THE

DESCRIPTION and USE

OF THE

Navigation Scale,

As improved in the Year, 1772.

By BENJAMIN DONN.

Printed for the AUTHOR; and sold by him, at the MATHEMATICAL ACADEMY, in BRISTOL.- Sold in LONDON by most of the principal Mathematical Instrument Makers .

The Price of this Pamphlet with the Scale, is FIVE SHILLINGS.—They will not be sold separate.

☞☞This Pamphlet is entered in the Hall-Book of the Company of Stationers.

To prevent the Public being imposed on by the Sale of pirated Scales, it may be proper to acquaint then, that I have appointed the following Mathematical Instrument Makers, in LONDON, *viz. Messrs.* ADAMS, HEATH *and* WING, LINCOLN, MARTIN, NAIRNE, WATKINS *and* WHITFORD, *to vend them, as they will not sell any without this Pamphlet, and their own Names as Makers stamped on the Scales ; and consequently their own reputation will not permit them to sell any made in an inaccurate or nonworkmanlike Manner.*

B. DONN.

Mr. DONN has lately published the following Instruments, &c. which are sold by Messrs. HEATH and WING, in the Strand, Mr. SAYER, Printseller, in Fleet-street, and Mr. JOHNSON, St. Paul's Church-Yard, viz.

1. and 2. An Analemma, pr. 3s. 6d. and Panorganon, pr. 6s. coloured, for solving the common Problems of the Globes.—3. Lunar and Tide Instrument, pr. 2s.
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Mr. Donn's Essays on Arithmetick, Book-keeping, Geometry, &c., may be had of the Booksellers.

OF THE

Improved Navigation Scale.

HAVING in many Years teaching observed that the Navigation Scale, commonly called by Sailors Gunters Scale, was generally inaccurately made, and very deficient in Lines of Equal Parts: I long wished for an improvement thereon; and in the Year 1764, being in London, I took that Opportunity to have some more accurately made, with some improvements of my own ; and in the beginning of the Year 1772, being again in Town, I readily embraced that Opportunity to make some farther Improvements, and a new Pattern with the Assistance of a good Workman ; so that I flatter myself if compared with the common Scales, they will be found more generally useful and accurate. Several incorrect pirated Copies made in a very unworkmanlike Manner, and some with even the Diagonals drawn wrong, having been sold by some Makers in London and Bristol, and perhaps in some other Places, as my improved Scales ; to prevent as much as possible my own Character from being injured thereby, and the Public from being

imposed on, I hereby desire that any of the prin-cipal Shops inclined to sell them, will apply to me to know with whom I have left the Pattern for the Trade, and to put under *Improved by B. Donn,* their own *Names* as *Makers*.

And the Public may be assured, that whoever shall offer to Sale, the Scale without this Pamphlet, is selling a pirated Copy of the Scale, and therefore not to be depended on.

The several Particulars in which this Scale, as now improved, excels the common Scales will plainly appear from the following Description and Use, to those who will take the trouble to compare it with the common Scales.

The Plane or Plotting Side, viz. that which has the Bevel Edge, contains the following Scales.

1st. A Scale of Inches divided into *Tenths* of an Inch. On the left or at the beginning of the Inches are several Brass Pins, with figures annexed ; which shew the Weight of the Ball to any Diameter of the Gun. For Example. If the Diameter of the Bore of a Gun be 5 Inches and 4 Tenths, it shews by Inspection that such a Bore will carry 18 Pound Shot. This Addition is made as it may be useful to Numbers of Sailors ; for whose Use it may be proper to hint, that the Weight of Powder for Service, is generally about half the Weight of the Shot.

2. Under the Line of Inches, a Foot is divided into 100 equal Parts, so as by Inspection to turn readily Inches into the Decimal of a Foot, or the

contrary. Its Use is known to such as are acquainted with Mensuration. Dimentions may also be taken in Feet and Decimal Parts instead of Feet and Inches &c. found by common Multiplication. For Example. Suppose a Plank is 20 Feet long and 1 Feet 50 hundredths broad, the 1. 50 multiplied by 20 gives 30 Feet, the Content required. *This line is not on the common Scales.*

3. The common Scales contain but few Scales of equal Parts, by which means the young Navigator and Surveyor was frequently at a Loss for a proper Scale to construct his Scheme with ; to remedy this, I have seen some Scales made, by the direction of an ingenious Gentleman, which contained more Scales of equal Parts than the common ones, but in order to make Room for them the Diagonal Scales were omitted ; But in Cases which require particular Accuracy in constructing, the Diagonal Scales are necessary, therefore I have contrived to give *even two more Scales and yet retained the Diagonal Scales*, by disposing of the Lines in different Order. The Scales of equal Parts are 10, 15, 20, 25, 30, 35, 40, 45, 50, and 60 to an Inch.

