AN

ESSAY

Towards the

Improvement of NAVIGATION,

Chiefly with Respect to the

INSTRUMENTS used at SEA.

By W. MAITLAND.

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TO THE

RIGHT HONOURABLE

The LORDS COMMISSIONERS

For executing the OFFICE of

LORD HIGH ADMIRAL
of *Great Britain*, *Ireland*, &c.

This ESSAY is, with the utmoſt Submiſſion and Gratitude, offered by

Your LORDSHIPS

moſt obedient Servant,

W. MAITLAND.

To the HONOURABLE

Sir *PETER WARREN*,

KNIGHT of the BATH, *&c.*

FLATTERY as it ſhews the baſeſt Mind in him who offers it, ſo it is juſtly deſpiſed by every Man of Worth and good Senſe; all who know You, Sir, are perſwaded that Honour, Bravery, and in ſhort, the Virtues which can render any Man happy in his own Mind, and beloved by all the Good and Wiſe, have in You been deſervedly rewarded by Fortune's Gifts, and your King's adequate Senſe of your great Merit.

To You, Sir, this firſt Attempt I ever made to appear as an Author, from

from my Perſwaſion of your Capacity of judging well, and the Senſe of my Obligations to You, is with equal Reſpect and Gratitude, addreſſed by

Your moſt Obedient Servant,

W. MAITLAND.

AN

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Towards the

Improvement of NAVIGATION.

THE Art of Navigation is of ſo great Conſequence to Mankind in general, that any Attempt to improve it is certainly in itſelf laudable: And whoever is ſo lucky as to ſucceed in an Enterprize ſo very uſeful, as he deſerves the Eſteem and Thanks of the Publick, will (no doubt) meet with theſe and other Rewards due to his Merit.

To ſome it may appear ſuperfluous, for one who is but little known to the World, (and ſuch I freely confeſs I am) to engage in a Subject in itſelf difficult, and which has been already ſo largely treated of by many, well known to be Men of the greateſt Genius and Knowledge.

But, I take it for granted, that Navigation, notwithſtanding the great Improvements already made in it, is ſtill capable of farther; and theſe I ſhall propoſe in the following Eſſay, I believe, are intirely New, the Reſult of a good deal of Thought, and a great many Experiments; and as for their Worth, that muſt be determined by ſuch, whoſe Knowledge and Candour will render them adequate and impartial Judges.

And here I muſt beg Leave to caution my Reader, that wherever I find Fault with any of the preſent Practices in the Art of Navigation, it is done, not with any ill-natured Intention; but from the Neceſſity there is of ſhewing the Defects of ſome of the Methods now in Uſe, in order to remedy them, or propoſe better in their ſtead.

To proceed then, I ſhall in the firſt Place conſider the uſual Methods of keeping an Account of a Ship's Way, upon the Suppoſition that the Inſtruments uſed to diſcover the Quantity, and Direction of her Motion, were free from Error: And next examine theſe Inſtruments to know what Errors they are liable to, and propoſe the beſt Means I can of leſſening theſe Errors.

The three ſeveral Methods by which a Ship's Reckoning is kept are, Plain, Middle Latitude, and *Mercator*'s (properly *Wright*'s) Sailing, of which in their Order.

PLAIN SAILING, ſo called from the Hypotheſis on which it is founded, which is, that the Earth (*i. e.* the Land and Water) forms a plain

plain Surface, bounded by equal and parallel ſtraight Lines; two of which, *viz.* the Northern and Southern Boundaries limit the greateſt North and South Latitudes, and are parallel to, and at equal Diſtances from the Equator, which is divided into 360 equal Parts, called Degrees of Longitude; through the extreme Points of Diviſion of this Line, Perpendiculars drawn, till they meet the Northern and Southern Boundaries on each Side, compleat the Parallelogram; and theſe laſt Perpendiculars from the Equator, Northwards and Southwards, being divided into 90 Degrees of Latitude each, and Parallels drawn to theſe thro' each Degree of Longitude, (called Meridians) and to the Equator through each Degree of Latitude, called Parallels of Latitude compleat the Plain Chart, which has the following Properties in common with a Globe, (which is known to be nearly the Figure of the Earth:) A Degree of Latitude is every where equal to a Degree of Longitude upon the Equator, as on the Globe. A ſtraight Line drawn in any Direction that is Oblique to the Meridians, or Parallels of Latitude, which is called a Rumb, will have this Property in common with a Rumb deſcribed on the Globe, that it will make equal Angles with all the Meridians it paſſes through.

But then, the Meridians in this Projection are Parallel and Equidiſtant, which in the Globe are not ſo, excepting juſt at the Equator from whence they all conſpire, and at length meet in the Poles. Hence, if two Places of an assigned Latitude and Longitude were marked upon the Globe, and these Places laid down by their Latitude and Longitude in this Chart, their Bearing and Distance on the Chart would be very different from their real Bearing and Distance on the Globe; the Distance being greater, and the Angle the Rumb makes with the Meridians, (that is the Bearing) also greater in the Chart than on the Globe. It is true, that upon or very near the Equator, where the Meridians are either Parallel or nearly so, this Projection will agree with the Globe; but no where else, and the greater the Latitude, the greater will be the Error in the Bearing and Distance of two Places, having equal Differences of Latitude and Longitude: So that at last if we imagine two Places, each in 89 $\frac{1}{2}$ Degrees of North Latitude, and their Difference of Longitude 180 Degrees; it is evident the Places will bear due North of each other, and their Distance will be just a Degree of the Meridian, or 60 Sea Miles, whereas by this Projection these Places will bear due East and West of each other, and their Distance will be nothing less than 180 Degrees of the Equator or Meridian, amounting to 10800 Sea Miles or 3600 Leagues; a monstrous Absurdity!

Plain Sailing then evidently appears to be a very erroneous Method of keeping a Ship's Way, and, I hope, none do practise it, unless at or near the Equator.

MIDDLE

MIDDLE LATITUDE SAILING, I allow to come nearer the Truth than Plain Sailing; but it is nevertheless false, and though the Error attending it is but trifling near the Equator, it will not be found so in greater Latitudes; add to this that there is hardly any Labour saved in keeping a Reckoning by this Method, and there must undoubtedly some Pleasure arise to a Man's Mind that loves Truth, from reflecting that the Method he follows will never lead him into any sensible Error; such is that commonly called *Mercator*'s Sailing, (though with great Injustice) for, in fact, it was the Invention of our worthy and ingenious Countryman Mr. *Edward Wright*, with whom this *Mercator* was Contemporary about 170 Years ago; to him Mr. *Wright* communicated his Invention, and *Mercator* basely pilfered and published it as his own: However, to do all the Justice we can to the Memory of so great a Genius, we will call it *Wright*'s Projection.

