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T H E
T H E O R Y
O F
HADLEY'S QUADRANT
DEMONSTRATED;

And from thence
Its NATURE, CONSTRUCTION, and
USES, are fully shewn.

With a NEW Table of
The SUN'S DECLINATION
For finding
The LATITUDE of the PLACE.

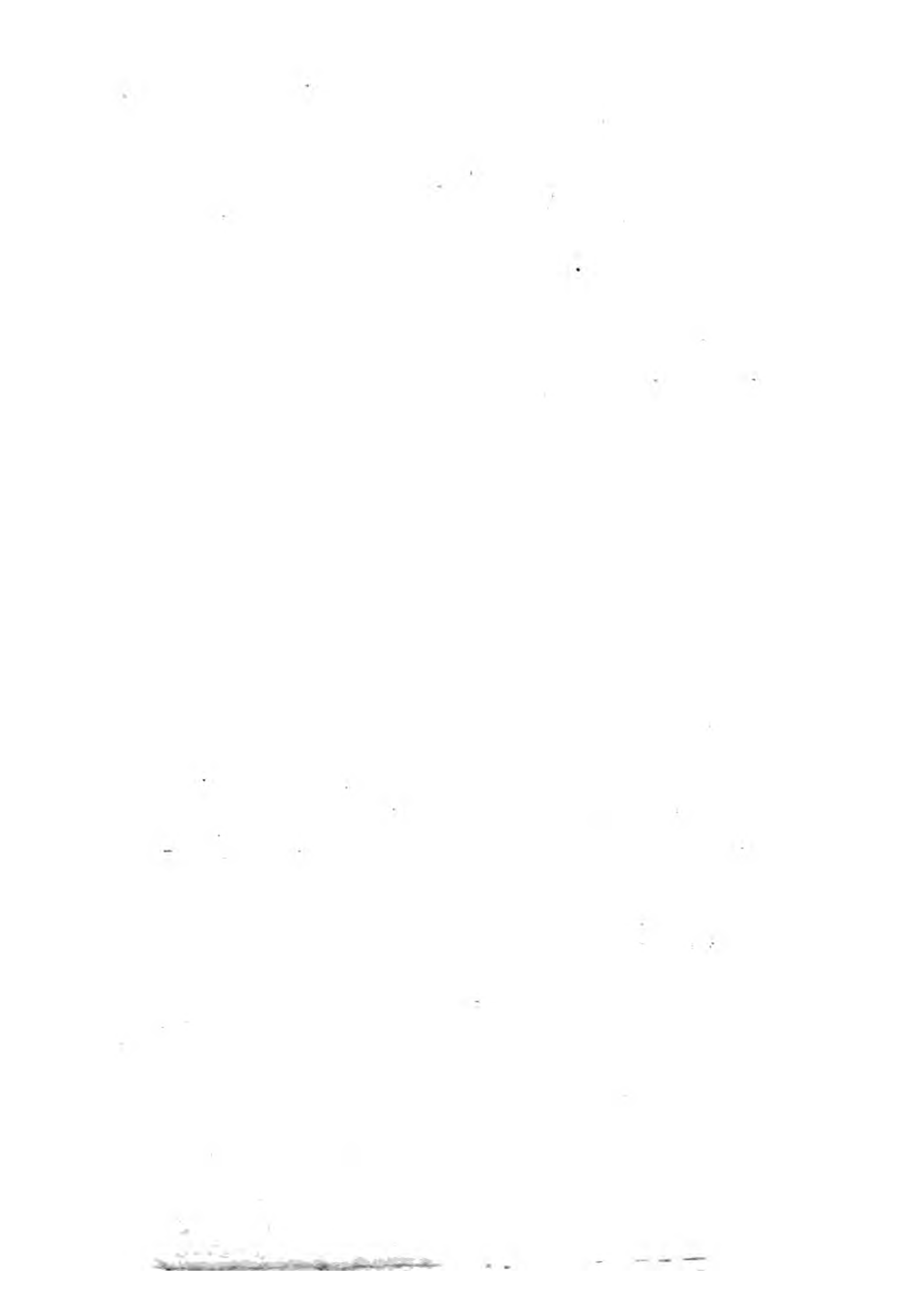
To which is added,
A NEW CONSTRUCTION of the QUADRANT,
which, by Means of an *artificial* HORIZON, renders
it of universal Use by SEA and LAND.

By BENJ. MARTIN.

L O N D O N :

Printed for the AUTHOR, at HADLEY'S QUADRANT
and VISUAL GLASSES, in FLEET-STREET. 1768.

2.



P R E F A C E.

I Have always looked upon the PRACTICE of any Art as very deficient without the THEORY; and the same may be said with regard to the Use of any Instrument; for as Errors in Practice are oftentimes unavoidable by the most ingenious Artist, and cannot be corrected without the Theory; so if any Fault happen in the Construction of an Instrument, it cannot be detected so well as by a Knowledge of the Rationale thereof, or of the Reason of every Part which composes it, and points out its Use. Nor is there any Art of greater Importance than NAVIGATION, nor any Instrument used in this Art of so much Consequence as HADLEY'S Quadrant, (originally invented by Sir I. NEWTON.) The Theory of this Instrument, therefore, ought, above all Things, to be understood by every Mariner who has any Share in conducting a Ship. But as I have not seen any Book where it is explained to the Capacity of young Navigators, I thought it would not be misapplying Time, if I offered him my Assistance in drawing up a plain and easy Demonstration of the Nature, Construction, and Use of this capital Instrument, and which I here present them with in the following small Tract. I have also added a new Table of the Sun's Declination, for finding the Latitude of the Place by the observed Meridian Altitude, and which ought to go with every Quadrant that is sold, to render its Use compleat.