4. This side contains likewise, Lines of Rumbs, Chords, Sines, Tangents, &c. as on the common Scales ; also two Lines corresponding to each other, one marked *M. Lon.* The other *Chord* ; by which is shewn by inspection how many Miles make a Degree of Longitude in any Latitude. For

Example, against 60 Degrees of Longitude, on the *Chord* you will find on the *M. Long.* that 30 Miles make a Degree of Longitude in that Latitude.

Nothing farther need be said to explain this Side of the Scale to those who are acquainted with the Use of common Scales. I shall therefore proceed to describe the Contents of the other Side, viz. that which is commonly called *Gunters*, from the Logarithms of Numbers, Sines and Tangents being first laid thereon by Mr. *Edward Gunter*.

The great usefulness of these Lines for the ready working Trigonometrical Canons, &c. is too well known to require a particular Description here.

The Design of this little Pamphlet being chiefly to explain those Things in which this Scale differs from others, and which without some Account, might not be so readily understood by Navigators in general.

However, for the sake of the young Student it may be proper to observe that, *To work a Canon or Proportion on Gunter's Scale, We have only to extend the Compasses from the 1st Term to the Second, on the proper Line, then will the same extent laid the same Way from the 3d Term, (viz. fom the Left to the Right, or from the Right to the Left, according as the 2d Term lay from the first) givs on its proper Line the 4th or required Number.*

As in the common Rule of Three it is no matter which of the two middle Terms are placed first, since the Product is the same ; so in working on the Gunters Scale, if at any Time it is found more convenient, we may extend the Compasses from the

First Term of the Proportion to the Third Term, then will that Distance extend from the Second Term to the Fourth or required Term.

In counting on the Line of Numbers it may be proper to observe, that the Numbers 1, 2, 3, 4, &c. represent not only 1, 2, 3, 4, &c. but 10, 20, 30 &c. thus. If the Canon you are working of, requires you to call the 1 in the middle of the Line of Numbers 100, then must the 2, 3, 4, 5, 6, 7, 8, 9, 10, on the Right Hand be called 200, 300, 400, 500, 600, 700, 800, 900, 1000 ; the 9, 8, 7, 6, 5, 4, 3, 2, 1, on the Left be called 90, 80, 70, 60, 50, 40, 30, 20, 10.

If the 1 in the middle be called 1000, the Figures 2, 3, 4, &c. on the Right will be 2000, 3000, 4000, &c. and 9, 8, 7, 6, &c. on the Left 900, 800, 700, 600 &c.

Again, if the 1 in the middle of the Line of Numbers be called 10, the Figures 2, 3, 4, &c. on the Right Hand must be 20, 30, 40, &c. and on the left 9, 8, 7, &c. will be only 9, 8, 7, &c.

Also, if the 1 in the middle be called 1, then 2, 3, 4, &c. on the Right Hand will stand for 2, 3, 4, &c. but 9, 8, 7, &c. on the Left, will be only 9/10, 8/10, 7/10, &c. &c.

For the young Student the Canons in common Use in working a Days Work are stamped on the Scale. Thus, R : Dist : : SC : Dep. : : SCC : D Lat. signifies that as Radius is to the Distance so is Sine of the Course to the Departure, and so is Sine Complement of the Course to the Difference of Latitude.

Again,

Again, D Lat. : Dep. : : Tan. 45 : T Course, is, as Difference of Latitude is to the Departure so is Tangent of 45 Degrees to the Tangent of the Course.

Also SC mid. Lat. : Dep : : R : D. Lon. is to be read, as Sine Complement of middle Latitude is to the Departure, so is Radius 90 Degrees to the Difference of Longitude. Or to find the Difference of Longitude by Meridional Parts, D Lat. : Dep : : MD Lat : D. Lon. which is to be read as Difference of Latitude is to the Departure, so is Meridional Difference of Latitude to the Difference of Longitude.

Lastly, SCL : S¤ Dec : : R : S¤ Amp. is to be read as Sine Complement of Latitude is to the Sine of the Sun's Declination so is Radius or Sine of 90 Degrees to the Sine of the Sun's Amptitude.

The *First Line* on the *Gunters Side* is marked *S Rumb*. That is Sines of Rumbs or Courses.

The *Second Line* is marked *Numb. Sqr.*, and is the common Line of Numbers intended to be used with the Sines or Tangents &c. In working the usual Canons in Trigonometry or Navigation. It is marked *Numb Square* because with the Line marked *Root* it will serve for squaring Numbers &c. of which farther Notice will be taken presently.

The *Third Line* marked S | CS | Sec. is the common Line of Sines, with the Addition of being numbered backward by small Figures : by which Addition it now serves the several Purposes

of

of a Line of S*ines, Cosines* and *Secants*. A Notion has pretty generally prevailed amongst Teachers of Trigonometry and Navigation, that the Canons in which Secants are concerned could not be solved by Gunters Scale ; and also amongst some Writers on Navigation, for Mr K – in his Navigators Tutor and Mr M – in his Rudiments of Navigation both positively affirm, that *If there is a Secant in the Proportion this Operation cannot be performed by the Scale*. But that they are mistaken may be readily shewn by only working one Example. Let us suppose the Angle A or Angle at the Base of a Rectangulare Triangle to be given equal to 50 Degrees, and the Base 86 Yards to find the Hypothenuse ? If the Base be made Radius the Canon is, as Radius is to the Base 86, so is Secant Angle A 50 Degrees to the Hypotheneuse.

