A

TREATISE

OF

MARITIM SURVEYING,

IN TWO PARTS:

WITH A

PREFATORY ESSAY

ON

DRAUGHTS AND SURVEYS.

BY

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A
PREFATORY ESSAY
ON
DRAUGHTS and SURVEYS of the SEA-COAST.

NO Branch of practical Geometry has been ſo little conſidered by Men of Science as Maritim Surveying. This Subject has never been particularly treated of by any Author, nor taught by a Maſter; nor have Surveyors given any Account of their Operations and Procedure in ſuch Surveys. To this Reſerve of Writers, and Silence of Practitioners, it may be aſcribed, that an Art of ſuch great Importance in Navigation has hitherto received ſo little Improvement; that in Practice little or no Diſtinction is made between Land-ſurveying and Coaſt-ſurveying, though they differ eſſentially from each other in their Nature and Circumſtances; that ſo few Draughts are found to anſwer the End propoſed by them; and that the Merits of the Draughts to which Seamen truſt their Lives and Fortunes, are ſeldom judged of by any other Rules than the Recency of the Publication, the Neatneſs of the Engraving, the Authority under which the Survey was executed; or, ſometimes, by the Rank and Reputation of the Perſons to whom they are inſcribed. Had Coaſt-ſurveying been conſidered with the Attention it deſerves, the various Sorts of Draughts which are often indiſcriminately made uſe of at Sea, would, before now, have been characteriſtically diſtinguiſhed from one another; the Particulars of which a complete Draught conſiſts would have been ſufficiently known; the ſeveral Methods of ſurveying compared together, and the moſt perfect Manner pointed out and explained. As yet, whoever undertakes a Survey of the Sea-coaſt is under the Neceſſity of deviſing a Plan of Procedure for himſelf, and performing moſt of the Operations by his own Ingenuity and Skill in the Principles, without the Advantage of the Speculations and Experience of others to aſſiſt him. This Want of previous Inſtructions, and the Difficulty and Trouble of frequent Inveſtigation, ſeem to be the chief Reaſons that Coaſt-ſurveyors commonly follow that Method which their antecedent Buſineſs or Applications ſuggeſt, rather than that which a thorough Knowledge of the Theory, and ſtrict Attention to the Nature and Circumſtances of the Coaſt would have directed. The Navigator, or experienced Seaman, conſtructs his Charts chiefly from Sea-journals of Courſes and Diſtances: the Engineer and Land-meaſurer, by a continued Menſuration of Sides and Angles; or by a connected Chain of Triangles: Some meaſure their Diſtances with a Wheel, ſome with a Chain, and others with a Rope: one takes his Angles with a Needle, one with a Theodolite, and a third with a common Compaſs: the Way in which one proceeds in a Survey neceſſarily reſtricts his Performance within narrow Bounds: another takes a Method, by which he ſurveys more Coaſt in one Year, than he could travel over in three; ſurveying a little himſelf, and copying a great deal from others, without diſtinguiſhing the certain from the uncertain.

Wherever the Safety of Shipping is concerned, the Public has a Right to ſome Satisfaction with reſpect to the Nature and Grounds of the Publication. It is not ſufficient to ſay, in the Title, that it is an actual Survey; or, a new and accurate Survey: it ought to be accompanied with, at leaſt, a ſhort Account of the fundamental Operations, and Manner in which the Survey was conducted. This would

would enable Seamen to form ſome Notion of the Merits of the Draughts they were truſting their Lives to, and to judge in what Circumſtances they might be depended on, and in what Circumſtances a Dependance on them would be imprudent. A faithful Anſwer to the following Queſtions would be ſufficient for this Purpoſe, and might be eaſily ſubjoined to the Title of any Draught.

1. *How long was the fundamental Baſe-line? Where, and how, was it meaſured?*

2. *In what Manner was the Survey carried on from that Baſe-line? And with what Inſtruments were the Angles taken?*

Or, if the different Sorts of Draughts were claſſed under different Heads, with Epithets, or Appellations, ſignificant of the Manner in which each was done, and publiſhed with that Epithet, or under that Appellation, only; this would in a great Meaſure anſwer the ſame End, and point out readily the Nature and Peculiarities of the ſeveral Draughts. Such a Capitulary is attempted in the following Enumeration of Draughts and Surveys; and will ſerve to explain what is here propoſed.

I. A General, or Nautical, Chart, is commonly conſtructed and drawn by ſome experienced Seaman from his own Obſervations and Journals of the Courſes and Diſtances from Head-land to Head-land, and Point to Point; with the intermediate Spaces filled up from ſuch Charts or Maps as are at Hand, or are in moſt Repute. Sometimes on the Margin of the Chart are added larger Sketches of ſome of the moſt noted Harbours he is acquainted with, drawn from his own Memory, or copied from others. Theſe Charts are always done by a very ſmall Scale, ſo as to comprehend a large Extent of Land and Sea. Rocks and Shoals are ſeldom, or or never, particularly examined, but laid down according to their apparent Diſtance from a noted Head-land, or by the Ship's Reckoning, which is looked upon as a ſufficient Direction for avoiding them.

In theſe Charts, as all the Diſtances are either taken by the Eye, the Log-line, or the Ship's Traverſe, without any certain Allowance for the Influence of Tides and Currents; and the Courſes, for the moſt part, deduced from the Reckoning, or ſometimes taken at Sea by a Compaſs; great Exactneſs is not to be expected: and as the Scale is very ſmall, no ſtriking Reſemblance of any Part of the Coaſt can be expreſſed in the Draught, to point out with Certainty where Shoals or Harbours lie. Notwithſtanding theſe Diſadvantages, ſuch general Charts are neceſſary to Navigation: and ſome take the Charge of conducting Ships who have no better Draughts to rely on: but then, if they are not particularly acquainted with the Places they are bound to, they ought always to carry a Pilot, who knows them; and never to truſt to ſuch Charts farther than for general Courſes at free Sea.

When theſe general Draughts are corrected by Latitudes and Longitudes carefully obſerved; and when the Publiſher is ſo juſt to himſelf and others, as to diſtinguiſh ſuch Courſes, Diſtances, and Tracts of Navigation as are delineated from his own repeated Obſervations and Experience, *from* thoſe which he has copied, or taken on Truſt from others; then they become very ſerviceable in ſailing from Land to Land, or along an open Coaſt; but near the Shore, where the Danger is greateſt; and in bad Weather, when a Ship is under the Neceſſity of running for a Harbour, or ſheltering in a Bay, theſe general Charts are of little or no Service. In ſuch Circumſtances, larger and more particular Draughts, or a ſkilful Pilot, are indiſpenſibly neceſſary.

