Q: where the Vertical Line V A (extended) cuts the Semicircle: A Ruler laid from Q, to each of those parts, will cross the *Horizontal Line* D O E (extended where need requires) in the Points * * *, &c.

Lastly, A Ruler laid to V, the *Zenith Point* and every of these Marks * * * in the *Horizontal Line*, if you draw Streight Lines thereby they shall be the *Azimuths* Required.

SECT. VII. Upon North or South Declining Reclining Plains.

THE inserting of this kind of Furniture into Declining Reclining Plains, differeth little from the inserting the same Furniture into East or West Recliners; For having drawn your Dial, proportioned your Stile to your Plain, described the two Tropicks and Equinoctial, as also the Horizontal Line proper to the Plain: You may proceed to the Inscription of the Azimuth or Vertical Circles, in manner following:

Figure
XIII.

First, From the foot of the Perpendicular Stile at K let fall a Perpendicular to the Horizontal Line of the Plain, as V K H, upon K raise a Perpendicular K N, making K N equal to F K the perpendicular Stile; which Line K N, make a *Radius*, and upon N as a Center, describe an Arch of a Circle, and upon it set 35 deg. the Complement of the Plain's Reclination from K to b, and draw the Line N b V. Also set 55 deg. the Reclination from K to a, and draw the Line N a H: So shall K H be the Tangent, K V the Tangent Complement of the Plain's Reclination, and consequently H N, the Secant of the Reclination.

Secondly, Make H O equal to H N, and upon O as a Center describe the Semicircle P H D, so is the Horizontal Line a Tangent Line thereto.

Thirdly,

Thirdly, Observe where the Hour-line of 12 cuts the Horizontal Line, which is at S: A Ruler laid from O to S will cut the Semicircle in Q, at which Point begin to divide the Semicircle into (either) 16 equal parts for the Points of the Compass, or (as I have here done) into 18 equal parts, at the Points $\odot \odot \odot$, &c. each containing 10 deg. as Astronomers account.

Fourthly, The Semicircle being thus divided, lay a Ruler to Q, and every of the Divisions $\odot \odot \odot$, &c. and where the Ruler crosseth the Horizontal Line, make Marks or * * *.

Lastly, If from the Point V, right Lines be drawn through these Marks or * * *, they shall be the Azimuths proper for the Declining Reclining Plain.

CHAP. VII.

Of the Almicanter, or Circles of Altitude, and how to inscribe them upon all sorts of Plains.

IN the Sphere, the *Almicanter* or Circles of *Altitude*, have the same habitude or relation to the *Azimuth* or *Vertical Circles*, as the *Parallels* of *Declination* have to the *Meridians* or *Hour-circles*: And therefore, As the *Equinoctial* it self, and also all the *Parallels* of *Declination* in a *Polar Dial*, (as Figure I.) are perfect *Circles*, so are the *Almicanter* perfect *Circles* upon *Horizontal Plains*.

The Inscription of these into all sorts of Plains, is (in a manner) the same with the Inscription of the *Parallels* of *Declination*: Only, whereas inscribing the *Tropicks* and *Parallels* of *Declination*, you took the *Hour-lines* out of your Plain and put them into a *Trigon*; so in the Inscription of these, you must take the *Azimuth Circles* out of your Plain, and put them into a *Trigon*, and from thence transfer them back again to your Plain as you did the other: And therefore, As the *Hour-lines* (in the other) must be first drawn upon the Plain, so (in this) must the *Azimuths* be first inscribed as in the preceding Chapter hereof was shewed how to do: And because these *Almicanter* are smaller *Circles* of the Sphere, as the *Tropicks* and *Parallels* of *Declination* were, they will (by the 3d. Affection) also be *Conick Sections*: Now the manner how to inscribe them upon all sorts of Plains, shall be shewed in this Chapter.

SECT. I. Upon Vertical, or Horizontal Plains.

THese Plains lie Parallel to the Horizon, and have the Zenith Point for their Pole, so that the foot of the Perpendicular Stile must be the Center upon which (in these Plains) the *Almicanter* must be described.

For the Numeration of these Circles, there are Two ways which are most in use. The one is according to Degrees and Minutes of Altitude; the other according to the Proportion that the height of any Upright Object bears to the Shadow of it.

I. By Degrees and Minutes of Altitude.

The Dial being drawn, with the Equinoctial and the two Tropicks upon it (to limit the rest of the Work) make the Perpendicular Stile of the Dial a *Radius*, and upon the top thereof (as a Center) describe a Semi-circle (or Quadrant) then will the Meridian or 12 a Clock Hour-line be a Tangent Line thereunto. — Divide this Quadrant into 90 equal parts or degrees, (or into each 5 or 10 deg. which may be sufficient) and from the top of the Stile draw Lines through those Divisions, till they cut the Meridian of the Dial, And through those Divisions upon the Meridian Line, Circles described upon the foot of the Perpendicular Stile, shall be the Circles of the Sun's Altitude when the Sun is so many degrees high as you divided your Quadrant into parts, whether every 5th. 10th. or any other number of Degrees of Altitude.

II. By the Proportion that Upright Objects bear to the Length of their Shadows.

If you make the length of the Perpendicular Stile a *Radius*, as you must (always) do, let it be divided into 10 (or rather 100) equal parts: Then, if you take the whole length thereof in your Compasses, and set it from the foot of the perpendicular Stile, upon the Meridian Line, and through that point describe a Circle, the point of the Shadow of the *Apex*, or top of the perpendicular Stile, when (at any time) that toucheth that Circle, the Shadows of all Upright Objects shall be equal to their Altitudes or Heights — Likewise if twice the length of the perpendicular Stile be set upon the Meridian, from the foot of the Stile, a Circle described through that point, when the Shadow of the top of the Stile cometh to touch that Circle, then are the Shadows of all Upright Objects double to their heights: — Likewise if Once, Twice, Thrice and an half, the length of the perpendicular Stile be set upon the Meridian Line from the foot of the Stile, and Circle, described through those points, the Shadow of the *Apex* coming to touch any of them, the length of Shadow shall be equal to either Once, Twice, Thrice and an half the height of the Object; These Circles may have written upon them 10, 20, 30, 40, &c. degrees of Altitude. Or *Aequalis, Dupla, Tripla, &c.* An Example of an Horizontal Dial with these Circles described upon it you have in the Ninth Tractate hereof, Page 220.

But if you would put in more minute parts of the Proportion of Objects to their Shadows, you must first enquire what Altitude the Sun must have to make the Shadow be in such proportion to the Object, as shall be required; and to find that, this is the Analogy, or Proportion: For,

As the parts of the Shadow,

Are to the parts of the Gnomon; or perpendicular Stile;

So is the Tangent of 45 deg. or *Radius*,

To the Tangent that the Sun's Altitude must be, to make the Shadow so long, as shall be required.

Example, Suppose I would know how high the Sun must be, to make the Shadow to be two times and an half the length of the Gnomon:

The Gnomon or perpendicular Stile, we will suppose to be divided into 100 equal parts, and measuring the Shadow thereby, you find that to be 350 parts, that is 3 times and an half, the length thereof; Say,

As 350, the parts of the Shadow,

2.54407

Are to 100, the Length of the Gnomon;
So is the Tangent of 45 deg. or *Radius*,

2.00000

10.00000

To the Tangent of 15 deg. 57 min.

12.00000

9.45593

And such Altitude must the Sun have to make the length of the Shadow to be Three times and an half the length of the Objects, height.

And according to this Proportion may you find any other Proportional Parts, the most usual I have here set down, with their Altitudes ready Calculated.

				deg.	min.
If you would have the length of the Shadow, to be in proportion to the height of the Object, as	10	1	Is to	7	07
	6	1		9	27
	5	1		11	18
	4	1		14	02
	3	1		18	26
	2	1		26	33
	3	4		33	41
	2	3		36	52
	5	4		38	35
	4	5		45	00
	3	4		51	29
	4	3		53	07
	3	5		56	19
	1	2		58	02
				63	21
				The Sun's Altitude must be	

And on the contrary, If you would know what Altitude the Sun must have to make the Shadow of what Length you shall Desire; then use the following Proportion:

As for Example, *What Altitude must the Sun have to make the Shadow to be 5 times the Length of the Gnomon?*

As 100, the Length of the Gnomon;

2.00000

Is to the Radius, Tang. 45 deg.

10.

So is 500 (the Length of the Shadow required

2.69897

12.69897

To the Tangent of 78 deg. 42 min.

10.69897

Whose Complement is 11 deg. 18 min. And such Altitude must the Sun have to make the Shadow 5 times as long as the Gnomon. And so of any other Length; As in the following Table:

A Table

A Table of the Proportion that the Shadow hath to the Length of a Perpendicular Gnomon, useful for the inserting of such Almicanterers into Sun-Dials.

D M		D M	
When the Sun's Altitude is	1 7	But, when the Sun's Altitude is	45 0
	2 5		51 20
	5 42		53 7
	7 7		56 19
	9 27		59 2
	11 18		63 26
	14 2		71 34
	18 26		75 58
	26 34		78 42
	30 58		80 33
	33 41		82 53
	36 52		84 18
	38 40		87 10
	45 00		88 54
The Shadow of the Gnomon is		The Shadow of the Gnomon is	
50		Equal	
20		As 5 to 4	
10		As 4 to 3	
8		As 3 to 2	
6		As 5 to 3	
5		As 4 to 3	
4		As 5 to 4	
3		As 4 to 3	
2		As 5 to 4	
Times as much, as the length of the Gnomon.		Times less than the Gnomon.	

SECT. II. Upon Upright Plains, either Direct or Declining.

UPON all these Plains, having first inscribed the *Tropicks*, *Equinoctial*, and *Horizontal Line*, together with the *Azimuths*, proper to the Upright Plain, whether it be *Direct* or *Declining*, — Upon the foot of the perpendicular Stile, erect a Perpendicular to the Horizontal Line of the Plain: equal in length to the perpendicular Stile of the Dial, — As for *Example*.
 Figure XI. In the Upright Declining Plain, Figure XI. Upon the foot of the perpendicular Stile at A, Erect the Perpendicular A O equal to A B, and perpendicular to C D, the Horizontal Line of the Plain, — Then prepare a *Trigon*, (as under the same Figure XI.) in this manner.

First, Draw a right Line E F, and upon E as a Center, describe an obscure Arch of a Circle G F H, on both sides of the Line E F, because it is a Declining Plain, and the Azimuths on each side of the foot of the Perpendicular upon the Horizontal Line are not equidistant therefrom, (whereas, if it had been a Direct Plain, one half of the *Trigon* would have served the turn) into these two Arches F G, and F H, from the point F, by help of the Scale of *Chords*, insert such *Arches*, as you intend to put *Circles of Altitude* upon your Plain. I have made choice of these, *viz.* 10, 20, 30, 40, 50 and 60, which I put into the *Trigon* from F, on both sides thereof towards H and G, at the Points *a b c d e* and *f*, and so draw the Lines E a, E b, E c, E d, E e and E f on both sides, setting the Numbers proper to them towards the ends of them: and these Lines I shall for the future call the *Lines of Altitude*.

Secondly, Take the length of the perpendicular Stile A B (to which A O is equal) out of your Dial, and set it upon your *Trigon* from E to M, and through the point M draw the Line M L, perpendicular to E F. So shall the Line E F of your *Trigon*, represent the *Horizontal Line* of your Dial, and

and the perpendicular Line *LM* that *Azimuth* or *Vertical Circle* which passeth through the foot of the perpendicular *Stile* in your *Dial*.

Thirdly, Out of your *Dial-Plain*, from the point *O*, the top of the perpendicular *Stile*, take the distances to the several points 20, 30, 40, 50, 60 and 70 (that is, where those *Azimuth* or *Vertical Circles*, cross the Horizontal Line of your *Plain CD*) on the West side of the *Dial*, and set them upon the Line *EF* of the *Trigon*, to the points 2, 3, 4, 5, 6 and 7, on the West side of the *Trigon*, and through those points, draw right Lines (all of them) perpendicular to the Horizontal Line of your *Trigon EF*, setting the Numbers to the ends of them as they are numbred in the *Dial-plain*, viz. 20, 30, 40, 50, 60 and 70: So shall these Lines 20. 2: 30. 3: &c. be the *Azimuth Lines* upon your *Trigon*. — In the same manner deal with the East Side of the *Dial*, by taking the distances from *O*, to the Intersections of the *Azimuths* with the Horizontal Line, setting them from *E* to *g, h, i, k, l* and *m*, and drawing the *Azimuth Lines* through the points, *g, h, i, &c.* on your *Trigon*, perpendicular to the Line *EF*, setting their respective Names or Numbers to them at the ends of them.

Your *Trigon* being thus prepared, the next Work will be to transfer the *Lines of Altitude* from the *Trigon* to the *Plain*, which to do,

Fourthly, Suppose, I would transfer the Parallel of the *Sun's Altitude* for 30 deg. from the *Trigon* to the *Plain*: — First, on the West Side: The Parallel of 30 deg. of *Altitude* is represented by the Line *Ec* 30; (1.) Observe where the Parallel of *Altitude* crosseth the *Azimuth* of 70, and from that point (2.) take the distance to the Line *EF*, which distance (3.) set upon the *Azimuth Line* of 70 upon your *Plain* from 70 to *n*, so shall *n* be the point upon the 70th. *Azimuth* of your *Plain*, through which the Parallel of 30 deg. of *Altitude* must pass: In like manner,

From the Point where the Line of 30 deg. of Altitude, crosseth the Azimuth Line of	$\left\{ \begin{array}{l} 60 \\ 50 \\ 40 \\ 30 \\ 20 \\ \text{Subst.} \end{array} \right\}$	Take the distance to the Horizontal Line of your <i>Trigon EF</i> , and set that distance upon your <i>Dial-plain</i> upon the <i>Azimuth Line</i> of	$\left\{ \begin{array}{l} 60 \\ 50 \\ 40 \\ 30 \\ 20 \\ \text{Subst.} \end{array} \right\}$	to	$\left\{ \begin{array}{l} d \\ p \\ q \\ r \\ s \\ t \end{array} \right\}$
---	---	---	---	----	--

Also, on the East Side of the *Trigon*, and the East Side of the *Dial*:

From the Point where the Line of 30 deg. of <i>Altitude</i> , crosseth the <i>Azimuth</i> Line of	$\left\{ \begin{array}{l} 10 \\ \text{South} \\ 10 \\ 20 \\ 30 \\ 40 \end{array} \right\}$	Take the distance to the Horizontal Line of your <i>Trigon</i> <i>EF</i> , and set that distance upon your <i>Dial-plain</i> , upon the <i>Azimuth Line</i> of	$\left\{ \begin{array}{l} 10 \\ \text{South} \\ 10 \\ 20 \\ 30 \\ 40 \end{array} \right\}$	to	$\left\{ \begin{array}{l} v \\ w \\ x \\ y \\ z \\ e \end{array} \right\}$
---	--	--	--	----	--

Then a Line drawn with an even hand, through the points *n o p q r s t v w x y z e*, so that it make no Angles, that Line, so drawn, shall be the Parallel of the *Sun's Altitude* of 30 deg. upon your *Plain*: And the like course is to be taken for all the rest of the *Parallels of Altitude*, as the Scheme, Figure *XI.* will better inform you than many words.

SECT. III. Upon East and West Recliners, as also upon North and South Declining Reclining Plains.

IN these Plains, the Meridian of the Plain (or Substile) and the Meridian of the Place (or Hour-line of 12) are two different Lines; Therefore (as in the describing of the Parallels of the Signs) you took the Substile or Meridian of the Plain, for 12 a Clock, and drew Horizontal Hour-lines on either side thereof, to facilitate the Work, (as in *Chap. II. Sect. IV. Fig. VII.*) So for the Inscription of the *Almicanters* or *Parallels of Altitude*, take the *Azimuth* which is perpendicular to the Plain (which will be always equal to the Declination) and equal on both sides thereof (from the foot of the perpendicular Stile) set off such *Azimuths* as you intend (whether points of the Compass or 10, 20, 30, &c.) for these must be drawn obscurely, that they may be wiped out again, if need be.

Figure XIV. Your Dial being thus prepared (which is a South Plain Declining 30 deg. and Reclining 55 deg.) with the *Horizon*, *Tropicks*, *Equinoctial*, and obscure *Azimuths*, as in *Figure XIII.* prepare a *Trigon* in this manner.

First, Draw a right Line *F B*, and upon *F* (as a Center) describe an Arch, or Quadrant, of a Circle, as *C D*, and upon it set such degrees of Altitude as you have a mind to inscribe upon your Plain (I have here made choice of 10, 20, 30, 40, 50, and 60 deg. of Altitude, and therefore from *F*, through these points, I draw the Lines *F 10. F 20. F 30. F 40. F 50. and F 60.* — Then make *A F* in your *Trigon*, (*Figure XIV.*) equal to *V N*, in your Dial, which is the *Secant* of 35 deg. the Complement of the Plain's Reclination, and draw the Line *A F* perpendicular to *F B*.

Secondly, Out of your Dial-Plain *Figure XIII.* take *V H* the *Axis* of the *Horizon*, and put it into your *Trigon*, from *A* to *B*, and draw the Line *A B*, and that shall be the *Axis* of the *Horizon*.

Thirdly, Out of your Dial-Plain, (from the *Point V*) take the distances to the several Intersections that the obscure *Azimuth Lines* make with the *Horizontal Line*, at the *Points 10, 20, 30, 40, 50 and 60* from *H* the *Azimuth* of the *Plain*, and set those distances into your *Trigon*, from *A*, upon the Line *F B*, drawing the Lines *F B, F 10, F 20, F 30, F 40, F 50 and F 60.* — And now your *Trigon* being prepared, you may easily insert the *Circles of Altitude* into your Reclining Declining Plain, as followeth.

Fourthly, To instance in the *Parallel* of 20 deg. of *Altitude* from the Intersection of the Line of 20 deg. of *Altitude* in the *Trigon* with the Line *A B*, take the distance to *A*, which distance set upon your *Dial-Plain* from *V*, upon the Line *V H* of your *Plain*, and it shall reach from *V* to *a*, so shall *a* be one *Point* upon the *Vertical Line V H*, through which the *Parallel* of 20 deg. of *Altitude* shall pass — Also,

Take with your Compasses the distance from <i>A</i> , to the Intersection of the 20th. <i>Parallel</i> of <i>Altitude</i> with the Line	<i>A 10</i>	And setting that distance from the <i>Point V</i> , upon the	<i>10th.</i>	Azimuth on both sides of the Line <i>V H</i> , it shall give the Points	<i>b</i>	<i>b</i>
	<i>A 20</i>		<i>20</i>		<i>c</i>	<i>c</i>
	<i>A 30</i>		<i>30</i>		<i>d</i>	<i>d</i>
	<i>A 40</i>		<i>40</i>		<i>e</i>	<i>e</i>
	<i>A 50</i>		<i>50</i>		<i>f</i>	<i>f</i>
	<i>A 60</i>		<i>60</i>		<i>g</i>	<i>g</i>
	<i>A 70</i>		<i>70</i>		<i>h</i>	<i>h</i>

Through

Through which Points, if you draw a Line with an even hand, so that it may make no Angles, the Line *h g f e d c b a b c d e f*, so drawn, shall be the *Parallel* of 20 deg. of *Altitude* upon the *Plain*: And in this manner may all the other *Parallels* of *Altitude* be inscribed into the *Plain*; As in Figure XIII. And

Of these *Circles* of *Altitude* inscribed upon a *West Reclining Plain*, where the *Azimuths* are put in according to the *Points* of the *Compass*, and the *Circles* or *Parallels* of *Altitude* according to the *Proportions* of *Shadows* to their heights, you have an Example in Figure XII.

C H A P. VIII.

Of the Domifying Circles, commonly called the Circles of Position, and how to inscribe them upon all sorts of Plains.

These are Great Circles of the Sphere, and therefore (by the I. Affection) they will be streight Lines; Their situation in the Sphere, is at the common intersection of the *Meridian* with the *Horizon*, and are reckoned, according to the *Rational way* of *Regiomontanus* (as the *Astrologers* term it) from the *Meridian* downwards to the *Horizon*, at 30 and 60 deg. which with the *Meridian* and *Horizon* are the *Cusps* of the Six *Celestial Houses* above the *Horizon*, so that these Circles being inscribed upon any Dial-plain, it may be known in which of the Twelve Houses the *Sun* at any time is, and in what part, how near or far off of the *Cusps*. They are Great Circles (as I said before) and their manner of inscription is very easie

SECT. I. Upon the Horizontal, direct East and West, and East and West Reclining Plains.

Bring all these sorts of Plains under one Head for this Reason, because in all these Plains they are *Parallels*, as the Hour-lines are in East, West and Polar Plains.

1. In *Horizontal Plains*, They are thus easily inscribed: For, if through the common intersections of the Hour-lines of VIII and X with the Equinoctial, you draw Lines parallel to the *Meridian* or Hour-line of XII, those Lines so drawn shall be the *Cusps* of the XII and XI Houses, — The *Meridian* is the *Cusp* of the X House. — And the two other Lines drawn parallel to the *Meridian* through the intersections of the Hour-lines of II and IV with the Equinoctial shall be the *Cusps* of the IX and VIII Houses — And lastly, the East and West parts of the Horizontal Line are the *Cusps* of the First and Seventh House.

An Example of an Horizontal Dial with these Circles inscribed upon it, you have in the Tenth Tractate hereof, Page 226.

2. In East and West Plains, the Circles of Position will be *Parallels* to the *Horizon*, as in the Horizontal they were to the *Meridian*; And the manner

Figure II. manner how to inscribe them into these Plains, is thus. Upon the Quadrant Q E L. Figure II. set 38 deg. 28 min. the Complement of the Latitude from E towards L, and laying a Ruler from Q to that point, it will cut the Horizontal Line of the Plain in *n*, so is Q *n* the Secant Complement of the Latitude, which must now be made a *Radius*, and so placed from the point E (the foot of the Perpendicular Stile) upon the Line E G extended, *viz.* to Q, that it may be perpendicular to the Equinoctial; so shall the Equinoctial be a Tangent Line thereto, and the Tangent of 30 deg. shall give the point *o*, and the Tangent of 60 deg. the point *p* upon the Equinoctial, through which points *o* and *p* two Lines being drawn parallel to the Horizon, they shall be the *Cusps* of the XII and XI Houses: As in Figure II.

3. Upon East or West Recliners: In these Plains, the Perpendicular Stile being made the *Radius*, find the Secant Complement of the Stile's height, and make that a New *Radius*; So shall the Tangents of 30 and 60 degrees set upon the Equinoctial Circle give points, through which to draw the *Cusps* of the Houses, which must be parallel to the Meridian or Horizontal Line of the Plain.

SECT. II. Upon North and South Plains, both Direct and Declining, Upon all Direct North or South Reclining, and upon all North and South Declining Reclining Plains.

ONE general Rule will serve for the inscription of these Circles into these several sorts of Plains, for here they meet in a Center, which Center is the Common Interfection of the Meridian and Horizontal Line upon the Dial, and the distance of the *Cusps* being 30 and 60 deg. upon the Equinoctial, which are equal to the Equinoctial hour distances of 8 and 10, and of 2, and 4 a Clock from the Meridian, therefore you have no more to do, but to draw right Lines from the Common Interfection of the Meridian with the Horizon, through the Intersections of the Hour-lines of 2, 4, 8 and 10 a Clock with the Equinoctial, and those Lines so drawn shall be the *Domifying Circles* required. Examples whereof you have in several Figures belonging to this Tractate.

As in an Equinoctial Dial Figure IV, where the Pricked Lines shew the *Cusps* of the XII, and XI Houses, the Meridian is the *Cusp* of the X. And the other two Pricked Lines the *Cusps* of the IX and VIII Houses.

Also in a Direct South Plain in Figure V. represented by the Pricked Lines in that Figure.

Likewise, in a Declining Reclining Plain, Figure VII. And Lastly, In a South Declining Plain, Figure XI.

CHAP. IX.

Of the Meridians of other Countries, and how to insert them into any Sun-Dial.

IT is easie to insert the Meridian of any other Country into any Sun-dial made for any other Country, if first you know the difference of *Longitude* between the two Countries, in Time; and also, whether the Remote Country lie *Eastward* or *Westward* from the *Home Country*: For,

If the Remote Country lie $\left\{ \begin{array}{l} \text{Eastward} \\ \text{Westward} \end{array} \right\}$ of the Home Country, it is Meridian or Noon-tide $\left\{ \begin{array}{l} \text{sooner} \\ \text{later} \end{array} \right\}$ in the Remote Country than in the Home Country.

As for Example, Suppose that in a Sun-dial here at *London*, I would insert the Meridian or Noon-tide of *Constantinople*. By the Tables of the latest and best Geographers, the Meridian of *Constantinople* lies *Eastward* of the Meridian of *London*, 30 deg. 45 min. which converted into Time (by allowing 15 deg. to one hour, and 1 deg. to 4 minutes of time) is 2 hours and 15 min. that is 2 hours and a quarter. Wherefore, if you subtract 2 hours 15 min. from 12 hours (because *Constantinople* lies *Eastward* of *London*) the Remainder will be 9 hours 45 min. or 3 quarters of an hour. Wherefore, if (upon any Dial here at *London*,) upon the Hour-line of 9 and 3 quarters, you write the Word (or make some mark for) *Constantinople*, the Shadow of the Stile of the Dial, when it shall fall upon that Word or Mark, you may conclude it to be Meridian or Noon-tide at *Constantinople* — and knowing at what time with Us it will be Noon to Them, it is easily known what hour it is there at any time here.

For if it be at London	4	in the Morning	It is at Constantinople	6	15	
	5			7	15	
	6			8	15	
	7			9	15	
	8			10	15	
	9			11	15	
	10			12 *	15	
	11			1	15	
	12 *			2	15	
	1	in the Afternoon		3	15	
	2			4	15	
	3			5	15	
	4			6	15	
	5			7	15	
	6			8	15	
	7			9	15	
	8			10	15	

In some of the Dials belonging to this Tractate you have several Countries inserted, especially in the Declining Reclining Dial, Figure VII.

And that the like may be done for other Countries, here followeth

A Table of Longitudes, or Difference of Meridians in Time, of
several Eminent Places in the World from London.

Places lying East of London.	Difference in Time.		Places lying West of London.	Difference in Time.	
	H.	M.		H.	M.
Paris in France	0	10	Edenborough in Scotland	0	2
Amsterdam in Holland	0	21	Madrid	0	16
Copenhagen	0	49	S. Helena Inf.	0	20
Stockholm	1	1	Dublin	0	26
Cape of Good Hope	1	5	Tanger	0	29
Rome in Italy	1	6	Madera	1	18
Venice	1	8	Tenariff	1	22
Dantzick	1	18	Cape Farewel	3	13
Cracovia	1	20	C. Raze	3	16
Constantinople	2	15	Surinam	3	42
Caro	2	16	Barbadoes west indies	3	53
Jerusalem	2	30	Bermudas	4	14
Aleppo in Spain	2	40	Boston in New England	4	40
Muscov — Russia metro:	2	48	New York	4	58
Bagdat olein Babylon	3	14	Port Royal	5	4
Ispahan persia metro:	3	46	Jame's Town	5	12
Surrat	5	6	Careleton Inf.	5	18
Fort St. George	5	30	Charle's Town	5	44
Agra mogols empire	5	34	Mexico	6	47
Bantam in Java . . .	7	1	New Mexico	8	31
Peking	7	51	P. Sir Francis Drake	9	40
Nangesagne	8	32			
Iedo	9	16			

It may be now expected I should here further shew how some other *Astronomical* and *Geographical Conclusions* might be inserted into *Sun-dials*; As the *Signs Ascending*, *Descending* and *Culminating*; The *Horizons* of other *Countries*, &c. But I do here purposely omit them, for that in the *Ninth Tractate* hereof, the manner how to inscribe such *Furniture*, not into *Regular Plains* only, but into *Irregular* also, as into *Concave*, *Convex*, or mixt of both, is treated of at large: And so I conclude this *TRACTATE*.

The End of the Fourth TRACTATE.

HOW ARE FURNITURE

SUNDRIES

Made to order and on hand

ANGEL'S

ALL NEW FURNITURE

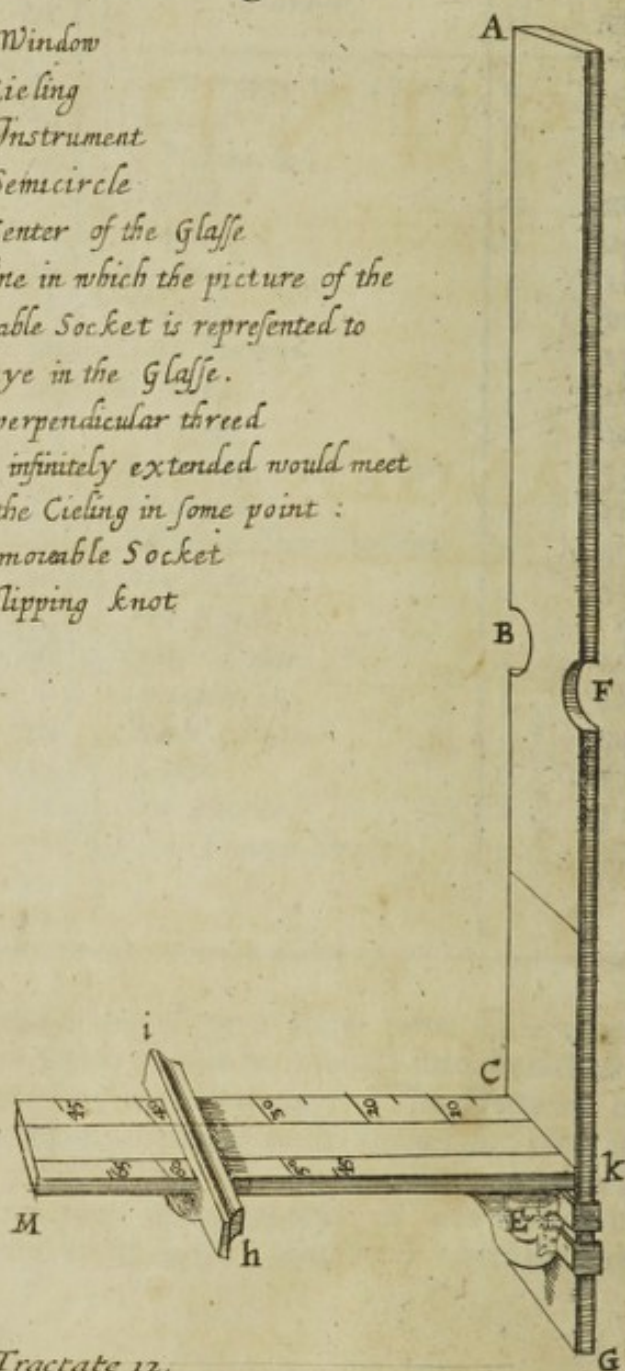
PREPARED

FOR THE

WINTER

The Instrument

- M. N . the Window
- O . the Ceiling
- C. D . the Instrument
- A. B . the Semicircle
- H . the Center of the Glasse
- H. I . the line in which the picture of the
moveable Socket is represented to
the eye in the Glasse.
- K. L . the perpendicular thread
- H. I . being infinitely extended would meet
with the Ceiling in some point :
- F. G . the moveable Socket
- I . the slipping knot



HOW THE FURNITURE OF SUNDIALS,

May be Inscribed upon all Sorts of PLAINS, by
the SCALES of

NATURAL
TANGENTS and SECANTS.

The Fifth TRACTATE.

P R O E M E.

BY the Scales of Chords, and Natural Tangents and Secants, the Ruler mentioned in the First Tractate, Page 15. Figure II. All FURNITURE may be inscribed upon all sorts of Plains; but as they are there Graduated upon a Strait Ruler, they are only serviceable to that Radius to which the Scales are made. But being (as in the forementioned 15th. Page is intimated) put upon a Sector, with an opening Joynt, they will be applicable to any proposed Radius, as in the performance of almost, all the Work in this Tractate it will be required so to vary.

And further note, That if a Line of Equal Parts (which Mr. Gunter, deservedly, calls the *Line of Lines*) be also put upon such a Joynt-Ruler it will, by the help of the Tables of Natural Tangents and Secants (brief ones whereof follow in the next Tractate) supply the use of the forementioned Scales, and in many Cases much better, especially when the Tangents or Secants of many degrees (as above 70, &c.) are required to be laid down upon any Line. I thought good to give intimation hereof in this place, because of the frequent use that will be made of these Lines or Scales for many purposes hereafter signified.

Of Proportioning of the Stile to the Plain.

FOrasmuch as by the Eighth *Affection*, Chapter I. of the foregoing *Treatise*, it is not the whole *Stile* or *Axis* of the *Dial* that gives the *Shadow* to these *Parallels*, *Azimuths*, &c. But some one *Point* therein assigned; good consideration therefore ought to be taken, that that *Point* be so chosen, that it may continue casting its *Shadow* upon the *Dial-plain*, as long as conveniently may be, and not taken at so large a distance from the *Center* of the *Dial*, as to cast its *Shadow* off of the *Plain*, so that the *Lines* drawn thereon, will be of no use, the *Apex* which should point to them, being remote from them, and casting its *Shadow* upon some other *Object* besides the *Plain*—On the contrary, This *Point* ought not to be chosen so near the *Center* of the *Dial*; so that the *Lines* or *Sections* drawn upon the *Dial* shall run so near (or be crowded) together, that at any competent distance of place they cannot be discovered. Therefore, that this *Point* may be judiciously chosen, observe these following *Directions*.

1. If your *Plain* be small, consider whether it be *Direct*, or *Declining*, and if *Declining*, whether much or little from the *South* or *North* Points.

2. If the *Plain* be *Direct*, the *Substile* may best be placed in the middle of the *Plain*; But if it do *decline*, then let the *Substile* be set on that *Side* or *part* which is opposite to the *Coast* of its *Declination*, i. e.

If the *Plain* decline $\left\{ \begin{array}{l} \text{Eastward} \\ \text{Westward} \end{array} \right\}$ set the *Substile* $\left\{ \begin{array}{l} \text{West} \\ \text{more on the East} \end{array} \right\}$ Side of the *Meridian*.

3. The *Substile* well placed, and room left about the *Edges* of the *Dial-plain* for the *Figures* belonging to the *Hour-lines* to stand, divide the remaining part of the *Plain* (from the *Center* to the lower *Margin*) into two parts; so, as that part next the *Center* of the *Dial*, may be the *Tangent* of the *Complement* of the height of the *Stile* above the *Plain*, (or of the new *Latitude*, as by *Affection VI. Chap. I.* of the *Fourth Treatise* beforegoing.) And the other part, the *Tangent Complement* of the *Sun's Meridian Altitude*, in the beginning of that *Tropick* which is remotest from the *Center* of the *Dial*.—Now the *Radius* (or *Tangent* of 45 deg.) which is proper to these *Tangents*, shall be the length of the *Perpendicular Stile*, and is to be placed in the *Point of Division* in the *Substile*, and must stand *Perpendicular* thereunto.

C H A P. II.

Of the inscribing of the *Parallels* of the *Sun's Course* in the beginning of each *Sign* of the *Zodiack*; or of the *Parallels* of the *Sun's Course* when the *Day* is either just 8, 9, 10, 11, 12, 13, 14, 15 or 16 hours long.

A *Sign* is the Twelfth part of the *Zodiack*, and so contains just 30 deg. and so the *Sun* passing about one of these degrees in a *Day*, the distance between the beginning of the *Sun's* entrance into one *Sign*, and his continuance therein to his entrance into the next, is about 30 days.

spective *Hour-lines*, through which the *Parallel* of the *Sun's Course*, at his entrance into either of these *Signs*, *Scorpio* or *Pisces* shall pass. — Repair to the former *Table*, where you shall find, that the *Sun* being in the beginning of either of those *Signs*, *Scorpio* or *Pisces*,

			d.	m.				d.	m.
His Altitude at	12	Of the Clock to be	27	01	Whose Comple- ment is	62	59		
	1		25	40		64	20		
	2		21	51		68	9		
	3		15	58		74	2		
	4		8	33		81	27		
Or	9		0	6		89	54		
	8								
	7								

Then having a *Sector*, take in your *Compasses* the length of the *Perpendicular Stile* of your *Dial*, and to that distance open the *Sector* in 45 deg. of the *Tangents*, and the *Sector* so resting, take 62 deg. 59 min. therefrom (which is the *Tangent Complement* of 27 deg. 1 min. the *Sun's Altitude* at 12 a Clock) and set that distance from the foot of the *Perpendicular Stile* upon the Line of 12, and that shall be the *Point* there, through which the *Parallel* of *Scorpio* and *Pisces* shall pass. — Also take from the *Sector* the *Tangent* of 64 deg. 20 min. (the *Complement* of 25 deg. 40 min. the *Altitude* at 1 or 11 a Clock) and set that distance from the foot of the *Perpendicular Stile* upon the *Hour-lines* of 11 and 1 a Clock, and those shall be the *Points* through which your *Parallel* is to pass.

			d.	m.			
Take likewise the Tangent of	68	And set them from the foot of the Perpendicular Stile upon the Hour-lines of	9	2	10	and	9
	74		2				
	81		27				
	89		54				
					5		7

So they shall give *Points* upon each respective *Hour-line*, through which the *Parallel* of *Scorpio* and *Pisces* must pass: And a *Line* traced with an even hand through those *Points* shall be the *Parallel* of the *Sun's Course* at such time as he enters *Scorpio* or *Pisces*: and the *Apex* or *Top* of the *Perpendicular Stile* shall, at that time of the year, by his *Shadow* exactly traverse this *Line* or *Section*. And in the same manner, as the *Points* for this *Parallel* were found, and its *Line* drawn, so must all the rest be drawn also.

Now generally, in *Vertical Dials Declining*, as also in such as *Recline* also, that is to say, upon all *Plains* whatsoever, (as is intimated in the Sixth *Affection* foregoing) draw an *Horizontal Dial* proper for the *Plain*, and inscribe the *Signs* or the *Parallels* of the *Length of the day* upon it, according as is before directed, by setting off the *Tangent Complements* of the *Sun's Altitude* from the foot of the *Perpendicular Stile*, upon the *Hour-lines* (the *Perpendicular Stile* being always made *Radius*) and at the ends of these *Tangents* so set off upon every respective *Hour-line*, will be a *Point*, by which *Points*, *Lines* drawn with an even hand shall be the *Parallels* desired. This *Horizontal Dial* being drawn in *obscure* or *occult Lines*, when the *Work* is done may be expunged, and the true *Hour-lines* belonging to the *Plain*, as also the *Parallels* of the *Sun's Course* before found, may only remain, for they will be the same, as if they had been drawn from the proper *Hour-lines* belonging to the *Plain*.

Note, In the following *Tractate* there are *Tables* Calculated for the ready describing of *obscure Horizontal Dials* upon all *Plains*, and also *Tables* of the

the *Sun's Altitude* at all hours (in diverse Latitudes.) And an Example of an Horizontal Dial with the Tropicks of *Cancer* and *Capricorn* you have in the *Ninth Tractate*, Page 220 — Also you have an Example of an Erect Direct East Dial, with the Parallels of all the 12 Signs upon it, in *Chap. 2. Pag. 115* and 118. *Figure II.* of the *Fourth Tractate*; And two other Examples of Plains with the Parallels of the length of the day upon them; One is a Polar Dial, *Figure I.* the other is a South Dial, *Figure IX.* of the *Fourth Tractate*.

CHAP. III.

Of inscribing the Vertical Circles, (commonly called Azimuths) upon all sorts of Plains.

Azimuths are great Circles of the Sphere, whose Poles lie in the Horizon, and do intersect each other in the Zenith and Nadir Points of the Heavens — The whole Horizon is divided by Mariners into 32 equal Parts or Points, which they call Winds or Points of the Compass and denominate them by North, N by W. N N W. &c. every Point containing 11 degrees and a quarter — This is their way of accounting, but the Account used by Astronomers and Geographers is more natural, and that is by 10, 20, 30, 40 degrees, &c. to 90 deg. from the Meridian, both ways, towards the East and West.

How to inscribe these into Dial-Plains.

SECT. I. In Horizontal Dials.

These Plains lying parallel to the Horizon, and these Azimuths being Great Circles, they (by the 1. Affection) being Projected upon such Plains become Streight Lines, and (by the 2. Affection) because these Plains lie Perpendicular to these Circles, in the Heavens, these Lines projected, shall all meet in a Center at equal Angles (which Center is the foot of the perpendicular Stile.) — Wherefore, making the foot of the perpendicular Stile the Center, describe thereon a Circle upon the Dial-Plain, and thereon set off (both ways) from the Meridian such Arches, either 11 degrees and a quarter for Points of the Compass, or 10, 20, 30, 40, &c. degrees for the Astronomical Account upon the Horizon; Through these Divisions, right Lines being drawn from the foot of the perpendicular Stile shall represent these Azimuths upon the Plain.

An Example of an Horizontal Dial with the Azimuths upon it according to the Mariner's Account by Points of the Compass, you have in the *Ninth Tractate* following, Page 220.

SECT. II. In Upright South or North Dials.

These Plains lying Parallel to the Vertical Circles in the Heavens, are (by the 2. Affection) right Lines, parallel one to the other. And to inscribe them into these Plains, you must — Through the Foot of the perpendicular Stile, draw a Line Parallel to the Horizon, and making the perpendicular Stile a Radius (or Tangent of 45 deg.) Upon this Line from the Meridian (on both sides) set off the Tangents of 11 deg. and a quarter, 22 deg. and a half, &c. for

for *Points of the Compass*, or the *Tangents* of 10, 20, 30 deg. &c. which best liketh you, — Now, if through these *points* you draw *right Lines perpendicular* to the *Horizontal Line* they will be all of them *parallel* one to another, and also *parallel* to the *Meridian* or 12 a Clock Line of the Dial, but at *unequal distances* one from another, according as the *Tangent Line* increases; And these *Lines* thus drawn, shall be the *Azimuth Lines* proper to those *Plains*.

An Example of a Direct South Dial with Azimuths drawn upon it, you have in Figure V. and a Direct East Dial with Azimuths you have in Figure II. of the Fourth Tractate.

SECT. III. In Vertical (or Upright) Declining Plains.

THE *Azimuth Lines* here are also *parallel* one to another, and must be inserted in all respects as in the former *Plains*, from the *Meridian* of the *Plain* (if you will) or from the *Meridian* of the *Place*, but then, just allowance must be made for the *Difference of Meridians*, or (which is all one) for the *Difference of Longitude* between the *Meridian of the Plain* and the *Meridian of the Place*.

An Example of a South Declining Plain, with Azimuths drawn upon it you have in Figure IX. of the Fourth Tractate.

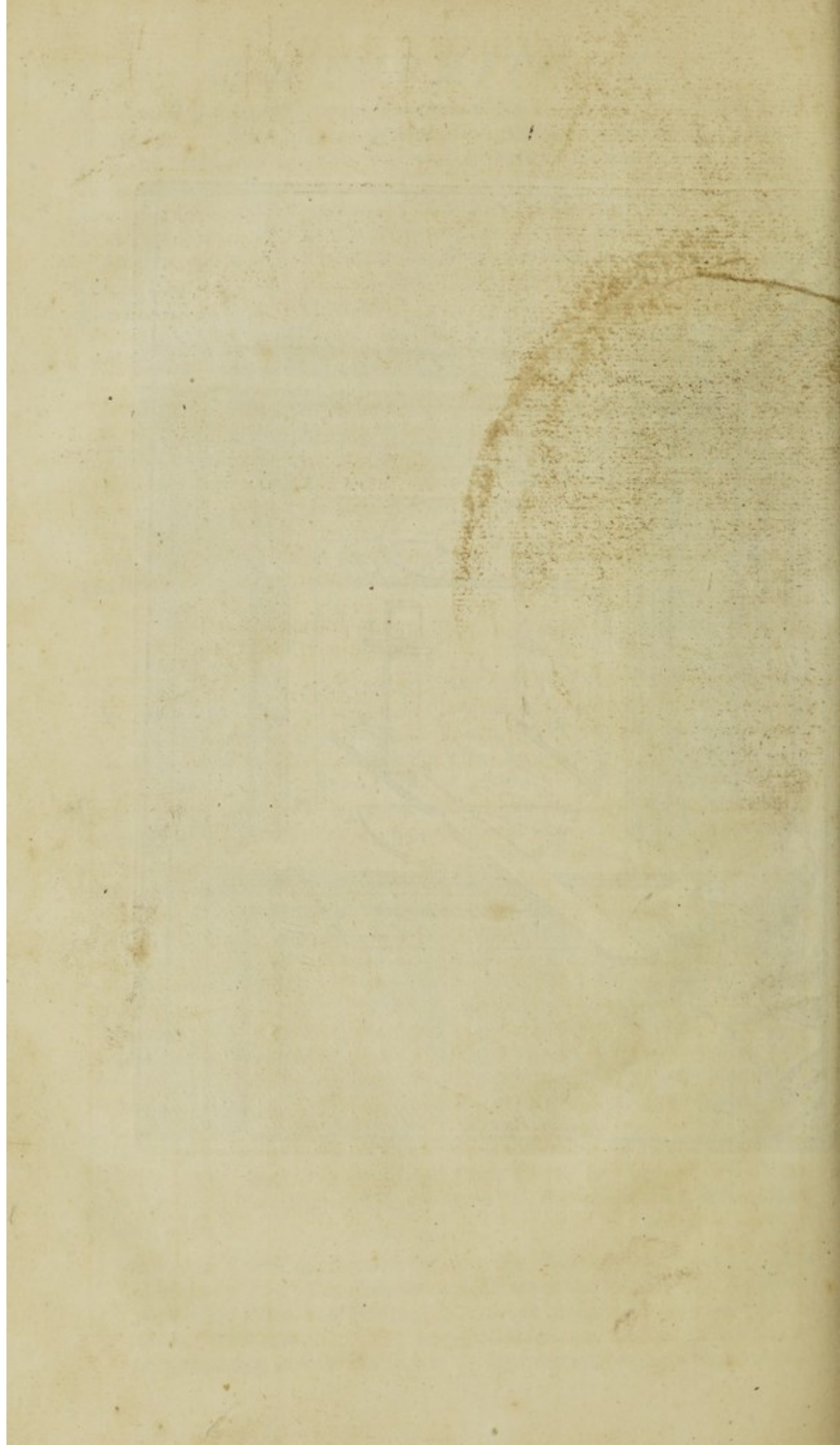
SECT. IV. In Declining Reclining Plains.

THE *Perpendicular Stile* being chosen, and made the *Radius* (or *Tangent* of 45 deg.) Take the *Tangent Complement* of the *Plain's Reclination*, and set it from the foot of the *perpendicular Stile*, to the *Meridian* of the *Place*, which point shall determine the *Zenith* of the *Place* upon the *Plain*, through which point, and the *Foot* of the *perpendicular Stile* (which is the *Zenith* of the *Plain*), a *right Line* drawn shall be *perpendicular* to the *Horizontal Line*, and shall (when drawn) concur with the *Equator* in the *Hour-line* of Six (if you have not committed some former error.) — Now therefore, if from the *Foot* of the *perpendicular Stile*, upon this *Perpendicular*, you set off the *Tangent* of the *Plain's Reclination*, a *Line* drawn from the end thereof at *Right Angles* unto it, that *Line* (so drawn) shall be the *Horizontal Line*, upon which *Line*, the *Tangents* of 11 and a Quarter, 22 and a half, &c. for *Points of the Compass*, or of 10, 20, 30, &c. degrees (the *Secant* of the *Plain's Reclination* being now made *Radius*) being set from the said *right Angle*, *Lines* drawn from them to the *Zenith* of the *Place*, shall be the *Azimuths* required, — And because these *Declining Reclining Plains* do lie *obliquely* to the *Azimuth* or *Vertical Circles* in the *Heavens*, therefore (by the former 2. Affection) though they be *Strait Lines*, and do meet in *one Center*, namely in the *Zenith* of the *Plain*, yet do they meet at *unequal Angles*.

The Examples in the Fourth Tractate of Reclining Plains with Azimuths described upon them are — (1.) A Polar Plain, Figure I. — (2.) An East Reclining Plain, Figure XII. — And (3.) A Declining Reclining Plain, Figure XIII.

Note here, That if the distance between the *Meridians* be known upon the *Horizontal Line*, the *Azimuths* which were accounted from the *Meridian of the Plain*, may be fitted to Account as from the *Meridian of the Place*, with ease. — For, Let the distance be the *Tangent* of the 20 deg. then that *Azimuth* which is 10 deg. from the one, is 10 deg. from the other





other also; And that which is 30 deg. on the same side of the *Substile* is 10 deg. on the other side of the *Meridian of the Place*. The like is to be observed for any other distance.

C H A P. IV.

Of *inscribing of the Almicanthar, (commonly called Circles or Parallels, of the Sun's Altitude) upon all sorts of Plains.*

A *lmicanthers* or *Circles of Altitude*, are *lesser Circles of the Sphere*, and therefore (by the 3. *Affection*) being described upon any *Plain* which lies not parallel to the *Horizon* of the *Place* become *Conick Sections*—These *Almicanthers* may not improperly be called *Parallels of Declination* from the *Horizon*, they having in all respects the same *Habitude, Relation* or *Affection* to the *Horizon*, which the *Parallels of the Signs* or of the *Sun's Course* have to the *Equinoctial*, to which they are *Parallel*. And therefore (as in the describing of the *Signs* or *Parallels of the day's length*) An *Horizontal Dial* proper for the *Plain*, being first (obscurely) delineated, as was (in the II. Section) shewed, that the *Points* through which the *Signs* or *Parallels* should pass upon every *hour*, might be obtained by applying the *Tangents* of the *Complements* of the *Sun's height* at those *hours* in those *Parallels*, from the foot of the *Perpendicular Stile* upon the respective *hours* to which those *Altitudes* did belong.

Now to find what *Altitude* the *Sun* shall have he being upon any *Azimuth*, shall be hereafter taught in the ensuing *Tractate*, where several *Tables* thereof are *Calculated* for *divers Latitudes*; Notwithstanding, I will here insert

A Table shewing what *Altitude* the *Sun* shall have in the beginning of each *Sign*, upon every *Tenth Azimuth*.

<i>Azimuth</i>	<i>Cancer</i>	<i>Gemini</i> or <i>Leo</i>	<i>Taurus</i> or <i>Virgo</i>	<i>Aries</i> or <i>Libra</i>	<i>Pisces</i> or <i>Scorpio</i>	<i>Aquar.</i> or <i>Sagitt.</i>	<i>Capric.</i>
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
<i>South</i>	62 0	58 42	50 0	38 30	27 0	18 18	15 0
10	61 43	58 24	49 38	38 4	26 30	17 45	14 25
20	60 51	57 28	48 33	36 46	25 9	16 5	12 41
30	59 52	55 52	46 40	34 34	22 27	13 15	9 45
40	57 20	53 29	43 55	31 21	18 48	9 14	5 34
50	54 3	50 12	40 11	27 5	13 58	3 57	0 6
60	49 50	45 53	35 23	21 41	8 0		
70	44 40	40 25	29 27	15 13	1 0		
80	38 11	33 46	21 29	7 52			
<i>Ea. or W.</i>	30 38	26 10	14 25	0 0			
100	22 27	18 2	6 45				
110	14 14	9 58					
120	6 34	2 30					

Your *Table* being thus prepared, and your *Dial* obscurely drawn, You are to make use of that *Azimuth* which is perpendicular to your *Plain* (which in all *Plains* is that which passeth through the *Foot* of the *Perpendicular Stile*) but all the other *Azimuths* also being inscribed obscurely, the *Tangent's Complement* of the *Sun's height* above the *Plain*, when he is in any *Azimuth*, applied from the foot of the *Perpendicular Stile*, upon the respective *Azimuth* gives a *Point*, through which that *Almicanthar* or *Circle of Altitude* upon that *Azimuth* must pass.

An Example of an Horizontal Dial with the Almicanter or Circles of Altitude, (as they are proportioned to the height of Perpendicular Objects to their heights) you have in the Ninth Tractate, Page 220. And another (*viz.* an East Reclining Plain) with the like Circles of Altitude upon it you have in Figure XII. of the Fourth Tractate; And upon a South Declining Plain in Figure XI. of the Fourth Tractate; And lastly, upon a Declining Reclining Plain in Figure XIII. of the same Fourth Tractate.

CHAP. V.

Of the Babylonish, Italian and Jewish hours, and how to describe them upon Sun-Dials.

I Do couch these three under one *Head* or *Table*, for that the manner of their Inscription into *Sun-Dials* is much after the same manner, and being they are *Hour-lines*, so *Great Circles*, and therefore, being described upon a *Plain*, they become by (the first Affection) *Strait Lines*.

SECT. I. For the Babylonish hours.

THE *Babylonish hours* are accounted the equal hours from the *Sun's Rising*, for at what time soever, at all times of the year, the *Sun* appears or rises, above the *Horizon*, that is the first minute of their day. These *Hour-lines* may be inscribed upon any *Plain* by help of those two *Parallels*, which do shew the *Longest* and *Shortest Days*, consisting of equal or entire hours in length in any *Latitude*, as here in the *Latitude* of *London* 51 deg. 32 min. the *shortest* day consisting of *Equal hours* is that day that is just 8 hours long, and the *Longest Day* in that *Latitude* is that which is just 16 hours long. By help of the *Parallels* of the *Sun's Course* for these two days, and the *Equinoctial*, all the *Babylonish hours* may be drawn upon any *Plain* in manner following.

		Length of the Day				
		8	12	16		
		hours	hours	hours		
Hours from Sun Rising, for Babylonish hours	1	9	7	5	13	1
	2	10	8	6	14	2
	3	11	9	7	15	3
	4	12	10	8	16	4
	5	1	11	9	17	5
	6	2	12	10	18	6
	7	3	1	11	19	7
	8	4	2	12	20	8
	9	5	3	1	21	9
	10	6	4	2	22	10
	11	7	5	3	23	11

It is evident, in this *Latitude*, that when the day is 8 hours long, the *Sun* rises at 8 of the Clock in the Morning, then at 9 a Clock the *Sun* hath been up *One* hour — When the day is 12 hours long, the *Sun* rises at 6, and at 7 a Clock it hath been up just *One* hour — When the day is 16 hours long, the *Sun* rises at 4 of the Clock, and at 5 it hath been up *One* hour, Wherefore to draw the *Babylonish hours* observe this Table

Table — If you draw a strait Line through the hour 9 in the Parallel of 8 hours, through the hour 7 in the Parallel of 12 hours, and through 5 in the Parallel of 16 hours, that right Line (for so it will prove to be, if you have committed no former error in the rest of your work) shall be the *First Babylonish hour*. Again,

A Line drawn through $\left. \begin{matrix} 10 \\ 8 \\ 6 \end{matrix} \right\}$ In the Parallel of $\left. \begin{matrix} 8 \\ 12 \\ 16 \end{matrix} \right\}$ Shall be the Second Babylonish hour.

And so of all the rest as in the Table above.

Note, That in *Winter* time, when the Parallel of 8 hours shall fail, the other two Points of 5 in the Parallel of 12 and of 3 in the Parallel of 16 will serve to draw the seventh hour from Sun Rising, because they be strait Lines. And after Six hours are drawn, you shall find the *Equinoctial* (or Parallel of 12 hours) will fail you, wherefore, some other *Diurnal Arch*, as of 9 or 10 hours, must be inserted to supply that defect.

SECT. II. For the Italian Hours.

THE *Italian hours* are accounted from the preceding *Sun Setting*, and are numbered by 1, 2, 3, 4, &c. from *Sun Setting* — To inscribe these hours, the same two *Parallels* of 8 and 16 hours, as also the *Equinoctial* or Parallel of 12 hours will serve to inscribe them, and also the same Points in the same *Parallels*, and the former Table will shew you through what 3 Points each hour is to be drawn — For a right Line drawn

Through $\left. \begin{matrix} 5 \\ 7 \\ 9 \end{matrix} \right\}$ In the Morning, in the Parallel of $\left. \begin{matrix} 16 \\ 12 \\ 8 \end{matrix} \right\}$ Shall be the hour of One,

Likewise, (observing the same order as before)

Through $\left. \begin{matrix} 3 \\ 5 \\ 7 \end{matrix} \right\}$ In the Afternoon, in the Parallel of $\left. \begin{matrix} 16 \\ 12 \\ 8 \end{matrix} \right\}$ Shall be the 23^d hour.

The *Night hours* 9, 10, 11, &c. are the *Morning hours* produced.

An Example of a Direct South Dial, with both the *Babylonish* and *Italian* hours upon it you have in Figure X. of the Fourth Tractate. And also some of the same upon a Polar Dial, Figure I. and all of them upon an *Equinoctial* Dial, Figure IV. of the Fourth Tractate.

SECT. III. For the Jewish Hours.

IT was the Custom of the *Ancient Jews* to divide their Day, as also their Night (whether long or short) into 12 equal parts; beginning their Day at Sun Rising, and their Night at the Sun's Setting, so that our 12 of the Clock at Noon, was always their Sixth hour of the Day, and our 12 at Night was always their Sixth hour of the Night, and according to this Division were their *Dials* made; So that all Summer long, when the Sun is in *Northern Signs*, the *Jewish hours* of the Day are longer than their hours of the Night; and all the Winter, while

while the Sun is in the Six Southern Signs, the hours of their Night are longer than the hours of their Day; But when the Sun is in the Equinoctial, the hours of their Day and Night are Equal, and the same with all other Nations.

The manner of inscribing these Hour-lines into Sun-Dials is not much different from the inscribing of the Babylonish and Italian hours.

Wherefore, having drawn the true Hour-lines upon your Plain, with the Half hours, and Quarters (which in this case is necessary to be done) describe thereupon also the Two Tropicks, and the Equinoctial; Which being drawn, Make choice of two Parallels of the length of the day, which must be either

Jewish hours.	The Parallel of 15 hours.		Equinoctial.	The Parallel of 9 hours.	
	H	M		H	M
1	5	45	7	8	15
2	7	0	8	9	0
3	8	15	9	9	45
4	9	30	10	10	30
5	10	45	11	11	15
6	12	0	12	12	0
7	1	15	1	0	45
8	2	30	2	1	30
9	3	45	3	2	15
10	5	0	4	3	0
11	6	15	5	3	45
12	7	30	6	4	30

of them equidistant from the Equinoctial on either Side thereof, which let be the Parallels of 9 hours, and 15 hours, one being 3 hours less than 12 hours, and the other 3 hours more than 12. Inscribe (obscurely) upon your Plain these two Parallels of 9 and 15 hours (they being the most convenient for this purpose) because the Jewish hours will fall (in these two Parallels) justly upon the hours, halves and Quarters of the common Hour-lines, and so will the Jewish hours (by that means) be the easier drawn. Now the Points through which every one of the Jewish hours must pass, this little Table plainly sheweth, wherein you may see, that the First Jewish hour must be drawn through 5 hours 45 min. (or 5 hours 3 quarters) in the parallel of 15 hours, through 7 hours in the Equinoctial, and through 8 hours 15 min. (or 8 hours and

a quarter) in the Parallel of 9 hours; This Line thus drawn through these 3 Points, shall be the First Jewish hour.

In like manner, a Line drawn through

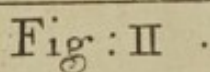
$$\begin{array}{l} 7 \text{ } 0 \\ 8 \text{ } 0 \\ 9 \text{ } 0 \end{array} \left. \vphantom{\begin{array}{l} 7 \\ 8 \\ 9 \end{array}} \right\} \text{In the Parallel of } \left. \begin{array}{l} 15 \\ 12 \\ 9 \end{array} \right\} \text{Shall be the Second Jewish hour.}$$

And so all the rest, as in the Table. Our 12 a Clock being their Six a Clock, and the rest in order from Sun Rising to the Sun's Setting.

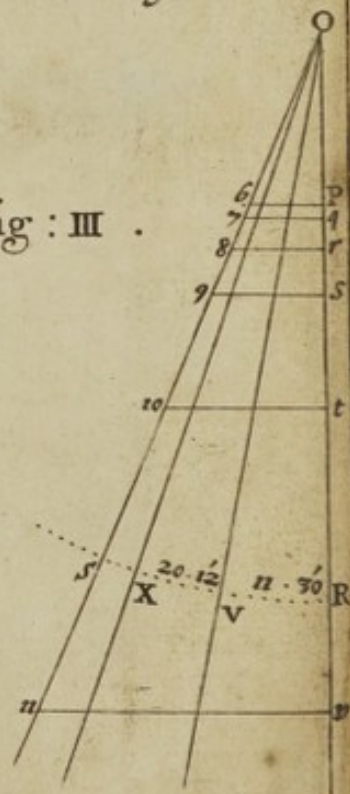
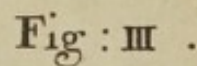
An Example of an Upright Declining Plain, with the Old Unequal or Jewish hours upon it, as also of all the Parallels of the day's length at equal hours, you have in Figure IX. of the Fourth Tractate.

The End of the Fifth TRACTATE.

The Trigon

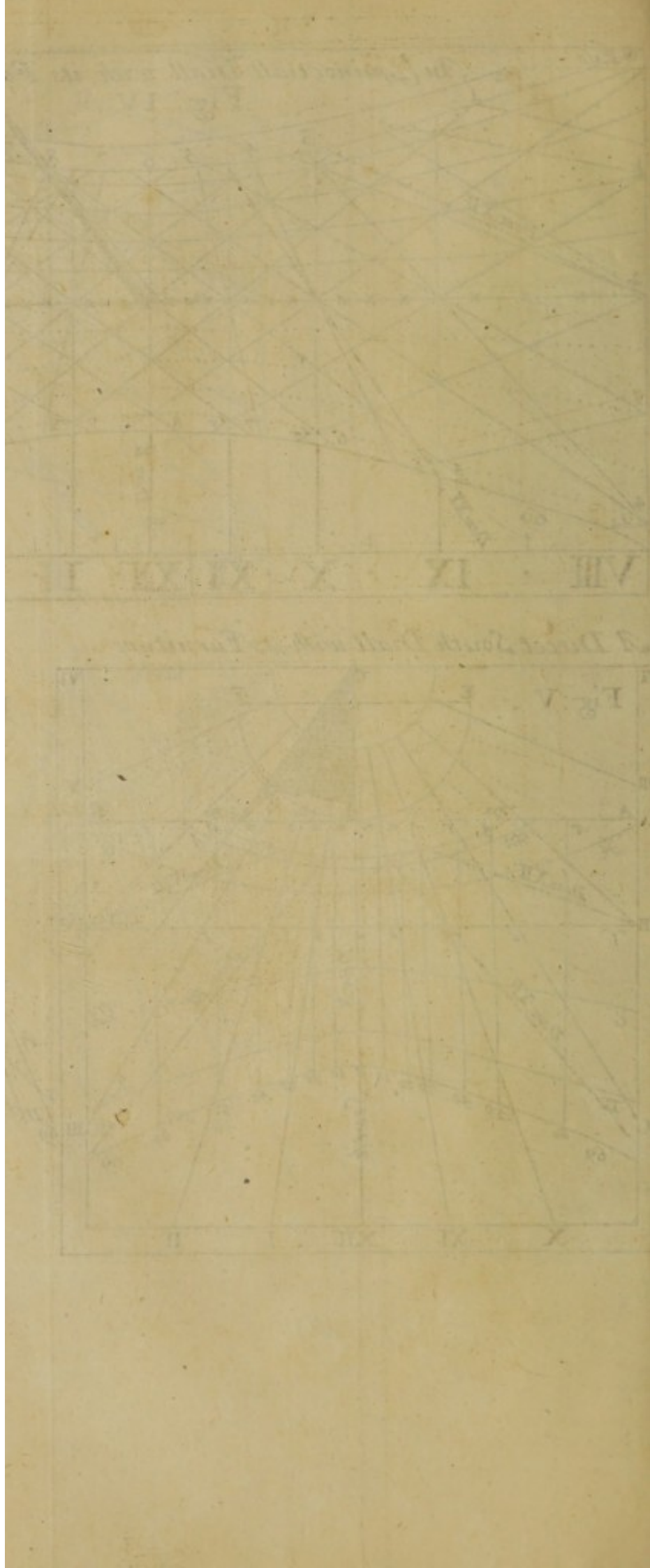


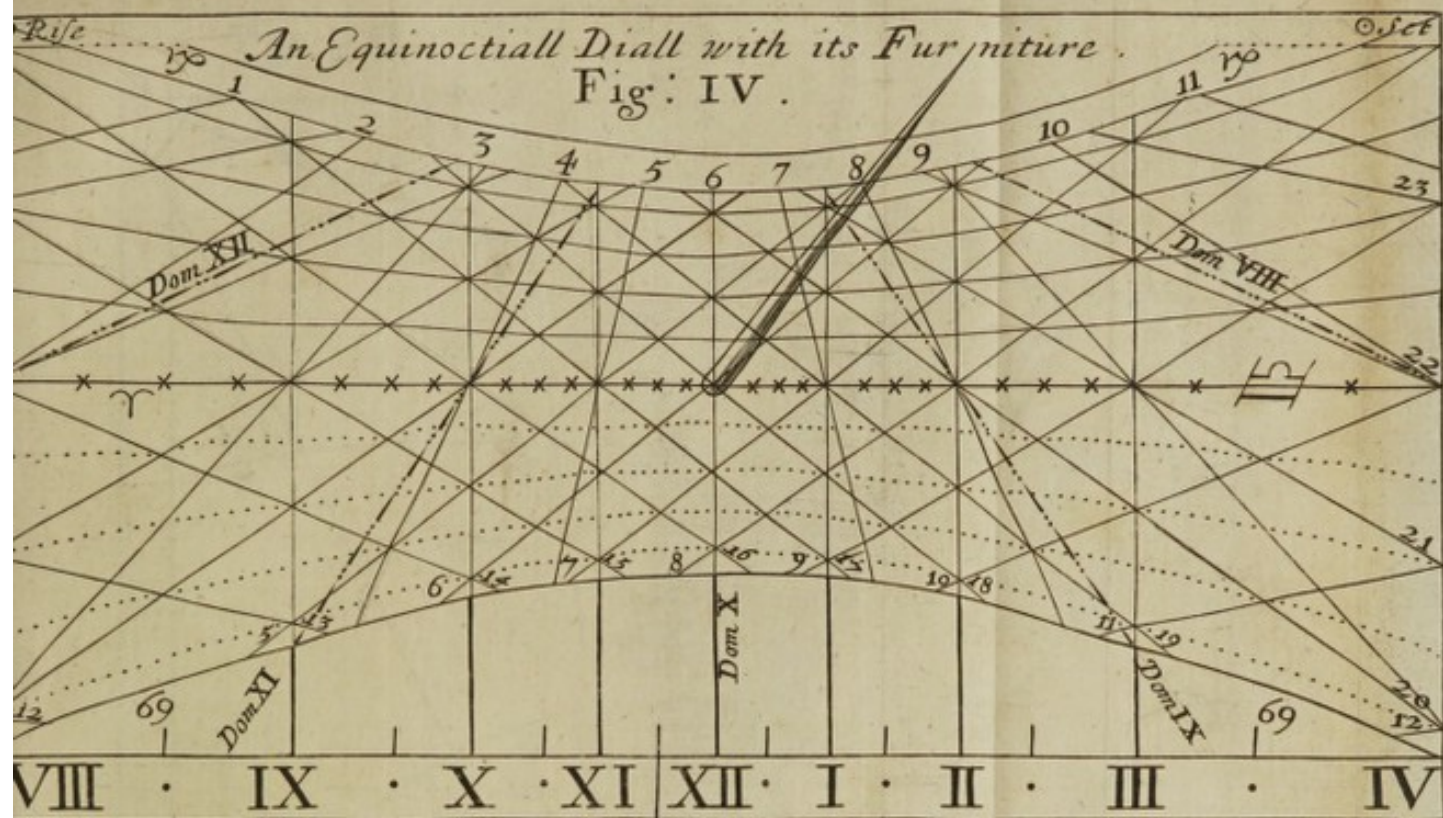
The Trigon .