As Sea-faring Men make that Class of People on whom a Maritime State has the greatest Dependance, (and no Nation is so conspicuous in that Character as GREAT BRITAIN) they ought, among us, to be distinguished with proper Regard; to be on all Occasions humanely treated; to have due Encouragement and adequate Rewards, and to have all the Helps afforded them to render their arduous Practice, in navigating a Ship, as easy and pleasant as possible. I should be glad if it were more in my Power to be subservient in promoting that great End. This is not the first, nor (probably) will be the last Instance of my Willingness and Readiness to contribute thereto;

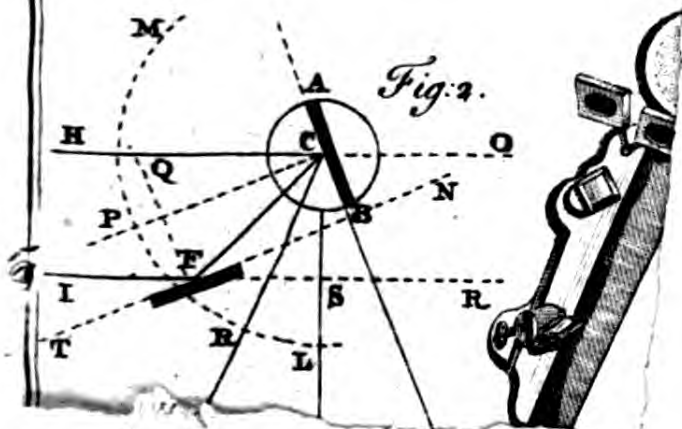
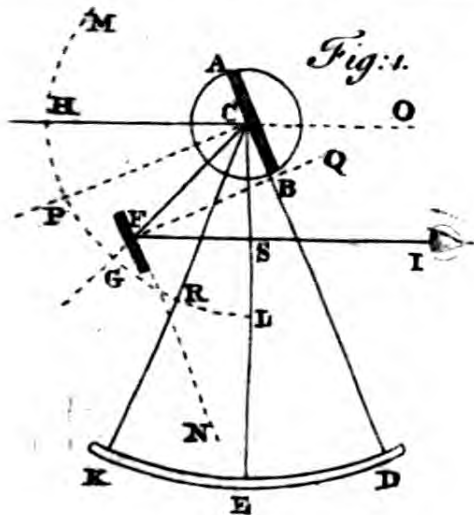
Who am,
with real Sincerity and Pleasure,
their most obedient Servant,

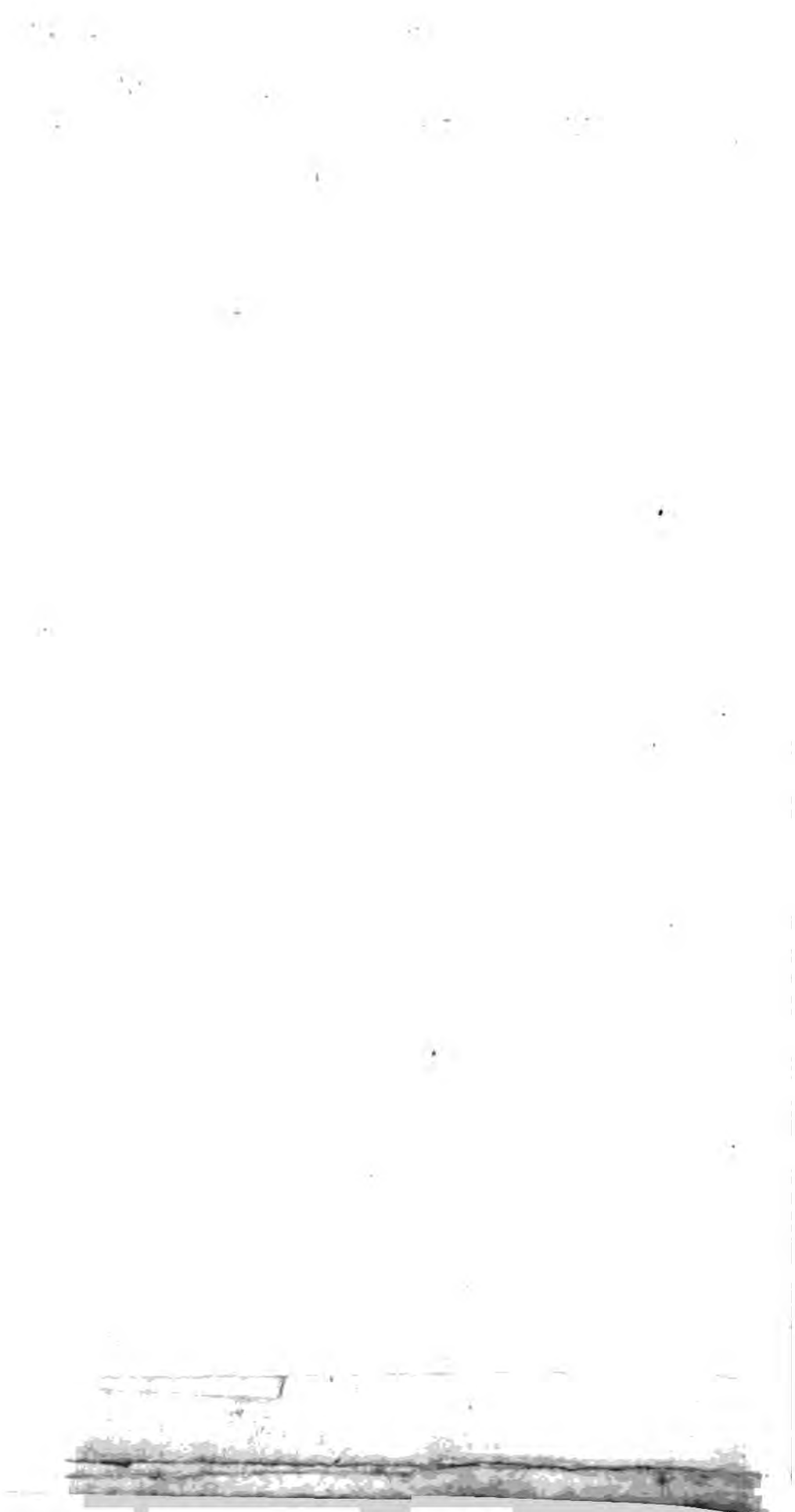
BENJ. MARTIN.