Charts

Charts of this Sort will not be brought to their utmoſt Perfection, till ſkilful Perſons are ſent on purpoſe, with good Inſtruments, to obſerve, on Land, or near it, the Latitudes and Longitudes of the moſt remarkable Points and Promontories which Ships have moſt frequent Occaſion to ſail along, or to *make*, when they approach the Land. If this ſhall ever be done, diſtant Views of the Land ought alſo to be taken; and each Obſervation, with its ſeveral Circumſtances, ſhould be preſerved and publiſhed along with the Chart conſtructed from them. A few Years, perhaps, would be ſufficient to accompliſh this on both Sides of the Atlantic Ocean; or of the German, or North Sea: and would produce an accurate and laſting Chart of theſe Parts, which would never after need Correction. When a proper Manner of Surveying is more generally underſtood by ſeafaring Gentlemen, the intermediate Parts might be ſurveyed in a particular and complete Manner; which (excepting ſome Banks and Channels that are of a variable Nature) would be as permanent as the other. If, by the Aſſiduity of Theoriſts, or the Ingenuity of Artiſts, that important Problem of finding a Ship's Longitude at Sea, ſhall become eaſy to ordinary Seamen, ſuch a Chart will be neceſſary to render that Diſcovery fully ſerviceable to Navigation.

2. Abbreviated Collections of Draughts, as they comprehend a great deal of Coaſt in a ſmall Compaſs, are of the ſame Nature with the nautical Chart laſt mentioned, and can ſerve for no other Purpoſes in Navigation but to direct Ship's Courſes from Land to Land, or from Promontory to Promontory along a Coaſt. Theſe are commonly the Chamber-performances of Map-ſellers and Drawers, who perhaps never ſaw any of the Places they delineate, and, for that Reaſon, cannot be ſuppoſed capable of making a proper Choice of the Draughts they abridge. Beſides, in contracting a Diverſity of Scales and Draughts into one, by the utmoſt Care they can hardly avoid introducing new Errors, or Inaccuracies, over and

above what might have been in the Originals before. By the Diminution of the Figure, the Diſtinctneſs that was in the Originals will certainly be loſt in the Abbreviation. Theſe miniature Collections often do more Prejudice than Service to Navigation: for, on account of the comparative Lowneſs of the Price, and the Names and ſpecious Authorities annexed to the Title, many are inconſiderately led to purchaſe and preſerve them; while the Originals, that would have been of much more Service, are as inconſiderately neglected and loſt.

3. A MEMORIAL SKETCH is, a Delineation of a Harbour, or any Part of a Coaſt, from the Memory only; without Notes, or immediate Sight.

When ſuch a Sketch is made by one who has been often in the Place, or who has viewed it with particular Attention, it may convey a general Idea of a Bay, Harbour, or Iſland, fit to gratify Curioſity, or enlarge Geography, by ſhewing that ſome ſuch Places are there: but as every Part of the Sketch was at firſt by Gueſs, and that Gueſs delineated by Recollection only, the whole muſt be very uncertain, and of little Service to Shipping; farther than to admoniſh Sailors to keep a Look-out when they ſail that Way. It is likely that moſt of the Iſlands in the *Eaſt Indies*, *Africa*, the *South-Sea*, and on the Coaſt of *Norway*, have been drawn and inſerted in our Draughts after this Manner.

4. An EYE-SKETCH is, a Delineation of any Harbour, or Part of a Coaſt, done by the Eye at one Station, without meaſuring Diſtances; and drawn according to the apparent Shape and Dimenſions of the Land.

Though here neither Bearings, Diſtances, the Figure of the Land, nor the Poſition of Rocks or Shoals, can be exact; yet a good Drawer may make ſuch a Sketch convey a ſufficient Notion of a ſmall Bay, Harbour, or Iſland, to be ſerviceable on ſome Occaſions; and in moderate Weather, with the Help of the Lead, to direct a Veſſel to the ſafeſt Channel and ordinary Anchorage. A great deal of the Benefit of ſuch a Draught depends on chuſing an advantageous Station to take it from, ſo that the principal Parts of the Harbour, or Bay, may not be too far from the Eye; for the remoteſt Parts will always be moſt unlike. It is likewiſe of Advantage to chuſe the Station near the Sea, on that Side of the Bay, or Harbour, which is next the common Channel; becauſe remarkable Parts on that Side of the Bay and Channel may then be delineated according to their true Bearings, by a Compaſs. Such a Sketch is ſoon made by one moderately ſkilled in Drawing: and if ſea-faring Gentlemen, when they are in Places unknown, or not ſurveyed, would be at Pains to take ſuch Sketches, it would be of ſome Service both to Navigation and Geography.

5. An AMBULATORY DRAUGHT, is made by walking along the Shore, taking the Bearings from Point to Point with a Compaſs, eſtimating their Diſtances by the Eye, and ſketching the Figure of the Coaſt between them. If to this, remarkable Objects on Land are added, and ſuch Rocks, Shoals, and Ledges as are viſible at low Water, or by Breakers, with the Depths in the principal Channel, and in the Anchorage, the Draught will be a diſtinct Repreſentation of any ſingle Bay, or Harbour, and prove ſerviceable to Veſſels on ſeveral Occaſions. But if it is continued for ſome Leagues on an irregular Coaſt, the erroneous Diſtances will affect the Bearings, and alſo the Figure and Dimenſions of the whole Draught: groſs Errors in the more conſiderable Parts muſt then be corrected by making the leſs conſiderable Parts more erroneous; till at length the whole will become too evidently diſtorted and out of Proportion to admit of farther Alterations; and then of Neceſſity the

the Survey muſt be diſcontinued. It is likely that moſt of the particular Draughts uſed by Seamen have been made in this Manner.