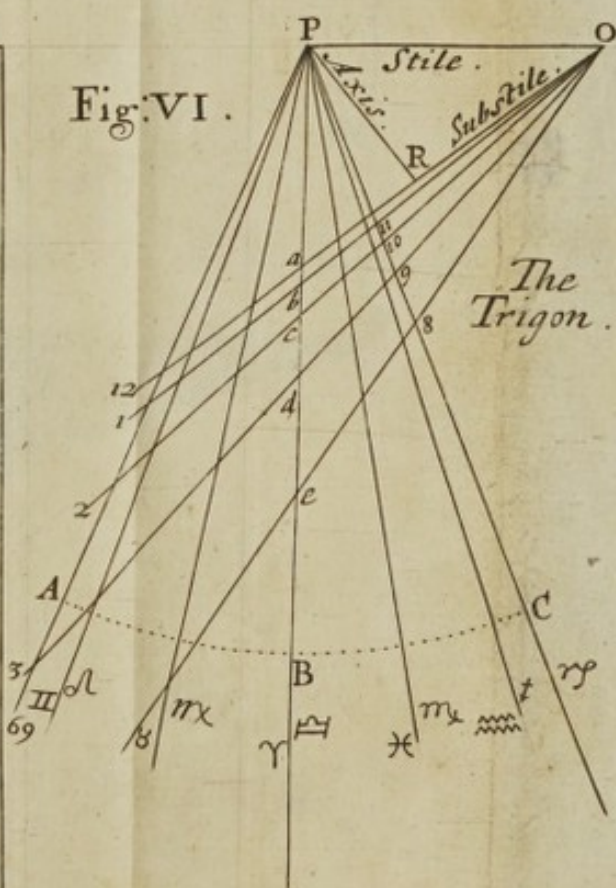
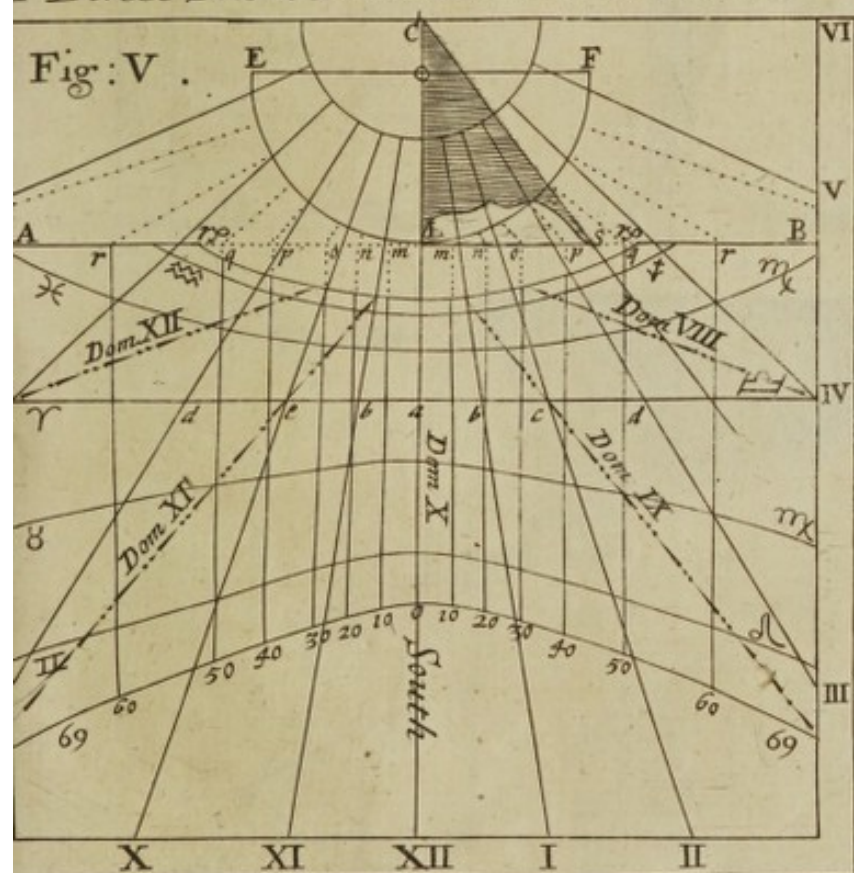
An
East Diall
with its
Furniture

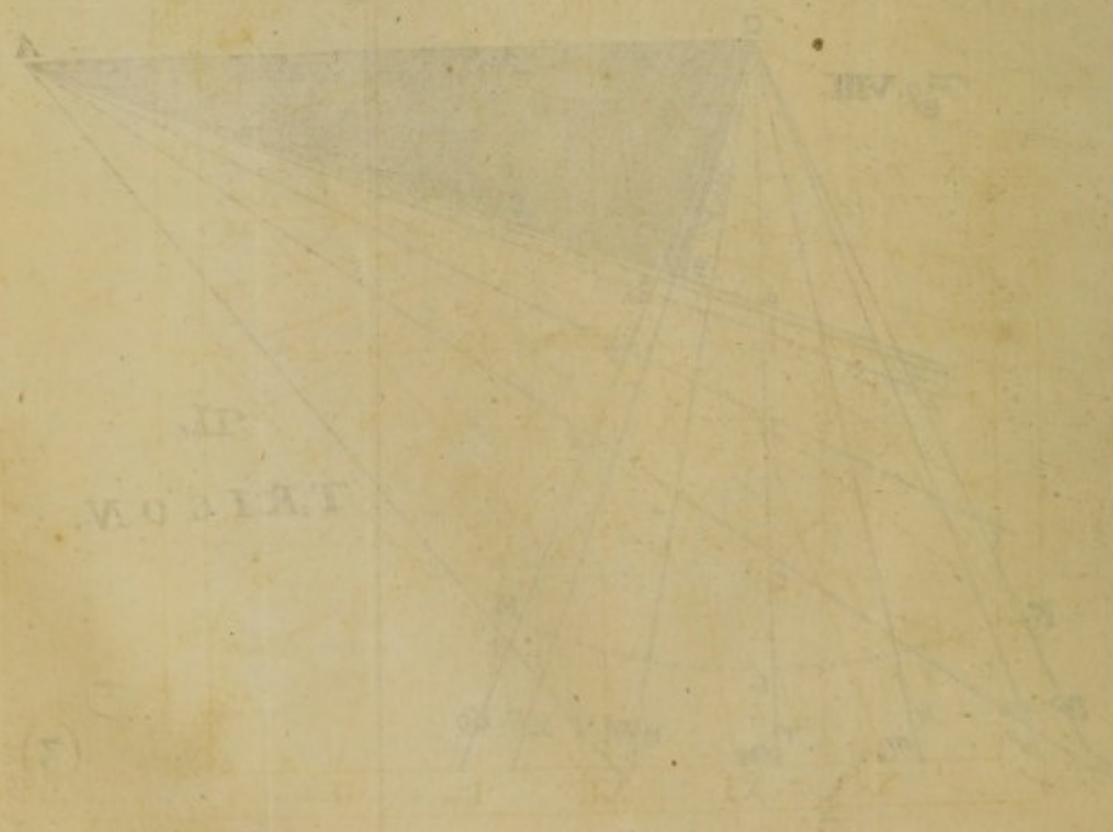
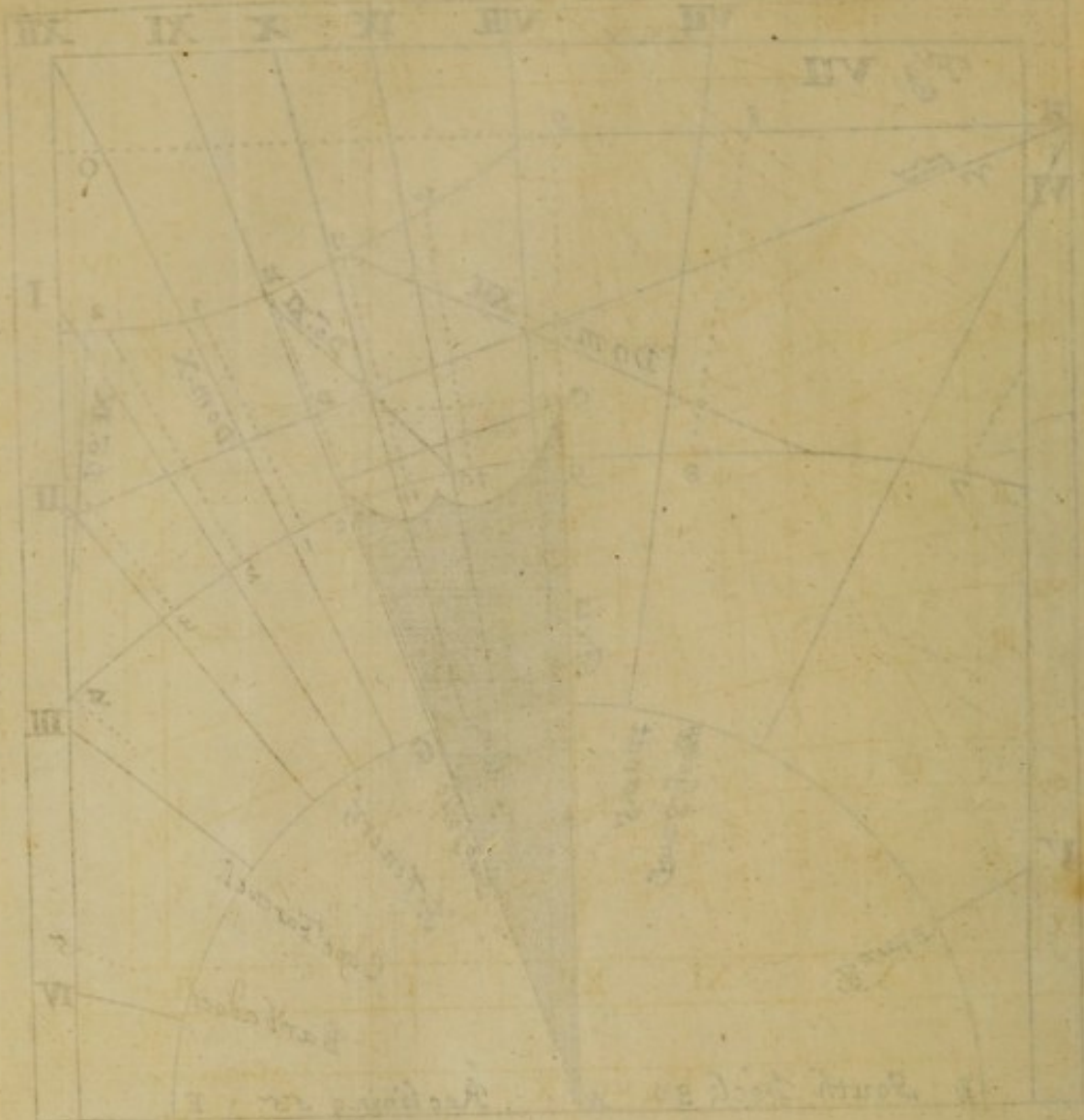
At the End of the Fifth Tractate

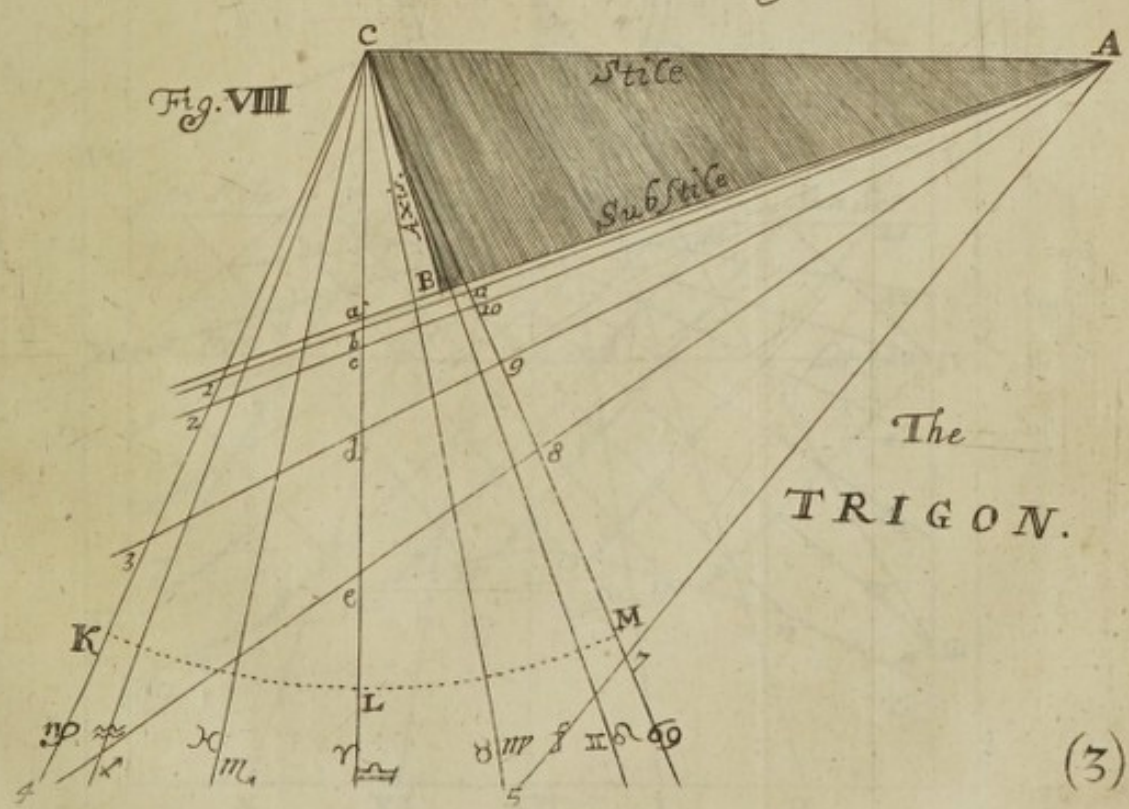
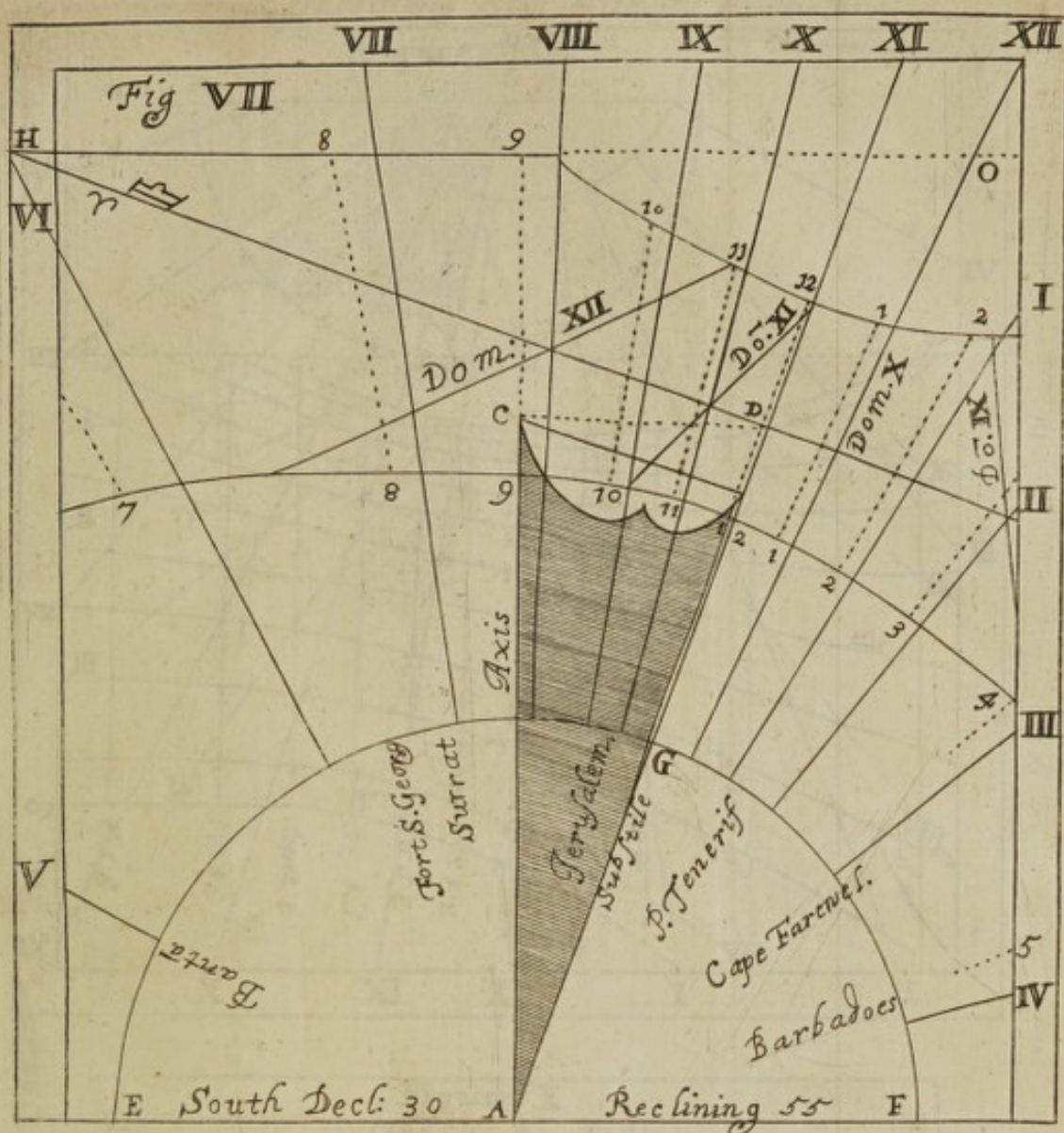


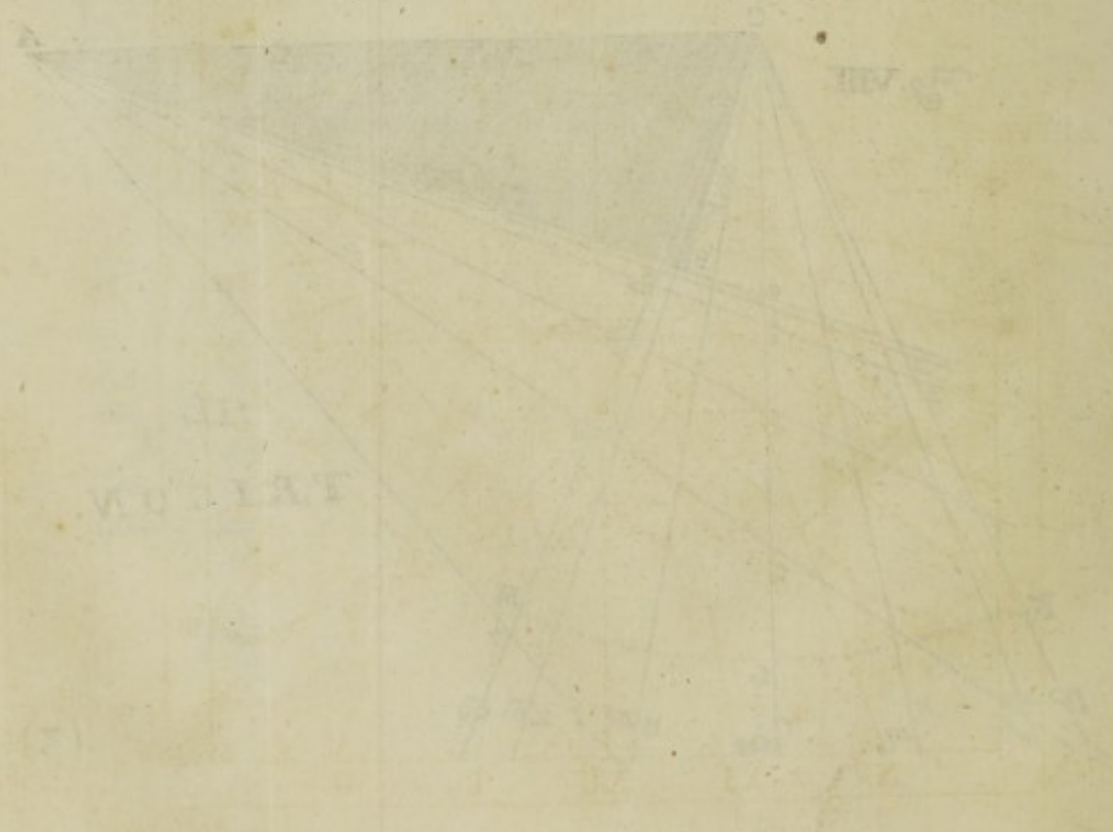
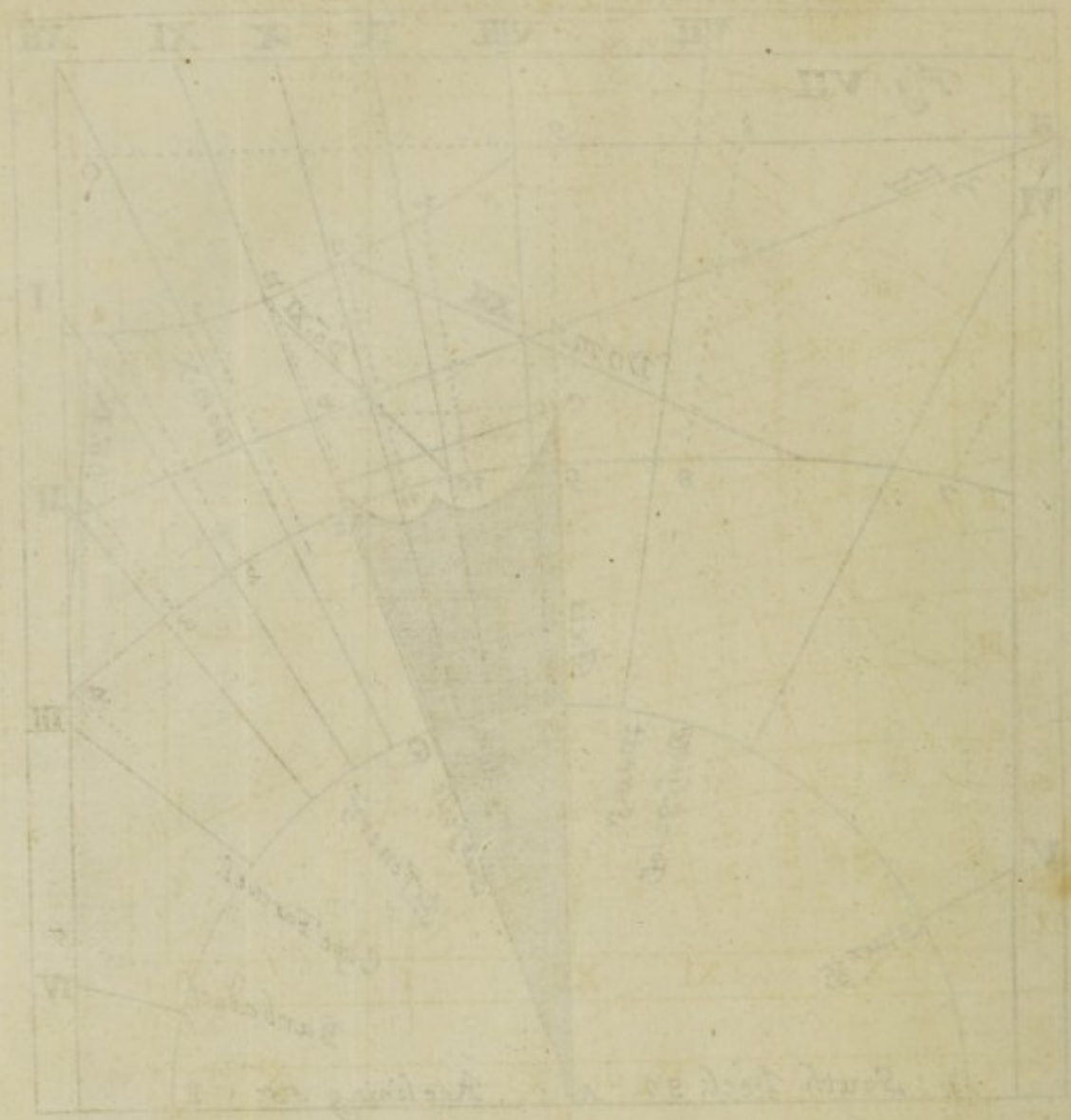


A Direct South Dial with its Furniture.

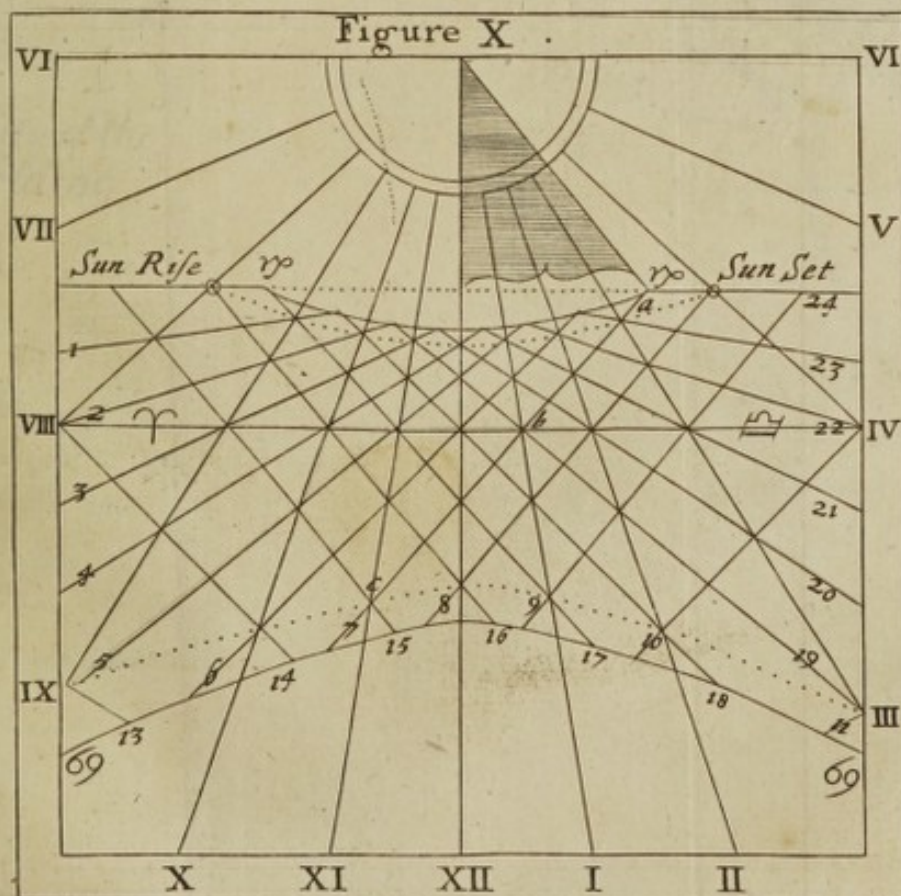
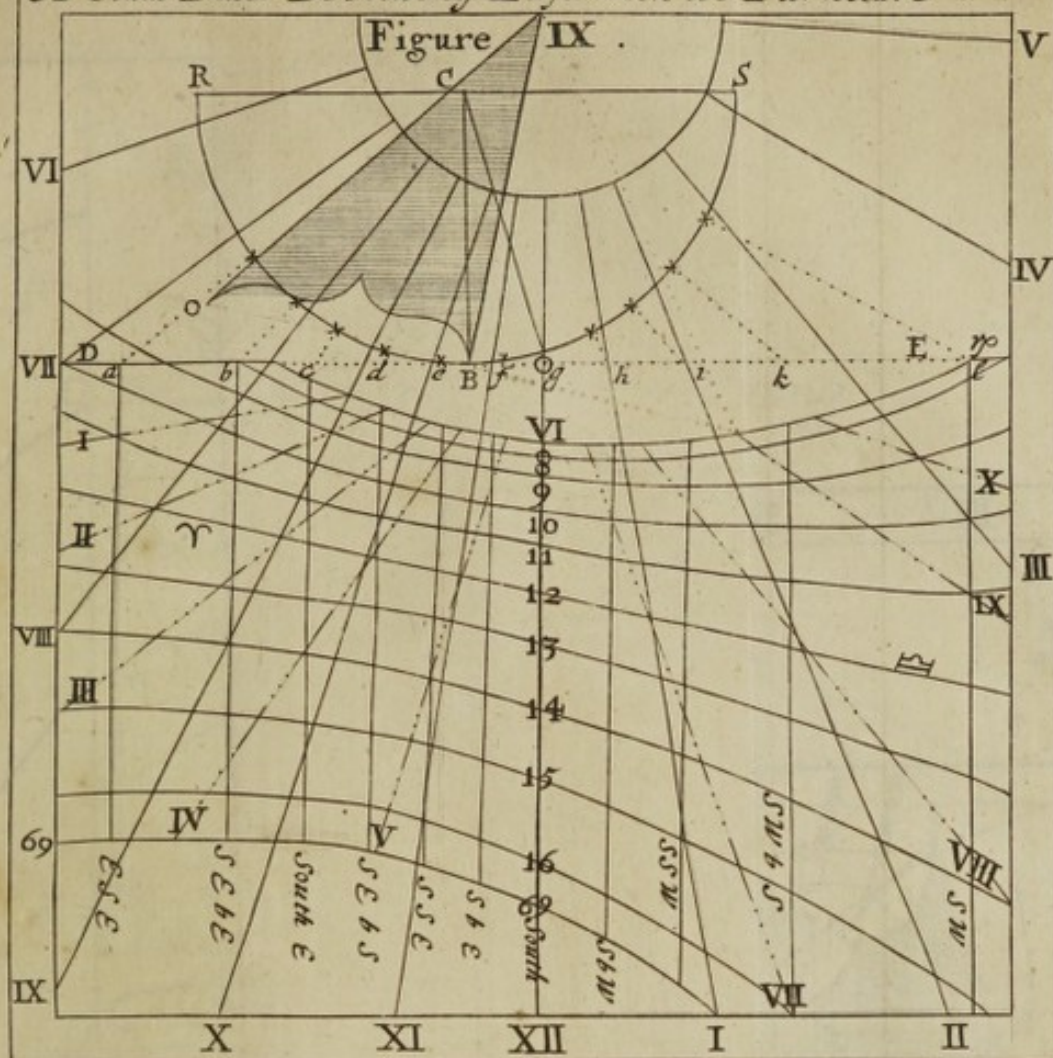


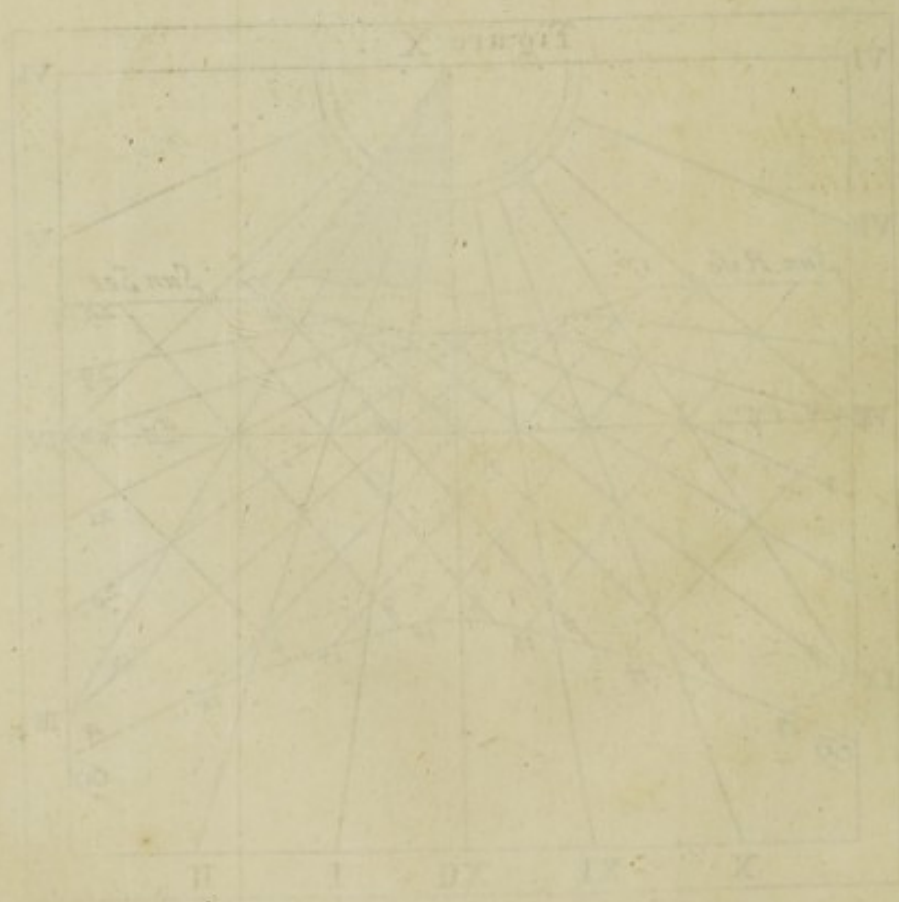
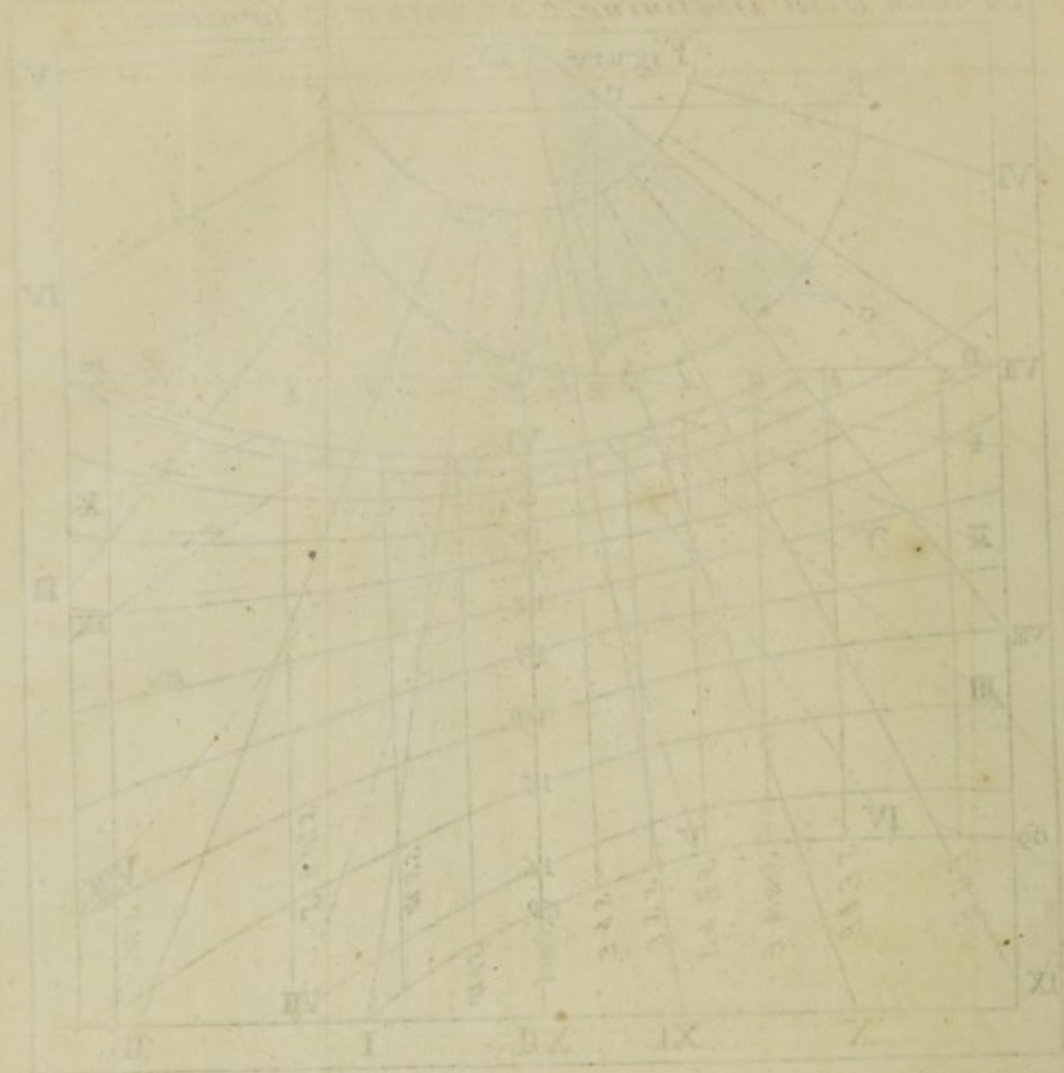


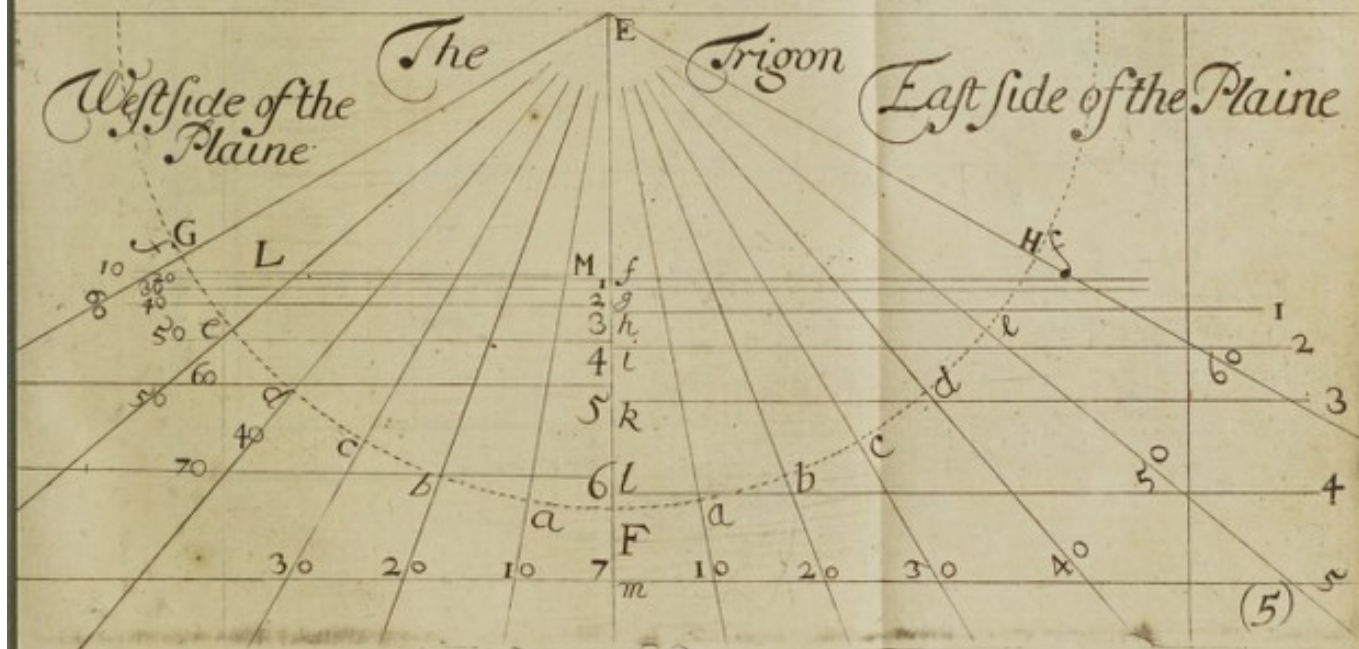
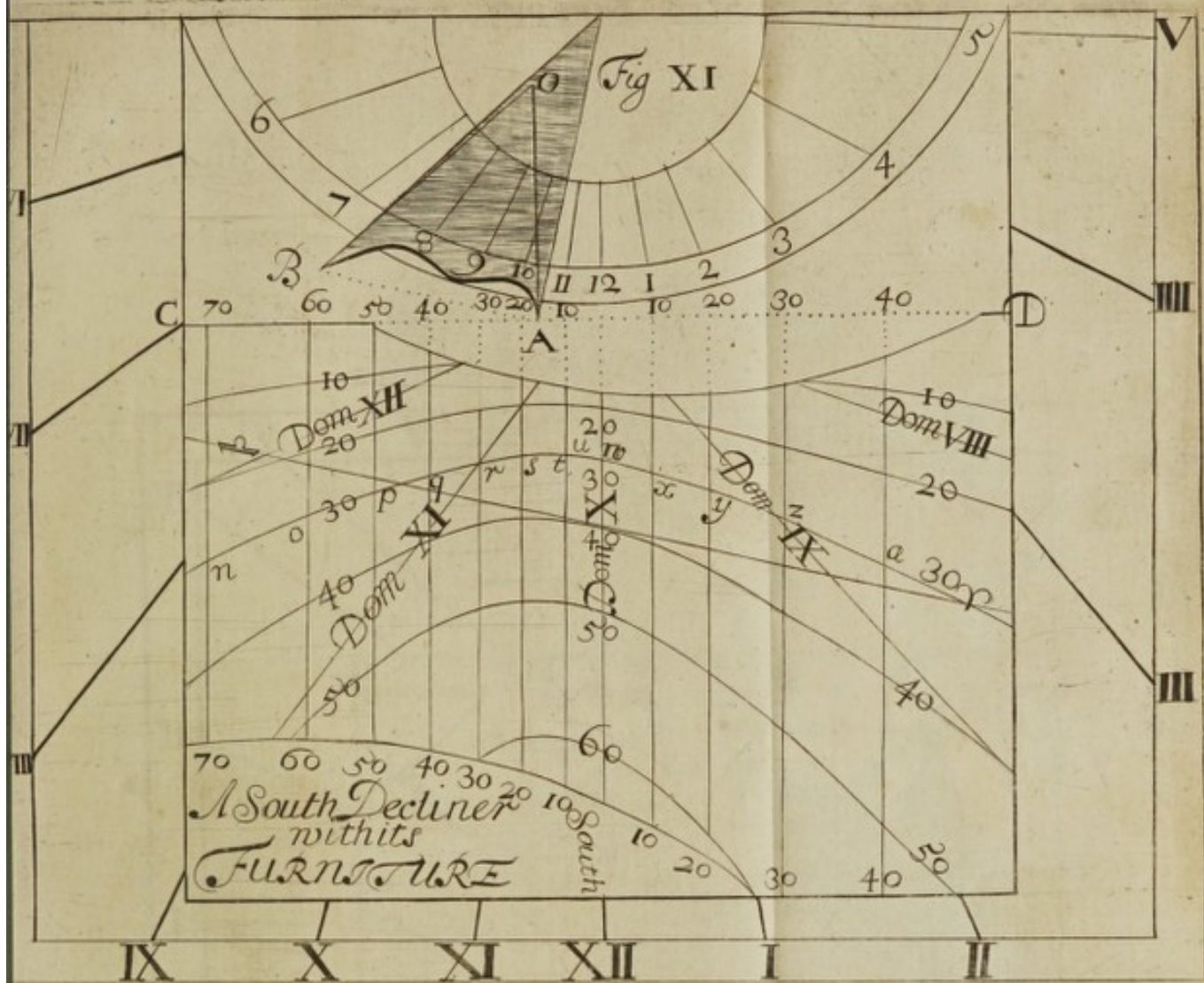


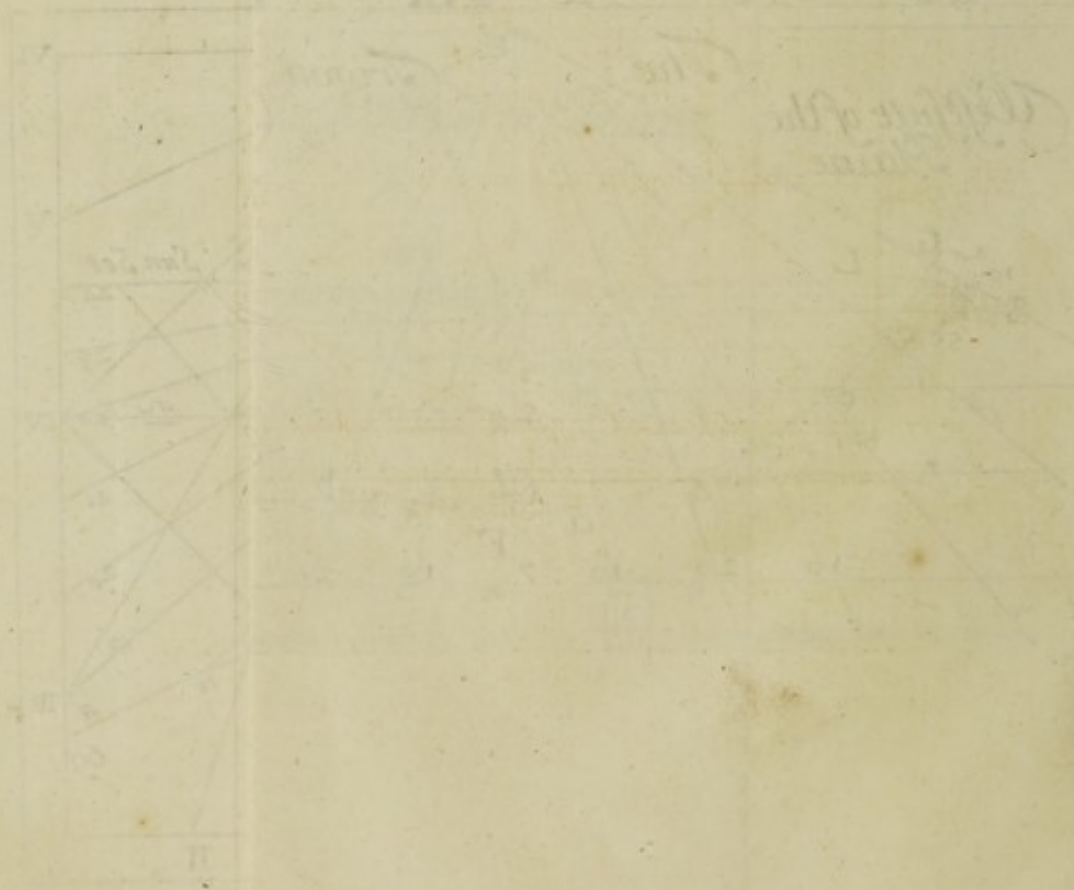
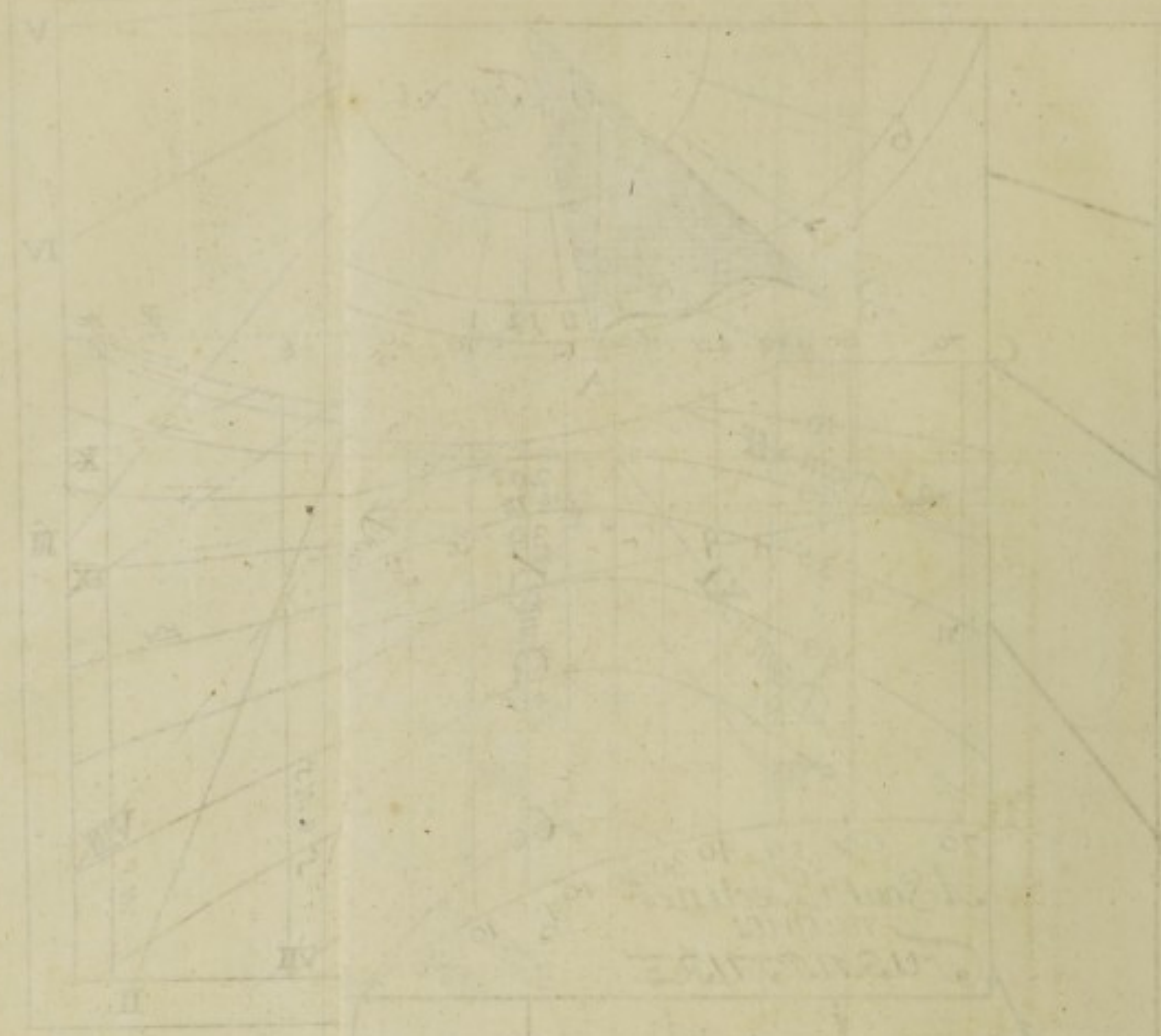


A South Diall Declining East with its Furniture .









*A West Plain Reclining
with its Furniture.*

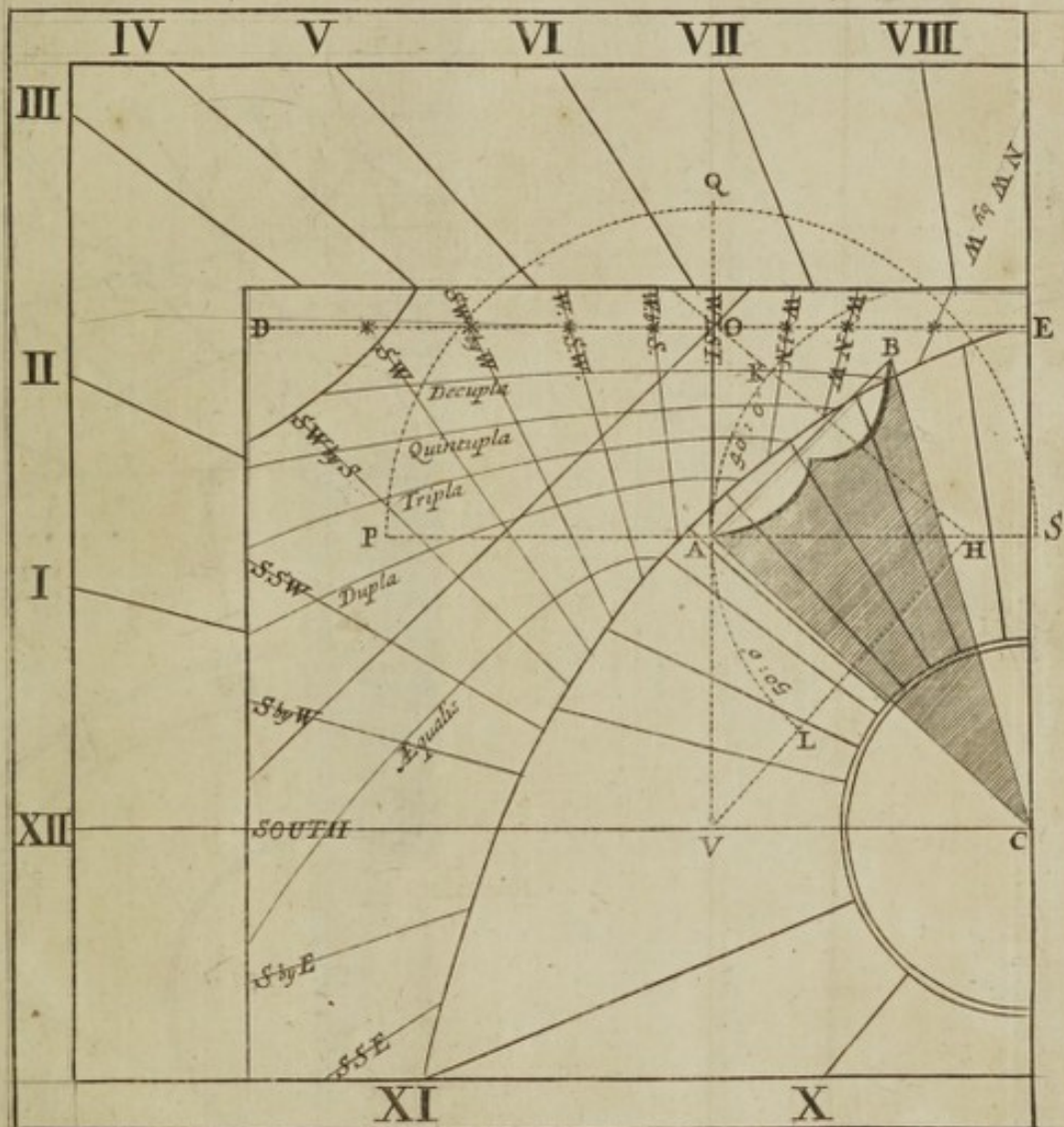
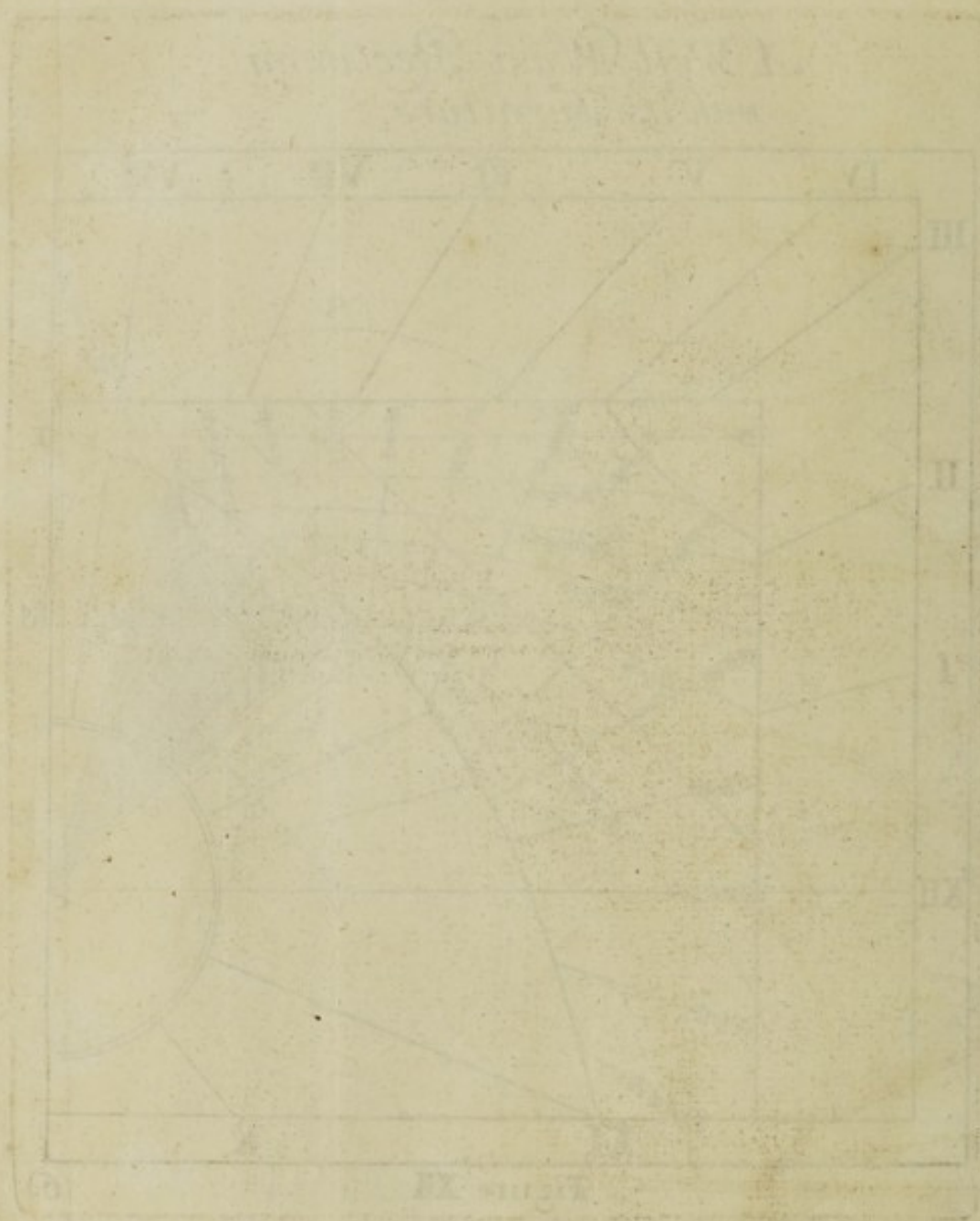


Figure XII



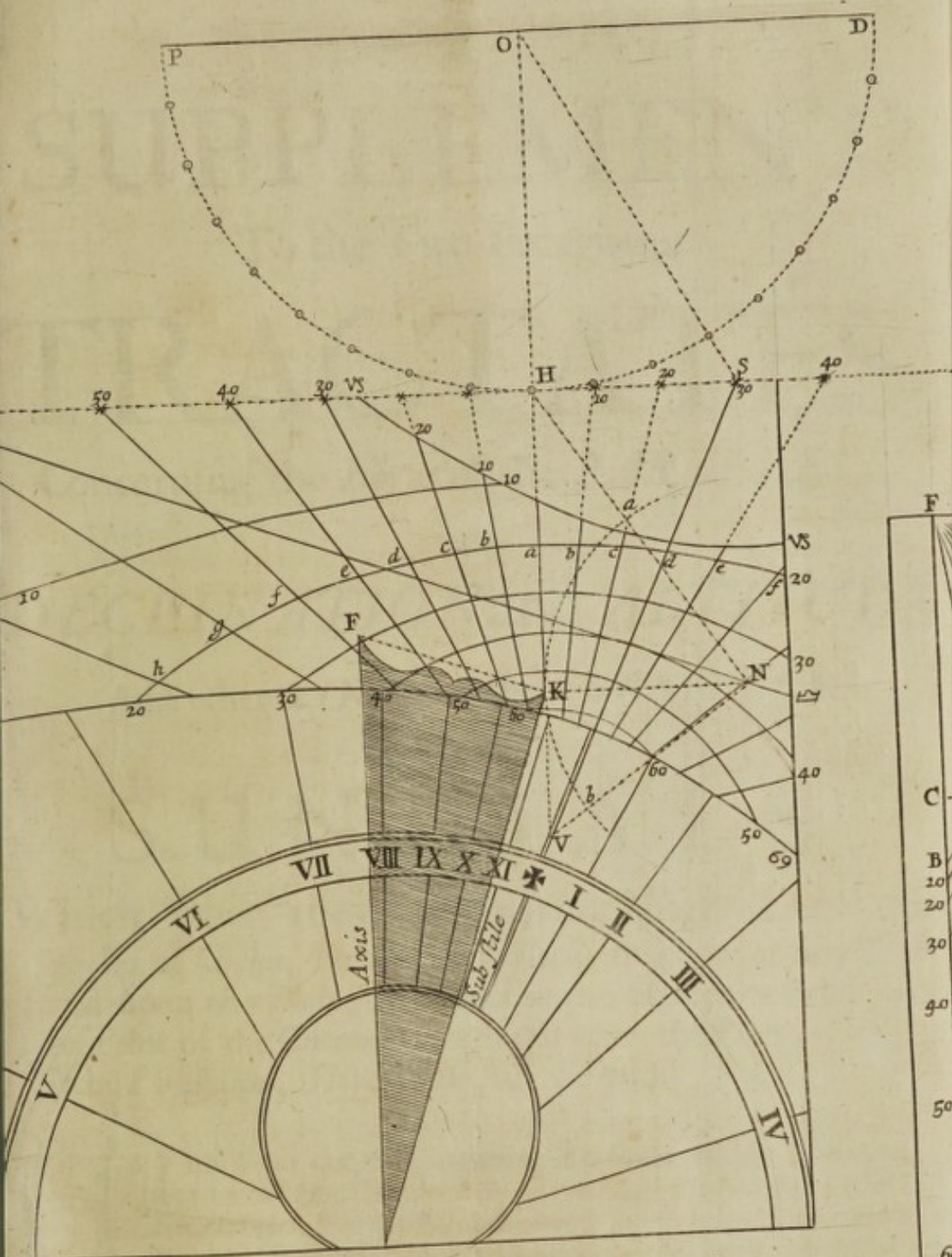
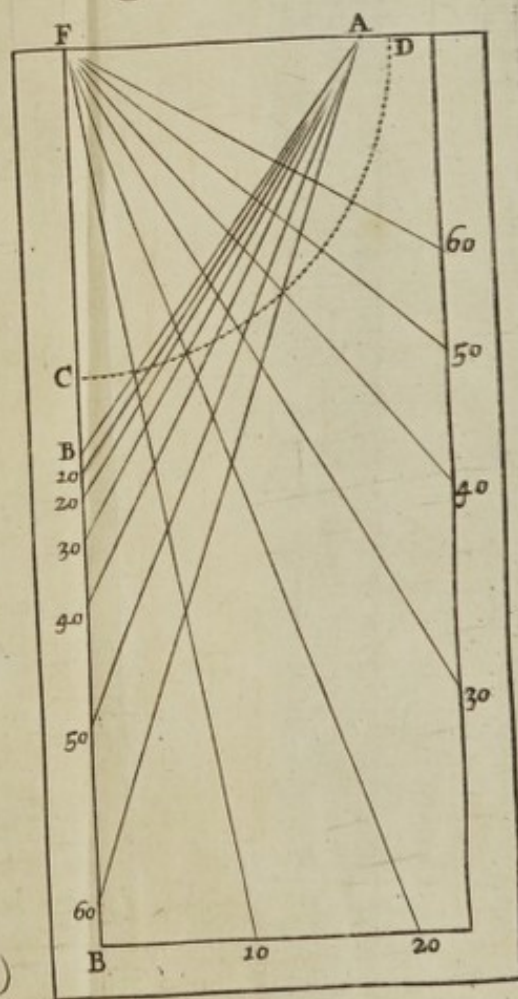
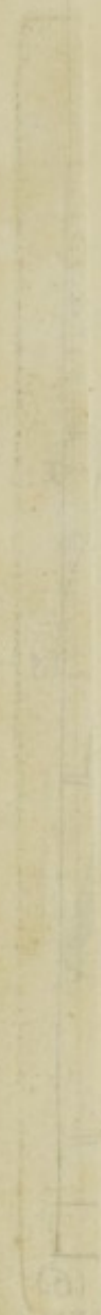


Figure XIII. South { Declining 30^{do}
Reclining 55^{do}

Fig: XIV.



(7)



A

SUPPLEMENT

To the Two Foregoing

TRACTATES,

Concerning the *Form* of the *PARALLELS*

O F

DECLINATION and *ALTITUDE*And other *LINES* of the *FURNITURE*

O F

SUN-DIALS,

Which when they are neither *Right Lines* nor *Arches* of *Circles*, but *Conick Sections*, to know at any *Time*, and upon any *Plain*, what *Section* the *Shadow* of the *Apex* or *Point* of the *Gnomon* traceth out upon the *Plain*, whether it be *Parabolical*, *Hyperbolical*, or *Elliptical*.

HAVING in the two foregoing *Tractates* taught several ways how to inscribe the *Parallels* of the *Sun's Course*, the *Azimuths*, *Almicanthars*, *Babylonish*, *Italian* and *Jewish hours* upon all *Dial-Plains*, as being things of most frequent use, yet in the following *IXth. Tractate*, is shewed how *Dial-plains* may be furnished with other *Varieties*, as of the *Signs Ascending*, *Descending*, and *Culminating*, the *Horizons* of other remoter *Countries*, and several other *Gnomonical Conclusions*.

Having, I say, there shewed the manner how to inscribe the forementioned *Spherical Lines* of the *Sun's Course* upon *Dial-plains* : It remains now that I should say somewhat concerning the *Form* of these *Parallels* when they are described upon *Dial-plains*, which, when they are not *Circles*, or *Strait Lines* (as under the *Poles*) they are all, and always, *Conick Sections*, as is demonstrated by *Mydorgius*, in the 34. *Prop.* of his *Book*. But to pass by his *Demonstrations* (as not at all proper for this place, this being a *Book* of *Practice* and not so much of *Demonstration*) it shall be here shewed, how, at any time, or place, it may be known what *Section* the

Shadow of the *Apex* or top of the *Gnomon* traceth out upon any *Dial-plain*; And although this be not absolutely necessary for the *Diallist* to know, for without the knowledge hereof he may make and finish his *Dial*, as hath been already taught.

For the Illustration of the Nature of these *Parallels of Altitude*, and the *Sun's Course* upon *Dial-planes*; I shall deliver *Three* brief *Rules*, which are proved by *Aquilonius* in the 83^d *Prop.* of his *Sixth Book of Opticks*, which *Rules* follow.

R U L E I.

When the Sun is in any Parallel, if the Plain of the Dial be Parallel to a Great Circle of the Sphere, which toucheth the Parallel, and the opposite thereunto, the Projection of the Shadow of the Apex shall be a PARABOLA.

R U L E II.

If the Dial-Plain be Equidistant to a Great Circle which cuts the Parallel, and the opposite thereunto, the Shadow of the Apex runs in an HYPERBOLA.

R U L E III.

If the Dial-plain be Equidistant to a Great Circle, which neither Toucheth nor Cutteth the Parallel, the Shadow of the Apex, or Top of the Perpendicular Stile (for so is meant all this while) shall trace out an ELLIPSIS.

For Illustration of the Three foregoing Rules, have recourse to the following Figure.

But first it will be requisite to acquaint you with a *CONE*, and the several *Sections* thereof.

First then, A *CONE* (as it is defined by *Euclide* in the 18th. 19th. and 20th. *Definitions* of his *Eleventh Book*) is a *Figure* made, when one Side of a *Rectangled Triangle* (*viz.* one of those that contain the right Angle) remaining fixed, the *Triangle* is turned round about, till it return to the place from whence it first moved. And if the fixed right Line, be equal to the other, which containeth the right Angle, the *Cone* is A right Angled *Cone*, but if it be less, it is an Obtuse Angled *Cone*: if Greater, an Acute Angled *Cone*——The *Axis* of a *Cone*, is that fixed Line about which the *Triangle* is moved——The *Base* of a *Cone*, is the *Circle* which is described by the right Line moved about.

- Figure 1. In this Figure, Let *ABXC* represent a *Cone*, then the *Cone* cut off by a Line *OP* parallel to the *Base AB*, the *Section* so cut shall be a *Circle*.
 2. If the *Cone* be cut off by a Line *KG*, parallel to the *Axis* of the *Cone AX*, the *Section* so cut off shall be an *Hyperbola*.
 3. If the *Cone* be cut by a Line *FD*, parallel to any of the Sides of the *Cone*, (as *FD* parallel to *AB*) the *Section* so cut off shall be a *Parabola*.
 4. If the *Cone* be cut obliquely through the *Axis* and Sides, as by the Line *NH*, the *Section* so cut off shall be an *Ellipsis*.

Wherein

Fig. I.

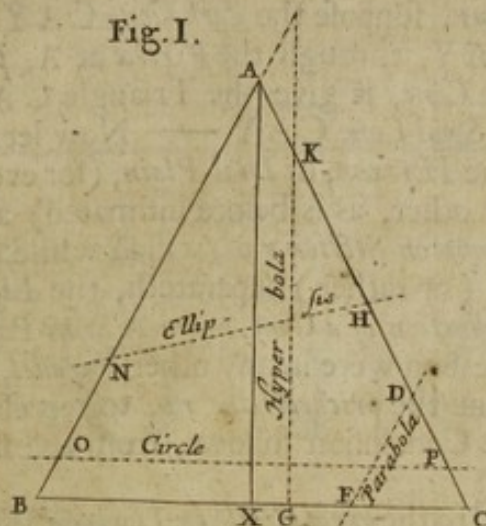
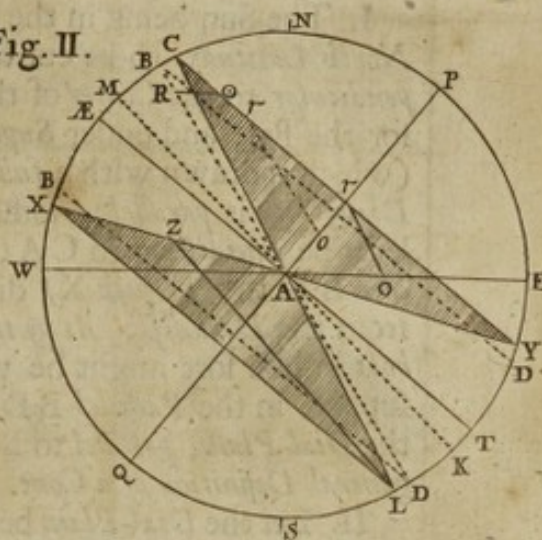


Fig. II.



Wherein the outward or primitive Circle WNES, represents the General Figure II.
Meridian of the Globe.

N and S, the Point of Zenith and Nadir.

WE, The Horizon.

EP, 51 deg. 32 min. the heighth of the North Pole, or the Latitude of London.

PQ, The Prime Vertical Circle, and Axis of the World.

P, The North, and Q, the South Poles.

ÆT, The Equinoctial or Equator.

CL, The Ecliptick.

CY, and XL, The two Tropicks.

BD, An intermediate North Parallel of the Sun's Course or Declination.

I. Now from the Scheme it is evident, that the Horizontal Dial for the Latitude of London 51 deg. 32 min. being equidistant to the Great Circle, or Horizon WE, which cuts the Tropicks, and all the Parallels between them, as that of BD, or any other, is (according to the First Rule) such, that the Shadow of the Apex of the Stile shall thereupon, all the year long, trace out Hyperbolas; but of different kinds, as the Plain shall cut several Parallels, more or less unequally.

II. But if a Dial were made parallel to the Ecliptick CL, which only toucheth the Tropicks (and doth not intersect or cut them) the Shadow of the Apex thereupon, when the Sun is in the Tropicks, shall trace out Parabolas.

III. If a Plain were equidistant, not to the Equator ÆT, but to some other Plain as MK, whose Great Circle neither Touches any of the Parallels, nor Cuts them, the Shadow of the Apex of the Stile there, shall always trace out some Ellipsis, but not always the same; but lesser as the Sun or his Parallel approacheth nearer the Equator, and greater in those Horizons which make more acute Angles with the Equator; until (at last) the Horizon WE, and the Equator ÆT, become co-incident; And then the Projection of the Shadow made by the Apex of the Stile shall trace out a perfect Circle. — Likewise let the Horizon be howsoever situate, if the Sun be in no Parallel, but in the Equator it self, the Projection of the Shadow made by the Apex of the Stile, shall be a right or strait Line.

I shall not here insert the Demonstration which Aquilonius useth to prove these three Rules, but endeavour to make it plain enough otherwise.

I. The

I. The Sun being in the *Southern Signs*, suppose the dark Cone CAY in *North Latitude*, to be cut by a Plain CAY , through the *Vertex* at A , perpendicular to the *Center* of the *Base* of the Cone, it gives the Triangle CAY for the flat, and under *Superficies* of the *Semi-Cone* CAY — Now let ro (which is drawn with a full Line) be the *Horizon*, or *Dial-Plain*, (for every *Dial-Plain* is parallel to some *Horizon* or other, as is before intimated) and let it be equidistant to CA , then the *Common Section* ro (which while the Sun is in the *Tropick* X) distinguisheth (or rather) separateth, the *Light* from the *Darkness*; As by the general Definition of a Cone. — A *Semi-Parabola* in like sort might be proved, if the Sun were in any other *Parallel*, as suppose in the *Parallel* BD , for supposing the pricked Line ro , to represent the *Dial-Plain*, parallel to BA , the same Conclusion follows, from the said general Definition of a Cone.

II. Let the *Dial-Plain* be $R\odot$, parallel to the great Circle or *Horizon* WE , which cuts the *Parallel* CY in $\odot$, then (by the said Definition General) the *Common Section* $R\odot$, which that day separates the *Light* and *Darkness* upon the *Plain*, is a *Semi-Hyperbola*. — Or, if instead of the *Semi-Cone*, one conceive the *Section* of the Cone, through the *Vertex* and *Axis* to be the plain Triangle, CAY , and $R\odot$ a right Line, to be only the *Diameter* of the *Section*, the thing is the same, and the *Section*, (by the 2. Definit. of the Third of *Mydorgius*) is an *Hyperbola*.

III. Lastly, (to avoid confusion of Lines, and multiplicity of Schemes) Let the Sun be in the *Northern Signs*, and XAL the dark Cone, and ZL the *Dial-Plain*, in *South Latitude*; equidistant to the great Circle MK , which neither cutteth nor toucheth the *Parallels*; it is evident, that ZL , or any Line equidistant to MK , shall cut the Triangle XAL , made from a *Section* from the *Vertex* as before, in both the Sides XA , and LA , and is therefore (by the 3d. of the 3d. Definition of *Mydorgius*) the *Diameter* of an *Ellipsis*, or (by the general Definition of a Cone) it is half an *Ellipsis* — And so, any other Line parallel to ZL , and greater than XL , is the *Diameter* of a greater *Ellipsis*, or rather, an *Ellipsis* of a greater Cone, which might be made, by producing the Lines AX and AL at pleasure.

This that hath been here delivered is (I hope) proof sufficient, for what hath been said of this matter, and I hope enough to make it intelligible.

The End of the SUPPLEMENT.

A
 CONNEXION
 OF
 TABLES

Of divers Kinds,

Calculated for several *Elevations* of the *Pole* (or
Latitudes) very useful, and really subservient to
 the ART

OF
 DIALLING:

THE WHICH

With the *TABLE* of Natural *SINES*, *TANGENTS*,
 and *SECANTS*, (hereunto annexed) and a *SCALE*
 (or *Sector* rather) having *Equal Parts* upon it; The *Parallels*
 of the *Signs* and *Diurnal Arches*, the *Azimuths*, *Almicanters*,
 the *Jewish*, *Italian* and *Babylonish Hours*, and other *FURNITURE*, may easily (and more exactly than by any
 other Means) be inscribed upon all *Dial-Plains* whatsoever.

The *SIXTH TRACTATE*.

A TABLE, shewing what *Declination* the Sun shall have, he being in any Degree of the *Ecliptick*.

Northern Signs.																				
Aries ♈			Taurus ♉			Gemini ♊			Cancer ♋			Leo ♌			Virgo ♍					
D.	M.	S.	D.	M.	S.	D.	M.	S.	D.	M.	S.	D.	M.	S.	D.	M.	S.			
0	0	0	11	30	44	20	13	21	23	31	30	20	13	41	11	30	44	30		
1	0	23	57	11	51	48	20	25	57	23	31	10	19	59	59	11	9	28	29	
2	0	47	53	12	12	41	20	38	59	23	30	35	19	47	7	10	48	2	28	
3	1	11	49	12	33	21	20	49	9	23	29	17	19	33	27	10	26	25	27	
4	1	35	44	12	53	50	21	1	15	23	27	51	19	19	26	10	4	38	26	
5	1	59	37	13	13	5	21	12	28	23	25	48	19	5	5	9	42	42	25	
6	2	23	28	13	34	8	21	23	8	23	23	18	18	50	22	9	20	36	24	
7	2	47	18	13	53	57	21	33	23	23	20	21	18	35	20	8	58	21	23	
8	3	11	4	14	13	32	21	43	15	23	16	57	18	19	48	8	35	38	22	
9	3	34	48	14	32	52	21	52	43	23	13	6	18	4	16	8	13	13	21	
10	3	58	28	14	51	59	22	1	45	23	8	48	17	48	15	7	58	27	20	
11	4	22	55	15	10	51	22	10	22	23	4	3	17	31	56	7	28	0	19	
12	4	45	37	15	29	27	22	18	35	22	58	52	17	15	18	7	5	6	18	
13	5	9	5	15	47	47	22	26	22	22	53	14	16	58	22	6	42	6	17	
14	5	32	29	16	5	52	22	33	44	22	47	1	16	41	9	6	18	59	16	
15	5	55	47	16	23	38	22	40	40	22	40	40	16	23	38	5	55	47	15	
16	6	18	59	16	41	9	22	47	1	22	33	44	16	5	52	5	32	29	14	
17	6	42	6	16	58	29	22	53	14	22	26	22	15	47	47	5	9	5	13	
18	7	5	0	17	15	18	22	58	52	22	10	35	15	29	27	4	45	37	12	
19	7	28	0	17	31	56	23	4	3	22	10	22	15	10	51	4	22	55	11	
20	7	50	7	17	48	15	23	8	48	21	1	45	14	51	59	3	58	27	10	
21	8	13	13	18	4	16	23	13	6	21	52	43	14	32	52	3	34	48	9	
22	8	35	38	18	19	48	23	16	57	21	43	15	14	15	32	3	11	4	8	
23	8	58	21	18	35	20	23	20	21	21	33	23	13	53	57	2	47	18	7	
24	9	20	36	18	50	22	23	23	18	21	23	8	13	34	8	2	23	28	6	
25	9	42	42	19	5	5	23	25	48	21	11	28	13	13	5	1	59	37	5	
26	10	4	38	19	19	26	23	27	51	21	1	15	12	53	50	1	35	44	4	
27	10	26	25	19	33	27	23	29	17	20	49	9	12	33	21	1	11	49	3	
28	10	48	2	19	47	7	23	30	35	20	38	59	12	12	41	0	47	53	2	
29	11	9	28	19	59	59	23	31	16	20	25	57	11	51	48	0	23	57	1	
30	11	30	44	20	13	21	23	31	30	20	13	21	11	30	44	0	0	0	0	
Pisces ♉			Aquarius ♊			Capricorn ♋			Sagittary ♌			Scorpio ♍			Libra ♎					
Southern Signs.																				

Degrees of the Ecliptick for Southern Signs.

The Description, Construction, and Use of this Table.

I. Its Description.

THE Table consisteth of Eight Columns; The first of which towards the right hand contains the Degrees that the Sun is in, being in any of the Six Northern Signs, (*viz.* *Aries* ♈, *Taurus* ♉, *Gemini* ♊, *Cancer* ♋, *Leo* ♌ or *Virgo* ♍) placed at the head of the Table. — And the last Column towards the right hand, contains the Degrees that the Sun is in, in any of the Six Southern Signs (*viz.* *Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐, *Capricorn* ♑, *Aquarius* ♒ and *Pisces* ♓) which are placed at the foot of the Table: — And in the other Six Columns you have the Declination that the Sun hath, he being in any Degree of any Sign of the Zodiack.

II. Its Construction.

The Place of the Sun in the Ecliptick being known, the Declination of the Sun from thence may be easily deduced, by this following Analogy or Proportion.

As the Sine of 90 Degrees	10.0000000
Is to the Sine of the Sun's greatest Declination 23 deg. 31 min.	9.6006997
So is the Sine of the Sun's distance from <i>Aries</i> or <i>Libra</i> , } (suppose 19 deg.)	9.5126419
To the Sine of 7 deg. 28 min. the Sun's Declination, when he } is in 19 deg. of <i>Aries</i> or <i>Libra</i> .	9.1133416

And in the same manner may you find that when the Sun is in 13 deg. of *Taurus* or *Scorpio*, the Sun's Declination will be 15 deg. 48 min. *ferè*, *viz.* 15 deg. 47 min. 47 Seconds, &c.

In what Sign and Degree of the Ecliptick the Sun will be any day of the Year may be found (exact enough for Instrumental Performances) by memory, if it be remembred that upon the first day of

January,	February,	March,	April,	May,	June,
the Sun is in					
21 ♈,	22 ♉,	20 ♊,	21 ♋,	20 ♌,	19 ♍,
July,	August,	September,	October,	November,	December,
the Sun is in					
18 ♎,	18 ♏,	18 ♐,	17 ♑,	18 ♒,	19 ♓.

For if you add the Days of the Month to the Degrees of the Sign that the Sun is in on the first day of the Month, the Sum is the degrees of that Sign the Sun is in; if the Sum exceed 30 it is in the following Sign; So

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in the Seventh of *May* the Sun will be in 27 degrees of *Taurus*; And on the Eighteenth of *October* the Sun will be in 5 degrees of *Scorpio*, &c.

III. Its Use.

Seek the Sign that the Sun is in, if it be a ^{Northern} Sign in the ^{Head} of the Table, and the degree of that Sign in the ^{Southern} ^{Foot} ^{First} Column of the Table ^{Last}

and in the Common Section or Angle of meeting of those two you have the Declination: So the Sun being in 25 deg. of *Leo*, seek *Leo* (it being a Northern Sign) in the Head of the Table, and 25 deg. in the first Column, and under *Leo*, and against 25 deg. you shall find 13 13 5. which shews that when the Sun is in 25 deg. of *Leo*, he hath 13 deg. 13 min. and 5 Seconds of Declination: — Also the Sun being in 17 deg. of *Capricorn*, seek *Capricorn* (it being a Southern) at the Foot, or bottom of the Table, and the 17 deg. in the last Column, and over *Capricorn*, and against 17 deg. you shall find 22 26 22 shewing that the Sun being in 17 deg. of *Capricorn*; his Declination will be 22 deg. 26 min. 22 Seconds: And so of the Rest. And

Note, If the Sun be in a ^{Northern} Sign, the Sun hath ^{North} Declination. ^{Southern} ^{South}

A

A TABLE shewing the length of the Artificial Day or Night, the Sun being in any Degree of the Ecliptick for 12 several Degrees of Latitude, viz. from 44 to 57 Degrees.