WRIGHT'S SAILING. Mr. *Wright* having duly considered the gross Errors arising from sailing by the Plain Chart, set about correcting it. He saw there was a Necessity of keeping the Meridians straight, and parallel Lines, otherways the Rumbs must be Spirals, as on the Globe; the describing of which on Paper, must be at once very troublesome and inaccurate: He also discovered the want of a just Proportion in the Plain Chart, between the

Degrees

Degrees of Latitude and thoſe of Longitude, both being every where equal here, whereas on the Globe they are only equal at the Equator, but theſe of Longitude leſs in all its Parallels, and juſt in the Proportion of the Radius of any Parallel (that is the Coſine of its Diſtance from the Equator, or its Latitude) to the Radius of the Globe; and this Proportion of the Coſine of the Latitude of any Parallel to the Radius, is that of the Radius to the Secant of that Parallel's Latitude; therefore any Arch upon the Equator, or Meridian, (ſuppoſe) of one Degree exceeds a Degree of Longitude on the Parallel (ſuppoſe) of Sixty Degrees, in the Proportion that the Secant of Sixty Degrees exceeds the Radius; and as the Secant of that Arch is twice the Length of the Radius, ſo is a Degree of Latitude twice the Length of a Degree of Longitude, on that Parallel. But ſince in this Projection, for the Conveniency of having the Rumbs ſtraight Lines, it was neceſſary to keep the Meridians Parallel, whence a Degree of Longitude on any Parallel is of the ſame extent as on the Equator, in order to keep up the Proportion that obtains in the Globe between a Degree of Latitude and of Longitude, at the Parallel of Sixty, which has been found as above, to be that of 2 to 1, there will be a Neceſſity of making the Degree of Latitude, at that Parallel, twice as long as a Degree of Longitude; and if in this Projection, the Degrees of Latitude are every where lengthened in the Proportion of the Radius, to the Secant of

of the Latitude of the ſeveral Parallels, there will every where the ſame Proportion obtain, between the Degrees of Latitude and Longitude, that does on the Globe itſelf; and the Plain Chart thus corrected will be as exact as the Globe, and much more commodious for the Purpoſes of Navigation.

From what has been ſaid of this valuable Projection, I preſume the Principles from which the Table of Meridional Parts is computed, and thence dividing the Meridian of the Chart muſt eaſily appear. The Conſtruction and Uſe of the Chart, as they are delivered at Length, by almoſt every Writer on Navigation, I ſhall here omit, my Deſign being in the plaineſt Manner I could, to ſhew by what Means the Plain Chart, from being a moſt abſurd Projection of the Surface of a Globe, is by Mr. *Wright*'s beautiful Correction, become the moſt accurate and commodious that has been, or perhaps ever will be contriv'd.

If ſailing by Mr. *Wright*'s Projection is the only true Method, and attended with very little (if any) more Trouble than either of the other two, which are manifeſtly falſe; it follows, that no other than his ought either to be taught or practis'd. Indeed, if it were neceſſary to work every ſingle Courſe a Ship makes, in this manner, it would often be tedious; but there is no Occaſion for that; for if the Difference of Longitude in a Day's Run is found once for all, it will be ſufficiently exact. But as the Courſe and Diſtance made good for the Day

Day, are the Ground-Work on which this Alteration of Longitude depends; ſuppoſing the Log-Board to contain the Data neceſſary for finding theſe, I cannot help thinking, that he who lumps two, three, or more Courſes together, making one of all, and leſſens the Diſtance as his Fancy directs, depends too much on his Skill, let it be the Effect of ever ſo long Practice: And I am certain, that after all the Helps the beſt Sea Inſtruments afford us, a Man may find Employment enough for his Judgment to keep his Reckoning tolerably near the Truth.

There is another Thing which cannot miſs being the Source of frequent Errors in Reckonings, and that is, the want of duly obſerving and keeping a proper Regiſter of the Leeway a Ship makes: The Quantity of the Leeway (when a Ship makes any) is altogether as neceſſary to be known in order to determine the Courſe ſhe makes good, as is the Point at which ſhe Capes; and it is certainly as unreaſonable to gueſs at the Leeway from the Sail the Ship has abroad, without ſetting her Wake by a Compaſs, as it would be to gueſs at the Point ſhe Capes at, without conſulting the Compaſs. It may be perhaps objected, that in the Night, there is no way of ſetting the Ship's Wake by a Compaſs, and therefore, it muſt be gueſſed at in the beſt Manner one can: But I ſhall propoſe a Way, by which it may be known then, as well as in Day-time: Thus, at ſome ſmall Diſtance from the Enſign-Staff on

on either Side of it, let there be fixed a Quadrant of Wood, of about 18 Inches Radius, the Arch turned outwards, one Radius placed parallel to the Direction of the Maſts, and the other will be parallel to the Beam; and let the Plain of each Quadrant dip about 20 Degrees below the Horizon, in ſuch manner, that when a Log or any ſmall Piece of Wood is let go a-ſtern by a Log-line, till out of the Eddy of the Ship's Wake, this Line may be nearly parallel to the Plain of the Quadrant; let the Arch of each Quadrant be divided into eight equal Parts, and Wooden Pegs fix'd in the Center, and in each Point of Diviſion; and each of theſe Parts being ſubdivided into four, may have ſmaller Pegs fix'd in their Points of Diviſion; by this Means each Quadrant will, by the great Pegs, be divided into Points of the Compaſs, and by the ſmall Pegs, into Quarters of a Point. Suppoſe now, in a dark Night, the Ship makes Leeway, and I want to know how much it is, imagine the Starboard Tacks on board, I go to the Quadrant on the Starboard Side, and having veered a-ſtern the common Length of a Stray-line, I make a Bight in it, and put it over a Pin I ſuppoſe fix'd in the Center of the Quadrant, and feeling whether the Line bears againſt any of the Pegs upon the Arch; if it does, I let it at Liberty, till it plays freely between ſome two of the Pegs; then I reckon (beginning at the End of the Arch toward the Right Hand) how many Spaces between the great Pegs till you come to the Line, for ſo many are the Points of Leeway,

and

and if you have any odd ſmaller Spaces, ſo many Quarter Points. If the Larboard Tacks are on board, you go to the Quadrant on the Larboard Side, and proceed in every Reſpect as before, only when you count the Points of Leeway, begin at the End of the Arch toward the Left Hand. The Reaſon why the Plain of each Quadrant muſt be placed ſo as to ſhelve towards the Water, will appear if we conſider that the Stray-line will be in a Direction oblique to the Horizon, ſuppoſing the Ship upon an even Keel; beſides the Allowance which muſt be made for her heeling to Leeward.

It is certain, that two Ships ſailing in Company, which ſteer the ſame Point by the Compaſs, and carry like Sail, will make different Leeway; nay, even the ſame Ship, in like Circumſtances, with Reſpect to Wind, Sails, *&c.* if only her Trim is alter'd, will not make the ſame Leeway; ſome again, every thing elſe alike, on one Tack, make more Leeway, than on the other: From which it appears highly unreaſonable for any Man (let his Experience at Sea be ever ſo great) to truſt to his Judgment only, in determining the Leeway of a Ship: I grant that in gueſſing often, he may ſome Time or other come near the Truth, but if we allow that every Error here, really affects the Courſe when corrected, as much as that Error amounts to, and that we may, by an eaſy Experiment, (of ſetting the Ship's Wake by a Compaſs in Day-time, or in the Night, by the Method I have propos'd) aſcertain the Leeway to leſs than a Quarter

Quarter of a Point, one would naturally conclude that Way ought to be practis'd, that is attended with the leaſt Error.

I ſhall now proceed to examine the Log, to ſhew how much it may be depended on for determining the Rate of a Ship's going, and to offer another Inſtrument which ſeems better to anſwer that Purpoſe.