When ſuch Draughts are confined to ſmall Parts of a Coaſt, or to ſingle Bays, or Harbours, the Errors in them are leſs ſenſible; and they become ſerviceable by exhibiting plainly what Kind of Bays and Harbours are to be met with on that Coaſt: and, when Rocks, Shoals, and Soundings are inſerted, they will be found a pretty good Direction for Veſſels that may happen to fall in with them, provided at the ſame Time they are ſure what Harbour it is which they have fallen in with: but to Strangers, and ſuch as are not well acquainted with the Land before, ſeparate Draughts of Harbours will not be found of great Uſe, eſpecially in bad Weather, when a Direction is moſt needed; becauſe of the Difficulty of finding where a particular Harbour lies, and the Danger of a Miſtake in running for it. A Ship muſt be off the Mouth of the Harbour before ſuch a Draught can be of Uſe; and the Pilot that is neceſſary to bring her thither, may likewiſe carry her in.

When one makes a Draught of a Bay, or Harbour in this Manner, at the ſame Time that he goes along the firſt Side delineating it, the magnetic Direction of the ſeveral Points and Heads on the other Side ſhould be drawn out on the Paper, and their Poſitions limited to that Direction, which will render the Bearings right, however erroneous the Diſtances may be: if this is neglected, both the Diſtances and oppoſite Bearings will be falſe, and the Draught unlike in every Reſpect.

None of the three laſt-mentioned Performances ought to go under the Name of Surveys, becauſe there is no Menſuration of Diſtances in them, nor any Thing determined in a geometrical Manner.

6. A Disjunct Survey is, when the Harbours, Bays, or Iſlands in any Country, are each ſurveyed ſeparately in a geometrical Manner.

Manner. Or, when one, or more, ſtraight Lines are meaſured on a Level Plane in each Harbour, Bay, or Iſland; the Angles taken with a good Inſtrument, and the Diſtances of the ſeveral Places determined from thence trigonometrically.

In this Survey, all the Rocks, Shoals and Channels are ſuppoſed to be carefully examined, and diſtinctly delineated, by a large Scale; and the Buoys, Beacons, Land-marks, remarkable Hills, Groves of Trees, Churches and Buildings, neceſſary for directing Veſſels on any Occaſion, inſerted in their proper Places and miniature Forms; the various Diverſities of the Sea-coaſt, and of the Rocks, Shoals and Sand-banks along it, repreſented ſo as theſe Varieties may be readily known by inſpecting the Draught. Such a Draught will be a minute and exact Repreſentation of each Place, as far as relates to Shipping; and is, or ought to be, the moſt complete of any, within the Limits of the Bay, Harbour, or Iſland ſurveyed. There is, however, one material Defect not to be avoided in Draughts of this Sort; which is, that Rocks, Shoals and Sand-banks that lie off the Harbour, or Coaſt, can ſeldom be laid down either in their juſt Dimenſions, or in their proper Places; nor can interſecting Bearings be given for finding them out; nor Land-marks for avoiding them on all Sides. The Reaſon is, each Draught comprehends ſo ſmall an Extent of Coaſt, that Objects properly ſituated for theſe Purpoſes cannot be included in it. *Lewis Morris*, in his Draughts of the Harbours of *Wales*, and Captain *Collins*, in his more diſtinct Draughts of Harbours in *Britain* and *Ireland*, very ſeldom give any Deſcription of the Rocks and Shoals they repreſent, nor Directions for avoiding them on all Sides: and theſe they deſcribe are ſo ſuperficially done, that it is not without much Trouble and Searching that the Shoal can be found at all: the Nature of their Surveys would not admit of being ſo particular as that requires. Detached Draughts of ſmall Extent, though never ſo exactly done, will not be found of much more Service to Navigation than the ambulatory Draughts before-mentioned:

for neither of them are of Use till a Vessel is in the Mouth of the Harbour; and then, the apparent Similitude between the ambulatory Draught and the Land, will direct her to the proper Anchorage as well as an exact Similarity in the geometrical Draught; for in sailing along, the Eye cannot perceive the Difference. No one that was not acquainted with the Coast, ever ventured to run for a Harbour by the detached Draughts that are to be seen on the Margins of some Maps and Charts; nor by those done by *Collins*, or *Morris*, though there is a general Chart along with them. However, disjunct Draughts, when well executed, give great Satisfaction, by making the Nature and Capacity of Bays and Harbours exactly and distinctly known, and are good Remembrancers to those who have been in these Harbours, and are so well acquainted as to know the Land at some Distance: but a Stranger to the Coast can receive very little Benefit by them, except that they may prove a Check on unskilful Pilots.

7. A LINEANGULAR SURVEY is, when the Coast is measured all along with a Chain, or Wheel, and the Angles taken at each Point and Turn of the Land with a Theodolite, or magnetic Needle.

Some few Bays, that happen to be bordered with Sand or Marsh, may be suited to such Operations; and then, if great Care is taken a pretty exact Survey may be made. But, it is only a small Part of any Coast that is level and smooth enough to admit of a continued Mensuration with any tolerable Degree of Exactness. And, when it is considered that every Error, or Inaccuracy, in any one measured Distance, occasions a proportional Error in all the other subsequent Distances; that every Inaccuracy in the Angles affects all the other subsequent Angles and Sides; that, among such a Number of Angles, Inaccuracies, perhaps Mistakes, are hardly to be avoided; and when they happen, harder to be found out, so as to be properly corrected; when these Things are considered, it will not be reckoned

a Paradox

a Paradox to affirm, that an irregular Coaſt may be ſurveyed by the Eye and a Compaſs, as exactly as in the lineängular Manner. A Surveyor will eaſily be ſatisfied of this, if he has ever tried to ſurvey an irregular Field, or ſmall Iſland, by meaſuring all the Sides, and obſerving the Angles between them: by his Field-book their Circumferences will never meet on the Paper. *That Reproach* of Surveyors is not to be wiped off by ſuch a Procedure. Surveys taken in this Way are tedious, troubleſome, and require many Hands conſtantly imployed: the Diſtances by the Draught, and by obſerved Latitudes, differ widely from each other; and the whole will come out larger than the Truth; except Errors in the Angles ſhall happen to counteract the Errors in the Sides; and in that Caſe, particular Parts muſt be very much out of Proportion. If the Diſtances are meaſured with a Wheel, inſtead of a Chain; or the Angles taken with a Needle, inſtead of a Theodolite; then the whole, and particular Parts, will be ſtill more erroneous. Lineängular Surveys that are continued beyond the Limits of a ſmall Bay or Harbour, are in no Caſe to be depended on: and very few even of theſe, can be exactly done in that Manner. This, however, ſeems to be the moſt common Method of geometrical Surveying.