Degrees of Latitude; Or, Elevation of the Pole.																											
		45		46		47		48		49		50		51		52		53		54		55		56			
		h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.		
☐		6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	☐	
1			1		1		1		1		1		1		1		1		1		1		2		2		29
2			3		3		3		3		3		3		3		3		3		3		4		5		28
3	6	5	6	5	6	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	6	7	6	7		27
4			7		7		7		8		8		8		8		8		9		9		10		10		26
5			8		8		8		10		10		10		10		11		11		11		12		12		25
6	6	10	6	10	6	10	6	11	6	11	6	11	6	12	6	12	6	13	6	13	6	14	6	14		24	
7			12		12		12		13		13		13		14		14		15		15		16		16		23
8			13		13		13		15		15		15		16		16		17		17		18		19		22
9	6	14	6	15	6	15	6	16	6	16	6	17	6	18	6	18	6	19	6	20	6	20	6	21		21	
10			16		16		17		18		18		19		20		20		21		22		22		23		20
11			17		18		19		20		20		21		22		22		23		24		25		25		19
12	6	19	6	20	6	20	6	21	6	22	6	23	6	24	5	24	6	25	5	26	5	27	6	28		18	
13			21		22		22		23		23		25		26		26		27		28		29		30		17
14			23		23		24		24		25		27		27		28		29		30		31		32		16
15	6	24		25	6	26	6	26	6	27	6	28	6	29	6	31	6	32	5	33	6	34	6	35		15	
16			25		27		28		28		29		30		31		33		34		35		37		37		14
17			27		29		30		30		31		32		33		35		36		37		39		39		13
18	6	29	6	30	6	31	6	32	6	33	6	34	6	35	5	37	6	38	5	39	5	41	6	42		12	
19			30		31		32		34		35		36		37		39		40		42		44		45		11
20			32		33		35		36		37		38		39		41		42		44		46		47		10
21	6	33	6	34	6	36	6	37	6	38	6	40	6	41	5	43	6	44	6	46	5	48	6	49		9	
22			35		36		38		38		40		41		42		45		46		48		50		51		8
23			37		38		40		40		42		43		45		47		48		50		52		54		7
24	6	38	6	39	6	41	6	42	6	44	6	45	6	47	5	49	6	50	6	52	6	54	6	56		6	
25			40		41		43		43		46		47		49		51		53		54		56		59		5
26			41		43		45		45		48		49		51		53		55		57		58	7	1		4
27	6	43	6	44	6	46	6	47	6	49	6	51	6	53	6	55	6	57	6	59	7	1	7	3		3	
28			44		45		47		49		51		53		55		57		59		2		3		5		2
29	6	46		47		48		50		53		54		56		59	7	1	7		3		5		7		1
☐	☐	47	6	49	6	50	6	52	6	54	6	56	6	58	7	0	7	3	7		5	7	8	7	10		☐
1			49		51		52		54		56		58	7	0		2		5		7		10		14		29
2			50		52		53		56		57	7	0		2		4		7		9		12		16		28
3	6	51	6	53	6	55	6	57	6	59	7	1	7	4	7	6	7	9	7	11	7	14	7	17		27	
4			52		54		57		59	7	1		3		6		8		11		13		16		19		26
5			54		56		59	7	0		3		5		7		10		13		15		19		21		25
6	6	56	6	57	7	0	7	2	7	4	7	7	7	9	7	12	7	15	7	17	7	21	7	24		24	
7			57		58	7	2		4		6		9		11		14		17		19		23		2		23
8	6	58	7	0		3		6		8		10		13		16		19		21		25		28		22	
9			0	7	2	7	5	7	7	7	9	7	12	7	15	7	17	7	20	7	24	7	27	7	30		21
10			1	7	4		6		9		11		13		17		19		22		27		29		32		20

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Degrees of Latitude; Or, Elevation of the Pole.

	45		46		47		48		49		50		51		52		53		54		55		56		
	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	
80 m	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	80 m
11	7	3		6		8		11		13		15		19		21		24		29		31		35	19
12	7	4	7	7	7	9	7	12	7	15	7	17	7	20	7	23	7	26	7	30	7	33	7	37	18
13		5		9		11		13		16		19		21		25		28		32		35		39	17
14		7		10		12		15		18		21		23		27		30		33		37		41	16
15	7	9	7	11	7	13	7	17	7	19	7	22	7	25	7	28	7	32	7	35	7	39	7	43	15
16		10		12		15		18		21		23		27		30		34		37		41		45	14
17		11		13		17		19		23		25		29		32		36		39		43		47	13
18	7	12	7	15	7	18	7	21	7	24	7	26	7	30	7	34	7	37	7	41	7	45	7	49	12
19		13		16		20		22		25		28		31		36		39		43		47		52	11
20		14		18		21		23		26		29		33		38		40		45		49		54	10
21	7	16	7	19	7	22	7	25	7	28	7	31	7	35	7	39	7	42	7	47	7	51	7	56	9
22		17		20		23		26		30		32		36		41		44		49		53		58	8
23		19		21		25		28		31		34		37		42		46		50		55		59	7
24	7	20	7	23	7	26	7	29	7	32	7	36	7	39	7	43	7	48	7	52	7	56	8	1	6
25		21		24		27		30		34		37		41		45		50		54		58		3	5
26		22		25		28		31		35		39		42		46		51		56	8	0		5	4
27	7	23	7	26	7	29	7	33	7	36	7	40	7	44	7	48	7	52	7	57	8	2	8	7	3
28		24		27		30		33		37		41		45		50		53		59		4		9	2
29		25		28		32		35		38		42		46		51		55		0		6		11	1
II 0 2	7	26	7	30	7	33	7	36	7	40	7	44	7	48	7	52	7	57	8	2	8	7	8	12	0 2
1		27		31		34		37		41		45		50		53		59		3		9		13	29
2		28		32		35		39		43		47		51		55		59		5		10		15	28
3	7	29	7	33	7	36	7	40	7	44	7	48	7	52	7	56	8	1	8	6	8	12	8	17	27
4		30		34		37		41		45		49		53		58		2		7		13		19	26
5		31		35		38		42		46		50		54		59		3		9		14		21	25
6	7	32	7	36	7	39	7	43	7	47	7	51	7	56	8	0	8	5	8	10	8	16	8	22	24
7		33		36		40		44		48		52		57		1		6		11		17		23	23
8		34		37		41		45		49		53		58		2		7		13		18		25	22
9	7	35	7	38	7	42	7	46	7	50	7	54	7	59	8	4	8	9	8	14	8	20	8	26	21
10		36		39		42		46		51		55	3			5		9		15		21		28	20
11		37		39		43		47		52		56	3	1		6		11		16		22		29	19
12	7	37	7	40	7	44	7	48	7	53	7	57	3	2	8	7	8	12	8	17	8	23	8	30	18
13		38		40		45		49		53		57		2		8		13		18		24		31	17
14		39		41		46		49		54		58		3		8		14		19		25		32	16
15	7	39	7	42	7	46	7	50	7	55	7	59	8	4	8	9	3	15	8	20	8	26		33	15
16		39		43		47		50		55		59		5		9		15		21		27		34	14
17		40		43		47		51		56	8	0		6		10		16		22		28		35	13
18	7	40	7	44	7	48	7	52	7	57	8	1	8	7	8	11	8	17	8	23	8	29	8	36	12
19		40		44		48		53		57		1		7		11		18		23		29		37	11
20		41		44		48		53		58		2		8		12		18		24		30		37	10
21	7	41	7	45	7	49	7	54	7	58	8	3	8	8	13	8	19	8	25	8	31	8	38		9
22		41		45		49		54		58		3		8		13		19		25		31		38	8
23		42		46		49		55		59		4		9		14		20		26		32		38	7
24	7	42	7	46	7	50	7	55	7	59	8	4	8	9	14	8	20	8	26	8	33	8	39		6
25		42		46		50		55		59		4		9		14		20		27		33		39	5
26		43		47		50		55	8	0		4		10		15		21		27		33		39	4
27	7	43	7	47	7	51	7	56	3	0	8	4	8	10	8	15	8	21	8	27	8	33	8	40	3
28		43		47		51		56		0		4		10		15		21		27		33		40	2
29		43		47		51		56		0		4		10		15		21		27		33		40	1
30 y	7	43	7	47	7	51	7	56	3	0	8	5	0	10	8	15	8	22	8	27	8	34	8	41	30 y

The Description, Construction and Use of this Table.

I. Its Description.

The Table consisteth of 14 Columns: in the first towards the Left hand, and in the last towards the Right hand, you have the *Sign* and *Degree* that the Sun is in; and in the other 12 intermediate Columns you have the *Semidiurnal* and *Semi-nocturnal* Arks, or half length of the *Artificial Day* or *Night*.

Now, the *Artificial Day* is an Arch of the *Natural Day*, and contains that space of time which is numbered from the *Rising* of the Sun unto the going down of the same; and this Arch is either *Equal* or *Unequal*. The mean or *Equal Artificial Day* contains always 12 hours, which evermore happens when the Sun is in the *Equinoctial*, but when the Sun is out of the same Line, it is unequal, and is then either *longer* or *shorter* than 12 hours, according as the Sun's Arch or *Parallel* caused by the greater or lesser Elevation of the Pole above the *Horizon*.

II. Its Construction.

The *Canon*, *Analogy* or *Proportion*, by which this Table is made, is this; The *Latitude* of the Place and the *Declination* of the Sun being known:— Let the *Latitude* be 47 deg. and let the Sun be in 19 deg. of *Aries*; at which time (by the former Table) the Sun hath 7 deg. 28. min. of *Declination*, Then the *Proportion* is.

As the Co-tangent of the <i>Latitude</i> 43 degrees	9.9696559
To the Tangent of the <i>Declination</i> 7 deg. 28 min.	9.1174724
So is the <i>Radius</i> 90 deg.	10.0000000
To the <i>Sine</i> of 8 deg. 4 min.	19.1174724
	9.1478165

This 8 deg. 4 min. converted into time is 32 min. and is the *Ascensional Difference* (or the distance in time that the Sun rises before or after Six:) which added to Six hours (because the Sun is in a Northern Sign) makes 6 hours 32 min. for the *Semidiurnal Ark*, or half length of the Day.

Note, The *Semidiurnal Ark* doubled is the length of the Day, and that doubled subtracted from 24 is the length of the Night, and the *Ascensional Difference* subtracted from Six hours, gives the time of the Sun's *Rising*, and added to Six hours, gives the time of the Sun's *Setting*.

III. Its Use.

Seek the *Sign* and *Degree* in which the Sun is in the first or last Column, and right against it (under the *Latitude* found at the head of the Table) you shall

shall have the *Semidiurnal Ark* if the Sign in which the Sun is be a *Northern Sign*, or the *Seminocturnal Arch*, if the Sun be in a *Southern Sign*.

Example 1. *The Sun being in a Northern Sign.*

Let the Sun be in the 12th deg. of *Gemini*, and let it be required to know the length of the day in the Latitude of 46 deg. Look for 12 deg. of *Gemini* in the First Column of the *Table*, and right against it (under the *Latitude* 46 deg. found in the head of the *Table*) you shall have 7 hours 40 min. for the *Semidiurnal Arch*, and time of the Sun's *Setting*, which doubled is 15 hours 20 min. for the *Length of the day*. — So likewise when the Sun is in 23 deg. of *Leo*, in the Latitude of 55 deg. the *Semidiurnal Arch* will be found to be 7 hours 23 min. which doubled makes 14 hours 46 min. for the *Length of the Day*. But,

Example 2. *The Sun being in a Southern Sign.*

Let the Sun be in 19 deg. of *Aquarius*, and let it be required to find the Length of the Day and Night, and also at what time the Sun *Rises* and *Sets* in the Latitude of 48 degrees, Look for 19 deg. of *Aquarius* (which you shall find in the last Column of the *Table* towards the right hand) and right against it, under 48 deg of *Latitude*, you shall find 7 hours 11 min. which is the *Seminocturnal Arch*, and the time of the Sun's *Rising* (because the Sun is in a *Southern Sign*) — This *Arch* doubled gives 14 hours 22 min. for the *Length of the Night*. And taken out of 24 hours, leaves 9 hours 38 min. for the *Length of the day*: — The half whereof, 4 hours 49 min. is the time of the Sun's *Setting*.

Here followeth

A TABLE, shewing what Amplitude, the Sun shall have, at his Rising or Setting, from the true East or West Points of the Horizon; towards either the North or South: At every whole (or equal) degree of his Declination, Northward or Southward.

And for all Latitudes (or Elevations of the Poles) from the Equinoctial to 60 degrees.

Degrees

Degrees of Latitude.

	1		2		3		4		5		6		7		8		9		10	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	2	0	2	0	2	0	2	0	2	0	2	0	2	1	2	1	2	1	2	2
3	3	0	3	0	3	0	3	0	3	0	3	1	3	1	3	1	3	1	3	3
4	4	0	4	0	4	0	4	0	4	1	4	1	4	2	4	2	4	2	4	4
5	5	0	5	0	5	0	5	0	5	1	5	1	5	2	5	2	5	3	5	5
6	6	0	6	0	6	0	6	1	6	1	6	2	6	2	6	3	6	4	6	6
7	7	0	7	0	7	0	7	1	7	1	7	2	7	3	7	4	7	5	7	7
8	8	0	8	0	8	0	8	1	8	1	8	2	8	3	8	4	8	6	8	8
9	9	0	9	0	9	1	9	1	9	2	9	2	9	4	9	5	9	6	9	9
10	10	0	10	0	10	1	10	1	10	2	10	3	10	4	10	6	10	7	10	10
11	11	0	11	0	11	1	11	1	11	2	11	3	11	5	11	6	11	8	11	11
12	12	0	12	0	12	1	12	1	12	3	12	4	12	5	12	7	12	9	12	12
13	13	0	13	0	13	1	13	1	13	3	13	4	13	6	13	8	13	9	13	13
14	14	0	14	0	14	1	14	2	14	3	14	4	14	6	14	8	14	10	14	14
15	15	0	15	0	15	1	15	2	15	3	15	5	15	7	15	9	15	11	15	15
16	16	0	16	1	16	1	16	2	16	4	16	5	16	7	16	10	16	12	16	16
17	17	0	17	1	17	1	17	2	17	4	17	5	17	8	17	10	17	13	17	17
18	18	0	18	1	18	1	18	2	18	4	18	6	18	8	18	11	18	14	18	18
19	19	0	19	1	19	1	19	2	19	4	19	6	19	9	19	12	19	15	19	19
20	20	0	20	1	20	2	20	3	20	5	20	6	20	9	20	12	20	16	20	20
21	21	0	21	1	21	2	21	3	21	5	21	7	21	10	21	13	21	17	21	21
22	22	0	22	1	22	2	22	3	22	5	22	7	22	10	22	13	22	18	22	22
23	23	0	23	1	23	2	23	3	23	5	23	8	23	11	23	14	23	19	23	23
23-31	23	31	23	32	23	33	23	35	23	37	23	39	23	42	23	46	23	50	23	54

Degrees of Latitude.

	11		12		13		14		15		16		17		18		19		20	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	1	1	1	1	2	1	2	1	2	1	2	1	2	1	3	1	3	1	4
2	2	2	2	3	2	3	2	4	2	4	2	4	2	5	2	6	2	7	2	8
3	3	3	3	4	3	5	3	5	3	6	3	7	2	8	3	9	3	10	3	12
4	4	4	4	5	4	6	4	7	4	8	4	10	4	11	4	12	4	14	4	16
5	5	5	5	7	5	8	5	9	5	10	5	12	5	13	5	15	5	17	5	20
6	6	6	6	8	6	10	6	11	6	13	6	15	6	16	6	19	6	21	6	23
7	7	8	7	9	7	11	7	13	7	15	7	17	7	19	7	22	7	24	7	27
8	8	9	8	11	8	13	8	15	8	17	8	19	8	22	8	25	8	28	8	31
9	9	10	9	12	9	14	9	17	9	19	9	22	9	25	9	28	9	31	9	35
10	10	11	10	13	10	16	10	19	10	21	10	24	10	28	10	31	10	35	10	39
11	11	13	11	15	11	17	11	20	11	23	11	27	11	30	11	34	11	38	11	43
12	12	14	12	16	12	19	12	21	12	25	12	29	12	33	12	38	12	42	12	47
13	13	15	13	17	13	20	13	24	13	27	13	32	13	36	13	41	13	46	13	51
14	14	16	14	19	14	22	14	26	14	30	14	34	14	39	14	44	14	50	14	55
15	15	17	15	20	15	24	15	28	15	32	15	37	15	42	15	47	15	53	15	0
16	16	19	16	22	16	26	16	30	16	35	16	40	16	45	16	51	16	57	17	4
17	17	20	17	23	17	28	17	32	17	37	17	42	17	47	17	54	18	1	18	8
18	18	21	18	25	18	30	18	34	18	39	18	45	18	51	18	58	19	5	19	12
19	19	22	19	26	19	31	19	36	19	41	19	48	19	54	20	1	20	8	20	16
20	20	24	20	28	20	33	20	38	20	44	20	51	20	57	21	4	21	12	21	20
21	21	25	21	29	21	35	21	40	21	46	21	53	21	0	22	8	22	16	22	24
22	22	27	22	31	22	37	22	43	22	49	22	56	22	4	23	12	23	20	23	29
23	23	28	23	33	23	39	23	45	23	51	23	59	23	7	24	16	24	24	24	34
23-31	23	59	24	5	24	11	24	17	24	24	24	32	24	40	24	48	24	58	25	8

Degrees of Latitude.

	21		22		23		24		25		26		27		28		29		30	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	4	1	5	1	5	1	6	1	6	1	7	1	8	1	8	1	9	1	9
2	2	8	2	9	2	10	2	17	2	12	2	13	2	15	2	16	2	17	2	18
3	3	13	3	14	3	15	3	17	3	18	3	20	3	22	3	24	3	25	3	28
4	4	17	4	19	4	20	4	23	4	25	4	27	4	29	4	32	4	34	4	37
5	5	21	5	23	5	26	5	28	5	31	5	34	5	36	5	40	5	43	5	46
6	6	26	6	28	6	32	6	37	6	37	6	41	6	44	6	48	6	52	6	56
7	7	3	7	33	7	37	7	41	7	43	7	47	7	51	7	56	8	0	8	6
8	8	34	8	38	8	42	8	46	8	50	8	54	8	59	9	4	9	9	9	15
9	9	39	9	43	9	47	9	51	9	56	10	1	10	6	10	12	10	18	10	24
10	10	43	10	48	10	52	10	57	11	3	11	8	11	14	11	21	11	27	11	34
11	11	48	11	53	11	57	12	3	12	9	12	15	12	21	12	29	12	36	12	44
12	12	52	12	58	13	3	13	9	13	16	13	23	13	29	13	37	13	45	13	53
13	13	57	14	3	14	8	14	15	14	22	14	30	14	37	14	45	14	54	15	3
14	15	1	15	8	15	14	15	21	15	29	15	37	15	45	15	54	16	3	16	12
15	16	6	16	13	16	20	16	27	16	35	16	44	16	53	17	3	17	12	17	22
16	17	11	17	18	17	26	17	34	17	42	17	52	18	1	18	12	18	22	18	32
17	18	15	18	23	18	31	18	40	18	49	19	0	19	9	19	21	19	31	19	43
18	19	20	19	28	19	37	19	46	19	56	20	7	20	18	20	31	20	41	20	54
19	20	24	20	33	20	43	20	52	21	3	21	12	21	26	21	39	21	51	22	5
20	21	29	21	39	21	49	21	59	22	10	22	22	22	34	22	48	23	2	23	16
21	22	34	22	44	22	54	23	8	23	17	23	30	23	43	23	57	24	12	24	26
22	23	40	23	50	24	1	24	12	24	25	24	38	24	52	25	6	25	22	25	38
23	24	45	24	55	25	7	25	19	25	32	25	46	26	1	26	15	26	32	26	49
23-31	25	18	25	29	25	41	25	54	26	7	26	22	26	37	26	52	27	8	27	25

Degrees of Latitude.

	31		32		33		34		35		36		37		38		39		40	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	10	1	10	1	11	1	12	1	13	1	14	1	15	1	16	1	17	1	18
2	2	19	2	21	2	23	2	25	2	26	2	29	2	30	2	32	2	34	2	36
3	3	29	3	33	3	35	3	38	3	40	3	44	3	45	3	49	3	52	3	55
4	4	39	4	44	4	46	4	50	4	53	4	58	5	0	5	5	5	8	5	13
5	5	50	5	54	5	58	6	2	6	6	6	11	6	16	6	21	6	26	6	32
6	7	0	7	5	7	9	7	14	7	20	7	25	7	31	7	37	7	43	7	50
7	8	10	8	16	8	21	8	27	8	33	8	40	8	47	8	54	9	1	9	9
8	9	20	9	27	9	33	9	39	9	47	9	54	10	2	10	10	10	19	10	28
9	10	31	10	39	10	45	10	52	11	0	11	9	11	17	11	27	12	37	11	47
10	11	41	11	48	11	59	12	5	12	14	12	24	12	33	12	43	13	55	13	6
11	12	52	13	0	13	9	13	18	13	28	13	39	13	50	14	0	14	13	14	25
12	14	2	14	11	14	21	14	32	14	41	14	54	15	6	15	18	15	31	15	44
13	15	13	15	23	15	33	15	45	15	56	16	9	16	22	16	35	16	50	17	4
14	16	23	16	35	16	45	16	59	17	1	17	24	17	38	17	52	18	8	18	24
15	17	34	17	46	17	58	18	12	18	25	18	40	18	55	19	10	19	27	19	45
16	18	44	18	58	19	11	19	26	19	40	19	55	20	11	20	28	20	46	21	5
17	19	56	20	10	20	24	20	39	20	55	21	11	21	28	21	47	22	6	22	26
18	21	7	21	22	21	37	21	53	22	10	22	27	22	46	22	5	23	25	23	47
19	22	19	22	35	22	51	23	7	23	25	23	44	24	4	24	24	24	46	25	9
20	23	31	23	47	24	4	24	22	24	40	25	0	25	22	25	43	26	7	26	31
21	24	43	25	0	25	17	25	37	25	56	26	17	26	40	27	3	27	28	27	53
22	25	55	26	13	26	31	26	52	27	12	27	35	27	58	28	23	28	49	29	10
23	27	7	27	26	27	46	28	7	28	29	28	53	29	18	29	44	30	11	30	40
23-31	27	43	28	3	28	24	28	45	29	8	29	32	29	58	30	25	30	53	31	22

Degrees of Latitude.

	41		42		43		44		45		46		47		48		49		50	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	20	1	21	1	22	1	23	1	25	1	26	1	28	1	29	1	31	1	33
2	2	40	2	41	2	44	2	46	2	50	2	53	2	56	2	59	3	3	3	6
3	3	58	4	2	4	6	4	10	4	15	4	19	4	24	4	29	4	34	4	46
4	5	18	5	23	5	28	5	34	5	40	5	45	5	52	5	59	6	6	6	14
5	6	38	6	44	6	51	6	58	7	5	7	12	7	21	7	29	7	38	7	48
6	7	57	8	5	8	12	8	21	8	30	8	38	8	49	8	59	9	10	9	22
7	9	18	9	26	9	35	9	45	9	55	10	6	10	18	10	30	10	42	10	56
8	10	37	10	47	10	58	11	9	11	21	11	33	11	47	12	0	12	44	12	31
9	11	58	12	9	12	21	12	34	12	47	13	1	13	16	13	31	13	46	14	5
10	13	18	13	31	13	44	13	58	14	13	14	27	14	45	15	2	15	21	15	40
11	14	39	14	53	15	7	15	23	15	39	15	55	16	15	16	34	16	54	17	16
12	16	0	16	10	16	30	16	48	17	6	17	25	17	45	18	6	18	28	18	52
13	17	21	17	38	17	54	18	13	18	33	18	54	19	16	19	39	20	3	20	29
14	18	42	19	0	19	18	19	39	20	0	20	23	20	47	21	12	21	38	22	6
15	20	4	20	23	20	43	21	5	21	28	21	53	22	18	22	45	23	14	23	44
16	21	25	21	46	22	8	22	32	22	56	23	23	23	50	24	20	24	51	25	23
17	22	48	23	10	23	34	23	59	24	25	24	53	25	23	25	55	26	28	27	3
18	24	10	24	34	24	59	25	20	25	55	26	25	26	57	27	31	28	6	28	44
19	25	33	25	59	26	26	26	54	27	25	27	57	28	32	29	7	29	45	30	25
20	26	57	27	24	27	53	28	23	28	56	29	30	30	7	30	45	31	25	32	9
21	28	21	28	50	29	19	29	53	30	27	31	3	31	42	32	23	33	6	33	53
22	29	46	30	16	30	48	31	23	32	0	32	37	33	19	34	3	34	48	35	40
23	31	11	31	43	32	17	32	55	33	32	34	13	34	57	35	43	35	34	37	26
23.31	31	54	32	27	33	2	33	41	34	20	35	2	35	48	36	34	37	26	38	20

Degrees of Latitude.

	51		52		53		54		55		56		57		58		59		60	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	35	1	37	1	39	1	42	1	45	1	47	1	50	1	53	1	56	2	0
2	3	10	3	15	3	20	3	24	3	29	3	34	3	40	3	46	3	53	4	0
3	4	46	4	52	4	59	5	6	5	14	5	22	5	31	5	40	5	50	6	0
4	6	22	6	30	6	39	6	49	6	59	7	10	7	22	7	34	7	47	8	1
5	7	58	8	8	8	19	8	32	8	45	8	58	9	13	9	28	11	45	10	2
6	9	34	9	46	10	0	10	15	10	30	10	47	11	4	11	23	13	43	12	4
7	11	10	11	25	11	41	11	58	12	16	12	35	12	56	13	18	15	41	14	6
8	12	47	13	4	13	22	13	41	14	2	14	24	14	48	15	14	17	41	16	10
9	14	24	14	43	15	4	15	26	16	15	16	15	16	42	17	10	19	41	18	14
10	16	1	16	23	16	46	17	11	17	37	18	6	18	36	19	8	21	42	20	19
11	17	39	18	3	18	29	18	57	19	26	19	57	20	31	21	6	23	45	21	26
12	19	18	19	44	20	13	20	43	21	15	21	50	22	26	23	6	25	49	24	34
13	20	58	21	28	21	57	22	30	23	5	23	43	24	23	25	7	28	54	26	44
14	22	38	23	6	23	42	24	18	24	57	25	38	26	22	27	10	30	1	28	56
15	24	17	24	51	25	28	26	7	26	49	27	34	28	22	29	14	32	10	31	10
16	25	59	26	36	27	16	27	58	28	43	29	32	30	24	31	21	34	22	33	27
17	27	41	28	21	29	4	29	50	30	39	31	31	32	28	33	29	36	35	35	47
18	29	25	30	8	30	54	31	44	32	36	33	33	34	34	35	40	39	52	38	10
19	31	9	31	56	32	45	33	38	34	35	35	36	36	43	37	54	41	13	40	37
20	32	55	33	46	34	39	35	35	36	36	37	42	38	53	40	12	44	37	43	16
21	34	48	35	36	36	33	37	33	38	40	39	51	41	9	42	34	46	1	45	47
22	36	32	37	29	38	31	39	37	40	46	42	4	43	27	44	59	49	40	48	32
23	38	23	39	24	40	20	41	40	42	56	44	20	45	50	47	30	50	21	51	24
23.31	39	20	40	21	41	29	42	43	44	2	45	30	47	2	48	49	50	44	51	53

The Description, Construction and Use of this Table.

I. Its Description.

The Tables being in number Six, do each of them contain Eleven Columns, the first whereof towards the left hand contains the several degrees of the Sun's *Declination* from 1 deg. to 23 deg. 31 min. and at the head of each Column are the several degrees of *Latitude* from 1 deg. to 60 deg.

II. Its Construction.

The *Latitude* of the Place and the *Declination* of the Sun being known, the *Canon*, *Analogy* or *Proportion* by which the Table is formed is This:

As the Sine Complement of the Latitude (suppose 43 deg. Latitude) 47 deg.

9.8641275

Is to the Radius 90 deg.

10.0000000

So is the Sine of the Declination (suppose 15 deg.)

19.4129962

To the Sine of the Amplitude 20 deg. 43 min.

9.5488687

deg. m.

So likewise if the Latitude were $\left\{ \begin{matrix} 21 \\ 35 \\ 56 \end{matrix} \right\}$ And the Sun's Declination $\left\{ \begin{matrix} 8 \\ 17 \\ 21 \end{matrix} \right\}$ The Amplitude would be found to be $\left\{ \begin{matrix} 8 \\ 20 \\ 39 \end{matrix} \right\}$ 34 55 51

And here Note. (1.) If the Sun's *Declination* be *North*, the Sun's *Amplitude* of Rising or Setting is towards the *North*, and the Sun Rises between the *East* and the *North*; and Sets between the *West* and the *North* — But (2.) If the *Declination* be *South* the Sun Rises between the *East* and the *South* and Sets between the *West* and the *South*: (3.) When the Sun is in the *Equinoctial* and hath no degrees of *Declination* the Sun hath no degrees of *Amplitude*, but Rises due *East*, and Sets due *West*.

III. Its Use.

Seek the Latitude in the Head of the Table, and the Sun's Declination in the first Column, and in the Common Angle or Section, you have the *Amplitude* — Example, In the Latitude 15 deg. the Sun having 20 deg. of North *Declination* I would know his Amplitude: — Seek 15 degrees in the Head of the Table, and 20 in the first Column, and right against 20 and under 15 you shall find 20 deg. 44 min. and such *Amplitude* shall the Sun have in the Latitude of 15 deg. when he hath 20 deg of *Declination*: And is *Northward* if the Declination be *North*, *South*, according to the foregoing Note.

Here

A
T A B L E

S H E W I N G

What Declination the SUN shall have

W H E N T H E

S U N Rises or Sets

Upon any even Point or half Point

O F T H E

C O M P A S S,

In any Latitude from the Equinoctial
to 60 Degrees.

Of the FURNITURE

The Point of the Compass upon which the Sun Rises and Sets.

☉ Rise ☉ Sets	East West	Half Point	E. by N. W. by S.	Half Point	E. N. E. W. N. W.	Half Point	N. E. by E. S. W. by W.	Half Point	N. East S. West	Half Point
<i>Degrees of the Sun's Declination North.</i>										
60	o o	2 49	5 36	8 21	11 2	13 38	15 8	18 30	20 42	22 44
59	o o	2 54	5 46	8 36	11 22	14 3	16 37	19 4	21 22	23 27
58	o o	2 59	5 56	8 51	11 42	14 28	17 7	19 38	22 0	
57	o o	3 4	6 6	9 6	12 1	14 53	17 37	20 13	22 39	
56	o o	3 6	6 16	9 21	12 22	15 18	18 6	20 47	23 18	
55	o o	3 14	6 25	9 35	12 41	15 42	18 35	21 21		
54	o o	3 18	6 35	9 50	13 0	16 5	19 3	21 54		
53	o o	3 23	6 44	10 4	13 19	16 29	19 32	22 27		
52	o o	3 28	6 54	10 18	13 37	16 52	20 0	23 0		
51	o o	3 33	7 4	10 32	13 56	17 16	20 28	23 32		
50	o o	3 37	7 12	10 46	14 14	17 30	20 55			
49	o o	3 42	7 22	10 59	14 28	18 1	21 22			
48	o o	3 46	7 30	11 12	14 51	18 24	21 49			
47	o o	3 50	7 39	11 25	15 8	18 46	22 18			
46	o o	3 55	7 47	11 38	15 25	19 7	22 42			
45	o o	3 59	7 56	11 51	15 42	19 30	23 8			
44	o o	4 3	8 4	12 3	15 50	19 50	23 32			
43	o o	4 7	8 12	12 16	16 15	20 10				
42	o o	4 11	8 20	12 28	16 31	20 31				
41	o o	4 15	8 28	12 40	16 47	20 51				
40	o o	4 19	8 36	12 51	17 3	21 10				
39	o o	4 22	8 43	13 3	17 18	21 30				
38	o o	4 26	8 50	13 14	17 33	21 49				
37	o o	4 30	8 58	13 25	17 48	22 7				
36	o o	4 33	9 5	13 35	18 2	22 25				
35	o o	4 37	9 12	13 46	18 16	22 43				
34	o o	4 40	9 18	13 56	18 30	23 1				
33	o o	4 43	9 25	14 6	18 43	23 18				
32	o o	4 46	9 31	14 16	18 55					
31	o o	4 50	9 38	14 25	19 9					
30	o o	4 52	9 44	14 34	19 21					
29	o o	4 55	9 50	14 43	19 33					
28	o o	4 58	9 55	14 51	19 45					
27	o o	5 1	10 1	15 0	19 56					
26	o o	5 4	10 6	15 8	20 7					
25	o o	5 6	10 11	15 16	20 18					
24	o o	5 9	10 16	15 23	20 28					
23	o o	5 11	10 21	15 31	20 37					
22	o o	5 13	10 25	15 38	20 46					
21	o o	5 15	10 30	15 44	20 55					
20	o o	5 17	10 34	15 51	21 5					
19	o o	5 20	10 38	15 56	21 13					
18	o o	5 22	10 42	16 2	21 20					
17	o o	5 23	10 45	16 8	21 27					
16	o o	5 25	10 49	16 12	21 34					
15	o o	5 26	10 52	16 17	21 41					
14	o o	5 28	10 55	16 22	21 47					
13	o o	5 29	10 57	16 26	21 53					
12	o o	5 30	11 0	16 30	21 58					
11	o o	5 31	11 3	16 33	22 3					
10	o o	5 33	11 5	16 37	22 7					
9	o o	5 34	11 6	16 40	22 12					
8	o o	5 35	11 8	16 43	22 15					
7	o o	5 35	11 9	16 45	22 19					
6	o o	5 36	11 11	16 47	22 21					
5	o o	5 37	11 12	16 49	22 23					
4	o o	5 37	11 14	16 50	22 26					
3	o o	5 37	11 14	16 52	22 27					
2	o o	5 38	11 14	16 52	22 29					
1	o o	5 38	11 15	16 53	22 30					
<i>Degrees of the Sun's Declination South.</i>										
☉ Rise ☉ Sets	East West	Half Point	E. by S. W. by S.	Half Point	E. S. E. W. S. W.	Half Point	S. E. by E. S. W. by W.	Half Point	S. East S. West	Half Point

The Point of the Compass upon which the Sun Rises and Sets.

Degrees of Latitude or of the Pole's Elevation.

The Description, Construction and Use of this Table.

I. Its Description.

THe Table Consisteth of Eleven Columns, in the First of which towards the left hand are contained all degrees of *Latitude*, from 60 deg. down to the *Equinoctial*;—And at the head of the Table are so many *whole* and *half Points* of the *Compass*, as the *Sun* may *Rise* or *Set* upon in those *Latitudes* counted from the *East* or *West Northwards*—And at the bottom of the Table are such *Points* and *half Points* of the *Compass*, as the *Sun* may *Rise* or *Set* upon in any of the forementioned *Latitudes* between the *East* or *West Points* and the *South*, as the Titles at the head and foot of the Table do exprefs; And under them are the degrees of *Declination* that the *Sun* shall have when he *Rises* or *Sets* upon those *Points* of the *Compass*.

II. Its Construction.

If you would know what *Declination* the *Sun* shall have when he *Rises* upon the *E. by N.* and *Sets* upon the *W. by N.* Point of the *Compass* in any *Latitude* (suppose in the *Latitude* of 35 deg.) The *Analogie* or *Proportion* is,

As the *Radius* 90 deg.

10.0000000

To the *Co-sine* of the *Latitude* 55 deg.

9.9133645

So is the *Sine* of the Point of the *Compass* from the

9.2902357

E. or W. viz. 11 deg. 15 min. (for *E. by N.*)

To the *Sine* of 9 deg. 12 min.

19.2036002

And such *Declination* must the *Sun* have when he *Rises* upon the *E. by N.* and *Sets* upon *W. by N.* Point of the *Compass* in the *Latitude* of 35 deg.

III. Its Use.

Seek the *Latitude* in the first Column of the Table towards the left hand, and the *Point* or *half Point* of the *Compass* upon which the *Sun* *Rises* or *Sets* in the head or bottom of the Table, and in the common *Angle* or *Section* you shall have the *Declination* that the *Sun* then hath.

Example. What *Declination* shall the *Sun* have when he *Rises N. E.* by *E.* and *Sets N. W.* by *W.* in the *Latitude* of 48 deg. Look for 48 deg. in the first Column, and for *N. E. by E.* in the head of the Table, and under those *Points*, and against 48 deg. you shall find 21 deg. 49 min. for the *Declination* that the *Sun* shall have when he *Rises N. E.* by *E.* and *Sets N. W.* by *W.* in the *Latitude* of 48 deg. —And the like in any other *Latitude*.

A TABLE

A TABLE shewing what Declination the Sun shall have, when the Day is any Number of whole hours long in any Latitude.

		The Difference between the Length of the Longest or Shortest Day, consisting of equal hours, and an Equinoctial Day of 12 hours.											
		1		2		3		4		5		6	
		7	3	15	5	22	3	40	0	31	3	45	0
		Decl.		Decl.		Decl.		Decl.		Decl.		Decl.	
		D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
Degrees of Latitude.	89	0	8	0	16	0	23	0	30	0	36	0	43
	88	0	16	0	31	0	46	1	0	1	13	1	25
	87	0	23	0	47	1	9	1	30	1	50	2	7
	86	0	32	1	2	1	56	2	0	2	27	2	50
	85	0	39	1	18	1	55	2	30	3	3	3	32
	84	0	47	1	27	2	18	3	0	3	39	4	14
	83	0	55	1	37	2	42	3	31	4	15	4	56
	82	1	3	1	46	3	05	4	01	4	52	5	39
	81	1	11	1	55	3	29	4	32	5	29	6	22
	80	1	19	2	37	3	52	5	3	6	7	7	6
	79	1	27	2	47	4	16	5	34	6	45	7	48
	78	1	35	3	07	4	40	6	05	7	22	8	31
	77	1	43	3	16	5	04	6	36	8	0	9	14
	76	1	51	3	37	5	28	7	07	8	38	9	57
	75	1	59	3	58	5	51	7	38	9	16	10	40
	74	2	8	4	15	6	16	8	10	9	5	11	25
	73	2	17	4	32	6	41	8	43	10	33	12	10
	72	2	26	4	49	7	06	9	15	11	12	12	56
	71	2	35	5	6	7	32	9	47	11	51	13	42
	70	2	43	5	23	7	56	10	19	12	30	14	26
	69	2	52	5	41	8	22	10	52	13	5	15	11
	68	3	1	5	59	8	49	11	26	13	41	15	57
	67	3	10	6	17	9	15	11	59	14	16	16	43
	66	3	19	6	35	9	42	12	33	14	52	17	29
	65	3	29	6	53	10	7	13	7	15	28	18	15
	64	3	28	7	12	10	35	13	43	16	15	19	02
	63	3	48	7	40	11	04	14	19	17	2	19	49
	62	3	57	7	59	11	32	14	55	17	49	20	37
	61	4	8	8	19	12	01	15	31	18	36	21	25
	60	4	17	8	30	12	28	16	6	19	23	22	12
	59	4	28	8	51	12	58	16	44	20	07	23	2
	58	4	39	9	12	13	29	17	23	20	51	23	50
	57	4	52	9	33	13	59	18	01	21	36		
	56	5	1	9	54	14	30	18	40	22	21		
	55	5	13	10	17	15	0	19	18	23	5		

The Difference between the Length of the Longest or Shortest Day, consisting of equal hours, and an Equinoctial Day of 12 hours.

	1		2		3		4		5		6	
	7	3	15	5	22	3	40	0	31	3	45	0
	Decl.		Decl.		Decl.		Decl.		Decl.		Decl.	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
54	5	25	10	40	15	33	19	59	24	2		
53	5	38	11	04	16	7	20	40				
52	5	50	11	27	16	40	21	22				
51	6	2	11	51	17	14	22	04				
50	6	15	12	15	17	48	22	45				
49	6	30	12	42	18	26	23	27				
48	6	42	13	09	19	03	24	09				
47	6	56	13	37	19	40						
46	7	17	14	04	20	18						
45	7	26	14	31	20	57						
44	7	43	15	2	21	40						
43	8	00	15	33	22	23						
42	8	17	16	04	23	06						
41	8	34	16	36	23	23						
40	8	50	17	9								
39	9	10	17	47								
38	9	29	18	24								
37	9	49	19	02								
36	10	12	19	39								
35	10	34	20	17								
34	11	00	21	09								
33	11	26	22	01								
32	11	52	22	53								
31	12	18	23	44								
30	12	44										
29	13	15										
28	13	48										
27	14	22										
26	14	57										
25	15	39										
24	16	20										
23	17	5										
22	17	54										
21	18	46										
20	19	44										
19	20	46										
18	21	53										
17	23	7										
16	24	26										

Degrees of Latitude.

The Description Construction and Use of this Table.

I. Its Description.

The Table consists of Seven Columns, in the first whereof are all degrees of Latitude from the Pole to 16 degrees: And at the head of the Table is the Difference between the length of an Equinoctial day of 12 hours long, and the even hours of any other days length; in great Figures, and under them in smaller Figures, is the half difference of that length in degrees and minutes, and under them the Declination that the Sun shall then have when the day is so much longer or shorter than an Equinoctial Day.

II. Its Construction.

If you would know what Declination the Sun shall have when the day is any number of even hours longer or shorter than an Equinoctial Day in any Latitude, Consider the difference of those Lengths, and an Equinoctial Day of 12 hours; and take the half thereof, which turn into Degrees and Minutes:--As suppose I would know what Declination the Sun shall have when the day is either 15 deg. or 9 hours long in the Latitude of 54 deg.

First, the difference between 9 or 15 hours and 12 hours (an Equinoctial Day) is 3 hours, the half whereof is 1 hour and a half, and that turned into time is 22 deg. 30 min.--Being thus prepared, the Analogy or Proportion to find the Sun's Declination at that time is,
As the Radius 90 deg.

Is to the Sine of half the diff. 1 hour 30 min. (viz. 22d. 30 m.)
So is the Co-tangent of the Latitude 36 deg.

10.0000000

9.5828397

9.8612610

To the Tangent of 15 deg. 33 min.
And such Declination shall the Sun have, when the day is either 9 or 15 hours long in the Latitude of 54 deg.

9.4441007

III. Its Use.

Seek the Latitude in the First Column, and the Difference between the day proposed and an Equinoctial Day in the head of the Table, among the great Figures, and in the common Section you have the Declination desired.

Example, What Declination shall the Sun have when the day is either 10 or 14 hours long in the Latitude of 76 deg.---The difference between 10 or 14 hours, and an Equinoctial day is 2 hours. Find 2 hours at the head of the Table, and under it, and against 76 the (Latitude found in the First Column) you shall find 3 deg. 37. min. and such Declination shall the Sun have when the day is either 10 or 14 hours long in the Latitude of 76 deg.

And so when the Day is either	11	13	Hours long in the Latitude of	20	The Sun's Declination will be found to be	19	44
	10	14		35		20	17
	9	15		48		19	03
	8	16		61		15	31
	7 or 17			70		12	30
	6	18		82		5	39

A TABLE of Horizontal Spaces shewing the Distance of each Hour-line from the Meridian: upon all Vertical or Horizontal Plains, as also upon Direct North or South Plains, whether Erect, Reclining or Inclining: Calculated to all Degrees of Latitude (viz. from 00 deg. to 90 deg.) that is, from the Equinoctial up to either of the Poles.

Degrees of Latitude for Vertical or Horizontal Plains, or of the Stiles being above any Direct North or South upon a Reclining or Inclining Plain.

	XI. I.		X. II.		IX. III.		VIII. IV.		VII. V.		VI.	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	0	16	0	34	1	0	1	44	3	44	90	00
2	0	32	1	09	2	0	3	27	7	25		
3	0	48	1	44	3	0	5	11	11	03		
4	1	05	2	19	4	0	6	54	14	36		
5	1	20	2	52	4	58	8	35	18	01		
6	1	36	3	27	5	58	10	16	21	19	90	00
7	1	52	4	03	6	57	11	15	24	27		
8	2	8	4	37	7	55	13	33	27	23		
9	2	23	5	09	8	54	15	10	30	17		
10	2	40	5	43	9	51	16	44	32	57		
11	2	55	6	17	10	48	18	17	35	27	90	00
12	3	11	6	51	11	45	19	48	37	49		
13	3	27	7	24	12	41	21	17	40	01		
14	3	43	7	57	13	36	22	44	42	04		
15	3	58	8	30	14	31	24	09	44	00		
16	4	13	9	02	15	25	25	31	45	49	90	00
17	4	29	9	35	16	26	26	52	47	26		
18	4	44	10	08	17	10	28	09	49	04		
19	4	59	10	39	18	02	29	25	50	33		
20	5	14	11	10	18	53	30	39	51	55		
21	5	29	11	41	19	44	31	50	53	09	90	00
22	5	44	12	13	20	32	32	58	54	21		
23	5	59	12	43	21	20	34	05	55	30		
24	6	13	13	13	22	08	35	10	56	37		
25	6	28	13	43	22	55	36	12	57	34		
26	6	42	14	12	23	40	37	13	58	34	90	00
27	6	56	14	41	24	25	38	11	59	27		
28	7	10	15	10	25	09	39	07	60	17		
29	7	24	15	40	25	52	40	02	61	04		
30	7	38	16	06	26	33	40	54	61	49		
31	7	05	16	34	27	15	41	44	62	30	90	00
32	8	05	17	01	27	55	42	30	63	11		
33	8	19	17	27	28	34	43	20	63	49		
34	8	31	17	54	29	13	44	05	64	24		
35	8	44	18	20	29	50	44	49	64	58		
36	8	57	18	45	30	27	45	31	65	30	90	00
37	9	10	19	09	31	02	46	12	66	10		
38	9	22	19	34	31	37	46	50	66	29		
39	9	24	19	58	32	11	47	28	66	56		
40	9	45	20	21	32	44	48	07	67	21		
41	9	57	20	44	33	16	48	39	67	47	90	00
42	10	10	20	07	33	46	49	12	68	11		
43	10	22	20	29	34	18	49	44	68	33		
44	10	32	21	51	34	47	50	10	68	54		
45	10	43	22	12	35	17	50	46	69	15		

A TABLE of Horizontal Spaces shewing the Distance of each Hour-line from the Meridian: upon all Vertical or Horizontal Plains, as also upon Direct North or South Plains, whether Erect, Reclining or Inclining: Calculated to all Degrees of Latitude (viz. from 00 deg. to 90 deg.) that is, from the Equinoctial up to either of the Poles.

Degrees of Latitude for Vertical or Horizontal Plains, or of the Stiles height above any Direct North or South upright Reclining or Inclining Plain.

	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
46	10 54	22 33	35 44	51 15	69 35	90 00
47	11 05	22 53	35 11	51 42	69 53	
48	11 17	23 13	36 37	52 09	70 11	
49	11 25	23 33	37 03	52 35	70 28	
50	11 35	23 52	37 28	53 00	70 43	
51	11 45	24 09	37 52	53 24	70 59	90 00
52	11 55	24 27	38 15	53 46	71 13	
53	12 05	24 43	38 37	54 18	71 28	
54	12 13	25 02	38 58	54 29	71 41	
55	12 22	25 18	39 19	54 49	71 54	
56	12 32	25 34	39 40	55 09	72 05	90 00
57	12 40	25 50	39 59	55 28	72 17	
58	12 48	26 05	40 18	55 45	72 28	
59	12 56	26 20	40 36	56 03	72 38	
60	13 04	26 34	40 54	56 19	72 48	
61	13 11	26 47	41 10	56 34	72 58	90 00
62	13 19	27 01	41 21	56 49	73 07	
63	13 26	27 13	41 42	57 03	73 15	
64	13 32	27 25	41 57	57 17	73 24	
65	13 39	27 37	42 15	57 30	73 32	
66	13 46	27 49	42 25	57 43	73 39	90 00
67	13 51	27 59	42 38	57 54	73 46	
68	13 57	28 09	42 50	58 05	73 53	
69	14 03	28 19	43 02	58 16	73 59	
70	14 08	28 29	43 13	58 26	74 05	
71	14 13	28 37	43	58 35	74 11	90 00
72	14 18	28 46	43 24	58 44	74 16	
73	14 22	28 54	43 36	58 53	74 20	
74	14 27	29 02	43 52	59 00	74 25	
75	14 30	29 07	44 00	59 07	74 30	
76	14 33	29 15	44 08	59 15	74 34	90 00
77	14 37	29 21	44 14	59 22	74 37	
78	14 41	29 27	44 22	59 27	74 41	
79	14 44	29 32	44 28	59 32	74 44	
80	14 47	29 37	44 34	59 37	74 47	
81	14 49	29 41	44 37	59 40	74 49	90 00
82	14 51	29 45	44 40	59 44	74 51	
83	14 53	29 49	44 44	59 47	74 53	
84	14 55	29 52	44 48	59 51	74 55	
85	14 56	29 54	44 53	59 54	74 57	
86	14 57	29 55	44 55	59 55	74 58	90 00
87	14 58	29 56	44 57	59 56	74 58	
88	14 59	29 57	44 58	59 58	74 59	
89	14 59	29 50	44 59	59 59	74 59	
90	15 00	30 00	45 00	60 00	75 00	

The Description, Construction and Use of the foregoing Table.

THE Table consisteth of Seven Columns, in the first is contained whole degrees of *Latitude* from 1 to 90 degrees: And may be called the *Column of Latitudes, Co-Latitudes, or of the Stiles* height of any *Direct Horizontal, North or South Plain, either Erect or Reclining.*

In the other *Six Columns* you have the Space or Distance that each hour hath from the *Meridian*, when the *Stile* is any number of degrees to be elevated above the *Meridian* or *Substile*, as are the others of *Column Seventh*.

The Tables Construction.

It is known that 15 degrees of the *Equinoctial* is equal to one hour of time, then 30 is equal to Two hours, 45 to Three hours, &c. And then

As the *Radius* or *Sign* of 90 deg.

Is to the *Sine* of the *Latitude*, *Co-Latitude* or *Stiles* height 25 deg.

So is the *Tangent* of 15.

To the *Tangents* of 6 deg. 28 min.

d. m. d. m. d. m. d. m.

And so is the *Tangent* of 30 00. 45 00. 60 00. 75 00.

To the *Tangent* of 13 43, 22 25, 36 12, 57 34.

And such are the true hour distances for an *Horizontal, Vertical, or any other Direct Reclining Plain*, where the height of the *Pole or Stile* is found to be 25 deg.

The Use of this Table.

It serves principally for the ready making of *Horizontal Dials*, for to be obscurely described upon *Declining* or *Declining-Reclining Plains*, whereby the *Furniture*, (the *Tropicks* and *Parallels* of the 12 *Signs* and *Diurnal Arches* I mean) is more easily inserted upon such *Oblique Plains*: As in the former *Tractates* is sufficiently declared.

[illegible]

Of the FURNITURE

A TABLE shewing what Altitude the Sun shall have at every Hour, Half and Quarter of the Day, at his Entrance into every of the XII. Signs.

Calculated for the Latitude of London, 51 deg. 32 min.

Hours and Quarters	 Cancer ☉ Alt. D. M.	 Leo ☉ Alt. D. M.	 Virgo ☉ Alt. D. M.	 Libra ☉ Alt. D. M.	 Scorpio ☉ Alt. D. M.	 Sagitt. ☉ Alt. D. M.	 Capric. ☉ Alt. D. M.
XII.	61 59	58 41	49 59	38 28	26 57	18 15	14 57
1	61 49	58 34	49 52	38 22	26 52	18 10	14 52
2	61 23	58 8	49 32	38 01	26 37	17 56	14 50
3	60 40	57 27	48 57	37 36	26 12	17 34	14 18
XI. I.	59 42	56 33	48 10	36 56	25 37	17 03	13 48
1	58 29	55 25	47 11	36 05	24 53	16 24	13 09
2	57 04	54 06	46 01	35 04	24 01	15 36	12 23
3	55 29	52 34	44 40	33 55	22 59	14 19	11 29
X. II.	53 45	50 55	43 11	32 36	21 49	13 36	10 28
1	51 53	49 07	41 32	31 08	20 31	12 24	9 19
2	49 54	47 12	39 47	29 34	19 06	11 06	8 03
3	47 51	45 13	37 57	27 53	17 36	9 42	6 41
IX. III.	45 42	34 07	35 59	26 05	15 57	8 11	5 13
1	43 31	40 58	33 57	24 12	14 13	6 34	3 39
2	41 16	38 45	31 49	22 15	12 23	4 51	1 59
3	38 59	36 30	29 40	20 13	10 30	3 05	0 15
VIII. IV.	36 41	34 14	27 28	18 08	8 32	1 13	
1	34 23	31 56	25 13	15 58	6 31		
2	32 04	29 37	22 56	13 46	4 25		
3	29 43	27 16	20 37	11 32	2 16		
VII. V.	27 23	24 56	18 18	9 17	0 05		
1	25 04	22 37	15 59	6 58			
2	22 46	20 17	13 39	4 39			
3	20 28	17 57	11 16	2 20			
VI.	18 12	15 42	9 00	0 00			
1	15 58	14 00	6 44				
2	13 46	11 13	4 24				
3	11 37	9 01	2 08				
V. VII.	9 30	6 52					
1	7 25	4 46					
2	5 24	2 42					
3	3 27	0 43					
IV. VIII.	1 34						

The Description, Use, and Construction of the foregoing Table.

I. Its Description.

THE Table consisteth of Eight Columns: The first whereof contains all Hours, Halves and Quarters, both before and afternoon; and in the other Seven, are the degrees and minutes of *Altitude* that the Sun hath at his entrance into any of the 12 Signs: as the Titles at the head of each Column do import.

II. Its Use.

Suppose I would know what *Altitude* the Sun shall have at Ten of the Clock, when he enters into either of the Signs *Virgo* ♍ or *Taurus* ♉. Look for *Virgo* or *Taurus* (which you shall find in the fourth Column) at the head of the Table, and under them and just against X. or II. a Clock (in the first Column) you shall find 43 deg. 11 min. And such *Altitude* will the Sun have at Ten or Two a Clock when he enters into *Taurus* or *Virgo*, in the Latitude of 51 deg. 32 min. — In like manner you shall find that

When the Sun enters into	{ <i>Cancer</i> <i>Leo</i> or <i>Gemini</i> <i>Sagittarius</i> or <i>Aquarius</i>	{ his <i>Altitude</i> at	{ XI. VIII. or IV. X.	{ I. II.	{ will be found to be	deg. min.	
						59	42
						34	14
						13	36

And the like for any other hour, half and quarter of the day, and at the entrance into any other of the Signs.

III. Its Construction.

1. If the Sun be in the *Equinoctial*, that is, at his entrance into *Aries* ♈ or *Libra* ♎, and so have no *Declination*, the Sun's *Altitude* at any hour may be found by one Single Proportion, — So the Sun being in the *Equinoctial*, and his *Altitude* at VIII. in the Morning or IV. in the Afternoon were required in the Latitude of 51 deg. 32 min. The Proportion to find the same is

As the Sine of 90	10.0000000
Is to the Co-sine of the Latitude 38 deg. 28 min.	9.7941496
So is the Co-sine of the hour from Noon 30 deg.	9.6989700

To the Sine of 18 deg. 8 min. 29.4931196

Which is the Sun's *Altitude* at Four or Eight of the Clock, when the Sun is in the beginning of *Aries* ♈ or *Libra* ♎, in the Latitude of 51 deg. 32 min.

This is the Proportion to find the *Altitude* at all Hours, when the Sun is in the *Equinoctial*, and hath no *Declination*; But when the Sun hath either North or South *Declination* from the *Equinoctial*, then there must be Two Operations to find the *Altitude* at all hours, except at VI a Clock, and at that hour One Operation will serve the turn.

Example, In the Latitude of 51 deg. 32 min. Let it be required to find the Sun's *Altitude* at Six a Clock when he enters into *Taurus* or *Virgo*, (his *Declination* then being 11 deg. 31 min.) The Proportion is,

Of the FURNITURE

As the *Radius* (or *Sine* of 90 deg.) 10.0000000
 Is to the *Sine* of the Sun's *Declination*, 11 deg. 31 min. 9.3002758
 So is the *Sine* of the *Latitude* 51 deg. 32 min. 9.8937452

To the *Sine* of 9 deg. 19.1940210

Which is the Sun's *Altitude* at Six a Clock.

For the *Altitude* of all other hours between XII and VI. (as at IV or VIII. a Clock) Two *Proportions* must be used;

(1.) As the *Co-sine* of the hour from the *Meridian* 30 deg. 9.6989700

To the *Radius* (or *Sine* of 90 deg.) 10.0000000

So is the *Tangent* of the *Latitude* 51 deg. 32 min. 10.0999135

To the *Tangent* of a *Fourth Arch* 68 deg. 30 min. 10.4007435

The *Fourth Arch* is deg. min.
 68 20 from which the Sun having 11 deg.
 31 min. of *Nor. Decl. Subst.* 11 31 and there remains

 56 46 for a *Fifth Arch*. Then Say,
 (2.) As the *Sine* of the *Fourth Arch* 68 deg 20 min 9.9681781

To the *Co-sine* of the *Fifth Arch* 33 deg. 11 min 9.7382412

So is the *Sine* of the *Latitude* 51 deg. 32 min. 9.8937452

To the *Sine* of 27 deg. 28 min. 19.6319864

And such *Altitude* shall the Sun have at Eight in the Morning, or Four in the

Afternoon when he enters into *Taurus* ♉ or *Virgo* ♍.

When the Sun is in the *Southern Signs*, as *Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐ & *Capricorn* ♑, *Aquarius* ♒ or *Pisces* ♓, and hath *South Declination*:— As suppose at X. or II. a Clock the Sun being in the beginning of *Sagittarius* ♐ or *Aquarius* ♒, (he having then 20 deg. 13 min. of *South Declination*:) Say,

(1.) As the *Co-sine* of the hour from the *Meridian* 60 deg. 9.0378506

To the *Radius* (or *Sine* of 90 deg.) 10.0000000

So is the *Tangent* of the *Latitude* 51 deg. 32 min. 10.0999135

To the *Tangent* of the *Fourth Arch* 55 deg. 27 min. 10.1620629

To his *Fourth Arch* deg. min.
 55 27 (the Sun's *Decl.* being 20 d. 13 m. *South*) must be
 added to it 20 13

And the Sum will be 75 40 for a *Fifth Arch*. Then Say,

(2.) As the *Sine* of the *Fourth Arch* 55 deg. 27 min 9.9157330

To the *Co-sine* of the *Fifth Arch* 14 deg. 20 min. 9.3936852

So is the *Sine* of the *Latitude* 51 deg. 32 min. 9.8937452

To the *Sine* of 13 deg. 36 min. 19.2874304

 9.3716974

And

And such *Altitude* shall the Sun have at Ten in the Forenoon or Two in the Afternoon, when the Sun is in the beginning of *Sagittarius* or *Aquarius*, and having 20 deg. 13 min. of *South Declination*.

For finding of the Sun's *Altitude* at any hour before Six in the Morning, or after Six at Night, the same *Proportion* foregoing will serve; Only note---That when the *Fourth Arch* is found, and the *Declination* of the Sun added to it (as it must always be) do exceed 90 deg. you must take the *Complement* thereof to 180 deg. for your *Fifth Arch*.

So the *Declination* being 20 deg. 13 min. *North*, And the *Altitude* at V. in the Morning or VII. at Night, were required, the *Altitude* will be found to be 6 deg. 52 min. For,

(1.) As the *Co-sine* of the hour from the *Meridian* 15 deg. 9.4129962

To the *Radius* 90 deg. 10.0000000

So is the *Tangent* of the *Latitude* 51 deg. 32 min. 10.0999135

To the *Tangent* of the *Fourth Arch* 78 deg. 22 min. 10.6869173

	deg.	min.
The <i>Fourth Arch</i> being	78	22
To which add the Sun's <i>Declinat.</i>	20	13

the Sum is

Whose *Complement* to 180 deg. is 81 25 is the *Fifth Arch*. Then,

(2.) As the *Sine* of the *Fourth Arch* 78 deg. 22 min. 9.9909859

To the *Co-sine* of the *Fifth Arch* 8 deg. 35 min. 9.1739077

So is the *Sine* of the *Latitude* 51 deg. 32 min. 9.8937452

19.0676529

To the *Tangent* 6 deg. 52 min. 9.0766670

Which is the Sun's *Altitude* at V. in the Morning, or VII in the Evening.

G g g

A TABLE

Of the FURNITURE

A TABLE shewing what Azimuth from the South, the Sun shall have at every Hour, Half and Quarter of the Day, at his Entrance into every of the XII. Signs.

Calculated for the Latitude of London, 51 deg. 32 min.

<i>Hours and Quarters</i>	Cancer  ◉ Azi.	Leo  ◉ Azi.	Virgo  ◉ Azi.	Libra  ◉ Azi.	Scorpio  ◉ Azi.	Sagitt.  ◉ Azi.	Capric.  ◉ Azi.
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
XII.	00 00	0 00	0 00	0 00	0 00	0 00	0 00
I	7 10	5 53	5 37	4 55	3 54	3 53	3 52
2	14 22	13 24	11 10	9 40	7 57	7 40	7 10
3	21 27	19 53	16 44	14 13	12 11	11 10	10 37
XI. I.	27 56	26 00	22 13	18 52	16 22	14 45	14 13
I	34 14	32 01	27 32	23 22	20 15	18 17	17 38
2	40 12	37 40	32 41	27 41	24 06	21 53	20 59
3	45 39	43 04	37 32	32 08	29 44	26 30	24 25
X. II.	50 51	47 57	42 05	36 24	31 50	28 52	27 47
I	55 31	52 41	47 04	40 30	35 35	32 18	31 00
2	61 43	57 11	50 51	44 26	39 10	35 39	34 17
3	64 11	61 18	50 33	48 13	42 36	38 50	37 34
IX. III.	68 10	65 16	58 47	51 56	46 02	42 04	40 38
I	71 52	69 56	62 33	55 33	49 25	45 16	43 40
2	75 26	72 37	66 10	58 59	52 43	48 21	46 42
3	78 48	76 05	69 38	62 22	55 59	51 22	49 40
VIII. IV.	82 00	79 30	72 57	65 40	59 00	54 22	
I	85 08	82 42	76 12	68 53	62 08		
2	88 10	85 38	79 23	72 06	65 12		
3	91 09	87 50	82 28	75 07	68 12		
VII. V.	94 15	91 34	85 30	78 06	71 10		
I	96 51	94 25	88 27	81 09			
2	99 38	97 16	91 23	84 06			
3	102 55	100 07	94 22	87 04			
VI.	105 08	102 54	97 12				
I	107 52	104 58	100 02				
2	110 36	108 26	103 00				
3	113 18	111 14	105 54				
V. VII.	116 03	114 03					
I	118 50	116 54					
2	121 41	119 47					
3	124 29	122 37					
IV. VIII.	127 24						

Of SUN-DIALS.

The Description, Use, and Construction of the foregoing Table.

I. Its Description

THis Table (as that foregoing) consisteth of *Eight Columns*; The First contains all the *Hours, Halves and Quarters* both before and afternoon; And in the other are the Degrees and Minutes of the Sun's *Azimuth* from the *South* at the Sun's entrance into every of the 12 *Signs*, as the Titles at the top thereof do signifie.

II. Its Use.

If you would know what *Azimuth*, from the *South*, the Sun shall have at IX. or III. of the Clock, when the Sun enters into *Virgo* or *Taurus* — Look for *Virgo* and *Taurus* at the Head of the Table, and under it (against IX. and III. a Clock) in the First Column, you shall find 58 deg. 47 min. And such *Azimuth* shall the Sun have from the *South* part of the *Meridian*. So likewise.

				d.	m.
When the Sun enters into	Cancer,	the <i>Azimuth</i> at	X. or VII. XI.	II. or III. V. I. will be found to be	50
	Leo or Gemini,				65
	Scorpio or Pisces,				71
	Taurus or Virgo,				72
					51
					16
					10
					13

III. Its Construction

If it were required to find what *Azimuth* the Sun shall have from the *South* part of the *Meridian*, at VIII or IV of the Clock at, the Sun's entrance into *Leo* or *Gemini* (he having then 20 deg. 13 min. of *North Declination*) — You must (by the foregoing Table) find what *Altitude* the Sun (at that time) hath, which will be 34 deg. 14 min. which known, the *Proportion* will be

As the *Co-sine* of the *Altitude* 55 deg. 46 min. 9.9173760

To the *Sine* of the hour from the *Meridian* 60 deg. 9.9375316

So the *Co-sine* of the *Declination* 69 deg. 47 min. 9.9723845

To the *Sine* of 79 deg. 30. min. 19.9099161

9.9926501

And such is the Sun's *Azimuth* from the *South* part of the *Meridian*.

A TABLE

Of the FURNITURE

A TABLE of the Sun's Altitude at all Hours of the Day, at the Sun's Entrance into any of the XII. Signs, and at every Tenth Degree thereof.

Calculated for the Latitude of 50 deg. viz.

Hours { Before. Aftern.		XII.	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	V. VII.	IV. VIII.
S. D.	S. D.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
☿ 0	☿ 0	63 30	61 1	54 39	46 13	36 52	27 14	17 46	8 46	0 35
20	10	63 7	60 39	54 20	45 50	36 35	26 58	17 29	8 28	0 16
10	20	62 0	59 36	53 24	45 5	35 47	26 9	16 39	7 36	
♈ 0	♈ 0	60 12	57 54	51 52	43 41	34 27	24 51	15 19	6 12	
20	10	57 46	55 34	49 48	41 47	32 40	23 5	13 30	4 18	
10	20	54 51	52 46	47 14	39 27	30 27	20 55	11 18	2 1	
♉ 0	♉ 0	51 30	49 33	44 16	36 43	27 52	18 24	8 46		
20	10	47 49	46 0	40 58	33 40	25 0	15 36	5 59		
10	20	43 58	43 58	37 28	30 26	21 56	12 39	3 2		
♊ 0	♊ 0	40 0	38 23	33 50	27 43	18 45	9 35			
20	10	36 2	34 30	30 9	23 36	15 31	6 29			
10	20	32 11	30 43	26 34	20 15	12 22	3 29			
♋ 0	♋ 0	28 30	27 8	23 9	17 2	9 21	0 36			
20	10	25 9	23 50	20 0	14 5	6 35				
10	20	22 14	20 58	17 15	11 30	4 10				
♌ 0	♌ 0	19 49	18 34	14 59	9 21	2 9				
20	10	18 0	16 48	13 17	7 45	0 40				
10	20	16 53	15 42	12 14	6 46					
♍ 0	♍ 0	16 30	15 19	11 52	6 25					

A TABLE of the Sun's Azimuth for every Hour in the beginning of each Sign, for the Latitude of 50 Degrees.

	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	IV. VII.	IV. VIII.
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
☿	60 41	37 34	20 23	6 48	4 N 48	15 37	26 18	37 24
♈	62 48	40 32	23 23	9 40	3 16	13 17	24 12	
♉	66 57	46 49	30 19	16 15	1 S 59	7 N 27		
♊	70 43	52 59	37 17	23 51	12 36			
♋	73 26	57 48	43 33	30 40	18 45			
♌	75 9	60 56	47 43	35 34				
♍	75 45	62 3	49 14					

Of SUN-DIALS.

A TABLE of the Sun's Altitude at all Hours of the Day, at the Sun's Entrance into any of the XII. Signs, and at every Tenth Degree thereof.

Calculated for the Latitude of 52 deg.

Hours.	{ Beforen. Aftern.		XII.	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	V. VII.	IV. VIII.
	S. D.	S. D.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
☿ 0	☿ 0		61 30	59 58	53 21	45 51	36 36	27 23	18 19	9 39	1 48
10	10		61 7	58 53	53 5	45 11	36 18	27 6	18 0	9 21	1 29
20	20		60 0	57 50	52 7	44 18	35 28	26 16	17 9	8 27	1 32
II 0	♏ 0		58 13	56 6	50 33	42 52	34 1	24 57	15 48	7 3	
10	10		55 47	53 47	48 25	40 54	32 14	23 5	13 54	5 5	
20	20		52 52	50 58	46 49	38 30	29 57	20 50	11 38	2 44	
♊ 0	♏ 0		49 30	47 43	42 48	35 42	27 18	18 18	9 2	0 3	
10	10		45 51	44 9	39 27	32 35	24 20	15 21	6 9		
20	20		42 0	40 23	35 54	29 16	21 12	12 26	3 8		
♈ 0	♏ 0		38 0	36 29	32 13	25 48	17 6	9 10			
10	10		34 2	32 36	28 21	22 19	14 38	6 0			
20	20		30 11	28 49	24 54	18 55	11 24	2 54			
♋ 0	♏ 0		26 30	25 12	21 27	15 31	8 19	0 56			
10	10		23 9	21 55	18 17	12 39	5 30				
20	20		22 41	19 2	15 31	10 2	3 2				
♌ 0	♏ 0		17 49	16 38	13 14	7 52	0 59				
10	10		16 0	14 52	11 31	6 15					
20	20		14 53	13 46	10 28	5 15					
♍ 0	♏ 0		14 30	13 21	10 3	4 51					

A TABLE of the Sun's Azimuth for every Hour in the beginning of each Sign, for the Latitude of 52 Degrees.

	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	V. VII.	IV. VIII.
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
☿	62 21	39 43	22 19	8 S 18	3 N 46	14 58	26 0	37 22
♏ II	64 11	42 23	25 6	10 S 58	1 N 16	12 44	24 0	
♏ III	67 52	48 6	31 26	17 14	4 S 39	7 N 7	18 49	
♏ IV	71 13	53 46	38 15	24 28	11 55			
♏ V	73 43	58 14	43 59	30 56				
♏ VI	75 19	61 10	47 56	35 36				
♏ VII	75 52	62 14	49 23					

Of the FURNITURE

A TABLE of the Sun's Altitude at all Hours of the Day, at the Sun's Entrance into any of the XII. Signs, and at every Tenth Degree thereof.

Calculated for the Latitude of 52 deg. 30 min.

Hours		Beforen. Aftern.	XII.	XI.	X.	IX.	IV.	VII.	VI.	V.	IV.
S.	D.		D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
♈	0	♈	0	61 0	58 50	53 7	45 20	36 33	27 27	18 27	9 55
	20		10	60 39	58 30	52 49	45 3	36 17	27 11	18 10	9 37
	10		20	59 32	57 26	51 50	44 9	35 36	26 20	17 19	8 43
♉	0	♉	0	57 43	55 41	50 15	42 42	34 2	24 58	15 55	15
	20		10	55 18	53 22	48 7	40 43	32 9	23 7	14 2	5 18
	10		20	52 22	52 32	45 29	38 17	29 51	20 51	11 45	2 55
♊	0	♊	0	49 1	47 17	42 27	35 28	27 10	18 14	9 7	0 12
	20		10	45 21	43 42	39 5	32 20	24 12	15 20	6 13	
	10		20	41 28	39 54	35 30	28 58	21 0	12 15	3 9	
♋	0	♋	0	37 30	36 1	31 49	25 30	17 43	9 4		
	20		10	33 32	32 8	28 6	22 0	14 24	5 52		
	10		20	29 39	28 19	24 27	18 33	11 8	2 44		
♌	0	♌	0	25 59	24 42	20 59	15 16	8 2			
	20		10	22 39	21 24	17 49	12 16	5 12			
	10		20	19 42	18 30	15 2	9 38	2 42			
♍	0	♍	0	17 17	16 7	12 44	7 27	0 39			
	20		10	15 28	14 20	11 9	5 49				
	10		20	14 21	13 14	9 57	4 44				
♎	0			14 0	12 53	9 36	4 29				

Of SUN-DIALS.

A TABLE of the Sun's Altitude at all Hours of the Day, at the Sun's Entrance into any of the XII. Signs, and at every Tenth Degree thereof.

Calculated for the Latitude of 54 deg.

Hours	{ Beforen. Aftern.		XII.	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	V. VII.	IV. VIII.
	S. D.	S. D.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
☾ 0	☾ 0		59 30	57 28	52 6	44 42	36 17	27 30	18 48	10 31	3 1
20	10		59 7	57 6	51 46	44 23	35 59	27 12	18 30	10 13	2 41
10	20		58 0	56 2	50 47	43 29	35 7	26 20	17 33	9 18	1 43
II 0	♏ 0		56 12	54 18	49 11	42 0	33 42	24 57	16 12	7 49	0 11
20	10		53 46	51 57	47 0	39 59	31 46	23 3	14 17	5 50	
10	20		50 51	49 6	44 22	37 30	29 25	20 45	11 57	3 27	
☿ 0	♐ 0		47 30	45 51	41 18	34 38	26 41	18 4	9 16	0 48	
20	10		43 49	42 16	37 54	31 27	23 39	15 7	6 19		
10	20		39 58	38 29	34 19	28 4	20 26	11 59	3 12		
♈ 0	♑ 0		36 0	34 36	30 36	24 34	17 5	8 45			
20	10		32 2	30 42	26 52	22 1	13 43	3 30			
10	20		28 11	26 54	23 13	17 34	10 25	2 20			
♉ 0	♒ 0		24 31	23 17	19 45	14 15	7 18				
20	10		21 9	19 59	16 33	11 13	4 55				
10	20		18 14	17 6	13 47	8 35	1 24				
♊ 0	♓ 0		15 49	14 43	11 28	6 23					
20	10		14 0	12 55	9 45	4 45					
10	20		12 53	11 46	8 42	3 44					
♋ 0			12 30	11 27	8 19	3 23					

A TABLE of the Sun's Azimuth for every Hour in the beginning of each Sign, for the Latitude of 54 Degrees.

		XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	IV. VII.	V. VIII.	
		D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	
☾	II	63 49	41 42	24 9	9 47	2 N 42	14 19	25 41	37 18	
♏	☿	65 24	44 6	26 44	12 17	0 1	12 10	23 46	35 37	
♐	♈	68 39	49 17	32 38	18 14	5 S 20	6 N 49	18 47		
♑	♉	71 40	54 29	38 58	25 2	12 14				
♒	♊	73 58	58 38	44 22	31 10					
♓	♋	75 27	61 23	48 6						
♔		75 59	62 23	49 29						

A TABLE shewing what Altitude the Sun shall have at every Hour of the Day, when he is in the Tropick of Cancer, the Equinoctial and Tropick of Capricorn.

Calculated from 36 to 66 $\frac{1}{2}$ deg. of Latitude.

Hours	{ Beforenoon Afternoon	XII.	XI.	X.	IX.	IV.	VII.	VI.
		D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
36	☉	77 30	72 0	61 16	49 22	37 15	25 14	13 33
	☿	54 0	51 24	44 29	34 54	23 52	12 5	0 0
	♄	30 30	28 50	24 5	16 52	7 51		
37	☉	76 30	71 20	60 57	49 17	37 19	25 26	13 53
	☿	53 0	50 19	43 46	34 23	23 32	11 56	
	♄	29 30	27 52	23 13	16 8	7 15		
38	☉	75 30	70 39	60 37	49 9	37 22	25 38	14 13
	☿	52 0	49 34	43 2	33 52	23 12	11 46	
	♄	28 30	26 54	22 21	15 24	6 39		
39	☉	74 30	69 57	60 15	49 1	37 24	25 49	14 32
	☿	51 0	48 39	42 18	33 20	22 52	11 36	
	♄	27 30	25 57	21 29	14 39	6 3		
40	☉	73 30	69 12	59 51	48 51	37 29	25 59	14 51
	☿	50 0	47 44	41 34	32 48	22 31	11 26	
	♄	26 30	24 50	20 37	14 55	5 27		
41	☉	72 30	68 27	59 26	48 41	37 25	26 9	15 10
	☿	49 0	46 47	40 49	32 15	22 10	11 16	
	♄	25 30	24 1	19 45	13 10	4 51		
42	☉	71 30	67 41	58 59	48 29	37 25	26 18	15 28
	☿	48 0	45 52	40 4	31 42	21 49	11 5	
	♄	24 30	23 3	18 52	12 45	4 14		
43	☉	70 30	66 54	58 31	48 16	37 24	26 31	15 47
	☿	47 0	44 57	39 18	31 8	21 27	10 55	
	♄	23 30	22 5	18 0	11 49	3 38		
44	☉	69 30	66 5	58 2	48 2	37 22	26 36	16 5
	☿	46 0	44 1	38 32	30 34	21 3	10 44	
	♄	22 30	21 7	17 7	10 55	3 2		
45	☉	68 30	65 17	57 31	47 46	37 19	26 44	16 22
	☿	45 0	43 5	37 46	30 0	20 42	10 33	
	♄	21 30	20 9	16 14	10 10	2 25		
46	☉	67 30	64 27	56 59	47 30	37 15	26 51	16 34
	☿	44 0	42 9	36 59	29 22	20 19	10 21	
	♄	20 30	19 11	15 22	9 25	1 49		
47	☉	66 30	63 36	56 26	47 13	37 11	26 58	16 57
	☿	43 0	41 12	36 12	28 50	19 56	10 10	
	♄	19 30	18 13	14 29	8 46	1 13		
48	☉	65 30	62 45	55 52	46 54	37 6	27 4	17 14
	☿	42 0	40 16	35 25	28 18	19 33	9 58	
	♄	18 30	16 16	12 43	7 9			
49	☉	64 30	61 53	55 20	46 36	37 00	27 15	17 31
	☿	41 0	39 6	34 37	27 40	19 9	9 35	
	♄	17 30	15 47	12 6	6 46			
50	☉	63 30	61 2	54 41	46 15	36 53	27 20	17 47
	☿	40 0	38 23	33 50	27 2	18 45	9 22	
	♄	16 30	15 18	11 30	6 24	☉ Set		

Degrees of Latitude.