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

I Have already taken Notice of the *inartificial Method* of dividing the Limb of the Octant for taking Altitudes by *Diagonal Lines*, in Page 12th and 13th; but there is another Part of the Construction of this noble Instrument which has passed hitherto unnoticed, and which is the more to be wondered at, as it answers no End or Purpose at all, and is therefore every Way absurd and preposterous; I mean the *foliating or quicksilvering the lower small Glass for the Back-observation*; since no Object that you view by Reflection in this Glass is seen in the quicksilvered Part; tho' it be so declared and described by the Authors who write on the Use of this Instrument. If you ask where then do the Objects appear in this Glass? I answer, in the transparent Slit, or unsilvered Slip of the Glass, and in that Part only; therefore this Part only should be silvered, and the Objects viewed in it would be seen much more vivid and strong than they now are; the Pretence of seeing the Edge of the Sea through that Slip, is vain, as there is nothing to make it necessary, or of the least Use; for the best and only rational Method of Proceeding in the Back-observation, is to look at the Object in a silver'd Part of this Glass with one Eye, and at the Horizon (or Edge of the Sea) with the other Eye; for then they will appear together, and most distinctly. That the Whole of what I have asserted is Fact, you may prove, by rubbing all the Quicksilver off from the Glass, and you will see no Difference thereby made in the Observation of Objects. Or thus; put a piece of black Paper or Pasteboard over the Glass, with a Slit in it just equal to that in the Glas., and exactly over it; then thro' the Slit in the Paper and Glass together, you will see every thing the same as thro' the Slip in the Glass alone; which will plainly prove the quicksilver'd Parts are of no Use.

The **THEORY** of **HADLEY**
demonstr



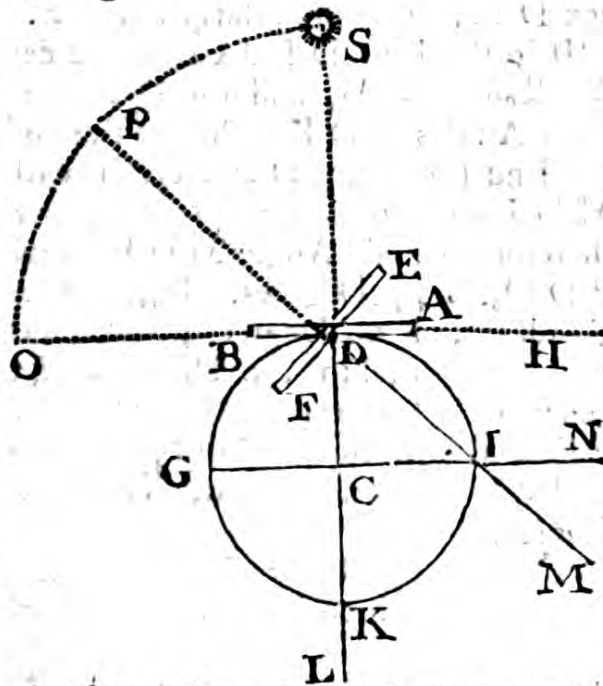


The THEORY of HADLEY'S QUADRANT
demonstrated.

IT is not to be supposed that any Person can understand the Use of any optical Instrument whatsoever, who is not acquainted with the *first Principle* (or rather *Axiom*) of OPTICS, *viz.* That in Case of Light falling on, and reflected from any polished Surface, or *Speculum*, the *Angle of Incidence* is ever equal to the *Angle of Reflection*.

This Principle is demonstrated by *Writers* on OPTICS, both from Reason and Experiment, and is easily illustrated by the annexed Figure.

Let E F be a Speculum, or plain Looking-glass, on which a Ray of Light S D falls in the Point D; then if the Line P D be perpendicular to the Glass in the Point D, and make the Angle P D O equal to the Angle P D S, the Line D O will be the *reflected Ray*; and in all Cases, the *Angle of Incidence* S D P will ever be equal to the *Angle of Reflection* P D O.



If D M be an Index fixed at Right-angles to the back Part of the Speculum F E in the Point D, it will then be in the Direction of the Perpendicular P D; and supposing the incident Ray S D continued from D to L, then by inclining or moving the Index D M towards
B
D L,

D L, the Glas F E will have the same Motion on the Point or Center D, and at Length arrive to the Situation A B, during which Time the Perpendicular P D will gradually approach to the incident Ray S D, and, at last, coincide with it.

But as the Perpendicular P D approaches the Ray S D, the Angle of Incidence P D S is constantly decreasing, and therefore, also, the Angle of Reflection P D O, which is always equal to it. And when P D coincides with S D, or D M with D L, then both these Angles vanish; and the incident Ray is reflected back upon itself, or in the same perpendicular Direction from D to S.

In the Time the Perpendicular P D moves through the Arch P S, the reflected Ray D O moves thro' the Arch O S, which is double the Arch P S. Therefore the Motion of the reflected Ray O D is twice as quick as the Motion of the Perpendicular P D, or of the Index D M, or of the Glas itself F E.

If in the Line D L a Circle be described on C, with the Radius C D, and the Diameter G I be drawn at right Angles to D K; then if the Index D M pass thro' the End I of that Diameter, it will contain an Angle M D L equal to half the Angle I C K, or 90 Degrees; therefore the said Angle M D L equal to S D P equal to P D O, is 45 Degrees. Hence the Arch O P S is a Quadrant, or 90 Degrees; and therefore, if the Glas A B be parallel to the Horizon H O, while it (or its Index D M) moves thro' 45 Degrees into the Situation E F, a Ray from the Sun S, in the Zenith, will be reflected from thence to the Horizon at O, which is 90 Degrees.

The Lines H O and G N being parallel, the straight Line P M, which crosses them both, will make the alternate Angles equal, or the Angle H D M equal to D I G; for it is evident, since D H and I N are parallel, they make the Angle H D I equal to the Angle N I M; but the Angle N I M is equal to the Angle D I G; therefore the Angle H D I is equal to the Angle D I G.

Every Thing we have hitherto premised, is, we presume, evident from a bare Inspection of the Figure, and is sufficient for understanding what we have further to say

say relating to the Reflection of Light from two Glasses, as they are put together in the Construction of *Hadley's Quadrant*, and from whence the *Rationale* of that Instrument will fully appear.

Let *AB* (Fig. 1.) represent the larger Glass of *Hadley's Quadrant*, moveable about the Center *C* of the Instrument, by means of the Index on which it is fixed; and let *PC* be perpendicular thereto in the Point *C*; then if any Ray of Light, as *HC*, fall upon it in the Point *C*, it will be so reflected as to make the Angle of Incidence *HCP* equal to the Angle of Reflection *PCG*; and therefore, by describing on the Center *C* the Circle *MGL*, and making the Arch *PG* equal to *PH*, the Line *CG* will be the reflected Ray.

Again; let *F* be the smaller Glass in a Position *FN*, parallel to that of the larger one *AB*, and suppose *FQ* perpendicular thereto; then, again, the Ray of Light *CG* falling on this Glass in the Point *F*, will be so reflected, that the Angle *CFQ* will be equal to the Angle *QFI*, if *FI* be the reflected Ray.