8. A Trigonocatenary Survey is when one long Baſe-line is carefully meaſured on a level Plane, the Angles taken with a good Inſtrument, and from that Baſe-line a connected Series of Triangles carried on along the whole Coaſt, by which the Diſtances of the ſeveral Heads, Points and Flexures of the Shore are determined trigonometrically.

By this Procedure, one Source of Error in the former Method is avoided, viz. that which ariſes from a continued Menſuration: but the other, perhaps no leſs conſiderable, which is found, by conſtant Experience, to flow from a long Chain of Triangles all depending on one another, ſtill remains to affect the mutual Bearings and Diſ-

 tances

tances of the Places. This Manner of ſurveying is liable to much the ſame Inaccuracies and Imperfections as the lineängular, only not to ſo great a Degree. When Objects, ſharp enough for forming the angular Points with Preciſion, are rarely to be met with (which is the Caſe on every Coaſt) Errors in Angles muſt neceſſarily ariſe: one Error cauſes another, that a third, and ſo on; each increaſing the Inaccuracies of the ſubſequent Triangles: and, after they have inſenſibly run through a few trigonal Links of the Chain, their Source becomes indiſcoverable; and, at length, the Error of the whole too great to be corrected in the material Parts, without making very groſs Errors in other Parts: the Survey muſt then of Neceſſity be either broke off, or continued with very ſtriking Imperfections.

If a Coaſt happens to be ſo circumſtanced, that level Planes may be met with on it at proper Diſtances from each other, and new Baſe-lines are meaſured on theſe Planes; and if Poles, or Signals, are ſet up forming Triangles all along the Coaſt; then, with great Care, the Angles may be taken, and the Survey continued with ſufficient Exactneſs. But, ſuch a Procedure would be extremely tedious: a Life-time would hardly be ſufficient to ſurvey the Coaſt of one Kingdom in this Manner, with the Care it requires. But as Planes of a ſufficient Length and Smoothneſs are ſeldom to be found on any Coaſt, whoever carries on an extenſive Survey this Way, will be often under the Neceſſity of making random Alterations in the Draught, at leaſt at every new Baſe-line; that the ſeveral Parts may connect with one another, and that the whole may agree better with obſerved Latitudes. And, after the whole is put together one Way or another, the original Scale muſt be changed, and a different one ſubſtituted in its Place, that is better adapted to the Latitudes, and to the Dimenſions of the whole: that is, a Survey taken in this Way muſt be finiſhed, before the Scale that ſuits it is known.

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9. An Orometric Survey is, when one long Baſe-line is exactly meaſured, and the Diſtance of the Summits of two, or more, high Mountains in the Neighbourhood found from thence trigonometrically: then, by Angles taken on theſe Summits, the Diſtances of all the Points, Heads, Turns and other viſible Objects on the Coaſt are aſcertained; and from them the Poſitions of other intermediate Objects and Places. From theſe Mountains likewiſe, the Diſtances of other Mountains, farther along, are found; which ſerve in the ſame Manner as the firſt, for determining Diſtances along that Part of the Coaſt which is adjacent to them.

By this Way of ſurveying a Coaſt, when the Foundation is carefully laid, the Errors which all the fore-mentioned Methods are liable to, are in a great Meaſure guarded againſt: for, the Error, or Inaccuracy, of any one Diſtance, or Angle, is not communicated to the reſt, but confined to that Diſtance, or Angle alone, or perhaps to an adjacent Point or two beſides, which are not of great Conſequence in the Draught, nor affect the Poſitions of other Parts. Therefore, in a mountainous Country, where the fundamental Triangles are few, and the Nature of the Coaſt otherwiſe favourable, a Survey may be continued a great Length, without any Error conſiderable enough to affect the Extent of the whole together. But then Shores are generally ſo low, and of ſuch a Nature, that particular Parts can ſeldom be perceived from the Tops of two remote and high Mountains; even large Buildings are not often to be ſeen from thence: and though Points and Promontories, in Groſs, may be perceived from both, yet it is ſcarce poſſible to diſtinguiſh the ſame Part of them from each Mountain. This will render the Angles, and of Conſequence, the Diſtances inaccurate; and cauſe the obſerved Points and Heads in the Draught to extend more, or leſs, from the reſt of the Coaſt than they ought: and other Diſtances and Bearings that depend on them will participate of their Error. However, if a moderate Degree of Care is taken, theſe Errors will not

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not be confiderable, and the Draught, in general, may agree fufficiently with obferved Latitudes and Longitudes. Though by this Method an extenfive Survey may be carried on with more Certainty and Exactnefs than by any of thofe before-mentioned, yet there is Ground to believe that it has feldom been put in Practice.

10. A STASIMETRIC SURVEY is, when the mutual Diftances of three, or more, proper Objects are carefully meafured; and by Means of thefe Objects, the Pofition and Diftance of all Stations along the Coaft determined trigonometrically, each at its refpective Station alone, independent of one another.

By this Manner of Surveying, the Errors which all the other Methods are liable to are avoided: for, the Diftances along the Coaft depending intirely on the Diftances of three Objects chofen at Pleafure, the moft proper may be felected for that Purpofe: or, if proper Objects are not to be had, others may be adapted to it by Signals, and their mutual Diftances previoufly determined to any Degree of Exactnefs. And if, by Overfight, an Error fhall happen in any Part, it is confined to that Part alone, without affecting other Parts; and may be corrected at any Time independent of the reft. This Way of carrying on a geometrical Survey, whether inland or maritim, will appear evidently to be much more perfect than thofe commonly practifed; and to furpafs them, not only in Accuracy, but in Expedition; and is the only Method from which an exact extenfive Survey is to be expected. Other Methods of furveying are defective either in their Foundation, or their Procedure, or in both: and their Errors, generally, flip infenfibly into all the Parts of a Survey, increafing as it goes on. Thence it is, that fo few Surveys have been continued beyond the Extent of a large Bay, or River; that the Errors of former Draughts are not to be corrected without an intire new Survey; that fome Places have been furveyed again and again, yet in Procefs of Time are found to require it anew; and that fo few Draughts are to be met with that anfwer the End

for

for which they are intended, viz. to direct Ships into ſafe Anchorage without a Pilot. The Deſign of the following Sheets is, to explain and recommend to more general Practice, the ſtaſimetric Manner of ſurveying; to render future Draughts of the Sea-coaſt more complete and ſerviceable than what have been hitherto offered to the Public; and to direct ſea-faring Gentlemen, who have gone through a Courſe of Navigation, how to make uſeful Draughts of ſuch Bays or Harbours as they may occaſionally be in; and by Means of ſuch Inſtruments *only* as Seamen are commonly provided with.