This may be worked on the Scale thus. Extend the Compasses from Radius or Sine of 90 Degrees to 50 Degrees on the same Line, counting backward from Radius by the small Figures for the Secant ; then one Leg of the Compasses being set at 86 on the Line of Numbers, that extent will, turned the contrary way (because the Secants must be conceived to run beyond the Scale) reach to 13 ½ the Distance, which was required.

The *Fourth* and *Fifth* Lines are the versed Sines and Tangents as on common Scales.

The *Sixth* is the Meridian Line which on the

common

common Scale is too short to be of much Service, but by making it on two Lines we are enabled to go to 80 Degrees of Latitude, and yet have the Degrees sufficiently large to divide the Meridian of WRIGHT's Chart into every 10 Minutes, or less Parts. – The length of the Degree of the Equator corresponding to these of the Meridian are annexed on the Left Hand, and marked *Eq Deg*.

The Meridian Lines being constructed by the Diagonal Scale of 20; if at any Time in the absence of Tables we are inclined to know nearly the Meridional Difference of Latitude between any two Places, we have only to take the Distance between the two Latitudes from the Meridian Line, then measuring the Distance on the Diagonal Scale of 20, we shall have nearly the Meridional Miles required. Thus for Example if it was required to find the Meridional Diff. of Lat. between the Latitudes of 20 and 30 Degrees, the distance between these Degrees taken from the Meridian Line will on the lesser Diagonal Scale measure 663 (reckoning each primary Division or half Inch 100 Miles) for the Meridional Difference of Latitude.

The *Seventh* and *Eighth* or two remaining Lines of this Scale are a *Single* and *Triple* Line of Numbers, marked *Numb. Root*, *Numb. Cube*, which together with the second Line or double Line of Numbers marked *Numb. Sqr.* are for *Squaring* or *Cubing* Numbers; or for extracting the *Square* and *Cube Root*, or for working *Proportions wherein Squares*

and

and Cubes or the Square or Cube Roots are concerned; of great Use in various Parts of the Mathematics.

We shall give a few Examples of their Use.

What is the Square Root of 144 or which is the same Thing what is the side of a Square whose Area is 144 Feet?.

Solution. Call the 1 at the beginning of the Line of Numbers (marked *Numb. Sqr.*) 100, and extend the Compasses from that Point to 144, then calling the 1 at the beginning of the Line of Numbers (marked *Numb. Root*) 10, and putting one Point of the Compasses in that Point the other will extend to 12 the required Root.

Example 2d. *The Areas of Circles being as the Squares of their Circumferences*, let us suppose the Weight of Cables of unequal Circumferences but of equal Lengths to be in the same Proportion.

On this Supposition let it be required to find the Weight of a Cable whose Circumference is 8 Inches, the Weight of one of equal Length of 10 Inches Circumference being 25 Hundred. Here, by the Supposition the Proportion is, as the Square of 10 is to the Square of 8 so is 25 to the required Weight.

To solve this on the Scale, extend the Compasses on the Line *Numb. Root* from 10 to 8, then on the Line *Numb. Sqr.* will that extent reach from 25 to 16 Hundred the Weight of the Cable of 8 Inches.

Example 3. What is the Cube Root of 1728,

or which is the same Thing, if a Cube or Die contains 1728 solid Inches what is the Side of the Cube?

This may be solved by a bare Inspection, for calling the 1 at the beginning of the Line *Numb. Cube* 1000, the 1 corresponding to it on the Line *Numb. Root* 10, then against 1728 on *Numb. Cube* you will see 12 the required Root on *Numb. Root.*

Example 4. Suppose a Ship of 300 Tons to be 75 Feet by the Keel, it is required to find the Length of the Keel of a Similar Ship of 500 Tons Burden.

Solution *Similar Solids being in Proportion as the Cubes of their like Sides* we have as 300 is to 500 so is the Cube of 75 to the Cube of the required Keel. Therefore extend the Compasses on the Line *Numb. Cube*. From 300 to 500 (or from 3 to 5) then will that extent on the Line *Numb. Root* reach from 75 to 89 Feet nearly, the Length of the Keel required. This Instance of a useful but troublesome Question, if solved by Arithmetic, being so expeditiously solved on the Scale, by the Addition of these Lines, is a sufficient recommendation of their Use.

What we have said on the Use of the improved Scale will be sufficient for those who are acquainted with the Use of the common Scales; as for others it would be adviseable for them to apply to a proper Master for Instructions. However, I intend to treat more fully of the Use of the several Lines with their Constructions, either in my Treatise of Plane Trigonometry or Navigation. The necessary Tables being now in the Press, are intended to be published in a few Months, in a Volume by themselves. Price 6s.

BRISTOL, *Mathematical Academy, 1 Sept.* 1772.