Hours	Beforenoon Afternoon	XII.		XI.		X.		IX.		VIII.		VII.		VI.	
		D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
51	☀	62	30	60	9	54	4	45	53	35	46	27	20	18	3
	☾	39	0	87	26	33	2	26	25	18	20	9	22		
	☾	15	30	14	20	10	57	5	38						
52	☀	61	30	59	16	53	26	45	31	36	37	27	25	18	19
	☾	38	0	36	29	32	13	25	48	17	56	9	10		
	☾	14	30	13	12	10	4	4	53						
53	☀	60	30	58	23	52	47	45	8	36	28	27	28	18	34
	☾	37	0	35	33	31	25	25	11	17	31	8	58		
	☾	13	30	12	24	9	11	4	7						
54	☀	59	30	57	29	52	8	44	44	35	14	27	31	18	49
	☾	36	0	34	36	30	36	24	34	17	5	8	45		
	☾	12	30	11	25	8	18	3	21						
55	☀	58	30	56	35	51	28	44	19	35	8	27	34	19	4
	☾	35	0	33	39	29	47	23	56	16	40	8	32		
	☾	11	30	10	27	7	14	2	36						
56	☀	57	30	55	41	50	46	43	53	35	57	27	36	19	18
	☾	34	0	32	42	28	58	23	17	16	14	8	19		
	☾	10	30	9	29	6	31	1	50						
57	☀	56	30	54	46	50	5	43	26	35	45	27	38	19	32
	☾	33	0	31	44	28	9	22	39	15	48	8	6		
	☾	9	30	8	31	5	30	1	4						
58	☀	55	30	53	52	49	23	42	59	35	32	27	39	19	46
	☾	32	0	30	47	27	19	22	0	15	22	7	53		
	☾	8	30	7	33	4	45	0	19						
59	☀	54	30	52	57	48	45	42	31	35	18	27	40	19	59
	☾	31	0	29	50	26	29	21	21	14	55	7	40		
	☾	7	30	6	34	3	51								
60	☀	53	30	52	1	47	56	42	2	35	4	27	39	20	12
	☾	30	0	28	53	25	40	20	42	14	29	7	26		
	☾	6	30	5	36	3	58								
61	☀	52	30	51	6	47	12	41	32	34	49	27	38	20	25
	☾	29	0	27	55	24	55	20	3	14	2	7	13		
	☾	5	30	4	38	2	5								
62	☀	51	30	50	10	46	28	41	2	34	34	27	37	20	37
	☾	28	0	26	58	23	59	19	23	13	35	6	59		
	☾	4	30	3	39	1	11								
63	☀	50	30	44	9	45	43	40	3	34	18	27	35	20	49
	☾	27	0	26	51	23	9	18	44	13	7	6	45		
	☾	3	30	2	41	0	18								
64	☀	49	30	48	18	44	57	39	59	34	1	27	33	21	0
	☾	28	0	25	3	22	19	18	3	12	40	6	31		
	☾	2	30	1	43										
65	☀	48	30	47	22	44	11	39	27	33	43	27	30	21	14
	☾	25	0	24	5	21	28	17	23	12	12	6	17		
	☾	1	30	0	45										
66	☀	47	30	46	26	43	25	38	54	33	25	27	26	21	22
	☾	24	0	23	8	20	38	16	43	11	44	6	3		
	☾	0	30												
66½	☀	47	0	45	58	43	2	38	38	33	16	27	24	21	27
	☾	23	30	22	39	20	12	16	23	11	30	5	29		
	☾	0	0												

Degrees of Latitude.

A TABLE shewing what Azimuth the Sun shall have
forom the East or West, at all Hours of the Day:

Calculated from 36 to 66 $\frac{1}{2}$ deg. of Latitude.

Hours	{ Beforenoon Afternoon	XII.		XI.		I.		X.		IX.		VIII.		VII.		VI.	
		Az.		Az.		Az.		Az.		Az.		Az.		Az.		Az.	
		D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
36	{ r w	90	0	39	55	17	32	5	7	3	N 50	11	40	19	21		
		90	0	65	29	45	30	30	26	18	44	8	57				
		90	0	74	17	59	59	47	19	36	41						
37	{ r w	90	0	42	14	19	15	6	17	2	N 59	11	12	19	7		
		90	0	66	0	46	11	31	2	19	10	9	7				
		90	0	74	25	60	3	47	31	36	47						
38	{ r w	90	0	44	20	20	57	7	33	2	N 7	10	42	18	52		
		90	0	66	29	46	50	31	37	19	34	9	22				
		90	0	74	33	60	16	47	45	36	53						
39	{ r w	90	0	46	16	22	35	8	45	1	N 16	10	13	18	38		
		90	0	66	56	47	28	32	11	19	58	9	34				
		90	0	74	41	60	28	47	54	36	59						
40	{ r w	90	0	48	5	24	7	9	49	9	26	9	46	18	23		
		90	0	67	22	48	4	32	44	20	22	9	46				
		90	0	74	49	60	39	48	4	37	7						
41	{ r w	90	0	49	46	25	43	10	57	0	24	9	17	18	8		
		90	0	67	47	48	39	33	16	20	45	9	58				
		90	0	74	56	60	50	48	13	37	8						
42	{ r w	90	0	51	20	27	10	12	4	0	24	8	49	17	53		
		90	0	67	52	49	12	33	47	21	7	10	10				
		90	0	75	3	61	0	48	23	37	12						
43	{ r w	90	0	52	49	28	37	13	5	1	16	8	19	17	37		
		90	0	68	33	49	45	34	18	21	29	10	21				
		90	0	75	9	60	10	48	0	37	15						
44	{ r w	90	0	54	12	30	4	14	13	2	27	7	47	17	20		
		90	0	68	54	50	16	34	47	21	51	10	32				
		90	0	75	15	61	19	48	39	37	18						
45	{ r w	90	0	55	29	31	26	15	16	2	59	7	17	17	4		
		90	0	69	15	50	46	35	16	22	13	10	43				
		90	0	75	22	61	28	48	46	37	20						
46	{ r w	90	0	56	39	32	43	16	18	3	50	5	48	16	47		
		90	0	69	34	51	15	35	44	22	34	10	55				
		90	0	75	26	61	36	48	53	37	22						
47	{ r w	90	0	57	45	33	59	17	23	4	32	6	18	16	29		
		90	0	69	53	51	43	36	11	22	54	11	5				
		90	0	75	31	61	43	49	0	37	29						
48	{ r w	90	0	58	48	35	15	18	23	5	24	5	49	16	12		
		90	0	70	10	52	9	36	37	23	13	11	16				
		90	0	75	36	61	50	49	5								
49	{ r w	90	0	59	43	36	20	19	17	6	6	5	16	15	54		
		90	0	70	27	52	35	37	2	23	22	11	26				
		90	0	75	41	61	57	49	10								
50	{ r w	90	0	60	38	37	26	20	12	6	49	4	N 53	15	3		
		90	0	70	44	53	00	37	28	23	52	11	36				
		90	0	75	45	62	4	49	16								

Degrees of Latitude.

Hours	Beforenoon Afternoon	XII.	XI.	X.	IX.	VIII.	VII.	VI.
		⊙ Azi.	⊙ Azi.	⊙ Azi.	⊙ Azi.	⊙ Azi.	⊙ Azi.	⊙ Azi.
		D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
51	⊙	90 0	61 31	38 37	21 20	7 31	4 N 20	15 18
	⊙	90 0	70 57	53 25	37 50	24 9	11 45	
	⊙	90 0	75 49	62 10	49 40			
52	⊙	90 0	62 20	39 41	22 16	8 19	0 N 43	14 59
	⊙	90 0	71 13	53 46	38 14	24 28	11 55	
	⊙	90 0	75 53	62 15	49 24			
53	⊙	90 0	63 5	40 42	23 12	9 3	3 N 18	14 40
	⊙	90 0	71 27	54 8	38 37	24 45	12 5	
	⊙	90 0	75 56	65 19	49 27			
54	⊙	90 0	63 48	41 40	24 6	9 47	2 N 49	14 20
	⊙	90 0	71 40	54 29	38 58	25 2	12 14	
	⊙	90 0	75 59	62 23	49 30			
55	⊙	90 0	64 28	42 36	25 0	10 29	2 N 13	14 0
	⊙	90 0	71 53	54 50	39 19	25 19	12 23	
	⊙	90 0	76 2	62 28	49 31			
56	⊙	90 0	65 7	43 32	25 55	11 13	1 N 29	13 38
	⊙	90 0	72 5	55 9	39 40	25 35	12 32	
	⊙	90 0	76 4	62 30	49 32			
57	⊙	90 0	65 43	44 25	26 45	11 55	1 N 8	13 17
	⊙	90 0	72 17	55 27	39 59	25 50	12 40	
	⊙	90 0	76 6	62 33	49 33			
58	⊙	90 0	66 17	45 15	27 36	12 38	0 N 29	12 58
	⊙	90 0	72 28	55 45	40 18	26 5	12 48	
	⊙	90 0	76 9	62 36	49 34			
59	⊙	90 0	66 49	46 3	28 25	13 18	0 N 29	12 35
	⊙	90 0	72 38	56 2	40 36	26 20	12 56	
	⊙	90 0	76 10	62 38				
60	⊙	90 0	67 26	46 50	29 13	13 59	2 N 29	12 15
	⊙	90 0	72 48	56 18	40 54	26 34	13 4	
	⊙	90 0	76 12	62 40				
61	⊙	90 0	67 48	47 35	29 58	14 40	1 N 29	11 53
	⊙	90 0	72 58	56 35	41 10	26 47	13 12	
	⊙	90 0	76 13	62 41				
62	⊙	90 0	68 16	48 17	30 45	15 21	1 N 20	11 31
	⊙	90 0	73 7	56 49	41 27	27 0	13 19	
	⊙	90 0	76 14	62 42				
63	⊙	90 0	69 13					
	⊙	90 0	72 18					
	⊙	90 0	75 9					
64	⊙	90 0	69 32					
	⊙	90 0	72 50					
	⊙	90 0	74 40					
65	⊙	90 0	70 0					
	⊙	90 0	71 3					
	⊙	90 0	73 0					
66	⊙	90 0						
	⊙	90 0						
	⊙	90 0						
66½	⊙	90 0						
	⊙	90 0						
	⊙	90 0						

Degrees of Latitude.

32

21110-0210

A
T A B L E
O F
N A T U R A L
Sines, Tangents
A N D
S E C A N T S,
To a Radius of 1.000000,
And to every Sixth Minute (or
Tenth Part of a Degree)
O F T H E
Q U A D R A N T.

Fitted for the more easie Inscription of the
Parallels of the Sun's Course, and other
FURNITURE

I N T O
S U N - D I A L S.

D. M.	Sine	Tang.	Secant	
0	000000	000000	1.000000	
6	174	174	1.000000	
12	349	349	1.000000	
18	523	523	1.000001	
24	698	698	1.000002	
30	872	872	1.000003	
36	1074	1074	1.000005	
42	1221	1221	1.000007	
48	1396	1396	1.000009	
54	1570	1570	1.000012	
1	0	1745	1745	1.000015
6	1919	1920	1.000018	
12	2094	2094	1.000021	
18	2268	2269	1.000025	
24	2443	2443	1.000029	
30	2617	2618	1.000034	
36	2792	2793	1.000039	
42	2966	2967	1.000044	
48	3141	3142	1.000049	
54	3315	3317	1.000055	
2	0	3489	3492	1.000060
6	3664	3666	1.000067	
12	3838	3841	1.000073	
18	4013	4016	1.000080	
24	4187	4191	1.000087	
30	4361	4366	1.000095	
36	4536	4540	1.000103	
42	4710	4715	1.000111	
48	4884	4890	1.000119	
54	5059	5065	1.000128	
3	0	5233	5240	1.000137
6	5407	5415	1.000146	
12	5582	5590	1.000156	
18	5756	5765	1.000166	
24	5930	5941	1.000176	
30	6104	6116	1.000186	
36	6279	6291	1.000197	
42	6453	6466	1.000208	
48	6627	6641	1.000220	
54	6801	6817	1.000232	
4	0	6975	6992	1.000244

90	0	1.000000	Infinite.	Infinite
54	99999	572.95721	572.95808	
48	99999	286.47773	286.47947	
42	99998	190.98418	190.98680	
36	99997	143.23712	143.24061	
30	99996	114.58865	114.59301	
24	99994	95.48947	95.49471	
18	99992	81.84704	81.85314	
12	99990	71.61507	71.62205	
6	99987	63.65674	63.66459	
89	0	99984	57.28996	57.29868
54	99981	52.08067	52.09027	
48	99978	47.73959	47.74997	
42	99974	44.06611	44.07745	
36	99979	40.91741	40.02962	
30	99965	38.18845	38.20155	
24	99961	35.80055	35.81451	
18	99955	33.69350	33.70834	
12	99950	31.82051	31.83622	
6	99945	30.14461	30.16120	
88	0	99939	28.63625	28.65370
54	99932	27.27148	27.28981	
48	99926	26.03073	26.04993	
42	99919	24.89782	24.91790	
36	99912	23.85927	23.88022	
30	99904	22.90376	22.92558	
24	99897	22.02171	22.04440	
18	99888	21.20494	21.22851	
12	99880	20.44648	20.47092	
6	99871	19.74029	19.76560	
87	0	99862	19.08113	19.10732
54	99853	18.46447	18.49153	
48	99844	17.88631	17.91424	
42	99834	17.34315	17.37196	
36	99823	16.83191	16.86159	
30	99813	16.34985	16.38040	
24	99802	15.89454	15.92597	
18	99791	15.46381	15.49611	
12	99780	15.05572	15.08889	
6	99768	14.66852	14.70257	
86	0	99756	14.30066	14.33558
D. M.	Sine	Tangent	Secant.	

D. M.	Sine	Tang.	Secant.
4	0 6975	6992	1.00244
	6 7149	7168	1.00256
	12 7323	7343	1.00269
	18 7497	7519	1.00282
	24 7671	7694	1.00295
	30 7845	7870	1.00309
	36 8019	8045	1.00323
	42 8193	8221	1.00337
	48 8367	8397	1.00351
	54 8541	8573	1.00366
5	0 8715	8748	1.00381
	6 8889	8924	1.00397
	12 9063	9100	1.00413
	18 9237	9276	1.00429
	24 9410	9452	1.00445
	30 9584	9628	1.00462
	36 9758	9805	1.00479
	42 9931	9981	1.00496
	48 10105	10157	1.00514
	54 10279	10334	1.00532
6	0 10452	10510	1.00550
	6 10626	10686	1.00569
	12 10799	10863	1.00588
	18 10973	11040	1.00607
	24 11146	11216	1.00627
	30 11320	11393	1.00646
	36 11493	11570	1.00667
	42 11667	11747	1.00687
	48 11840	11924	1.00708
	54 12013	12101	1.00729
7	0 12186	12278	1.00750
	6 12360	12455	1.00772
	12 12533	12632	1.00794
	18 12706	12810	1.00817
	24 12879	12987	1.00839
	30 13052	13165	1.00862
	36 13225	13342	1.00886
	42 13398	13520	1.00909
	48 13571	13698	1.00933
	54 13744	13876	1.00958
8	0 13917	14054	1.00982

86	0 99756	1.430066	1.433558
	54 99744	1.395071	1.398651
	48 99731	1.361740	1.365407
	42 99718	1.329957	1.333711
	36 99705	1.299615	1.303457
	30 99691	1.260620	1.274549
	24 99677	1.242883	1.246899
	18 99663	1.216323	1.220427
	12 99649	1.190868	1.195059
	6 99634	1.166449	1.170728
85	0 99619	1.143005	1.147371
	54 99604	1.120478	1.124931
	48 99588	1.098815	1.103355
	42 99572	1.077967	1.082595
	36 99556	1.057889	1.062605
	30 99539	1.038539	1.043343
	24 99522	1.019878	1.024769
	18 99505	1.001870	1.006849
	12 99488	984481	989547
	6 99470	967680	972833
84	0 99452	951436	956677
	54 99433	935723	941051
	48 99415	920515	925931
	42 99396	905788	911292
	36 99376	891520	897110
	30 99357	877688	883367
	24 99337	864274	870040
	18 99317	851259	857112
	12 99296	838625	844566
	6 99275	826355	832384
83	0 99254	814434	820550
	54 99233	802847	809051
	48 99211	791581	797872
	42 99189	780622	787001
	36 99167	769957	776424
	30 99144	759575	766129
	24 99121	749465	756107
	18 99098	739615	746345
	12 99074	730017	736835
	6 99050	720661	727566
82	0 99026	711536	718529

D. M.	Sine	Tangent	Secant.
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D. M.	Sine	Tang.	Secant
8	0 13917	14053	1.00982
	6 14090	14232	1.01007
	12 14262	14410	1.01032
	18 14435	14588	1.01058
	24 14608	14766	1.01084
	30 14780	14945	1.01110
	36 14953	15123	1.01137
	42 15126	15302	1.01164
	48 15298	15480	1.01191
	54 15471	15659	1.01218
9	0 15643	15838	1.01246
	6 15815	16017	1.01274
	12 15988	16196	1.01303
	18 16160	16375	1.01331
	24 16332	16554	1.01361
	30 16504	16734	1.01390
	36 16676	16913	1.01420
	42 16848	17093	1.01450
	48 17020	17273	1.01480
	54 17192	17452	1.01511
10	0 17364	17632	1.01542
	6 17536	17812	1.01574
	12 17708	17992	1.01605
	18 17880	18173	1.01637
	24 18051	18353	1.01670
	30 18223	18533	1.01703
	36 18395	18714	1.01736
	42 18516	18895	1.01769
	48 18738	19076	1.01803
	54 18909	19256	1.01837
11	0 19080	19438	1.01871
	6 19252	19619	1.01906
	12 19423	19800	1.01941
	18 19594	19981	1.01976
	24 19765	20163	1.01012
	30 19936	20345	1.02048
	36 20107	20527	1.02085
	42 20278	20709	1.02121
	48 20449	20891	1.02158
	54 20620	21073	1.02196
12	0 20791	21255	1.02234

82	0 99026	7.11536	7.18529
	54 99002	7.02636	7.09717
	48 98977	6.93951	7.01120
	42 98952	6.85475	6.92730
	36 98929	6.77198	6.84542
	30 98901	6.69115	6.76546
	24 98875	6.61219	6.68738
	18 98849	6.53502	6.61109
	12 98822	6.45960	6.53655
	6 98795	6.38586	6.46369
81	0 98768	6.31375	6.39245
	54 98741	6.24320	6.32278
	48 98713	6.17418	6.25464
	42 98685	6.10663	6.18797
	36 98657	6.04051	6.12272
	30 98628	5.97576	6.05887
	24 98599	5.91235	5.99632
	18 98570	5.85024	5.93509
	12 98540	5.78938	5.87511
	6 98510	5.72974	5.81635
80	0 98480	5.67128	5.75877
	54 98450	5.61396	5.70233
	48 98419	5.55776	5.64701
	42 98388	5.50264	5.59277
	36 98357	5.44857	5.53957
	30 98325	5.39551	5.48740
	24 98293	5.34345	5.43621
	18 98261	5.29235	5.38599
	12 98228	5.24218	5.33671
	6 98195	5.19292	5.28833
79	0 98162	5.14455	5.24084
	54 98129	5.09704	5.19421
	48 98095	5.05036	5.14841
	42 98061	5.00451	5.10344
	36 98027	4.95944	5.05926
	30 97992	4.91515	5.01585
	24 97957	4.87162	4.97319
	18 97922	4.82881	4.93127
	12 97886	4.78673	4.89207
	6 97850	4.74534	4.84956
78	0 97814	4.70463	4.80973
D. M.	Sine	Tangent	Secant.

D. M.	Sine	Tang.	Secant.
12	0 20791	21255	1.02234
	6 20961	21438	1.02272
	12 21132	21620	1.02310
	18 21303	21803	1.02349
	24 21473	21986	1.02388
	30 21643	22169	1.02427
	36 21814	22352	1.02467
	42 21984	22535	1.02507
	48 22154	22719	1.02548
	54 22325	22903	1.02589
13	0 22495	23086	1.02630
	6 22665	23270	1.02671
	12 22835	23454	1.02713
	18 23004	23639	1.02756
	24 23174	23823	1.02798
	30 23344	24007	1.02841
	36 23514	24192	1.02884
	42 23683	24377	1.02928
	48 23853	24562	1.02972
	54 24022	24747	1.03016
14	0 24192	24932	1.03061
	6 24361	25118	1.03106
	12 24530	25303	1.03151
	18 24699	25489	1.03197
	24 24868	25675	1.03243
	30 25038	25861	1.03290
	36 25206	26048	1.03336
	42 25375	26234	1.03383
	48 25544	26421	1.03431
	54 25713	26607	1.03471
15	0 25881	26794	1.03527
	6 26050	26982	1.03576
	12 26218	27169	1.03625
	18 26387	27356	1.03674
	24 26555	27544	1.03724
	30 26723	27732	1.03774
	36 26891	27920	1.03824
	42 27060	28108	1.03875
	48 27228	28297	1.03926
	54 27395	28485	1.03978
16	0 27563	28674	1.04229

78	0 97814	4.70463	4.80973
	54 97778	4.66458	4.77056
	48 97741	4.62518	4.73205
	42 97704	4.58641	4.69416
	36 97667	4.54826	4.65689
	30 97629	4.51070	4.62022
	24 97591	4.47374	4.58414
	18 97553	4.43734	4.54863
	12 97514	4.40151	4.51368
	6 97476	4.36622	4.47928
77	0 97437	4.33147	4.44541
	54 97397	4.29724	4.41206
	48 97357	4.26352	4.37922
	42 97317	4.23029	4.34688
	36 97277	4.19756	4.31503
	30 97236	4.16529	4.28365
	24 97196	4.13350	4.25274
	18 97154	4.10216	4.22229
	12 97113	4.07127	4.19228
	6 97071	4.04081	4.16271
76	0 97029	4.01078	4.13356
	54 96987	3.98116	4.10483
	48 96944	3.95196	4.07651
	42 96901	3.92315	4.04859
	36 96858	3.89474	4.02107
	30 96814	3.86671	3.99392
	24 96770	3.83905	3.96716
	18 96726	3.81177	3.94076
	12 96682	3.78484	3.91472
	6 96637	3.75827	3.88904
75	0 96592	3.73205	3.86370
	54 96547	3.70616	3.83870
	48 96501	3.68061	3.81403
	42 96455	3.65538	3.78970
	36 96409	3.63047	3.76568
	30 96363	3.60588	3.74197
	24 96316	3.58159	3.71858
	18 96269	3.55761	3.69548
	12 96221	3.53392	3.67268
	6 96174	3.51052	3.65017
74	0 96126	3.48741	3.62795
D. M.	Sine	Tangent	Secant.

D. M.	Sine	Tang.	Secant
16	0 27563	28674	1.04029
	6 27731	28863	1.04082
	12 27899	29052	1.04134
	18 28066	29242	1.04187
	24 28234	29431	1.04241
	30 28401	29621	1.04294
	36 28568	29811	1.04349
	42 28736	30001	1.04403
	48 28903	30191	1.04458
	54 29070	30382	1.04513
17	0 29237	30573	1.04569
	6 29404	30764	1.04625
	12 29570	30955	1.04681
	18 29737	31146	1.04738
	24 29904	31338	1.04795
	30 30070	31529	1.04852
	36 30236	31721	1.04910
	42 30403	31914	1.04969
	48 30569	32106	1.05027
	54 30735	32299	1.05086
18	0 30901	32491	1.05146
	6 31067	32685	1.05206
	12 31233	32878	1.05266
	18 31399	33071	1.05326
	24 31564	33265	1.05387
	30 31730	33459	1.05449
	36 31895	33653	1.05511
	42 32061	33848	1.05573
	48 32226	34042	1.05635
	54 32391	34237	1.05698
19	0 32556	34432	1.05762
	6 32721	34628	1.05825
	12 32886	34823	1.05889
	18 33051	35019	1.05954
	24 33216	35215	1.06019
	30 33380	35411	1.06084
	36 33545	35608	1.06150
	42 33709	35805	1.06216
	48 33873	36002	1.06283
	54 34037	36199	1.06350
20	0 34202	36397	1.06417

74	0 96126	3.48741	3.62795
	54 96077	3.46458	3.60601
	48 96029	3.44202	3.58434
	42 95980	3.41973	3.56294
	36 95931	3.39770	3.54181
	30 95881	3.37594	3.52093
	24 95832	3.35443	3.50031
	18 95782	3.33317	3.47994
	12 95731	3.31215	3.45982
	6 95681	3.29138	3.43994
73	0 95630	3.27085	3.42030
	54 95579	3.25055	3.40089
	48 95527	3.23047	3.38171
	42 95476	3.21063	3.36275
	36 95424	3.19100	3.34402
	30 95371	3.17159	3.32550
	24 95319	3.15239	3.30720
	18 95266	3.13341	3.28911
	12 95212	3.11463	3.27123
	6 95159	3.09605	3.25354
72	0 95105	3.07768	3.23606
	54 95051	3.05950	3.21878
	48 94997	3.04151	3.20169
	42 94942	3.02372	3.18478
	36 94887	3.00611	3.16807
	30 94832	2.98868	3.15154
	24 94776	2.97143	3.13519
	18 94721	2.95437	3.11902
	12 94664	2.93747	3.10302
	6 94608	2.92076	3.08720
71	0 94551	2.90421	3.07155
	54 94494	2.88782	3.05606
	48 94437	2.87160	3.04074
	42 94380	2.85555	3.02558
	36 94322	2.83965	3.01058
	30 94264	2.82391	2.99574
	24 94205	2.80832	2.98105
	18 94147	2.79289	2.96652
	12 94088	2.77760	2.95213
	6 94028	2.76246	2.93789
70	0 93969	2.74747	2.92380
D. M. Sine Tangent Secant.			

D. M.	Sine	Tang.	Secant.
20	0 34202	36397	1.06417
	6 34365	36594	1.06485
	12 34529	36792	1.06553
	18 34693	36991	1.06622
	24 34857	37189	1.06691
	30 35020	37388	1.06760
	36 35184	37587	1.06830
	42 35347	37786	1.06901
	48 35510	37986	1.06971
	54 35673	38206	1.07042
21	0 35836	38386	1.07114
	6 35999	38586	1.07186
	12 36162	38787	1.07258
	18 36325	38988	1.07391
	24 36487	39189	1.07404
	30 36650	39391	1.07478
	36 36812	39592	1.07552
	42 36974	39794	1.07627
	48 37136	39997	1.07702
	54 37298	40199	1.07777
22	0 37460	40402	1.07853
	6 37622	40605	1.07929
	12 37784	40809	1.08006
	18 37945	41012	1.08083
	24 38107	41217	1.08161
	30 38268	41421	1.08239
	36 38429	41625	1.08317
	42 38590	41830	1.08396
	48 38751	42036	1.08475
	54 38912	42241	1.08555
23	0 39073	42447	1.08636
	6 39233	42643	1.08716
	12 39394	42860	1.08797
	18 39554	43066	1.08879
	24 39714	43273	1.08961
	30 39874	43481	1.09044
	36 40034	43688	1.09127
	42 40194	43896	1.09210
	48 40354	44105	1.09294
	54 40514	44313	1.09378
24	0 40673	44522	1.09463

70	0 93969	2.74747	2.92380
	54 93909	2.73262	2.90985
	48 93849	2.71792	2.89604
	42 93788	2.70335	2.88237
	36 93728	2.68891	2.86884
	30 93667	2.67462	2.85545
	24 93605	2.66045	2.84218
	18 93544	2.64642	2.82905
	12 93482	2.63251	2.81605
	6 93420	2.61874	2.80317
69	0 93358	2.60508	2.79042
	54 93295	2.59156	2.77780
	48 93232	2.57815	2.76529
	42 93169	2.56486	2.75291
	36 93105	2.55169	2.74065
	30 93041	2.53864	2.72850
	24 92977	2.52571	2.71647
	18 92913	2.51288	2.70455
	12 92848	2.50017	2.69274
	6 92783	2.48757	2.68105
68	0 92718	2.47508	2.66946
	54 92652	2.46272	2.65798
	48 92587	2.45042	2.64661
	42 92520	2.43825	2.63535
	36 92454	2.42618	2.62418
	30 92387	2.41421	2.61312
	24 92321	2.40234	2.60216
	18 92253	2.39057	2.59130
	12 92186	2.37890	2.58054
	6 92118	2.36733	2.56987
67	0 92050	2.35585	2.55930
	54 91982	2.34446	2.54882
	48 91913	2.33317	2.53844
	42 91844	2.32197	2.52815
	36 91775	2.31086	2.51795
	30 91706	2.29984	2.50784
	24 91636	2.28890	2.49782
	18 91566	2.27806	2.48788
	12 91495	2.26730	2.47803
	6 91425	2.25662	2.46827
66	0 91354	2.24603	2.45859
D. M.	Sine	Tangent	Secant.

D. M.	Sine	Tang.	Secant.
24	040673	44522	1.09463
	640833	44732	1.09548
	1240992	44941	1.09634
	1841151	45151	1.09720
	2441310	45362	1.09807
	3041469	45572	1.09894
	3641628	45783	1.09982
	4241786	45994	1.10070
	4841945	46206	1.10159
	5442103	46418	1.10248
25	042261	46630	1.10337
	642419	46843	1.10427
	1242577	47056	1.10518
	1842735	47269	1.10609
	2442893	47483	1.10700
	3043051	47697	1.10792
	3643208	47911	1.10885
	4243365	48126	1.10978
	4843523	48341	1.11071
	5443680	48557	1.11165
26	043837	48773	1.11260
	643993	48989	1.11355
	1244150	49206	1.11450
	1844307	49423	1.11546
	2444463	49640	1.11643
	3044619	49858	1.11740
	3644775	50076	1.11837
	4244931	50294	1.11935
	4845087	50513	1.12034
	5445243	50732	1.12133
27	045399	50952	1.12232
	645554	51172	1.12332
	1245709	51393	1.12433
	1845864	51613	1.12534
	2446019	51835	1.12636
	3046174	52056	1.12738
	3646329	52278	1.12840
	4246484	52501	1.12944
	4846638	52724	1.13047
	5446792	52947	1.13152
28	046947	53170	1.13257

66	091354	2.24603	2.45859
	5491285	2.23552	2.44897
	4891212	2.22510	2.33948
	4291140	2.21475	2.43004
	3691068	2.20448	2.42069
	3090996	2.19429	2.41142
	2498923	2.18418	2.40222
	1890850	2.17415	2.39310
	1290777	2.16419	2.38406
	690704	2.15431	2.37509
65	090630	2.14450	2.36620
	5490556	2.13477	2.35738
	4890482	2.12510	2.34863
	4290408	2.11551	2.33995
	3690333	2.10599	2.33135
	3090258	2.09654	2.32282
	2490183	2.08716	2.31435
	1890107	2.07784	2.30595
	1290031	2.06859	2.29762
	689955	2.05941	2.28936
64	089879	2.05030	2.28117
	5489802	2.04125	2.27304
	4889725	2.03126	2.26497
	4289648	2.02334	2.25697
	3689571	2.01448	2.24903
	3089493	2.00568	2.24115
	2489415	1.99695	2.23334
	1889337	1.98827	2.22559
	1289258	1.97966	2.21789
	689179	1.97110	2.21026
63	089100	1.96261	2.20268
	5489021	1.95417	2.19517
	4888941	1.94578	2.18771
	4288861	1.93746	2.18031
	3688781	1.92919	2.17296
	3088701	1.92098	2.16568
	2488620	1.91282	2.15844
	1888539	1.90471	2.15126
	1288458	1.89666	2.14414
	688376	1.88867	2.13707
62	088294	1.88072	2.13005
D. M.	Sine	Tangent	Secant.

D. M.	Sine	Tang.	Secant.
28	046947	53170	1.13257
	647101	53395	1.13362
	1247255	53619	1.13468
	1847408	53844	1.13574
	2447562	54069	1.13681
	3047715	54295	1.13789
	3647869	54521	1.13897
	4248022	54748	1.14006
	4848175	54975	1.14115
	5448328	55202	1.14225
29	048480	55430	1.14335
	648633	55659	1.14446
	1248785	55888	1.14557
	1848938	56117	1.14669
	2449090	56347	1.14782
	3049242	56577	1.14895
	3649394	56807	1.15009
	4249545	57038	1.15123
	4849697	57270	1.15238
	5449848	57502	1.15353
30	050000	57735	1.15470
	650151	57967	1.15586
	1250301	58201	1.15703
	1850452	58435	1.15821
	2450603	58669	1.15940
	3050753	58904	1.16059
	3650904	59139	1.16178
	4251054	59375	1.16299
	4851204	59611	1.16419
	5451354	59848	1.16541
31	051503	60086	1.16663
	651653	60323	1.16785
	1251802	60562	1.16909
	1851951	60800	1.17033
	2452100	61040	1.17157
	3052249	61280	1.17282
	3652398	61520	1.17428
	4252547	61761	1.17534
	4852695	62002	1.17661
	5452843	62244	1.17789
32	052991	62486	1.17917

62	088294	1.88072	2.13005
	5488212	1.87283	2.12308
	4888130	1.86499	2.11617
	4288047	1.85720	2.10931
	3687964	1.84946	2.10250
	3087881	1.84177	2.09573
	2487798	1.83412	2.08902
	1887714	1.82653	2.08236
	1287630	1.81899	2.07574
	687546	1.81149	2.06918
61	087461	1.80404	2.06266
	5487377	1.79664	2.05619
	4887292	1.78928	2.04976
	4287206	1.78197	2.04339
	3687121	1.77471	2.03705
	3087035	1.76749	2.03077
	2486949	1.76031	2.02452
	1886863	1.75318	2.01833
	1286776	1.74609	2.01217
	686689	1.73905	2.00606
60	086602	1.73205	2.00000
	5486515	1.72509	1.99397
	4886427	1.71817	1.98799
	4286339	1.71129	1.98205
	3686251	1.70445	1.97615
	3086162	1.69766	1.97029
	2486074	1.69090	1.96447
	1885985	1.68419	1.95869
	1285895	1.67751	1.95296
	685806	1.67087	1.94726
59	085716	1.66427	1.94160
	5485626	1.65771	1.93598
	4885536	1.65119	1.93040
	4285445	1.64471	1.92485
	3685355	1.63826	1.91935
	3085264	1.63185	1.91388
	2485172	1.62547	1.90844
	1885081	1.61913	1.90305
	1284989	1.61283	1.89769
	684897	1.60656	1.89236
58	084804	1.60033	1.88707
D. M.	Sine	Tangent	Secant.

D. M.	Sine	Tang.	Secant						
32	0	52991	62486	1.17917	58	0	84804	1.60033	1.88707
	6	53139	62729	1.18046		54	84712	1.59413	1.88182
	12	53287	62973	1.18176		48	84619	1.58797	1.87660
	18	53435	63217	1.18306		42	84526	1.58184	1.87142
	24	53582	63461	1.18437		36	84432	1.57574	1.86627
	30	53729	63707	1.18568		30	84339	1.56968	1.86115
	36	53877	63952	1.18701		24	84245	1.56365	1.85607
	42	54024	64198	1.18833		18	84151	1.55766	1.85102
	48	54170	64445	1.18967		12	84056	1.55169	1.84601
	54	54317	64692	1.19101		6	83961	1.54576	1.84102
33	0	54463	64940	1.19236	57	0	83867	1.53986	1.83607
	6	54610	65189	1.19371		54	83771	1.53399	1.83115
	12	54756	65438	1.19507		48	83676	1.52816	1.82627
	18	54902	65687	1.19644		42	83580	1.52235	1.82141
	24	55058	65937	1.19782		36	83484	1.51657	1.81659
	30	55193	66188	1.19920		30	83388	1.51083	1.81180
	36	55339	66439	1.20059		24	83292	1.50512	1.80703
	42	55484	66691	1.20198		18	83195	1.49943	1.80230
	48	55629	66944	1.20339		12	83098	1.49378	1.79760
	54	55777	67197	1.20480		6	83001	1.48815	1.79293
34	0	55919	67450	1.20621	56	0	82903	1.48256	1.78829
	6	56063	67705	1.20764		54	82806	1.47699	1.78367
	12	56208	67959	1.20907		48	82708	1.47145	1.77909
	18	56352	68215	1.21050		42	82609	1.46594	1.77454
	24	56496	68471	1.21195		36	82511	1.46046	1.77001
	30	56640	68728	1.21340		30	82412	1.45500	1.76551
	36	56784	68985	1.21486		24	82313	1.44958	1.76104
	42	56927	69243	1.21633		18	82214	1.44418	1.75660
	48	57071	69501	1.21780		12	82114	1.43881	1.75219
	54	57214	69760	1.21928		6	82015	1.43346	1.74780
35	0	57357	70020	1.22077	55	0	81915	1.42814	1.74344
	6	57500	70281	1.22227		54	81814	1.42285	1.73911
	12	57643	70542	1.22377		48	81714	1.41759	1.73480
	18	57785	70803	1.22528		42	81613	1.41235	1.73053
	24	57928	71056	1.22680		36	81512	1.40713	1.72627
	30	58070	71329	1.22832		30	81411	1.40194	1.72205
	36	58212	71592	1.22985		24	81310	1.39678	1.71785
	42	58354	71857	1.23140		18	81208	1.39164	1.71367
	48	58495	72122	1.23294		12	81106	1.38653	1.70952
	54	58637	72387	1.23450		6	81004	1.38144	1.70540
36	0	58778	72654	1.23606	54	0	80901	1.37638	1.70130
					D. M.	Sine	Tangent	Secant.	

D. M.	Sine	Tang.	Secant.
36	058778	72654	1.23606
	658919	72921	1.23763
	1259060	73188	1.23921
	1859201	73457	1.24080
	2459341	73726	1.24239
	3059482	73996	1.24400
	3659622	74266	1.24561
	4259762	74537	1.24723
	4859902	74809	1.24885
	5460042	75082	1.25049
37	060181	75355	1.25213
	660320	75629	1.25378
	1260459	75904	1.25544
	1860598	76179	1.25711
	2460737	76455	1.25878
	3060876	76732	1.26047
	3661014	77010	1.26216
	4261152	77288	1.26386
	4861290	77567	1.26557
	5461428	77847	1.26729
38	061566	78128	1.26901
	661703	78410	1.27075
	1261840	78692	1.27249
	1861977	78975	1.27424
	2462114	79259	1.27600
	3062251	79543	1.27777
	3662387	79828	1.27955
	4262524	80115	1.28134
	4862660	80402	1.28314
	5462756	80689	1.28494
39	062932	80978	1.28675
	663067	81267	1.28858
	1263202	81558	1.29041
	1863338	81849	1.29225
	2463473	82140	1.29410
	3063607	82433	1.29596
	3663742	82727	1.29783
	4263876	83021	1.29971
	4864010	83316	1.30160
	5464144	83612	1.30350
40	064278	83909	1.30540

54	080901	1.37638	1.70130
	5480798	1.3713	1.69722
	4880696	1.36632	1.69317
	4280592	1.36133	1.68915
	3680489	1.35636	1.68515
	3080385	1.35142	1.68117
	2480281	1.34650	1.67721
	1880177	1.34160	1.67328
	1280073	1.33672	1.66938
	679968	1.33187	1.66552
53	079863	1.32704	1.66164
	5479758	1.32223	1.65780
	4879652	1.31745	1.65398
	4279547	1.31268	1.65019
	3679441	1.30794	1.64642
	3079335	1.30322	1.64267
	2479228	1.29852	1.63895
	1879122	1.29384	1.63525
	1279015	1.28919	1.63156
	678908	1.28455	1.62790
52	078801	1.27994	1.62426
	5478693	1.27534	1.62065
	4878585	1.27077	1.61705
	4278477	1.26621	1.61347
	3678369	1.26168	1.60992
	3078260	1.25717	1.60638
	2478152	1.25267	1.60287
	1878043	1.24820	1.59937
	1277933	1.24374	1.59590
	677824	1.23931	1.59245
51	077714	1.23489	1.58901
	5477604	1.23049	1.58560
	4877494	1.22612	1.58220
	4277384	1.22176	1.57882
	3677273	1.21741	1.57547
	3077162	1.21309	1.57213
	2477051	1.20879	1.56881
	1876939	1.20450	1.56551
	1276828	1.20023	1.56223
	676716	1.19598	1.55896
50	076604	1.19175	1.55572

D. M. Sine Tangent Secant.

D. M.	Sine	Tang.	Secant
40	064278	83909	1.30540
	664412	84207	1.30732
	1264545	84506	1.30925
	1864678	84806	1.31118
	2464811	85106	1.31313
	3064944	85408	1.31508
	3665077	85710	1.31705
	4265209	86013	1.31902
	4865342	86317	1.32101
	5465474	86622	1.32300
41	065605	86928	1.32501
	665737	87235	1.32702
	1265868	87543	1.32905
	1866000	87852	1.33108
	2466131	88161	1.33313
	3066262	88472	1.33519
	3666392	88784	1.33725
	4266523	89096	1.33933
	4866653	89410	1.34142
	5466783	89724	1.34352
42	066913	90040	1.34563
	667042	90356	1.34775
	1267172	90674	1.34988
	1867301	90993	1.35202
	2467430	91312	1.35417
	3067559	91633	1.35634
	3667687	91954	1.35851
	4267835	92277	1.36070
	4867944	92601	1.36289
	5468072	92925	1.36510
43	068199	93251	1.36732
	668327	93578	1.36955
	1268454	93906	1.37180
	1868581	94235	1.37405
	2468708	94565	1.37632
	3068835	94896	1.37859
	3668961	95228	1.38088
	4269088	95562	1.38318
	4869214	95896	1.38550
	5469340	96232	1.38782
44	069465	26568	1.39016

50	076604	1.19175	1.55572
	5476492	1.18753	1.55249
	4876379	1.18334	1.54928
	4276266	1.17915	1.54609
	3676153	1.17499	1.54292
	3076040	1.17084	1.53976
	2475927	1.16672	1.53663
	1875813	1.16260	1.53351
	1275699	1.15851	1.53040
	675585	1.15443	1.52732
49	075470	1.15036	1.52425
	5475356	1.14632	1.52120
	4875241	1.14229	1.51816
	4275126	1.13827	1.51514
	3675011	1.13427	1.51214
	3074895	1.13029	1.50916
	2474779	1.12632	1.50619
	1874663	1.12237	1.50323
	1274547	1.11843	1.50030
	674431	1.11451	1.49738
48	074314	1.11061	1.49447
	5474197	1.10672	1.49158
	4874080	1.10284	1.48871
	4273963	1.09898	1.48585
	3673845	1.09513	1.48301
	3073727	1.09130	1.48018
	2473609	1.08749	1.47737
	1873491	1.08368	1.47457
	1273372	1.07990	1.47179
	673254	1.07612	1.46903
47	073135	1.07236	1.46627
	5473016	1.06862	1.46354
	4872896	1.06489	1.46081
	4272777	1.06117	1.45811
	3672657	1.05747	1.45541
	3072537	1.05378	1.45273
	2472417	1.05010	1.45007
	1872296	1.04644	1.44742
	1272176	1.04279	1.44478
	672055	1.03915	1.44216
46	071933	1.03553	1.43955

D. M. Sine Tangent Secant.

A

Succinct and Demonstrable

Way of Describing

HOUR-LINES

Upon all Sorts of

PLAINS.

And also,

For the Inscription of other Sciaterical Furniture
into SUN-DIALS.

Translated from a *Latin* Manuscript written, *Anno* 1640.
By *Samuel Foster*, sometimes Professor of Astronomy in
Gresham Colledge, LONDON.

The Seventh TRACTATE.

IN all the six Schemes — NESW represents the Horizon. — NPS the Meridian — TRL the Plain — P the Pole of the Word — Z the Pole of the Horizon — O the Pole of the Plain — DN or DS, the Declination of the Plain, which two Arks are Complements of each other; and unto which, the Angles PZO or OZS are Equal.

The Horizontal Line of the Plain is TZL — The Vertical Line VZ — The Inclination of the Plain to the Horizon, is the Arch VC, to which OZ is equal.

That the Axis and Hour-lines may be duly seated, we must of necessity solve the Spherical Triangle PZO, in which there are given, (1.) PZ, the Complement of the Latitude, (2.) ZO, the Inclination of the Plain to the Horizon, (3.) The Angle PZO, the Declination of the Plain from the North.

Therefore, it is evident, by the Fourth Axiom,

First, The Base PO, whose excess above a Quadrant in the III. Scheme, is the Complement to a Quadrant in the other Schemes; And therefore PR is the Elevation of the Pole above the Plain.

N n n

Secondly,

note, the figures this Tractate is page 49. of the first.

Secondly, By the Third Axiom.
 As the Sine of the Arch, before found, OP
 Is to the Sine of the Declination PZO, or OZS,
 So is the Sine of the Inclination of the Plain to the Horizon OZ,
 To the Sine of OPZ. The difference of Longitude between the Meridian of the Plain, and the Meridian of the Place.

Thirdly, By the Third Axiom.
 As the Sine of the Arch OP,
 Is to the Sine of the Declination ZO, or OZS;
 So is the Sine of PZ, the Complement of the Latitude of the Place,
 To the Sine of the Angle POZ, or RV.
 Which is the distance of the Substile and Meridian.

¶ *To find the Substile and to place the Axis upon it.*

The Substile is distant from the Vertical Line of the Plain, by the quantity of the Arch RV, and towards the same Coast, as appears by the Scheme. The Stile standing perpendicular upon this represents the Axis of the World; and therefore looks towards the Elevated Pole, making an Angle with the Substile equal to the Arch PR.

¶ *To find the Distances of the Hour-lines from the Substile.*

The Hour-lines are placed from the Substile, in the same Order which they keep in the Schemes; their Angles being found out by this Proportion.

As Radius
 Is to the Sine Elevation of the Pole above the Plain PR.
 So are the Tangents of the Angles RP₁₂, RP₁, RP₂, RP₃, RP₄, RP₅,
 RP₆, &c. — RP₁₁, ZP₁₀, RP₉, RP₈, RP₇, RP₆, &c.
 To the Tangents of the Arches upon the Plain, R₁₂, R₁, &c. R₁₁, R₁₀,
 &c.

From the Measures of these Arches, let there be Angles described upon the Plain; and if you draw strait Lines from the Centre through those Points, they will be the Hour-lines: And the Schemes will shew the Order of their Numeration.

The true Angles RP₁₂, RP₁, &c. RP₁₁, RP₁₀, &c. are discovered by being compared with the difference of Longitude OPZ, whether it be 1, 2, 3, 4, &c. hours from the Meridian, by taking either their Sum or Difference, which is easily apprehended from the Schemes.

Moreover, It is to be noted, That the Angle OPZ is Acute, or at the most not exceeding a Right Angle. — But if at any time it fall out to be Obtuse, the same shall be the Supplement of the Plain's Difference of Longitude. The same is to be understood in any Case whatsoever, when the Angle RP_m, is either equal to, or Supplement to the Angles RP₁₂, RP₁, &c.

I have assumed these Inventions in the last place, because they are more commodious for animadversion.

How

How to know under what Scheme, any Plain falls.

As Radius,
Is to the Co-sine of the Plain's Declination,
So is the Tangent of the Plain's Inclination to the Horizon,
To a Fourth Tangent:
In North Incliners N^m ,
In South Incliners S^m ,
In both which, if the Fourth Arch N^m be lesser than the Elevation of the Pole NP.
The Plain shall be like that in Scheme II.
If Greater like that in Scheme III.
If Equal the Plain is Meridiah.

And in these,
If the said Fourth Arch S^m be greater than the Elevation of the Equator SÆ, or Equal to it, the Plain will agree with Scheme IV — But if lesser with Scheme V.

Let Erect Plains be represented by Scheme I. where, If the Declination be 90 deg. the Plain shall be NPZS.

For Direct Incliners beholding the East or West, the VI Scheme will serve. — But where the Inclination to the Horizon is 90 deg. the Plain shall be NZS Meridiah.

Hitherto of the Description of Hours.

CERTAIN

(52)

CERTAIN PRECEPTS. FOR THE INSCRIPTION OR OTHER Sciaterical Furniture UPON SUNDIALS.

P R O B L. I.

To find the Distances of the Verticals of their Plains, from the Verticals of the Horizon.

THE Verticals of the Plain is VZ or DC,
The Verticals of the Horizon are ZQ, ZF, ZG and ZH, &c.
The Verticals of the Arch sought of the Distances in Plain are VY, VI, VK, VM, &c.
But because the Declination of the Plain SD or NC, and the Horizontal Distances of the Verticals NQ, NF, NG, NH, &c. from N are known: The Distances also or Sums of the same (according as shall be required) shall be made known: Namely the Arches CQ, CF, CG, CH, &c.
And because ZV is the Complement of the Inclination of the Plain to the Horizon, therefore

As ZC Radius
To Sine of ZV.
So the Tangents of the Arches CQ, CF, CG, CH, &c.
To the Tangents of the sought Arches VY, VI, VK, VM, &c.
In Erect Plains, which pass through the Vertex of the place, those Arches vanish.

P R O B L. II.

The Declination of the Parallel from the Equator being given, to find its Distance from the Vertex of the Plain, to any Hour.

LEt the Parallel be A ∞ , and the hour ZPA, the Eighth from Midnight or Four before Noon, and let an Arch of a great Circle OA be drawn, then in the Triangle OPA the Sides PA, (by the Declination from the Equator

quator BA) and PO (from the former computation) being known, with the comprehended Angle OPA, made from the Sum or Difference of the Angles OPZ the Difference of Longitude, and ZPA the hour given, the Base OA may be found, by the Fourth Axiom: which is the Distance of the Point A from O the Vertex of the Plain.

In the same manner, the Distances to all Parallels and hours are to be sought.——But to seek them beyond 80 deg. will be needless.

A P P E N D I X.

If it be sought, in what Vertical Circle of the Plain this Distance shall happen, use this following Analogy.

As the Sine of the Side OA

To the Sine of the opposite Angle OPA.

So (by the Axiom 3) is the Sine of the Side PA

To the Sine of the opposite Angle POA.

Which is the Latitude, between the Vertical of the Plain OA, and the Substilar OP.

P R O B L. III.

To find the Distance of any Circle Parallel to the Horizon from the Vertex of the Plain, to any Vertical Circle.

Let the Parallel or Almicanter passing through the Point X be the Vertical of the Circle ZF and let the Distance of the Point X be sought, from O the Vertex of the Plain.

Then let the Arch of a great Circle OX be described, so as to make the Triangle OZX, in which from the given Sides OZ (equal to the Inclination VC) and ZX (the Complement of the Distance of the Parallel X, from the Horizon F) together with the comprehended Angle OZX, (the Supplement of the Angle CZF before found) the Base OX may be found (by Axiom 4.) which is the Distance required.

The same is to be found in all other as well Verticals as Parallels. But to seek the Distances beyond 80 deg. is needless.

A P P E N D I X.

But if it be further required in what Vertical Circle of the Plain, this Distance shall happen, it may be found in the Third Axiom in this manner:

As the Sine of the Side OX

Is to the Sine of the opposite Angle ZOX,

So is the Sine of the Side ZX

To the Sine of the opposite Angle ZOZ,

Which shews how far the Vertical of the Plain, which passeth thro' X, is to be distant from that Vertical of the Plain OZV.

The Use of these Problems is for the describing of Vertical Circles parallel to the Equator, and parallel to the Horizon.

In the first place the Gnomon is to be assigned, according to whose situation and length all things whatsoever that are to be inserted in Dials are determined.

Therefore any Point in the Stile being assigned for the Apex or point of the Gnomon :

A right line from that point perpendicularly extended to the Plain, shall be the length of the Gnomon: And that point of the Plain upon which that right Line falleth, shall be taken for the foot of the Gnomon.

To the Gnomon thus constituted, are to be fitted both an Horizontal and a Vertical Line upon the Plain, in which also the Zenith of the Horizon is to be fixed, all which we shall use in the description following.

The Horizontal Line may be described by marking upon the Plain a Point *in equilibrio* with the Apex, and drawing through that point upon the Plain, a Line parallel to the Horizon, both which may be done by an ordinary Inclinary or Quadrant, or by any other apt or convenient means.

And a right Line drawn through the foot of the Gnomon, perpendicularly to the Horizontal Line, shall be the Vertical Line of the Plain accommodated in like manner to the Apex.

Also a right Line perpendicularly erected from the Center of the Earth, to the Vertex of the Horizon, shall design out (in the Vertical Line) the Vertical Point of the Horizon, called the Zenith; which also the concurrence or intersection of the Vertical Line with the hour-line of 12 will effect.

And because below the Horizon, there is nothing in the Heavens further discerned, therefore in the Plain nothing is to be described above the Horizontal Line. wherefore it behoveth the Artist to order the Apex of the Gnomon in such a place of the Stile, so that all things may be described upon the Dial-plain in a decent and orderly manner.

In the last place, all things depending upon the Apex of the Gnomon, and contained between the Tropicks and the Horizon.

To describe the Azimuth or Vertical Lines.

1. In any Inclining Plain, from the Zenith point of the Horizon noted upon the Plain, describe a Circle, in which (from a Vertical Line drawn upon the Plain, through the foot of the Gnomon) set off such Angles as are equal to those Arches found by the first Problem, for the right Lines drawn at those Divisions towards the true Coast of the World will be the Vertical Lines.

In an Horizontal Plain.

The equal Angles at the foot of the Gnomon reckoned from the South describe the Vertical or Azimuth Circles.

In any Erect Plain.

The Zenith cannot be fixed, neither can the Vertical Lines meet, therefore there is no need of the computation of the first Problem. Only the forming of the Angles at Z, or of the Horizontal Arches, CF, CG, CH, &c. is here required. But the Tangents of these Angles (the length of the Gnomon being made Radius) set from the Foot of the Gnomon towards their due Coast, will find points upon the Horizontal Line, by which Perpendicular Lines being let fall will supply the places of the Vertical Circles. But every Azimuth or Tenth Circle may be described from the South, and a number proper there-

to ascribe, viz. 10, 20, 30, &c. Or also those Select Points answerable to the Points of the Marriners Compass. Eight whereof complete a Quadrant or fourth part of a Circle, and to the same those names may be fixed according as every Nation denominateth them.

Lastly, All the Uses of the Vertical Circles may in some measure be hither-to transferred.

To Describe the Lesser Circles.

1. The Parallels of the Equator.

1. Seek the Distance of the Parallel to be described at every hour (by *Probl. 2*) then making the length of the Gnomon Radius, apply those Tangents to the Hour-lines from the foot of the Perpendicular Stile for where that concurrence or intersection is made, through that point the parallel will pass. But if a Section appear uncertain or dubious use the Appendix of *Probl. 2.* that is, enquire in what Vertical Circle that Section shall happen: which being known, if from that part of the Substilar Line which is most convenient you form the Angle of the Vertical in the foot of the Gnomon, you will have the precise Section of the foresaid Tangent and hour.

By this means are to be described Parallels.

1. Of the Signs of the Zod.
2. Of the Diurn. Arches.
3. Of the Latitude of Principal Cities, whence you may know, whether the Inhabitants of such or such a Place be *Anthiscii, Heteroscii, or Periscii.*
4. The Parallels proper to every Festival Day, and such like things.

But the true Parallel proper to any designed business is first to be found out, and then to be managed according to the requisites of *Probl. 2.*

2. The Parallels of the Horizon, or Almicantheras.

The Almicanthers are to be infered into the Vertical Lines in the same manner as the Parallels of the Equator were into the hour-lines, for the Tangents of the Distances (found by *Probl. 3.*) set from the foot of the Gnomon (to whose length also the Tangent is to be limited) to their proper Verticals, will give the Points through which the Oblique Line representing the Almicanth. is to be drawn: — But if the Section appear dubious, a remedy for this inconvenience may be used from the Appendix of *Probl. 3.* For thence it will appear what Vertical Line numbred, from the Vertical in the Plain V Z, shall pass through that same Section; Which if (from that part of the Vertical V Z which you see most convenient) you express in a due Angle framed at the foot of the Gnomon you will have the exact point of Section.

In this manner may be inscribed every 10 Parallel from the Horizon, thence so to be numbered by 10, 20, 30, &c. or from them some more select, which will shew the Proportions of Shadows to their Gnomons: such as are these to be Numbred from the Vertex, not from the Horizon.

Almicanth.		Umb. ad	
deg.	min.	Gnom.	
84	18	10	ad 1
82	53	8	1
81	53	6	1
78	42	5	1
75	58	4	1
71	34	3	1
63	26	2	1
56	19	3	2
53	08	4	3
55	20	5	4
45	00	1	1
38	40	4	5
36	52	3	4
33	41	2	3
30	58	3	5
26	34	1	2

Of

Of the Hours of other Nations, and how they may be put into Dial-Plains.

The Astronomers and Umbreans number equal hours from South to South.

The Egyptians and Romans from Midnight, as we use also to do in our Civil Account.

To both these Computations those hours suffice which we before taught how to inscribe.

The Bohemians and Italians still retain their equal hours, but begin their Numeration from Sun Setting.

The Babylonians and Balearick Islands begin from the Sun Rising.

The Jews were wont to divide every Day (and Night) into 12 Parts, the number whereof among them began at Sun Rising, and ceased at Sun Setting: The hours from Sun Rising, and Sun Setting are easily inserted; if first these Parallels of the Diurnal Arches which answer to the like number of hours, (*i. e.*) 8, 10, 12, 14, 16, be described. For the Sun Rising in the Easterly Horizon is the beginning of the hours from the East. And his Setting in the Westerly Horizon is the beginning of hours from the West.

If therefore a right Line be drawn through the two first Horary Points from the Horizon in any two Parallels, it will be the first hour from the East, or the 23 deg. from Yesterdays West. And if through the two second Horary Points from the Horizon, a second right Line be drawn, that also will be the second hour from the East, and the 22. from the West; and so of all the rest.

The Jewish hours (which are also Planetary) are by the same artifice inserted: For if in the Parallels of the Diurnal Arches of the hours of 15 and 9, right Lines be described through each, there $\frac{1}{2}$ here $\frac{1}{2}$ from the Horizon, they will give the Judaick hours, which also will pass exactly enough thro' the equal hours in the Equator; For, if we look to the exactness herein, the Planetary hours cannot be shadowed out by right Lines because in the Sphere they are not great Circles.

The End of the Seventh TRACTATE.

Concave and Convex
SPHERICAL and *CYLINDRICAL*
DIALLING.

The Eighth TRACTATE.

FIRST,
OF CONCAVE DIALLING;

S H E W I N G,

How to draw Hour-lines in the Inside of any Regular Concave Hemisphere in any Position, either Parallel, Perpendicular, or Oblique to the Axis of the World :

A N D A L S O,

To describe the Parallels, Azimuths, Almicantrs, and other Furniture into such Concave Dials.

TH E S E Regular Concave Hemispheres, (for of such now we only treat) are the most natural Plains upon which Hour-lines may be described, for that they do so naturally represent the Sphere, and the manner how the Hour-lines and other Furniture may be inscribed upon them, is no less easie, and how both may be effected, shall be the Work of this Tractate.

C H A P. I.

To make a Vertical or Horizontal Concave Dial.

HA V I N G a Concave Hemisphere prepared : as, S N E W. divide the Limb into 4 Quadrants, noted as the former Letters; one of the Quadrants divide into 90 degr. open your Compasses to the Quadrant, and setting one foot upon E or W. with the other draw the Meridian or 12th hour
 P p p S Z N.

Figure
I.

page 64

S Z N. take out of the Quadrant the Latitude 51 deg. 30 min. and set those degrees upon the Meridian from S. towards Z to P. which P shall be the Pole of the World; then placing your Compasses upon P. (they being opened to a Quadrant) draw the Equator E A W. which divide into 12 equal parts; your Compasses being opened as before to a Quadrant, and one foot being placed in those marks made in the Equator, with the other foot describe Circles, which shall be the Hour-lines required; the Stile must be erected in P. with an Angle equal to the Latitude; equal to the length of 60 deg. of the Quadrant, the top must hang over the Centre Z. and be parallel with the Limb, or erect a Style in the Point Z of the same length with the former which shall shew the hour with the Top only.

CHAP. II.

To make an Erect, Direct South or North Concave Dial.

THIS Dial is made altogether like the former, only instead of setting of the Latitude from S to P. you must only set off the Complement of the Latitude, and the Hour-lines only from 6 to 6, are described therein, the rest of the Hour-lines are reserved for a Vertical Dial beholding the North.

CHAP. III.

To make a Meridional Erect, Direct, East or West Concave Dial.

Figure
II.

LET the Hemisphere be Z S N G. the Limb being divided into four Quadrants, one of those into 90 deg. From N. upwards, and from S. downwards, set the Latitude to P. then open your Compasses to a Quadrant one foot in P. with the other draw the Circle Q E A. which Semicircle divide into twelve equal parts, your Compass being opened to a Quadrant, one foot placed in each of these marks, with the other draw Circles which shall be the Hour-lines required; as in the Figure. The Style may be a wire laid from P to P. or a wire erected in the Center E equal to the Semidiameter of the Quadrant; for better Instruction see Figure II. which is an East Dial.

In the same manner is an Equinoctial Dial made, only all the hours from six in the Morning till six at Night, must be drawn, as the rest above those proper for the East or West Dials are, and as the pricked hours 9 8 7 and 6 in the Figure are.

Also the Hour-line of six, viz. the Line P. VI. P, must be P 12 P, and the rest numbred as in the Figure is expressed and numbred with Arithmetical Figures.

CHAP. IV.

To make a Vertical, or Erect South or North Declining Concave Dial.

Figure
III.

YOUR Concave being prepared and quartered and marked with the Letters Z N E W, your Compasses being opened to a Quadrant, and one foot in Z or N, draw the Horizontal Circle E S W. take the Declination and

prick it down in the Horizontal Line from W to H, one foot of your Compasses remaining in H, being opened to a Quadrant describe the Meridian or hour of XII. in which from Z set off the Complement of the Latitude, or from its intersection with the Horizontal Line set off the Latitude to P, one foot of your Compasses in P, with the other (the Compasses being opened to a Quadrant) draw the Equator Q Æ A, and where it is intersected by the hour of 12, begin to divide it into 12 equal parts, one foot of your Compasses being placed in each of these Points, and being opened to a Quadrant, draw Lines which shall be the Hour-lines required; for the Style, that must be erected in the point P, and the top of it must pass through the Center of the Limb of the Concave and be equal to the length of 60 deg. of the Quadrant, or you may erect the Style in the point S perpendicular to S, the length equal to the former, which will shew the hour of the day with the very top of it: for your better instruction see Figure III.

CHAP. V.

To make a South or North Reclining, Declining Concave Dial.

YOur Concave being prepared as before, quartered and divided, one Quadrant into 90 deg. let the Concave be mark'd with the Letters E W N S. Figure IV.
First, draw the Horizontal Line in the Circle S N, from S set off the Reclination to H, one foot of the Compasses in H being opened to a Quadrant, describe the Horizon E M W, in which according to the Declinations from W or E, set off the Declination, and one foot of your Compasses being in that Point with the other describe the Meridian or hour of XII. from M, its intersection with the Horizontal Line in the Meridian set off the Latitude to P, so P shall be the Pole; in P, with the Compasses opened to a Quadrant draw the Equator, and where it's intersected by the Meridian, begin and divide it into 12 equal parts, which you may do by 15 deg. of the Quadrant, your Compasses being opened to a Quadrant, setting one foot in each of these Points, with the other foot describe Circles, which shall be the Hour-lines required; for the Style it must be erected in the Point P, and come to the Center of the Limb, and must be the length of 60 deg. of the Quadrant, or you may as before erect a Style in the Center L, of the same length to shew the hours with its top; for your better instruction behold the Figure. page 62

CHAP. VI.

To make a Polar Concave Dial.

A Polar Concave Dial is no other than an Horizontal Dial in the Latitude of 90 deg. and of all others is most easie to be made, for if you divide the Limb of the Concave Hemisphere into 24 equal Parts, and from the Center of the Hemisphere (by help of a thin Ruler that will bend) draw strait Lines to each of them, those shall be the true Hour-lines.

For the Style, it must be a strait Wire, perpendicularly erected in the Center of the Concave, whose shadow will at all times (the Sun shining) give the hour of the day, and the hours in these Dials must be numbred from XII to XII.

C H A P. VII.

To draw the Hour-lines in a Concave, when the Axis cuts the Hemisphere into two unequal Parts.

Figure V. **L**ET the Hemisphere be $ABCD$, and the Axis ABE , on the Point E describe a Circle, which begin and divide into 24 parts upon some Plain, and from the Center E ; by those parts draw Lines, which shall divide the Circumference $ABCD$ into 24 unequal parts, the Circle CED must be divided into such unequal parts, and they shall be the Points by which the hours must pass; then for the finding of the Center by which the Hour-lines shall pass in the Spherical Body, do thus: To find the Centers of 11 . or 1 . the Hour-line of 11 . is marked FG , divide the Circumference betwixt F and G into two parts at H , so H shall be the Center for the drawing of the Circle of 11 , if E be the Pole, but if A and B be the Poles, then the distance between F and H , or G and H shall be the Centers for drawing of the hours of seven and five, by placing one foot of your Compasses in 7 or 5, and turning the other foot into the Circle CED , shall give the Center for those Hour-lines; and in like manner you must find the Centers for the rest of the Hour-lines. The Stile, (if AB be the Poles) may be a Wire laid from A to B ; but if E be the Pole, then you must erect a Wire in the Point E , equal to the length of the Line EB , as is done upon the Plain, or equal to half the length of the Line AB the top of the Style must hang over the Point E , and be even with the top of the Concave; see the Figure.

C H A P. VIII.

To draw the Hour-lines in a Concave when the Axis doth but only touch the Superficies of the Sphere.

IF the Axis cut the Sphere in one point as P , and the Axis be perpendicular to P ; for the drawing of the Hour-lines do thus, divide the Circumference or Limb into 12 equal parts, beginning at P ; for the drawing of the Hour-lines divide the spaces betwixt P , and the intersections of the Hour-lines in the halves, and those shall be the Centers for the Hour-lines: But if the Axis be APX , then divide the Circle PM into six equal parts; then to find the Centers divide the spaces betwixt the Pole P , and the Divisions into halves, and those Points shall be the Centers of the Hour-lines; for your better instruction behold the Figure.

C H A P. IX.

To describe the Furniture upon Concave Sun-Dials.

S E C T. I. *To draw the Parallels of the Sun's Declination, &c. in any Concave Dial in which the Axis passes through the Center.*

TH E Equator being drawn, set off the degrees of Declination from the Equator in the Meridian of the Plain or Substilar both upwards and downwards; then place one foot of your Compasses in the Pole, and extend the other to those you marked; from the Equator, draw Circles, which shall be the Parallels of the Sun's Declination required, as for example, the drawing two Tropicks, which decline 23 deg. 30 min. from the Equator; take 23 deg. 30 min. and prick it down, in the Meridian both ways, and place one foot of your Compasses in the Pole, with the other extended to the 23 deg. 30 min. describe the two Tropicks, as in Figure I. appears. *page 64 in plain dialling*

S E C T. II. *To draw the Azimuths or Vertical Circles.*

DIvide the Horizon into 180 deg. beginning where it's intersected by the Meridian, if you would draw every 10 Azimuth, then you may only divide it into 18 equal parts, beginning at the same place; but if you would only draw every 15 Azimuth, then divide the Horizon into 12 parts, beginning as before at the Meridian; if you would draw the Points of the Compass, divide the Horizon into 16 parts, then open your Compasses to a Quadrant, place one foot in any of those Divisions, where the other foot intersects the Horizontal Line shall be the Center for drawing that Azimuth.

S E C T. III. *To draw the Almicanthers.*

HAVING found the Points of *Zenith* and *Nadir*, the distance of these Points to the Horizontal Line into 90 deg. one foot being placed on one of those Points, the other extended to those degrees, Circles drawn from one Tropick to another shall give Almicanthers or Circles of Altitude.

The Proportion of the Shadow to a Gnomon may also be drawn on the same manner.

S E C T. IV. *To draw the Planetary or unequal Hours in any Concave Dials.*

FOR the drawing of the Planetary or unequal hours, having first described the Horizon, Equator, and the two Tropicks, divide that part of the Tropick which is intercepted betwixt its intersection with the Horizontal Circle, into 12 equal parts beginning at 12, the Equator being before divided into 12 equal parts by the Hour-lines, open your Compasses to a Quadrant,

one foot being placed in one of those Divisions, move the other foot until you find the Center, which will draw both those Points into one Circle, and draw Circles which shall be the unequal hours required.

SECT. V. *To draw the Hours from Sun Rise to Sun Set, called the Italian and Babylonish Hours.*

Place one foot of the Compasses in the Pole, and extend the other to the intersection of the Horizon and Meridian, and describe the Parallel of the Latitude, which shall be divided into 24 equal parts by the Hour-circles, place one foot of your Compasses in each of those Divisions (the Compasses being opened to a Quadrant) the other foot being placed within the Circle of the Latitude; in the Hour-circle which passes through the Point where the Compasses is set in the Circle; making that the Centre describe Circles from one Tropick to another, which shall be the Hour-lines from Sun Rise to Sun Set; and shall pass by the Intersection of the Hour-lines and the Equator.

You may also draw the *Circles of Position*, the *Signs in the Meridian*, the *Signs ascending and descending*, the *Circles of Longitude*, with many other, as the *Parallels of the length of the Day and Night*, the *Parallels of the Sun's Risings and Settings*, the *Day of the Month*, and the *Zodiack*.

SECT. VI. *To draw the Equator, Parallels of Declination, &c. in a Concave Dial, when the Axis cuts it into two Unequal Parts, or at Oblique Angles.*

ON that Point of the Axis which you assign for the Center of the World describe a Trigon of the Signs, or Parallels of Declination, &c. so the middle Point upon the Limb betwixt those Intersections shall be the Centers for the describing of the Parallels, &c.

I shall not need to give Examples, or make any Scheme for the farther illustrating of what I have here said concerning the inscribing of the Furniture into these Concave Dials, for what hath been already delivered in the Fourth, Fifth and Sixth Tractates, and that which followeth in the Ninth, Tenth and Eleventh Tractates, will make it very obvious to the meanest Capacity, and so I will conclude this of Concave Dialling.

SECONDLY,
Of **CONVEX** **D I A L L I N G,**
S H E W I N G,

*How to make a Dial upon the Convex Superficies of a Globe, which shall shew the Hour by the Shadow, which separateth the En-
lightned Hemisphere from the Opacous.*

TH E Performance hereof is very easie, for (the Globe being truly Spherical) if the *Equinoctial Circle*, the two *Tropicks*, and (if you please) the two *Polar Circles*, which will be necessary for ornament only to be described thereon, and the *Equinoctial* divided into 24 equal Parts, and Points, or Stars, or other marks there made, they shall be the true Hour-points: And if this Globe be set upon a Neck or *Pedestal*, and the Poles of the Globe so elevated and depressed as to respect the real Poles in the Heavens, and one of the Hour-points, which must have the Number VI. set to it, to behold the Meridian of the Place, then will the two XII. of Clock Hour-points behold one the East, and the other the West Parts of the Horizon; And then the Sun at all times shining upon the Globe, will Enlighten one Hemisphere, and the other will be Shadowed, and where the Line of Shadow falleth amongst the Hour-points upon the *Equinoctial*, it shall there shew the hour of the Day in two places; namely, one on the East, and another on the West Side of the Globe. And let this suffice for Convex Sphericals.

THIRDLY,
Of **CYLINDRICAL** **D I A L L I N G,**
E I T H E R
CONVEX or **CONCAVE.**

I. *Of those that fall in a Right Sphere, i. e. such as lie Parallel to the Axis of the World, and their Bases Parallel to the Equinoctial.*

HOur-lines may be drawn upon those Cylinders with great ease and facility, although in them there may be various Positions of the Axis.

I. *If the Axis fall in the very Centre of the Base of the Cylinder; Then, divide the Circumference of the Base of the Cylinder into 24 equal parts, and draw Lines from the Centre to each of those Points, which shall be the Hour-lines for the Base of the Cylinder: — And where those Lines cut the Circum-*

Circumference, Lines drawn from them down the Cylinder's Side, they shall be the true Hour-lines, which will be all parallel each to other.

II. *If the Point of the Axis fall not just in the Center of the Base of the Cylinder.* Through that Point where the Axis falls, and the Centre of the Cylinder draw a line, and with a pair of Compasses take the nearest distance from the Axis-point to the Circumference of the Cylinder, and with that distance upon the Axis-point describe a Circle, which divide into 24 equal parts, (beginning at the Diameter first drawn) Lines drawn from the Axis-point through every of them, and extended to the Side or Circumference of the Base of the Cylinder shall be Hour-lines, and again Lines drawn from thence down the Side of the Cylinder shall be Hour-lines also.

III. *If the Point of the Axis fall in any part of the Periferie of the Cylinder's Base.* Then divide the Circumference of the Cylinder's Base into 12 equal parts, beginning at the Axis-point; Lines drawn from thence to the several Points in the Periferie of the Circle, and also down the Cylinder's Side, they shall be the Hour-lines.

IV. *If the Axis-point fall without the Base of the Cylinder.* Then the distance between that Point and the nearest part of the Periferie of the Cylinder's Base being made Radius, and a Circle (or Semicircle) be thereon described, and divided into 12 equal parts; then Lines drawn from the Axis-point, through those Divisions shall each of them cut the Periferie of the Cylinder's Base in two Points, from which Lines drawn from one to the other (each to his correspondent) they shall be Hour-lines, and from those Points, Lines must be drawn down the Side of the Cylinder also.

More might be said concerning drawing Hour-lines, and other Furniture also, upon Cylinders, and other Solid Bodies either Regular or Irregular, as also of Rings, Quadrants, Parallelograms and other Dials, which give the hour, &c. by help of the Sun's Altitude, the making whereof is so well known to every Artificer, and Maker of Mathematical Instruments, that nothing more of it need be said in this place. And besides the Precepts delivered in the Fourth, Fifth, Sixth, Ninth and Tenth Tractates hereof are so ample, that it were but *Actum agere*, to say any thing more concerning these Matters: And so I conclude this Tractate.

The End of the Eighth T R A C T A T E.

PROJECTIVE DIALLING:

CONTAINING,

Several General and most Easie Ways to *Project* Hour-Lines upon all kinds of *Superficies*, whether *Plain* or *Carved*; *One* or *Many*; *Contiguous* or *Separate*: and that without any regard had to their *Situations*, either in respect of *Declination*, *Reclination* or *Inclination*.

AND ALSO,

How to insert all usual *Furniture* into *Sun-Dials*, drawn upon such *Superficies*; by the Joynt Use of the *Horizontal Projection* or *Planispheres*, and a *Semicircle* or *Quadrant* fitted for those Performances.

The Ninth TRACTATE.

P R O E M E.

THE *Precepts* in this following *Traçtate* delivered, most of them (with little alteration) are the *Inventions* and *Practices* of the late Learned and Industrious Mr. *Samuel Foster*, sometime *Astronomical Professor* in *Gresham College* in *London*; and some of them were Printed, *Anno* 1659. in his *Posthumous Miscellanies*: And others of his (not there Printed) are here added, as they were transcribed out of a *Manuscript* of his, which (for the excellency of many things therein contained) he Entituled *GOLD*. Those which I found there concerning *Projective Dialling* are here inserted: and others which concern *Reflective* and *Refractive Dialling* shall come in their proper places.