The Log, and manner of uſing it at Sea, are too well known to want any Deſcription here: Let it ſuffice to mention, that from the moſt accurate Obſervations of the greateſt Mathematicians, made in different Parts of the World, on purpoſe to determine the Length of a Degree of the Meridian, Equator, or any great Circle of the Earth, it appears to be more than 360000 *Engliſh* Feet; however, as this is a round Number, and nearly the Meaſure of a Degree, if we divide it by 60 (the Minutes in a Degree) the Quotient 6000 will be the Number of Feet contain'd in a Sea-Mile, and this divided by 120, quotes 50 Feet; that is, 50 Feet is the $\frac{1}{120}$ Part of a Sea-Mile; and the $\frac{1}{120}$ Part of an Hour being half a Minute (the Time allow'd for the Experiment) 'tis evident that if a Ship runs 50 Feet in Half a Minute, and goes on at the ſame Rate, ſhe muſt run 120 Times 50 Feet (that is 6000 Feet, or a Sea-Mile) in 120 times Half a Minute (that is 60 Minutes, or one Hour) and on the Suppoſition that the Log keeps its Place in the Water, as many times 50 Feet as the Ship runs from the Log in half a

 Minute;

Minute; ſo many Miles in an Hour will ſhe ſail at the ſame Rate of going. How the Length of a Knot came to be ſhortened from 50 to 42 Feet, I know not, but am apt to think it was firſt done to keep the Reckoning a-head of the Ship; if ſo, it was erring too much on the ſafe Side, in a Voyage of 700 Leagues to look out for Land which was ſtill 112 Leagues diſtant: But having found by Experience, that this Odds was too great, the Time for the Experiment was by Degrees leſſened from Half a Minute, or (30 Seconds) to about 27 Seconds, which is nearly the Time in the ſame Proportion to 42 Feet (the uſual Length of the Knot) that Half a Minute bears to 50 Feet. If in Place, however, of ſhortening the Knot, the Time had been lengthened, it would have anſwer'd the cautious Purpoſe of keeping the Reckoning a-head of the Ship, with this Advantage beſides, that the Log would have been ſomewhat leſs liable to Error.

I ſhall now go on to ſhew that the Log is a very inaccurate Inſtrument for determining a Ship's Rate of ſailing, which I preſume will appear from the following Conſiderations:

Suppoſe a Ship ſailing at the Rate of 10 Knots an Hour, and that the Log is hove; let 26 Seconds be called the juſt proportional Meaſure of Time, to the Knot of 42 Feet; ſuppoſe then the Glaſs takes only 25 Seconds in running, and that the Man who holds the Glaſs, turns it one Second too late, and calls Stop, one Second too ſoon; in that caſe it is evident, the Time

Time which is taken for 26 Seconds is no more than 23; and though ſhe really goes at the Rate of 10 Knots, yet by the Log ſhe goes not quite 9 Knots: Again, let the Glaſs be ſuppoſed to run 27 Seconds, and after being turned preciſely, ſuppoſe him who holds it to call Stop one Second too late; in this caſe what is look'd upon as 26 Seconds is really 28, and the Ship ſeems by the Log to go almoſt 11 Knots, when ſhe really goes no more than 10. Hence 'tis plain, that from a ſmall Error in the Glaſs, and a little want of Care in him who turns it, the Ship may appear by the Log, to go one Mile *per* Hour, more or leſs, than ſhe really does; which, if ſhe goes at the ſame Rate for twenty-four Hours, is likely to produce an Error of ſo many Miles.

That a greater Error than I have ſuppos'd, often happens in the Glaſs, is conſiſtent with my Experience, and I dare ſay that of many others; nor will the Error I have ſuppos'd in the Management of it, appear extravagant to any who has often ſeen and ſtrictly obſerved the Manner of heaving the Log.

A new Log-line after being ſtretch'd, and the Knots divided from the uſual Meaſure, for ſome Time after it is uſed, will ſhrink a good deal; and when it has been long uſed, will ſtretch again beyond its firſt Length: So that unleſs great Care is taken oftner to adjuſt the Length of the Knots, than I could ever obſerve uſed at Sea, conſiderable Errors muſt enſue.

But

But ſuppoſing the Glaſs an exact Meaſure of the Time, and managed without Error, and the Knots to be of a juſt Length; it is requiſite that the Log ſhould remain in the ſame Place in the Water; for if it follows the Ship with a ſlower Motion, the Reſult of the Experiment is only the Difference of the Motion of the Ship and of the Log, which will be leſs than the Ship's Rate of going; and if the Friction of the Reel has no Effect in making the Log follow the Ship (which I can hardly agree to) it is certain, that when the Ship goes before a briſk Gale of Wind, the Log muſt be drove towards the Ship with ſome ſlow Motion: Suppoſing, again, that it blows a briſk Gale, and the Ship upon a Wind; it is plain that in this Caſe the Log will be drove from the Ship with a ſlow Motion. In the firſt Caſe, the Log will give leſs than the real Motion of the Ship; and in the laſt, the Ship will ſeem to make more Way than ſhe really does. Upon the Whole, if the Glaſs is allowed to err but a little, if he that turns it may be out a Second or two, if the Knots are a little longer or ſhorter than they ought, and if the Log ſhifts its Place in the Water (all which I think may be preſumed as highly probable or certain:) Theſe Errors though each of them be ſmall, yet, when they all conſpire together, muſt greatly magnify or leſſen a Ship's real Motion: If indeed they happen at any Time to have equal and contrary Effects (which muſt very ſeldom

ſeldom be expected) then, and then only will the Log aſcertain the true Rate of a Ship's going. And now, that I think it muſt be evident, that the Log is an Inſtrument very little to be depended on; I ſhall deſcribe one which I take to be liable to much leſs Error.

Imagine a Ball of Metal (ſuppoſe Braſs) of a known Diameter, admit of three Inches; the Metal of ſuch a Thickneſs, that the Ball will be nearly of the ſame Weight with its Bulk of Sea-Water; that is, of the ſame ſpecific Weight with it: Suppoſe there is a Hole of about half an Inch Diameter cut in it, and a Piece made to ſcrew into this Hole, ſo that when ſcrewed home, its outer Surface may be of the like Convexity, with that of any other equal and like Part of the Surface of the Ball; and in the Middle of this Piece let a ſmall Hole be drilled; big enough to receive a common-ſized Log-line, which imagine paſſed through the Hole (the Piece being unſcrewed) and faſtened (by a Knot made on the End of the Line) on the concave Side, and then the Piece ſcrewed home: The Line thus faſtened to the Ball may be 15 or 20 Fathoms long.

Suppoſe now, in a Ship going at a ſmall Rate of perhaps 3 Knots an Hour, this Ball is hove from the Poop, and let veer a-ſtern the whole Length of the Line, when brought up it will be in Tow of the Ship, and Part of the Ball will be above the Surface of the Water, while it meets with a certain Reſiſtance in paſſing

paſſing through the Water; ſuppoſe the Ball brought on Board, the Piece unſcrewed, and a ſmall Quantity of Bird-ſhot being put into it, the Piece again ſcrewed home, and the Ball veered a-ſtern as before; if the Specific Weight of the Ball is now enough encreaſed, it will be altogether under Water, and the Reſiſtance it will meet with in paſſing through the Water, will be greater than formerly, the Ship going at the ſame Rate.

Let the Ship now be ſuppoſed to go at the Rate of 10 Knots, and the Ball enough loaded to keep under Water, and veered a-ſtern, it will meet with much more Reſiſtance in paſſing through the Water, than before.

In general, the Reſiſtance the Ball meets with in paſſing through the Water (ſo it is enough loaded to keep under Water) will be greater, as the Ship's Rate of going is encreaſed; and leſs, as that is diminiſhed; and the ſame always, when the Ship goes at the ſame Rate: Whence it follows, that if we can Meaſure the Quantity of this Reſiſtance at the ſeveral Rates of a Ship's going, we ſhall be able thence to determine the preſent Rate a Ship goes at. The moſt convenient Way of meaſuring this Reſiſtance, ſeems to be, by Means of a Spring, which will from every different Pull of the Line, ſuffer a new Degree of Tenſion; and any one Degree of this Tenſion may eaſily be compared to its equal known Weight, by ſuſpending ſuch a Weight at the Spring, as will reduce it to the given Degree of Tenſion.

Hence

Hence, the ſeveral Weights in Pounds, Ounces, *&c.* which are equal to the ſeveral Strains of the Spring, correſponding to the various Reſiſtances the Ball meets with at the ſeveral Rates of a Ship's going, being known; it is eaſy to ſee that any Number of Springs, (let their Degrees of Elaſticity be ever ſo different) may be with certainty adjuſted for this Purpoſe. It is true, that the Accuracy of this Inſtrument muſt depend upon the Care that is uſed in being well aſſured of the ſeveral Rates of a Ship's going, which, I think, may be very nearly known, if a Ship is made to Sail at a good Number of different Rates, between two Points of Lands, whoſe Diſtance is well determined, and a good Watch uſed to meaſure the Time in which the Ship, with different and uniform Velocities runs the ſame known Diſtance.