Now because the two Glasses *AB*, and *F*, are in a parallel Position, therefore the Perpendiculars *PC* and *FQ* will also be parallel; therefore the right Line *CF* which crosses them in *C* and *F* will make the alternate Angles *PCF* and *CFQ* equal; and consequently, the Angle *HCP* will be equal to the Angle *QFI*, which proves that the Ray *FI*, after two Reflections, is parallel to the incident Ray *HC*.

Hence it follows, that in all Positions of the Quadrant (while the Glasses remain parallel to each other) the Eye at *I* will view any very distant Object in the same Place by the reflected Ray *FI*, as it would do by the incident Ray at *O*, if the Glass *AB* were removed. Hence the Reason of adjusting the Quadrant by a *distant Object*, either the Horizon itself, or any other remote Object, since in such a Case, the Object seen by the direct Ray *HC*, and the Image shewn by the reflected Ray *FI* do coincide, or appear in one and the same Place.

But this will not be the Case when the Object is so near, that the Line or Distance *CS* subtends at the Object a sensible Angle, because then the Incident and reflected Rays *HC* and *FI* intersect each other; and

therefore the Object and Image, in the Glass at F, will appear in two different Places. The least Distance of an Object, by which the Glasses can be truly adjusted, is about half a Mile; but farther off, the better.

If the Position of the small Glass (Fig. 2.) F be perpendicular to that of the large Glass A B, or T F N perpendicular to A B D, and the Line Q F perpendicular to the said Glass in F; then the Angle H C P is equal to the Angle P C F, as before; and also the Angle C F Q is equal to the Angle Q F I; therefore the Angle C F N is equal to the Angle I F T; but T N is parallel to P C; therefore the Angle C F N is equal to the Angle F C P, and also to the Angle P C H; consequently the Angle T F I is equal to the Angle P C H. But T F is parallel to P C, therefore the reflected Ray I F is parallel to the incident Ray H C. Wherefore the Image of an Object, at a great Distance, is seen at R, by an Eye at I in the same right Line with the Object itself, but in an opposite Part of the Hemisphere; which gives the Reason *why the Second, or lowermost of the small Glasses is placed in that Position on the Side of the Quadrant for the Back-observation.*

If while the Glass F retains its Position (as in Fig. 1.) the large Glass A B be moved on the Index from its parallel Position in A D to any other as A X (Fig. 3.) then while the Index C X describes the Angle D C X, the Perpendicular P C will describe the equal Angle P C p. In this Situation of the Glasses, let M C be the incident Ray, and F I the last reflected One, produce M C till it intersects the reflected Ray in I; then will the Angle M I F be equal to twice the Angle D C X.

For in this Case, the Angle by the first Reflection is increased from G C H to G C M, by the Excess H C M; but the Half the Angle G C M is G C p, and its Excess above G C P (the Half of G C H) is the Angle P C p; therefore the whole Excess H C M of the whole Angle G C M above G C H must be equal to twice the Angle P C p, or twice the Angle D C X; but since H O is parallel to F I, the Angle M C H is equal to the Angle M I F; consequently, the Angle M I F, is equal to double the Angle D C X; therefore the Angle M C H (equal to M I F) is also double the Angle D C X.

Or

Or thus; since the Glass F is immoveable, and also the Point C, which is the Center of the moveable Glass A B; it is easy to understand that the Rays C F and F I will each of them be fixed; and therefore the Ray C F may be considered as falling on the Glass A B in the Point C, and thereby reflected in the Direction C M; but C M, considered as the reflected Ray, has twice the Motion of the reflecting Glass A B, or its Index A X; that is, while the Index moves from D to X, the Ray is reflected from H to M, and the Arch H M is double the Arch D X, as we shewed in the Beginning was always the Case in a single Reflection.

Hence it appears, that by moving the Index over any Number of Degrees on the Limb of the Quadrant, you measure an Arch in the Heavens just equal to twice that Number of Degrees. And therefore the *Octant*, or *eighth Part* of a Circle, is, by this Construction, rendered equivalent to a *Quadrant* or *fourth Part* of a Circle for measuring Angles.

But the greatest Advantage of this Instrument, and by which it excels all others for Sea-use, consists in this, *that the Image of an Object, by the second Reflection, is quiescent, or at Rest, while the Quadrant is in Motion*; I mean, that Motion which is made in a vertical Plane passing through the Object. For let the Instrument have what Position it will in that Plane, the Angle M I F is not thereby affected or altered, and consequently the Position of the last reflected Ray is the same, and therefore the apparent Place, or Image of the Object, must necessarily be invariable, or at rest.

To demonstrate this in the easiest Case, we need only consider, that as the Quadrant moves on the Point C, or Axis of the Glass A B (Fig. 1.) the Perpendicular P C will be carried to, or from the fixed Line H O, and thereby the Angle P C H becomes diminished or increased; but the Angle P C F will ever be equal to P C H; and because the Perpendicular Q F is always (in this Case) parallel to P C, therefore the Angle C F Q is equal to P C F; and consequently C F I is always equal to F C H; therefore the reflected Ray F I is parallel to H C constantly, and will of Course shew the Object ever in the *same Place, or at Rest*. The Reasoning

ing is the same for Fig. 2, and 3, or any other Position of the Glasses, provided they are parallel to each other when the Index is at the Beginning of the Degrees on the Limb of the Quadrant.

If the Quadrant librates sideways, or has a Motion contrary to the former, there will, indeed, be a Motion of the Image produced, because, since the Image is always formed in the Plane of Reflection, which passes through the Object and the Eye of the Spectator; it is evident, if that Plane be changed, the Place of the Image must change with it, and a Motion of the Image will be the Effect of such a Motion of the Instrument. But then this Motion is so far from being detrimental, that, on the contrary, it is of very great Use in many Cases, which the Mariner very well knows.

These are all the essential Particulars which constitute the Nature and Theory of this capital Instrument; the Form of which, as it is fitted for Use, with a *Nonius*, is that in Fig. 4.

Directions for the Use of HADLEY'S QUADRANT at SEA, with the Rationale of each particular Process.

THE Quadrant being applied in the usual Manner to take Altitudes by reducing all celestial Objects to the Level or *Edge of the Sea*, this we may call the *Marine Horizon*, in Contradistinction to the *true or natural Horizon*.