The *Precepts* in this *Traçtate* being performed (for the most part) *Mechanically* and by *Instrumental Operation*, and not by *Geometrical Protraction*; apt and proper *Schemes* or *Diagrams* cannot be expected to every distinct *Chapter* or *Section*, for that, to the Ingenious would be unnecessary: And besides, it is supposed the Reader to be already acquainted (at least, in part) with what hath been delivered in the foregoing *Traçtates*; and then, the *Precepts* themselves, without *Examples* will be sufficient for the understanding of what shall be deliver'd in this *Traçtate*: Notwithstanding, There are in several places *Illustrative Schemes* inserted, by which, whatsoever is there only verbally expressed, may be ocularly discerned; nay, I may aver, will give more light to the Ca-

of those numbers, and write them in the sixth Column, under the numbers there already placed, you shall then have the lengths of the Semidiameters of the same several Parallels. And lastly, if from each of these Semidiameters, you take the Tangents of the fourth Column, which were before translated and are already standing in the sixth Column, every couple as they stand, then shall you produce the distances of the Centers of every Parallel, from the Center of your Projection, which is the thing now required. And so the numbers of the second Table are made up also.

See here the Form of the whole Calculation.

The First Table.

	Arches	Halfs	Tangent	Diamet.		
§	28.00	14.00	24932	155254	24932	§
	105.00	52.30	130322		77627	
∩	31.17	15.38	27983	166296	27983	∩
	108.17	54.00	138313		83148	
⋈	40.00	20.00	36397	199582	36397	⋈
	117.00	58.30	163185		99791	
≈	51.30	25.45	48234	255555	48234	≈
	128.30	64.15	207321		127777	
∩	63.00	31.30	61280	336027	61280	∩
	140.00	70.00	274747		168013	
⋈	71.43	35.51	72255	429211	72255	⋈
	148.43	74.21	356956		214605	
∩	75.00	37.30	76732	477810	76732	∩
	152.00	76.00	401078		238905	
I Col.	2 Col.	3 Col.	4 Col.	5 Col.	6 Col.	

The Second Table.

Tab. of Centers.		Tab. of Intersect.	
52695	§	§	24932
55165	∩	∩	27983
63394	⋈	⋈	36397
79543	≈	≈	48234
106733	∩	∩	61280
142350	⋈	⋈	72255
162173	∩	∩	76732

How to make the Table of Intersections, and of Centers more fully.

1. TAKE half the complement of your Latitude, and comparing it with 33 deg. 15 min. find out both the sum, and difference of them, and set this sum and difference in the uppermost cell of the Arches answering to *Cancer* 00 deg. and for better distinction, note them with A and B. These two numbers are for the first point of *Cancer*, and are as Radical Numbers, by help of which all the rest are made.

2. To these two numbers A and B, add such numbers of the Table following as do stand at such degrees (of every Sign) as you intend to put into your projection (as in a large one of 30 inches diameter, you may insert every degree, or each two degrees for one of 15 inches, or each third degree for 10, or each fifth degree for six inches diameter) and place each couple of these last Products in one cell, so shall you make up the column of Arches, such as in the following Table made for the Latitude of 51 deg. 30 min. to the beginning of each Sign, only for an example.

3. For these Arches of the first column, set the Tangents belonging thereto, as appeareth in the second column by the numbers C and D, &c.

4. Then for the third column of Diameters, and Semidiameters, it is thus perfected, add the two Tangents standing together in each cell, and put the sum of them in the third column, in the same line with the uppermost of the second column; So shall these sums be the Diameters of such Parallels in the Projection as do pass through the above-mentioned degrees, chosen for the Projection. So C D added together, make E: G H make I: L M make the number N, &c.

5. If half these Diameters be taken, by a Bi-section of the Diameters before found, the same will be the Semidiameters, and are to stand in the same third column, as the second line in each cell sheweth; So E being Bi-sected makes F, I makes K, N makes O, &c. From these thus prepared the two fore-mentioned Tables will easily be excerpted in this manner.

6. The inferiour Tangents of each cell in the second column, are the very numbers which do make up the Table of Intersections. If therefore, they be only transcribed, you shall have the same Table perfected, as H M, &c. in the second column being transcribed, will make up P Q R, &c. the full Table of Intersections.

7. The differences of the inferiour numbers of the second and third columns, being gathered into the particular cells of the Table of Centers, do make up the numbers of that same Table; So D taken from F, makes S: H taken from K, gives T: and M from O, makes V: &c. And thus are the two Tables to be made up.

A Table for the Horizontal Projection, made to the Latitude of 51 Degrees 30 Minutes, shewing where every Parallel that passeth through each Degrees of the Ecliptick is to cut the Meridian Line.

The Table of Intersections.

	♈	♉	♊	♋	♌	♍	
0	2493	2802	3640	4823	6128	7226	30
1	2493	2826	3676	4867	6172	7252	29
2	2493	2842	3709	4910	6212	7259	28
3	2496	2864	3746	4953	6253	7306	27
4	2500	2886	3782	4997	6297	7332	26
5	2503	2908	3819	5040	6338	7359	25
6	2506	2931	3855	5084	6379	7382	24
7	2512	2956	3892	5128	6420	7404	23
8	2515	2981	3929	5169	6457	7427	22
9	2521	3003	3966	5213	6498	7449	21
10	2527	3029	4006	5258	6540	7467	20
11	2537	3057	4047	5302	6577	7490	19
12	2543	3083	4084	5347	6615	7508	18
13	2552	3108	4122	5388	6652	7522	17
14	2561	3137	4163	5433	6690	7540	16
15	2571	3166	4200	5479	6728	7558	15
16	2583	3195	4241	5500	6766	7572	14
17	2596	3224	4283	5566	6805	7586	13
18	2608	3252	4321	5608	6839	7600	12
19	2620	3281	4362	5654	6873	7609	11
20	2633	3314	4404	5696	6911	7623	10
21	2645	3343	4445	5739	6946	7632	9
22	2661	3375	4487	5785	6976	7641	8
23	2676	3404	4526	5828	7011	7646	7
24	2692	3437	4568	5871	7046	7655	6
25	2708	3469	4610	5914	7076	7659	5
26	2726	3502	4653	5957	7107	7664	4
27	2745	3538	4695	6001	7137	7669	3
28	2764	3571	4738	6044	7168	7673	2
29	2783	3607	4781	6084	7199	7673	1
30	2802	3640	4823	6128	7226	7673	0
	II	♈	♉	♊	♋	♌	

The Table of Centers, for the Latitude of 51 Degr. 30 Min.

This Table sheweth how far the Centers of every of the former Parallels, are from the Center of the Horizontal Circle in the Horizontal Projection.

	☿	♈	♊	♉	♊	♈	
0	5269	5519	6339	7954	10673	14235	30
1	5269	5535	6380	8026	10789	14342	29
2	5269	5554	6418	8099	10897	14451	28
3	5272	5573	6460	8173	11006	14562	27
4	5274	5593	6502	8249	11129	14674	26
5	5277	5612	6545	8326	11243	14787	25
6	5279	5631	6589	8404	11359	14883	24
7	5284	5654	6633	8484	11477	14980	23
8	5286	5677	6678	8558	11586	15078	22
9	5291	5697	6724	8641	11709	15177	21
10	5296	5720	6775	8726	11834	15258	20
11	5203	5746	6826	8812	11949	15359	19
12	5308	5770	6874	8899	12066	15441	18
13	5315	5794	6922	8981	12185	15503	17
14	5323	5820	6976	9072	12306	15587	16
15	5330	5849	7026	9165	12430	15670	15
16	5340	5876	7082	9252	12556	15735	14
17	5350	5904	7138	9348	12684	15799	13
18	5359	5933	7191	9438	12800	15864	12
19	5369	5961	7249	9538	12918	15907	11
20	5379	5994	7308	9682	13053	15973	01
21	5390	6023	7369	9727	13175	16017	9
22	5402	6056	7430	9833	13284	16061	8
23	5415	6086	7487	9932	13411	16083	7
24	5428	6120	7550	10034	13539	16128	6
25	5440	6154	7615	10137	13653	16150	5
26	5456	6189	7680	10242	13770	16172	4
27	5472	6228	7747	10349	13888	16195	3
28	5487	6263	7815	10458	14007	16217	2
29	5503	6303	7884	10560	14129	16217	1
30	5519	6339	7954	10673	14235	16217	0
	II	♈	♊	♉	♊	♈	

Thus

Thus are these two Tables to be made up.

	Arches.	Tangents.	Diameters and Semidiameters.			Intersections	Centers	
☉	A 52.30 B 14.00	C 130322 D 24933	E 155255 F 77627	☉		P 24933	S 52694	☉
☾	X 54.09 X 15.49	G 138399 H 28015	I 166414 K 83207	☾		Q 28015	T 55192	☾
☿	Y 54.30 Y 20.00	L 163185 M 36397	N 199582 O 99791	☿		R 36397	63394	☿
♈	Z 64.15 Z 25.45	207321 48234	255555 127777	♈		48234	79543	♈
♉	70.00 31.30	274748 61280	336028 168014	♉		61380	106734	♉
♊	74.21 35.51	356957 72255	429212 214606	♊		72255	142351	♊
♋	76.00 37.30	401078 76732	477810 238905	♋		76733	162173	♋

Præcepta superiora, characteribus compendiosè expressa.

$$33 \text{ Deg. } 15 \text{ min. } \pm \frac{1}{2} \text{ Complement Latit.} = \frac{A}{B}$$

$$\frac{A}{B} + b, c, d, \&c. \text{ in tab. sequ.} = X, Y, Z, \&c.$$

Quorum arcuum Tangentes sunt C, D, G, H, L, M, &c.

$$C + D = E. \quad G + H = I. \quad L + M = N, \&c.$$

$$\frac{E}{2} = F. \quad \frac{I}{2} = K. \quad \frac{N}{2} = O, \&c.$$

D=P. H=Q. M=R, &c. Atque hæc est tabula Intersectionum.

F-D=S. K-H=T. O-N=V, &c. Atque hæc est tabula Centrorum.

And here, it must not be forgotten; that the Precepts of making up these Tables, are proper to those Latitudes that exceed 23 deg. 30 min. for in those Latitudes, which are less than 23 deg. 30 min. some North Parallels will not intersect upon the South part of the Meridian at all, but altogether upon the North, and then, for such Parallels, their North Declinations must not be taken out of the Latitude, but the Latitude out of them, and so the Superiour Arches of the second Column will at first decrease in such Latitudes, and after again increase, and the Diameters in the first Column (for such Parallels as are altogether North, of which only we now speak) must be made by the Differences (not Sums) of the Numbers of the fourth Column; And the Sums (not Differences

rences) of the Numbers in the Sixth Column, give the Distances of the Centers of such Parallels we now mention, from the Center of the Instrument. Now to know how many degrees of Declination will intersect both Lines on the North side of the Meridian, in a North Latitude is easie: Namely, all those Parallels whose Declination from the Equinoctial is greater than the Latitude, and none else. And for those only, all this caution is made; The rest of the Table for other Parallels must be finished as before prescribed, and what is true here of North Latitude, and North Parallels, is respectively true of South Latitude, and South Parallels.

SECT. III. *The Delineation of the Parallels upon the Instrument.*

After you have described the Circle upon the Horizon (which is to contain the whole Work) and quartered the same, and set out partitions for the limb, to divide it as the usual manner is into 360 deg. you are to make a *Decimal Scale* of the same length, with the innermost Semi-Diameter of your Instrument, for this Scale by help of your Tables will pitch out the whole Work.

For looking first into your Table of Intersections, see what the first Number there is, namely, 24932, take this in your Compasses upon your Decimal Scale from 2 forward, as the Letters of *a* and *b* do declare; the same length of *ab* will reach upon the South part of the Meridian, from Z the Center of your Instrument unto A upon the Meridian Line, which gives the Point of Intersection between the Parallels of α , and the Meridian. So the second Number being taken in your Compasses from the Decimal Scale, will give the length Zc, shewing where the Parallel of α and π is to pass through the Meridian. The third Number so ordered, will give the Point *i*, the fourth *o*, the fifth *u*, the sixth *m*, and the last will give *x*, where the rest of the Parallels of π and γ , α and ν , π and κ , γ and ω , and lastly ω , must intersect with the Meridian.

After these Points of Intersections, you are next to prick down your Centers answering to them. For the first Number in the Table of Centers being taken from the Decimal Scale, and pricked down upon the North part of the Meridian from Z (towards N) and it will reach to A. And so the second Number will be extended from Z to E, the third from Z to I, the fourth to O, and the fifth to V, the sixth to M, and the seventh and last to X.

Having gone thus far, the rest will be easie; For if you set your Compasses from A, the first Center, to *a* the first Intersection, you may describe the first Parallel of *Cancer*: And so if from E the second Center, you extend to *e* the second Intersection, you shall describe the second Parallel passing through *e*: and so forward with the rest, having due regard to every Intersection, with his proper Center: And thus are the Parallels to be described, amongst which that which passeth through *o*, is the *Æquinoctial*, and if it be true done, will pass through W and E, each tenth Parallel must be distinguished with somewhat a bigger Line than the rest, and where every fifth or third will not come in for want of due space, as about *Cancer* and *Capricorn*, where they grow close, there may you put in every fifth or tenth only, which will serve in those narrow spaces as well as more.

SECT. IV. *The Delineation of the Hour Circles.*

First, you must prick down the North Pole (which in our supposition is elevated 51 deg. 30 min.) in this manner. Take the Complement of the Latitude, viz. 38 deg. 30 min. and half it, which will be 19 deg. 15 min. seek then the Tangent of 19 deg. 15 min. you shall find it to be 34921, take this upon your Decimal Scale, and prick it upon the North part of the Meridian from Z, towards N, you will find it to fall in P, that Point P therefore is the North Pole in this Projection, through which all the Hour-circles now to be drawn must pass.

The first hour Circle to be described is the hour of six, upon which all the rest have their dependance; now to effect this, you are to look for the Secant of your Latitude (which is as before 51 deg. 30 min.) which will be found to be 160638, this Number taken out of the Decimal Scale must be extended upon the South end of the Meridian from P, and you shall find it will reach unto B; upon B therefore as your Center with the distance B P, describe the Hour-circle of 6, which, if all be right, will pass through the Points of E and W exactly, where the Equinoctial also cutteth, if it be justly described; now through the Point B, with the Center of this hour of 6, draw the infinite Line C B D, both ways perpendicular to the Meridian Z S B, for upon this Line shall stand all the Centers of the other Hour-circles, which to design you are to work thus:

Make a second *Decimal Scale*, equal in length to B P, the Semidiameter of the hour of 6, then by help of the Canon of Tangents, take out of this Scale, first, the Tangent of 15 deg. or 1 hour, which will be 26794, and prick it down upon the infinite Line C D, both ways from B to F, and from B to G; Again seek the Tangent of 30 deg. which is 57735, and take it in the same Scale, and prick it down upon the Line C D, both ways to H and I; Thirdly, seek the Tangent of 45 deg. 100000, which set as before, will just reach to C and D. Then fourthly, the Tangent of 60 deg. 173205 will so reach to K and L: Lastly, set the Tangent of 75 deg. which is 373205, from B to R, and from B to T. This done, if now you set one foot of your Compasses in F as Center, and open the other to the Point P in the Instrument, you shall describe the Hour-circle of 7, on the East side of the Meridian, and carrying one foot with the same extent unto G, will reach unto P again, which swept on the other side, will describe the hour of 5.

* The Line C D is supposed to be infinitely extended from B, both ways, and therefore (for want of room in this place) the Letters R K and L T could not be in this Figure placed according as their true Tangent distances do require.

So also in the same manner may you describe from H and I, as two Centers of the hour, of 8 and 4, passing through the same Point P; And upon the Centers C and D as before, you may describe the hours of 9 and 3; * And from K and L, the hour of 10 and 2. Lastly, from R and T, the hours of 11 and 1, all which are exactly to pass through P the Pole; And so the like is to be done for the half hours, &c.

Thus have we done with those Lines which do properly belong to the Projection: but because the Instrument, if it pass thus, will not perform all the uses for which it is intended, I have therefore added other Lines to it, which may well stand without defacing any of the Work, the description whereof is in brief, as followeth.

SECT. V. *The Description of what Lines are added to the Projection, which vary not with the Latitude, as the Projection it self doth.*

COUNT from N to ∞ and ∞ , both ways upon the Limb, the Sun's greatest Declination $23\frac{1}{2}$ deg. and draw the Chord $\infty \infty$, then look the Secant of 23 deg. 30 min. in the Canon of Secants, which will be found 109044 , take this upon your first Decimal Scale, and prick it down upon the Meridian from Z to h , then again setting one foot of your Compasses in h , open the other to ∞ , and describe the Arch ∞, r, w .

Again, Having obscurely drawn the cross Diameter of East and West, take so much of it as may conveniently be used on both sides the Center, namely, Z ∞ , and divide it into 11 equal parts, and of the same equal parts let Z r upon the Meridian contain 12 , then draw the two strait Lines $r \infty$, on both sides of the Meridian: these may be called the Triangular Lines, to distinguish them from the rest: Thus are all the Lines to be drawn, now follows the manner of their Division.

SECT. VI. *The Division of the Triangular Lines.*

DIVIDE each of those Lines first into two equal parts at b and d : then again divide each of those halves $b r b \infty, d \infty, d \infty$ into 45 such parts as a Tangent Line of 45 deg. or a Radius of that length would require, so shall each of the whole Lines contain 90 parts, unto each 30 Division whereof are the Characters of the twelve Signs to be set.

SECT. VII. *The Division of the Arch and Chord.*

ON the Limb of your Instrument, number the Complement of Latitude from N to p , and draw the infinite Line Zp , then prolong the Chord ∞ and w both ways, so shall it meet with Zp , at n ; Now to the Radius $b n$, describe the Semicircle nkr , cutting the Meridian extended at k , and divide this Semicircle into 180 equal parts, or degrees; which done, if you first draw right Lines from each degree thereof to the Center b , and beyond, till it cross through the Arch divided in the Instrument, (as you see each 30 th degree in the Scheme doth) you shall by that means divide the Arch into its proper parts. Secondly, if from each degree on both sides k , you draw Lines parallel to the Meridian of the Instrument Zk , till they cut through the Chord, they will so divide the Chord into its requisite parts.

*The Line $r n$ is
a Line of Ver-
sed Sines.*

Hitherto have you near had the whole description of the Instrument it self in every part, after which all superfluities being first drawn away, you must affix such Characters and Figures as are necessary to help you in your several Accounts; to the effecting whereof, the Picture it self will be of sufficient direction, and much better than many Words.

SECT.

SECT. VIII. *Of the Ruler.*

THere remains only a Ruler to be fitted to the Instrument, the breadth whereof may be as you will, about the 10th or 12th part of the length, and the length to reach over as a Diameter to the whole Planisphere, you must take care that the fiducial edge be very strait, and at the middle of it a little Semicircle left, whose Center A, being truly placed, upon the very middle Point of the fiducial Line must be pierced through with a small hole, that so it may be fixed through it, to the Center of the Instrument at Z. Next of all, you are to fit the Ruler for the Graduation, which is done by drawing two Lines parallel to the fiducial edge; one very near it to receive the degrees, the other farther off, to receive the Figures for Distinction, and Numeration.

For the Graduation of it, set off the length A B both ways from A, equal to Z N, the Semidiameter of the innermost Circle of the Planisphere, which is also equal to your first Decimal Scale; then the easiest way to graduate it will be by the joynt help of the Canon of Tangents, and your Decimal Scale, in this manner; look into the Canon for 45 deg. and it will be 100000, equal to the number of the whole Scale, and those are signified upon the Ruler already by A B, A B; then look half a degree less, namely, $44\frac{1}{2}$ whose Tangent is 98269, take that out of your Decimal Scale with your Compasses, and setting one foot in A, with the other draw the first Division, between the edge and the parallel Line next to it, upon both sides the Center A; Then again, Look the Tangent of half a degree less, *viz.* 44, whose Tangent is 96568, which take off, and set it both ways from A, as before, and thus proceed by half degrees till you have gone down through the forty five first whole degrees of the Canon, and then you shall find that you have inscribed twice 45 degrees, that is 90 parts upon each half of the Ruler, which represent such degrees as here are required, every 10th and 15th of them must be distinguish'd from the rest with a longer Line, and numbred inwards towards the Center by 10, 20, 30, &c. to 90, as in the Figure sufficiently appeareth. After this is ended, you are to pin down the Ruler to the Instrument, as is before shewed, and then will your Planisphere be fitted to the uses which now follow.

C H A P. II.

An Explanation of the Circles, and Lines in the Projection.

THE Limb of the Planisphere representeth the Horizon of the place for which it is made; The Diameter N S stands for the Meridian whose Sections with the Horizon at N S, signifie the North and South Points of the same Horizon, and the Points W and E, being each a quarter of the Circle distant from the former, do represent the Points of East and West, and a Diameter drawn through them and the Center, is the prime Vertical or East and West Azimuth; The Center noted with Z, signifies the Zenith or Pole of the Horizon. The Ruler therefore, being fixed thereto, shall represent any Azimuth, or Vertical Circle, all which do pass through the Zenith Point, and the degrees and numbers upon the Horizon, will shew what Azimuth from North or South; the Ruler being fixed at any place doth represent.

represent. The degrees upon the Ruler denote the degrees of any, or all the Azimuths, and so perform the Office of Almicanthers, or Parallels of Altitude above the Horizon.

Within the Projection it self, the Point P upon the Meridian signifies the North-Pole, and all the Circular Lines meeting there, (but spreading over the whole Superficies) are the Meridians of the Sphere such as stand for the hours of the place, according whereunto they have their Figures set upon them, shewing what hour each of them stand for.

The Parallels which cross through the Meridian, or Hour-circles, are the Diurnal Arches of the Sun at several times of the year; There are so many of them drawn as the Instrument will well contain, the rest must be supplied by imagination to pass between them that are drawn; even so many as may answer to every degree of the Ecliptick. And according to that supposition, each 30th deg. or Parallel hath such Characters, or Signs annexed unto it, as it doth cut through in the Ecliptick, and the intermediate Lines stand for those 30 Parallels that pass through the 30 degrees of each Sign, and accordingly must be estimated, and numbred.

The other Lines which are inserted, are not properly of the Projection, neither shall any explication of them be needful, more than when it is treated to shew the use of them.

C H A P. III.

The Use of the Planisphere, digested into several Propositions.

Some of the Propositions of this Chapter have been delivered by others, what I have added of my own, or omitted of theirs, may easily be found by comparing their Books with this. Their only purpose being barely to perform these things upon the Instrument, and to go no farther; that use indeed may be made of this Chapter, but my intent is beyond these, for that which is here performed is premised only, and prepared for what is to be done in the next Chapter, which is the only aim and scope, which these three first Chapters drive at.

SECT. I. *To find the Degree of the Ecliptick that the Sun is in every day, and the Parallel belonging to it.*

YOU may know the degree of the Sun in the Ecliptick (if no better way) well enough for your purpose by remembring the day upon which in every Month it entereth into the several Signs, and allowing the motion of it, to be one degree every day, so shall you know how many degrees it is gone into any Sign, or how many degrees it wants to come to the beginning of the Sign, as *Aug. 7th* I know the Sun entreth into ♈ the 13th day, and that the 7th day wants six days of the 13th: Therefore I conclude the Sun to want six degrees of ♈, and so to be in the 24th of ♎; And again, for *Aug. 16*, because 16 is three days more than 13, (the day of the Sun's entrance into ♈) therefore I say that the Sun is in the third degree of ♈: And these Notes give (near) their beginning, *Jan. 11 ♎, Feb. 8 ♏, March 10 ♐, April 10 ♑, May 11 ♒, June 11 ♓, July 13 ♈, Aug. 13 ♉, Sep. 13 ♊, Octo. 13 ♋, Nov. 12 ♌, Dec. 11 ♍,*
U u u Then

Then to find the Parallel for 7th of *August* is not hard; For if you remember every Sign hath 30 Parallels upon the Planisphere, (either expressed or to be supposed, or supplied by imagination) you may accordingly find where the 24th Parallel from α to π is to be placed, and so imagine a Line to run all along even with the rest, and the same shall be the Parallel of the day, and the like may be done for all the days of the Year.

SECT. II. *At any time to find the Sun's Azimuth.*

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Observe the Sun's Altitude, or in what Almicanther the Sun is by a Quadrant, or otherwise, as is shewed in the fourth Chapter by the Semi-circle, count this Almicanther or Altitude upon the Ruler, and (keeping it upon the due Coast from South, either Westward, or Eastward, according as you made your observation either in the Morning or Evening) move it till the Altitude thereon numbred, do meet with the Parallel of the day whereupon your observation was made, and there fix it, so shall it lie in the same Azimuth wherein the Sun at the time of observation was, and the Numbers in the Horizon or Limb, will give you how many degrees that Azimuth is from the South, if it shall be required: Example, at *London*, Latitude $51\frac{1}{2}$, observation made *Aug.* Seventh, the Sun in α 24, Altitude 35 Evening, Parallel α 24, Azimuth $65\frac{1}{2}$.

SECT. III. *To find at what Altitudes above, or Profundities (or Depressions) under the Horizon, every Hour-circle cuts upon any Azimuth.*

The Ruler being laid to the Azimuth, as in the former Proposition, or otherwise, will shew the things required of it self. As supposing the Azimuth to be $65\frac{1}{2}$ from South toward the West, as was now found out, then shall the hours above the Horizon cut those number of degrees and minutes. Namely, 12 cuts 90, as it ever doth, 1 cuts 79, 2 cuts 63, 3 cuts 43, 4 cuts $17\frac{1}{2}$ deg. and these are to be accounted Altitudes above the Horizon: then out of the other part of the Ruler, 5 cuts 7 deg. 6 cuts $27\frac{1}{2}$, 7 cuts $42\frac{1}{2}$, 8, 53, 9, 63, 10, $71\frac{1}{2}$, and 11 cuts 80 deg. below the Horizon. And note ever, that from the Center of this Instrument towards that part of the Ruler whereon the Altitude of the Sun, and parallel for the day do intersect, I say on that half of the Ruler the Intersections of the hours are to be accounted Altitudes from the Horizon to the Zenith of those very hours that do intersect: On the other part of the Ruler the Sections are to be esteemed Depressions, or Profundities under the Horizon down to the Nadir, not of those hours that do intersect the Ruler on that Coast as they are placed on the Instrument, but of their opposite hours in the contrary part of the Heavens; which they may well do because each opposite hours are equal in this respect, one to the other; and so in our Example though 5, 6, 7, &c. hours lie upon the North-East part of the Horizon upon the Morning, yet by them you are to understand the same hours of 5, 6, 7, &c. on the South-West part of the Heavens on the Evening tide.

SECT. IV. *To find what Number of Degrees each Hour beareth from 12, upon the Limb or Horizon of the Instrument.*

THis is easie to be done, for in a Projection for *London*; you shall find 11 and 1, to be distant from 12 at Noon, 11 deg. 51 min. 10 and 2 are distant 24 deg. 19 min. 9 and 3, 38 deg. 3 min. 8 and 4, 53 deg. 35 min. 7 and 5, 61 deg. 6 min. 6 and 6 are distant 90 degrees. So likewise, you may find 5 in the Morning, and 7 at Night, to be distant upon the Horizon from the South 108 deg. 54 min. and 4 in the Morning with 8 in the Evening to be distant 126 deg. 25 min. the use of this Proposition will appear in the next Chapter.

SECT. V. *To find upon the Planisphere, 1. The Parallel of the 12 Signs. 2. The Parallel for every length of the Day. 3. The Parallel of every known Declination.*

1. **F**Or the first, which are the Parallels of the beginnings, or any other part of every Sign, the Instrument it self will shew readily, because there are the Characters of the Signs annexed to them, and these Parallels are so framed that they answer to each degree of the Ecliptick, as in the structure of the Instrument is declared, and in this Chapter, Proposition the first.

2. For the Parallels noting out the just length of day, look into the Arch and Chord mentioned *Chap. 1. Sect. 7.* for those two Lines will help you in this fully after this manner. Let the day be 14 hours long, take $\frac{1}{2}$ that length, viz. 7, that shews the time of Sun-setting; to this time reckoned in the same Chord now mentioned apply your Ruler, so shall it shew you upon the Arch, the place in which the Sun is at that time when the day is 14 hours long, which is γ or α , 29 at *London*. If then according to Proposition 1. in this Chapter, you look for that degree of *Taurus* 1, or *Leo* 29, amongst the Parallels there may you affirm the Parallel for that length of the day to pass along, so if the length of the day had been $10\frac{1}{2}$ hours, half that length $5\frac{1}{4}$ shews the time of Sun-set. If therefore you look upon the Chord of 5 hours 15 minutes of an hour, which is as much as $3\frac{3}{4}$ deg. and thereto apply the Ruler, you shall find it to cut upon the Arch of $\approx$ 22 or $\times$ 8 degrees, which are the degrees of the Ecliptick wherein the Sun being makes the day of 10 hours and 30 min. length.

3. The manner to find the Parallel upon your Instrument answering to any known Declination, may be seen by an Example. Suppose the Declination from the Equinoctial to be $15\frac{1}{2}$ deg. Northward, count that Declination upon the Limb of your Instrument from N towards W, and thereto lay the Ruler, which will also immediately shew you upon the Arch the Sun's place to be γ 11 or α 19. And if the same Declination had been Southerly, then must you have counted it on the Limb from N towards E, and the Ruler there laid shews upon the Arch the degrees of the Ecliptick answerable, to be μ 11, $\approx$ 19, if then according to the first Proposition, you look for the Parallels of those degrees in that Instrument, they shall be the Parallels of the fore-named Declinations.

SECT. VI. *The Intersection of any Hour-circle with any Parallel being assigned, to find what Altitude the same shall have above the Horizon.*

THis is useful for many purposes, (as hereafter is shewed) and most easie to be performed; For having your Parallel given, you by the last Proposition, shall see quickly where every Hour-circle cuts through the same; unto those Intersections apply your Ruler, so shall the degrees of the same Ruler, being counted from the Horizon, shew you the Altitudes required: So in α 1, or α 29, when the day at *London* is 14 hours long, the Sun's Altitude at 9 or 3 a Clock will be 36 deg. above the Horizon: And in α 19 degrees, the Sun's Altitude at 9 and 3 a Clock, will be $38\frac{1}{2}$ degrees; and so of all other Parallels and Hours.

SECT. VII. *The Descendant Point of the Ecliptick being assign'd, to find, 1. What Point of the Ecliptick is in any Hour-circle, and 2. What Altitude it hath.*

Example; **L**Et the beginning of *Leo* descend at *London*, I would then know what degree of the Ecliptick is in the hour of 3, and in the hour of 10, at that very instant: First, I lay the Ruler upon the beginning of α counted in the Arch, where I shall find it to cut upon the Chord 7 hours, and 9 degrees, which hours are to be taken for Afternoon hours: Now from 3 a Clock to 7, and 9 degrees Afternoon, are 4 hours, and 9 degrees, which turned into degrees, makes 69 degrees: And so from 10 a Clock, to 7 and 9 degrees Afternoon, are 9 hours, and 9 degrees, or 144 degrees: These being fore-knownn, go to the Triangular Lines, and because the Sign descending is supposed to be α , lay your Ruler at α in that Line betwixt N and E, and mark where it cuts the Limb, namely, at $2\frac{1}{2}$ degrees from 60 towards 50. Now from hence count upon the Limb *secundum ser. signorum*, 69 degrees, your first number of degrees, which will fall between N and W upon $11\frac{1}{2}$ degrees, whereto again lay your Ruler, which you shall find to cut upon the Triangular Line $\approx$ the 12, almost; And this is the degree of the Ecliptick which is in the hour of 3, when the beginning of α is descending at *London*; And if you apply the Ruler to $\approx$ 12, in the hour of 3: the Altitude of it shall be $21\frac{1}{2}$. Secondly, lay your Ruler again at α in the Triangular Line, that it may cut $2\frac{1}{2}$ degrees, from 60 towards 50, and from the Ruler so laid, count 144 degrees, which is the Number for 10 a Clock, so shall the Number go from N towards W $84\frac{1}{2}$, whereto if you apply your Ruler, you shall find it to cut about the 25th deg. of τ , and this is the degree of the Ecliptick that is in the hour of 10, when the beginning of α is descending under the Horizon at *London*, and if you apply the Ruler to τ 25 deg. in the hour of 10, you shall find the Altitude of it $10\frac{1}{4}$. The like may be done for any other Sign, or degree; And remember that when α is descending, then is $\approx$ the opposite Sign ascending above the Horizon, and what is done for the descending of α , is likewise done for the ascending of $\approx$.

SECT. VIII. *The Culminant Point of the Ecliptick being assigned, to find at that time; 1. What Point of the Ecliptick is in any Hour-Circle. 2. What Altitude it hath there.*

THe Culminant-Point, is that Point which is in the Meridian at any time. This Work will be somewhat easier than the former, as will best appear by an Example: Suppose at *London* (or any where else, for the first part of the Proposition is general, and therefore a man may make Tables if he list, for this first part of the Proposition, which will serve for all Latitudes) the beginning of *Leo* were Culminant, and I would know what degree of the Ecliptick is in the Hour-Circle of 8 in the Morning: Because from the Meridian to 8 a Clock, is 4 hours, or 60 deg. and that forward *secundum seriem signorum*, therefore first I apply the Ruler to α in the Triangular Lines, where it cuts in the Limb $2\frac{1}{2}$ deg. from 60 towards 50; from thence I count 4 hours or 60 deg. forwards towards N, which will fall in the Limb upon the quarter N, W, or $2\frac{1}{2}$ deg. from N, and then the Ruler shews upon the Triangular Line about ≈ 3 deg. to be in the 8 a Clock hour: Now the Altitude of that Point in that hour, is 17 degrees, as the Ruler applied to it will shew: Again, if the beginning of α be supposed Culminant, and I would know what degree is in the hour of 5 Afternoon at that same time; because from the Meridian to 5 a Clock, are 75 degrees, and that *contra ser. signorum*; therefore having first laid the Ruler upon the beginning of α in the Triangular Lines, which cuts as before, $2\frac{1}{2}$ deg. from 60 towards 50, in the Limb, from whence I count backwards towards E and S, in the Limb 75 deg. which will fall upon $4\frac{1}{2}$ deg. from 50 toward 40 in the South Equator, and the Ruler being laid here will cut upon the Triangular Line on the opposite part of the Instrument about the 19 deg. of γ , and such is the deg. of the Ecliptick, which possesseth the hour of 5 a Clock Afternoon, when the beginning of α is in the Meridian.

Then for the second thing which is particular to every Latitude, if you apply the Ruler to the 19 deg. of γ , in the hour of 5, you shall find the Altitude of that Point to be 23 deg. in the Latitude of *London*: The opposite Points are in the opposite hours below the Horizon, at the same time when the beginning of α is in Culmination, or the beginning of the opposite Sign $\approx$ is in *Imo Caeli*, is as easie to be understood.

What Propositions soever are here done for hours (as what Altitude any thing hath upon Hour-circles,) do the same also upon Azimuths, for there will be need of them hereafter, in putting the Furniture into refracted Water-Dials, &c.

APPENDIX.

The Description of the SEMICIRCLE.

THE Semicircle it self, and the two Squares that are in it, are so commonly known, that I shall not need to say any thing of the Division of either of them, especially since the Figure of it is here ready to represent the same as fully as can be required; only remember that I call M N the Semidiameter of it, and L K the Diameter.

The difficulty that is, is in the contrivance of it. The Limb above the Semicircle noted with I K, must be of such breadth, that if the Thread hang upon the Diameter L K, the Plummets may have liberty enough without touching the Ruler A B at all: upon that breadth also you are to set two Loops as at E and F, through which the Ruler must have just room to slip up and down as occasion shall be: and that it may be fastned from slipping when it is required it should be fixed, you must either make two Scrues at the back-sides of those Loops, or two Wedges, such as are signified by G and H, which Wedges must be so shaped, that though they be loosed, yet they shall not slip out, and to that purpose, at their lesser ends they have little knots left, as the Figure declares. Yet if you draw out the Ruler to turn the other edge of it towards the Semicircle, (as sometimes of force you must) then may the Wedges be taken out if need require; and again, first, put in before the Ruler, that when the Ruler is put in, they may be kept there, and not lost. The Ruler being thin as of Brass, or other Metal, such as this Figure represents, must be sharp at both ends of one of the Edges, as the Picture shews, but if it be of Wood, and so become of more thickness, then must you line the two very ends of the edge of your Ruler with a little plate of Brass like the Figure R O P, laid in strait and even with the end of the Ruler, and at the end of that plate make two sharp points, as O and P do manifest, standing even with the two very edges of the upper flat of the Rule; And so the other end of the Rule must be placed upon the same edge in the same manner.

Let the Ruler be about three times the length of the Diameter of the Semicircle.

Now instead of this Semicircle in narrow places, and where room is wanting, may a Triangle of past-board be used for the elevation, or depression of any thing, the Figure whereof appears with the Semicircle.

The use of the Semicircle is general; As upon a Line drawn any where, to project any Altitude or Depression above or below the Horizon, from a fixed Point that stands at a distance from that Line.

It will be convenient to have 2 or 3 Semicircles of several bignesses.

THE manner is easie: For if you hold the edge of your Ruler to the fixed Point, and also apply the point of that edge to the Line given, removing it higher, or lower, till the Thread hanging down by the side of the Semicircle directed to it, at full liberty, do fall upon the Altitude intended, then doth the Ruler lie at the Altitude or Depth, and project it from the fixed Point

Point into the Line, as is required: You must in this Work (as occasion is) turn the Ruler, and remove your Semicircle, and so in other occasions.

¶ Note, That wheresoever in the following Precepts I mention the Semicircle, a Quadrant so fitted with a Ruler, and divided on both sides, will sufficiently serve the turn.

C H A P. IV.

A general and most easie way to project Hour-Lines upon all kinds of Superficies without any regard had to their standing, either in respect of Declination or Inclination.

LET a Gnomon, being first sharpened into a Point, be shaped, and fastned in such wise, that it no way hinder either the draught of the Horizontal Line, or the Point of the shadow from having free access to the Dial at all times of the Year.

2. Draw an Horizontal Line, by help of your Semicircle in a true Level both in regard of it self, and also to the Point of the Gnomon, through the whole Superficies on which the Dial is to be described. Or having two Points in the same Level with the Point of the Gnomon, project it upon your Superficies, if it be a rugged one. And if the Superficies be more than one, or if any of them be very much inclined toward the Horizon, or else be very rugged, or far remote from the Gnomon, so that it will not at all, or not so well, receive an Horizontal Line upon it, you may *Either* set up some Board, or such like Object, upon which for a time you are to inscribe the Horizontal Line, and by help of which the Hours are to be projected upon the Superficies; Or else (which perhaps will be better) you may extend a Thread in the Air (it matters not which way, nor whether from the Gnomon towards the Sun, or from the Sun: whether stretcht out in one length, or with returns, so long as it lieth justly parallel, in every Point of it, to the Horizon, and in the same Level with the Point of the Gnomon:) which being fixed in this manner, will very well supply the use of the Horizontal Line: or the Horizontal Line may be partly Thread, and partly drawn upon the Superficies, as occasion shall be. And upon it may any Point be transferred, and signed out by slipping knots of Thred tied upon it.

3. Upon the Superficies of the Dial, observe the Point of the Shadow of the Gnomon (making a mark at it) and the Sun's Altitude, both of them at the same instant of time.

4. By the Altitude observed, compute the Azimuth of the Sun from the Meridian.

5. The same Azimuth must be transferred unto, or projected upon, the Horizontal Line by help of a Perpendicular Thread, covering to your sight (as it hangeth down) the Points of the Gnomon and Shadow both together; and at the same view cutting through the Horizontal Line: observe then punctually where it cuts through the same Line, for that same Section being signed thereon, shall be the Azimuth projected into the Horizontal Line.

6. Let any kind of board or past-board be now applied to the Point of the Gnomon; so, as that it may be staid, either upon the Horizontal Line (where
it

it may so be conveniently) or at least so placed toward the Horizontal Line, that it may have a just respect unto it, and in that posture may have some stay for the edge of it to rest upon, that after it is furnished with such necessary Lines as must be drawn upon it, it may be placed in its former just posture without any Impeachment. Upon this Plain so placed, let the Point of the Gnomon be signed, which may be called the Center; and from this Center, to the Sign of the Azimuth, before projected into the Horizontal Line, draw a right Line: this right Line so drawn, shall represent upon the board or past-board, the same Azimuth which was before computed.

7. Then taking away the same Plain, draw upon it the Meridian or Line of 12; extending it from the Center before noted, at the true Angle that it hath from the Azimuth before computed and described, and also toward the true Coast of the World. And let it be extended on both sides the Center if need be.

8. To the Meridian so pitched upon the past-board, draw (from the Center) the Lines of an Horizontal Dial made to that Latitude wherein you are.

9. Then again, let the plain board or past-board be applied to its former situation, the Center of the Horizontal Dial resting upon the Point of the Gnomon, and every thing else answering to the same just posture that it had at the first. Which done, let a Thread be fixed in the Center of the Horizontal Dial, by help whereof you may transfer every hour from the past-board into the Horizontal Line. Let every hour be therein noted (by fixing marks upon the Horizontal Line where it is drawn, or by slipping knots set upon the Thread, where a Thread Horizontal Line is used) especially mark out the hour of 12: For which (if it chance to run besides the Superficies) some kind of Object (whereon the Horizontal Line is also to be drawn) or an Horizontal Thread must be fastned, that may receive it, till such time as your Dial be finished.

10. After all this, take your Plain away (for there will now be no more need of it) and conjecture whereabouts the Axis of the World, would pass from the Point of the Gnomon to the Poles of the World, for into that place is the Meridian to be projected. Which that it may be done more commodiously, if no object stand in the way that will receive it, you must place one there, it matters not whether above or below the Gnomon, chuse that which is most convenient: Or, a Thread laid aslope in the Meridian justly as it ought, will serve as well as may be. If then you hold up a perpendicular Thread, so that by your eye you may see the Point of the Gnomon, and also the Point of 12 in the Horizontal Line, both together, the same Thread so hanging, shall shew where the Meridian is to be drawn. Or, you may extend a Thread from the Point of the Gnomon to the Point of 12 in the Horizontal Line, which Thread shall represent the Line of 12: And staying your Thread there, close to it, hang up two perpendicular Threads at a good distance, so shall the same two Threads, give you the track of the Meridian Line.

11. The next Work will be to project one of the Poles of the World (that namely, which lies the same way that this projected Meridian doth from the Point of the Gnomon) into this Meridian. And this is done by elevating or depressing your Semicircle, from the Point of the Gnomon towards the Meridian Line, according to the Latitude of your Place; for so will the Ruler of the Semicircle, or a Thread extended along by it, Sign out the very Pole Point. If now you extend a Thread from this Pole Point, to the Point of the Gnomon, the same shall represent the Axis of the World.

12. Last of all; by these helps, all the hours may easily be projected. For if

if the eye do lay, or project, this Thread or Axis upon each Point of those hours that were inserted before into the Horizontal Line, the Axis upon an hour Point, or a Point upon the Axis, each one of those Projections shall represent upon your Dial, each of the hours required, and will shew upon every Object that stands in the way, where the hours are to be drawn. Or, where convenient room is wanting to place the eye, so as it may make this Projection; there may 2 Threads be used for the same purpose, one whereof must be fastened to the Point of the Gnomon, the other to the Pole designed in the Meridian Line. Then stretching one of the Threads to any of the Points noted in the Horizontal Line, and holding it there, you may take the other, and extend it to the Superficies, so as it may closely pass by the first Thread, by which Work you may make as many Points upon your Superficies as you please, through which each hour is to be drawn. Having thus traced the way before hand, you may afterward draw the hours without any difficulty, be the Superficies never so irregular. Among which Lines, the Shadow of the Point of the Gnomon, as it creepeth along, will shew the Time of the Day.

C H A P. V.

Let this stand as a briefer and less troublesome way, than the former: The Problem may be propounded more generally than before, in this manner.

IF a Point be assigned upon any Superficies Flat or Curved, one, or more, wherein the Hour-Lines and Axis shall concur, how to project the Hours to that Point, and to set up an Axis after the ordinary manner to give Shadow to them without any knowledge how the Dial standeth, in respect either of Declination or Inclination.

1. To the Point assigned (upon any side of it) by direction of your Semi-circle or other Level, stretch out an Horizontal Thread, serving for the Horizontal Line; this Horizontal Line need not be one direct Line, but may be turned at one or more Angles, provided that it lie totally in the Superficies of the Horizon.

2. With a perpendicular Thread held up, project the Sun into the assigned Point, and into the Horizontal Thread, and tie a little mark of Thread upon the same Horizontal, through which the Shadow cutteth. At the same instant also, take the Sun's Altitude.

3. By the Altitude taken, find out the Azimuth; This Azimuth, whatever it be, is represented by the knot.

4. Apply a past-board to the assigned Point, and hold it flat that it may answer to the Horizontal Thread also, and upon this past-board protract your Azimuth by a Thread extended from the Point assigned for the Center, to the mark upon the Horizontal Thread. This done,

5. By help of that Azimuth upon your past-board, protract the Meridian Line, observing the true Coast, and quantity of the Angle from the Azimuth: and to the Meridian describe an Horizontal Dial.

6. Applying the past-board to its place again, all things standing right as before, project all the hours into the Horizontal Thread from off the past-board, and set marks upon the same for the points of each several hour which marks may be little moveable knots to slip to and fro upon the same Thread.

7. Project the Meridian Point by a perpendicular Thread upon some object into that place whereabouts you imagine the Axis of the World would pass, above or below from the Point assigned for the Center.

8. With your Semicircle elevated or depressed (as it shall be required) from the Point assigned for the Center, according to your Latitude project the Pole of the World.

9. Extend a Thread from the Point assigned for the Center to the Poles of the World, which shall represent the Axis.

10. By the Point upon the Horizontal Thread, and this Axis (either by your eye, laying the Axis to the hour-points, or laying the hour-knots to the Axis) you may project all the hours and draw them; Or else you may let the Axis alone, and content your self with the Pole-point projected into the Meridian, for if from the point assigned to be the Center or meeting of the hours and Axis, you extend a Thread to each hour-point in the Horizontal Line, and do repose (with your eye) the same Thread upon the Pole-point, then shall the Shadow of the Thread give you that hour-line, and so do in all the rest.

11. Your Thread or Axis lying in its true situation, you may easily fit an Axis to the same posture. If your Dial be described upon a plain Superficies, you may then (by one side of a Nominal Square, applied to a Thread or Axis, and the other side lying upon the plain) find out the subtilty, and measure from it the elevation of the Axis above the plain: But if the Dial be described upon a curved Superficies, you must be content to set up your Axis by the direction of the Thread only.

12. This point assigned for the Center being a point of the Axis, is as it were the Apex of the Gnomon, unto which all the Work is projected. But if it be required to set up an Axis to such a Superficies, upon which the Axis and hours will not meet in any tolerable manner, because perhaps the Axis may be but of very small elevation above the Superficies, and yet an Axis is required: in this case, set up any point (of Wire, or such like) of such distance from the Superficies, as that the Axis and hours may be distinct: And through that point let it be required to make the Axis pass, you have no more to do but only to project to this point, as before, by letting the Shadow of a perpendicular Thread pass through that point, and noting the same upon your Horizontal Thread and counting that end of the Wire as your Center, proceed as before, for the Thread that lies to project the hours is a pattern for the Axis.

This way is as general as the former, serving to project the hours upon many Superficies, be they plain or curved, and however situate whether contiguous, or separate, and that without any laborious inquisition of any of their Situations, in respect of Inclination or Declination. If you will put in that Furniture which is usual, you must make some mark (notch, or button) upon your Axis, unto which (as representing the Center of the World) by help of your Semicircle you are to project the Altitudes of such greater or lesser Circles as you intend to insert; As hereafter shall be taught.

The 12 Propositions in the first way were to project to an Apex.

These 12 Propositions answerable in the second way are to project to an Axis.

C H A P. VI.

Being a Third Way, of drawing Hours upon all Plains whatsoever, by the joynt Use of the Semicircle and Horizontal Projection or Planisphere, without knowing their Situation at all.

(I.) *To draw the Hour-Lines upon any Plain.*

(II.) *To project Hour-Lines upon any Superficies, not Plain.*

1. **S**Hape your Gnomon into such a Form, and set it in such order, as that the Shadow of the Apex may not be hindered from coming clear to any of the hours at all times of the Year, and to the Apex of it draw an Horizontal Line, by the help of your Semicircle, which is instead of a Level.

2. At any time (except betwixt 10, and 2 a Clock) observe the point of the Shadow, and make a mark at it; and so again, when the Shadow is gone a good distance forward, make a second observation of the end of it, and mark it also: These Observations are not necessary to be made upon the same day, but may be done at leisure, only it must be remembred upon what days they were made; And more Observations may be made, but not fewer.

3. These 2 Points thus noted are to be taken; First, as 2 Azimuthal Points; and therefore the Azimuths whereto they belong must be projected upon the Plain in this manner. Hold a perpendicular (Thread, or what else) to the Apex of the Gnomon, and then (keeping your eye at a good distance from the Thread that the Work may be the more exact) remove your eye until you see your first mark upon the Plain; or hold a perpendicular any where, and move both it and your eye till you can see the Thread to cut both the Apex of the Gnomon, and the Point upon the Plain, then mark some other Point under the appearance of the Thread upon the Plain; so a strait Line drawn upon the Plain from these two Points shall be that Azimuth-Line, wherein the shadow of the Apex was first observed, and it must be drawn over the Plain blindly, as far as conveniently it may both upwards and downwards: in the same manner must the second Azimuth be projected and drawn through the second point of observation: And because these Lines should not go further from the Gnomon than the length of the Ruler of your Semicircle will reach, and yet if you should work all upon the Plain, longer Lines should be required, you may therefore (to help forward your Work) affix two little boards edge-wise upon your Plain, which may receive the aforesaid Azimuths projected upon them by the Thread held as before, all under one Work.

4. These two Points are again to be considered as the Points of two Almicanthers, to which, that you may know what they are, apply one point of the Ruler of the Semicircle to the first of them, and the edge of the Ruler to the Apex of the Gnomon, the Semicircle it self in the mean time hanging down right with his Thread and Plummet at full liberty; so shall the Thread amongst

you may best set up two Threads, which may appear in perpendicular, either before, or behind the Gnomon's Point; either upright, or a slope, provided only that they appear in perpendicular.

If a moveable Gnomon of light be made of one upright piece of wood, or stone in a window, then may the hours be drawn there-to by this Planisphere and Semicircle.

mongst the degrees of the Semicircle shew you what Altitude, or Altitude the Sun was in at that time, of the first observation; the like must be done for the second; and if you have need hereafter of more Azimuths, you may make more Observations.

5. The next work will be to insert points into the Azimuthal Lines, through which to draw hours: And for this purpose you must have recourse to your Horizontal Projection, and lay the Ruler thereof to the Situation answering to your two Azimuthal Lines, as is shewed in the remembrance *Chap. 3. Proposition 2.* and the Ruler so laid is an Azimuth, the same with your first Azimuthal Line drawn upon the Plain; wherefore if the Altitudes and Profundities of every hour upon that Azimuth, or Ruler so laid be noted, as is shewed in the Third Proposition, *Chap. 3.* and accordingly by the Semicircle be inserted into the first Azimuthal Line, below and above that Horizontal Line, you shall have the points of 12 hours, which may be for the present blindly figured, that you may only know them again. The manner how to insert them is by keeping the edge of the Ruler of your Semicircle to the Apex, and the foot of it to the Azimuthal Line, where ever it be, either plain or board, &c. still moving it therein higher or lower, till upon the Semicircle, and Plummets hanging right down, the Thread sheweth the Altitude requir'd. The Altitudes are to be set below the Horizontal Line, and the Profundities above. In the same manner you must count the second Altitude upon the Ruler, and apply it to the proper Parallel of the day when your second observation was made, and so again place your Azimuthal Ruler upon the Planisphere in its due Situation answering to the second Azimuthal Line upon your Plane; and upon it so laid, having seen what Altitudes and Profundities each of the 12 hours have, you must express the same Altitude and Profundity upon your second Azimuthal Line, in like manner as you did before upon the first, and if you have any more, you may do the like upon them, though two will serve turn.

6. Such Points then as fall upon the Plain will give you where to draw the hours, if like be joined with like; as if you draw a right Line from the point of 4 in the first Azimuthal Line to the like point of 4 in the second, that same shall be the Line of 4, and so of all the rest, both whose Points fall upon the Plain it self. * But for the rest you must by a Thread project them with your eye in this manner: Fasten a Thread to the Apex of your Gnomon, and stretch it with one hand from thence to any point on the Azimuth nearest to you; (Or, contrariwise, if it shall be convenient fasten it at the hour-point upon the Azimuth, and stretch it to the Apex of the Gnomon, and beyond if need be) then holding the Thread still, turn your eye, till it repose the Thread upon the answerable Hour-point upon the other Azimuth; so shall the Thread give to your eye the tract of the hour to be drawn upon the Plain. And in this manner you may draw all the hours except 12, for that hour-point falleth always into the very Zenith and Nadir point, where the two Azimuthal Lines concur, which are directly under and above the Apex of the Gnomon, so that you have not two distinct points to draw it through, as you have for the rest of the hours, for that therefore we must have some peculiar way which may first be this.

1. Having cleared your Plain of all necessary superfluity of Boards, Lines, and Figures, &c. Observe where 6 a Clock cuts the Horizontal Line, for if upon a past-board applied to the Horizontal Line you draw a Line from that Section, to the Apex of the Gnomon, and from the same Apex draw another upon the past-board perpendicular to the former, extending it till it cut the Horizontal Line, the point where it cuts is the point through which 12 must pass,

pass, if then you hold a perpendicular Thread till through it you see the Apex of the Gnomon, and that point together, the appearance, or shadow of the Thread upon the Plain is the Line of 12 required.

2. Another way may be by choosing any other hour, as well as 6: for if you observe upon the Horizon or Limb of the Projection, what degrees lie betwixt it (suppose 9, and 12) you may apply a past-board as before to the Horizontal Line, and from the Section of 9 thereon, to the Apex draw a Line, and upon the past-board out of the Apex as a Center delineate that Angle, and draw a Line for it, so shall that Line be the hour of 12 upon the past-board, and shew upon the Horizontal Line where 12 should be, which may be projected again as before.

3. Another way will be if you'll prolong any one of your Hour-lines (but the farther from 6 the better, for 6 is altogether unfit for this Work) that way which from the Apex of the Gnomon, you shall conceive to go toward the Axis of the World (which your own knowledge of the Heavens will direct you in) there the Ruler of your Semicircle being kept at the Apex of the Gnomon, the point of it may be removed upon the hour till such time as the Plummets hangs at your Latitude, and the Ruler then will lie in the Axis of the World, and at the foot of your Ruler so placed in that Hour-line make a Point. This Point is that which in other ways of Dialling, is the Center of the Dial, to this therefore the hour of 12 must come; If then you by a perpendicular Thread, will see the Apex of your Gnomon and this Point together, the same Thread shall upon the Plain, shew you also the place where 12 must be drawn. And note that from the points upon one Azimuth to this point (found by the third way) you might draw or project all the former hours, or most of them, in such sort as is shewed before. And further be ever mindful that you draw all the Hour-lines (in what place of the Plain soever they happen to be) down that way that they may come under the Horizontal Line, by sufficient extending them thither; for otherwise they will not be of any use: since the shadow of the Apex is always under, never above the Horizontal Line.

These Precepts though they are here set down as for plainness only, yet the ingenious will easily find how to apply them to any curved Superficies; only the Work in them will be a great deal more, and of more trouble; but these will be better done by my last way, which is more simple and general than this: yet notwithstanding for the Furniture of Dials, both here and in my last, I intend to make use of this way by the Horizontal Planisphere, which is the easiest that ever was. And when I mention the Horizontal Planisphere: I would not have the Reader think, that these things can be done by no other Instrument; for the Mathematical Jewel of Mr. *Blagrave's* first contrivance, since amplified by Mr. *John Palmer* Rector of *Ecton* in *Nor-thamptonshire*, will do all these things to all Latitudes, whereas this will do them but for Dials in one Latitude; and otherways I can do, and so I doubt not but others will also find; but I would have him know this withal, that no one Projection is so easie for this Work, as this, and therefore I made choice of it, and have fitted it with such Lines as I could yet find to be most useful for the purpose intended. I proceed therefore to shew how by it and the Semicircle, all that other men have written on this Subject may most easily be performed.

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C H A P. VII.

Upon a Plain (but not upon a curved Superficies) to make a Dial with an Axis, to any Point assigned for the Center.

FIRST, project a Dial to the Point of a Gnomon, the projective way; then having assigned your Center, from it, draw hours parallel to the projective ones, so are you furnished with hours. For the Axis do thus:

Note, That it must pass through the Center of the Dial, and must be parallel to that Axis that was drawn from the Point of the Gnomon.

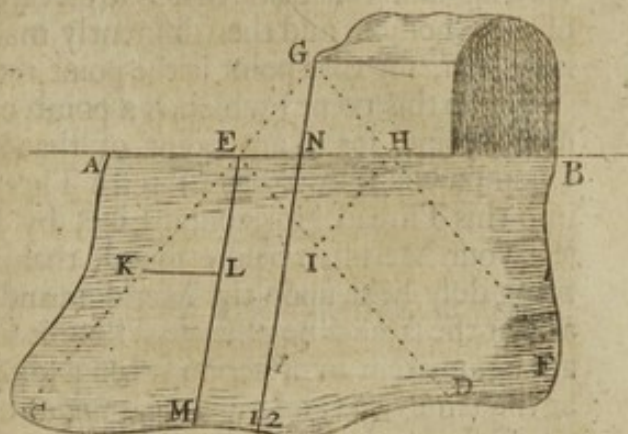
Now to set it absolutely parallel, it must be remembred, that when the Gnomonical Axis is reposed upon the Center of this new drawn Dial, it must also cover the new Axis, that is, to your sight, must lie just under it, and being limited to that Superficies you may the more easily stretch a Thread from the Center, parallel to the Gnomonical Axis: Or use your Semicircle being elevated to your Latitude, and kept in the fore-named Superficies.

C H A P. VIII.

How to Project Hours upon a Glass-Window, where the Hours shall be drawn within, the Gnomon standing without where you cannot come at it.

1. **F**IX your Gnomon on the out-side of the Window, and observe the point of the Shadow that it makes upon the Glass, making a mark at it, and take the Sun's Altitude at the same instant, whereby the Sun's Azimuth at that moment may be discovered.
2. By help of a Quadrant, Semicircle, or Level, draw an Horizontal Line upon the Glass, true to the Point of the Gnomon. This may be done if you hold the upper side of your Quadrant or Instrument truly level with the Horizon (which the Thread falling upon the perpendicular Line will direct you to do) and the Instrument being kept so levelled, must be fitted up higher or put lower, till such time as your eye viewing along the forenamed level-edge can discern the Point of your Gnomon. Observe at that time and in that posture, where the Point of the Gnomon appears upon the Glass, and make a mark at it, and so do the second time, and make a second mark; through these two marks a Line drawn will be an Horizontal Line upon the Glass, lying level with the Point of the Gnomon.
3. By a perpendicular Thread directed to the mark of the Azimuth, and to the point of the Gnomon both together, the same Azimuth must be projected into the Horizontal Line upon the Glass, with the Section of the Horizontal Line, and the Thread appearing upon the Glass will determine for you.

4. From this Azimuth must a Meridian Line be found out, wherein will be a little trouble, the way that I go about it is this. Apply a past-board, as A B C D. to the Horizontal Line upon the Glass which is A B. upon the past-board being held truly Horizontal Project with a perpendicular Thread the Azimuthal Point E which was before inserted into the Horizontal Line A B. and let the Line projected be C E. Then again (towards that Coast whereunto your Meridian Line standeth) with a perpendicular Thread, project upon the same past-board (held Horizontal, and in the same place as before) any other Azimuth at adventure, as F G. cutting through the Point of the Gnomon at G. and through the Horizontal Line at H. To F H. draw E D Parallel, and from E C. which is your Azimuth before found, set off E M. for the Meridian, according to the true Coast and Angle. Next of all, you are to draw a Meridian Line parallel to E m, which may pass through the point of the Gnomon, all which to effect there are many ways, amongst them I will give this one. From H draw H I parallel to E C. cutting E D at I. then also make E K upon E C equal to H I. and from K draw K L parallel to A B. the Horizontal Line cutting E M, in L; And to K L make E N. upon the Horizontal Line equal; so shall N. be the point of 12 upon the Horizontal Line, whereon it must be inscribed, and N 12, being drawn parallel to E M. shall be the Meridian or Line of 12, upon the past-board (if there were any use of it there) fully respecting the point of the Gnomon at G.



Or if you desire to save all this labour of these 4 precedent Sections, observe upon some other Dial, or by some Meridian Line before found, when the Sun comes to the Meridian; and at the same instant make a mark upon the Glass at the point of the Gnomon's shadow, so shall that mark be one point of the Meridian or 12 a Clock line. But this serves only for such Windows as look upon the South; for North-Windows therefore, the former way must of necessity be used.

5. Having found one point of 12 by one of these ways, you are next to project the Meridian Line upon the Glass, which because it is also an Azimuth, as well as a Meridian may be projected by help of a perpendicular Thread so held until the eye shew it at once to fall both upon the mark of the Meridian noted before upon the Glass; and also upon the point of the Gnomon; the shadow then of this Thread so held shall shew upon the Glass where the Meridian is to be drawn. Remember also to draw it both ways, that is above and below the point of the Gnomon.

6. Into this Meridian you are next to project the point through which the Axis of the World would pass, which if you were without the Window, and could come at the point of the Gnomon, might be done as in the other Dials by the Semicircle; But because you are within, and the Gnomon without, you must help your self some other way, as thus. Hold your Semicircle or Quadrant,

drant, so as that the side which must find the forenamed point may be elevated according to the height of the Pole, and being continually so kept at that elevation and directed also to the point of the Gnomon, lift up or depress the Instrument, keeping one end of it always in the Meridian Line, until your eye viewing along that side that is so elevated shall direct the same upon the point of the Gnomon, and then diligently mark in what part of the Meridian Line it resteth, for that point is the point required.

7. To this point (which is a point of the Axis passing through the Gnomon's point, for to any point of that Axis the hours being described, the Gnomon will shew true) stretch a Thread Horizontal Line level with it, and into this Thread Horizontal Line, by help of a perpendicular Thread project your Meridian before found, that is, repose this perpendicular Thread being duly held, upon the Meridian and point of the Gnomon both together, and at the same time observe where it seems to cut the Horizontal Thread, at the apparent intersection fasten a knot for the point of 12. You may also at the same time and view (all under one) project the Meridian upon some object standing there whereabout you suppose the Axis of the World would pass, for the appearance or shadow of the Thread shews that also at the same view.

8. To that point upon the Glass as a Center, apply a past-board, upon which from that Center to the Point of 12 draw the Line of 12. and to this Center and Line of 12. draw an Horizontal Dial upon the past-board, and applying the past-board to its former due place, project the hours from the same into the Horizontal Thread, and fasten knots of Thread as marks of every hour.

9. Project the Meridian upon the top or bottom of the Room, or upon some object placed in the way whereabout you imagine the Axis of the World would pass, as is declared in the seventh Section going before. And with your Semicircle elevated or depressed according to your Latitude, project the Pole of the World from the forenamed Center, or Point of the Glass into the Meridian now last of all fitted to receive it, and stretch a Thread from the one to the other, which may represent the Axis of the World.

10. By this Axis and the points of the hours upon the Horizontal Thread, you may easily project the Hour-lines upon the Glass, and accordingly draw them, and so finish up your Dial.

Another Way to draw the Hour-Lines, may be thus:

Having drawn what is prescribed in the Fourth Section, you may piece out your past-board A B C D: (or transfer all the Lines upon it, to a larger paper where more room is) that it may contain the exterior part of the Draught E G N H: This exterior Draught you may therefore some ways supply, and to G being the Center, & G N the Meridian, you may draw an Horizontal Dial, and project the hours upon A B, the Horizontal Line of the Glass or past-board. Now then if you apply your past-board so furnished with these Horizontal Points, to its first Situation which it had, and transfer the same Points to A B the Horizontal Line drawn upon the Glass, then may you upon a flat Glass-window through those Points draw strait Lines from the Point of the Axis found by the Sixth Section: which Lines shall be the same hours with them which were drawn the other way. Or, if the Glass-window be not flat, then you may by the 3 Points given (*viz.* the Point of the Axis, the Point of the Gnomon, and the Hour-points on the Horizontal Line) and a Thread, project the Lines on a curved Glass Superficies. Remember that the Point mentioned

tioned in the Sixth Section, stands above the Horizontal Line, if the Window look Southward, and below if the Window look Northward.

C H A P. IX.

How to delineate the Hours upon any Superficies, without that way by the Semicircle of elevating an Axis; by observing both the Hour and Azimuth at one Altitude taken.

(1.) **F**ix a Gnomon. (2.) Observe the Sun's Altitude, and make a mark of the shadow of the Gnomon's point both at one moment. (3.) By the Altitude conclude the Azimuth, and the hour or part of it. (4.) Project the Azimuth into the Horizontal Line. (5.) By that Azimuth protract an Horizontal Dial upon past-board, and amongst the rest that hour or part of an hour that was observed [which must be therefore calculated what Angle it maketh with the Meridian upon the Horizontal Plain thus. As the *Radius* to the Sine of the Latitude: so the Tangent of that hour or part, to the Tangent of the Space or Angle required.] And project the Meridian, and all the Hour-points from the past-board into the Horizontal Line. (6.) Having now the Meridian Point (by a perpendicular Thread) project the Meridian Line, or Line of 12, and draw (upon a Plain or Project upon a rugged Superficies) that hour or part occultly that it may be put out, of which you have two points given, one by Observation, the other by Imposition into the Horizontal Line. (7.) By these two Hour-lines, this last and the Meridian find out the Axis with your eye, *ut pag. sequ. Sect. 2.* (8.) Then by the Axis project all the Hour-lines by the points upon the Horizontal Line, &c.

2. Or, without observing the hour, but using the Semicircle do thus, keeping the work for the most part as is above declared, enquire what Altitude some one hour in the Horizontal Line hath upon that Azimuth; And first, having drawn the Azimuth Line projected upon the Superficies, expresse by the Semicircle the Altitude found, upon the Azimuth drawn: So having two points for one hour; one in the Azimuth, the other in the Horizontal Line, project the same hour by the Semicircle, and draw it, as also the Meridian. By these two hours make an Axis, &c. as before: Or as here followeth.

If you will stay to observe, from some other Sun-Dial, the Sun's approach to any one hour justly, then make a mark there, you shall not need to put in any other hour to be afterwards blotted out, but that which is so put in shall be a true hour, neither shall you need to calculate, as is before required.

Hours being drawn to a Gnomon, how make an Axis.

The Point of the Index is one Point of the Axis, if another Point were known besides, then might the Axis be drawn, or a Thread placed so as the Axis ought to be. To find another Point use either of these two ways.

1. Fasten one Thread from the Point of the Index to any one Hour-line a good way below the Horizontal Line, and another Thread to another hour that may be 5 or 6 or 7 hours from the former (the more near to 6 hours the better) these Threads being held or fastned as is prescribed, there must be stretched out from each of these Hour-lines (in some other part) to their proper Threads, two Threads more, so as that they may only touch (and not force upon) the two first fastned Threads, and these two Threads being brought together in that manner till they meet, and cut each other, this Point of Intersection will be another Point where through the Axis is to pass. If therefore, a Thread be extended from the Point of the Index or Gnomon unto this Point of Intersection, the same Thread is the representative Axis of the World, and an Axis of Iron (&c.) laid in place of it will give the true shadow for the Hour-lines.

2. Or the Axis may be found thus : Fasten a Thread at the Point of the Index or Gnomon, and stretch it out with your hand till you see it to cover any one Hour-line, there hold it fast by staying or resting your hand upon some sustentacle; Then try by your eye whether the Thread so standing will cover another hour, that is 5 or 6 or 7 &c. hours from the former, if it do so, and do not make any Angles with it, then is it the true Axis; If it do not so, then is it to be removed until it fit in such manner as is declared; so may the pattern of the Axis be easily stretched out by a Thread.

C H A P. X.

How to Project an Hour-line from a Wall upon a Board, which standeth as an hindrance, so that you cannot extend any strait Thread from the Point of the Gnomon (or Glass) to the said Hour-line at all, because of the same Board.

Make a mark upon the Hour-line in any part of it; Then extend a strait Thread, one of whose ends let be fastned to the foresaid mark, and the other end at a good distance from the Gnomon's Point any where, then repose the Thread with your eye upon the Point of the Gnomon, and observe the shadow, or appearance of the Thread upon the Board, and draw a Line along with it. Again stretch your Thread out strait to some other place, so as you may see the Gnomon again under the Thread, and then mark where this shadow of this second placed Thread seemeth to cross the former Line drawn upon the Board, there make one mark; then again repeat the same Work, that is, make a new mark upon the Hour-line, and fastning a Thread to it, find out another Point upon the Board in the same manner as you did before, so shall you have a second Point: Through these two Points you may draw your Hour-line.

Note, That the Board must be supposed so to stand, that though you cannot come to stretch a strait Thread from the Gnomon Point to any part of the Hour-line, yet you may have room to stretch a Thread crookedly over or under, or upon one side of the Board.

This Case supposeth a Board to stand between the Hour-line and the Gnomon;

mon; but if in case you were to project the hour from the Board to the Wall that is beyond it, do thus.

Make a mark in the Hour-line upon the Board, and stretch a Thread from the Gnomon to any part of the Wall, at a good distance from the Board, and repose this Thread upon the mark on the Board, then draw the shadow, or line, that the Thread makes upon the Wall, and upon the other side of the Board too, which you may do (if not both together, yet) after that is drawn upon the Wall, for by help of it you may easily draw one upon the other side of the Board: Then again stretch out the Thread to some other place of the Wall, and repose it again upon the fore-named mark, and observe then where it crosseth the former Lines drawn on the Wall, and on the other side of the Board, and make marks at those crosses. Thus again you are to do over the same Work to another second mark made upon the Hour-line, by which means you may draw the same Hour-line upon both Board and Wall, if need be, through these two first and second crosses found upon them. Now if it fall out that upon the Wall you cannot draw a Line though you have two marks, by reason the Wall is not flat, then will the Line (or one part of it) which was drawn upon the side of the Board that looks to the Wall help you to project upon the uneven Wall. For stretching a Thread through the two Points given upon the Wall, and tying another Thread to any Point of the Hour-line drawn upon the face of the Board that looks upon the Wall, you may (by this tied Thread apply'd to the other stretcht Thread) project the hour upon the uneven Wall. So that the Hour-line drawn upon the backside of the Board serves to do that which the Point of the Gnomon (if it could be come to) should do. In the same manner the Wall will help to project the hour upon the Board, if the same should prove uneven.

This Work (at first) did not appear to me any ways useful: For if a right Line cannot be drawn from the Point of the Gnomon to the Wall, how can the Sun-Beams (which is a strait Line) come at it from that Gnomon, and if it come at it what use is it of? At present thinking it of no use (as many Notions of the like kind have sometimes been to me;) Yet this transferring the Hour-line from the Wall to the Board, may sometimes be (and once was to me) of use: For if a Sun-Dial be drawn upon a Board, and it fall out that that Board be taken away, so as that the Sun-Beams thereby be taken off too, then it will be good to transfer the hours from the Board, to the Wall or Superficies standing behind, to save them that they be not utterly lost.

C H A P. XI.

To draw a Dial upon a flat Superficies by means of Three Shadows of a Stile, caused by the Sun upon the same Superficies in one Day, without knowing either the Sun's Declination, the Elevation of the Pole, or Situation of the Plain. fig 1, 2, 3, 4. page 95 Geometrical dialling.

IN the first Figure; Let the Plain be C D F, and the Stile A B, whether perpendicular to the Plain or not, for it sufficeth, to know the Shadows of the extremity B, viz. D E F, observed in one and the same Day; that is required by means of those three Shadows, and of the Stile A B, to trace a Dial proper for the place of Observation. Figure I.

From

From the Point B, (the extremity or top of the Stile) by help of a Square let fall B C, perpendicular to the Plane, meeting with it in the Point C, (if it happen that the Stile be not perpendicular) then from C, to the Points D E F, draw the Lines C D, C E, C F.

Figure

II. Then, (in the second Figure) make a right Line at pleasure 1, 4 equal to C F, and take therein a Line 1, 2 equal to C E, and 1, 3 equal to C D, let the perpendiculars, 2, 5: 3, 6: 4, 7. be raised upon 1, 4, and every one equal to B C, the height of the Stile in the first Figure; then from Point 1, to each of the Points 5, 6, and 7. let right Lines be drawn as 1, 5: 1, 6: 1, 7: making with 1, 4: the Angles, 5, 1, 2: 6, 1, 3: 7, 1, 4: in degrees to the height or Elevation of the Sun above the Horizon at that time of observation of the Shadows, *viz.* the Angle 5, 1, 2, the Shadow being at E; 6, 1, 3, the Shadow being at D; and 7, 1, 4, the Shadow being terminated in F. And from Point 1, as a Center, and at the distance 1, 5: let be described the Arch of a Circle 5, 10, 11, cutting the Lines 1, 6: 1, 7, in the Points 10, 11. from whence let fall Perpendiculars upon 1, 4, which let be 10, 8: 11, 9.

Figure

III. Then coming to the third Figure; upon another Plain, as, *a m n o*, let be taken the Point *a*, and by it draw the three Lines *d a o*, *c a n*, and *b a m*, making amongst themselves Angles equal to the Angles made by the Lines C F, C E, C D; in Figure I. each to his own, and on the same side, *viz.* *o a n*, equal to F C E, and *n a m* equal to E C D, as the third Figure sheweth; And these Lines being prolonged on the contrary side, as *o a*, as far as *d*, and making *a d*, equal to 1, 9: which is the distance betwixt 1, and the Point where the Perpendicular falleth which comes from the Point marked in the Line 1, 7. by the Arch of a Circle 5, 10, 11, in Fig. II. for as much as 1, 4: represents or resembles C F, (in Fig. 1.) and C F, resembles *a o*, in like manner make *a b*, equal to 1, 8: (in Fig. 2.) because that 1, 4: (in Fig. 2.) resembles C F, (in Fig. 1.) and C F, resembles *a o*, (in Fig. 3.) in like manner *a b*, equal to 1, 8, (in Fig. 2.) because 10, 8, comes or is made of the length, 1, 3: which is equal to C D, (in Fig. 1.) and C D, of the same situation or disposition as *a m*, Make for the same reason *a c* equal to 1, 2: and draw the right Lines *c d*, *c b*, as long as shall be needful, and on them in Point *c*, raise *c e*, and *c f*, perpendicular either of them equal to B C, (in Fig. 1.) and at the Point *d*, let *d g*, be raised perpendicular to *c d*, and equal to Perpendicular 10, 8: (in Fig. 2.) because *a d*, is equal to 1, 8: Likewise on the Point *b*, let be raised the Perpendicular *b h*, (on the Line *c d*) equal to 11, 9: (in Fig. 2.) and drawing the Lines *c g i*, *f b k*, cutting *c d*, *c b*, in I and K, and if you draw the Line I K, it will give the disposition or situation of the Equinoctial Line, respecting or relating to the Lines *o a d*, *n a c*, *m a b*, and making *e l*, Perpendicular to I K, that will represent or shew the disposition or situation of the Meridian-line of the Plain representing or relating to the same Lines *o a d*, *n a c*, *m a b*.

This so prepared make the Angle G C E, (in Fig. 1.) equal to the Angle *a c k*, (in Fig. 3.) and drawing G C I, that will be the Meridian of the Plain; then make G C, (in Fig. 1.) equal to *c l*, (in Fig. 3.) and drawing C H, Perpendicular to C I, and equal to the height of the Stile, drawing H G; Let H I, be made Perpendicular to H G, cutting G C, in I, then will the Point I, be the Center of the Dial. Moreover let G O, be drawn at right Angles with or upon G C, which will be Equinoctial; and let G P, be made equal to G H, and from the Point P, as Center, and at the distance P G, describe the Circle G M N, which will represent the Equinoctial.