I would not be thought to mean that this Contrivance, though executed and applied in the Manner I have propoſed, will preciſely diſcover the Rate a Ship goes at; but it bids fair to aſſign it much nearer the Truth than the Log, and if upon Trial it is found ſo to do, ought certainly to be uſed in Place of it: From the Trials I have made with it, it appears to be much preferable to the Log; however, as it is very common for People to be prejudiced in Favour of their own Inventions, I am willing that from impartial Trials of it and the Log, it may be determined which beſt anſwers the Purpoſe for which both are intended. I know

it

it will be objected, that this Ball continually in Tow of the Ship, will in some Measure lessen her Way; I grant it may a little slacken her Motion; but, if it is hove once in a Quarter of an Hour, this Effect will almost vanish; and the four several Rates of going in the Hour (if they are different) being sum'd, and one fourth of their Sum took for the Mean, will approach pretty near the Truth, and may be mark'd in the Log-board as such.

It may perhaps also be objected, that the Quantity of Bird-shot necessary to keep the Ball under Water, as it must be different to every new Rate of Sailing, is not easily to be known; in answer to this, I believe, there is hardly a Seaman who cannot guess at what Rate a Ship goes, within perhaps a Knot or thereabout; and if he puts what Quantity would keep the Ball under Water, supposing her to go a Knot more, (and this Experience will discover) it will scarce make any Odds.

Thus having given the Construction and Use of the best Instrument, I could think of, for measuring a Ship's Way, I have little more to add on this Subject; only a Hint which perhaps may by some ingenious Mind be improved to bring this material Part of practical Navigation nearer to Perfection.

It seems evident, that what Effects are produced by great or swift Motions, ought to flow from less or slower Motions in a less Degree; we observe that a Projectile thrown in a Direction not contrary to that of Gravity (suppose it

it horizontal) describes a kind of Curve; in the Progress of the Body in this Curve, it is plain, that as the projectile Force by degrees loses its Effect, the Force of Gravity by like degrees encreases its Action on the Body, till at length the former becoming extremely small or nothing; the latter recovers all its Effect, and the Body is acted upon by the Force of Gravity alone. One would be apt to conclude from this, that the absolute Gravity of a Ship, in her progressive Motion, should be less than when at Rest; and that the greater this progressive Motion is supposed to be, her absolute Gravity should be the more diminished.

If, I say, the Action of Gravity upon a Body moved in a horizontal Direction is less, and farther diminished as this Motion is encreased; and if any practical Method can be devised, to measure these several Diminutions of the Force of Gravity; we may then know when a Ship's Motion is affected by a Current, and how much that Effect is; which are things as necessary as difficult to be known, by any Methods now in Use. I am of Opinion, that if a Ball (of Brass suppose) were to act by its Gravity on a Spring made of Steel-wire, in form of a Screw, and the Pressure of the Ball nearly such, that a Line drawn from its Center, perpendicular to the Horizon, might be the Axis of the Spring (supposing it a Cylinder) and such a Pressure of the Ball might be nearly had in a Ship under Way, by hanging the whole as a Compass is, with a proper Weight to keep it as ſteady as poſſible: If, I ſay, the Diminution of Gravity from the progreſſive Motion of a Ship is ſenſible; the Axis of this Spring thus preſſed by the Ball, will be ſhorter, when the Ship is at Reſt, than when under Way: Or, (which is the ſame Thing differently expreſſed) the Ball will be nearer to the other End of the Spring when the Ship is at Reſt, than when ſhe is under Sail, and this Diſtance will be greater as the Rate of her going encreaſes.

I ſhall juſt mention another Thing, which ſeems to be the Effect of the progreſſive Motion of a Ship, and that is, that the Surface of Water in a Bowl or other Veſſel on board a Ship under Sail, deviates more from an horizontal Situation, than the Rowling of a Ship would appear to cauſe it; I mean in ſuch ſort, that a Line coinciding with the Surface of the Water, and parallel to the Courſe made good by the Ship, will be more inclined to the Horizon, than any other Line of a different Direction, and that alſo coincides with the Surface of the Water; if this Deviation I have deſcribed, is found on Trials to be ſenſible, and to encreaſe with the Rate of a Ship's going; it might (one would think) be improved to meaſure the Rate of her going, and the Courſe ſhe makes good, even when affected with both Leeway, and a Current running under Foot. It is probable that Quickſilver may be a Fluid more proper than Water, for making ſuch Trials, on account of its much greater ſpecific Weight

Weight, than that of Water, or indeed any other Fluid.

I now proceed to conſider the Compaſs, and endeavour to rectify ſome things I take to be amiſs in its Conſtruction and Uſe.

Not only the Perſon to whom the Honour of ſo glorious an Invention is due, but even the Country is uncertain; the *Chineſe* claim it as theirs; but the *Portugueſe* of all the European Nations are ſaid to have been the firſt, who by Means of the Compaſs, ventured to plow the wide and pathleſs Ocean, and it ſeems they had no better Method than ſwimming the Needle on a Piece of Cork in a Bowl of Water; but finding that way of uſing it to be inconvenient and inaccurate, the Contrivance of hanging it by a Cupola upon a Braſs Point was juſtly preferred; and the Box that held the Card and Needle thus ſuſpended, was in ſuch manner hung by Means of a double Axis, as that notwithſtanding the Heel or Rowling of the Ship, the Card is nearly kept horizontal.

Whatever is the Cauſe to which the wonderful Effects of the magnetic Needle ought to be aſcribed; we find the Force which reduces it to the magnetic Meridian, and keeps it nearly ſo, is but ſmall; and if there is any conſiderable Friction between the Cupola and the Point on which it turns, it will either quite overcome this Force, or greatly leſſen it: But ſuppoſing two Cards, having Needles of equal magnetic Force, to be hung on Points equally blunt;

blunt; if one of theſe Cards weighs twice as much as the other, the Friction of the Heavier, will certainly be greater, as the Preſſure is more, and ſeeing the Force which muſt (at leaſt ought to) overcome that Friction is the ſame to both, it is plain the lighter Card may have its Needle brought to the magnetic Meridian, while the heavier Card cannot. Hence then (every thing elſe alike) the lighter a Card is, and the finer the Point on which it turns, the Friction will be the leſs, and the ſame magnetic Force will with more freedom act upon the Needle, and ſooner bring it to its Meridian.

If the Pin that ſupports the Cupola, and the Cupola itſelf, are both made of Braſs, the Point will ſoon wear blunt, and be apt to work a ſmall Hole in the Cupola, which being fitted to the Size of the Point that form'd it, will render the Friction much greater than would happen from the Bluntneſs of the Point only; therefore it is requiſite, that the Pin ſhould be made of harder Stuff than Braſs, and the Cupola ought to be of ſtill harder Stuff than the Pin; if in place of Braſs, the Pin is made of good Steel, ſomewhat harden'd, and the Cupola of ſound Agat, and if the Pin has been brought to a fine Point, the Friction muſt in a long Time be very ſmall, eſpecially as the Card and Needle ought to be as light as they well can be made: It may be perhaps alledged, that if the Needle is very light in Proportion to its Length, it cannot have Magnetiſm ſo ſtrongly communicated to it, as it might, if made more ſubſtantial

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ſtantial; but granting that a heavier Needle does receive ſome more Magnetiſm from the Stone, yet if its greater Weight increaſes the Friction more than this additional Magnetiſm has Power to overcome (and I believe Experiment will ſhew it does) in that caſe there is no Advantage gain'd by making the Needle heavier, but the Friction really left greater in Proportion to the ſmall Force which muſt overcome it.