To explain this Matter (Fig. 5.) let A B D be a Part of the Surface of the Sea; C, the Center of the Earth; A C, its Semidiameter equal to 43946552 *English* Feet. Then if A H be any Height to which the Eye is elevated above the Surface of the Sea at A, and through the Point H you draw H O perpendicular to H C, that
Line

Line HO will be the *true Horizon*: And if from the Point H you draw HE to touch the Surface of the Sea in some Point B ; then is the Line HE the *Marine Horizon*, or that which appears to the Eye. Lastly, the Angle contained between the two, *viz.* the Angle OHE is called the *Dip of the Marine, or visible Horizon*.

Hence, when the Altitude of the Sun or Star at S is taken by the Quadrant, the Angle measured on the Limb is SHE , greater than the true Altitude SHO , by the said Dip, or Angle OHE , which therefore must be subtracted from the measured Altitude in the *fore Observations*.

The Quantity of the Dip, or Angle OHE is computed from the Triangle BCH , right angled at B , in which the Side BC is known, and also the Side CH when the Height of the Eye AH is given.

Thus when AH is 44 Feet, the Angle OHE is 8 Minutes,

34	—	—	7
25	—	—	6
17	—	—	5
11	—	—	4
6	—	—	3
3	—	—	2
1	—	—	1

which corresponding Measures are more particularly expressed in Fig. 6. where AB is a Scale of Feet for the Height of the Eye, and CD a Scale of Minutes adapted thereto.

Besides this, there is another Correction of the apparent Altitude of Objects measured by the Quadrant; for by Reason of the Refraction of Light through the Atmosphere, or Body of Air, the Places of all Bodies are raised higher above the Horizon than what they really are; so that suppose S the true Place of the Sun or Star, its apparent Place will be at I by this Refraction of the Air. And it is the Angle or Arch GE which is measured by the Instrument, and not the Arch FE , which is the real Altitude above the Sea; and therefore from the measured Arch GE we subtract on one Hand the Dip of the Marine Horizon OE ; and on the other, the Arch FG , the
Quan-

Quantity of Refraction ; and then we get the Remainder $F O$ for the true Altitude required, of the Object at S .

If we have Regard to the Zenith Distance $Z F$ of the Object S , it is plain, that is made less by Refraction, being only $Z G$; therefore the Arch $F G$ is to be added to the apparent or measured Zenith Distance, to have the true Zenith Distance $Z F$, of the Sun or Star at S .

The more obliquely the Rays fall on the Atmosphere, the greater will be the Refraction, and consequently the horizontal Refraction will be greatest of all, and at the Zenith, where the Rays are perpendicular there will be no Refraction at all. The Altitude observed, must therefore be corrected by a Table of Refractions ; such an one I have here added, as follows.

Ap. Alt.	Refract.	Ap. Alt.	Refract.	Ap. Alt.	Refract.	Ap. Alt.	Refract.
0	1 11	0	1 11	0	1 11	0	1 11
0	33. 0	13	3.43	26	1.47	48	0.47
1	23.50	14	3.27	27	1.42	50	0.44
2	17.43	15	3.13	28	1.38	52	0.41
3	13.44	16	3.01	29	1.34	54	0.38
4	11.05	17	2.50	30	1.30	59	0.35
5	9.10	18	2.40	32	1.23	58	0.32
6	7.49	19	2.31	34	1.17	60	0.30
7	6.48	20	2.23	36	1.12	65	0.24
8	5.59	21	2.16	38	1.07	70	0.19
9	5.21	22	2.09	40	1.02	75	0.14
10	4.50	23	2.03	42	0.58	80	0. 9
11	4.24	24	1.57	44	0.54		
12	4.02	25	1.52	46	0.50		

As the Meridian Altitude of the Sun is the common Means for finding the Latitude of the Place, it ought to be known with the utmost Accuracy ; but this depends on knowing the true Quantity of Refraction in the Atmosphere at a given Altitude, which will be variable according

ording to the different Temperature and Density thereof at different Seasons of the Year. This is the Reason why all Tables of Refraction are in some Degree uncertain, in small Altitudes especially; and those given by different Authors, variable; some making the horizontal Refraction $35' 30''$, while others make it only $32' 20''$. We therefore chuse to give that, which is a Mean among them all, and is nearly the same with that proposed by Sir J. NEWTON.

An example or two will make all plain. Suppose the Observer's Eye 25 Feet above the Sea, finds the Altitude of the Sun, by the Quadrant, to be $15^\circ 30'$. Now to the Elevation of the Eye A H 25 Feet, the Dip of the visible Horizon is $6'$, and to the Altitude of $15^\circ 30'$, there answers a Refraction in the Table $3'$; the Sum of both is $9'$, which deducted from the observed Altitude $15^\circ 30'$, leaves $15^\circ 21'$ for the true Altitude above the real Horizon, or Angle F H O.

But in Case of a Back-observation, the Process will be different; because as all Objects do in the lower Glass appear *inverted*, it must follow, that those which are above the true Horizon will appear below it; and those which are below will appear in this Glass above it. And, therefore, since upon moving the Index, the Object, whose Altitude is taking, will appear to rise upwards, it will meet the Marine Horizon or Edge of the Sea, before it comes to the true Horizon in the Glass. To the Arch thus measured you must therefore *add* the Dip of the Sea, and from that Sum *subtract* the Refraction, and the Remainder will be the true Altitude of the Sun or Star.

For Example. Suppose by the Back-observation, I find the Height of the Sun $15^\circ 18'$

The Eye's Height 25 Feet.

Add the Dip $6'$

Sum $15^\circ 24'$

Subtract the Refraction $3'$

Remains the true Altitude $15^\circ 21'$

as before.

C

N. B.

N. B. Since the Zenith Distance is the Complement of the Altitude, the Refraction is ever to be *added* to that, as it is always subducted from the horizontal Altitude.

As all Objects in the Back-Observation are made to ascend by moving the Index forwards, so they will apparently descend by moving the Index backwards; therefore if the Index be set to the Beginning of the Degrees, and then moved backwards, you will see the reflected Horizon, in the Glass, descend to the visible Horizon or real Edge of the Sea; and since the reflected Horizon is as much above the real Horizon, as the visible Horizon is below, 'tis evident, that, to make both coincide, the Index must be moved back from the Beginning of the Arch, just so much as is equal to *double the Dip of the Sea*; whence it appears, that by this Means, the Dip may be known at any Time, without measuring the Height of the Eye above the Water.