To

To finish the Dial.

THE Meridian of the place must be found, which will be done if from the Point B, (the extremity, or top of the Stile) a Thread be let fall with a Plummets sharp at the end, until the point thereof touch the Plain, as here in point K, (in *Fig. 1.*) by which from point I, drawing a right Line I K L, that shall be the Meridian of the place. If the Plummets let fall from B, the top of the Stile do not touch the Plain, then put the Butt or end of a Ruler to I, the Center of the Dial, and so as that one of the Arrests or Sides passing by the point B, the top of the Stile, then find a point in the Ruler, from whence a Thread and Plummets let fall may cut or touch the Plain as aforefaid, which will be the Meridian of the place.

And if the Plain be Vertical, that is perpendicular to the Horizon, which is easily known by applying a Thread and Plummets to the Plain, for if it rase and touch the Plain, then is the Plain an upright Plain; And then to find the Meridian, is but to apply the end of the Thread to I, the Center of the Dial, and letting the Plummets hang at liberty, draw a right Line by the Thread, which shall be the Meridian-line of the place. Lastly, Produce I K, the Meridian of the place, till it cut the Equinoctial as in the point L, to which from the point P, let be drawn a right Line P L, cutting the Circle G M N, in M, that Line will represent the Equinoctial, the Line of 12 a Clock of the place for which the Dial is made; Divide therefore the Circle into 24 equal parts, beginning from the point M, and from the point P, by every of those Divisions draw Lines to the Equinoctial, and then from the Center of the Dial I, draw Lines to those Points in the Equinoctial, which will be the Hour-lines for the Dial; to which Hour-lines, give the Number or Denomination according to that of the Lines drawn from P, to the point of the Equinoctial Line by which it passeth, (as for Example) drawing a right Line from P, by N, which is the third Division after M (supposing M, to be on the East) that shall be the Line of Three a Clock which shall cut the Equinoctial in O, drawing I O, that will be the Line of Three a Clock of the Dial, and doing so for the rest, the Dial is finished, in which the Hours shall be shewn by the Shadow of the top of the Stile only.

It is to be observed, that in all Dials the Morning Hours ought to be marked on the West-side, and the Evening Hours on the East.

To explain what was said before about finding the Meridian-line of the Place, by a Ruler, with a Thread and Plummets.

LET in the fourth Figure the Stile be A B, the Center of the Dial D, if then from B, be let fall a Thread and Plummets, the Thread joined to B, happens to fall without the Plain, the Ruler I D, must be applied so as that one Arrest or Side thereof, touch both the Center of the Dial in that Figure D, and the top of the Stile B; then finding a point in the Ruler from whence letting fall the Plummets it meeteth with the Plain, that point shall be the Meridian of the place, and drawing from the Center of the Dial D, by that point a right Line, that right Line shall be the Meridian of the place; But if the point in which the Plummets toucheth the Plain be so near the Center that it is difficult to draw the Line exactly,

B b b b

then

Figure
IV.

then do thus. Take a point at pleasure in the side of the Ruler as E, to which apply the Thread with the Plummets hanging at liberty, then taking another Thread, staying one of the Butt ends on the point B, and extending the other towards the Plain in such sort that it may cut the other Thread that hangs at liberty, in perpendicular; that point of meeting of the two Threads, being the point to which the Thread extended from B, will meet the Plain as H, shall be the Meridian, and drawing D H, it is found.

We speak not here of all the Difficulties that may happen in describing a Dial by three Shadows; as when the Center of the Dial is not in the Plain, nor when the Meridian of the place cannot be there, because the solution of those Difficulties would require a compleat Gnomonist.

It may be observed from our construction in the third Figure, that if *bcd*, be in a right Line, then that Line is the Equinoctial of the Plain, and that it is a Polar-plain; And that if the Plain be Vertical, its Meridian-line will be that of Six a Clock of the place, to wit, in the oriental or East side, Six in the Morning; and of Six at Night in the West Face: The height of the Stile is for the Semidiameter of the Equinoctial as B C, in the first Figure, but the Hour-lines of the place instead of meeting in the point I, the Center, are all Parallels one unto another.

C H A P. XII.

Shewing several ways whereby to find the Star's Hour readily, and consequently the true Hour of the Night by the Stars.

THere are several ways by which the *Stars* Horary distance from the Meridian (call'd the *Star's* Hour) may be obtained: As,

I. *By any Quadrant, or other Instrumental Dial, which giveth the Hour of the Day by the Sun.*

IWill Illustrate this in the Use of Mr. Gunter's Quadrant, it being an Instrument more frequently known than any other of that kind: For, If you observe the same Rules in finding the *Star's* Hour, as is directed for finding of the Hour of the Day by the *Sun*; that is, by setting the Bead to the *Star's* Declination, instead of the *Sun's* Declination, and then observe the *Star's* Altitude as if it were the *Sun's* Altitude, the Bead shall then shew among the Hour-lines the *Star's* Hour, or the *Star's* Horary distance from the Meridian.

But here you are to Note, That this way of finding the *Star's* Hour, is peculiar to such *Stars* only as are between the Tropicks. Wherefore, another more general way may be this:

II. *By*

II. By a Sun-Dial made under the Soyl, and on the Jaums of a Jetty Window, on the inside of a Room. And such a Dial may be made by the Rules deliver'd in the 4th, 5th, 6th and 7th Chapters of the Eighth Tractate; or according to these Directions following.

HAVING made a small round hole in any Quarry of Glas in the Window, and darkned the other part of the same Quarry round about the hole, you must upon the Window-Board draw a Meridian Line, which Line must pass directly under the hole before made, and must be transferred to the Cieling of the same Room, by the help of Perpendicular Threads.

Then from the hole in the Window, to the Meridian Line on the Cieling, extend a String, till (by the help of your Semicircle) it make an Angle equal to the *Latitude* of the place you make the *Dial* in, and where the String (with this condition) so resteth, fix the end of the String in that point of the Cieling, letting the other part of the String hang at liberty.

This done, by help of an *Horizontal Dial*, whose Center (for the present) must be placed in the hole in the Window; the Lines of which *Dial* must also be extended by a Thread fixed in the Center thereof, by which Line extended over each Hour, and the String before fixed in the Cieling, the Hour-lines may be transferred and marked upon, or under the Window-Board; and also upon the *Jaums* and *Cheek Posts* of the said Window, and there numbred by Letters or Figures.

Now such a *Dial* being made, I shall shew

How to find the Hour by the Sun in the day time, and any Star's Hour (or his Horary distance from the Meridian) in the Night Season.

1. By the Sun.

THE *Sun* shining through the hole before made in the Window, move the String, whose end is fixed in the Cieling, along the Hour Points which are marked about the Window, until such time that the Spot of Light that cometh through the hole of the Window shineth upon the String, and then see upon what Hour, or part of an Hour the String resteth, for that is the true time of the Day.

2. By the Stars.

THIS differeth little from the former; for when through the Window you see a known *Star*, and would know his Hour, move the String along the Hour Points as before, till such time as you bring your Eye, the String, the Hole, and the *Star*, all four in one and the same Plain, or right Line; for then will the String rest upon that *Star's* Hour, or his *Horary* distance from the Meridian.

III. By

III. *By a Dial made in a Yard or Garden.*

IN some convenient open place, erect a Pole perpendicular to the *Horizon*, about 10 or 12 foot high; then provide a Frame of Wood in form of a *Parallelogram*, of what bigness you please, (but the sides being 2 foot broad, and 3 foot long, is a competent bigness) within the *Area* of this Frame make the true Hour-Lines of an East and West *Dial*; which Hour-Lines may be of reasonable big Wyre, and upon the edges of the Frame, which ought to be of a competent breadth (as 4 or 5 inches) to draw Lines upon, and to set the Numbers of the Hours, the Forenoon Hours on the East side, and the Afternoon Hours on the West side, and over the Hour-Line of six erect an *Axis* (of a competent length) as if it were a *Sun-Dial*: Which *Dial* being thus prepared, if you set it upon the former erected Pole, so that the two ends of the Frame may stand due North and South, and the *Stile* thereof Parallel to the *Axis* of the World, then is it fit for use, either to find the Hour of the Day by the *Sun*, or the *Star's* Hour in the Night.

1. *By the Sun.*

THis is all one as if it were a *Dial* made against a Wall; for the shadow of the *Axis* upon the Frame will shew the Hour of the Day.

2. *By the Stars.*

When you see a *Star* you know, and would find that *Star's* Hour; move your self about the *Dial* Post (coming nearer to it, or going farther from it) as occasion offereth, till you bring your Eye, the *Axis*, and the *Star* in the same Plain or right Line, and then mind upon what Hour-Line (or between what two Hour-Lines) is intercepted by that view, for that is that *Star's* Hour; and by this *Dial* you may at any time know,

What Stars are upon the Meridian. For,

IF you go behind the North end of the Frame, and look by the side of the Frame, you shall see what *Stars* are then upon the South part of the Meridian.

And if you go behind the South end of the Frame, and look by the side of the Frame you shall there see what *Stars* are upon the North part of the Meridian.

And thus, the *Star's* Hour (by any of the forementioned ways) being obtained, the true Hour of the Night may be also known, by help of the following *Tables* of the *Sun's* and *Star's* right Ascension.

A TABLE of the Complement of the Sun's Right Ascension in Hours and Minutes for every Day in the Year.

Days.	Jan.		Febru.		March.		April.		May.		June.	
	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>
1	4	25	2	18	0	33	10	39	8	46	6	41
2	4	21	2	14	0	28	10	35	8	42	6	37
3	4	17	2	10	0	24	10	31	8	38	6	33
4	4	13	2	6	0	21	10	27	8	34	6	29
5	4	9	2	2	0	17	10	24	8	30	6	24
6	4	4	1	58	0	14	10	20	8	26	6	20
7	4	0	1	54	0	10	10	16	8	22	6	16
8	3	56	1	50	0	7	10	13	8	18	6	12
9	3	51	1	46	0	3	10	19	8	14	6	8
10	3	47	1	43	11	59	10	6	8	10	6	4
11	3	43	1	39	11	55	10	2	8	6	6	0
12	3	38	1	35	11	52	9	58	8	2	5	56
13	3	34	1	31	11	48	9	54	7	58	5	52
14	3	30	1	27	11	45	9	50	7	54	5	48
15	3	26	1	24	11	41	9	47	7	50	5	43
16	3	22	1	20	11	37	9	43	7	46	5	39
17	3	18	1	16	11	34	9	39	7	42	5	35
18	3	14	1	12	11	30	9	35	7	38	5	31
19	3	10	1	8	11	27	9	31	7	34	5	27
20	3	6	1	5	11	23	9	28	7	30	5	22
21	3	2	1	1	11	19	9	24	7	26	5	18
22	2	57	0	57	11	16	9	20	7	22	5	14
23	2	53	0	54	11	12	9	16	7	18	5	10
24	2	49	0	50	11	8	9	12	7	14	5	6
25	2	45	0	47	11	4	9	9	7	10	5	2
26	2	41	0	43	11	1	9	5	7	6	4	58
27	2	37	0	39	10	57	9	1	7	2	4	54
28	2	33	0	35	10	54	8	57	6	50	4	50
29	2	29			10	50	8	53	6	54	4	46
30	2	25			10	46	8	50	6	49	4	41
31	2	22			10	43			6	45		

A TABLE of the Complement of the Sun's Right Ascension in Hours and Minutes, for every Day in the Year.

Days.	July.		August.		Sept.		Octob.		Nov.		Dec.	
	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>	<i>h.</i>	<i>m.</i>
1	4	37	2	35	0	41	10	50	8	53	6	45
2	4	33	2	31	0	37	10	48	8	49	6	39
3	4	29	2	27	0	34	10	45	8	45	6	35
4	4	25	2	23	0	30	10	41	8	41	6	31
5	4	21	2	20	0	27	10	38	8	37	6	26
6	4	17	2	16	0	23	10	34	8	33	6	22
7	4	13	2	12	0	19	10	30	8	29	6	18
8	4	9	2	9	0	16	10	26	8	24	6	13
9	4	5	2	5	0	12	10	22	8	20	6	9
10	4	1	2	2	0	9	10	19	8	15	6	4
11	3	57	1	58	0	5	10	15	8	11	6	0
12	3	53	1	54	0	1	10	11	8	7	5	55
13	3	49	1	50	11	58	10	7	8	2	5	51
14	3	45	1	46	11	54	10	3	7	58	5	46
15	3	41	1	43	11	51	10	0	7	53	5	41
16	3	37	1	39	11	47	9	56	7	49	5	36
17	3	33	1	35	11	43	9	52	7	45	5	32
18	3	29	1	32	11	40	9	48	7	41	5	27
19	3	25	1	28	11	36	9	44	7	37	5	23
20	3	21	1	25	11	33	9	40	7	32	5	19
21	3	17	1	21	11	29	9	36	7	28	5	15
22	3	13	1	17	11	25	9	32	7	24	5	11
23	3	9	1	14	11	21	9	28	7	20	5	6
24	3	5	1	10	11	18	9	24	7	15	5	2
25	3	2	1	7	11	15	9	21	7	11	4	57
26	2	58	1	3	11	11	9	17	7	7	4	53
27	2	54	0	58	11	7	9	13	7	3	4	49
28	2	50	0	56	11	3	9	9	8	58	4	44
29	2	46	0	52	10	59	9	5	8	54	4	40
30	2	42	0	49	10	56	9	1	8	49	4	35
31	2	39	0	45			8	57		4	4	30

A Table of the *Right Ascension* of some eminent *Fixed Stars*, and by them to find the Hour of the Night, and when they will be upon the Meridian.

The Stars Names.	R. Ascension.	The Stars Names.	R. Ascension.
	h. m.		h. m.
<i>The Southerm. in Whale Tail.</i>	0 27	<i>North Ballance.</i>	3 0
<i>Girdle of Andromeda.</i>	0 51	<i>The Crown.</i>	3 25
<i>Foremost Horn of the Ram.</i>	1 36	<i>Scorpion's heart.</i>	4 9
<i>Whale's Belly.</i>	1 36	<i>Hercules right Shoulder.</i>	4 16
<i>South-Foot of Androm.</i>	1 43	<i>Hercules Head.</i>	5 0
<i>Whale's Jaw.</i>	2 45	<i>Ophinons Head.</i>	5 20
<i>Brightest of the Seven Stars.</i>	3 28	<i>Lyra, The Harp.</i>	6 22
<i>Bull's Eye, Aldebaron.</i>	4 17	<i>Vulture's Tail.</i>	6 51
<i>The Goat, Capella.</i>	4 50	<i>The Swan's Bill.</i>	7 18
<i>Orion's foremost Shoulder.</i>	5 8	<i>The Vulture.</i>	7 35
<i>Orion's Head.</i>	5 17	<i>Lower Horn of the Goat.</i>	8 3
<i>Orion's Belt, the Middle.</i>	5 20	<i>Swan's Breast.</i>	8 11
<i>Great Dog, Cyrius.</i>	6 31	<i>Swan's Tail.</i>	8 31
<i>Little Dog, Procion.</i>	7 22	<i>Lower Wing of the Swan.</i>	8 33
<i>Lower head of the Twins.</i>	7 26	<i>Cepheus Girdle.</i>	9 25
<i>North Afellus.</i>	8 23	<i>Pegasus Mouth.</i>	9 28
<i>South Afellus.</i>	8 25	<i>Pomahaut.</i>	10 39
<i>Lion's Heart.</i>	9 30	<i>Scheat.</i>	10 48
<i>Lion's Tail.</i>	11 32	<i>Mereha.</i>	10 49
<i>Vindemiatrix.</i>	0 47	<i>Head of Andromeda.</i>	11 50
<i>Spica Virginis.</i>	1 8	<i>Cassiopea's Chair.</i>	11 53
<i>Arcturus.</i>	2 1		
<i>Boote's left Should.</i>	2 19		
<i>South Ballance.</i>	2 23		

The Use of these Tables.

1. *Example* : Suppose that upon the 31st of *December* I find the *Great Dog's* Horary Distance from the Meridian (or his Hour) to be 9 Hours and 22 Minutes,

	h. m.
The Comp. of the Sun's Right Ascension for <i>Decemb. 31.</i> is,	4 30
The Right Ascension of the <i>Great Dog</i> is,	6 31
And the <i>Star's</i> Hour (by your <i>Dial</i>) is,	9 22

These being added together, make

20 23

From which take 12 Hours, and there rests 8 Hours and 23 min. for the true Hour of the Night.

2. *Example.*

2. *Example*, Upon the 11th. of *December* I observed the Horary Distance of the *Bull's Eye* to be 8 Hours and 56 minutes from the Meridian, and I would know the true Hour of the Night,

	<i>h.</i>	<i>m.</i>
<i>Decemb. 11.</i> The <i>Sun's</i> Right Ascension is,	6	00
The Right Ascension of the <i>Bull's Eye</i> is	4	17
That <i>Star's</i> Hour is (by the <i>Dial</i>)	8	56
These three being added together, make	20	13
From which Subtract	12	00
There remains	8	13

Which is the true Hour of the Night.

3. *Example*. I observed the Hour of *Arcturus* upon the 6th. of *February* to be 24 minutes after 6; and I would know the true Hour of the Night.

	<i>h.</i>	<i>m.</i>
<i>February 6.</i> The Comp. of the <i>Sun's</i> Right Ascension is,	1	58
The Right Ascension of <i>Arcturus</i> is	2	01
The <i>Star's</i> Hour observed by the <i>Dial</i> , was	6	24
The Sum of these make	10	23

Which is the true Hour of the Night.

For, This is a general Rule; If you add the *Right Ascension* of any *Star*, The Complement of the *Sun's Right Ascension*, and the *Star's* Hour, all three together (deducting 12 Hours if the *Sun* be greater) that Sum shall be the true Hour of the Night.

For Trial; Let us take the first *Example* before going, where upon the 31 of *December* the *Great Dog's* Hour was 9 Hours 22 minutes from the Meridian---The Complement of the *Sun's Right Ascension* was 4 Hours 30 minutes---And the *Right Ascension* of the *Great Dog* was 6 Hours 30 minutes; these three numbers being added together, and 12 Hours abated (because the *Sun* was 20 Hours 22 minutes) there will 8 Hours and 22 minutes remain, for the Hour of the Night, thus:

	<i>h.</i>	<i>m.</i>
<i>Great Dog's</i> Hour	9	22
Complement of the <i>Sun's</i> Right Ascension	4	30
<i>Great Dog's</i> Right Ascension	6	31
Their Sum	20	23
Deduct	12	00
There remains	8	22

Which 8 Hours 23 min. is the true Hour of the Night, as by this and the former Work.

In like manner by these *Dials* may be found the Hour of the Night by the *Moon* (and this may be useful for such as know not the *Stars*) but they must then know the Age of the *Moon*, which any *Almanack* will afford.

The End of the Ninth TRACTATE.

PROJECTIVE DIALLING:

OR, OF

Inserting the Usual *FURNITURE*

I N T O

SUN-DIALS,
PROJECTIVELY.

The Tenth TRACTATE.

C H A P. I.

Of Furniture in General.

1. **A** *Zimuths, or 2 Points of the Compass,* may be projected into any Dial directly, as the hours were in this manner. Upon the Plain (whereon you drew the Horizontal Dial, and from the same Center therein fixed) describe a Circle; and upon it, set off from the Meridian Line, each tenth Azimuth by dividing each Quadrant of the Circle into nine equal parts, or each Point of the Compass by dividing the several Quadrants into eight equal parts; and applying the Plain to its first posture, by a Thread from the Center of the Circle, project these Azimuths or Winds into the Horizontal Line, making marks in the same Line for each one of them, as you did before for the hours. After this, from the Point of the Gnomon, set a Thread perpendicularly either upward or downward, which may represent the Zenith Line, and is therefore the Axis of all the Azimuths. By this Thread then, and the Points signed out in the Horizontal Line, you may project the Azimuths or Winds in the same manner as you did the hours before. Or thus: Stretch a Thread from the Point of the Gnomon, to the several Points of the Azimuths in the Horizontal Line; and note the Nadir Point directly under the Point of the Gnomon, upon some object laid there for that purpose. Then if with your eye you repose the Thread before extended upon the same Nadir Point, the shadow or appearance of the Thread will shew upon the Dial Superficies where the same Azimuth is to be drawn. The like must be done for every Azimuth or Point of the Compass severally.

3. *Almicanters* may be projected by the Semicircle it self, without any other help. For if you lift up the Semicircle to such a Number of Degrees as answers to the Almicanther which is to be inserted, and apply the Ruler

D d d d

of

of it, being in that posture to the Point of the Gnomon and to each Hour-line, or to the several Azimuth Lines, or else to any part of the Superficies which you will, the same Ruler will sign out Points, through which the Almicanthers are to be drawn.

4. *Such Almicanthers as shew the Proportions of Shadows (cast upon Horizontal Plains) to their upright Bodies*, may be projected in the self-same manner, by elevating the Semicircle to such Numbers in the Geometrical Square (which is upon the Semicircle) as answer to the Proportions that shall be required. That Point of the Square which is $3\frac{1}{2}$ answers to 18 deg. and is the Crepusculum Line.

¶ These four Particulars may be inserted in this manner generally in all Latitudes alike, and are therefore as Universal as are the former Precepts for the hours. The rest that follow must have particular Tables framed for them, agreeable to every Latitude. The Computation of which Tables may be in such manner as is hereafter shewed.

5. *Parallels of the Sun's Declination*; 6. *Parallels of the Length of the Day*; 7. *Parallels of the beginning of the Twelve Signs*, must first be known what Parallels they are from the Equinoctial, or what Declination they have, and likewise what Altitudes each of them have upon every hour in your own Latitude. The Parallels of Declination are soon found if you determine which of them to put in, as every fifth, or tenth from the Equinoctial, for their Declination is according to their Number. The Parallels of the 12 Signs are these 11 deg. 30 min. for $\varnothing$ ♊ ♋ ♌ : 20 deg. 12 min. for ♍ ♎ ♏ : 23 deg. 30 min. for ♐ and ♑ : the Equinoctial it self serving for γ and ♒ . Only it must be remembred which Signs are North, and which South, that so they may be placed either above or below the Equinoctial. The Parallels for the days length of 16, 15, 14, 13, 12, 11, 9, 8 hours, of what Declination from the Equinoctial they are, must be searched out (as they shall agree to each particular Latitude) in this manner: As the *Radius*, to the Sine of half an hour, that is to the Sine of 7 deg. 30 min. So is the Co-tangent of your Latitude, to the Tangent of the Declination of that Parallel, which being North, makes the day 13 hours long, or being South makes it 11 hours long. So likewise, as the *Radius*, to the Sine of two half hours or 15 deg. 00 min. So is the Co-tangent of your Latitude, to the Tangent of that Parallel that makes the Day 14 or 10 hours in length. And as the *Radius* to the Sine of 3 half hours or 4 half hours, that is $22\frac{1}{2}$ deg. or 30 deg. So is the Co-tangent of your Latitude to the Tangents of the Declinations or Parallels that make the Day of 15 and 9, and of 16 and 8 hours length, &c. A large Table to this purpose you have ready calculated for all Latitudes, from 16 to 90 deg. in the *Sixth Tractate* among the Tables there.

Having found such Parallels of Declination as you mean to use for the three former Purposes, you are then to compute upon each of them, the Altitudes of the Sun for every hour. And amongst many ways, let this be one, which is general to them all, and best wrought by the natural Canon in this manner.

First, for the Equinoctial, which is the Line that passeth through the beginning of γ and ♒ , and from whence all Declinations are counted, as also the Line upon which the Day is every where 12 hours long, the Altitudes for each

each hour may be found by this Proportion. As the *Radius*, is to the *Cofine* of your Latitude; So are the Sines of 1, 2, 3, 4, 5, 6 hours, to the Sines of the Altitudes of the hours 7, 8, 9, 10, 11, 12, in the Morning, or of 5, 4, 3, 2, 1, 12, in the Afternoon, when the Sun is in the Equinoctial. At 6 the Sun is juſt in the Horizon. Now for inserting the Equinoctial Line upon a plain Superficies any two Altitudes for two ſuch hours as are at a convenient diſtance, will ſerve turn; becauſe the Equinoctial being a great Circle of the Sphere, is projected upon a Plain into a ſtrait Line, and two Points are ſufficient to direct where to draw a ſtrait Line upon a Plain. But if the Superficies be manifold or uneven, all the Altitudes muſt be made uſe of, or two Altitudes and the Point of the Gnomon will ſhew the Equinoctial Superficies, and ſo it may be projected with a Thread.

Secondly, For all other Parallels this courſe may be taken.

1. Find out the Sines of the Altitudes of 6 a Clock in all North Parallels by this Proportion; As the *Radius* to the Sine of your Latitude; So is the Sine of every Declination, to the Sine of the Altitude of 6 a Clock in that Parallel of Declination. By this Sine found, and entred into the Canon of Sines, you may get the Altitude of 6 for every Parallel.

2. For the ſame North Parallels, add the Declination of your Parallel to the Complement of your Latitude, the Sum will be the Altitude of the Sun for 12 a Clock in that Parallel. Then out of the Sine of this Altitude of 12, take the Sine of the Altitude of 6, reſerving the *Difference*.

3. As the *Radius*, to this Difference; So the Sines of 1, 2, 3, 4, 5 hours, to ſeveral fourth Numbers, or Sines.

4. To every one of theſe fourth Numbers, add the Sine of the Altitude of 6; So ſhall the ſeveral Sums produce the Sines of the Altitudes for every hour between 6 and 12.

5. Take as many of theſe fourth Numbers as you can, out of the Sine of the Altitude of 6; ſo ſhall the ſeveral Remainders make the Sines of the Altitudes of ſuch hours as are between 6 and Sun-riſing, or Sun-ſetting.

6. Take the Sine of the Altitude of 6, out of all ſuch of the fourth Numbers, as are bigger than it, ſo ſhall the Remainders give the Sines of the Altitudes of the Sun upon ſuch South Parallels which have the like Declinations from the Equinoctial, that theſe North Parallels have.

¶ Thus having found out the Altitudes required in each kind, they muſt be ordered into Tables, and reſerved for uſe. And if according to the uſual manner of working by the Semicircle, you inſert from the Point of the Gnomon into the particular hours ſuch Altitudes as your Tables afford, you ſhall find prickſ through which to draw each requiſite Parallel. But, to ſave this labour, there are in the *Sixth Tractate*, Tables for this Purpoſe ready calculated for ſeveral Degrees of Latitude, and for the Sun's entrance into every Sign of the Zodiack, and every 10th Degree thereof.

C H A P. II.

Of Signs of the Ecliptick Aſcending, Deſcending, and Culminating.

IF you would inſert the Signs into the Hour-lines, you muſt find out what Altitudes the Interſections of the Ecliptick have with the hour Circles (two of them at the leaſt, to ſet them upon a Plain, but more are better, that they

they may serve in all Cases, and to all Superficies) at that moment of time, when the beginning of any Sign is Ascending, Descending, or Culminating, which will be found a hard Calculation. It would be as easie to find what Altitudes the Ecliptick hath at those times with some chief Azimuths. But the most easie way, that I know, will be to find out what Amplitude the beginning of every Sign, rising or setting, hath, and what Altitude the Ecliptick at the same time cutteth upon the Meridian. And for Signs Culminating, it must be enquired what Altitude the beginning of each Sign hath when it is in the Meridian, and what Amplitude also it hath at the same time upon the Horizon.

Then for *Signs Ascending*. If γ ascend, then is the Amplitude 00, and ψ is in the Meridian, and so the Meridian Altitude of ψ is the Altitude of the Ecliptick upon the Meridian whilst the first Point of γ is ascending. So if the first Point of α be ascendant, then likewise the Amplitude will be 00, and α will be in the Meridian; so that the Meridian Altitude of α is the Altitude of the Ecliptick upon the Meridian, whilst the beginning of α is ascending. For the other Signs, to know what Altitude the Ecliptick cuts upon the Meridian at their ascent above the Horizon, there must be inquired;

1. Their Amplitude;
2. The Oriental Angle, or the Angle made between the Ecliptick and Horizon at the same time.

1. The Amplitude is thus known; As the Sine of the Latitude, is to the Sine of the Declination of the beginning of any Sign; So is the *Radius*, to the Sine of the Amplitude from the East. This for North Signs being added to 90, for South Signs subducted from 90, produceth the Amplitude reckoned from the South.

2. The Oriental Angle, is thus found. As the Co-sine of the Declination of the Point ascending, is to the Sine of your Latitude; So is the *Radius*, to the Sine of the Angle made between the Meridian that passeth through the Point ascending, and the Horizon. This Angle added to the Angle made by the same Meridian and Ecliptick, gives the true Oriental Angle. Now the Angles made by the Ecliptick and Meridians that pass through the beginning of each Sign, are these γ 113 deg. 30 min. δ 110 deg. 38 min. η 102 deg. 16 min. θ 90 deg. 00 min. ι 77 deg. 44 min. κ 69 deg. 22 min. λ 66 deg. 30 min. These, I say, are the Angles before mention'd, which in these Northern Latitudes, and while they are in the Ascendant, do look upwards from the Horizon toward the Zenith and North Pole, or towards the Arch included between them. But their Supplements must be taken in South Latitudes. And although the Oriental Angle do fall out to be obtuse, and the Tangent of it is used in the next Work, whereas Tangents serve no further than 90, it is to be remembred here that any Arch and the Supplement thereof have one and the same, as Sine, so Tangent, and Secant also.

3. As the *Radius*, to the Tangent of the Oriental Angle; So the Sine of the Amplitude from the South, to the Tangent of the Ecliptick's Altitude upon the Meridian. Now these Altitudes upon the Meridian being computed for γ δ η θ ι κ λ will be sufficient; for μ ascending, the Ecliptick hath the same Meridian Altitude that it hath when δ ascends: and ν the same with η , and ξ with θ , ζ with ι , μ with κ .

¶ The two Tables then of Amplitudes and Meridian Altitudes being framed, you may by them insert the 12 Signs ascending in this manner with least trouble, though enough too. Piece out your Horizontal Line by a returning

returning Thread where need is; and upon it project the Amplitudes of the ascending Signs from the South, amongst the Morning hours. They must be protracted first upon a Plain or past-board as the hours and Azimuths were before, and from thence transmitted to the Horizontal Line, and marks or knots set thereunto. Then if the Meridian Line be there all is well; but if it be not upon the Dial Superficies, you must, for a time, draw or stretch one in the Air by a Thread placed in the plain of the Meridian in such manner as that it may receive what is now to be inserted into it. Into the same Meridian therefore, by help of your Semicircle, insert the several Meridian Altitudes of the Ecliptick, and set marks at them. After this, you may without any great difficulty, project the several Positions of the Ecliptick, thus: Stretch a Thread, fixed at one end to the Point of the Gnomon, to the several marks set in the Horizontal Line, and at every such extent let your eye repose the Thread upon that point in the Meridian which answers there to the same Sign that the Thread was extended unto in the Horizontal Line, so shall the shadow of the Thread shew you upon the Dial, where the Line for that ascendant Sign is to be drawn. And so having projected them all (12 in number) you may at the East end, among the Morning hours, write *Signs Ascending* with the Characters of those set upon each of them, which properly belong unto them: and, among the Evening hours, write *Signs Descending*, setting upon each Line the Characters of those Signs that are opposite to the former, because when any Sign is ascending, the opposite is descending.

Descending Signs then are put in by the same Work that ascending are.

Note, That in Dials that look towards the North, you must by your Semicircle project the same Meridian Altitudes upward, above the Horizontal Line, and not downwards, as in Dials looking towards the South.

9. For *Signs Culminating*. You must first find their Meridian Altitudes, which is easily done for the beginnings of every Sign. For having their Declinations before set down, you must, if they be North Signs, add their Declinations to the height of the Equinoctial, or to the Complement of your Latitude, or in South Signs, subduct the Declinations out of the Complement of your Latitude, so the Numbers produced will be the Meridian Altitudes of the beginnings of the twelve Signs. Secondly, you must seek what Amplitudes the Ecliptick hath, when the beginnings of the twelve Signs are in the Meridian. To which purpose also, the acute Angle made between the Meridian that passeth through the beginning of each Sign, and the Ecliptick, must be had in readiness: and they are these, $\gamma \approx 66 \text{ deg. } 30 \text{ min.}$ $\delta \approx 69 \text{ deg. } 22 \text{ min.}$ $\Pi \approx 77 \text{ deg. } 44 \text{ min.}$ $\ominus \approx 90 \text{ deg. } 00 \text{ min.}$ And likewise it must be noted, that any Sign from $\ominus$ to γ being in the Meridian, the *Ortive Amplitude* of the Ecliptick from the South is less than 90 deg. the *Occasive* more. But any Sign from γ to $\ominus$ possessing the Meridian, the *Ortive Amplitude* is from the South more than 90 deg. the *Occasive* less. Now then the Amplitude is found by this Proportion; As the *Radius*, is to the Sine of the Meridian Altitude of the beginning of any Sign; So is the Tangent of the Angle at the Meridian (set down before for every Sign) to the Tangent of the Ecliptick's Amplitude at that time from the South. The Amplitudes *Ortive* of the Ecliptick when $\ominus$ and γ are in the South are always 90 deg. and if you enquire the

Ortive Amplitudes of α γ ϵ η ζ , their Supplements are the Ortive Amplitudes for Π δ ν κ ω , remembring the Cautions given before. And the Ortive Amplitude of the Ecliptick from the South when any Sign is culminating is equal to the Occasive Amplitude of the Ecliptick from the South when that Sign that is as much distant from $\odot$ as the fore-named Sign was, is culminating.

¶ The Tables of the Ecliptick's Amplitudes from the South, and Meridian Altitudes being fitted, you must now accommodate your Horizontal and Meridian Lines as you did before for ascending Signs; and then among the Morning hours from a plain Board or past-board, project your Amplitudes into the Horizontal Line for the 12 Signs, and their Meridian Altitudes into the Meridian Line by your Semicircle. And being thus prepared you may project the Eclipticks severally into your Dial Superficies, and Character each Line with that Sign that belongs unto it, and with the Character of the opposite Sign that is in *Imo Cali* at the same time.

C H A P. III.

By Help of the Parallels of the Length of the Day may be inscribed these that follow.

10 Hours from Sun-rising. 11 Hours from Sun-setting. 12 Planetary Hours. 13 The six Houses that are above the Horizon.

THE Eastern part of the Horizontal Line is the beginning of the hours from Sun-rising, as the Western part is the beginning of the hours numbred from Yesterday's Sun-set. Look then for any two Parallels of the Days length that are of equal or even number (and not odd) as 8, 10, 12, 14, 16: and if your Dial be described upon a Plain, count upon any two of those Parallels the first hour from the Horizontal Line, and draw a strait Line through those two Points: the same Line if it be from the East part of the Horizon is the first hour from or after Sun-rising, if from the West it is the 23 hour from Yesterday's Sun-set. So the right Line drawn through these two second Points from the East part of the Horizon is the second hour from Sun-rising, or from the West part it will be the 22 hour from Yesterday's Sun-set, which are accordingly to be figured. And so of all the rest.

For the Planetary hours, choose out the Parallels of the day's length 15 and 9 hours; and in the first take each 5 quarters from the Horizon, in the second each 3 quarters, and draw strait Lines through them if the Superficies be plain; the same Lines are the Planetary hours, the Meridian being 6, the West Horizon 12. But in all these, if the Superficies be not plain, but either many Plains together, or one curved and irregular, you are to stretch a Thread so as that you may see the two Points for each hour before-mentioned, and the Point of the Gnomon altogether upon the Thread; then shall the shadow of the Thread in that Position expresse where every such Hour-line must be drawn.

For the Houses, find out by your Semicircle, that Point in the hour of 12 that is level with the Point of the Gnomon. If then your Dial be upon a plain Superficies, draw strait Lines from the fore-named Point through each second Hour-point in the Equinoctial Line on both sides 12; the same Lines

shall

shall be the 6 Houses above the Horizon, and the Meridian Line is the tenth House. But if the Superficies be curved, hold a Thread so as that you may see through it the foresaid two Points of each House, together with the Point of the Gnomon; for then the shadow of the Thread will shew to your eye where each House is to be drawn.

CHAP. IV.

14. Of the Rising, Culminating, and Setting of any Fixed Star.

Suppose the Star to be *Lucida Pleiadum*.

THE Declination of the *Star* Northward is 23 deg. 00 min. the right Ascension 51 deg. 42 min. First then, get the Semidiurnal Arch of the *Star* by this Proportion, As the Co-tangent of your Latitude, to the Tangent of the *Star's* Declination: So is the *Radius* to the Sine of the *Star's* Ascensional difference, which being added to 90 deg. (because the Declination is North, else it should be subtracted) gives the *Star's* Semidiurnal Arch. For *London* it would be 122 deg. 15 min. This taken out of the *Star's* right Ascension, leaveth (289 deg. 27 min.) the right Ascension of *Medium Cæli* when the *Star* is rising. Or the Semidiurnal Arch added to the *Star's* right Ascension, gives (173 deg. 57 min.) the right Ascension of *Medium Cæli* when the *Star* is setting. Then lastly also, the right Ascension of the *Star* is the right Ascension of *Medium Cæli* when the *Star* culminates. Now having gotten these right Ascensions, you may get the Points of the Ecliptick, their Declinations, and the Angles of Ecliptick and Meridian answerable, in this manner. As the *Radius*, to the Sine of $66\frac{1}{2}$ deg. So is the Tangent of right Ascension, to the Tangent of the Point of the Ecliptick answerable. As the *Radius*, to the Sine of right Ascension; So the Tangent of $23\frac{1}{2}$, to the Tangent of the Declination of that Point to which the right Ascension belonged. As the *Radius*, to the Sine of $23\frac{1}{2}$ deg. So the Co-sine of right Ascension, to the Co-sine of the acute Angle made by the Ecliptick and Meridian.

Then note, that if the right Ascension of *Medium Cæli* be in the second or third quarters of the Equator, the *Ortive Amplitude* of the Ecliptick from the South is less than 90 deg. the *Occasive* more. But if the right Ascension be in the first or last Quarters, then is the *Ortive Amplitude* more than 90, the *Occasive* less. — Having found *Medium Cæli*, say, As the *Radius*, to the Sine of $23\frac{1}{2}$; So the Sine of *Medium Cæli*, to the Sine of the Declination of *Medium Cæli*. By this Declination compared with the Altitude of the Equator, you may also find the Altitude of *Medium Cæli*, which is the Meridian Altitude of the Ecliptick. Then again, say, As the *Radius*, to the Sine of the Eclipticks Meridian Altitude; So is the Tangent of the Angle between the Ecliptick and Meridian, to the Tangent of the Ecliptick's Amplitude.

In this manner also may the appulse of any Fixed *Star* to any Azimuth, or Almicanther, or Meridian, or any other standing Circle, be computed and inserted; If namely, the Situation of the Ecliptick at that same moment be projected upon the Dial.

¶ These being found, will help to put in such Lines as shew the *Star's* Ascension above the Horizon, Descension, and Culmination. The manner of

of putting them in, is the very same that was used before for inserting the Signs of the Ecliptick *Ascending, Descending, Culminating*, so that more Words about it will be needless.

These are the principal things wherewith Sun-Dials are usually furnished. If these be well understood, it will not be hard to insert the Cosmical, Acromical, or Heliacal rising and setting of Stars, or any such like requisites. All the several uses of each kind of Lines is shewed by the shadow of the Point of the Gnomon, as it creepeth along through them.

CHAP. V.

Other Precepts concerning the Inserting or Projecting of the Furniture into Sun-Dials.

I. Of the Equator, and two Parallels thereto.

THE Parallels of the Equator are usually distinguished by these three Names. 1. Parallels of Declination. 2. Parallels of Signs. 3. Parallels of the length of the Day. Now all these Parallels being but of one kind though of several Relations, must be put into a Dial in one and the same manner; only you are to find which Parallels upon the Planisphere are answerable to each of these, and this is shewed before in *Chap. 3. Sect. 5.*

Now in general also be admonished, that all things which are inserted by this manner of Work, are done by their Altitudes above the Horizon; and if they be great Circles, such as are the Equator, Eclipticks, Azimuths and Horizon, then will two Altitudes in any two hours of your Projection serve to insert such into any Plain, because every great Circle projected upon a Plain becomes a strait Line, and two Points are enough to shew where a strait Line is to be drawn; But for every lesser Circle you must have as many Points of Altitude as there are hours, through which Points your lesser Circle is to be described with a light hand.

1. Therefore if you would put in the Equinoctial, choose any two hours upon your Plain (of as good distance as may be, that your Work may be the truer) and look upon your Planisphere what Altitudes the Equinoctial Circle hath upon those two hours (as which to do is shewed before, *Sect. 6. Chap. 3.*)

Then with your Semicircle express those two Altitudes upon the said two hours of your Dial, and you shall have two Points through which if you draw a strait Line, it shall be the Equinoctial Line, upon which you are to fix the Characters of γ and α .

2. To draw any of the Parallels of Declination, look upon your Planisphere which Parallel answers to it, and then look there what Altitudes the same Parallel hath upon every hour (*per Prop. 6. Cap. 3.*) and with your Semicircle express those Altitudes upon the Plain, each Altitude in its proper hour; So shall you have Points in every hour, through which the same Parallel is to be drawn; If they be every 10th. you must number them by 10, 20, &c. above and below the Equator. The same is to be done for the Parallels of the beginnings of the 12 Signs, upon which when they are drawn you must set the Characters of the 12 Signs in their proper places; And

And three for the Parallels of the length of the day, upon which you are to write the numbers of the length of the day, nor shall I need to make more words about them.

II. *Of the Horizon with the Parallels thereof called Almicanthers, and of them such as shew the three Proportions of the length of the Shadow to any upright Body : Of the Azimuths or Vertical Circles, and (among them) of such as serve for the Points of this Compass.*

1. The Horizon was inserted at the first beginning of the Work, and is represented by the Horizontal Line lying wholly in the same Level with the Apex of the Gnomon.

2. The Almicanthers or Parallel of the Sun's Altitude above it may be inserted by the Semicircle alone without the Planisphere; For if upon every hour you express by your Semicircle one and the same Altitude (*v. g.* the 10th. deg. of Altitude) and through those Points draw an Oblique Line as the manner is, the same Line will stand for the (10th.) Almicanther required; and so of the rest.

3. For such Almicanthers as shew any common proportion between the shadow and the upright Body; The easiest way will be to have marked out upon your Semicircle, such Almicanthers as you desire to put in, or which is better and more handsom you may describe in each of the two Quadrants which do make up the Semicircle, two Geometrical Squares, the sides whereof may be divided into 120 equal parts, and numbred as the usual manner is, and is expressed in the Figure of the Semicircle ordinarily, so shall you have all proportions fitted to your hand. As if I would put in that Almicanther which shews the shadow to the upright Body to be as 5 to 3. that is, as 120 is to 72; count 72. from the Semidiameter of the Semicircle towards the middle Point of the Square, and then I insert that Point into every of the hours upon the same, and accordingly to draw a curved Line through them, and write upon it $\frac{2}{3}$ or *superbipartiens tertias*: But if I would insert the contrary proportion, as of 3 to 5, then I count upon the Square the former number 72 from the Diameter of the Semicircle towards the middle Point of the Square, and then I insert that Point as before, and write upon the Almicanther $\frac{3}{5}$ or *supertripartiens quintas*. Now whensoever the Apex of the Gnomon comes into the first of these Lines (then the shadow $3\frac{2}{5}$ upon the Square is the Crepusculum Line or 18th Almicanther which will shew the Twilight upon the opposite Parallel) then you may conclude that the shadow of an upright Body or Building being cast upon a flat level plain, is in proportion to the upright Body as 5 to 3; that is, if you divide the shadow into 5 equal parts, three of the same parts will give you the Altitude of the upright Body; So in the second Example, if you divide the Shadow into 3 equal parts, five of the same parts will give the length of the upright Body; And thus the shadow of the Sun performs the uses of the Geometrical Square.

4. If you would put the Azimuths into your Dial, lay the Ruler upon your Planisphere to that Azimuth which you mean to put in, then observe any two hours (the further distant the better) where they intersect the Ruler, and count the Altitude of their Intersections from the Horizon, and insert them by help of your Semicircle into the Dial, each Altitude into its proper hour; so shall you have two points through which you may draw your Azimuth;

F f f f

and

and so must you do with the rest of them, and number them from the South by Tenths or Fifths, according as you put in every Tenth or Fifth.

The same course is to be taken for the Points of the Compass which are also Azimuths, and each $11\frac{1}{4}$ deg. of the Horizon represents them, for there are 8 only in a Quadrant, now 8 is contained in 90 degrees $11\frac{1}{4}$ times, so that no more needs to be said of these; they are to have their proper names signified by their Letters, as the first, second, and third from the South, Eastward, are noted by these Letters S b E : S S E : S E b S : &c. and so the rest as most know.

III. Of such things as concern the moving of the Ecliptick. And 1. of the putting in such Lines as shew what Signs are at any time Rising or Setting (commonly called Signs Ascending or Descending.)

See the Figure
of the Horizon-
tal Dial.

2. Such Lines as will shew what Signs are at any time in the Meridian, commonly called Signs Culminating.

1. Supposing any Sign to be descending you are taught by your Planisphere (*Prop. 7. Chap. 3.*) to know what degree of the Ecliptick is in any Hour-circle: Choose you then 2 Hour-circles answering to such as are upon your Plain of a competent distance, and enquire what degrees of the Ecliptick are in them at the same time, and find out their Altitudes by the same 7th Proposition, then by your Semicircle insert those Altitudes into their proper hours upon the Plain, and from the two points inserted draw a strait Line (because the Ecliptick is a great Circle) which shall be the Line, shewing when such a Sign is descending, and the opposite Sign ascending; Wherefore upon that Line you must set (suppose γ were descending) γ D, and the opposite to it π A. Or better. The Signs ascending may be characterized upon your Dial, at the West end of the Line with this written amongst them [*Signa Ascendentia*] and the Signs descending at the East end of the Line with [*Signa Descendentia*] written to them.

2. The very same course you are to take for the Signs culminating, if you make use of the 8th. Proposition of the former Chapter, so that it shall not be needful to make more words of them; and they must have set upon them the Characters of the 12 Signs with [*Signa Culminantia*] written amongst them at the one end of the Lines, and the opposite Characters at the other end with [*Signa in Imo Caeli*] written.

Concerning the using of these Lines when they are drawn, consider the Caution on the opposite sides inserted.

IV. Of the Hours of other Countries.

Horæ ab ortu; Besides the hours which we have already described which only are in use amongst us, and are called Astronomical, some Countries number their hours from the Horizon, and that three ways, therefore are called by three names usually, *Horæ ab ortu*; *Horæ ab Occasu*; *Horæ Planetariæ vel Judaicæ*, the two first kinds are equal hours, as those with us are, and of the same length really, but are numbred from 1 to 24. that is from one Sun-rising to the next, and so from one Sun-setting to the next, but the last are numbred from Sun-rising to Sun-set, every day being equally divided into 12 hours, which makes the hours of several days to be unequal one to the other, whence they are also call'd *Horæ inæquales*, How to put these into Dials, if the Parallels of the length of days be drawn before, then there is no difficulty. For,

1. The

1. The hours *ab Ortu*, begin from the East part of the Horizon; look therefore upon your Dial for two of those Parallels on which the day makes an even number of hours, as for Example 16 and 8, upon the first of which the Sun riseth at 4 in the Morning, upon the latter at 8; Then observe again upon these two Parallels the Intersections that every Hour-line of the Dial makes upon them, as next to 4 and 8, through which the Horizontal Line passeth, you shall see the Section of 5 and 9 to follow, and then 6, and 10, &c. If now through the Intersections of 5 and 9 with those Parallels you draw a strait Line, the same shall be 1. hour *ab Ortu*; and one drawn from the Intersections of 6 and 10, shall be the second hour, and so of all the rest. But if the forenamed Parallels be not drawn, you must prick down where they should be drawn, as was before shewed in this Chapter, and so make use of those Points for the same purpose, which is all one with the former.

2. The hours *ab Occasu*, are in like sort to be dealt withal; for if you make use of the same Parallels before mentioned, as 16 and 8, where the Sun sets upon the West end of the Horizontal Line on the Dial, in the first at 8, in the latter at 4 Clock, which setting is to be accounted the 24 hours, then it is evident that in the same Parallels 7 a Clock and 3 are the 23 hour, 6 and 2 are the 22 hour, 5 and 1 are the 21 hour, and so of the rest; wherefore if from these mentioned pairs of hours where they intersect the Parallels, you draw strait Lines (upon Plains not else) they shall be the 23. 22. 21 hours *ab occasu hesterno*, and the West end of the Horizontal Line is the 24 hour *ab occasu*.

3. The Planetary hours are to be dealt withal in this manner, upon your Planisphere, choose such Parallels of the days length as are easiest to be divided into 12 parts, such as are 15 and 9, in the first of which $1\frac{1}{4}$ of an hour makes $\frac{1}{2}$ part of a Planetary hour of the day, $2\frac{1}{4}$ hours makes two Planetary hours, $3\frac{1}{4}$ hours makes 3 Planetary hours, &c. In the latter $\frac{1}{4}$ of an hour makes one Planetary hour, $\frac{2}{4}$ or $1\frac{1}{2}$ hour makes 2 Planetary hours, $\frac{3}{4}$ or $2\frac{1}{4}$ hours makes 3 Planetary hours, and so forward. If then the said Parallels of 15 and 9, be drawn upon the Dial, you may prick on them the places where the Planetary hours should pass, but if those Parallels be not drawn you must then take the Altitudes of these Sections, or imagine points upon your Planisphere, and express them upon the answerable hours and parts of hours upon your Dial-plain, you shall then find 2 points for each Line of those Planetary hours to be drawn, and accordingly draw them, which if they fall out just, should pass through the hours upon the Equinoctial Line; but this is not altogether to be expected, because the Planetary hours are not really great Circles upon the Sphere, and so not absolute strait Lines upon the Dial, though near enough to give an estimate of such a Division of the day, you may therefore for more accurateness draw them a little bending, that so they may pass through the hours of the Equinoctial. The 12 a Clock is always 6, the rest numbred accordingly.

V. Of the Six Houses above the Horizon, and how to protract them also.

From the Point where 12 cuts the Horizontal Line to the hours of 8. 10. 12. 2. 4. in the Equinoctial Circle draw right lines, and they are the 6 Houses above the Horizon, those below are not to be shewed by the Sun, who is then below too: The West end of the Horizon is the beginning of the Seventh House, the next Line begins the Eighth House, the next the Ninth House, the Meridian the Tenth House, and so forward, according to which rate they are to be numbered.

VI. Of the Horizon of any City or place, whose Longitude and Latitude is known, and how to insert it into a Sun-Dial.

The speediest way that I can pitch upon, is this. After you know what kind of Longitude (whether East or West) and what kind of Latitude (whether North or South) the Horizon or Place hath, and consequently having considered whether the East or west part of the Horizon be to be inserted, or both East or West (for all these cases may fall out.) Having I say considered of all these things fully before hand, you may respectively order your Work, as for an Easterly Place whose Latitude is Northern, this Example will shew. Suppose I would put the Horizon of *Constantinople* into a Dial. First, I know *Constantinople* to have a North Latitude of 43 deg. and that it differs from the Longitude of *London* 2 hours 16 min. and that towards the East: Now because it lies Eastward from us, therefore the Sun riseth in the Equinoctial, and setteth there also before it doth with us; and this rising in the Equinoctial before us, is so much in time as the difference of Longitude comes to, viz. 2 hours 16 min. If therefore you describe the Equinoctial Circle upon your Dial (both above and below your Horizontal Line) and then either on the East part of it count the difference of Longitude from the hour of 6 always, and (in the Example here given) above the Horizontal Line on the East part (because the Sun riseth with them before us) or again, you may below the Horizontal Line on the West part (nothing is to be above the Horizontal Line in any part) count upon the Equinoctial the same difference of Longitude from 6 a Clock, thus is 16 min. before 4 a Clock on either part, or 3 a Clock and 44 min. so shall one of these two points (that which is most convenient) and the Gnomon give you two points, whereby to project the Horizon of *Constantinople*, and that must be extended so far as the projection of the 2 Tropicks and Horizontal Line do go, that so it may serve for all times of the Year which are possible. If in this Example on the East part the Projection fall quite out of those forenamed limits, it must there be quite neglected, and only put on upon the West part of the Dial.

How to find a Third point. It may be done many ways upon your own Meridian thus: As the *Radius* is to the Co-sine of the difference of Longitude; So the Tangent of the Latitude of *Constantinople*, is to the Co-tangent of the Arch of our Meridian intercepted between the North Pole (in this Example) and the North part of the Horizon of *Constantinople*, or from the South Pole, or South part of that Horizon. If therefore you stretch a Thread into the Air that may lie on the Planities of your Meridian, you may by your Semicircle insert this point; But first you must consider how far it is from this point to your Zenith: If therefore (in this Example) it be the point of the North part of your Meridian, add the Complement of your Latitude to the intercepted Arch before found; if it be the South point of your Meridian, or of the Horizon of *Constantinople*, then subtract the Complement of your Latitude out of the forenamed Arch, so shall you get the distance of this point of your Meridian from your Zenith, the Complement or excess whereof is, the Altitude or Depression from your Horizon. Afterwards by your Semicircle you may put it into the Meridian Line or extended Thread, by counting the Complement of that same distance, or the Altitude upon the degrees of your Semicircle.

Now

Now then by the point before found in the Equinoctial, and by this point thus found in the Meridian, and by the point of the Gnomon; I say by these 3 points may the Horizon of *Constantinople* be inserted; and so the Horizon of any other Place.

2. *Another way to find two Points for the same purpose, upon two Hour-Lines.*

Take any hour (as 9 a Clock in the Morning) count the distance of it from 6 (3 hours or 45 degrees) and because the hour is West of 6 a Clock in the Morning, but the place East, add the 3 hours to the difference of Longitude, which is 2 hours 16 min. the Sum is 5 hours 16 min.

In general get the difference of Longitude between the Section of your places Horizon (which Section will either be East or West) with the Equinoctial, and the hours, that is, get the Arch of the Equator contained between them.

Then say, as the *Radius* is to the Co-tangent of the Latitude (43 deg.) of the Horizon (of *Constantinople*) so is the Sine of (79 deg.) that Arch of the Equator to the Tangent of an Arch (46 deg. 38 min.) of the Hour-circle of 9 contained between the Equator and the same Horizon: And because the Latitude of *Constantinople* is North, therefore the Arch falls upon the South side of the Equator: So that if such a point, or degree were inserted upon that Hour-circle of 9, then was one point found. Now to insert it we must know what Altitude or Depression that point bears from our Horizon, which to find by calculation, we have first the Complement of our Latitude, which Complement is 38 deg. 30 min. Secondly, The distance of that point of the Circle of 9 from the North Pole, that is 90 deg. and 46 deg. 28 min. or 136 deg. 28 min. And Thirdly, The Angle of the hour of 9 from the Meridian, which is 45 deg. that is to say 2 sides, and the Angle comprehended by them; so that the Base, or third side (whose Complement is here required) may be found. Having then found this Altitude or Depression (which in the present Example) is 15 deg. 20 min. it may be inserted into the hour of 9 by the Semicircle. And in the same manner may another point be inserted into another hour. These two points then with the point of the Gnomon (3 in all) will serve to project the Horizon required.

Upon the hour of 6 a point may be found more easily, and the Altitude or Depression of it: First, for the point in the Hour-circle of 6: As *Radius* is to the Co-tangent of the Latitude of *Constantinople*; So is the Sine of the difference of Longitude to the Tangent of 30 deg. 57 min. an Arch of the hour of 6 comprehended between the two Horizons, ours and theirs. This Arch (in this Example) must be added to 90 deg.. So the Sum gives the difference of that Section upon 6 from the North Pole: But then as the *Radius* is to the Sine of our Latitude; So is the Sine of that (30 deg. 57 min.) Arch of 6 a Clock to the Sine of the (27 deg. 59 min.) Depression of the Section of *Constantinople* Horizon with our 6 a Clock Line-depression I say, because the point of Intersection is below the Horizon of *London*.

Depression is
28 deg. *Latitude*
Constantinople 43 deg.
Dif. Long. 34
deg. *Declinati-*
on South East
83 deg. 00
min. *Reclinati-*
on North 65
deg. 40 min.

3. *Another way to put in such an Horizon.*

First, get the Declination (83 deg. 00 min. South East) of it, and the Reclination (65 deg. 40 min. North) or Inclination, with the Coast where-
G g g g to

to it declineth. This Work may be performed by a Spherical Triangle made by the Poles of the Equator and of the two Horizons of *London* and *Constantinople*. Then having found these things; you may insert them thus. First, from the East point of your Horizon, count the Declination to the true Coast, and insert it into the Horizontal Line, for that shall be one point where *Constantinople* Horizon is to pass. Then again from the Meridian point insert into the Horizon (to the true Coast) the same Declination; so that this point of the Declination from the former may be distant 90 deg. To this last point having relation also to the point of the Gnomon, stretch a Thread in the Air, or draw a Line, that may lie in and represent the Azimuth passing through those two points (which a perpendicular Thread reposed upon those two points will direct you) then by your Semicircle project into this Azimuth Line or Thread the Reclination from the Zenith of your place, either above or below your Horizon, as you shall discern the Position of it to require. So then, by this means you have another point where through the same Horizon must pass. These two therefore with the point of the Gnomon will serve to project the same Horizon upon all Superficies that shall be found to stand in the way.

Another way for the same.

When the Parallels and points are drawn first upon the Dial, with the hours you may put in any Horizon without great trouble, thus. The West part of *Constantinople* Horizon; The difference of Longitude is 34 degrees, therefore the Sun in the Equinoctial sets 2 hours 16 minutes with them before it sets with us. The West point therefore of that Horizon is upon the Equator at 3 hours 44 min. this is one point. Then find another point upon some other Parallels as ϖ or ν , let it be ν , on the shortest day at *Constantinople* the Sun setteth at 4 hours 24 min. that is the day is then 1 hour 36 min. shorter than in the Equinoctial, and setteth 1 hour 36 min. sooner: Therefore from the Horizontal point noted before upon the Equinoctial count 1 hour 36 min. sooner (that is towards our 12 a Clock) and find that hour or point of time in the Parallel of ν , and there you shall have a second point of the Horizon: These with the Gnomon make the three requisite points to draw or project the Horizon: And this is the easiest way; but more ways might be found to perform the same thing, yet these may very well suffice.

CHAP. VI.

I. *The Use of all the Lines of the Furniture.*

THE Point of the *Gnomon's* Shadow sheweth (among the *Equator* and Parallels thereto.) 1. The Sun's Parallel of Declination. 2. Parallel of the days length. 3. The Sign wherein the Sun is—Amongst the *Almican- ters* it sheweth; 4. How high the Sun is above the Horizon. 5. What Proportion the Shadow of any upright thing, cast upon an Horizontal Flat, beareth to the upright Body—Amongst the *Azimuths* it sheweth. 6. What *Azimuth* the Sun is in. 7. What Point of the Compass the Sun is on—Amongst the projected *Eclipticks* it shews. 8. What Sign is ascending above the Horizon, or descending. 9. What Sign is Culminating—Among the hours of other Countries Account, it shews 10. The hours of $\odot$ Rising.
11. Or

11. Or from and to $\odot$ setting. 12. It shews also the Planetary hours. 13. What house the $\odot$ is in. 14. And principally the hour of the Day. And what else may be deduced out of these.

II. Of the Commodities of these Projective Ways.

Less cost bestowed; No Inquisition after the site of the Superficies in respect of Declination or Inclination; Not material whether it be upon one, or more Superficies together; Nor whether the Description be drawn upon a plain Superficies, or curved one, or more; Not material how those more Superficies do stand, whether contiguous, or remote, one to another; The tediousness of an *Axis* both making and setting avoided; The Insertion of the Furniture infinitely bettered and eased; No trouble in the observation of Cases comparable to the other;—The greatest trouble is the finding out the Sun's *Azimuth*, which yet may be avoided, if an Observation be made just in the Meridian.

No trouble by reason of inconveniences that fall out, when the Stile hath but small Elevation, and the Dial without a Center, the other ways are very troublesome. — The way that all men hitherto went, was first to make the Dial, then to set the *Gnomon*; But this is quite contrary and much better because the trouble of setting the *Gnomon*, is much harder than fitting the hours to it: For here the *Gnomon* is first set, and then the hours fitted to it; Cases in Declination, and Reclination avoided; In great Recliners it is hard by other ways to pitch the Work true, for a small error in the Horizontal Line, may cause a degree or two in the Vertical, upon which all depends; The very plaining of the Superficies (if no thing else were to be done) is more troublesome, than all this work of finishing the Dial.

P O S T S C R I P T.

IT was my intent, in this Place, to have inserted a Figure in Perspective, representing the inside of a Room, with several *Hour-lines*, *Tropicks*, *Azimuths*, *Almicanters*, and other Lines of the Furniture of Sun-dials drawn upon the Walls, Window-boards and Jambs, and other various Plains which the insides of almost all Rooms are incumbered with, and therein several *Capits* or small Figures representing the *Actings* of those things, namely, the extending and projecting of Lines, hanging of *Perpendicular Threads*, and other performances in this *Tractate* required to be done and there only verbally directed; but being (my self) no Designer or Draught's-man, I could not meet with any person that with convenience (to my satisfaction) could hit my intention in that kind; but that was my intent to have done both in this of *Projective* and the next *Tractate* of *Reflective Dialling*: but being thus disappointed of my intentions in this kind, I shall give you a short account of some Dials, made after these *Projective* ways.

First, If in the Glass-window of any Room, one Pain or Quarry of Glass be darkned, and a hole about a quarter of an inch Diameter about the middle thereof, the Sun shining upon the Window will, thro' that hole, cast a bright Spot of Light into the Room, which as the Sun in his motion passeth by the Window, the Spot of Light will be also removed from place to place, sometimes upon the Window-boards, sometimes upon the Jaumbs, sometimes upon the

the Sides, and sometimes upon the Floor of the Room.---If such a Hole should be supposed to be the *Gnodus* or Point of the top of the Perpendicular Stile of any Dial, I say from it the Hour-lines of a Sun-dial or of several Dials (for every side or part of the Room is a different Plain) may be made about the Room, If,

1. Horizontally you apply an Horizontal Dial to the Hole in the Glass-window, and extend a third Horizontally also from that Hole over every Hour-line (or half and quarter Hour-line) till it touch the Sides, Doors, Windows, Jambs, or other Objects or Impediments (standing in the way) about the Room: Then,

2. The Twelve a-clock Hour-line being both an *Hour-line* and an *Azimuth* also, you may (by a Perpendicular Thread or Threads,) transfer the same to the Ceiling or Floor of your Room, or to which of them will best serve your Turn, and sometime there may be occasion for both: Then,

3. In this Meridian Line find another Point, from which, a Line or Thread extended to the Hole in the Window may represent either the Direct (or Reverted) *Axis* of the World, and unto that Point or Points all the Hour-lines which you draw in that Room will have respect unto (or be in the same Plain with) this *Axis*: And therefore,

4. If you fix a Thread in one or both of these Points (or Poles rather) and extend that String by the Side of another String extending from the Hole over any Hour-line or Point found on the side of the Room as before, that moveable String being gently moved by the Side of the Horizontal String shall trace out (upon all Objects that it meets withal) the Hour-line which the extended Horizontal String doth represent.

Secondly, If a Spot, or the Sign of the Sun (or what ever else you fancy) be made or painted upon any Pain of Glass in a Window; And on the outside of the Window some Horizontal Border (Semicircular, or of any other form) be made of Wood or Wire; and a Meridian Line found which shall pass thro' that Hole, another Point of the *Axis* may be found, in which Lines extended by the Horizontal Lines extended from the Hole to the Horizontal Points in the Border, those Hour-lines may be projected to the Monions of the Windows, and there fastned, as also to the Horizontal Border, and these shall be true Hour-lines, whose Names or Numbers being set in a Border of Paper pasted (or painted) about the Pain of the Glass-window, where the Spot is: Then the Strings without (which are the Hour-lines) when the Sun shineth, with all of them, cast their Shadow upon the Pain of Glass, and the Shadow of that which toucheth (or is nearest to) the Spot made or painted in the Window gives the hour of the day.

Infinite are the Varieties of this kind, of which you shall have hints of many at the end of this Book, in the Description of the *Pyramidical Body of Dials*: And so I shall conclude this *Treatate*, giving you here only the Figure of an Horizontal Dial for the Latitude of *London*, with its Furniture.

The End of the Tenth T R A C T A T E.

Projection, it is required that there be room convenient; and because these are made for the most part in Windows, where the reflection of Light may be best made in the shady places of the inner parts of the Rooms; it will be required that liberty be allowed to work without the Window also. It is not absolutely necessary that the Glass should be flat, it may be of another Form, if you desire to have it so, but then your Hours cannot be so easily projected, because they will not be strait but crooked Lines upon a plain Superficies, and the trouble augmented to find so many several points, as will be requisite to the drawing of such bending Lines. But because most Glasses are flat, and it will be harder to procure one that is not so, than one that is; and because also, any that is ingenious this way, will of himself (though some things are here also delivered, which will be Directions enough) be able to find out the manner of projecting from an irregular Glass, after he is possessed with this that is here in the first place delivered; I will only shew how to do it, to a flat Glass, in what Situation soever it stands, because by it any of the other Forms will be understood. If any will reflect upon Water and other Liquors, it is apparent that they will ever lie Horizontal; and so the way to do that will be the same with the Horizontal Glass, which comes after in its due place.

C H A P. II.

Of Reflected Dials.

For Glasses there are most varieties of Situations; Liquors lying all Horizontally flat without any Inclination at all.

Reflection is best made by a piece of Looking-glass, which is so much the better, by how much it is thinner; for the thickness of it causeth a double ray of Light to be reflected, and requireth a greater elevation of the Sun Beams than a thin one doth: it must be about Seven times the thickness in breadth; and because Glass reflects from the upper and neather Superficies, and so makes two spots, colour the lower Superficies therefore with Oyl Colour, or (which is better) rub or grind it, on a rough Brick, Tyle, or Grind-stone, and it will make but one spot. Now a Glass may be placed either Horizontally or Obliquely; and the inner Rooms of Houses (for which this way is most accomodate) may fall out to be either flat or turned, both on the Cieling and Walls. In all these Varieties it will be esteemed none of the easiest works to protract true Hours; and what others have written in this kind, is only for to draw Hour-Lines to a Glass placed truly Horizontally, reflecting upon a flat Cieling, which is likewise *in equilibrio* with the Horizon; which very particular I will here also shew how to perform in a much more easie way than hath yet been practised, after I have first delivered in general (amongst many) Three several Ways.

C H A P.

C H A P. III.

How to project Hours from a Glafs, however it stands upon any Superficies whatfoever, or how manifold foever it be.

S E C T. I. *The First General Way.*

YOU must stretch an Horizontal Thread, between the Glafs and the Sun, at any reasonable distance from the Glafs, and *in equilibrio* with it; upon this Glafs and upon the Horizontal Thread (by help of a proper Thread) project the Sun or shadow of the Thread, just as was before taught in making a Dial with an Axis; and according to those Precepts (supposing the Glafs to be as the point there assigned) make up here (in the same manner as is there taught) the first of these Precepts, so shall you find the Pole of the World, as at the end of the Eighth Precept is declared. These things being thus prepared, you are to begin with your Reflections in this order and manner.

First General Way for Flat Glasses.

1. Reflect the true Pole of the World, before found, upon some Object, which is done by looking into the Glafs, till you see the fore-named true Pole. And to the end you may the sooner discover it, you may find this or the like helps: Stretch a Thread, or draw your Finger from the Glafs to the true Pole; which Thread or drawing of your Finger (if you follow the shadow all along as it appears in the Glafs) will bring you to the sight of the true Pole; and this same course must be used in all other Reflections, which may serve as a general Admonition once for all, in all the rest of the work. And when you have discovered it in the Glafs, place some mark then at your Eye (suppose some Wire or Thread fixed at one end, the other end at liberty in your Hand, the Thread having a slipping Knot upon it. This Thread and moveable Knot may be removed to any posture, and serves as a Mark or Point; so that looking or laying the same Point upon the Glafs, with your Eye you may also justly see the true Pole or Mark of it in the Glafs) then may you extend a Thread from the Glafs to this Point or Knot, up to the top of the House (or to the Walls or Floors according as things are placed) and so make a point there, which may be called the Reflected Pole. (Or the former Point, if it stand firm, may as well serve to supply the use of the Reflected Pole.) To this Reflected Pole fix a Thread, which will perform all the Projection that hereafter followeth. This Thread, for distinction, may be called the Reflecting Thread.

This may be called the way to discover.

If you will take pains to stretch Threads to every Hours Point, and to project the Parallels thereinto by the Semi-Circle, you may reflect the Knots, and so reflect the Parallels by your Eye.

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2. All the Hours will be projected by these helps very easily; for having by your Eye discovered in the Glass any of your Hour Points fixed in the Horizontal Thread (your Eye being at a good distance from the Glass) take the Reflecting Thread, and interpose it between your Eye and the Glass (the further off it the truer) so as that the Eye may repose the Thread upon the Hour Point of the Horizontal Line appearing in the Glass; and the Thread in this Position fixed, will give the Hours reflected upon any Superficies whatsoever it be that stand in the way.

3. Having fixed the Reflecting Thread, as before, fix (or let one hold) another Thread (a Projecting Thread) to the Glass, and taking the other end of it your self, apply it all along the side of the Reflecting Thread, drawing it out at full length, till (namely) it reach to the Top, or Walls, or Floor of the Room; so shall you prick out the Tract of the Course of the Hour Line upon all Superficies, as lie in the way, where through you draw out your Projecting Thread; and if the Superficies, be flat, you need not make above two Points upon one Superficies, and so draw a strait Line through those two Points. The same work is to be repeated every Hour particularly, and in the self same manner; so that I shall not need to spend more words.

And Note, That in all Projections (Direct as well as Reflected) if you have the Gnomon, or Point, or Glass (but the Glass must be flat) and any one part of an Hour Line drawn upon the Superficies, you may, after the Dial is finished, transfer that Hour to any Superficies beside, by stretching one Thread from the Apex of the Gnomon to any Point of that Hour Line that is drawn; and then by stretching another Thread from the same Line, by the sides of the first Thread, till it touch the Superficies, upon which you would have it Projected, and into as many Points as shall be required, through which the Hour-Lines may be described.

A Note concerning Drawing of Hour Lines to be Reflected upon from Concave or Convex Glasses.

This is the general way to Reflect Hours from all Positions of a flat Glass to all kind of Superficies.

If the Glass be not Flat, but Convex or Concave, you must extend a Thread from the Reflected Pole to the Points or Hours in the Horizontal Thread, and there fix it; then discover in the Glass several Points of the same Thread, making standing Marks (one at a time) for the several Points and from the Glass through those standing Marks (one to be done before you go about the other) extend a Thread to the Roof, or Wall, or Floor; this extended Thread shall give one Point for the intended Hour. Thus you are to do for other Points of the same Hour, by which means you shall find several Points for one Hour, through which Points you must draw a Line, which will not be strait, because the Glass is not Flat. In the same manner do for all the Hours.

SECT.

S E C T. II.

The Second general Way is this, and it concerns only Flat-Glasses.

HAVING stretched an Horizontal Thread, and fixed Hour Points upon it, as in the former way, you must find the Glasses Zenith Point; Second general Way for Flat Glasses. which is easily done, if you look till you see your own Eye Reflected in the midst of it; for if you there set a standing Mark (as was before shewed) and by another Thread extended from the Glass to that Mark, continue the Extension of it until you meet with some Object (*viz.* Walls, Cieling, or Floor,) this Thread will there give you the Glasses Zenith Point; from which Point to the Glass a Thread must be fixed, representing the Glasses Zenith Line.

Now because Angles of Incidence and Reflection, are the same in quantity from the Zenith Line, but cast to the contrary Coast and because likewise the Lines of Incidence and Reflection are both in the same Superficies with the Zenith Line (that is to say, the Superficies wherein they three are, is ever proper to the Superficies of the Glass.) If therefore you extend Threads, one from the Glass, to a Knot in the Horizontal Thread, and another second Thread from the Glass also; but on the other side of the Glasses Zenith Line (which second Thread must lie in the same Superficies with the first Thread and Zenith Line, which when it doth so, your Eye will discern, for in this case all the Threads will lie to view, one upon another) making an Angle with the Zenith Line on the contrary side, equal to the Angle made by the first Thread with the Zenith Line. How to make this Angle equal, I leave here to be described hereafter.

Let the first Point Reflected from the Horizontal Thread, be the Meridian or 12; the Thread then so disposed (as before) will give one Point of the Meridian, upon the Roof or Wall of the House. And by the Zenith Line or Thread of the Glass, by reposing of it with your Eye upon this Meridian Point, you may draw the Reflected Meridian Line; then consider whereabouts the true Pole of the World, which is elevated above the Glass, is and elevate it by the Semi-Circle in the true (not Reflected) Meridian, and cast it upon some Object (Cieling or Wall, &c.) and from the Glass to it extend a Thread, which is the true Axis of the World. This must now be Reflected, by making another Thread to pass from the Glass, on the contrary side of the Zenith Line, but making equal Angles from it with the first. And to do this, and to judge when it is contrary, is before shewed in the Projecting the Points of the Horizontal Line. This Thread is to be fixed, and represents the true Axis, and is therefore to be called, *The Reflected Axis of the World*. So then all the work will be now, to Reflect the several Points of the Hours upon the Horizontal Line, unto the Roof or Walls, or what Object soever (Flat or not Flat) stands in the way; and then by this Reflected Axis to Project them, by those Reflected Points, all over all the Objects that stand in the way. This is the Second General Way, which cannot in all particulars be applied to curved Glasses, because a curved Glass cannot be counted as one Plain, and cannot have one Zenith Line.

S E C T. III.

The Third General Way is only for Flat Glasses.

Third General Way for Flat Glasses.

1. **Y**our Glas being set, and the Sun shining, observe the spot of Light Reflected, and make a Mark at it; At the same instant take the Sun's Altitude, and inquire what Azimuth the Sun then had.
2. You are to make a Reflected Horizontal Line thus; set any two Points *in equilibrio* with the Glas, Reflect those two Points in the same manner as was shewed before, and make two standing Marks, as was before declared; then through those two standing marks extend a Thread; this Thread (though nothing at all Parallel to the Horizon) shall represent the Horizontal Line, and must be fixed, and called, *The Reflected Horizontal Line*. This may be turned or continued sideways, upwards or downwards, as occasion shall offer it self, by turning a Thread from the ends of it, in such wise that the casting (with your Eye) the first fixed Thread, upon (or unto) the Glas, the continuation, or returning Thread, may be seen all one with the first Thread, and so lie in the same Superficies with the first Thread and the Glas. All these Threads are to be accounted for the Reflected Horizontal Line.
3. Your own Zenith or Nadir Point must be Projected, which is done by setting some Marks or Points, perpendicularly over or under the Glas; and removing your Eye till you can see the same in the Glas: then when you see it, set a standing Mark, so shall a Thread extend from the Glas to this standing Mark, and so till it meet with some Object, represent the Zenith or Nadir Line (not of the Glas but) of the Horizon, to which end let the Thread be there for a while fixed.
4. By reposing this Thread upon the spot of Light before found (which respects the Azimuth wherein the Sun was at the time of Observation) you may project the Sun's Azimuth into the Reflected Horizontal Line, where you are to tie a Mark; for this guides all the Work that follows.
5. Next consider whether the Azimuth were East or West, and consequently, on which side of it the Meridian will fall; which being known you must upon this Reflected Horizontal Line protract the said Azimuth in the same manner that is used in the former way, from that Reflected Horizontal Line into the Past-board; only you must observe to do some things (though the same in substance, yet) different in a peculiar manner, as thus: Upon a Past-board (or any other Flat) being held to the Glas, as the Apex of a Gnomon, and staid so by resting upon some Substantacle, that (though it be taken away, yet again) it may be applied to the self same posture: I say upon a Past-board fitted to the purpose, and applied to the Center of the Glas (being taken here as the Center of an Horizontal Dial) and directed also towards the Reflected Horizontal Line, that it may fall into the same Plain; stretch out a Thread from the said Center to the Point of the Azimuth noted upon the Horizontal Reflected Line, and note the Line that the Thread makes upon the Past-board, for the same Line represents the afore-said Azimuth.
6. For this Azimuth, observing the true coast of Reflection, set off the

the Meridian, and so to describe upon Past-board an Horizontal Dial (remembering how to number your Hours by considering unto what Coast the Reflection will carry them) and putting your Past-board upon its former Situation, with a Thread from the Glafs or Center, project all the Hours from the Past-board to the Reflected Horizontal Line; and tie Marks at each of them severally.