From a great Number of accurate Experiments made by the ingenious Mr. *George Graham*, Watchmaker, in *Fleet-ſtreet*, and from ſome of which, a daily Variation in the Needle appeared, amounting to about half a Degree; from many Trials, I ſay, he was ſatisfied that the light Needles are the beſt, and alſo that about four Inches and a Half is the beſt Length they can be made of: And, as I queſtion whether the World can produce his equal, conſidered as a Mathematician, and a curious and nice Artiſt, we may ſafely depend on the Reſult of his Experiments.

We conclude then, that a light Needle about four Inches and a Half long, with an Agate Cupola, and turning on a fine Steel Point is the beſt; and that we may ſtill have the Point fine, it ſeems requiſite to carry ſeveral of them to Sea, ſo well fitted, that any one when ſuſpected to be blunted, may be readily unſcrew'd and another put in its place; and for this Purpoſe, the Box in which the Card plays, ought to be ſo made as to be readily opened, and ſhut

quite

quite close that no Wind can come at the Card to disturb it; nor ought two Compasses ever to be placed so near as to affect each other, nor so near any Iron as to be attracted by it.

Some Years ago I contrived a Method of hanging the Compass, which I take to be better than that now in use; I shew'd one of them executed by my Direction, to the Right Honourable the Board of Admiralty, which they approv'd of; and having tried one of them in two Voyages since, I find it to keep much steadier, and is less affected with the Ship's Motion, than these hung in the common Way. Whoever chuses to see one of them, may, by calling at Mr. *Liford*'s, a Mathematical Instrument-maker, near the New Church in the *Strand*.

In bad Weather at Sea, it is common to steer by what is called a Foul Weather Compass, that is, whose Card turning on a blunt Point cannot be supposed readily to come to its Meridian; what could introduce this absurd Custom I cannot imagine; but one would reasonably conclude, that when the Steerage of a Ship is most difficult, there were then the most need of a good Compass, which will shew truly every Yaw the Ship takes, and much better inform the Men at the Helm, when, and how much they ought to check her, in order to bring her near her Course.

I should be sorry if the Freedom I take in finding Fault with some Sea Instruments, now in use, and the more than possible degree of Accuracy,

Accuracy, which many are apt to expect from them, should give Disgust; but sure I am, that whoever sets out on my Design (which was originally to take Notice of such Errors as might be expected from their Use, and to propose the best Means I could to diminish these Errors) will find himself under the like Necessity with me to engage in the unpleasing Task of finding Fault; and there seems Reason to hope, that when a Man's Aim is the Improvement of so useful an Art as Navigation, he will be indulged in a Freedom so necessary to, and closely connected with his Purpose.

Of all the Instruments now commonly used at Sea, I do not know one from its Construction so clumsy, or in the Use of which People are more imposed on, than that which goes by the Name of the Azimuth Compass: By it, 'tis generally imagined, that the Sun's Magnetic Amplitude, or even Azimuth, may be found at Sea, to the Preciseness of five Minutes, and consequently the Variation of the Needle to the same Pitch of Accuracy. I shall not need to describe this Instrument, as a great many Trading Ships, and all His Majesty's Ships carry it to Sea; let it suffice to observe, with respect to its Construction, that it is a very unweildy Instrument, enough for two Men to lug upon Deck; that whereas it requires a great Weight to keep the Compass-Box tolerably steady, it has one, much too small, which never can answer that Purpose; that the Card in it being eight Inches Diameter, is much too large, and too heavy, to conform itſelf to the Magnetic Meridian with that Briſkneſs it ought; and that the Luggage of a heavy Index, moving on a much heavier Braſs Circle, is altogether unneceſſary, and can only ſerve by the Diviſions being carried to the Exactneſs of five Minutes, to amuſe People (who have not enough conſidered the Inſtrument) with the Fancy, that ſuch Preciſeneſs it to be expected from it; which I ſhall ſhew it is impoſſible to come at, even by an Inſtrument much better adapted for its Purpoſe. This will be very evident, if we recollect, that (from Mr. *Graham*'s Experiments, we may be well aſſured) the Needle and conſequently the Card alters its Direction at different Times of the ſame Day, and in the ſame Place, to the amount of Half a Degree; admit then, that the Card is not in the leaſt affected by the Motion of the Ship, and that there is no Friction at its Center, yet will the Obſervation (however accurate otherways) be uncertain as to the Half Degree juſt mention'd, unleſs we know which Way to allow for it: This, I preſume, will ſhew the Uſeleſneſs of a Circle, divided to every five Minutes; but if to this we add the Effects of a Ship's Rolling, of her Yawing, and of the Friction at the Center of the Card, I am perſwaded a Man muſt be very careful, if he determines the Sun's Amplitude, and eſpecially his Azimuth, to a Degree and a Half,

Half, even with a much better Inſtrument than this.

There is no ſuch thing as Preciſeneſs to be expected from any Mathematical Sea Inſtrument whatever, as moſt of them are liable to Error from the Motion of the Ship; it is well if we can come ſomewhat near the Truth, and theſe Inſtruments are certainly the beſt, by the Help of which, our Concluſions are attended with the leaſt Error.

The Quantity, and Kind, of the Needle's Variation are (no doubt) of great Importance, and without the knowing of which, it is impoſſible to determine any one ſingle Courſe a Ship makes good; the Obſervation of the Sun's Amplitude at his riſing or ſitting, as both it, and the Computation from it, are more Simple than theſe of an Azimuth, ought certainly to be preferred when it can be had: But when an Amplitude cannot be obſerved; by the following Method, one may come as near the Variation, as by the Azimuth, the Computation of which is to many very tireſome.

I would chuſe a Braſs Compaſs Box that was well hung, with a ſufficient Weight to keep it as ſteady as poſſible, and in place of a Card, would uſe a neat light Needle, playing freely on a fine Steel Point; a Diameter being drawn in the Bottom of the Box, imagine a Circle deſcrib'd from the Center, with a Radius of about two Inches and a Quarter, which I ſuppoſe Half the Length of the Needle, and this Circle divided

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into Degrees, which let be number'd either Way from each End of the Diameter; let two Brass Sights be fitted, one at each end of the Diameter, so that the longer Sight having a Vertical Thread or Wire fix'd in it, and the other a small Hole to look through; the Plain supposed to be erected perpendicular to the Bottom of the Box, and coinciding with the Diameter, may also coincide with the Wire in the longer, and with the small Hole in the shorter Sight; the longer Sight may be about the Length of the Diameter of the Box, to take in any Object whose Altitude does not exceed 45 Degrees. Imagine now, that while another is with a good Quadrant, observing the Sun's Altitude, if it is less than 45 Degrees before Noon; I observe his Bearing to be 50 Degrees to the Eastward of the South Point of the Needle: In the Afternoon, let the same Person continue to observe, till the Sun has fallen so low as to have the same Altitude as when he observed in the Forenoon, and let his Bearing then be observed, (imagine) 70 Degrees West from the same South Point of the Needle; if we add these two Arches of 50 and 70 Degrees, the Sum is 120, the Half of which, *viz.* 60, is the Number of Degrees the Sun would have bore from the South Point of the Needle, Eastward in the Forenoon, and Westward in the Afternoon, if the Needle had no Variation; but as the South End of the Needle pointed 10 Degrees to the Eastward of this 60 Degrees, and consequently, the