Of the DIVISION of the LIMB on the QUADRANT by DIAGONAL LINES, and a NONIUS.

AS each Degree on the Limb is divided into 3 equal Parts of 20 Minutes each, so each one of these is again subdivided into 10 others by the common Contrivance of diagonal Lines, consequently the Altitude may be taken to 2 Minutes by a Quadrant of 18 or 20 Inches Radius.

But the usual Construction of this diagonal Limb seems faulty, as it makes so great a Confusion in the Divisions by such numerous Intersections of Lines; for as there are 270 diagonal Lines, and 10 circular Ones, they make no less than 2700 Intersections, and in so small a Space, that one would wonder how such a dazzling and complicated Division of a Quadrant, in such constant and universal Use, could have been so long tolerated by
Custom;

Custom; and nothing more verifies the Poet's Distich,

CUSTOM, which Mankind into Slavery brings,
The dull Excuse for doing silly Things.

And it is the more to be wondered at, when we consider how readily we find a Remedy in a Division just as accurate and vastly more perspicuous and easy, by diagonal Lines without any Intersections at all. For 10 Divisions on the fiducial Edge of the Index, answer all the Purpose of 10 concentric Circles as to Accuracy, and with an hundred Times the Perspicuity.

But the Division of Degrees into Minutes, by that Contrivance called the NONIUS, is beyond Dispute, the most excellent and elegant of all others; it is also very easy to be understood and used when rightly considered. For since each Degree is divided into 3 equal Parts, there will be 21 of those Parts in 7 Degrees, each of which contains 20 Minutes. Then if, on that Piece of Ivory called the Nonius, we take a Length just equal to 7 Degrees, and divide it into 20 equal Parts, it is evident, that since 20 of these answer to 21 on the Limb, each one of those will exceed each one on the Limb by $\frac{1}{20}$ Part, that is, by *one Minute*; therefore 2 on the *Nonius* will exceed 2 on the Limb of the Quadrant by 2 Minutes; 3 on the *Nonius*, by 3 Minutes; and so on. Consequently, if the Line at the Beginning of the Divisions on the *Nonius* be any where between two Divisions on the Limb, there will be a Coincidence of one Division on the *Nonius*, with one on the Limb somewhere; and by observing where that Coincidence is, you will see at the same Time how many Minutes the Index has passed the last Division on the Limb. Thus if the Coincidence be at the 3d Division on the *Nonius*, it shews the Index has passed the last Division by 3 Minutes; if the Coincidence be at the 7th Line on the *Nonius*, then is the Index 7 Minutes beyond the last on the Limb, and so of the rest.

But to make this Matter yet clearer, let A B (Fig. 7.) represent a Portion of the graduated Limb of the Quadrant, and C D the *Nonius* on the Index, placed appo-
C 2
fitely

sitely thereto. And in taking an Observation, suppose the Beginning of the Divisions on the *Nonius* be found between 23° and $23^{\circ} 20'$, as in the Figure; then looking for the first Coincidence of Lines on the *Limb* and *Nonius*, you find it to be at the 6th Division of the *Nonius*, therefore the Altitude is $23^{\circ} 06'$.

If two Lines on the *Limb* should fall within two Lines of the *Nonius* (as will sometimes happen) then that shews you must reckon $\frac{1}{2}$ a Minute, or $30''$ more than the Left-hand Division denotes.

If the first Line or Index of the *Nonius* has moved over a Space less than half a Division on the *Limb*, then the Coincidence will be on the Right-hand in the *Nonius*; if it has moved over more than Half, it will be found on the Left-hand; if over just Half, the Coincidence will be at $10'$. This shews the Reason why the Beginning 0 is placed in the Middle of the *Nonius*, and not at the End, because in such a Case you must look through all the Divisions of the *Nonius* at once for the Coincidence, whereas now we need look over but one half of them.

But if 20 Divisions on the *Nonius* be equal to 19 on the *Limb*, then a Division on the *Limb* will exceed one on the *Nonius* by $\frac{1}{20}$ Part, that is, by one Minute (for $20 : 19 :: 1 : \frac{1}{20} = 1 - \frac{1}{20}$.) Therefore the Figures of the *Nonius*, in this Case, must be placed contrary Ways, *viz.* to tell towards the Left-hand for the first 10 Minutes, and towards the Right-hand for the 10 last. This shews the Reason, why some Instruments have the Figures of the *Nonius* placed one Way, and some the other.

To find the Latitude of a Place by the Meridian Altitude, and Declination of the SUN.

THE Altitude of the Sun is taken by the Quadrant, and the Tables adjoined give the Declination of the Sun for every Day in the Year at Noon; then in the Diagram (Fig. 8.) you observe the Circle E N Q S is the Meri-

Meridian ; E Q, the Equator ; N S, the Earth's Axis ; H O, the Horizon ; Z R, the prime Vertical.

Now the Sun (or Star) may be upon the Meridian at (a) between the South Part of the Horizon O, and the Equator E ; or it may be at (b) between the Equator E, and the Zenith Z ; or it may be on the North Part of the Meridian at (c) between Z, and the Pole N ; or at (d) between the Pole and the Horizon at H. It also may be in the Equator at E, and in the Zenith Z ; and so upon the Whole, there will be the following *six Cases* with regard to the Latitude.

Case I. Let the Meridian Altitude be O a, and South Declination E a ; then their Sum is O E, which taken from O Z, or 90° , leaves E Z, the Latitude of the Place.

Case II. Suppose the Sun in the Equator at E, then its Meridian Altitude O E, taken from 90° , leaves the Latitude E Z.

Case III. Let it have North Declination at (b) between the Equator and Zenith, then subtract the Declination E b from the Meridian Altitude O b, and it will give O E, the Co-Latitude of the Place. Or, in this Case, the Declination E b, added to the Zenith Distance Z b, will give the Latitude E Z.

Case IV. If the Sun be exactly in the Zenith Z ; then its Declination E Z, in the Table, is the Latitude of the Place.

Case V. If it be between the Zenith and the elevated Pole at (c) ; then the Co-Declination c N taken from the Meridian Altitude H c, leaves H N, the Pole's Height, or Latitude required.

Case VI. Let the Phænomenon be at (d) between the Pole and the Horizon ; then its Meridian Altitude H d taken from its Declination Q d, leaves Q H the Complement of the Latitude sought.