7. You are then to Reflect the Pole, and to fix a Reflected Axis in this manner: First, Reflect the Zenith or Nadir Point, and make a standing Mark at it; then extend a Thread so, as that through the length of it you may see the Point of 12 in the Horizontal Line, the Reflected Zenith and Nadir Point, and the Glafs, all three together, so shall you, by that means, lay this Thread in the Planities of the Meridian. Now in the Meridian lie the Poles of the World, distant from the Horizontal Line (that distance being counted in the Meridian Superficies) so much as the Elevation of the Pole, or the Latitude of the Place, or the Supplement of the Latitude cometh to. Now whether to choose the Latitude or the Supplement thereof, the disposition of the Work will be ready to shew you. After this then apply a Past-board to the Glafs, and set it always directly towards that Thread in the Plain of the Meridian, and let it always rest upon some stay, that though it be taken away, yet it may be again placed in the former true posture. Then from the Glafs to 12 upon the Horizontal Line, extend a Thread, and draw upon the Past-board the Line that the Thread sheweth; and upon the same Past-board from that Line so drawn, and from the Glafs, as a Center, or place the of it on the Past-board, protract an Angle of you Latitude, or the Supplement of it, that way that the Reflected Pole would happen, and applying your Past-board to its old place again, by a Thread from the Glafs extending along that Line on the Past-board and fixed, you have the Reflected Axis.

8. Having fixed this Reflected Axis, by it and the Points upon the Horizontal Reflected Thread, you may project the Hour Lines upon any Object (flat or curved) whatsoever it be, and after draw them, and distinguish them as before hath been shewed.

For further Observation herein, Note, That it falls out oftentimes that Windows are so disposed, that no Axis can be fastned to project withal; and the Rooffs likewise so uneven, that a true Horizontal cannot be protracted: In such cases, if the Glafs lie flat, you may help your self in this manner: Extend an Horizontal Thread in the Air, lying level with the Glafs; upon this Thread project the Points of an Horizontal Dial; likewise stretch another Thread in the Air, directly East and West, parallel to the Horizon, elevated above the Meridian at an Angle from the Glafs $38\frac{1}{2}$, equal to the Equinoctial's Altitude; and upon this Thread also project Hour Points by an equal Circle or Past-board, &c. Now if you extend Threads from the Center of the Glafs to the Horizontal Hours, and from those extended Threads, do extend others to the equal Points upon the Roof, you shall make points enough through which to draw the Hours.

C H A P. IV.

How, to a Glass laid in the Window, and placed truly Horizontal, to Draw Hours upon a Cieling that is also truly Horizontal, and Flat, not Curved.

THE following way of the next Chapter is projective: This is for the most part Lineary, and suitable to other Draughts. This is also more particular, tied to the Cieling, and to that also as flat only and single, not any way curved or multiplied. The other following will be for all kinds and numbers of Superficies in general. This more frequent and more easie also, that more seldom happening and more difficult.

This is branched into two Cases, that is more generally delivered in one way; in both which this is common, namely, First, Observe a Spot of the Sun's Light made upon the Cieling, and to make a mark at it, and take the Sun's Altitude at the same instant, and inquire what Azimuth the Sun then had.

These things so prepared, you are likewise to find a Meridian Line, to which end you must also find the Zenith Point of the Glass upon the Cieling in this manner: Hold a Perpendicular Thread to the Cieling, in such place that through it you may at once see both the Mark made for the spot of Light observed, and also the Center of the Glass, then protract that Line (blindly) upon the Cieling, which the Thread so hanging seems to make upon it; this Line so drawn represents the Sun's Azimuth at the time of Observation. Again, Hold up to the Cieling, in any other place of it, the same proper Thread, and remove your Eye till you see (through the hanging Thread) the Center of the Glass, and (your Eye there standing) observe where the same Thread cuts through the Azimuth Line before drawn; at the apparent intersection make a Mark, for that is the Zenith of the Glass, or the Point that is just over it perpendicular. Upon this Point, now being taken as a Center, describe a piece of a Circle from the Azimuth Line, and set off (upon it) the distance of the Meridian from the Azimuth, keeping the true Coast that it should have, which your own Judgment will tell you well enough; then from the Center to this distance, a Line drawn, will give you the Meridian Line. Having thus found a Meridian Line or Line of 12, the rest of the Work will branch it self into two Forms, according as the Window shall look, towards either South or North.

S E C T. I.

If it be a Window, whose Aspect is towards the South.

FROM the Glass elevate your Semi-Circle towards the North part of the Meridian which you have Drawn upon the Cieling; I say elevate your Semi-Circle directly from the Glass to the Meridian, unto the Altitude

Altitude of your Equinoctial, and where the Ruler of your Semi-Circle points (which may be found by a Thread apply'd to, and extended along, the same Ruler, till it meet with the Plain or Cieling) into the Meridian, there make a Point; through this Point draw an infinite Line, perpendicular to the Line of 12 or Meridian; this Line represents the Equator, upon which you are next to insert the Hour Points in this manner: Take with a pair of Compasses the Distance between the Glasses Center and this Point of Intersection, between the Meridian and Equinoctial Lines, the same Distance you must account as a Radius, and is therefore to be divided into 1000, or more, Decimal Parts, as your Decimal Scales use to be. Then out of this Scale, and by help of a Natural Canon, take the Tangents of each Hour, or 15 deg. *viz.* 15, 30, 45, 60, 75, and prick them down upon the Equinoctial Line on both sides the Line of 12, so many as the Room will receive, so shall you have 5 Points on each side of the Meridian (or so many of them as the Room will give way for,) through which all the Hours are to pass; and so if the Center of the Dial, or the common Point of their concourse were within the Room, it were a very easie business to draw all the Hours from those Points to that Center and the Six a clock also through the same Center, perpendicular to the Line of 12. But because the Centers of these Southerly Dials do most commonly fall without the Room, therefore this way cannot be used. The best way therefore that I can judge of is this, You must have an Horizontal Dial Calculated for your Latitude, then supposing the space betwixt 12 and 11, or 1, the next Hours on either side to be 11 deg. 51 min. you may take the Complement of that space, which is 78 deg. 09 min. and upon the Points of the Hours next to 12, as upon two Centers describe two Arches of Circles, and protract the Angle of 78 deg. 9 min. from the Equinoctial Line, so shall Lines protracted at those Angles from the Equinoctial Line, be the true Hour Lines required. For if the Angle between 12, and the next Hour be 11 deg. 51 min. and the Angle between the Equator and Meridian be a right Angle, then must the Angle betwixt the Hour and the contingent Line be the Complement of 11 deg. 51 min. that is 78 deg. 09 min. Thus you may do for all the rest of the Hours till you come to 6. For the 6 a clock Line you must know, that it is to be drawn Parallel to the Equinoctial Line, and to be distant from it, as much as the Co-secant of the Latitude taken to the fore-named Radius, or decimal Scale will extend unto.

For the other Hour Lines that are further remote from 12 than 6 is, it will be best to do thus; draw a line in any place, but perpend. to the Line of 6, and observe at what Distance and Angles the Hours already drawn do stand from 6, and what Angles they make with the perpendicular last drawn. Set the same distance upon the Line from 6, and at those Points protract the same Angle to the Line last drawn, so shall the Lines protracted be the true Hours required.

But if in this case your Equinoctial Line is not long enough to hold all the five Hour Points between 12 and 6, you may help your self thus, Prick down as many of them as you can from 12, three at the least then draw a Line Parallel to the Equator Line, so that the length of it betwixt 12 and any Hour, may be $\frac{1}{2}$ or $\frac{1}{4}$, or some such like part of the length of the Equator intercepted between 12 and the same

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Hour,

Hour, that the work may be the more easily proportioned ; when this is done, you may upon this last Line set off from 12, or, of the Tangents before-mentioned, which will give the Points in the said Line, through which the Hours must pass; and because the Line is parallel to the Equator, therefore at those Points you must make the same Angles with this new drawn Line, that the same Hour would have made with the Equator, and therefore they must be protracted in the same manner. And if you would cast the Hours from the Cieling to the Walls, you may do it by the general way set down in the fore-going Precepts to transfer any Hour by the Apex of the Gnomon, any part of that Hour being given or drawn.

You may turn the Secant of your Latitude at any other Hour, as 4, and divide it into the Tang. 30. Or you may at the third Hour Point from 12 in the Equinoctial, turn up a Perpend. to the Equin. or a Parallel to 12, and make that Line to be in length equal to the Co-secant of the Latitude taken out of the former Decimal Scale or Radius. If now at the end of this length you draw a Line Parallel to the Equinoctial, the same will be the Line of 6. Then further, taking the Co-secant of the Latitude as a Radius, or Decimal Scale, set upon it (as a Radius) from the Point of 6 the Tangents of 15, 30, and 45, that is the Tangents of 1, 2, 3, Hours; the third Hour Point being at the meeting of the Equator, and this Point, or the whole length of the Line, and (which I should have said before) draw this Line quite beyond, as far as the Cieling will suffer, and from the Point of 6, both ways, or on both sides of it, set on the Tangents as before; so have you the Points through which all the Hours must pass. Then if it be known at what Angles to this Line the Hours do lie, it will be easie to protract such Angles upon the fore-placed Points, and accordingly to draw the Hour Lines. Now the Angles that each Hour Line makes, with this Line last drawn, are the same that they make with the Line of 12, and accordingly must be protracted.

S E C T. II.

If it be a Window looking towards the North.

HAVING found a Meridian Line, as is shewed before; from the Glasses Center upwards into the Meridian Line, elevate your Semi-Circle, according to the Latitude of your place, and observe (by a Thread joyned to the Ruler of the Semi-Circle, if need require) where the Ruler of the Semi-Circle Points out the same Latitude, there make a Point, for that is the Center of your Dial, which is nothing but a plain Horizontal Dial. If you describe a Circle upon the Center, and likewise out of that Center erect a Perpendicular to the Meridian, you are fitted to perform your work; for you have no more to do but to set off either from the Hours of 6 or 12 (which you like best) all the other Hours, according to their spaces, in an Horizontal Dial from 6 or 12; and so this case proves easier than the former did.

C H A P. V.

How by this manner of Work upon a Flat Window that is truly Horizontal, and to a Point set up, as the Point of a Gnomon, may Hours be protracted to a direct Shadow : Thus,

OBSERVE the shadow of the Point, mark it, take the Sun's Altitude at the same instant, and require the Azimuth; then with a Perpendicular Thread project the mark of the Azimuth, upon the Point of the Gnomon, and draw that shadow or tract of the Thread made upon the Window-board, which Line will be the Azimuth. Again, Hold up your Perpendicular Thread, and Through it view the Point of the Gnomon, and at the very instant (your Eye and Thread being both immoveable) see also where the Thread appears to cut the Azimuth before drawn, and mark that point of intersection; upon that Point, as a Center, describe a Circle, and upon the same Circle (from the Azimuth toward the true Coast) set off your Meridian and draw it. Then,

S E C T. I.

If it be a Window looking towards the South.

FROM the Point of the Gnomon down to the Meridian, let fall your Semi-Circle, so much as the Complement of the Latitude comes to, and mark the Point which the Ruler of your Semi-Circle then makes upon the Meridian: Perpendicular to the Meridian, in this Point, draw the Equinoctial Line, and then finish all your Work, as is taught before in CielingDials; for it is the same quite through, without any manner of difference at all; and so there needs no more to be said of it.

S E C T. II.

If the Window look towards the North.

FIND out the Meridian, as you did before, then from the Point of your Gnomon, depress your Semi-Circle, into, or upon, the Meridian, so much as your Latitude is, and note the Point in the Meridian, that the Ruler pointeth out, for that is the Center of the Dial; from which Center a perpendicular to the Meridian, is the Line of 6; and from 6 and that Center you may protract all the Hours, as before in Cieling Dials, that look towards the North.

C H A P. VI.

How from a Glafs Horizontally placed (or from Water or other Liquors) to Reflect Hours upon any Superficies Flat or Curved, one or more.

All the Furniture of Dials may be put into Horizontal Flat Glasses, by expressing upon the Hour Lines (with your Semi-Circle) such Altitudes as are true, and that above (not below) the Glafs or Horizon.

THIS is for Reflected Dials within a Room, and is not yet limited to a plain Superficies, but in general to all, Flat or Curved, lying Horizontal or standing Upright, or else Leaning. It is general, in respect of the Superficies, whereunto the Description is to be made, but particular in respect of the posture of the Glafs, for that is here required that it should be Horizontal. Now to place it Horizontal, do thus, Lay it into a little Board, flat and even with the Board, and either make it fast, by forcing it into the Board (the place of it being strait and just fit) or else overlay it with a Plate of Lead beaten very thin, but before it lie true to the flat of the Board; then with a small Level lay the Board truly Flat or Horizontal, which will be done without any great difficulty, which is to lie for the most part in the Window.

1. The Glafs being laid, observe the Spot of Light that the Sun casts, and make a mark at it.

2. And immediately observe the Sun's Altitude, and find the Azimuth.

3. Then extend an Horizontal Thread in the same Level with the Glafs, but within the Room.

4. Afterwards project the Azimuth into the Horizontal Thread, by holding up a Perpendicular Thread in such a place, that though it hang at liberty, you may at once discern both the mark of the Spot of Light, and the Glafs likewise; and then observe where the Perpendicular Thread seems to cut the Horizontal Thread; at that apparent intersection tie a short Thread for a mark of the Azimuth.

5. Apply a Past-board to the Glafs, and so that it may be staid upon some rest, that after it is taken away it may be restored to the first posture without impeachment: Let it be also held Horizontally, so as that it may have full Relation to the Horizontal Thread.

6. At the Glasses Center make a Point for a Center upon the Past-board, and extending a Thread from the Center of the Past-board to the mark of the Azimuth upon the Horizontal Thread, draw upon the Past-board that Line which the Thread so extended figures out thereon. Afterwards, unto the same Azimuth, upon the Past-board, draw a Meridian, and to it an Horizontal Dial, and applying the Past-board to its first Situation, project the Hours thereon, unto the Horizontal Thread, and the Knots; all which is done in the Room.

7. Then project the Meridian (by a perpendicular Thread, covering, in appearance, both the Knot of 12 and the Glafs) unto the contrary Coast to that wherein the Pole is elevated (above the Horizon) that is to say in our Northern Climats you must project the Meridian Southwards from the Glafs, because the North Pole is elevated. And in the Meridian, elevate your Semi-Circle from the Glafs Southwards, till it rise up to your Latitude; so shall the Ruler of the Semi-Circle point out (upon some Object set to receive it) the North Pole Reflected

Or

Or else if that be not convenient (because in Windows or such like places that stand towards the South, the North Pole will be without the Room, and so the Axis above the Glass extended towards that Pole will be without also) you may in such cases find out the opposite Pole to it, that is to say, the Pole which the former reflected Axis being extended through the Glasses, and below it, would sign out, and that may be effected in this manner:

Project the Meridian Line towards the Pole that is elevated, that is with us towards the North Pole, and then (because the North Pole is elevated by Reflection towards the South, so, by the same reason the South Pole must be depressed towards the North) with the Ruler of your Semi-Circle, directed even with the Center of the Glass, express or project your Latitude downwards (but towards the North) so shall the Ruler of the Semi-Circle point out the Reflected South Pole in the Meridian. Now whether you will or can (most conveniently) use the reflected North Pole above the Glass, or the reflected South Pole below it, you are to take your choice, for both the one and the other of them do represent the reflected Axis of the World.

8. By this reflected Axis, and the Hour Points signed out upon the Horizontal Thread, you may easily project the reflected Hours, in the same manner that hath been heretofore declared upon any kind of Superficies, one, or more, what ever they be that stand in the way.

C H A P. I.

How to make a Dial to a Flat Glass laid aslope, reflecting the Hours all obliquely, and upon any kind of Cieling, whether Flat or Curved, or mixt of both, &c. If the Window wherein it is placed look towards the South.

ALthough somewhat hath been said hereof before, yet this being in some particulars different, it shall be set down in several by it self.

S E C T. I.

Of setting the Glass, and fitting it for the intended use.

IF it be a piece of Looking-glass foiled, then the Work of the Dial will be the most visible, and so more expedite; but then it will reflect two spots of Light at the least, the darkest whereof coming from the upper Superficies, will be the Spot that the Dial will answer unto; but if the Foil be rubbed off, and the back-side (instead of Foiling) be covered over with thick Oyl Colour, or rubbed on a Brick, &c. then will it reflect only the dark Spot from the upper Superficies of the Glass, and the light Spot (which in the other came from the Whiteness and Politeness of the Foil) will (in this) be utterly lost. This will be the

truer way to go, but the more obscure for Reflection, both in making and using of the Dial. Which soever of the two Glasses you will use, let it be of an indifferent large Diameter (about $\frac{1}{4}$ of an inch or more) that the Reflection may be the more facile, as hereafter will be shewed. Let it be inlaid into a piece of Lead or else Wood, such as the heat of the Sun Beams may not alter; and there fixed with hard Wax, or such like glutinous matter; then place it aslope in such conveniency for Reflection as you shall judge fittest, namely, so as the work may be (most of it at least) cast upon the top and sides of the Room, and as little as may be upon the Floor. And if the Stool of the Window wherein you fix it be broad, then let it not stand upon the Stool of the Window, but above it, at some reasonable distance, least by the same Stool you, perchance, be hindered in the Reflection. Upon the middle of your Glass, as near as you can guess, make a small spot of Ink, which spot hereafter is called the Center of the Glass.

S E C T. II.

Of the Observation to be made by the Sun, and fitting all things for further progress.

TO perform this work of Observation, you are to do all things, as if you were to make a direct Sun-Dial, to the Center of the Glass, as the Gnomon; and that all common impediments may be removed, let all the panes of Glass, where the Reflecting Glass lieth, be taken down out of the way, that you may have convenient room to do that which now followeth:

1. First, set an Horizontal Thread *in equilibrio* with the Glasses Center.
2. Hang up a perpendicular Thread, betwixt the Sun and the Center of the Glass, so as that the shadow of it may pass through the Center of the Glass; and in that position you must diligently observe where the shadow of the same perpendicular Thread, doth (at the same time) cut the Horizontal Thread. And to perform this the better, let your perpendicular Thread be bigger than ordinary; and besides hold in your hand some fair Paper (which may better receive and represent to you the shadow of the Perpendicular Thread) so as that you may thereon see where the shadow of the Perpendicular Thread doth cut the shadow of the Horizontal Thread, and in the apparent intersection draw a slipping Knot (ty'd before for that purpose upon the Horizontal Thread) along the Horizontal Thread, till the shadow of this Knot fall into the former intersection of shadows; and when this work is done, (which will be troublesome enough and so you will need one to help you) immediately take the Sun's Altitude.
3. And by that Altitude compute the Azimuth of the Sun, which is represented by the fore-mentioned slipping Knot, fixed in its due place as before.
4. By that Azimuth, and a Past-board (Horizontally apply'd to the Center of the Glass, and so lying level with the Horizontal Thread) insert the Meridian Point, and the Points of all the other Hours, as is used in Direct Dials, in the Horizontal Thread, and there affix Knots severally.
5. By a perpendicular Thread held up within the Room, and ordered

in the hanging so, as that you may see through it (at once) both the Meridian Knot, and the Center of the Glas; project the same Thread upon the top of the Room, this Projection shall be the Meridian Line, which passeth directly over the Center of the Glas.

6. From the Center of the Glas into this Meridian Line, direct your Semi-Circle, and elevate it to your Latitude, and so (by it) inject the North Pole into the same Meridian, which, in those Windows that look towards the South, will fall within the House upon the Cieling.

7. From the Center of the Glas to this North Pole extend a Thread for the Axis of the World, and for that purpose fit a Wire with a head like a Pin, then fasten that Wire into, or near to the Wood whereon the Reflecting Glas is laid, and bow down the Head of it, until it touches the Glasses Center; then fasten your Thread Axis to this Head of the Wire, at one end, and to the Cieling at the other end.

Thus are all things fitted for further progress in the Work. That which is hitherto delivered, no what differing from what is prescribed for making Dials for the direct Rays of the Sun.

S E C T. III.

Of further fitting the Work that is pre-required to the Reflecting of Hours.

Before any Reflection can be made, it will be requisite, that the direct Hours be so expressed, that they may from thence be brought into the Glas, and from thence again Reflected to the Cieling or Sides, or any other part of the Room. And the readiest way that I can find for this purpose is this.

HAVING before prepared your direct Axis, and likewise the Hour Points upon the Horizontal Thread, you may by them project (with your Eye) each Hour severally without the Window, by one of these two ways:

1. Lay a long Stick or Pole without the Window (upon two Rests) about as low at least as the Reflecting Glas, half a yard from the Reflecting Glas, some little Stick or Wand upon the outwards towards the Sun, and let it lie (as low or) near about the Level of the Reflecting Glas: There is no exactness required in this.

1. Nail down somewhat near, and lie about half a yard without the Window towards the Sun, and some small quantity within, that it may be conveniently turned about with some stiffness; make a notch in the very end of the Stick, that a Thread may lie and stay in it without slipping.

2. When things are thus fitted you are first to project each of the direct Hours severally (by help of the direct Axis, and of the Hour Points upon

upon the Horizontal Thread) upon the Posts of the Window. The way is, by reposing the Knot (of that Hour you would project) upon the Thread-Axis, and then your Eye (limited to that posture) will project the Axis, (or the fore-said Hour) upon the Window Posts. Of which appearance or Projection of the Axis, take notice of that Point only upon the Window sides, which is nearest to the extremity thereof, or which looketh most

Upon the Pole laid without the Window, in that point of the Post fasten a Nail.

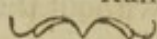
3. Upon that Nail, at the very entry of it into the Post, hang a Thread, and put the same Thread upon the out-side of the Stick, or Pole that is laid without the Window, and so turn it under again, and bring it into the Window, where you may hang some small weight at the end of it only to keep it strait.

4. Set your Eye again in the self-same Position, or Posture that it had before, that is, let the Axis be reposed again upon the Point wherein the Nail was driven, and on which the Thread now hangeth, and keeping your Eye fixed there, remove the Thread which goes about the Stick, until you see it justly close with the Axis, and when you have situated the Thread in this Position, let it stand; for now the Center of the

Upon the extremity or notch of the Stick lying without the Window, there in that Point of the Post fasten a Nail.

3. Upon the Nail (where it enters upon the Post) hang a Thread and put the same Thread into the Notch at the end of the turning Stick, and hang some little weight at the end of it only to keep it strait. Thus is there a Thread extended from the Nail to the end of the Stick.

4. Set your Eye again to the same posture that it was before, that is to say, repose the Axis again upon the Point whereon the Nail was driven, and whereupon the Thread now hangeth, and keeping your Eye fixed there, turn the moveable Stick, in the Notch whereof the lower end of the Thread rideth; turn it, I say, until the whole Thread fall justly in with the Axis; and when you have situated the Thread thus, let it stand; for now the Center of the



Glass, and this newly situated Thread do lie in the Superficies of that Hour which you are about to project; and consequently wherever the Sun is in the plane of that Hour, then will the shadow of the Thread fall upon the the Center of the Glass, which is the Ground of the whole Work of Reflection, which now followeth: Let this be called, *The Directing Thread*.

S E C T. IV.

Of Reflecting the Hour-Lines from the Hour Thread to the Cieling.

1. **T**O prepare yet further for the Reflection of the Direct Thread, fasten a Nail upon some Post of the Window or other (if it be near right over the Glass, it is the more convenient for use) and on it tie a Thread, which for distinction sake, call, *The Reflecting Thread*, and let

let the length of it be such as may reach to the Stool of the Window, or any other Stool set for the purpose in the way, upon the edge whereof this Reflecting Thread may be stayed from wavering; and for more stability, hang a Weight at the end of it.

2. Upon the same head of the Wire, tie another Thread, and let it hang loose by you, until need shall call for it; call this, *The Projecting Thread*.

3. Look now into the Reflecting Glass, until you see the Projecting Thread, which if you have once or twice tryed, you will easily find without long looking. And when you do see it, carry your Eye, according to the length or course of the Thread, still keeping it in your Eye, until you have brought your Eye as much over the Reflecting Glass, as conveniently you can; and then also see that your Eye lay the Hour Thread just in the Center of the Glass. When this is done, move the Reflecting Thread till you can perceive it to lie justly between your Eye and the Glasses's Center; and likewise the direct Thread appearing in the Glass; that is, let all be done so justly, that your Eye may at once see all these three justly together in one Point, namely, the directing Thread (represented in the Glass) the Reflecting thread, and the Center of the Glass; and when you see them all three together, hold your Eye as far off as you can, that they may appear in more exactness; then let the Reflecting Thread rest against the edge of some Stool, set for that purpose and bring the slipping Knot, that it also may justly (to your sight) lie upon the Glass's Center, and the represented Directing Thread: and so let them rest.

4. Then take the Projecting Thread, and draw it out to the Cieling, so as it may touch the slipping Knot before-mentioned; and when it doth so, note in what Point it toucheth the Cieling or Walls, &c. of the Room. Note that Point (I say) for one Point (of the former Directing Thread) Reflected.

5. As in the last 3 Section, so in this place again, look for the same Directing Thread in the Glass, and follow it down till your Eye come as low (I do not mean near) to the Glass as you can; and keep the represented Thread upon the Center of the Glass: Then bring the Reflecting Thread betwixt your Eye and the Glass; and move it and the slipping Knot upon it until your Eye (at a good distance off) can see this Knot, the Center of the Glass, and the represented Thread, all three justly together, one upon the other. And then fix your Reflecting Thread.

6. Afterwards take the Projecting Thread, and by it (as in the last 4th Section) project the Point or slipping Knot up or down to the Cieling or Walls, or Floor of the Room; so shall you get a second Point (of the same Directing Thread) Reflected.

7. Then having two Points of one Hour found out, you may extend your projecting Thread to one of them, and with your Eye repose the Thread upon the other of them; so shall the appearance of the Thread give you all the Points, through which the Reflected Hour Line must be drawn. And by this manner of Work, the same Reflected Hour may be continued, or carried quite through the Room.

8. In the same manner all the other Hours must be drawn severally. First, They must be set or projected directly into the Thread Hours, called, *The Directing Threads* (as in the 4th Sect. of the IIId.) and afterwards from

M m m m

thence

thence they are to be Reflected, as in this 4th and the Sections hereof is shewed.

C H A P. VIII.

How the former Precepts are to be apply'd to Windows looking Northward.

1. **A**LL the Observation, and laying of the Horizontal Thread within the Room, &c. is to be done as before.
2. But in these Windows, the Direct Axis will rise from the Glass upwards without the Room (not within it, as the last did) There must therefore something be set up to receive it, that it may be fixed from the Center of the Glass to that which is to receive it.
3. Then you are to lay some long Stick or small Pole (at some convenient distance from the Glass) without the Window, laying it as low as the Glass: This is to receive the direct Hours, which to place right do thus.
4. Project with your Eye the Hour Points (or Knots that are upon the Horizontal Thread) upon the direct Axis, so shall the Shadow (or Projection) of the Axis, give the same Hour upon any Object that lies in the way, as namely, upon the Pole that way laid on purpose to receive it. And this Work you may do either of these two ways:

First Way,

Second Way.

Make Marks only upon the Pole, for each several Hour, and when they are all Marked, tie a Thread to the top of the true Direct Axis, or, take the true Direct Axis it self (or Pole of it) and then stretch that Thread to any of the formerly noted Points; the same Thread shall represent each Direct Hour, according as it is applyed to each such Point. These are the Direct Hours, and may be Reflected as is taught before.

The work is the same as before to make Marks upon the Pole for the several Hours, which being done, you must first Reflect the Pole, and mark a point of it within the Room; this Point is the Reflected Pole: Then reflect each Point upon the Pole into the Room, so have you the Hour-Points Reflected. After this fasten a Thread to the Reflected Pole, and then stretch the same to any of the Reflected Hour Points; and then project this Thread upon the Glasses Center so shall the Thread shew where to draw the Hours. Thus do for all the Hours.

But if some of these Points upon the Pole fall to be below the Glass (and so cannot be Reflected) then stretch a Direct Thread from the true Pole to any such Hour; and do further, as in the first of these ways; so these North Windows are compleated too.

Note,

Note, Instead of the 3d. Section of this Direction where you are prescribed to lay some small Pole, you may nail down a small Stick, or Wand, upon the Stool of the Window, as is before prescribed Sect. 3. Num. 1. of South Windows.

C H A P. IX.

How to make East and West Dials to aslope Glafs upon any Walls or Cieling.

THese Windows that look near to full East or West, cannot have any Direct Axis extended as other (North and South) Windows have, because the Posts of the Window will stand in the way, so is this here added, that the Horologigrapher should not be left destitute. And now, although no Axis (either Direct or Reflected) can be extended, yet the Direct North Pole may be found (and then the Dial made) in this manner:

1. Having set the Horizontal Thread within the Room, even with the Center of the Glafs, make an Observation of the Azimuth, as is before directed in South Windows.

2. Then amongst many ways take this, Stretch a Thread from the Center of the Glafs to the Knot of the Azimuth, ty'd in the Horizontal Thread; this Thread so stretched shall represent the observed Azimuth. Or if you cannot (because of some hinderances that shall lie in the way) stretch out a Thread in that manner, lay on just over those two Points (of the Glafs and Horizontal Thread) and let it also be equidistant from them both, which you may do by your Compasses.

3. Assume some one Point of this Azimuth Thread for a Center, fixing some firm Point there, and call that Point the Center. Then upon Past-board (or such like) protract the Azimuth and (the North or South part of) the Meridian, or the Angle that is made between them. Afterwards lay the Center of this Angle upon the fixed Center before mentioned, and direct one of the Legs of the Angle under the forenamed Azimuth Thread, so shall the other Leg of the Angle (if you hold it right, which your judgment will easily direct you in) design where the Meridian shall be, which project upon some Object (as Cieling or Walls) as the manner is, upwards to the North Pole.

4. In this Meridian, with your Semi-Circle, find the Pole, and (from the fixed Center to it) extend an Axis: This Axis is parallel to that which should go up from the Glafs.

5. Above and below this Axis stretch another Thread Parallel to it, at a good distance, which to do, there are many ways [as see the *Lemma* after these Precepts] which now I suppose known; so that now you have two Axes, by which you shall find the true North Pole to the Center of the Glafs (though you cannot extend an Axis from thence) namely thus:

6. Repose (with your Eye) one of these Axes upon the Center of the Glafs, and mark where it shadoweth upon some fit place to receive the

the Pole (a good way from the Glafs, and if there be nothing to receive it, fet up ſomething) there draw a Line. Then reſoſe the other Axis upon the Center of the Glafs, and mark where it ſeemeth to croſs the former drawn Line, that croſſing is the North Pole to the Glaſſe's Center.

7. Then having found the Pole, faſten a Thread at it; and without the Window lay a Pole as before ſhewed, as low, or lower than the Glafs. The work that now remains, is to ſet Hours without the Window, that ſo they may from thence be Reflected into the Room.

8. Take the Pole Thread, and lay it to one of the Hour Points upon the Horizontal, and reſoſe it with your Eye upon the Glaſſe's Center, that ſo through this projecting Thread you may at once ſee the Knot upon the Horizontal Thread, and the Center of the Glafs. In this Propoſition the ſhadow of the Thread will Project two Points, one upon the Barrs or Poſts of the Window, and the other upon the Pole that lies without. You may ſo ſtretch a Thread from theſe Marks, and that Thread ſhall be the direct Hours without the Window; and you may try whether you have ſet it true by the Pole Thread applied again to the Hour Point in the Horizontal Thread. When the direct Thread is thus placed, you may Reflect it, as hath been before ſhewed.

L E M M A.

How by having one Thread extended in the Air, to ſet another Parallel to it.

FIrſt project the Radiation of the ſtanding Axis, that way that you mean to ſet up your new Axis; then in that Radiation let two Threads be extended, touching the Axis both of them, and both making Angles with the Axis (the nearer Right Angles the better) and both hidden in the former Radiation, and both faſtned; ſo theſe two Threads do keep both in one Plain, and both in the ſame Plain with the Axis; and the new required Axis is to touch theſe two Threads ſo placed: Wherefore extend another new Thread for a new Axis, which may touch theſe two Threads always; and in that touching Poſition try with your Compaſſes, until you find it equidistant from the other Axis. You may help your ſelf by ſetting any ſolid thing that may touch the firſt Axis towards each end, in a Point whereon the foot of the Compaſſes may ſtand without quavering, and ſo eaſily try whether and when the new Axis is Parallel to it.

Another way to ſet an Axis juſt under or over the firſt.

HAng up the two Perpendicular Threads towards both ends, that may touch the firſt Axis, and put ſlipping Knots upon them, in thoſe Points wherein they do touch; then put two more ſlipping Knots at one, or any equal diſtance below or above thoſe two firſt Knots: And when this is done, let the two Perpendicular Threads hang at liberty, and quietly. If now you extend a new Thread, that may touch theſe two laſt Knots upon the Perpendicular Threads, the ſame extended Thread ſhall be another Axis Parallel to the former. And this (as I ſaid before) muſt needs lie juſtly above or juſtly below the former Axis, and will do the buſineſs.

C H A P.

C H A P. X.

If a Flat Reflecting Glass should by mishap, be put out of his place, how to restore it again.

THOUGH I speak only of Flat Glasses, yet I intend to direct how such a Flat Glass may be restored to its true Position, whether it be to lie Flatly or Obliquely. One may be thus:

Because such Glasses lie most commonly in Windows, or such places, you may so, (when your Hours are drawn upon the Cieling or other-where) stretch a Thread from the Glass to any one Hour, and then with your Eye project the same Hour Line, or one Point of it, (if it be not so done before) upon some other Object then is the Cieling, such namely, as stand either Perpendicular, or at some sensible Angle to the Cieling or Superficies upon which your Hours are drawn (as the Glass or Posts of the Window) and make some mark of this Projection, with some Sign, or Note upon it, or Figure, that you may afterwards know again, to what Hour it belongeth; so do with some other Hours also, that is, two or three, or four Hours distant from the former; so shall you (by the foresaid Hours, and their Marks, now mentioned) be able to restore the Glass, if it were taken away. In this manner:

By the two Hours, and their two Marks, you may find the reflected Axis again, by which the Hours were, or might have been projected at the first; for two Threads, being first fastned to the two Hours, and these Marks, you may from those Hours (and by their two Threads, closely touching them) stretch out two other Threads, and where they (upon those conditions of touching the two new extended fastned Threads, shall intersect one another, there is one Point of the Reflected Axis, and there is some set Mark or Point of Wood to be for a time fixed. So again, the same two Threads in the same manner extended, to touch two other parts of the first fastned Threads shall find another Point of the Reflected Axis, at which Point again, another Mark or Point of Wood is to be fastned. This projecting, or re-finding the reflected Axis, may be done other ways (as by the Eye) which they that have practised these Precepts in this Book, will be ready of themselves to find without any more Directions.

Now in any part of this reflected Axis (with a Thread extended from the two fore fixed Marks, or Points of Wood quite along, as far as is needful will shew) you may fix the Glass again: I say in any part of it, if your Dial have nothing but hours in it, but if it be furnished with other Circles of the Sphere, then not any Point of the Axis, but one only Point where it stood before, must be found again, for that only will serve all turns: And the readiest Directions to find that Point will be this:

If your Dials be furnished with Parallels of the Length of the day, count that Parallel which is equal to the day's length, in which you would restore the Glass, for along that Parallel should the spot of Light move all that day: Wherefore you have no more to do but to prepare a Glass, and move it to

and fro upon a small bit of Wax, till the spot of Light be Reflected upon the said Parallel of the length of the day, and there fix it. The like may be done if the Parallel of the Signs (and not the length of the day) were inscribed upon your Cieling; if first by the Planisphere you find in what Parallel the Sun is upon that day in which you intend to restore your Glafs. But if neither the Parallels of the length of the day, nor the Parallel of the Sun's course; but the Azimuths (or only the common Hours) be upon the Cieling, yet you may help your self thus. At some convenient time of the day find by the Planisphere what Altitude the Sun shall have upon that Azimuth or Hour, on the day you intend to restore the Glafs, then (before that time of the day come) extend a Thread from the place where the Glafs is to rest, to some part of that Hour or Azimuth, for which you have before computed the Sun's Altitude, moving of it backward or forward along the said Azimuth or Hour, till the Thread and Plummets of the Semi-Circle being apply'd thereto, hangs upon the Altitude before found; and where your extended String resteth upon the Azimuth or Hour, make a Mark; and observe diligently when the Sun comes to that Azimuth or Hour: Then move the Glafs in its place to and fro, till the spot of Light be Reflected upon the Point before found, upon the Azimuth or Hour; and there fix the Glafs.

The End of the Eleventh TRACTATE.

REFLEX DIALLING,

S H E W I N G,

The Way to Draw all manner of *DIALS*, which shall shew the Hour by a Spot of Light, *Reflected* from a *Glass* upon any *Cieling*, or other *Object* whatsoever, without any respect had to the *Axis* of the *World*, either *PROJECTED* or *REFLECTED*.

A S A L S O,

Whether the *Glass* lie *Parallel* to the *Horizon* or *Oblique* unto it.

T O G E T H E R

Will all necessary *FURNITURE* belonging thereunto.

All performed by an easie *INSTRUMENT* fitted with *Lines* to that purpose.

By JOHN TWYSDEN, M.D.C.L.

The Twelfth T R A C T A T E.

C H A P. I.

The Description of the Instrument.

LET there be a strait Ruler of Wood or Brass made, as *AG*, the length, breadth, and thickness, at Discretion: About the middle of it, or nearer to the end *A*, let the hollow *B* be made large enough to compass a Socket of Brass, into which the Glass must be fitted, and so that the fiducial edge *ABC*, may be imagined to pass thro' the Center of the Glass, when it is fixed. On the other side, as at *F*, may be made another hollow, like that at *B*, to the end you may use either edge of the Ruler, as occasion may serve; to the end of this Ruler must be added another at right Angles *CM*, made moveable, yet so supported by a Bracket *E*, behind, that it may stand steady at right Angles, and unto this let there be fitted a slipping Socket with a fiducial edge *hi*; let the piece *CM* be divided as a Tangent Line to the Radius *BC*, and of that length that it may contain about 47, or 48 degrees, which you need not divide beyond 45. On the other side *KM*, to a shorter Radius, let the Tangent Line be continued

tinued to 64 degrees, or thereabouts, which will be far enough for most Dials of this kind, the whole representing two sides of a Rectangular Parallelogram, or Carpenters Square, the one Leg longer than the other, all which by the Figure annexed, is easily understood.

CHAP. II.

Precepts for the Ready Use of this Instrument.

First, in the place where you intend the Glass shall lie, make fast some piece of Wood or Brass, exactly Horizontal, unto which, you may joyn some other large piece of Board, Past-board, or other, it matters not, so as it be made to stand firm and Horizontal, till the Dial shall be finished, and then taken away.

Secondly, Having upon any part of your fixed piece of Wood made a Mark, over which precisely shall be the Center of your Glass; upon this Mark as a Center describe so much of a Circle as is necessary, to as large a Radius as the Past-board will give way, and then the Sun shining, hold up a Thread, so that the shadow of it may pass through the Center of your Circle; and mark where it cuts the Circumference, and at the same instant take his Altitude, and find his Azimuth, either trigonometrically, or by some Astrolabe: of all projections of the Sphere, I know none so exact for the performance of all things necessary for the making these Dials, and the solution of all other Astronomical Problems, as that commonly called *Blagrove's Jewel*, now put out, every way much amended and altered by Mr. John Palmer, Rector of *Eton* in *Northamptonshire*, my especial Friend.

Thirdly, having found his Azimuth, set off now the South or East Line, by help of a Scale of Chords made to the Radius of your formerly described Circle, we will take the Example of an East Dial: As for Example, In the Latitude of 52 deg. 15 min. I observed in the Tropick of *Cancer* the Sun's Altitude 15 deg. 00 min. By my Astrolabe I find his Azimuth, then from the East, or six of Clock Line was 19 deg. or 71 deg. from the Meridian or Midnight Line Northward, but because in this Example the Meridian could not be expressed, I set off 19 degrees upon my Circle to the right Coast, and there through the Center draw a Line, which shall represent the East Azimuth.

Fourthly, Your East or Meridian Line, if it may be, being thus drawn, have recourse to your Astrolabe, or by Trigonometry find these ensuing things. First, for all necessary Hours which will come upon the Dial, find the Sun's Azimuth, and likewise what Altitude it hath in that Hour and Azimuth; do this for the Tropick, the Horizon (in Dials made to Oblique Glasses) the Equinoctial, or for as many of the Sun's Parallels as you please; I have made choice of the Distance upon the Horizon, and Tropick of *Cancer*, for a Flat Roof two are enough, because the Hours will be strait Lines otherwise if the Roof be concave, convex or any way uneven, it will require the finding of more points; write these down, as in the Table ensuing.

In the Latitude of 52 degrees, 15 minutes.

*Distances from the East
on the Horizon.*

*In the Tropick of Cancer.
Hon. Azim. from East. Suns Altit.*

Hours	deg.	min.	
4	36	00	From East Northward
5	18	40	
6	00	00	
7	18	40	From the East South- ward.
8	36	20	
9	51	40	
10	65	30	
11	78	20	
12	90	00	

H.	m.	D.	m.	D.	m.
4	00	37	30	02	00
5	00	25	40	10	00
6	00	15	00	18	30
7	00	03	30	27	30
8	00	09	00	37	00
9	00	22	30	45	30
10	00	40	00	53	30
11	00	62	30	59	20

*The Sun's Azimuth, Altitude, and Amplitude, for every Hour in the E-
quinoctial and Tropicks, calculated from 50 to 65 deg. of Latitude.*

		H O U R S.											
		Before Noon.		XI	XI	X	IX	VIII	VII	VI	V	IV	
		After Noon.		XI	I	II	III	IV	V	VI	VII	VIII	
Latitude 50 deg.	Trop. ☉	{ Azi.	90 00 60	38 37	26 20	12 6	49 48	53 15	36 26	19 37	24		
		{ Alt.	63 30 61	02 54	41 46	15 36	53 27	15 17	47 8	48 00	37		
	Equinoct.	{ Azi.	90 00 70	44 53	00 37	28 23	52 11	36 00	00				
		{ Alt.	40 00 33	23 33	50 27	02 18	45 9	35 00	00				
	Trop. ♀	{ Azi.	90 00 75	45 62	04 49	16							
		{ Alt.	16 30 15	18 11	30 6	24	☉ set						
		Amplitude	90 00 78	24 66	09 52	33 37	00 19	17 00	00 19	17 37	00		
Latitude 51 deg.	Tropi. ☉	{ Azi.	90 00 61	31 38	37 21	20 7	31 48	20 15	18 26	10 37	24		
		{ Alt.	62 30 60	09 54	04 45	53 36	45 27	20 18	03 9	14 1	13		
	Equinoct.	{ Azi.	90 00 70	57 53	25 37	50 24	05 11	45 00	00				
		{ Alt.	39 00 37	26 33	02 26	25 18	20 9	22 00	00				
	Trop. ♀	{ Azi.	90 00 75	49 62	10 49	40							
		{ Alt.	15 30 14	20 10	57 5	38	☉ set						
		Amplitude	90 00 78	14 65	50 52	09 36	38 19	02 00	00 19	02 36	38		
Latitude 52 deg.	Tropi. ☉	{ Azi.	90 00 62	20 39	41 22	16 8	19 38	43 14	59 26	01 37	23		
		{ Alt.	61 30 59	16 53	26 45	31 36	37 27	25 18	19 9	41 1	50		
	Equinoct.	{ Azi.	90 00 71	13 53	46 38	14 24	28 11	55 00	00				
		{ Alt.	38 00 36	29 32	13 25	48 17	56 9	10 00	00				
	Trop. ♀	{ Azi.	90 00 75	53 62	15 49	24							
		{ Alt.	14 30 13	12 10	04 4	53							
		Amplitude	90 00 78	05 65	32 51	46 36	14 18	47 00	00 18	47 36	14		

O o o o

HOURS

		H O U R S.																								
Before Noon.		XI	XI	X	IX	VIII	VII	VI	V	IV	III	II	I	XII	XI	X	IX	VIII	VII	VI	V	IV	III	II	I	XII
After Noon.		XI	XI	X	IX	VIII	VII	VI	V	IV	III	II	I	XII	XI	X	IX	VIII	VII	VI	V	IV	III	II	I	XII
Latitude 53 deg.	Trop. ☉	{ Azi. 90 Alt. 60	00'63 30'58	05'40 23'52	42'23 47'45	12'09 08'36	03'32 28'27	18'14 28'18	40'25 34'10	52'37 07'02	21'16 02'26															
	Equinoct.	{ Azi. 90 Alt. 37	00'71 00'33	27'54 33'31	08'38 25'25	31'24 11'17	45'12 31'08	05'00 58'00	00'00 00'00																	
	Trop. ♀	{ Azi. 90 Alt. 13	00'75 30'12	56'65 24'09	19'49 11'04	27'07 07'07																				
	Amplitude	90	00'77	55'65	15'51	23'35	52'18	33'00	00'18	33'35	52'															
Latitude 54 deg.	Tropi. ☉	{ Azi. 90 Alt. 59	00'63 30'57	43'11 29'52	40'24 08'44	06'09 44'36	47'22 14'27	49'14 31'18	20'25 49'10	42'37 33'03	19'16 03'03															
	Equinoct.	{ Azi. 90 Alt. 36	00'71 00'34	40'54 36'30	29'38 36'24	58'25 34'17	02'12 01'08	14'00 45'00	00'00 00'00																	
	Trop. ♀	{ Azi. 90 Alt. 12	00'75 30'11	55'62 28'08	23'49 18'03	30'07 21'07																				
	Amplitude	90	00'77	46'54	58'51	02'35	31'18	19'00	00'18	19'35	31'															
Latitude 55 deg.	Tropi. ☉	{ Azi. 90 Alt. 58	00'64 30'56	28'12 35'51	36'25 28'44	00'10 19'36	29'22 08'27	13'14 34'19	00'25 04'10	32'37 59'03	16'16 39'39															
	Equinoct.	{ Azi. 90 Alt. 35	00'71 00'33	55'54 39'29	50'39 47'23	19'25 56'16	19'12 40'08	23'00 32'00	00'00 00'00																	
	Trop. ♀	{ Azi. 90 Alt. 11	00'76 30'10	02'02 27'07	28'49 24'02	31'36 36'07																				
	Amplitude	90	00'77	31'64	41'50	41'35	11'18	07'00	00'18	07'35	11'															
Latitude 56 deg.	Tropi. ☉	{ Azi. 90 Alt. 57	00'55 30'55	06'43 41'50	31'25 46'43	53'11 53'35	10'12 57'27	31'13 38'19	40'25 18'11	21'37 25'04	13'13 15'15															
	Equinoct.	{ Azi. 90 Alt. 34	00'72 00'32	05'55 42'28	09'39 58'23	40'25 17'16	35'12 14'08	32'00 19'00	00'00 00'00																	
	Tropi. ♀	{ Azi. 90 Alt. 10	00'76 30'09	05'62 29'06	31'49 31'01	33'50 50'07																				
	Amplitude	90	00'77	29'64	25'50	20'34	51'18	55'00	00'18	55'34	51'															

C H A P. IV.

How to fasten the Glafs and draw the Hours.

HAVING gone thus far, your next work will be to fasten your Glafs in its Socket, to what Obliquity you please, at adventure, and so to order all things that the Center of of your Glafs may be directly over the Center of your formerly described Circle, and the height of the Center of your Glafs, equal to the thickness of your instrument; so that the hollow part of the Ruler encompassing the Socket, the fiducial edge may pass through the Center of your Glafs, which you may mark with a little speck of Ink, till your Dial is done.

The Hours are to be Drawn in this manner: First, get the Points where the Hour Lines shall cut or touch the Horizon in the Cieling, by which Points the Horizon it self may at the last be drawn. These Points you shall get, as in this Example in the Latitude of 51 deg. 00 min. when the Sun riseth at Four, I find by the Table annexed in the Column belonging to that Latitude, that his Amplitude or Distance from the East Northward, is 37 deg. 19 min. Place therefore the Radius of your Instrument to that Amplitude or Azimuth, marked before in your Circle upon the Horizontal Board; and the Socket being set to the Sun's Altitude, which is 60 deg. 00 min. observe, with your Eye, where the fiducial edge of the Socket, in the point of intersection with the Altitude, will be reflected from the middle of the Glafs, which you shall find always in the same Azimuth, if the Glafs be Horizontal; but if the Glafs be Oblique to the Horizon, the Reflection will swerve toward the Pole Zenith of the Glafs, more or less, as the Obliquity is. Hang a Thread, or fasten it in any place, so that holding it between your Eye and the Glafs, it may catch this reflected Socket wherever it comes, and where it cuts the Thread tie a slipping Knot. Now a Thread extended from the Center of this Glafs, by this Knot to the Cieling, shall touch the Point where the Hour Line of Four is to cut the Horizon. In like manner you shall find the Points for 5, 6, 7, 8, if need be; and if you will also, for 9, 10, 11, and 12, working by the Amplitudes of the several Hour Lines, as you did by the Amplitude of Four. A Line drawn through these Points, shall represent the Reflected Horizon, if you shall have a desire to draw it.

Then lastly, Go to your Table for the Tropick of *Cancer*, and in the Azimuths marked in your Circle, and belonging to every Hour you intend to draw, place the Radius of your Instrument, as before you did for the intersections of the hours with the Horizon, and move the Socket in the upright Ruler of your Instrument to the degree of Altitude belonging to that hour you intend to draw, which you shall find in your Table calculated for the Elevation of the Pole, from 50 deg. to 56. deg. and with your Eye Reflect it by help of a Thread hung up any where, and held between your Eye and the Glafs in the same manner as you did the Reflected Horizon; and where a Thread extended from the Center of the Glafs by the Knot touches the Cieling, that is the Point for that Hour, and

a Line drawn from thence to its correspondent in the Horizon, shall represent the Line where the Reflected spot of Light will be for all the year.

As for Example in the Latitude of 51 deg. 00 min. I find by my Table that the Sun's Amplitude or Azimuth from the East Northward in the Tropick of ϖ is 37 deg. 19 min. at the hour of Four. There I place the Radius of my Instrument, and move the Socket to 1 deg. 13 min. the Sun's Altitude in that hour, then the Instrument remaining in this situation, I reflect the Socket as before was shewed. This you must repeat for such Hours as you intend to draw, and finish your Dial if you think fit.

Note, When you cannot readily find the Image of your Socket, in the Glafs, being narrow, you shall lay a broader piece upon the narrower, and having found it in the broader (which will soon be done) keep your Eye upon it till some body remove the broader Glafs, and you shall easily find it in the narrower, for there about it will pass.

Note, also, That if you find not your Latitude in the Tables, you must work a proportional part, in this manner: Suppose I desire to draw a Dial in the Latitude of 51 deg. 32 min. and would find where the Hour of Four intersects the Horizon; I find not that Latitude, but find 50 deg. 00 min. and 51 deg. 00 min. In 50 deg. 00 min. I find the Amplitude at 4 hours 00 min. is 37 deg. 24 min. In 51 deg. 00 min. it is 37 deg. 19 min. their difference is 5 min. Therefore, As 1 deg. : to 5 min. :: So 32 min. : to 2 min. 40 sec. which being subducted out of the Amplitude belonging to the Latitude of 50 d. 37, 24 shall give you 37 d. 21 min. 20 sec. the Amplitude required. Or, adding it to the Amplitude of 51 d. 00 m. you shall find the same thing.

CHAP. IV.

Of the Furniture of Dials.

THE Parallels of Declination, of Altitude, the Azimuths, Proportions of the shadows of their Gnomons, and the like, commonly called the *Furniture of Dials*, may be easily inserted by this instrument, if any man shall desire it. Though to speak my own judgment, I think these kind of additions rather for Ornament than use. First, Because they are many of them in their own nature difficult to describe, being Sections of a Cone, and must therefore be drawn from many points, which hath some difficulty in the performance, except where they fall out to be Circles, which case will only happen where the Plain passeth by the vertex of the Cone makes Right Angles with the Axis, there the common Section is a Circle. If the Plain touch the Cone, it will be a Parabola. If it cut it, an Hyperbole. Lastly, If it neither makes Right Angles with the Axis, and neither cuts, nor touches the Cone, it will be an Ellipsis or streight Lines, as the Azimuths in a Flat Roof.

Secondly,

Secondly, because when they are Drawn, every Astrolabe will resolve the Problems more truly than they will.

I might add a third Reason, because the multitude of Lines often hinders those that are not used to them, to tell the Hours of the day, which is the chief use of Sun Dials, especially of those of this kind, where the shadow of one Point of the Axis gives the Hour.

Yet, least any should think this Instrument imperfect, I shall shew the Description of some of them, and leave the rest to the Industry of every Man.

CHAP. V.

The Parallels of Declination.

THese are of as great use as any, because the two Tropicks being the Parallels of the greatest Northern or Southern Declination, may serve to limit or bound the Dial, and for them I need add no new Precept, having before in the third Chapter taught you the Description of the Tropick of ϵ . The Tropick of ϖ is described in the same manner by help of your Table, placing your Instrument to the Azimuth belonging to every Hour, and marked in your Horizontal Circle, and Reflecting the Socket, being before placed to the due Altitude. If you desire the intermediate Parallels, either you must take the pains to Calculate Tables or by an Astrolabe, you may perform it exactly enough for this purpose.

CHAP. VI.

The Parallels of Altitude.

THe Parallels of Altitude are inserted after this manner; not much differing from the former. Suppose I would insert the 20th. Parallel of Altitude. Move the slipping Socket to 20 degrees in the Ruler, and the Radius being placed in any part of the Horizontal Board, Reflect with your Eye, by the help of a Thread, and a slipping Knot the image of the Socket, and carry it to the Ceiling; do thus till you have found as many Points as you Please, through which a Line drawn, shall represent that Almicanter.

C H A P. VII.

The Proportions of the Shadows to their Gnomons.

THese are no other than Circles of Altitude to a determined proportion, and may thus be set on. Consider first, what proportion you desire to express. As for Example, I desire to know when the Shadow is double to the Radius. I take in my compasses the length of the lesser Radius of my Instrument, and upon the upright Ruler from 00 deg. 00 min. measure that length twice, you will find the Compasses to fall upon 63 deg. 30. min. to that degree and minute, set your moveable Socket, then your Instrument being placed as before is taught, *viz.* That the fiducial edge of it, pass through the Center of the Glasse, remove it upon the Horizontal Board, from place to place, and reflect several Points through which draw a Line. At all times when the Spot is in that Line, the shadow of all upright things whatsoever, shall be double to their length; by which means you may find what height any Steeple or the like is, by measuring the shadow of it. In the same manner may all other Proportions be inserted.

C H A P. VIII.

To put in the Azimuths.

Look what Azimuth you desire to express: As for example, I desire to put in the 10th Azimuth from the Meridian. First, upon your Horizontal Circle, mark that Azimuth, and next examine what Altitude the Sun hath in that Azimuth, in any parallel you think fit, or which is most proper to be made use of, and to that Altitude set the Socket, and place your Radius in the said Azimuth, then reflect the image of the Socket, and carry it to the Cieling, it will meet with the parallel if you have wrought truly, there make a mark. Do this for the Horizon, where the Sun hath no Altitude, and mark the Reflected point, though those two, draw a strait Line, if the Roof be flat, otherwise you must seek more points. After the like manner may the unequal hours, the degree of the Sun that culminates, and such like, be inserted, which I leave to the industry of every Practiser to perform. I shall now shew a ready way by this Instrument to make Dials to a flat Glasse, these precepts hitherto being fitted to Glasses that lye aslope or Oblique, whether Convex, Flat, or Concave.

C H A P. IX.

*How to draw the Hour-lines to a Glafs that lies Parallel
to the Horizon.*

DO as you as you are directed in the foregoing precepts only instead of Reflecting with your Eye you may now place the Radius of your Instrument, so that the upright Ruler may be within the Room then applying it over in the Azimuth given for that Hour, move the Socket to the Altitude of the Sun in that Hour, and from the Center gently extend a Thread which shall shew you one Point, do this for as many Parallels as you desire, if the Roof happen not to be Falt, otherwise two are enough.

For example, in the Latitude of 51 deg. 30 min. I draw a Meridian if I can, which is likewise an Azimuth, and find that in the Tropick of *Cancer*, the Sun will then be 62 deg. 00 min. high, to which I move the Socket, and gently extend a Thread by it to the Roof which shall give the point required. Do this for the Equinoctial, and through the Points found draw the Hour Lines.

A N O.

A N O T H E R W A Y O F R E F L E X D I A L L I N G, B E I N G.

The Extract of a LETTER

Written by Mr. I. M. HALTON from Grays-Inn.

S I R,

“**B**UT that my occasions do and will detain me yet for some time
“in Town, I should not have given you this trouble of a Letter;
“for I purposed in my first Vacation from business to have seen
“you; yet because in our last discourse, there was something
“started of *Reflexed Dialling*, the Theorie whereof I told you, I thought
“I could manifest in Two or Three *Diagrams*, and we not having oppor-
“tunity *propter locum ambulandi datum*, to design the same, whereof you
“seemed a little earnest, is the occasion of this, and the rather for that, I
“am not certain of seeing you.

First therefore, you are to take notice of this general Synopsis of Dials
or Plains, whereon Dials may be described.

All Plain Super- ficies's whereon Di- als may be descri- bed, are	Horizontal			Horizontal	1
	Perpendicular	Direct	Meridian or Polar	East	2
				West	3
			Prime Vertical	South	4
				North	5
		Declining	South	East	6
				West	7
			North	East	8
				West	9
	Re- In-clining	Direct	Meridian	East	10
				West	11
			Prime Vertical	Equino.	12
				Polar	13
		Declining	South	East	Polar 15
West				Non Po. 16	
North			East	Polar 17	
			West	Non Po. 18	
South			East	Polar 19	
			West	Non Po. 20	
North	East	Polar 21			
	West	Non Po. 22			
			So		

So

So that the names of the Dial Plains are in number 22. The first admits of no variety; in others the same direction or calculation will serve for two of one kind, in some for four.

Now for the particular description of each, so many have made it their business and ingenuity, that here shall be no more said than what is already evulgated, which is more than sufficient, although I could *Symbolum offerre*, and that as currant as some of the rest; but because the occasion is *Reflexed-Dialling*, and that from a Plain and Reflecting Superficies howsoever posite, know that this Superficies must necessarily be some one of the 22 varieties abovesaid, this is proved *inductivè*, by a perfect enumeration of all the singulars; for all Plains must singularly be in some one of these 22 Positions.

2. Again, the Plain of the Glass (considered as an ordinary plain for a Dial) must be taken as a plain in a Counter-position to that ordinary plain, as for instance in the Horizontal, an Horizontal Glass reflects an Horizontal Dial, as should ordinarily be made to the Antipodes of the same place reflected; and so the like in the rest of the plains, where you must be still sure to apprehend the plain of the Glass to make an Antipodical Dial to the same plain taken with a reflection.

3. As all Dials in their delineations or tracing of their hour-lines, respect their proper Axis, Horizons, and Equators, so likewise do these the same in their reflexed posture; and here how you are to proceed to argue and state these, so as you may take your practice in them, as in the ordinary plains, I shall be so free with you as to give you my conceptions and therefore,

4. Because the Poles of the Equator and Horizon are so called in the common Nomenclature, as they are Perpendiculars, so for that reason shall I call the Perpendicular of the Glass, the Pole of the Glass, concerning which Pole, take these 4 Theorems.

That the Azimuth.	} upon which the Pole of the Glass is found compared with the	{ 1 Meridian is the Declination.	} of that Glass
That the Hour-lines.	}	{ 2 Meridian, is the Inclination of Meridians, or difference of longitude.	
		{ 4 Equator is the latitude or altitude of the Stile, viz. if it lie on the under or South side of the Equator South latitude, otherwise North latitude.	

5 How to find this Pole of the Glass, the Glass it self being so small, and set within a Socket, as no Instrument can be applied to the Plain of it, there are two ways.

1. Geometrically; For suppose the Sun shining on the glass at C, the spot or reflection ☉ at D. A Ruler, finger, or such like thing, held up at B, so as the sides of a Triangle BCD may be measured. Then the side DB cut in E by the 6 lib. *Euclid* prop. 3, shall give CE the Pole of the Glass. Then an Horizontal Pastboard applyed to C (the Meridian

Figure
I.

- ridian being first found thereon) will by a Perpendicular Thread hung up, give you the Pole of the Glass, and a Quadrant Applied to that Pole his Altitude or Depression in respect of the Horizon.
2. By Trigonometry, or Calculation; For the Sun shining upon your glass take his Altitude, and at the same time mark with a Pencil the spot or reflection; for by this (without the Sun shining any more) there is enough to draw the whole Dial with all the lines of the Globe; for supposing C in the Center of the Earth (as all Nodus's of Styles are supposed) and C O the spot or Reflection to pass into the Heavens into a certain part as C $\odot$, which comes from thence. It is not to be doubted that the Arch of a great Circle O $\odot$ would be made thereby, the $\frac{1}{2}$ whereof would be C ϕ the pole of the Glass, for the Angles of incidence and reflection are equal, both in respect of the Perpendicular, as also the plain of the Glass, And so from the Azimuth and Altitude of the Sun taken, as also of the spot, the Azimuth, Altitude, Hour-lines, and Distance from the Equator of the Pole of the Glass (the four things which are before directed) are easily found.

6. For the speedy finding of the reflected Axis both of the Equator and Horizon (for without these the reflected hours and Azimuths are not to be drawn) as also the reflected Horizon, Equator and Tropicks, there are two ways.

1. By Instrument, 2 By Calculation. The first way directs the second, and so of the second I shall say but little, that my Letter may not swell; And for the first, for Example, I will propound the Horizontal Instrument of the place, where the Dials are intended to be drawn, suppose at London, where the Latitude is 51 deg. 32 min. So then let this be the Question, which is propounded in *Centesim's* of degrees.

P R O B L E M.

Figure
II.

In the Latitude N. 51 d. 53 c. $\frac{1}{2}$ the Sun being in the first scruple of Cancer, having post meridional Azimuth from the South 50 deg. 85 c. and Altitude 53 deg. 75 c. casts from a Glass a reflection O of post meridional Azimuth from the North 21 deg. 74 c. and of Altitude 26 deg. 69 c. I desire to know the Plain.

I. S O L U T I O N.

IN the Horizontal Diagram of the Latitude proposed, let the Sun $\odot$, the spot O, the Zenith Z, the Pole of the Glass ϕ , and the Azimuths and Altitudes be laid down according to the Data's in the proposition, and the manner of the Diagram, *Queritur* $\odot$ O, the $\frac{1}{2}$ whereof $\odot \phi$, and so Z ϕ .

And again P ϕ and P Z ϕ equal to the declination of the Glass, viz. N A.

Also twice Z ϕ = Z E the reflected Zenith of the glass, and EX = 90 deg.

And V X Z the proper Horizon or plain of the Glass.

Lastly, Twice P ϕ gives you P D the reflected Axis, &c. for the reflected Zenith and the reflected Axis of the Glass, are those whereby the Hours and Azimuths are to be drawn; which together with the Equator and Horizon (because they only are great Circles and bisect the Globe) will be strait lines *in plano*.

But

But because, as perhaps, through haste (and the short contraction of this, which I had rather have discoursed than thus made up into a Letter) any error may have happened in the designing of the Triangles upon the Horizontal Diagram, take this second Solution by the Globe.

2. SOLUTION.

THE Pole of the Glas being as by the fifth found, by his Azimuth and Altitude assign a point upon the Globe, by some piece of white paper or other thing clapt thereon, from that point with your Quadrant of Altitude usually made therewith, or rather Semi-circle of Steel, Brass, or Whale-bone, application being made to the Pole of the World, Zenith, two points in the Equator and Horizon (because great Circles) Tropicks, &c. the opposite equal Arches thereof, shall give you the respective reflexed points; having always a regard from this point or Pole of the glas assigned, that you make the Angles of Reflection equal to the Angles of Incidence. From hence now some neat Conclusions may be deduced, such as these:

1. First, That the Sun being at the point D (that is having North Declination 19 deg. 43 c. $\frac{1}{3}$, post-meridional Azimuth 80 deg. 31 c. $\frac{1}{3}$; Altitude 32 deg. 53 c. $\frac{1}{3}$, and Hours 4 $\frac{1}{8}$) shall give a reflection to P, that is parallel to the Axis of the World, and so by consequence the Sun in his own position to the Glas (if by observation you watch that moment) shall shew you the reflected Axis of the Glas.

And so at *London* this reflected Axis is found, when the Sun is in the Meridian having North Declination 13 deg. 6 c. $\frac{2}{3}$, the plain of the Glas lying Horizontal.

2. By this the Superficies of the Glas, or the Plain of the Glas, appears to be one of the 22 varieties of Plains, and that it declines 60 deg. and reclines 54 deg.
- 3 That by the plain of the Glas represented in the Horizontal Diagram by V X Y, you have the Hour-lines expressible upon that Plain, or which can be reflected by that Glas, and also the time of the Year when the Sun will first shine thereon, and the continuance.

4. That without any Glas, you may from a point taken, assign a reflexed Axis where you please, by an Azimuth and Altitude taken to your own fancy; as suppose at D, then will ϕ the Pole of your Glas be found as before, and you must be careful in bringing the Center of your Glas into this point, and so place it, which is also very feasible several ways.

7. For the practice, or making of these Dials, with all the Furniture thereof (the Theory being thus laid down) I suppose you are well enough acquainted therewith; I should propound for my own practice any one of these.

1. Having got the reflected Axis, which will always pass through the Center of the Glas both into the Air and into the Room [if the transome of your Window lie not directly in the Meridian] and having erected a Paste-board, or such like thing at Right-angles thereto, parallel to the reflected Equator, you may by Threads design the Hours, as is now a very familiar practice in making of String-Dials, which serve both for the Hour of the Day by the Sun, and hour of the Night by the Stars.

2. By a Plain set Parallel to the Superficies of the Glafs at a convenient distance, whereon you are to design what you intend to be put on this Dial; and if the Parallel Plain be of Paste-board or Paper, a Thread fastned at the Center of the Glafs, strikes your whole Dial *de morsa papyro*. The distance of the Plain from the Glafs, will be as you please; viz. The distance of a plain from a Nodus.

3. The Pole or Perpendicular of the Glafs being drawn out and designed, you can easily propound to your self, what, and in what position the Sun's rays will make an Angle of incidence with that perpendicular; and so by a Semicircle or Tangent of fine Pastboard fastned to that perpendicular, you can, on the other side, assign the like Angle for Reflection. And for the Horizon which is to be reflected, two Points may many times easily be got by the Eye, looking into the Glafs, and so between the Eye and the Glafs interposing a mark as by Sect. 5 two points are sufficient to design that.

And thus by one or other of these ways you shall be sure to hit of your purpose.

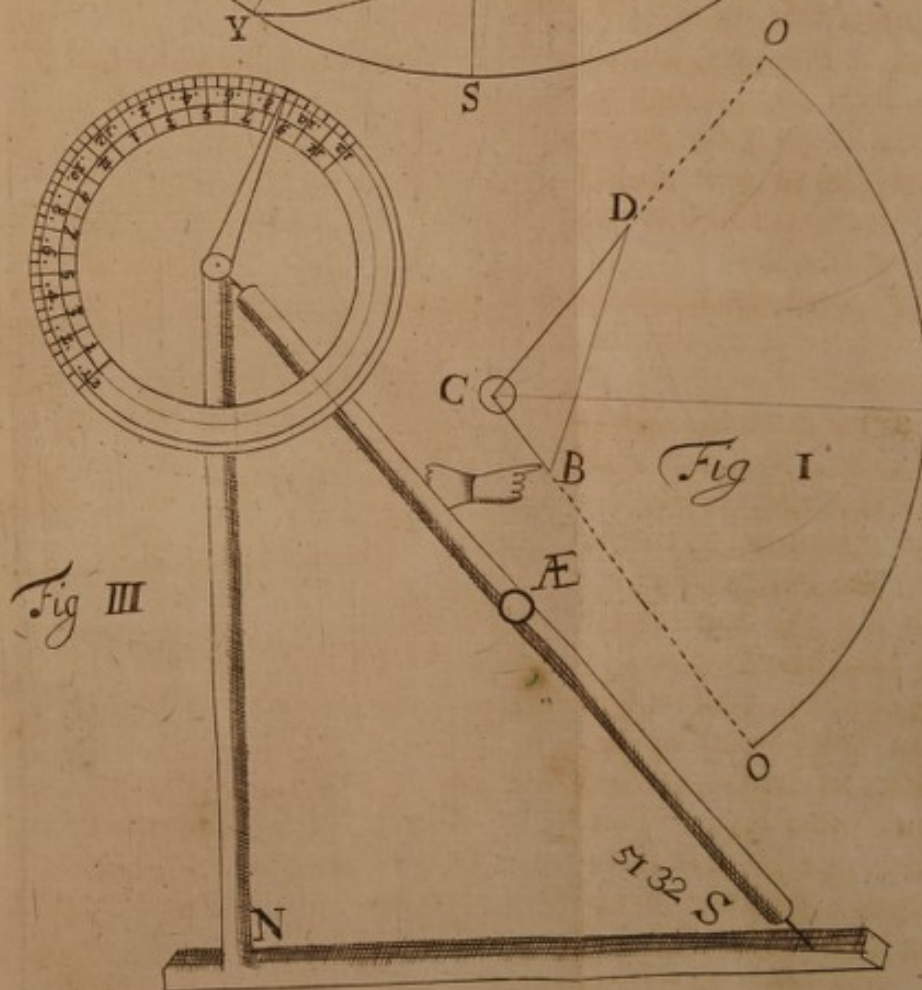
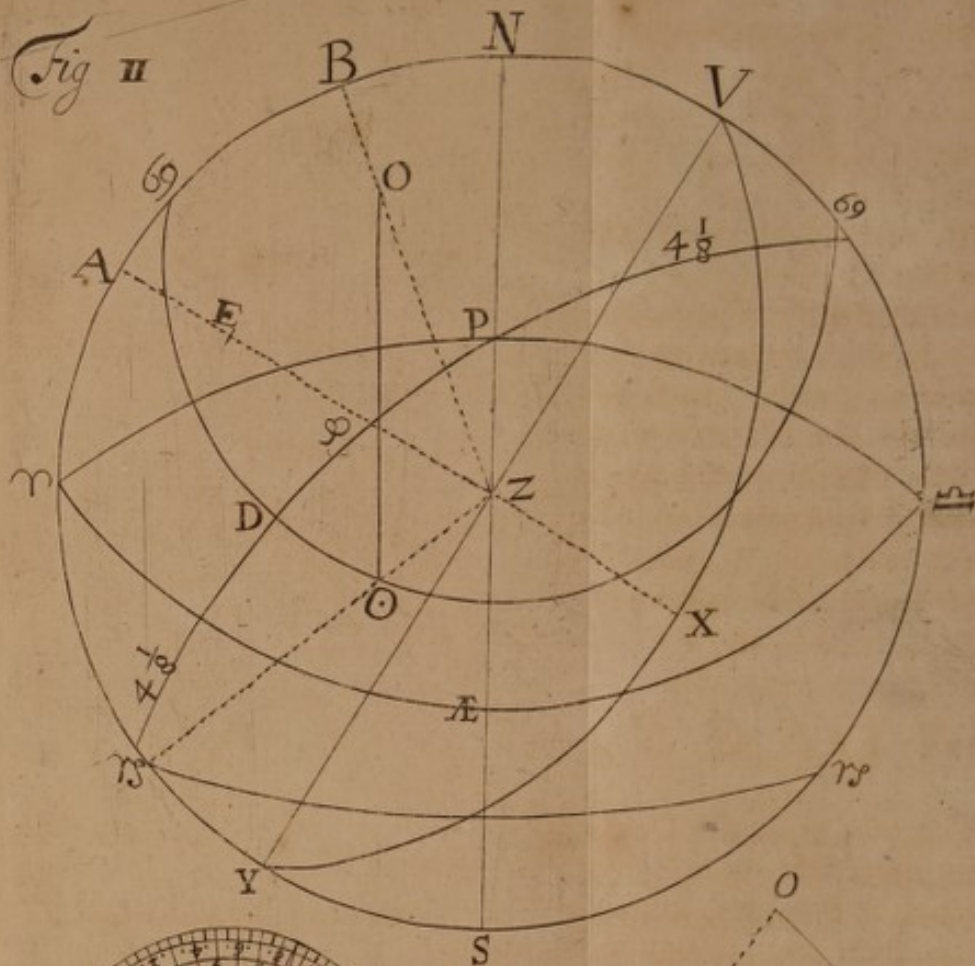
POSTSCRIPT.

I Shall conclude this Tractate with the Description and Use of an Instrument, or Dial for my own Use, which by one single Hour-line designed within a Room, and that at Pleasure, (which will prevent the soiling of Hangings, Cupboards, or such like things in a Room) shall most readily give you the Hour, and actually (if your Room be large) every day in the Year. The Instrument may be of neat use in Gardens, being set near the North side of a Wall or Tower, yet so that the Sun may shine thereon, and the reflection be made in the shadow,

It is very plain and ready, and the hours upon the *Equinoctial* naturally divide themselves into $7\frac{1}{2}$ deg. a-piece, and the reason thereof (that is, the demonstration) is very apparent.

This Reflexed Dial here mentioned is no other than an *Equinoctial* Dial, such as is described in the XV Chap. Sect. I. Fig. X. of the First Tractate, or that in Chap. XVII. Sect. I. Fig. XVII of the same; for all are to one effect, those Plains lying parallel to the Axis of the World, and therefore the Stile lies parallel to the Plains: that is, the Plains do lie in some one Hour-circle or other. Then if the Superficies of a plain Glafs (I mean the Spot designed for a Reflex Dial) be so placed, the Axis (because parallel to the Plain) will have no Incidence, and so, by consequence, no Reflection: The Perpendicular of this Glafs (being an Imaginary Point) lies in the Equator: so that the Superficies of the Glafs fixed in a Gnomon to turn round (now all Gnomons look into the Elevated Pole) will continually cast a Spot (the Sun shining) into some one Hour-line or other, which let be drawn at pleasure within the Room. And then fixing a small Circle with an Index to turn round, such as is the Hour-Circle of a Globe, that Index then rectified to the true Hour, when the Spot shews upon the Hour line in the Room, bringing the Spot afterwards at any time to the said Hour-line, the Index unaltered will give the true Hour.

Now



Place this at *y* End of *y* XIIth Tractate to fold out.

Now why the Hours upon the Hour-Circle comprehend $7\frac{1}{2}$ degrees a-piece is very apparent. For the Perpendicular of the Reflecting Glass will always bisect the Equinoctial Arch intercepted between the Sun and the Spot (which is the Sun reflected) and so by consequence the Plain or Superficies of the Glass, moving as doth the Perpendicular, or Imaginary Point notified by the Index of the Hour-Circle, is only promoted $7\frac{1}{2}$ degrees every Hour. I need not lay down a Demonstration at large in so easie a matter, nor describe this Instrument further than I have said; the Figure III. will better inform you than many words: NS being both a Meridian and Horizontal Line, PS the Axis of the World, *Æ* the Glass, P the Hour Wheel fixed, but the Index moveable.