the North End of it, 10 Degrees to the Westward of the opposite Point; the Variation plainly appears to be 10 Degrees Westerly. From this Example, I apprehend, the Advantages of the Instrument I have been describing, and of the Method I have proposed of finding the Variation of the Needle at Sea, by Means of it, will be evident; for granting that an Error amounting to two Degrees, were committed in observing or estimating the Point of Bearing, it is certain, that in the Variation thus found, the Error would be lessened to one Degree: And in general, this Instrument must from its Nature and Construction admit of much more Accuracy in observing the Point of Bearing of any Object, than the Azimuth-Compass; and I think indeed, must be preferable to any Compass whatever, that has its Needle loaded with a Card. In the Example I have given of finding the Variation, I have not taken Notice of the Alteration of the Sun's Declination, and the new Latitude the Ship may have arrived in, during the Time between the Observation before Noon, and that made after Noon; but both of these Alterations may be easily had from the Log-board, and the Effect they may have in making the Sun's equal Altitude in the Afternoon, happen a little sooner or later than it would have done, had the Ship been still in the same Place; I say, this Effect of the Ship's changing her Place, may be with sufficient Accuracy allow'd for. It seems almost needless to to obſerve, that if the Needle is not quite ſettled it its Meridian, in Time of Obſervation, then the Middle of the Arch intercepted between the extreme Points of its Vibrations or Swings, muſt be took for that, at which it would ſettle, if it were not diſturbed. If ſeveral Altitudes are taken in the Forenoon with the correſponding Points of Bearing, and in the Afternoon the Points of Bearing found when the Sun has fallen to the ſame Altitudes; theſe Obſervations will be a Check upon each other, for if the Middle of every two Bearings correſponding to the ſame Altitude, falls upon the ſame Degree in the Compaſs-Box, it may be concluded that the Obſervations have been good, and the Variation thence found may be depended on; but if the Middle of the Bearings falls upon different Degrees upon the Limb, ſome Error muſt have been committed in obſerving either with the Quadrant or the Needle, and the Variation not turning out the ſame from each Obſervation, cannot be truly aſſign'd; although if this Difference is but ſmall, the Obſervations have been pretty accurate, and the mean Variation thence found will be near the Truth.

Another Advantage may attend making ſeveral Obſervations, at the Diſtance (perhaps) of Half an Hour from each other; that in the Afternoon, if it ſhould be overcaſt ſo, that we cannot obſerve when the Sun has fallen to one Altitude, it may be clear enough, by the Time he has fallen to ſome other.

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Some People may think they can with greater Eaſe, and equal Certainty, determine the Variation from an Amplitude or Azimuth; I muſt confeſs I am of a different Opinion; however, if in their Obſervations they will make uſe of ſuch a Needle as I have deſcribed, in place of that almoſt uſeleſs Inſtrument the Azimuth-Compaſs, I am perſwaded their Concluſions will approach a great deal nearer the Truth.

If this Needle were really no better to obſerve with, than the Azimuth-Compaſs; yet, if we conſider that the whole Inſtrument when neatly finiſhed, is much handier than, and not more than the third Part of the Price of an Azimuth-Compaſs, it certainly ought to be preferred: And as it is probable that this Inſtrument, and others propoſed and deſcribed in this Eſſay, may one Time or other come to be generally uſed; I hereby give warning, that none do preſume to claim the Invention of, or to make or ſell all or any of them, without having my written Licenſe for that Purpoſe.

I come now to examine the Inſtruments commonly uſed for finding the Latitude a Ship is in at Sea.

Davis's Quadrant, as it is in almoſt every Seaman's Hands, needs no Deſcription; but I find that moſt People by it expects to arrive at a Degree of Accuracy, altogether inconſiſtent with the Nature and Conſtruction of this Inſtrument; to me it is evident from great Numbers

bers of Obſervations I have made, and been preſent when made by others with it, that even when there is a good Horizon, a bright Sun, the Ship not rolling much, and every thing, in ſhort, favourable for the Obſervation, the Latitude cannot be determined by this Inſtrument, nearer than to ten or a dozen Minutes: When, I ſay, there have been a good many obſerving at once on board the ſame Ship, with *Davis*'s Quadrant, I have generally found the Latitudes computed from the Sun's greateſt and leaſt obſerved Zenith-Diſtance, to differ 10, 12 and ſometimes 15 Minutes, and which of them was neareſt the Truth, could not eaſily unleſs from a better Inſtrument be determined.

Hadley's Quadrant of all others that have hitherto appeared, is undoubtedly the beſt Inſtrument for finding the Latitude at Sea, when there is a clear Sky, and well defined Horizon; for one may depend upon an Obſervation carefully made with this Inſtrument (if well adjuſted) even to one or two Minutes; which is but a ſmall Error, and not more than a ſixth Part of what we may expect in uſing *Davis*'s Quadrant. But then there ought to be great Care taken that the Glaſſes in *Hadley*'s Quadrant, are of the ſame uniform Thickneſs, and the Surfaces of them quite flat, as well as that they are juſtly placed, and that the Diviſions are neat and accurate.

Some

Some Years ago Mr. *Bird*, Inſtrument-maker, at the Sea-Quadrant in the *Strand*, contrived and executed an Octant, differing from *Hadley*'s, in that it is held (otherways than his) very firmly againſt the Obſerver's Shoulder, and gives the Images of the Sun and Horizon by a ſingle Reflection, from two Glaſſes placed at the Center, one of which is fixed, and the other carried along with the Index: The Inſtrument is elegantly contrived, and executed by him with the utmoſt Neatneſs and Accuracy; and from many comparative Trials with it and *Hadley*'s, I am ſatisfied it is not leſs exact though cheaper.

While I was on the North American Coaſt, in one of his Majeſty's Ships, under the Command of the Honourable Sir *Peter Warren*, we had frequent thick Fogs, which depriving us of a Sight of the Horizon, rendered our Quadrants of no uſe to us in determining our Latitude, though the Sun's Body might often be ſeen about Noon; and as we were obliged to truſt to our Latitude by Account, for ſeveral Days together, and in that hardly any two Perſons agreeing, we were left in the utmoſt Uncertainty, and were at length got in ſhoal rocky Soundings, and ſometimes not more than five Fathom Water; there was not much Wind, and the Honourable Perſon, juſt mention'd, foreſeeing Danger, ordered an Anchor to be dropt, which brought us up; as the Ship had then but little Motion, and the Sun's Diſk faintly appeared,

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Sir *Peter* having desired me to make the best Guess I could to fix our Latitude, even to half a Degree, if it could be had no nearer; accordingly I tried (by measuring the Angle of Reflexion from the Surface of a Vessel of Water, placed for that Purpose) to assign the Zenith Distance of the Sun, and thence deduced the Latitude much nearer the Truth than I could have expected: The Latitude I thus found, being nearly that of the Seal Islands, (a Parcel of small rocky Islands lying off *Cape Sable)* we concluded we were got near them, and by Sir *Peter*'s Order, rode at single Anchor till next Morning, when about ten o'Clock, the Fog beginning to clear up, we were fully convinced of the Danger we had justly apprehended; for we saw the Islands round us, and the farthest at no great Distance: As it continued to clear up, the Horizon, as well as the Sun, appeared time enough for every one to observe for the Latitude, and it turned out nearly the same that is given these Islands in the Books of Navigation, and (as it happened) not more than 6 Minutes different from such an Observation as I was able to make in the Fog.

After being so sensibly convinced of the great Usefulness of a well contrived Instrument, for finding the Latitude when the Sun might be seen; but the Horizon was obscured by a Fog, I tried many ways, some of which answered pretty well; but that which I found to come nearest the Truth, was a Contrivance which

which I adapted, with Mr. *Bird*'s Leave, to his Quadrant, which upon great Numbers of Trials, made by many others as well as myself, always determines the Latitude (without using the Horizon) to the Nearness of 5 or 6 Minutes: And now that I have mentioned Mr. *Bird*, I must do him the Justice to say, that his Instruments for Neatness and Accuracy, do in my Opinion come up to, if not exceed any I have seen or used, nor do I mean this to the Prejudice of any other Workman; how far I am just, will appear to whoever has seen the curious Astronomical Quadrant, and other Instruments done by him, for the Royal Observatory at *Greenwich*.