Therefore it is clear, that you can find the Latitude by Means of the Quadrant, and Table of the Declination of the Sun, which on that Account we have here subjoined.

Month's Days	Jan.		Feb.		March		April		May		June	
	Sun's Declin. South.		Sun's Declin. South.		Sun's Declin. South.		Sun's Declin. North.		Sun's Declin. North.		Sun's Declin. North.	
	0	'	0	'	0	'	0	'	0	'	0	'
1	23	0	16	57	7	23	4	44	15	14	22	9
2	22	54	16	40	7	0	5	7	15	32	22	16
3	22	48	16	22	6	37	5	30	15	49	22	24
4	22	42	16	4	6	14	5	53	16	7	22	31
5	22	35	15	46	5	51	6	15	16	24	22	38
6	22	28	15	27	5	27	6	39	16	41	22	44
7	22	20	15	9	5	4	7	1	16	57	22	50
8	22	12	14	50	4	41	7	24	17	14	22	55
9	22	3	14	30	4	17	7	46	17	30	23	0
10	21	54	14	11	3	54	8	8	17	45	23	5
11	21	45	13	51	3	30	8	30	18	1	23	9
12	21	35	13	31	3	7	8	52	18	16	23	13
13	21	25	13	11	2	43	9	14	18	31	23	16
14	21	14	12	50	2	10	9	35	18	45	23	19
15	21	3	12	30	1	56	9	57	19	0	23	22
16	20	51	12	9	1	32	10	18	19	13	23	24
17	20	39	11	48	1	8	10	39	19	27	23	26
18	20	27	11	27	0	45	11	0	19	40	23	27
19	20	14	11	5	0	21	11	21	19	53	23	28
20	20	1	10	44	0N.	3	11	42	20	6	23	29
21	19	48	10	22	0	27	12	2	20	18	23	29
22	19	34	10	0	0	50	12	22	20	30	23	29
23	19	20	9	38	1	14	12	42	20	41	23	28
24	19	5	9	16	1	37	13	2	20	52	23	27
25	18	51	8	53	2	1	13	21	21	3	23	25
26	18	36	8	31	2	25	13	41	21	14	23	23
27	18	20	8	8	2	48	14	0	21	24	23	21
28	18	4	7	46	3	11	14	19	21	33	23	18
29	17	48			3	35	14	37	21	43	23	15
30	17	31			3	58	14	56	21	52	23	12
31	17	14			4	21			22	0		

Month's Days	July		August		Sept.		Octob.		Nov.		Dec.	
	Sun's Declin. North.		Sun's Declin. North.		Sun's Declin. North.		Sun's Declin. South.		Sun's Declin. South.		Sun's Declin. South.	
	°	'	°	'	°	'	°	'	°	'	°	'
1	23	8	17	58	8	9	3	22	14	37	21	56
2	23	3	17	43	7	48	3	45	14	56	22	5
3	22	59	17	27	7	25	4	8	15	15	22	13
4	22	53	17	11	7	3	4	32	15	34	22	21
5	22	48	16	55	6	41	4	55	15	52	22	29
6	22	42	16	38	6	18	5	18	16	10	22	36
7	22	35	16	21	5	56	5	41	16	28	22	43
8	22	29	16	4	5	33	6	4	16	45	22	49
9	22	22	15	47	5	11	6	27	17	2	22	55
10	22	14	15	30	4	48	6	50	17	19	23	0
11	22	6	15	12	4	25	7	13	17	36	23	5
12	21	58	14	54	4	2	7	35	17	52	23	10
13	21	49	14	35	3	39	7	58	18	8	23	14
14	21	40	14	17	3	16	8	20	18	24	23	17
15	21	31	13	58	2	53	8	42	18	39	23	20
16	21	21	13	39	2	29	9	5	18	54	23	23
17	21	11	13	20	2	6	9	27	19	9	23	25
18	21	0	13	0	1	43	9	49	19	25	23	27
19	20	49	12	41	1	19	10	10	19	37	23	28
20	20	38	12	21	0	56	10	32	19	51	23	29
21	20	27	12	1	0	33	10	53	20	4	23	29
22	20	15	11	41	0	9	11	15	20	17	23	29
23	20	3	11	20	0 S.	14	11	36	20	30	23	28
24	19	50	11	0	0	38	11	57	20	42	23	27
25	19	37	10	39	1	1	12	18	20	54	23	25
26	19	24	10	18	1	25	12	38	21	5	23	23
27	19	10	9	57	1	48	12	58	21	16	23	21
28	18	56	9	36	2	12	13	19	21	27	23	18
29	18	42	9	15	2	35	13	39	21	37	23	14
30	18	28	8	53	2	58	13	58	21	47	23	10
31	18	13	8	31			14	18			23	6

N. B. As it is most convenient, when Exactness is required, to observe the Sun's Altitude by the under or upper Limb touching the Edge of the Sea, I presume the young Navigator need not be told that in the former Case the Sun's Semidiameter, or 16', is to be *added*, and in the latter to be *subtracted* from the observed Altitude, to have the true Altitude of the Sun's Center. And that on the Contrary, with Regard to the *Zenith Distance*, the 16' is to be subtracted from the lower Limb, and added for the Upper, to have his true Distance from the Zenith.

A new Construction of HADLEY'S QUADRANT with an artificial HORIZON.

IN the Use of HADLEY'S QUADRANT, the Index moves about an Axis at Rest; if then a black Right-Line be drawn on the Index Glass A B, and placed exactly on the Center of Motion C, it will represent that Axis, and consequently *be at Rest* while the Index moves about it.

The Image of this Line in the Glass F will be plainly seen by the Eye at I, and it will there appear also without Motion, let the Quadrant or Index move as they will.

If the Plane of the Quadrant be perpendicular to the Horizon, the Axis of Motion will be parallel thereto; and therefore the apparent black Line in the Glass F will be fixed in a Position parallel to the Horizon, in every vertical Position of the Quadrant.

Lastly, in that Position of the Quadrant where the middle Point E of the Limb is in a Line C E perpendicular to the Horizon, the Line in the Glass F will be in the Plane which passes through the Eye, and is at the same Time parallel to the Horizon. Therefore the said black Line in the Glass F will become a fixed ARTIFICIAL HORIZON, as required, to render the Use of this excellent Instrument *universal* on SEA and LAND.