USEFUL

USEFUL NOTES.

	Inches
The English Foot is	12
The Paris Foot	12,788
The Amsterdam Foot	11,172
The Danish great Foot	12,465
The Swedish Foot	11,692

	Feet
A Yard - - - -	3
A Fathom - - - -	6
A Cable-Length 100 Fathom, or	600

	Yards
An English Statute Mile is - - - - -	1760
A Geometrical Mile - - -	2038,6
A League, 3 Geometrical Miles - - -	6115,8
A French League, called Lieu legale - -	3996,46
A Sea League of France - - - - - -	6394,375
The Dutch League of 18000 Rhinland Feet - -	6186
The common German Mile of 22800 Rhinland Feet	7829,666
The League of Sweden 30000 Rhinland Feet -	10310

	English Miles
A Degree of the Meridian in Britain -	69,5
A Degree at the Equator - - -	67,75
A Degree at the Pole - - -	70,1
The Chord of one Degree of the Meridian	69,150
The Chord of half a Degree - -	34,960
The Diameter of the Earth - -	7910, or, 41798117 Feet

The Sun's Semidiameter about the Equinoxes is -	16′
About the Middle of Summer is - - -	15′, 45″
About the Middle of Winter is - - - -	16′, 15″
The Sun's greatest Declination is - - -	23°, 28′, 9″

Geometrical Miles in a Degree of Longitude.

Deg. of Lat.	0	5	10	15	20	25	30	35	40
Miles and Parts.	60	59,77	59,09	57,95	56,28	54,38	51,96	49,15	45,96
Deg. of Lat.	45	50	55	60	65	70	75	80	85
Miles and Parts.	42,43	38,57	34,41	30,00	25,36	20,52	15,53	10,42	5,23

MARITIM

MARITIM SURVEYING.

PART I.

Containing the geometrical Principles and other Pre-requisites of Surveying.

CHAP. I.

Of the geometrical Principles, and other Pre-requisites of Surveying, in general.

BEFORE one undertakes a geometrical Survey of the Sea-coast, it will be found of Advantage to have learned Drawing; at least so much of it as to be capable of shading with Indian-ink, or etching with a Pen, Hills, Rocks, Cliffs, miniature Buildings, and the Coast-line of a Map; of sketching, from Nature, the Out-lines of them; and of taking distant Views of the Land, from Sea. This can only be attained by long Practice, together with a few Instructions from a Drawing-master. A Surveyor who is not capable of sketching readily, and shading with some Neatness, ought to have a Drawer along with him for that Purpose.

He should also be acquainted with the Elements of Geometry and Astronomy; at least with as much as is taught in a common Course of Navigation; so as to be ready in protracting Lines and Angles, and calculating the Cases

 of

of plain and ſpherical Trigonometry by logarithmic Tables, when the Proportions are ſtated; and applying the former to the Menſuration of Diſtances, and the latter to that of ſpherical Arcs and Angles; of taking the Altitude of the Sun, or a Star, with a Quadrant on Sea and Land, and from thence finding the Latitude of a Place; and of knowing by the Eye a few of the fixt Stars, eſpecially ſuch as are near the elevated Pole.

He ſhould alſo make himſelf acquainted with the Structure of the principal inſtruments uſed in ſurveying; ſuch as the Theodolite, the aſtronomical Quadrant, and Hadley's Octant, or Sextant; and underſtand how to examin, adjuſt, and obſerve with them. If he is defective in any of the above Particulars, his Operations and Obſervations will be tedious and inaccurate, or his Draughts void of Neatneſs and Elegance.

CHAP. II.

Trigonometrical Solutions.

THE Caſes in plain Trigonometry that occur in ſurveying, are the four following.

1. Having two Angles of a Triangle, and a Side oppoſite to one of them, to find another Side; uſe the following Proportion.

As the Sine of the Angle oppoſite to the Side given,
Is to the Sine of the Angle oppoſite to the Side required;
So is the Side given,
To the Side required.

2. Having two Sides and an Angle oppoſite to one of them, to find another Angle; uſe the following Proportion.

As the Side oppoſite to the Angle given,
Is to the Side oppoſite to the Angle required;
So is the Sine of the Angle given,
To the Sine of the Angle requir'd.

In

In the above Cases, it will assist the Memory to observe, that when a Side is wanted, the Proportion must begin with an Angle; and when an Angle is wanted, it must begin with a Side.

3. Having two Sides of a Triangle, and the included Angle, to find the other Angles, and Side; use the following Proportion.

As the Sum of the two given Sides,
Is to their Difference,
So is the Tangent of half the Sum of the two unknown Angles,
To the Tangent of half their Difference.

Then half their Difference (thus found) added to half their Sum, will be the greatest of the two Angles sought; which is the Angle opposite to the greatest Side. If the third Side is wanted, it may be found by Solution I. for two Angles are known, and a Side opposite to one of them.

4. The three Sides of a Triangle being given, from thence to find the Angles; proceed by the following Steps and Proportions.

PLATE I. FIG. I.

1. Let A B C be the Triangle: make the longest Side A B the Base: from C, the Angle opposite to the Base, let fall the Perpendicular C D, on A B; which will divide the Base into two Segments A D and D B. Then,

2. Find the Difference of A D and D B, by the following Proportion.

As the Base A B,
Is to the Sum of the other Sides (A C + B C)
So is the Difference of the Sides (A C — B C)
To the Difference of the Segments of the Base (A D — D B.)

Half the Difference of these Segments (thus found) added to the half of A B, gives the greatest Segment A D; or subtracted, leaves the least D B. Then,

3. In the Triangle A D C, by Sol. 2. find the Angle A C D: for the two Sides A D and A C are known, and the right Angle at D is opposite to one of them. The Complement of A C D is the Angle A. Then,

4. In the Triangle A B C, you have two Sides A B and B C, and the Angle at A opposite to one of them; from thence (by Sol. 2.) find the Angles C and B required.

CHAP. III.

Longimetrical Operations and Problems.

SEC. I. OPERATION I.

How to proceed in measuring a straight Line.