There is another kind of Sea Quadrant executed by Mr. *Cole*, which seems an Improvement of *Davis*'s, and may possibly be more exact; but as I never had an Opportunity of trying it at Sea, I cannot pretend to judge of its Goodness.

As for the Fore-Staff, Nocturnal, *&c.* they are deservedly laid aside, by all who would use good Sea Instruments.

Mr. *Harris* indeed, in that excellent Book of Navigation, he published about 20 Years ago, describes a very ingenious kind of Fore-Staff for measuring Altitudes at Sea, when they do not exceed 40 Degrees, and which from its Construction must be much more Accurate than the other; but I believe then, *Hadley*'s

 Quadrant

Quadrant was either not known, or but little uſed.

The ſame Gentleman, has in his Treatiſe juſt mentioned, took Notice of a great many Errors committed in Reckonings at Sea, ſome of which he has with equal Judgment and Clearneſs ſhewn to ariſe from a falſe Theory, while others are owing to the Uſe of inaccurate Inſtruments, and the miſtaken Notion, that the Concluſions drawn from Obſervations made with them, are nearer Truth than they poſſibly can be.

To the Inſtruments uſed at Sea, it may not be improper to add the uſual Charts and Tables, as they are indeed a kind of Inſtruments.

It has been already ſhewn in this Eſſay, that Mr. *Wright*'s Projection (erroneouſly called *Mercator*'s) is much the moſt proper for all the Purpoſes of Navigation, and nearer the Truth than any other: As to what difference there has been found, (by ſome curious Obſervations of late Years) between the Equatorial and Polar Diameters of the Earth, it is ſo very ſmall, as to have no ſenſible Effect in Navigation; in which we ſtill ſuppoſe the Land and Water to have a ſpherical Figure: And it ſeems not worth while to uſe a Table of Meridional Parts computed from the Hypotheſis of the Earth's being an Oblate Spheroid, as the longer Diameter is found to exceed the ſhorter, by only about 32 Miles.

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The Difference of Latitude, and Departure to each Diſtance and Courſe (after Allowance has been made for the Needle's Variation, the Leeway, and Current when there is any) is uſually taken from a Table computed for that purpoſe to every Point, quarter Point, and Degree of the Quadrant; and if this Table is correct, theſe Things thence found, and regularly transferred to the Traverſe Table, will give the Difference of Latitude, Departure, Courſe and Diſtance made good upon a whole Day's Run exact enough; which are Data ſufficient from whence to find the Difference of Longitude: But I cannot help preferring the *French* Method of working their Traverſes by a Sinical Quadrant, which will give theſe Things near enough the Truth, and with this Advantage beſides; that as in this Way, every one of the Quantities given or ſought, appears in its real, or at leaſt, proportional Magnitude, the Idea upon the whole muſt be more diſtinct; and the Error of transferring one or more Figures wrong from the Table, or miſtaking one Figure for another (Things that frequently happen) will here be avoided.

Mr. *Cole*, the Inſtrument-maker, in *Fleet-ſtreet*, has lately ſhewn me a Quadrant, which I take to be as exact as the Sinical Quadrant; and as it is much more Simple, muſt alſo be attended with leſs Error in Practice; ſuch a Contrivance I once at Sea executed, and found it anſwer the Purpoſe of determining

mining the Courſe, Diſtance, Difference of Latitude and Departure, from the proper Data, with as great Accuracy, and a leſs Chance of Error than the common Tables, and as ſuch I beg Leave from my own Experience to recommend it to every ingenious Seamen.

And as the Method of finding the ſame Things by *Gunter*'s Scale is very eaſy and expeditious, if not equally exact with the others, it will at leaſt ſerve as a good Check, and diſcover every Error of any Conſequence that may have crept in; and as ſuch, I would beg Leave to recommend the frequent Uſe of it.

To a Man that would keep a good Reckoning, it muſt be a Satisfaction to know, that he has truly deduced his daily Difference of Longitude from the proper Data; and as nothing can be a better Check upon his Computation of it, than a well divided *Wright*'s Chart, he will, by pricking off the Ship's Place every Day, not only acquire a truer Notion of her ſucceſſive Change of Place, but alſo have it in his Power to diſcover, whether he has err'd in computing her Place upon the Surface of the wide extended Ocean: I dare ſay, whoever conſiders theſe Advantages, will be induced to make uſe of this valuable Chart; but the Misfortune is, that few would be at the Pains to divide a Chart of this kind as it ought, nor indeed is it well practicable on board a Ship, where the Inſtruments requiſite to divide it accurately, are ſeldom to be had; therefore

therefore, that every one who will uſe ſo neceſſary a Check, may, with little Trouble, and at a ſmall Expence, have it; I intend ſoon to publiſh a Set of them, carefully divided from a convenient Scale, and to have as many caſt off from the Copper-Plate as may be wanted.

Moſt Books of Navigation have the neceſſary Tables, but in a great many of them they are very incorrect, and as the Proportions work'd from theſe muſt of conſequence be erroneous, it were to be wiſh'd, we had an Edition in which great Care had been taken to have the Numbers correct, printed with a clean Figure, on a ſtrong good Paper, and of a convenient Size: As I am apt to think, that none who know the Value of correct Tables at Sea, would grudge beſtowing a few Shillings upon ſuch a compleat Set, I have a Deſign to publiſh one, a Copy of which any Perſon ſhall have *gratis*, if he diſcovers one material Error in it.

The Rules and Directions commonly given by the Writers of Navigation, for gueſſing at the Place of a Ship, when the obſerved Latitude differs from the Latitude by Account, ſeem to be pretty reaſonable; only it is pity that none of them can be apply'd in the Caſe, when a Ship's Courſe has been nearly that of four Points from the Meridian; nor can I ſee any better Way left for making a tolerable Judgment in a Caſe of this Nature, than uſing the beſt Means we can to diſcover the real Diſtances ſail'd on each Courſe, and then, when at at Length the obferved Latitude is found to differ from that by Account, to attribute this Difference to the want of due Care at the Helm, or to the unavoidable Errors of Steerage.

If indeed, there were any practicable Method fhewn to difcover the Longitude a Ship is in at Sea; by that, and a good Quadrant, her Place might be truly affign'd at any Time, and the true Bearing and Diftance of any Harbour or Point of Land (whofe Latitude and Longitude are known) might be accurately determined.

But though this much defired and really great Improvement of Navigation, has been attempted by many, whofe Qualifications might give hopes that they would have fucceeded; we find they have all in the Event been difappointed.

To me it feems evident, that all who have attempted the Difcovery of this valuable Practice, have err'd in that; either being led on by too fanguine Hopes of enjoying the great Reward offered to whoever fhall be fo lucky as to fucceed; they have not thoroughly weigh'd their feveral Schemes laid for reducing this Problem to Practice; or have not well confidered the Difficulties attending fuch a Difcovery; or, (which I am apt to think has been a more prevailing Error than the other two) that People who had not enough confidered the Nature of the Thing, imagin'd the Invention to lye in fome fubtil Knack, which might be accidentally hit upon by fome Man of a clear Head, and a Mechanical Genius; fo that the Imagination being let roam at full Liberty, the firft Contrivance that ftruck it with a favourable Afpect, was fure to meet with a kind Reception, and the Mind fo intent upon viewing the Excellencies of its own Invention, could not well be fuppofed to fpare Time to view it coolly and impartially.

But if we give ourfelves the Trouble to reflect, that the Improvements already made in this, or indeed any other Art, have never been by the Lump, but gradually, and often by very fmall Degrees; we muft conclude with a Parity of Reafon, that this fo difficult in itfelf, and wherein fo many have laboured to no Purpofe (if ever it is difcovered) will be promoted by flow and regular Advances, till it may poffibly be brought at laft to anfwer the Defign.