For

For the more ready and expeditious Use of this new constructed OCTANT, it is placed on a Foot or Stand, with a Plumb-line, or Spirit-level, to bring it precisely into a perpendicular Position by adjusting Screws at the Bottom; through the Stem there passes a strong Screw into the back Part of the Quadrant which keeps it very steady and firm for Observation. On the Top of the Stand is a strong Joint on which the Quadrant is immediately placed in a *vertical, oblique, or horizontal* Position, as Use requires; and thus all Angles are measured from the Zenith to the Nadir, all round the Horizon, and in any oblique Circle, by proceeding according to the following Directions.

*The Use of HADLEY'S QUADRANT in taking
ALTITUDES at Land, by Means of the
ARTIFICIAL HORIZON.*

PLACE the Quadrant on a firm Table, and in a vertical Position with its Limb downwards, where fasten it by the Screw in the Stem, and adjust it by the Plumb-line or Spirit-level, to a true perpendicular Position. Then move the Index forward till the Object is brought down to the artificial Horizon in the small Glass, and then it will appear in the real Horizon, and the Angle of Altitude above the Horizon will be shewn to a Minute on the Limb of the Quadrant. This Method is most ready and accurate for all Objects both *Terrestrial and Celestial*.

But with respect to the Sun, its Altitude may be taken, without looking at it through the Quadrant; for on the Sight-vane, which is white on the Inside, is a black Line drawn through the Sight-hole parallel to the Horizon; therefore by only moving the Index, the Shadow of the artificial Horizon will be seen on the Vane, and when it exactly coincides with the black Line, the Altitude of the Sun is then shewn on the Limb of the Quadrant. In this Construction of the Quadrant, the Mo-

D

ment

ment of Time when the upper and lower Limb of the Disk of the Sun or Moon touches the artificial Horizon, may be observed; and from thence the Time of the Transit of the whole Disk over a right Line may be known for any Altitude, which may be of frequent Use in Astronomy.

The Use of the QUADRANT (thus constructed) for taking the Angle of DEPRESSION below the HORIZON.

THE Quadrant being moveable on a Joint is to be inverted, or turned with its Arch upwards, where it is fastened by the Screw in the Stem; and adjusted to a perpendicular Situation by the Plummet or Level. Then if the Index be moved till any Object be gradually raised up to touch the *artificial Horizon*, it will then appear in the true Horizon; and the Angle of Depression, or Depth, will be expressed to a Minute on the Limb of the Quadrant above.

Thus all Angles of Altitude or Depreffion above and below the Horizon, from the Zenith to the Nadir, are measured with the greateft Exactness and Ease.

N. B. In all Cafes, the artificial Horizon is to be understood of a Line paffing thro' the Eye parallel to the Horizon of the Place. And therefore the Height of the Eye is to be added or subtracted in taking *Altitudes* or *Depths*, in the same Manner as in common Quadrants.

The Use of the QUADRANT in measuring HORIZONTAL ANGLES.

THE Quadrant for this Purpose is placed in a Position parallel to the Horizon, or nearly fo (for Exactness in this Respect is not necessary.) Then that Line which before was the *artificial Horizon*, is now a general Perpendicular

cular to the Horizon. Then if there be any Number of Objects A, B, C, D, &c. whose angular Distances you would know, proceed thus: Bring the general Perpendicular in the Glass to coincide with the first Object A on the left Hand, and fix the Quadrant firmly; then move the Index till you see the Object B on the perpendicular Line in the Glass, and the Angle between A and B is then shewn by the Index on the Limb of the Quadrant to a Minute.

In the same Manner you proceed, by moving the Index to bring the other Objects C, D, &c. to the artificial Perpendicular, and their angular Distances from A, and from each other, are immediately known.

If it happens that D be more than 90 Degrees from A, and C be less, then loosen the Screw of the Socket, and turn the Quadrant round till the Object C be exactly on the perpendicular in the Glass; then you measure the Angle between C and D, as before; which added to the Angle between A and C, gives the Angle between A and D. And thus you may proceed to measure Angles quite round the Horizon, in the same Manner as with a Theodolite, but much more exactly.

*The manner of using this new constructed
QUADRANT at SEA.*

TO the Mast of a Ship let a strong Bar of Iron be fixed, from the End of which, by means of a Gimbol, let a Pendulum be suspended; if the Ball be very heavy, and the Pendulum of 3 or 4 Feet length, the better. To this Pendulum the Quadrant is applied, and thereby kept always in a perpendicular Situation.

Then suppose the Ship in Harbour, surrounded with high Lands, Clifts, Houses, &c. so that no Horizon appears in the Parts towards, or opposite to the Sun; in such a Case the common Use of *Hadley's Quadrant* ceases; but with the *artificial Horizon*, the Altitude of the Sun

may be taken when it shines, thus; turn the Quadrant on the Pendulum to the Sun, and move the Index till you observe the Image of the artificial Horizon coincide with the horizontal Line on the Ivory Sight-vane, and then the Altitude of the Sun is shewn on the Limb of the Quadrant.

Again, in hazy or foggy Weather, when the Sun does not shine, and no Horizon appears, yet the Place where the Sun is, is often-times very easy to observed, and if this be viewed in the *pendulous Quadrant*, and brought upon the artificial Horizon, the Sun's Altitude is shewn on the Limb nearly as exact as if it had shone. The Manner of making these Observations is very easy with a little Practice.

Or with a *single Lens* the Image of the Sun, whether bright, or behind a Cloud, may be cast on the Line of the Sight-vane, and thereby its Altitude is immediately discovered.

These *new Quadrants* may be otherways constructed, to be used at Sea, for taking the Altitude of the Sun or Stars, when no Horizon appears. I have shewn them to many Gentlemen who are good Judges of the Nature and Uses of this Instrument, who have unanimously approved of it; and to whom I have sold many of them, of different Sizes, from 6 Inches to 2 Feet Radius.

N. B. These Quadrants no sooner were made Public, than they were pirated; but as their Truth depends upon some *nice Punctilios* in the Construction, which they who are unacquainted with the *Theory of Optics* can know nothing of, those Gentlemen who encourage the Piracy, are not to wonder if they find themselves disappointed in the Use of a bad constructed Instrument.

F I N I S.

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l. s. d.

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[The text in this image is extremely faint and illegible. It appears to be a list or a series of entries, possibly containing names and dates, but the characters are too light to be transcribed accurately.]