BEFORE any Distance can be measured trigonometrically, the Length of one straight Line, or Distance, must be first found mechanically, by measuring it on a Plane with a Pole or Chain. And as this Mensuration is more or less exact, so will all the other Distances be that are deduced from it. The utmost care therefore ought to be taken in measuring this first Distance, or fundamental Base-line, exactly; and all Sources of Error in the Operation guarded against, as much as possible. The following Directions will be found sufficiently exact for any Survey.

1. Prepare a Measuring-pole 20 or 30 Feet long, precisely measured, square at one End, and a firm oblong Ring at the other; or a Chain 60 Feet long: three Poles, each 10 Feet long, with white, or dark-coloured Flags, to be tied to their Tops, according as they may appear on the Land, or between you and the Sky: 12 Poles, each 5 or 6 Feet long, with a small Flag on every fourth Pole: four iron Reels and Stakes, such as Gardners use, with about 200 Yards of small Cord to each Reel: 20 cylindrical Pins for counting the Number of Poles, or Chains, as you are measuring, each about 8 Inches long, and sharpened at the Point for piercing the Ground easily: two wide-mouth'd Canvas-pockets to carry the Pins in, with Strings for tying one of them round the Middle of each of the Measurers.

2. Pitch on a level Plane, as long as can be had; such as a smooth Sand, a Salt-marsh, or (which is by far the best) a frozen Lake.

In this Plane, chuse such a Direction for the Line to be measured, as that the principal Objects whose Distances are required, may be seen from both

its

its Extremities; and that the greateſt Angle any of theſe Objects make with it, may not be too oblique (or not above 140 Degrees:) and, if convenient otherwiſe, let one End of this Line run directly on ſome remarkable Part of a remote Object; ſo that, at the other End, its Direction may be readily found, at any time, by that Object.

4. At each End of the Line to be meaſured, ſet up a long Pole, with a white Flag flying at the Top of that which appears on the Land; or a dark Flag on that which appears between you and the Sky, or on white Sand; ſo that they may be eaſily ſeen from each other: about the Middle between theſe two ſet up the other long Pole, exactly in a Line with them: and in a right Line between theſe three ſet up ſhorter Poles all along, about 200 Yards aſunder, with a Flag at the Top of every fourth or fifth Pole.

5. Stretch a Line, or Cord, from Pole to Pole, touching the ſame Side of each Pole as it paſſes them.

6. Immediately before you begin meaſuring along theſe Lines, try the Length of your Meaſuring-pole, or Chain, with a Six-foot mahogany Rod divided into Feet; one of the Feet into Inches and Tenths of an Inch; the Thickneſs of the Wire of the Ring at the End of the Meaſuring-pole is not to be included in its Length: Count alſo the Pins, put them in the Canvas-pocket, and give them all to the Leader, or foremoſt Man, that carries the Pole.

7. Lay the Meaſuring-pole exactly along the Cords, with the Ring at the Part you begin the Meaſurement from, and its Square-end foremoſt; at the Square-end, juſt touching it in the Middle, the Leader is to ſet down a Pin, and to go on with the Pole until the Follower (or he who carries the Ring-end) comes up to that Pin, and puts the Ring round it; then the Leader laying the Pole exactly along the Cord, muſt thruſt down another Pin at the Square-end. When that is done, he calls to the Follower, who muſt take up the Pin in the Ring, put it into the Canvas-pocket which is tied round his Middle, and go on to the next Pin, putting the Ring round it; and when the Leader has put down another Pin, and called, then the Follower muſt take his Pin up, put it in the Pocket, and go on to the next,

as before; proceeding in this manner till all the Pins are put down by one, and taken up by the other. Then leaving the Measuring-pole exactly placed along the Cord, without a Pin at any of its Ends, let the Pins be counted over, to be sure that none are wanting, and the Number marked down on Paper, and all of them given back to the Leader, to begin anew, by placing a Pin at his End of the Pole, as it lies along the Line, which the Follower is to put his Ring round, and take up as before, and so go on till the whole Distance proposed is measured.

The Use of the Ring at one End of the Pole, instead of laying one Pole at the End of another, is, to confine the Measurers to more Exactness; which will be found a necessary Precaution for a Surveyor.

A Chain is not so exact for measuring with, when great Precision is required, as a Pole; but is much more conveniently carried; and, when Care is taken to lay it straight, and to prevent the Links from riding on one another, it will be found sufficiently exact on most Occasions.

8. If the Sand measured has a sensible and gradual Declivity, as from High-water Mark to Low-water, then the Length measured may be reduced to the horizontal Distance (which is the proper Distance) by making the perpendicular Rise of the Tide, one Side of a right-angled Triangle, the Distance measured along the Sand the Hypothenuse, and from thence finding the other Side trigonometrically, or by Protraction on Paper; which will be the true Length of the Base-line. If the Plane measured is on the dry Land, and there is a sensible Declivity there, the Height of the Descent must be taken by a Spirit-level, or by a Quadrant, and that made the perpendicular Side of the Triangle.

If, in a Bay, one straight Line of a sufficient Length cannot be measured, let two, or three Lines, forming Angles with each other, like the Sides of a Polygon, be measured on the Sand along the Circuit of the Bay: these Angles carefully taken with a Theodolite, and exactly protracted, or calculated, will give the straight Distance between the two farthest Extremities of the first and last Line. In taking the Angles, let the Center of the Theodolite be placed exactly over the Point where the two Sides meet, by a Plum-

 met,

met, or by dropping a Stone down; and let Poles be ſet ſtraight up in the Ends of the two Sides that form the Angle: for a ſmall Error in the Angle, eſpecially in the firſt, will often make a conſiderable Error in the Diſtance deduced from it.

Some Surveyors meaſure their Diſtances by a *Wheel.* But as a Wheel has a ſmall ſerpentine Motion from Side to Side, occaſioned by the Steps of the Perſon that leads it; and beſides, traces all the little Inequalities of the Ground, which, however ſmooth to Appearance, no Plane (if it is not ſmooth Ice) is quite free from; this way of meaſuring cannot be reckoned ſufficiently exact for a fundamental Baſe-line. Much leſs is any Diſtance meaſured by a Line, or Rope, to be eſteemed ſufficiently exact: for that will lengthen more, or leſs, by the Strength applied in ſtretching it along the Ground; and likewiſe lengthens, or ſhortens, by the various Degrees of Heat, or Moiſture in the Air, or on the Plane meaſured.