It would be endlefs to mention the feveral Schemes that have been fallen upon, to make the Longitude at Sea known from Obfervation; and I believe the Right Honourable the Board of Admiralty are not feldom, nor a little teazed by our Longitude Finders; but it is certain, that if the Variation of the Compafs were obferved with great Care through the whole Courfe of moft Voyages, and thefe feveral Variations of the Needle properly regifter'd, with the Latitude well determin'd from Obfervation, and the Longitude as well as it could be guefs'd at, in which each Variation was obferved, this would be one very good Step towards coming

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ſomewhat near finding the Longitude from Obſervation.

For in any following Voyage, at no great Interval of Time, wherever any one of theſe Variations well obſerved were found; the Longitude correſponding to that Variation, would ſoon appear from the Regiſter I have ſuppoſed to be kept.

A good Pendulum Clock, which is the moſt exact Inſtrument we have for meaſuring Time, cannot be uſed at Sea, on account of the Ship's Motion; and as to Watches, or indeed any other Movements for this Purpoſe, they are in general liable to ſo many Irregularities from Heat and Cold, and perhaps the State of the Atmoſphere, that the beſt of them will not meaſure Time, near the Truth.

Mr. *Harriſon*'s Clocks, undoubtedly bid faireſt for meaſuring Time truly at Sea, of all that ever were invented for that Purpoſe; and his unwearied Pains to bring his curious Machines to ſtill greater Degrees of Exactneſs, will in Proceſs of Time (we hope) have the deſired Effect. But granting we had a juſt Meaſure of Time at Sea, there is ſtill requiſite a good Method of finding the apparent Time, in that Place where the Ship is; as it is from comparing the true and apparent Time that the Difference of Longitude muſt be had; and I muſt frankly acknowledge, that I know of no Method by which to determine the apparent Time at Sea, with leſs Error than that of ſome Minutes,

Minutes, which if we take to be only five, this Error, when reduced to its proportional Part of the Equator, will amount to no leſs than 75 Sea-Miles: It is true, the ſame Error in Time will have a leſs Effect in high Latitudes, not that it will occaſion a leſs Error in Difference of Longitude; but for this Reaſon, that an Error of 75 Minutes of Longitude at the Parallel (ſuppoſe) of 60 Degrees, does not exceed one Half of 75 Sea-Miles, that is 37 and a Half.

Having now made almoſt an End of what I propoſed to write on this Subject, and what I call New in it, is at leaſt ſo to me; I ſhall venture to make ſome Obſervations which perhaps may ſeem worthy the Peruſal of a curious and candid Reader; not that I would preſume to aſſert from Experiment, that every thing will be found to anſwer as I have apprehended, but in Effect, if the Hints given may be uſeful any how, I have my Aim.

Of all the various Methods which have been thought of, for to know the Difference of Longitude a Ship makes at Sea, from her ſeveral Motions (whether guided by Deſign or Chance) the obſerving of the Eclipſes of *Jupiter*'s Satellites (or Moons) ſeems to bid much the faireſt, were it practicable, in ſpite of the Rolling and other Motions of the Ship: But as I believe that no Art has yet appeared, by which a Teleſcope of a ſufficient magnifying Power, can be kept ſteady enough at Sea for making ſuch

ſuch Obſervations; of courſe the Uſe of a good Glaſs there, is extremely little, or next to none at all; and though I cannot ſay whether this valuable Inſtrument, after all the Improvements it has had of late, (chiefly from Mr. *Short*) may ever be brought to anſwer the great Purpoſe juſt mentioned; yet, if it can be uſed, even to diſcover with more Certainty, what Objects preſent themſelves at no greater Diſtance than the Verge of the viſible Horizon; even this, I ſay, is not ſeldom of very great Moment at Sea.

Under the neceſſary Limitation then, which I have lately mentioned; let us imagine a Perſon who has been uſed to the Management of a good Teleſcope, of the reflecting Kind, a-ſhore, to be ſituated ſo in a Ship, that like a Compaſs which is well hung, he may not be affected with a great deal of the Ship's Rolling, or other Motion, and we ſhall allow that this cannot be leſs than to throw his Eye off, perhaps five Degrees on one Side or other of an Object it was pointed upon; from this Suppoſition, the Effect of the Ship's Rolling will be, that his Eye will be the Vertex of a ſort of Cone, whoſe Angle at the Eye will not exceed ten Degrees, and the Circumference of whoſe Baſe the Object will ſeem to deſcribe. Now if the Teleſcope could take in a Field of about ten Degrees, it is plain that the Obſerver might always keep the Object in View; but as I believe no good Glaſs can take in ſo much, and at the ſame Time be diſtinct; let us try to leſſen ſtill farther the Effect of the Ship's Motion; thus,

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A reflecting Teleſcope of about 6 Inches of Mr. *Short*'s making, will very diſtinctly diſcover *Jupiter*'s Moons; imagine ſuch a ſmall one properly fixed to ſomething in form of a leathern Cap, the Eye-piece ſo near the Eye as may be moſt convenient, and a Finder to collimate nearly with the Teleſcope; and at ſuch a Diſtance, that when the Glaſs is thrown off the Object, the other Eye by means of the Finder may readily bring it back into the Field of View; and let this Cap or Head-piece be ſo made as to be eaſily faſtened to the Obſerver's Head; then has Nature provided us with a curious Apparatus for the Management of the Teleſcope, I mean the Capacity every Man in Health will find he has, of moving his Head to a great Nicety, ſo as with his Eye, to trace the real or apparent Motion of any Object.

In this Manner one would be led to think, that if the Obſerver could not keep a conſtant View of the Planet and his Moons, he might at leaſt have them in the Teleſcope as often as the Ship came to be a little more ſteady, which ſhe will often, as one Sea has loſt its Effect upon her Rolling, till another meets her. If, in fact, by this Means a diſtinct Sight of the Planet and his Moons can be had once or twice in a Minute of Time, I am well aſſured that no Man whoſe Fortune and Leiſure would incline him to try the Experiment, would have any Reaſon to repent his well intended Labour: For my Part, Fortune is not ſo friendly as to

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put it in my Power to try that, and many other Things, which seem in my Opinion likely to increase the useful Knowledge of Mankind.

This last described Proposal for rendering the reflecting Telescope useful at Sea, was thought of by a very ingenious Gentleman, now dead, I mean Mr. *Richard Graham*, but whether before or after I hit upon it, is what I cannot with certainty determine; only this I know, that in Conversation with him some Years ago, I hinted at such a Thing as useful, if practicable; and he agreed with me in thinking it was: It is probable, this Gentleman might have thought of the very same Contrivance with me, and possibly about the same Time too; and therefore I would no farther pretend to claim the Invention, than seems to every impartial Reader consistent with strict Justice; nor indeed can its Value, but from frequent and good Trials be ascertained.

If upon the whole this first Essay is found to be really what it was intended, an Improvement, I shall have in a great Measure my Aim; though I will not be so inconsistent with the Truth as to deny, that I could heartily wish the public Good, and my private Interest were at no Variance; and, if this does not seem so modest, I am sure it is true. Neither have I ventured to let it make its Appearance to the World, before I was well assured it had undergone the Perusal of such, whose Judgment seemed to me, and I believe is, in fact, preferable by great odds to mine,

Before

Before I conclude this Essay, I must beg Leave to inform the Public, that I am fully satisfied that Mr. *Morgan*, in *Finch-lane*, near the *Royal Exchange*, makes with Neatness and Accuracy, all kinds of Mathematical Instruments; and as I have an Intention to employ him to make those described in this Essay, I only do him justice, when I say, that such may be had of him as may be depended on.

F I N I S.