Figure
III.

“ But I cease to give you further trouble at this time, desiring rather
“ your pardon for this confidence I take, in adding to your *Mathematical*
“ store, wherein, and in the right use of your other fortunes, you are *Craso*
“ *ditior*. And hoping your occasions will, &c.

The End of the Twelfth TRACTATE.

R r r r

REFRACTIVE DIALLING,

OR, OF

DIALS by *REFRACTION*.

SHEWING,

(Two Different Ways, *Viz.*)

INSTRUMENTALLY *and* PROJECTIVELY,

How to make *Sun Dials* in the inside of any *Concave Vessels* (either *Regular* or *Irregular*) and to inscribe into them all Usual *Furniture*.

Which *Dials* shall shew the true *Hour* of the Day, the *Altitude*, *Azimuth*, and *Declination* of the *Sun*: The *Jewish*, *Italian*, and *Babylonish* Hours. The Sign *Ascending*, *Descending*, and *Culminating*: The *Position* (or *Domifyng*) Circles, &c. When the *Vessel* shall be quite filled with *Water*, or when it shall be partly *Full* and partly *Empty*.

The Thirteenth T R A C T A T E.

Of Refracted Dials in General.

THE Sun Beams are refracted by any transparent Body that they fall upon, if the same be more Dense or more Thin and Rare, than the *Medium* thorow which they first shine. Such Bodies are either Solid or Liquid. In both which kinds the most Common Bodies are Glass or Chrystal, and Water.

Refractions (as we are here to Use them) may be divers ways considered, First in Solid Bodies, the Superficies Refracting may be either Plain or Curved, and this either truly Regular, such as is Spherical or such like, or else various of no determinate Regular Form. And likewise the Plain especially (but the other also in some sort) may be either Horizontal or otherwise placed, upright or leaning.

Again,

Again, In Solids pellucid, the Rays of the Sun from the point of an Index, standing without side the pellucid, between the Sun and it, must pass, either first from the Index through the Air, and then into the Solid, and so meeting with an opacous Body, close joyned to the out-side of the transparent Body, may there be terminated, and so suffer but one Refraction at its first entrance into the pellucid, or else the opacous body (upon which the shadow of the Index stayeth and pierceth no further, but is made visible) may stand at some distance from the pellucid; and so the Sun Rays pass out of the pellucid into the Air again, before they come to the Opacum; by which means they suffer a double Refraction, one at their entrance into, the other at their going out of the pellucid Body.

Or further, The point of the Index may be within the pellucid, and so the Sun Beams must first enter into the pellucid, and suffer one Refraction before it comes to the point of the Index, and afterwards either meet with an opacous body, close joyned to the outward Superficies of the Pellucid; and so suffer no more Refraction, but be there terminated, or else if the Opacum stand at a distance from the pellucid, the Sun Beams must again pass through the Air, and suffer a second Refraction (at their going out of the pellucid) before they meet with the opacous Body, or dark Superficies that stays them.

All these Cases are varied according as the Index and Opacous and Pellucid Bodies do stand.

Or again, The point of the Index may stand without the pellucid, and the Sun Beams be twice Refracted through both Superficies, before they come to the point of the Index, the pellucid being interposed between the Sun and the point of the Index, and the point of the Index standing between the pellucid and opacous Bodies.

Secondly for Water, or any such transparent liquid; the varieties are not so many, because the Superficies of it is always level with the Horizon; and because likewise the liquid applies it self contiguously to the opacous Body or Vessel that contains it; onely besides one fraction, the irregularity of the Vessel that contains the Water is troublesome. Now the refraction by Water alone can be but One, which is at the Sun Beams entrance into the Water; but the variety of projecting the Lines of the Dial is two-fold, according as the Index Point may stand, either within or without (that is above) the Water.

Many Varieties besides the Irregularity of the Opacous Bodies that are to receive the Lineaments which of themselves are infinite.

But if Water be put into a Glass, or any such pellucid Vessel, then may the varieties be as many as were the former of Solids, in respect of the situation of the Index, Pellucid and Opacum. Yea and more, because before, the Pellucid was simple and similar, but this Pellucid mixt or dissimilar; so that the Refractions are here multiplied into four Varieties or Breaches (whereas the other had but two) *causa ipsius mixiones vel compositiones duorum Pellucidorum*: The first fraction is at the entrance into the Glass; the second at the going out of the Glass into the Liquid; the third at the going out of the Liquid, and entrance into the Glass; the fourth at the going out of the Glass into the Air.

Now all these Complications of infinite Varieties, gather such an incomprehensibility, or innumerable number of difficulties in drawing hours so many ways, and quantities Refracted, that it will be thought to exceed the comprehension of humane reason to accomplish it; especially being so infinitely varied by the irregularity of those Superficies that are to receive the Lineaments. If all the Cases mentioned were intermingled, there would be no end of Varieties.

And thus may the Varieties be still augmented by making Refractions thorow more Pellucids at once.

And

And because the quantities of the several Refractions, at their several Incidences, are unknown, and although they were known, yet by reason of the irregularity of most Pellucid Solids, the Angles and Coasts of Incidence would be altogether unknown, and in that regard the Refractions, both in quantity and coast unknown also. In all these regards it is altogether impossible to give any Rule, either by Calculation, or Geometrically, by drawing lines how the hours should be delineated.

In Water (indeed) where the Superficies is both a true Plain, and also lying truly Horizontal, the Varieties will be fewer, and so the Work more easie. But of this I will speak afterward peculiarly, because things necessary in this kind may be more vulgarly had (being more obvious) and the way much more easie in it self, though commonly also thought to be exceeding difficult, being esteemed as a rarity above the common apprehension and performance. And if this that is easiest be so esteemed of, what shall the former (so difficult) be accounted of, being involved in such an innumerable number of various Varieties.

By the way
note, That the
Index must of
necessity be a
Point, not a
Line or Axis.

Of Refracted *Sun-Dials* in *Water*.

*How to Draw them by the Semicircle and Planisphere
joyntly together.*

1. **T**HE Refractions to all Inclinations or Altitudes in Water must be had, as I have framed a Table for that purpose, which is here inserted.
2. The Vessel that holds the Water may be of any fashion, regular or irregular, it matters not, but it must be furnished with every tenth or fifth Azimuth, as need shall be; the manner whereof in brief may be this, Set the Vessel so upright as it must stand, when the Water is in it: and assume a Point for the South, and over against it (in the same Horizontal Level) another for the North, both opposite to each other in respect of the Point of the Gnomon, which must first of all be fixed, that is, having taken one Point for the South, in the same level with the Point of the Gnomon (for to it an Horizontal Line is first to be drawn in the Vessel, or else extended by a Thread) from that South Point extend a Thread out-right over the Point of the Gnomon, which will find the North Point on the other side of the Vessel. Afterwards in the Horizontal Line (drawn round about the Vessel, or otherwise represented with Threads conveniently) by help of a Past-board set upon the Gnomons top, and by help of the North and South Points, you may project each fifth or tenth Azimuth, and make marks in the same Horizontal Line for each of them. This being done, by the Semicircle, find out the Zenith Point in the Vessel, that is, apply the Ruler to the Gnomons Point, and holding it upright there, the foot of it will shew the Point required; for the Vessel now standing (and as it must be justly afterwards placed) in this posture. Then lastly, if you lay a Thread to the Azimuthal Point, and to the Apex of the Gnomon, and so to the opposite Point of each Zenith

(two

A TABLE of Refracted ALTITUDES to every Degree of the Quadrant.

True Altit.	Refracted Altitudes.			True Altit.	Refracted Altitudes.			True Altit.	Refracted Altitudes.		
Deg.	D.	M.	sec.	Deg.	D.	M.	sec.	Deg.	D.	M.	sec.
0	41	28	0	30	49	32	0	60	68	0	0
1	41	30	48	31	50	04	0	61	68	42	24
2	41	33	36	32	50	36	0	62	69	24	48
3	41	36	24	33	51	08	0	63	70	07	12
4	41	39	12	34	51	40	0	64	70	49	36
5	41	42	0	35	52	08	0	65	71	32	0
6	41	50	48	36	52	42	0	66	72	15	24
7	41	59	36	37	53	16	0	67	72	58	48
8	42	8	24	38	53	50	0	68	73	42	12
9	42	17	12	39	54	24	0	69	74	25	40
10	42	26	0	40	54	58	0	70	75	09	0
11	42	40	12	41	55	34	24	71	75	53	0
12	42	54	24	42	56	10	48	72	76	37	0
13	43	08	36	43	56	47	12	73	77	21	0
14	43	22	48	44	57	23	40	74	78	05	0
15	43	37	0	45	58	00	0	75	78	49	0
16	43	56	24	46	58	38	24	76	79	33	24
17	44	15	48	47	59	16	48	77	80	17	48
18	44	35	12	48	59	55	12	78	81	02	12
19	44	54	36	49	60	33	36	79	81	46	36
20	45	14	0	50	61	12	0	80	82	31	0
21	45	37	48	51	61	52	0	81	83	15	48
22	46	01	36	52	62	32	0	82	84	00	36
23	46	25	24	53	63	12	0	83	84	45	24
24	46	49	12	54	63	52	0	84	85	30	12
25	47	13	0	55	64	32	0	85	86	15	0
26	47	40	48	56	65	13	36	86	87	00	0
27	48	8	36	57	65	55	12	87	87	45	0
28	48	36	24	58	66	36	48	88	88	30	0
29	49	04	12	59	67	18	24	89	89	15	0
30	49	32	0	60	68	0	0	90	90	0	0

(two being always opposite one to the other, and may well go together) you may repose this Thread upon the Zenith Point lately found; so shall the umbrage of the Thread shew all along the Vessel, where the same Azimuth is to be drawn; and the same is to be done in all others. Or without Drawing or Projecting either, Threads may be fixed for Azimuths, from the Point in the Horizontal Line to the Zenith.

3. These things being thus prepared, it is left to choice whether the Point of the Gnomon shall lie always hidden in Water, or else stand above the Water. These two cases are very different, and so must be treated of in several, as two distinct Cases.

I. *When the Gnomon is bidden all under Water.*

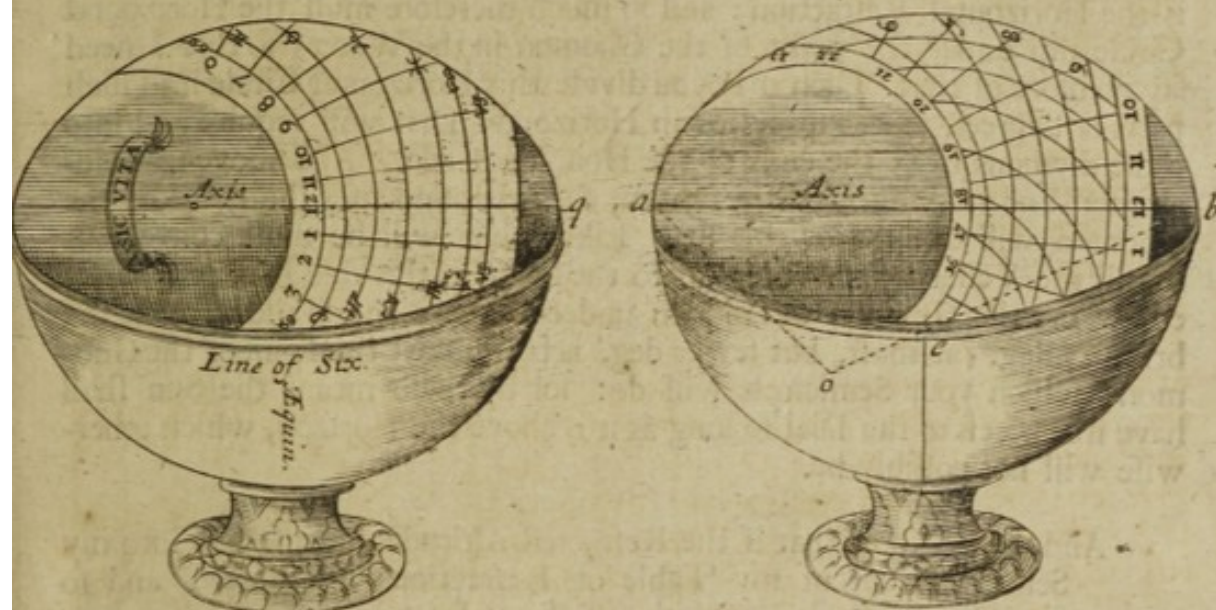
IN this case you are not tied at all how full to make your Vessel, only be sure to cover the Gnomon's Point, it matters not how much, whether more or less, for both are one. Then for the Line of 12, that is already drawn, being the same with the North and South Azimuth; but the rest must be intcribed by Points severally fixed into each particular Azimuth; the manner whereof may be thus:

Upon the Planisphere, lay the Ruler to any Azimuth (as the 60th) from the South, and there see what degree of the Ruler (or what Altitudes) each Hour Circle cutteth, and write them down in a Table.

Thus do upon every 10th or 5th Azimuth (as you shall think fit) making a Table of all those Altitudes or Intersections. Then coming to the Table of Refractors, and to each particular Altitude of the Table, find amongst the Refractions, how much belongs to each of them, and add the same to the Altitude (before found by the Projection) particularly, so shall you have turned the direct Altitudes into refracted ones.

After all this, come again to the Vessel, and with the Semicircle insert each particular Refracted Altitude into his proper Azimuth where it belongeth, so shall you have points in each Azimuth, for so many Hours as the same Azimuth is capable of. Having then these helps, through each Point belonging (in every particular Azimuth) to the same Hour, as suppose the Hour of 9, draw one continued curved Line, which must serve for the Hour of 9 a Clock, so through all the Points in every Azimuth, serving for 8, draw one continued Line, which must in like manner serve for the Hour of 8 a Clock; and so do for all the rest. The Horizontal Line will be about 37 deg. below the Point of the Gnomon, so much, namely, as the Horizontal Fraction cometh unto; and up to this Horizontal Line (and not any higher) must the curved Hour Lines be drawn. The Coasts North and South will be opposite (in the Vessel) to those of the Heavens, in the same manner here as they are in other Dials. This work cannot be done by projecting the Hours, with help of an Axis, as in other Projections; for neither the Rays from the Eye can possibly fall upon the Water to project in the same manner that the Sun Beams do (which in direct Projections is not requisite, but in Refracted it is) nor the projection made by the Sun Beams themselves (though of the same Hour Circle) will be the same in fashion, the Sun standing in several positions to make this projection, as in one instance (in a right Sphere) will sufficiently appear;

pear; for in a right Sphere the Axis (as all know) must lie parallel to the Horizon, or Superficies of the Water; and the Hour of 6 will be the same with the Horizontal Line. If therefore we suppose such an Axis in a round Spherick Concave Vessel, full of Water, to be laid from the one side of the Vessel to the other, and the Sun to rise or set in the Equinoctial which is proper to the Axis; then shall the Hour of 6, or the one half of the Horizon, be projected, dipping down (from each point of the Axis, projected by the Parallel Rays of the Sun) so much as the Horizontal Refraction comes to (about 37 deg.) whence it must follow, that this Projection of the Horizon must dip most under the Axis in the Projected Equinoctial Circle, and nothing at all under the two ends of the Axis, which concur with the sides of the Concave Vessel; whence the Sun, being in the Equinoctial as we now suppose it to be, the Axis and Horizon, or 6 a Clock Line in a round Vessel, would appear thus, as in the Figure.



But again, If the Sun being out of the Equinoctial, as in one of the Tropicks, and there be supposed to rise and set, then shall the Horizon, or Hour of 6, be projected so by the Sun, as that a Ray from the Sun upon the middle Point of the Axis, shall project the Horizon in the lowest Point; which lowest Point will be in the projected Tropick, and not in the Equinoctial, as the former Projection was. So that now the Axis and the Line of 6, will appear in the same Vessel, in the form of *aob*, whereas before it was like *aab*; whence first it is evident, that an Axis cannot project (in all Positions of the Sun, to the Axis and Water) one single Line for each Hour, as they ought to be; and therefore that way by an Axis is in this work to be rejected as unserviceable.

Secondly, It follows also, that (though the Sun should (by reason of infinite remoteness) make requisite Lines, yet) the Eye cannot in this kind perform what the Sun doth; because it being always near to the Superficies of the Water, doth receive distances from several parts of the same Superficies of different quantities, great and lesser; and so the Rays passing from the Eye, do make several Angles of Inclination, and consequently several Refractions, which the Sun by his immane distance

france doth not, but is thereby freed from it; so that the Hour Lines cannot be projected (by help of an Axis) with the Eye in the same fashion that the Sun requires; nor yet if they could, would they be of any use, as is before said. Thirdly, Again it follows, that a point only (and not a Line, or part of the Axis) is to be used for a Gnomon. Fourthly, That the inscription of the Hours must needs be done by finding certain Points, thro' which they are to be drawn. One way of which Protraction is now delivered; this former way supposeth the Refractions to be single upon a Meridian, lying in a Horizontal level, and to be known also according to all inclinations.

How to make the Hours close right with the Horizontal Circle.

YOU must first draw the Refracted Horizontal Circle, which is all one as if you would draw the 37 deg. Almicanter (for about 37 deg. is the Horizontal Refraction; and so much therefore must the Horizontal Circle dip under the point of the Gnomon in the Water) so that I need say no more of that: Then may you divide this Horizontal Circle into such parts or degrees, as the spaces of an Horizontal Dial will require and into those divisions must the ends of the Hour-lines run. Also above this Horizontal-line nothing needs be drawn, for it is of no use, the Point of the Gnomon will never grow higher. Likewise it will be most convenient to fill the Vessel with Water up to the brim in this case here propounded, where the Gnomon lies hidden under Water; and so also to make the brim 37 deg. (at most, but fewer deg. is best) above the Point of the Gnomon; which your Semicircle will do: for by these means the Sun shall have free access to the Dial so long as it is above the Horizon, which otherwise will not possibly be.

And here Note, that if the Refracted Altitudes be inserted into my Semicircle out of my Table of Refractions in Water, and so made into a Scale or Limb; if this (I say) be done, then may you immediately (without turning your direct Altitude into refracted, according as is prescribed in the precedent page) put in the same things in the same manner and quantity, if you count these Altitudes in your Refracted Scale (and not in the common limb) and accordingly do insert them all, your Thread and Plummets hanging upon the Altitude taken into the same Scale; so will the former labour of turning one into the other be taken quite away. And so much will serve for this first Case, when the Gnomon is quite covered under Water. The Second follows, which is,

II, When

II. *When the Point of the Gnomon stands above the Water.*

1. **T**HE Gnomon being set, and the Vessel fitted (as is before prescribed) with Azimuths convenient, you must set the Vessel upright, according to the self same posture that you intended it should have when it is fitted with Water, and in that situation let it be fixed, till your Work be done at the least.

2. Next you are to consider how high you will fill it with Water, for to that Altitude you must draw an exact true Horizontal line upon the sides of the Vessel, the very same that the edge, or Superficies of the Water will make when it is filled up to it: This is necessary to be done, first, as also you must draw another Horizontal line about the sides of the Vessel, which must be *in equilibrio* with the Point of the Gnomon, and this will be (most conveniently) the very edge of the Vessel, that so the Sun (all the time that it is above the Horizon) may have access to the Gnomon's Point, and shew the Hour too; both which cannot be, unless the Vessel's brim be just in Equilibration with the Gnomon's Point.

3. Between this brim of the Vessel, and the Water Horizontal Line is part of the Dial to be drawn by direct Projection; and below this, namely where the Water filleth up, is to be drawn the rest of the Dial by Refracted Projection; and accordingly we are to give distinct Rules for both.

4. For the upper part, it may be delineated either by the Horizontal Planisphere, and the Semicircle, or else by projecting it with an Axis.

I. *By the Planisphere.*

YOU may find what Altitudes are due to every Hour upon every Azimuth, and by the Semicircle you may put them into the right Azimuths, and so from point to point, draw the Hour lines till you come down to the Water Horizontal Line; and for the upper ends of the Hours, to make them fall true into the brim of the Vessel, you must do as before in the former Work was done; that is, you must describe (in the brim or Horizontal Line of the Dial) the spaces of an Horizontal Dial, and in those Points or Spaces must the Hours begin to issue forth. So again for the lower ends of the direct Hour Lines, to find the very points into which they are to run upon the Water Horizontal Line, the Work will be either harder or easier, according as the Vessel, and standing of the Gnomon, are Regular or Irregular — For if the Vessel be round, and the Point of the Gnomon do stand just in the Center of it, then it will be easie to do it, for then the Water Horizontal Line is a true Almicanter; and by your Semicircle you may know what Almicanter it is. If accordingly therefore you consider upon your Planisphere how many degrees of that Almicanter are comprehended between 12, and each Hour, and insert the same spaces or degrees into the same Almicanter or Water Horizontal Line, those

T t t t

Points

Points shall be the Terms of the Hours into which they must come. But if the Vessel be not Regular, or though it be, if the Situation of the Gnomon be not Regular to it, then it will be difficult; and indeed so difficult, that it is not *operæ pretium* to use it, I will refer it to this next Projective way of putting in this Superior part of the Hours, which will perform this thing easily. But by the way, after you have inserted the one part of the Hour Line, by drawing it as I now shewed, you may continue it whither you will by Projection, as I have heretofore shewed; and so you may continue it downward unto the Water Horizontal Line.

II. *By Projection.*

THIS is done in the same manner that I have often heretofore shewed, either by an Axis and Horizontal Points, or else by the Equinoctial Points, and for these you need draw no Azimuths; or else by Azimuthal Points, put into two Azimuths, which only are necessary to be done: I need not make Repetition of it here again. So then the upper part of the Dial above the Water is described.

The lower Refracted part which lies within the Water may also be done two ways; either by the Planisphere and Semicircle: Or else by Projection alone.

I. *By the Planisphere.*

SEEK how much each Hour is elevated upon every such Azimuth as is described in the Vessel, and by your Table of Refractions turn it into Refracted Altitude, as was before shewed; so these two Altitudes may be called, The First, The Direct, and the Latter, the Refracted Altitude. Or when you come to insert these by your Semicircle, for the Direct Altitudes you may count them upon that Limb which is divided into equal degrees, and the Refracted Altitudes you may insert by that Limb which is made for Refracted Altitudes by Water. And so you must understand me when I bid you to put in the Direct Altitude and the Refracted Altitude, that is, to count the same Altitude in the Direct, or equally graduated Limb, and in the Limb of Refractions, and so shall you need no Table of Refractions, because this new inserted Limb performs the use of the same Table immediately, without any turning of one Altitude into another. Both Altitudes we are here to use. First, We suppose the Vessel set as it must stand when it is filled with Water, and in this situation look what Azimuth you mean to deal with, or into which you intend to insert the Hour points, from the same Azimuth noted in the Water Horizontal Line, and in the true Horizontal Level, and just also under the Point of the Gnomon, which is to say just in the Zenith Line (or from the Azimuthal Point in the Water Horizontal Line to, or directly towards the Intersection of the Water Horizontal Plain with the Zenith Line) stretch a Thread, and (having first put upon it a Bead that may slip up and down, or else a Slipping Knot may be put on afterwards) there fasten

fasten it. After this is done, by help of the Semicircle applied to the Point of the Gnomon, put upon that Thread (as being the Azimuth) the Direct Altitude which you mean to insert, and thereto slip the Knot or Bead; then again from this Bead down unto the same Azimuth drawn upon the Vessel sides, project (with your Semicircle or Rulers edge applied thereto) the Refracted Altitude, and there make a Mark; for in that mark must the Hour (whose Altitude you now insert) run, the same Work you are to do for all the Hours and their Altitudes that pass thorow this Azimuth; and the like must be done in other Azimuths also for the same Hour Points. Then lastly, Having found Points for every Hour, you may thorow those Points draw the Hour Lines, and so finish the Dial in every particular.

II. By Projection.

BUT now the Vessel must be filled up to the Water Horizontal Line, and be in all Points fitted as when it is really to shew the Hour of the Day; and being so prepared, you shall need to inscribe no Azimuths at all into the Vessel; but as in other Projecting of Hours, so here do thus: Make two Points for North and South, and set the Hour Points upon the Brim of the Vessel which you take to be *in equilibrio* with the Gnomon's Point (however put those points into the Horizontal Line, which is *in equilibrio* with the Gnomon's point; or if there be none drawn in the Vessels, set Threads there round about it, as the manner of other Dials hath been, and into them insert Knots or Hour points) and erect an Axis as in other Dials: Then project (as you use to do) the Axis upon those points, and with some File or Dent make a Mark where the point of the Gnomon is reposed thorow the Water upon the side of the Vessel which Mark shall serve for one point thorow which to draw that same Hour. Then removing your Eye a little higher or lower, still repose the Axis upon the same Hour point, and mark again the place upon which the point of the Gnomon seems to lie; for this also will be another point thorow which the same Hour is to be drawn. Thus remove the place of your Eye so often, and do the same Work over, untill you have found points sufficient to finish the draught of the whole Line. In the same manner you must find points, and thorow them draw each of the other Hours. This kind of Work is necessary for that part of any Hour which lies under the Water; but for the part above the Water, that is projected at one view, as hath been before shewed; for that not going down into the Water at all, is freed from Refraction. Remember also that the Axis must always go above the Gnomon's Point, and keep in the Air, but at no hand go down into the Water. To the Water it may go, and be fastened below too in the Water; but my meaning is, you must not then project by that part of it which is within the Water, because the Refraction will deceive you. And be careful that the projecting part of the Axis (namely all that which lies above the Water) do lie at the true Elevation of your Pole, and that you project only by that same part. And thus have we finished these two Cases, which were to shew, How to draw Hours in a Vessel of Water, where the Gnomon lies within the Water, or where it stands above it. Now if besides the Hours, any shall in these two Cases, desire

To put in the other Furniture.

THEY may in brief do it thus: It must be remembred that all Furniture is to be put in by the Planisphere and Semicircle, as I have already shewed. And that all things that way are put in by Altitudes, such as in each kind the Planisphere will help unto. The very same manner of Work is here again to be used, only in the first case you must altogether use Refracted Altitudes, and in the latter case, you must use both Direct and Refracted Altitudes, one after the other.

For the first Case then it will be as easie as if you were to work in the way heretofore taught by the Planisphere, applying the Ruler of the Semicircle to the point of the Gnomon and to the Hours, only you must remember to count all your Altitudes in the Refracted Limb of the Semicircle, and not in the common Limb of Equ. degrees, because all, both Gnomons point and Hours are under Water. And this will be enough to admonish concerning the first Case, where all things are totally refracted: Or you may put all in by the Semicircle, projecting upon the Azimuths, not Hours, as follows in the other way. Then again, in the second Case, where the Work is partly direct and partly refracted, so much of your Work as is above Water. may be furnished with direct Projection, as hath been shewed heretofore in the use of the Planisphere and Semicircle. But for the other part which is below in the Water, there are several ways to be used, but the best will be to project all upon the Azimuths that were at first prescribed to be drawn upon the Vessel sides; and so all will be easie, whereas otherwise they will be very hard. Having then by the Planisphere found such Altitudes upon the Azimuths as are requisite, you are then prepared to put the same in; but it must be by using the same way that was before put in practice for the Inscription of the Hours; namely this: Let your Vessel have no water at all in it, but yet set true, as hath been before prescribed. Then from any Azimuthal point in the Water Horizontal Line, to the Intersection of the Water Horizontal Superficies with the Zenith Line falling from the point of the Gnomon, stretch out a Thread and fasten it there, and upon it let be put a slipping Knot or Bead. Then look what Altitudes you have to put in (for Parallels of the Equinoctial or Almicanter, or Sections of the Ecliptick with the Azimuths, or any such like) the same must be put into the Thread first, by applying the Ruler of the Semicircle to the Gnomon's point, and fitting it up, till (the side of it also touching the Thread) the Plummets hang at the direct Altitude of the equal Limb, then to that point of the Thread where the edge of the Ruler crosseth it, slip your Knot and Bead, afterwards again, apply the Edge of your Semicircle to this Knot, and keeping it still there close to it, lift it up till the Plummets and the end or point of it keep also in the Azimuth where-to the Thread is annexed; that part of it, I mean, which goes up to the side of the Vessel into the Water: so shall the end or point of the Ruler, give you the point of the Refracted Altitude required. Thus do till you have found all the points of such things as you mean to put upon

upon that Azimuth, and then go to another Azimuth, and do so there too, until you have done as much as you desire. Then lastly, throw every correspondent point draw such Lines as you require. This is the sum of what is to be done in this Case.

And Note here, That if it be so, that then Altitudes of some things cannot be had upon the Azimuths by the Planisphere (such as are those things that concern the motions of the Ecliptick) in such a Case you may (by the Planisphere) find in what part the Ecliptick cuts any Hour Circle, as is shewed before in the use of the Planisphere; and thereto apply the Ruler of the Planisphere, which will shew you in what Azimuth this shall happen: this Section (I say) of the Ecliptick with the same Hour. If now you put in the same Azimuth into the Horizontal Line, and project it into the Vessel, you shall find the same point of intersection with the Hour, and throw that point must the Ecliptick Circle pass. The like may be done for all the other points of Intersection. And this you may do, without finding what Altitudes the Ecliptick hath upon any Azimuth; which I believe the Planisphere will not do very well. Therefore in such Cases this Direction may be ready, or else take that way which is adjoyned to this if you think not much of your labour, whereto that way will put you.

This way I have given as the best, but I fear the Planisphere will not do (as I said) his part. I have now added the Water, to help forward the business; and that all may be the better known and understood at least, I will add another Direction here, which every one may refuse or use at his pleasure, as he shall like: And this is projectively without the Planisphere. Therefore now again fill your Vessel with Water as full as it must be, and having the Axis and the Hour points found and placed as even now they were, you may on the projecting side (that is on that side on which you do stand when you project any point from the Gnomon to the Vessel, or on that side which the Sun is on when it casteth his shadow) from some superiour point of the Axis (or from the Supreme point of the whole Axis) stretch out a Thread, and with your Eye repose it and the Axis and the point of any one Hour, all three in one; and in that same position fasten your Thread; this done find upon this Hour (by your Planisphere) such Altitudes as you require, and from the Gnomon's point insert them into the new fastned Thread by help of your Semicircle, and there tie Knots upon the same Thread for Marks: Then come to project the same Knots, which is done by reposing with your Eye those same Knots upon the point of the Gnomon, and in that position both these points will be reposed also upon the sides of the Vessel within the Water. Observe therefore where these Points are reposed by the Eye, and upon the Vessel sides (with some Bodkin or Dent) make a Mark; for that must be the projected Point, answering to that upon the Thread from whence it was projected. In the same manner are the other points to be projected and marked, and so you are to deal with other Hours

U u u u

too,

too, only for each of them you must place a new Thread, and furnish it with Knots, as before was done. This may serve for Direction in this way. Other ways a man may find out of himself as necessity shall put him to it, and therefore I will mention no more here.

As concerning Azimuths, it may be observed that they only of all other Circles, suffer no Refraction by Water, because they all stand perpendicularly to the Superficies of it; and therefore they are already put in as is prescribed in preparing the Vessel for the rest of the Work, both for Hours and other Furniture: for in both these their help is requisite. But when all Inscriptions are made, if they prove cumbersome to the rest of the Work, by filling it over-full; they may then in such Cases be wiped out.

The End of the Thirteenth T R A C T A T E.

OF THE FIVE
REGULAR,
OR,
PLATONICK;
(and of other *Polyhedron*)
BODIES.

*The manner how to Cut them in Wood or Stone,
and to Furnish them with Sun Dials.*

The Fourteenth TRACTATE.

CHAP. I.

Of the Five Regular (or Platonick) Bodies.

IN this Tractate I shall shew the manner how to cut these Five Regular Bodies in *Stone* or *Wood*, and what *Dials* will serve to furnish each *Body*: With *Tables* of all the *Requisites* and *Hour Distances* belonging to each *Dial*: With the *Chapters* in this Book which shews the making of the same. Also the description of another *Regular Polyhedron*, or *Body* consisting of *Plains* of several Sorts, as *Triangles*, and *Squares*, intermixed: Their *Declinations*, *Reclinations* and *Inclinations*: All which Bodies I shall here shew how to describe upon fine *Pastboard*, *in plano*, the vacancies whereof being cut away, the *Plains* representing the *Body* shall remain; and these being joyned together by the edges, with *Glew*, shall compleat the *Body*, as if it were cut in *Stone*; Upon each of which *Plains*, you may draw the *Dial* proper for the same, and cut *Stiles* of *Pastboard*, fixing them in their due place; And by this means your fancie will be much informed concerning the harmony there is between the *Dials* of so many several *Plains* upon one *Body*; as to see the *Stiles*, all of them, to be *Parallel* one to another, and to point directly to either of the *Poles* of the *World*, &c.

For

For Instance Then:

THE Five Regular (or *Platonick*) Bodies are, 1. The *Hexaedron* or *Cube*, 2. The *Tetraedron*, 3. The *Octaedron*, 4. The *Dodacædron*, 5. The *Icosædron*: To which I shall Add, 6. The *Canted Cube*; or *Hexicosaedron*,

C H A P. II.

Of the *Hexaedron* or *Cube*.

Figure
I.

THIS is a Solid Body consisting of six Sides, Plains or Bases, each being a Geometrical Square, and it also containeth Eight Solid Angles.

I. *How to Cut this Body.*

I Need not spend time in giving any directions for the cutting of this Body in Stone or Wood, it being a Body so well known to all Artificers and others; for it is no other than a Piece of Wood or Stone, cut exactly in the form of a Gaming Dye.

The manner how to cut this Body out in Pastboard is discovered in Figure I.

Of the *Dials* that will *Furnish* this Body.

THIS Body is capable to receive Five Dials, the sixth Side being the Base or Foot upon which the Body standeth: And so, if you set any one side to behold the *South*, that Plain shall be capable to receive the *South Dial* and the side opposite thereunto a *North Dial* whose descriptions, Figures, and Table of Hour distances you shall find in Tractate I. Chap. X. Fig. II. and III.

The other two Sides shall be capable to receive, one an *East*, and the other a *West Dial*, The Descriptions, Makings and Figures, are described in Tractate I. Chap. XI. Fig. IV and V.

The Uppermost Plain will be capable to receive a *Vertical* or *Horizontal Dial*, whose Description, making and Table of Hour distances you shall find in Tractate I. Chap. IX. Fig. I. So that I shall need to say nothing more of them in this Place—Thus if you will set one of the Sides of the *Cube* to behold the *South*; But----If you will have one of the Angles of the *Cube* to look towards the *South*: Then the 12 a Clock Hour line of the *Horizontal Dial* must be drawn on the uppermost Plain from Angle to Angle: And then will the four upright Plains be *North* and *South Decliners* towards the *East* and *West* 45 deg. which Dials must be made by the directions and cautions given in Tractate I. Chap. XII and XIII. and Fig. VI. But because the Examples and Tables in the XII and XIII. Chapters are not made for *North* and *South* Plains declining 45 deg. (as these belonging to this Body do,) but for 30 deg. and 35 deg. I shall therefore here insert a Table of the *Requisite Hours*, and *half Hours distances* belonging to *North* and *South* Plains declining 45 deg. suitable for this Body.

South

		South and North declining.		45 ^d	00 ^m
		Height of the Pole or Stile		26	06
		Deflection.		29	20
		Plain's Diff. of Longitude.		51	57
Hours and halves from the Substile.	Substile	0 ^d	00 ^m	Substile	0 ^d 00 ^m
	9 3	3	4	half	0 15
	half	6	28	8 4	3 34
	10 2	10	3	half	6 59
	half	13	57	7 5	10 36
	11 1	18	18	half	14 33
	half	23	20	6 6	19 0
	12	29	20	half	24 9
	half	36	42	5 7	30 19
	1 11	45	57	half	37 55
Hours and halves from the Substile.	half	57	41	4 8	47 30
	2 10	72	11	half	57 38
	half	88	46	3 9	74 31

The Figure of this Body as a Solid, is described in *Figure I.* and as it may be cut out in Pastboard also. In which

The Plain	A	is to have upon it	An Horizontal Dial.	If you set one of the sides to behold the South.
	B		A South Dial.	
	C		A North Dial.	
	D		An East Dial.	
	E		A West Dial.	
	F	The Base or Foot.		

But if one of the Angles behold the South: then,

The Plain	A	is to have upon it	An Horizontal Dial.
	B		A South Dial declining East 45 ^d .
	C		A North Dial declining West 45
	D		A North Dial declining East 45
	E		A South Dial declining West 45
	F	The Foot or Base.	

CHAP. III.

Of the Tetraedron.

THE *Tetraedron* is a Solid Body, containing four Bases, and four Solid Angles, each Base or Plain being an *Equilateral Triangle*.

Figure II.

I. How to Cut this Body in Wood or Stone.

ON any Rough piece of Stone or Timber, make one side Plain and Flat; upon which I describe an *Equilateral Triangle* so large as the Plain is capable of: Then set a Level, (or cut a Templet in Wood) to

X x x x

70 deg.

70 deg. 31 min. 42 sec. And Plain another side of the Piece to fit both the other side and the Level, making his Second side as the former. Then cutting away the residue of the Wood or Stone, and planing the Plains even by the Stroaks or Marks, you shall have constituted the *Tetraedron* required.

The Figure of this Body, as it is a Solid, and also as it is to be delineated upon Paste-board, you have in Fig. II.

II. Of the Dials that will furnish this Body.

MAKE any of the Sides the Base, as G in Fig. II. then will the other three Plains each of them Recline 19 deg. 28 min. 16 sec. And if the Angle at A be set towards the South; the Plain F will be a direct North Plain, Reclining as before; and the Dial will be made by the directions in Tract. I. Chap. XVI. Fig. XIV.

The other two Plains will be capable of two other Dials, *viz.* K will be capable of a South Dial declining East, and C of a South Dial declining West 60 deg. and Reclining 19 deg. 28 min. 16 sec. One Dial will serve for both these Plains, and are to be made according to the directions and Figure belonging to the second Variety, in Tractate I. Chapter XVII. and Figure XVIII. The Requisites and Hour distances belonging to which Dials are in the Tables following.

North Re. 19. 28. 16			
Stiles h. 57. 56. 16			
Hours and halves from the Merid.	12	0 ^d	00 ^m
	half	6	22
	11	12	48
	half	19	21
	10	26	4
	half	33	2
	9	40	17
	half	47	50
	8	55	44
	half	63	57
7	5	72	27
	half	81	10
	6	90	00
Hour distances on the Plain.			

South Reclining. ———			
Declining East and West 19. 28. 16			
Dist. between Merid. and Hori. 60. 00. 00			
Arch between Plain and Zenith 60. 00. 00			
Height of the Stile 35. 15. 52			
Deflection 1. 50. 53			
Differ. of Longitude. 2. 36. 56			
54. 46. 43			
Hours and halves from the Substile.	Substile	00 ^d	00 ^m
	half	0	4
	9	3	19
	half	0	35
	10	2	52
	half	1	10
	11	1	32
	half	2	0
	12	2	37
	half	3	31
1	11	5	0
	half	8	8
	2	10	19
Hour distances on the Plain.			
Hours and halves from the Substile.	Substile	00 ^d	00 ^m
	8	4	10
	half	0	25
	7	5	41
	half	0	58
	6	6	18
	half	1	42
	5	7	13
	half	2	55
	4	8	0
3	half	5	56
	9	10	16
	half	29	2
Hour distances on the Plain.			

C H A P. IV.

Of the Octaedron.

THE *Octaedron* is a Solid Body containing eight Bases and six Solid Angles; each Base or Plain, being an Equilateral Triangle.

Figure
III.

I. How to Cut this Body in Wood or Stone.

PROVIDE a *Paralellipipedon* (or Long Cube) If the breadth both ways be 1000. let the Length be 1.414: Or if the Length be 500000, the Breadth both ways must be 3.53553. Square the Piece to these Measures Exactly, and divide the Length and Breadth just in the middle; then draw Lines both ways at all the six Sides; and also the Diagonal Line from the midst of the Length to the midst of the Breadth: Then cutting away the Waste by these Diagonal Lines, and the *Octaedron* will be finished. The Figure of this Body as it is a Solid, and also as it is to be cut out in Pasted-board you have in Fig. III.

II. Of the Dials that will Furnish this Body.

THE Body being thus prepared, Let the Angle of that which you set for the Horizontal Plain, be towards the South; and then the same Dials which furnished the *Tetraedron* will serve this Body also: For one shall be a South Inclining, and his opposite a North Reclining 19 deg. 28 min. 16 sec. And the two South declining 60 deg. and reclining as before, will have their opposite North Declining and Inclining as much; So the Dials and Requisites being the same as in the foregoing Tables, it were needless here again to repeat them.

So in Figure III. If you set the Angle * of the Horizontal Plain P to behold the South: Then,

The Plain	{ S M O Q N R }	will be a	{ South Plain Inclining } 19d 28' 16"	
			{ North Plain Reclining }	
			{ South declin. East } 60d and Reclining } 19. 28. 16	
			{ South declin. West }	
			{ North declin. East } 60d and Inclining }	
			{ North declin. West }	

Figure
IV.

C H A P. V.

Of the Dodecaedron.

THE *Dodecaedron* is a Solid Body consisting of twelve Sides, and twenty Solid Angles, each Base being an Equilateral Pentagon.

I. How

I. How to Cut this Body in Wood or Stone.

TAKE a Piece of Round Stone or Timber, and if you make the Diameter thereof to be 100000, then the length thereof must be 0.81005, Or the proportion of the Diameter to the length of the Cylinder, must be, as 4.906 to 3.973 : This Piece being now a perfect Cylinder, exactly Turned, and the ends Plained : divide the Circumference of the two ends into 10 equal Parts, and by these Divisions draw Perpendicular Lines from Division to division at either end, along the Cylinder, Hewing or Planing away all the Stone or Timber that is between Line and Line; so will your Piece be a Solid of 10 equal Sides.

Then making the whole Diameter of the Circle at that end of your Cylinder to be 1.000. take 0.309 of those Parts in a pair of Compasses, and with that distance on the Centers at each end of your Piece, describe two Circles; and if from Angle to Angle, (each to his opposites) of your ten sided Figures at each end, you draw Lines, those Lines shall give you Points upon the two little Circles whereby to describe two *Pentagons*, which will be two of your *Pentagonal Plains*, Equal and Parallel to each other.

These two sides or Plains thus prepared; for the other 10 Plains do thus: Divide the length of your Cylinder into 1.0000 equal Parts, and take out of them 0.3821, which distance set from the two ends of the Piece, upon the 10 Angles of the Piece; and draw Lines from Point to Point round about the Piece; so will there remain (of the length of the Cylinder) between these two Lines drawn about 0.2358 parts of the former 1.0000. Lastly, Lines drawn Diagonally upon all the 10 sides of the Piece will direct you what to cut away, and to compleat your Body: The exactness whereof you may examine by cutting of a Bevel or Templet to an Angle of 116 deg. 33 min. 54 sec.

The Figure of this Body as a Solid; and also how to be described upon Pasteboard you have in Fig. IV.

II. Of the Dials which will furnish this Body.

THIS Body consisting of 12 Plains, hath one of them for its *Base*, and the opposite Plain thereto will be capable to receive an *Horizontal Dial*, as the Plain P in Figure IV. Then if you will set the Angle ☉, of the Plain P, to behold the South, Then shall there be about that Horizontal Plain five other Superiour Plains namely the Plains T V W X and Y, each of them Reclining 26 deg. 33 min. 54 sec. and opposite to them five inferiour Plains, namely, Z Æ A B C inclining as much, namely 26 deg. 33 min. 54 sec. — The Angle ☉ of the Horizontal Plain P, being set to behold the South as aforesaid, And then,

The Plain	{	X	{	North Plain Reclining	{	d.	m.	sec.
		T		South declin. East				
		V		South declin. West				
		W		North declin. West				
		Y		North declin. East				

shall be a } 36 d and recl'in. } 26 . 33 . 54 }

} 72 d and recl'in. }

And

And the five inferior Plains Z Æ A B C opposite to these Superiour Plains shall Incline and Decline answerable to the five Superior; so that the same Dials will serve for both Faces, the Requisites belonging to them with the true Hour distances, are exhibited in the three following Tables.

N. Re. } 26 ^d . 33'. 54"			
S. Incl. }			
Stiles h.	65.	1.	54
Hours from the Merid.	12	00 ^d	00 ^m
	half	6	48
	11	13	39
	half	20	35
	10	27	38
	half	34	49
	9	42	12
	half	49	41
	8	57	30
	half	65	00
	7	73	32
	half	81	44
	6	90	00

North Recl. 26 ^d . and Decl. 72 ^d .			
Arch of the Plain between the Me-			
ridian and Horizon.		36. 0. 0	
A. of the Me. betw. Pl. and Zenith.		58. 16. 57	
The height of the Pole or Stile		31. 28. 20	
Deflection		82. 4. 40	
Differ. of Longitude.		85. 50. 41	
Hours from the Substile.	Substile	00 ^d	00 ^m
	6	6	2
	half	6	10
	7	5	10
	half	14	17
	8	4	19
	half	24	30
	9	3	31
	half	38	7
	10	2	47
	half	57	9
	11	1	57
	half	83	37
Hours from the Substile	Substile	00 ^d	00 ^m
	half	1	42
	5	7	5
	half	9	43
	4	8	9
	half	14	49
	3	18	12
	half	24	48
	2	30	18
	half	37	25
	1	46	35
	half	56	8
	12	68	22
	half	85	26
	12	85	5

South De. 26 ^d . 33' 54" Re. 36 ^d		0' 0"	
The Ar. of the Pl. between			
the Mer. and the Hor.		72 0 0	
The Ar. bet. Pl. and Ze.		31 43 2	
The height of the Stile.		5 44 15	
Deflection.		3 33 36	
Plain's Difference of Longit.		31 53 40	
Hours and halves from the Substile.	Substile	00 ^d	00 ^m
	10	2	00
	half	00	11
	11	1	01
	half	01	57
	12	02	44
	half	02	36
	1	03	34
	half	04	41
	2	06	06
	half	07	57
	3	10	10
	half	14	36
	4	23	15
	half	45	32
Hours and halves from the Substile.	Substile	00 ^d	00 ^m
	half	00	34
	9	3	01
	half	2	20
	8	4	09
	half	3	03
	7	5	06
	half	05	21
	6	6	56
	half	09	07
	5	12	26
	half	18	13
	4	31	09
	half	71	41

C H A P. VI.

Of the Icofaedron.

Figure
V.

THE Icofaedron is a Solid Body consisting of 20 Equal Sides, or Bases, and 12 Solid Angles; each Base being an Equilateral Triangle.

I. How to cut this Body in Wood or Stone.

Prepare a Round Piece of Stone or Timber, and if you make the Diameter thereof to be 1.0000, let the length thereof be 0.8075, or in lesser terms, if the Diameter be 4910, let the length be 3974. Then divide the ends of the Cylinder into 6 equal Parts, making the two ends, two Hexagons or figures of 6 equal sides, drawing lines down the sides, and Plaining away the Residue between Line and Line. Then making 5000 the former Semidiameter, now to be 1.000, take 616 of those Parts, and on the two Centers at each end of the Piece, describe two Circles, and by drawing Lines from each opposite Point of the six sided figures, you shall have Points in the smaller Circle whereby to draw two Triangles for two Bases or Plains of your Body, Equal and Parallel to each other.

Then making the length of the Piece to be 1.000, set .379 and .095 upon the edges of the Piece from each end, and by those Points draw lines round the Piece, Lastly, Diagonal lines being drawn round the Piece, from Point to Line; and from Line to Point; shall direct you how to cut the Body at 12 Cuts. And if you cut a Bevel or Templet to an Angle of 138 deg. 11 min. 23 sec. You may examine the truth of your Body when it is thus Finished.

The Figure of this Body as a Solid, as also how to describe it upon Pastebord, you have in Fig. V.

II. Of the Dials which will furnish this Body.

This Body consisting of 20 Plains, of which one being made the Foot or Base, its opposite Plain will be capable to receive an Horizontal Dial as the Plain D, and if you set any Angle thereof as that marked with 2 to behold the South; then, the *Requisites* and *Hour Distances* belonging to all the rest of the Plains, will be such as the several Tables following do exhibite.

Angle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2
4	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3
5	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4
6	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5
7	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6
8	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7
9	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8
10	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9
11	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10
12	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11
13	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12
14	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13
15	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
17	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
19	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
20	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

I. For

I. For the North Plain G. Reclining 48 deg. 11 min. 23 sec.

North Re. 48d. 11' 23"			
Stiles h. 86 39 23			
Hours from the Meridian.	12	00 ^d	00'
	half	7	29
	1 11	14	59
	half	22	28
	2 10	29	57
	half	37	27
	3 9	44	57
	half	52	27
	4 8	59	57
	half	67	28
	5 7	74	59
	half	82	29
	6 6	90	00

South Re. EF 48d 11' 23"			
Declining 60 00 00			
The Arch of the Pl. between the Merid. and Hor.	37	45	41
The Arch of the M. between the Pl. and the Ze.	65	54	19
Stiles Height	22	06	03
Deflection	16	41	13
Diff. of Longit.	38	30	50

Hours from the Substile.	half	00 ^d	24
	10 2	3	14
	half	6	11
	11 1	9	19
	half	12	46
	12	16	42
	half	21	19
	1 11	27	0
	half	34	13
	2 10	43	45
	half	56	34
	3 9	73	16
Hours from the Substile.	Substile	00	00
	9 3	2	26
	half	5	20
	8 4	8	25
	half	11	45
	7 5	15	32
	half	19	56
	6 6	25	17
	half	32	0
	5 7	40	48
	half	52	36
	4 8	68	13
	half	87	12

South Rec. H I. 19d 28' 16"			
Declin. 22 14 29			
Ark of the Plain between the Mer and Horizon.	82	14	19
Arch of the Mer. between the P. and Zenith.	20	54	18
Stiles Height	16	22	19
Deflection	6	26	34
Diff. of Longit.	21	49	56

Hours from the Substile.	11 1	1 ^d	56 ^m
	half	4	07
	12	6	27
	half	9	00
	1 11	11	55
	half	15	24
	2 10	19	44
	half	25	26
	3 9	33	22
	half	45	09
	4 8	63	01
	half	87	38
Hours from the Substile.	Substile	00	00
	half	0	11
	10 2	2	19
	half	4	32
	9 3	6	53
	half	9	29
	8 4	12	30
	half	16	06
	7 5	20	37
	half	26	38
	6 6	35	8
	half	47	49
	5 7	66	58

North

North Re. K.L.	19d	28'	16"
Declining E and W. 82	14	19	
The Arch of the Pl. between the Merid. and Hor.	22	14	19
The Arch of the M. between the Pl. and the Ze.	69	05	41
Stiles Height	19	53	19
Deflection	71	17	00
Diff. of Longit.	83	25	34

half	00 ^d	19
5 7	2	53
half	5	33
4 8	8	23
half	11	31
3 9	15	06
half	19	21
2 10	24	38
half	31	38
1 11	40	42
half	53	37
12	71	17
Substile	00	00
6 6	2	15
half	4	53
7 5	7	40
half	10	43
8 4	14	10
half	18	14
9 3	23	13
half	29	35
10 2	38	08
half	50	01
11 1	66	26
half	87	17

Hours from the Substile.

Hour distances upon the Plain.

North Rec. M.N.	19d	28'	16"
Declin.	19	28	16
Ark of the Plain between the Mer and Horizon.	75	31	11
Arch of the Mer. between the P. and Zenith.	24	50	41
Stiles Height	46	26	21
Deflection	43	02	04
Diff. of Longit.	56	54	32

half	3 ^d	12 ^m
9 3	8	41
half	14	19
10 2	20	12
half	26	24
11 1	33	2
half	40	13
12	48	2
half	56	32
1 11	65	44
half	75	32
2 10	85	44
Substile	00	00
8 4	2	14
half	7	43
7 5	13	19
half	19	9
6 6	25	17
half	31	50
5 7	38	55
half	46	37
4 8	55	0
half	64	4
3 9	73	46
half	83	55

Hours from the Substile.

Hour Distances upon the Plain.

Thus have you all the Requisites and Hour Distances belonging to the Ten Superiour or Reclining Plains noted with E F G H I K L M N, the which will also serve for the Nine inferiour or Inclining Plains: By observing the directions given in *Treatise I. Chap.*

For { $\begin{matrix} O \\ P \\ Q \\ R \\ S \\ T \\ V \\ W \\ X \end{matrix}$ } The Recliner, shall be opposite to { $\begin{matrix} E \\ F \\ G \\ H \\ I \\ K \\ L \\ M \\ N \end{matrix}$ } Its Incliner

C H A P.

C H A P. VII.

Of a Regular Polyhedron, called the Canted Cube.

THIS Body consists of which 26 Plains, of 16 are Geometrical Squares; and 8 are Equilateral Triangles, the sides of both being equal.

I. To Cut this Body in Wood or Stone.

Prepare a *Parallelepipedon*, or Long Cube; and if you make the side of the Square at the End to be 9000, the length of the depth of the piece must be 7244: Then divide the sides of the Squares at each end of the Piece into 3 equal Parts, so will each of them contain 3000 Parts, and from the ends of these lines, draw lines down the sides of the Piece, Then take 2122 of those Parts, and set them upon all the side lines from both ends, gageing lines round about the Piece; so shall you have lines to direct you to cut the Body at 8 Cuts: called,

Icosa-hexaedron or Hexicosaedron.

II. Of the Dials proper for this Body.

Designing the Square Plain for the Horizontal Dial, and setting any of the Angles thereof, as that marked with φ , to behold the South, then will the four superiour *Triangular Plains* B C D and E answer to the four Cardinal Points of the Horizon, namely to the *East, West, North* and *South* Points, and all of them will Recline 35 deg. And the four inferior *Triangular Plains* F G H and K will Incline as much, and so

The Plain $\left\{ \begin{array}{l} B \\ C \end{array} \right\}$ will be a direct $\left\{ \begin{array}{l} \text{South} \\ \text{North} \end{array} \right\}$ Dial Reclining 35 deg.
 $\left\{ \begin{array}{l} D \\ E \end{array} \right\}$ will be a direct $\left\{ \begin{array}{l} \text{South} \\ \text{North} \end{array} \right\}$ Dial Reclining 35 deg.

The four inferior *Triangular Plains* F G H K, will be East, West, North and South Incliners 35 deg. and the Dials of the Recliners will serve for the Incliners.

The four Superiour Square Plains L M N and O, will be Recliners Declining; For each of them do Recline 45 deg. and Decline as much.

The Plain $\left\{ \begin{array}{l} M \\ N \\ L \\ O \end{array} \right\}$ will be a $\left\{ \begin{array}{l} \text{South declining} \\ \text{North declining} \end{array} \right\} \left\{ \begin{array}{l} \text{East} \\ \text{West} \\ \text{East} \\ \text{West} \end{array} \right\} 45 \text{ degrees}$

Of the *CANTED CUBE*.

The Four inferiour Square Plains *YZÆJ* will be South-East, South-West; North-East, and North-West; Declining 45 deg. and Inclining 45 deg. also, and the Dials for the Superior or Recliners will serve for their opposite Incliners also:

The other Eight Square Plains *PQRSTVWX*, are all Erect Plains, And of them,

The Plain $\left\{ \begin{array}{c} P \\ Q \\ R \\ S \end{array} \right\}$ is an Erect Direct $\left\{ \begin{array}{c} \text{South} \\ \text{North} \\ \text{East} \\ \text{West} \end{array} \right\}$ Plain

And

The Plain $\left\{ \begin{array}{c} T \\ V \\ W \\ X \end{array} \right\}$ is an Erect Plain declining from the $\left\{ \begin{array}{c} \text{South} \\ \text{North} \end{array} \right\}$ $\left\{ \begin{array}{c} \text{Eastward} \\ \text{Westward} \\ \text{Eastward} \\ \text{Westward} \end{array} \right\}$ 45 degrees.

And thus have you 25 Dials upon one Body, besides the Base, and in these you have Examples of all sorts of Dials, viz.

Of $\left\{ \begin{array}{l} \text{Erect Direct} \\ \text{Erect Declining} \\ \text{Direct Reclining, and Inclining} \\ \text{Declining, Reclining and Inclining} \end{array} \right\}$ Plains.

The End of the Fourteenth TRACTATE.

WEDDING

The four interior square P...
W... th-Half, and North...
42... and the Dial to...
The... Square P...
And at noon...

South
North
The P...
P...
P...

The P...
W...
degrees

And the...
since you have...

South
North
P...
P...
P...

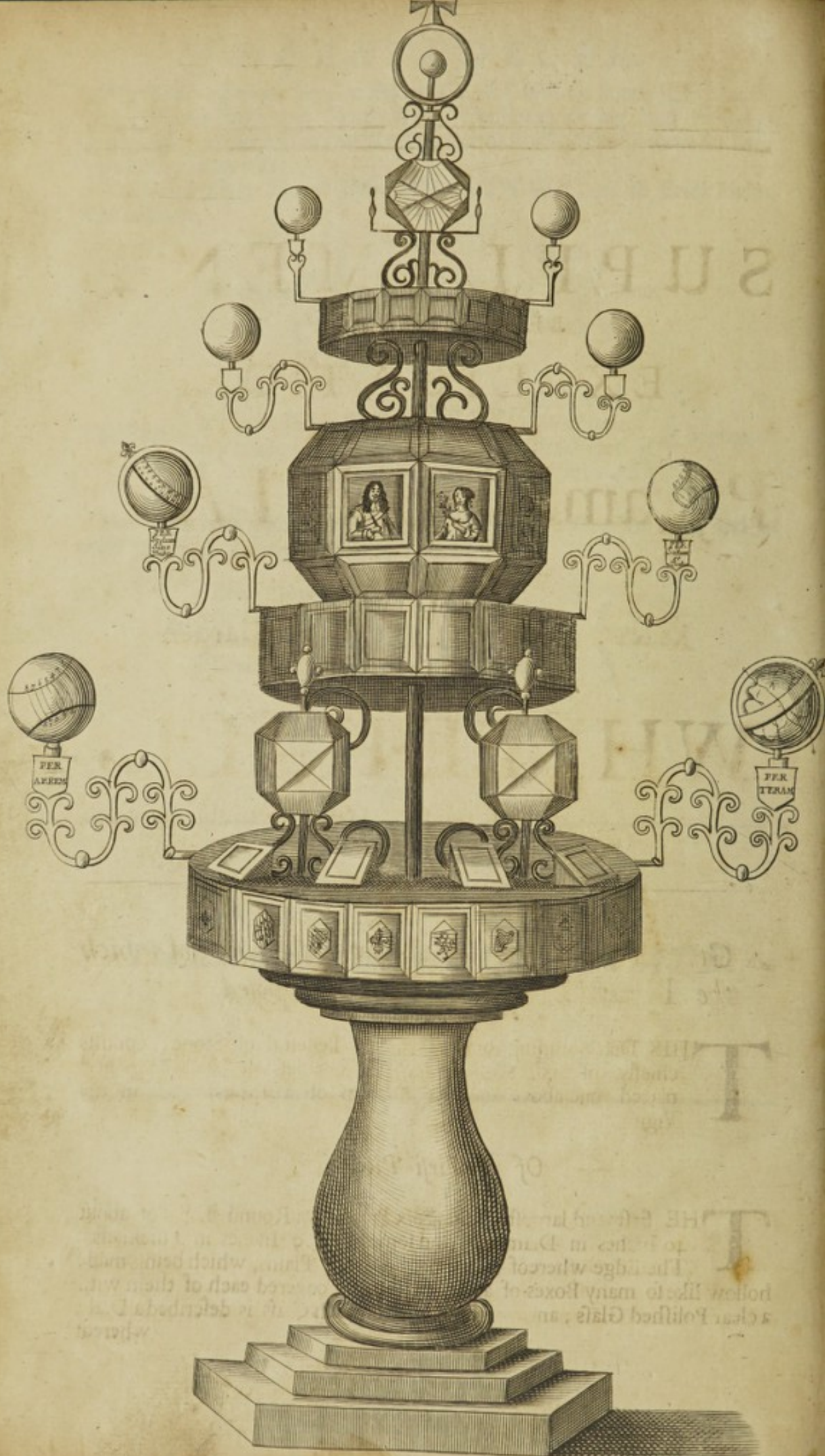
WEDDING

WEDDING

WEDDING

WEDDING

WEDDING



A
 SUPPLEMENT,
 BEING A BRIEF
 EXPLICATION
 OF A
 Pyramidical DIAL,
 Which was set up in the
 KING'S MAJESTY'S Privy Garden
 AT
 WHITE-HALL,
 A N N O 1669.

*A General Description of the several Parts, of which
 the Pyramid (or Body) was composed.*

THIS Dial standing on a Pillar or Pedestal of Stone, consists chiefly of Six Parts or Pieces, one less than another, and placed one above another in Form of a *Pyramis*, as in the Figure.

Of the First Piece.

THE first and largest of these Six Pieces, is a Round Table of about 40 Inches in Diameter, and some 8 or 9 Inches in Thickness : The Edge whereof is cut into 20 equal Plains, which being made hollow like so many Boxes of an Inch deep, are covered each of them with a clear Polished Glass ; and on the in-side of each Glass is described a Dial ;

whereof

whereof some of them shew the Hour according to the Ancient or *Jews* manner of counting the Hours: Others according to the counting used by the *Babylonians*: Others according to the *Italians*: Others according to the way of counting used by *Astronomers*: And lastly others shew what Hour it is according to our usual and ordinary way of counting the Hour used in most parts of *Europe*. These 20 Dials thus described on the Edge of this Table or First Piece, are all Vertical Declining Dials; whose Stile or Gnomon is either a Lions Paw, or Unicorns Horn, or such like, relating to His Majesty's Arms, and painted on the bottom of the Box.

Moreover upon the upper Part of this Table, are placed Eight Reclining Dials, all made hollow, and covered with Polished Glass like the former, but differ chiefly in this; that they shew only the usual Hour in different ways: One of them shewing the Hour by the Shade of the Stile falling upon the Hour-Lines: Another by the Shade of the Hour-Lines falling upon the Stile: A Third without any Shade either of Hour-Lines or Stile, &c.

Upon this Piece stand also 4 Globes, cut into several Panes: Upon one of which Globes are described several Dials belonging to Geography: On another, Dials belonging to Astronomy: the Third Dials shewing several things appertaining to Astrology, as what Planet Reigns every Hour: The Horoscope, Aspect of the Sun with the Stars, &c.

There are also belonging to this Piece, and issuing out of the Sides thereof towards the East, West, North, and South, Four Iron Branches supporting each of them a Glass Boul which shew the Hour in Four different ways.

Of the Second Piece.

THE Second Piece of the Pyramis is also a Round Table, almost like the former, but somewhat less, having only 30 Inches in Diameter: It stands upon the First, held up by Four Iron Supporters. The Edge or Circumference of this Table is cut into 16 Equal Plains, all made hollow, and covered with Glass, like those of the First Table. But they differ from them in this, that here the Dials are not described on the Glass Covers, but on the bottom of the Boxes: Neither do they shew the Hour but the different Risings of the most remarkable Stars, according to the three manner of Risings observed by Astronomers, *Viz.* Cosmical, the Acronycal, and the Heliacal Rising. The Style to these Dials is a little Star painted upon the Inside of the Glass Cover, the better to keep it from the weather.

Out of the Sides of this Piece issue out Four Branches towards the East, West, North, and South, and carry on each of them a Glass Boul to shew the Hour, like those of the First Piece, but in a different way. For one of them shews the Hour by a Style without a Shadow, another shews it by a Shadow without a Style, &c. whereas those of the First Table shew it by the Four Elements, Fire, Air, Water, Earth.

On the upper part of this Table are placed Eight Reclining Planes, Four whereof are covered each of them with a Plate of Looking Glass, on which the Hour Lines, or Style of the Dial, being painted, are Reflected upon the bottom Inclining Plains, of the Third Piece, and there shew the Hour.

Other Four have all Dials upon them, which are to be seen each of them in a Looking Glass placed upon the said bottom Inclining Plains, of the Third Piece.

Of the Third Piece.

THE Third Piece of this Pyramidical Dial, is a great hollow Globe, of about 24 Inches in Diameter, and is placed immediately without any Supporter upon the second Piece. The Superficies of this Globe is cut into 26 Plains, two whereof being *Octogons*, serve for top and bottom; the rest are divided into 8 equal Reclining Plains, 8 equal Inclining Plains, and 8 equal Vertical or Upright Plains. These Plains are all of them made hollow, like those of the first and second Piece. The Incliners are not covered with Glass, but left open, that they may the better receive and shew the Dials Reflected from the second Piece.

Two of the 8 Upright Plains looking towards the North, have no bottoms, but are covered only with clear Glass, as serving only for Windows to look into the Globe, and behold there the Dials described on the Globe, which are seen as well without the same, as within. The other 6 have not only each of them a cover of clear polished Glass, with a Dial described thereon, like those of the first Piece, but have also a Glass for their bottom, which Glass is thinly painted over with White Colour, to the end the shade of the Hour Lines, drawn upon the Cover, may be seen as well within the Globe as without. On these bottom Glasses are drawn several Pictures, holding either a Scepter or a Truncheon, or the like, the end whereof points the Hour you look for.

Two also of the Recliners looking towards the North, have only a Glass Cover, serving for a Window to look into the Globe. The other 6 have a double Glass, like the former. Their Dials are some drawn upon the Cover, others upon the bottom, but all so contrived, that the Hour cannot be known by them, but only by looking within the Globe.

Moreover, From the top of this Globe issue 4 Iron Branches towards the four parts of the World, each of them carrying a Glass Bowl, proportionably less than those of the first and second Piece; on which Bowl are also Dials described, but different from the former, shewing the Hour according to the several ways of counting the Hours. These Bowls are painted on the inside with thick Colour, to keep out the Light, except a little place which is left clear, like a Star, for the Suns Beams, to pass thorow and shew the Hour, and the place also where the Hour Lines are drawn, only painted on the outside thinly with White Colour, that the light of the Sun passing thorow, the said Star may be seen and shew the Hour.

Of the Fourth Piece.

THE Fourth Peice standing on the aforefaid Globe, and held up by the four Iron Supporters, like to thofe which hold up the fecond piece, but proportionably lefs, is alfo a Round Table of about 20 inches Diameter, and 6 in thicknefs. The edge of this Table is cut into 12 equal Superficies, not plain as heretofore, but concave like fo many concave Semi-Cylinders; on each of which is defcribed a Dial, which fhews the ufual Hour by the fhade of a *Flower de Luce*, fixed at the top of each Semi-Cylinder.

From the top of this Table iffue forth four Iron Branches carrying each a Glafs Bowl, juft like thofe of the Firft, Second, and Third Piece, though proportionably lefs. The Dial defcribed on thefe Glafs Bowls, differ from thofe of the Third Piece, not only becaufe they fhew only the ufual Hour, but alfo becaufe here the Hour Lines are all left clear for the Suns Beams to pafs through; that by fo paffing they may exhibite the like Dial on the oppofite fide of the Bowl; which fide is for that purpofe thinly painted over with White Colour, that the faid Hours may be feen, and fhew their Hour by their paffing over a little Star, painted in the middle thereof.

Of the Fifth Piece.

THE Fifth Piece ftanding upon the Fourth, and held up alfo by four Iron Supporters, is a Globe of about four Inches Diameter, whole Superficies is cut into Fifteen Plains, eight whereof are Triangles Equal and Equilateral; the other fix are Equal Squares. The Dials defcribed on thefe Plains fhew only the ufual Hour, by the fhade of a *Flower de Luce*, faftned to the top or bottom of each Plain.

Of the laft or higheft Piece.

THIS higheft Piece or top of the Pyramid, is a Glafs Bowl of fome feven Inches Diameter, ftanding upon a foot of Iron placed on the middle of the Fifth piece. The North fide of this Bowl is thinly painted over with White Colour, that the fhade of a little Golden Ball, that is placed in the middle of the Bowl, may be feen to pafs over the Hour Lines, which are drawn upon the faid White Colour, and note the Hour. The Bowl is included between two Circles of Iron gilded, with a crofs on the top. And thus much concerning this *Pyramidical Dial* in general.

I. Of the Twenty Vertical Dials described on the first Piece.

Four of those Dials have a	{ Lion Harp with a Scepter Flower de Luce Unicorn Lion also	{ Painted in the bottom of the Box, and shew the	{ Jewish Babylonish Italian Astronomical Common	{ Hour by the shadow of the Lines drawn upon the Glass passing over the	{ Paw of the Lion. Top of the Scepter. Top of the Flower de Luce. Unicorns Horn. Lions Paw.
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II. Of the Eight Reclining Dials, standing upon the First Piece.

These four Recliners which stand upon the South part,

The	{ First Second Third Fourth	{ Shews the hour	{ By the Stile passing over the Hour Lines.
			{ Both by the Shadow of the Hour Lines passing over the Stile.
			{ By the shadow of the Stile passing over the Hour Line, and the Hour Lines over the Stile.
			{ Without shade either of Stile or Hours.

Those four Recliners standing on the North part,

In the	{ First Second Third Fourth	{ You see the Hour Lines, but no Stile.
		{ You see the Stile but no Hour Lines.
		{ You see neither Stile nor Hour Lines.
		{ You see both Hours and Stile.

III. Of the four Glass Bowls which stand upon the First Piece.

These four Bowls shew the common Hours by four different ways : viz.

The	{ First Second Third Fourth	{ by	{ Fire Water Air Earth	{ By applying your Finger to the Meridians.
				{ By the Rays of the Sun passing through the Water.
				{ By two Objects made in the Globe, and reposing your Eye.
				{ By a Terrestrial Globe described upon the Bowl.

IV. Of

IV. *Of the four great Globes standing on the First Piece.*

EACH Globe consisteth of 32 Plains, of which 20 are Equilateral Triangles, and 12 Regular Pentagons; the Triangles are all Plains, and some of the Pentagons also, and the Stiles of these Dials are a sharp pointed Iron, perpendicularly erected.

Of these Dials described on the First Globe,

Some shew in what part of the World	{	<i>It is time of Rising or 6 a Clock,</i>
		<i>It is time of Dining or Mid-day.</i>
		<i>It is Supper time or 6 a Clock.</i>
		<i>It is Mid-night or 12 a Clock.</i>
		<i>The Sun is in the Zenith.</i>

The Dials upon the 20 Triangles shew what a Clock it is in divers other Countrys in the World.

Of the Dials drawn upon the Second Globe, shew

Some of them	{	<i>The Azimuth or distance of the Sun from the South.</i>
		<i>The Almicanter or degrees of Altitude.</i>
		<i>The Suns Rising.</i>
		<i>The Suns Setting.</i>
		<i>The Amplitude or distance of rising from the East or West.</i>
		<i>The Day of the Month, &c.</i>

Of the Dials described upon the Third Globe.

This Globe consisteth of 20 Equilateral Triangles, some whereof are made hollow like Cones, the rest left Plain.

The Dials shew by the shadow of the Stile	{	<i>What Con-</i>	{	<i>Begins to Rise.</i>
		stellation.		<i>Begins to Set.</i>
				<i>Begins to pass the Meridian.</i>
				<i>Is just East or West.</i>
				<i>Is in our Zenith.</i>
				<i>Will be just East or West at 8 at Night.</i>
				<i>Will be just South at 8 at Night.</i>

Of the *Dials* upon the *Fourth Globe*.

This *Globe* (as the former) consists of 20 *Equilateral Triangles*; and the *Dials* described upon them,

Shew by the Shadow of the Stile	{	What Sine is ascending.
		What Sine is culminating.
		What Sine is descending.
		In which of the 12 Houses the Sun is.
		What Planet Reigneth any day of the Week.
		What fixed Stars are in Conjunction with the Sun.
		What Aspect the Sun hath to fixed Stars.

V. Of the *Dials* on the edge of the *Second Piece*.

The *Dials* described upon the edge of this *Second Piece*,

Shew the { *Cosmical*
 Achronical } Rising and Setting of the fixed Stars.
 Heliacal }

VI. Of the 8 *Reflected Dials*, placed on the top of the *second Table*.

THE *Dials* made upon the top of this *second Table*, being high and above the Eye, are made by *Reflection*; for the *Dials* drawn upon the *Inclining Plain*, the *Stile* being a *Flower de Luce*, painted upon the *Looking-glass*, placed on the *Table*, appears not, but only the shadow thereof appears, which being *Reflected* upon the *Hour Lines*, drawn on the bottom of the *Globe*, shews the *Hour*.

VII. Of the *Four Dials* supported by the *Four Branches* Of the *Second Piece*.

THESE four *Dials* are drawn upon four *Glass Globes*, of about five inches *Diameter*, and shew the usual *Hour* for several ways.

The First shews the *Hour* by moving the *Stile* (which here is a *Flower de Luce* fixed on a moveable *Equator*) to and fro till it cast no shadow upon the *Globe*; so shall the *Equator* rest upon the *Hour*.

The Second shews the *Hour*, by observing where the part of the *Globe*, enlightned by the *Sun*, meets with the part not enlightned, for that will be at the true *Hour*.

The Third shews the *Hour*, by the shadow of a *Stile* perpendicularly erected upon the *Superficies* of the *Globe*.

The Fourth shews the Hour by placing of your Body so as to behold your Face in the middle of a little Convex Looking-glass placed for that purpose in the South Pole of the Bowl or Globe; you shall at the same time (if the Sun shine) behold the Picture thereof at the Hour.

VIII. *Of the Dials described on the great Globe, which stands on the Second Table.*

THis Globe consists of 24 Plains, 8 Recliners, 8 Vertical, and 8 Inclining Plains: For the Dials upon them, six of the upright Plains are made hollow and covered with Glass, having Dials drawn upon them: The bottoms here also are covered with Glass thinly painted over with White Colour, that the Dials may be seen as well within as without the Globe; the two Hollows towards the North being left open as Windows to look into the Globe. On the bottom Glasses are drawn several Pictures, as of the King, Queen, &c. In the King's Picture the Hour is shewed by the Hour Lines Passing over the top of the Scepter. In the Queen's, by the Shadow passing over the Center of a Flower in her Hand; and the rest over several Truncheons, &c. held in their Hands.

For the Dials described upon the Reclining and Inclining Plains; they are of the like kind (by Reflection) as those before described in the former Globe.

IX. *Of the Four Glass Bowls, supported by the Four Branches of the great Globe.*

THese four Bowls are gilded over, except where the Hour Lines are drawn, which is thinly painted over with White Colour, to the end, the Sun Beams passing through a little Star, left clear on the top of the Bowl, and making the like Star of Light upon the Hour Lines, may be seen to note the Hour. The Hours were such as shew the Hour according to different Nations.

X. *Of the uppermost Piece of the Pyramis.*

THis Fourth and uppermost Piece, consisting of 12 Concave Semi-Cylinders, and standing upon the Great Globe, held up by four Supporters, like those which held up the second Piece. Upon each of those Semi-Cylinders is a Dial described, shewing the usual Hour by the light of the Sun penetrating through the Hour Lines, and passing over a little Star, painted on the lower part of the Bowl.

The Fifth Piece consisting of eight plain Equilateral Triangles and six equal Squares, and held up by four Supporters, have Dials described upon them, shewing the Hour by the shade of a *Flower de Luce*.

The Sixth and last Piece is a great Glass Bowl, standing upon the Fifth, supported by a foot of Iron, and encompassed with two Iron Circles. Which Bowl also shews the Hour by the shade of a little Golden Ball placed in the middle of the Glass.

Thus have I given a brief Account of this (now demolished) Dial which Account and Figure thereof together, may give some light to the ingenious Practitioner (with what is delivered in the foregoing Treatises) to invent infinite Varieties in this kind.

FINIS.

21 MAY 1954

[illegible]