OPERATION II.

How to meaſure a ſtraight Line on the Surface of the Sea.

Firſt, prepare a Meaſuring-line of ſtrong Cord, two or three hundred Yards in Length, with ſmall Pieces of Cork of equal Thickneſs made faſt to it at ſmall Diſtances, all along, like a Fiſhing-net, ſo that it may float ſtraight on the Surface of the Water: if the Line has been well ſtretched, or much uſed before, it is the better: alſo prepare two Ropes ſomewhat longer than the greateſt Depth of the Water to be meaſured, with a Pig of Lead or Iron Ballaſt (which we ſhall call an Anchor) 50 or 60 Pounds-weight, tied by the Middle to one End of each Rope, that when it is at the Bottom it may be able to anchor a Boat, and bear to be ſtretched ſtraight without ſhifting the Place of the Anchor. Let the Meaſuring-line be thoroughly wet immediately before you begin to uſe it, and then ſtretched on the Water cloſe by the Shore, and its Length meaſured there with a Pole. Then, in the Direction intended to be meaſured, take two remarkable ſharp Objects on the Land in a Line, one near the Shore, the other as far up in the Country as you can: if ſuch are not to be had, place Buoys on the Water at proper Diſtances in that Direction.

2.

2. Take the Objects, or Buoys, in a Line, and holding one End of the Meaſuring-line faſt on the Shore, carry out the other in a Boat, in that Direction, till it is ſtretched ſtraight at its full Length by one Man in the Boat, and exactly at the End of the Line let another Man drop the Anchor, which will mark one Length of it. There keep the Boat, and the End of the Meaſuring-line, cloſe to the Anchor-rope, drawn right up and down, till another Boat takes in the other End which was on the Shore, and rows farther on, and lays it ſtraight in the Direction of the Land-marks, or Buoys, and there drops another Anchor, which will mark the ſecond Length of the Meaſuring-line. Go on thus till the whole propoſed Diſtance is meaſured; and immediately after let the Meaſuring-line be again meaſured with a Pole on the Water near the Shore, as at firſt, and if the Lengths differ, take the mean between them for the true Length. It is obvious, that to meaſure with any Exactneſs this way, the Sea muſt not only be ſmooth, but void of a Swell, and of all Stream of Tide; either of which will hinder the Line to lie ſtraight. This Method of meaſuring a ſtraight Line may be convenient on ſome Occaſions; and if Care is taken to keep the Anchor-rope right up and down when the Meaſuring-line is applied to it, will be found ſufficiently exact for many Purpoſes, but not for a fundamental Baſe-line from which other Diſtances are to be deduced.

There is another way of meaſuring a ſtraight Line, mechanically, on the Sea, which is ſo well known to Seamen, that it is needleſs to deſcribe it particularly here: and that is, by heaving the Log over a Ship's Stern while ſhe is under ſail, and obſerving how many Knots of the Log-line runs out in half a Minute; for the Line is ſo divided that the Ship will run (or, is ſuppoſed to run) ſo many miles in an Hour, in a ſtraight Courſe; and twice as much in two Hours, and ſo on. But this Concluſion is founded on three Suppoſitions, neither of which are certain, viz. That the Log remains in the ſame Place during the whole half Minute that the Line is running out from the Ship's Stern; that the Ship continues to ſail with the ſame Velocity, and alſo in the ſame Direction, during an Hour, or two, that ſhe did during the half Minute: the contrary of which is more likely in moſt Caſes. For the Log-line may ſhrink, or ſtretch, while it is running out; or may drag after the Veſſel by the Weight of the Line, or by not running eaſily and readily off the Reel; the Swell of the Sea may alter the Place of the Log; and

3 Currents

Currents or Streams of Tide, ſtronger or weaker below the Surface than at it, an unſteady Helm, Lee-way, and varying Winds may change the Direction, or Celerity of the Ship's Motion; for neither of which can any certain Allowance be made. This way, therefore, of meaſuring a ſtraight Line, or Diſtance, is not to be depended on as exact: but is mentioned here, becauſe Rocks, Shoals, or Iſlands ſometimes lie ſo far from the Coaſt, that there is no other way of forming any Notion of their Diſtance. If any ſuch Diſtance is to be meaſured after this manner, let the Log-line be thoroughly wet when it is meaſured; let the Length between each Knot be 51 Feet, which is the Hundred-and-twentieth Part of a geometrical Mile, as half a Minute is $\frac{1}{120}$th Part of an Hour; chuſe Neap-Tide, as much ſlack Water as can be got, and a moderate Breeze of following Wind; let the Line be run off the Reel ſo as never to be ſtretched quite ſtraight; and if the Half-minute is meaſured by a Watch that ſhews Seconds, rather than by a Glaſs, it will generally be more exact. Perhaps one Second ſhould be allowed for the Loſs of Time in calling out at the Beginning, and ſtopping it at the End of the Time; except the Perſon who holds the Watch can contrive to obſerve the going out of the red Rag at the Beginning, and alſo to ſtop the Line himſelf at the End of the Time; which does not ſeem a difficult Matter.

OPERATION III.

To find the Diſtance of two Places, by the Flaſh and Report of a Gun.

Stand in one of the Places with a Stop-watch in your Hand; the Watch ſtopt with the Second-hand at 60, and your Finger at the Stopper: let a Gun be fired at the other Place, at an appointed time. When you ſee the Flaſh, or Smoke, that inſtant ſet the Watch agoing; and immediately as you hear the Report, ſtop it; and it will ſhew the Number of Seconds of Time between the Flaſh and Report. By that Number multiply 1142, and the Product will be the Diſtance of the two Places in Feet: for Sound is found to move 1142 Feet in a Second.

This Operation ſhould be repeated two or three Times, for more Certainty; and the exacteſt of them, if it is certainly known, fixed on for the true Time:

or a Mean of all, if no Diſtinction can be made. It ſhould alſo be performed when there is little Wind; for a Breeze of Wind, with or againſt the ſound, is found to quicken or retard it a little. It is likely that ſome ſmall Variation may alſo ariſe from different Degrees of Denſity, and Elaſticity in the Air; the former retarding, and the latter accelerating Sound. But this has not yet been aſcertained by Experiments.

By this way of meaſuring Diſtances, ſuch as are not more than two Miles cannot be reckoned exact; becauſe of the Difficulty of ſetting the Watch agoing, and ſtopping it at the preciſe Times; which may cauſe an Error of, at leaſt, one Quarter of a Second or 90 Yards, which is too much in ſo ſhort a Diſtance. If the Diſtance is four Miles, or more, it may be reckoned ſufficiently exact for ordinary Purpoſes. I incline to think, if half a Second is allowed for the Time loſt in ſtopping the Watch and ſetting it agoing, that, after a little Practice, one may meaſure two Miles pretty exactly by this Method; provided the State of the Air is ſuch as it was when the Experiments for determining the Velocity of Sound were made.

It is to be wiſhed that thoſe Experiments were repeated over again by ſome careful Perſon, who would attend to the ſeveral Circumſtances of the Air and Wind that might affect the Celerity of Sound, and publiſh the Effect of each, for the Conveniency of Surveyors, and the farther Satisfaction of the Curious.

SECTION II.

Longimetrical Problems.

PROB. I.

Having the Length of a Baſe-line X Y, *to find the Diſtance of two, or more remote Objects* A, B *and* C, *from it, and from each other.*

PLATE I. FIG. II.

BY PROTRACTION.

With a Theodolite, or Hadley's Quadrant, at one End of the Baſe-line X, take the Angles Y X A, Y X B, Y X C; at the other End Y, take the Angles

Angles X Y A, X Y B, X Y C, and write them down in a Book. Then draw a Line on the Paper of a ſufficient Length, and in a convenient Poſition: pitch on any convenient Part of that Line for the Point X; and taking the Length of X Y from a Scale of equal Parts, ſet it off from X to Y: at X draw the obſerved Angle Y X A; and at the other End Y, draw the obſerved Angle X Y A, and the Interſection of theſe two Lines will be the Point A; and X A, meaſured on the Scale from which X Y was taken, will be the Diſtance of A from X. In the ſame manner the Points B, or C, may be determined; and the Length of A B, or B C, meaſured on the Scale, will give the Diſtance of A from B, or B from C: and ſo for any other Points whoſe Diſtances are required, whether they lie on one Side of the Baſe-line or the other.

Let it be obſerved, that if X Y is drawn on the Paper according to its magnetic Direction, then the Points A, B, and C, will likewiſe be in their magnetic Directions from X and Y, and from each other.

To render protracted Diſtances more exact, the Length of the Baſe-line ſhould not be leſs than one ſeventh, or one eighth Part, of the Diſtance of the fartheſt Object; none of the Angles ſhould be too oblique, or above 140 Degrees; the Protractor ſhould be at leaſt 12 Inches Diameter, and each Degree ſubdivided into four Parts; or more minutely by an Index with a vernier Scale on it.

BY CALCULATION.

In the Triangle X Y A there are given the meaſured Side X Y, and the obſerved Angles Y X A and X Y A, and therefore the Angle Y A X, their Compliment to 180°; that is, two Angles and a Side oppoſite to one of them: therefore, (by Trigon. Sol. 1. Page 2.) the Side X A may be found. In the ſame manner, in the Triangle X Y B, may X B or Y B be found. Then, in the Triangle A X B, there are given the two Sides X A and X B, and the included Angle (the Difference of the obſerved Angles Y X A and Y X B;) hence A B may be found, by Trigon. Sol. 3. Page 3.

PROB. II.

To find the Distance of two Places, when the Latitudes, their Bearing by the magnetic Needle, and the Variation of the Needle are known.

PLATE I. FIG. III.

BY PROTRACTION.

1. Draw the Line X A right up and down on the Paper, for the magnetic Meridian.

2. Pitch on a convenient Point X in that Line, to represent one of the Places; and at the Point X make the Angle A X B equal to the Variation, and on the East-side of X A, if the Variation is West; but on the West-side of it, if the Variation is East; and X B will be the true Meridian.

3. At X make the Angle A X Y equal to the magnetic Bearing of the other Place from X.

4. Take from a Scale of equal Parts the Difference of Latitude of the two Places in geometrical Miles, and set it off on the true Meridian from X to B.

5. At B raise a Perpendicular B Y cutting X Y in Y; and the Point Y will be the other Place; and X Y, measured on the Scale, will be the Distance of the two Places in geometrical Miles.

If their Distance is wanted in English Miles, say, as 60 is to 69, 5 so is their Distance in geometrical Miles, to their Distance in English Miles: for 69 and a half English Miles make 60 geometrical Miles.

BY CALCULATION.

In the right-angled Triangle Y B X, there is given the Angle Y X B, in this Case, equal to the Bearing of Y and Variation of the Needle together; and

and therefore the Angle at Y is alſo known; and the Side X B oppoſite to one of them: hence (by Trigon. Sol. 1.) X Y is found.

In this Problem, the greater the Difference of Latitude of the two Places is, and the nearer they are to the ſame Meridian, their Diſtance will come out the more exact. For, an Error of half a Minute can hardly be avoided in the Latitudes, though taken with the beſt portable Quadrant; nor an Error of 15 Minutes, ſometimes, in the Bearing of Y from X, though taken with the beſt Needle: more eſpecially as the Polarity of Needles is found to vary, in the ſame Place, above 20 Minutes in a Day, according to the State of the Atmoſphere, as is thought. To be ſufficiently exact, therefore, the Difference of Latitude of the Places ſhould be no leſs than 15 Miles, and the Angle B X Y no greater than 45 Degrees.

The Accuracy of this Problem depends chiefly on the Accuracy of the two Latitudes: for ſuppoſing the Needle to be twenty Minutes wrong, it will not occaſion an Error of a Quarter of a Mile in a Diſtance of thirty Miles, if the Interſection of the Bearings is not oblique: and therefore, if the Quadrant with which the Latitudes are found, and the Obſervations likewiſe, are not known to be good, the Diſtance deduced from them is not to be depended on as exact. In calculating the Latitudes by the Sun's Meridian Altitude, remember to make the proper Allowance for the Sun's Semidiameter, (at a Medium 16′, as in the Table, Page 17,) the Refraction, Variation of the Sun's Declination for the Time between your Meridian and the Meridian of the Tables; and if the Altitude is taken with Hadley's Quadrant, by the viſible Horizon, make Allowance alſo for the Depreſſion of the Horizon, or Altitude of the Eye above the Surface of the Sea; according to the Table in Page 18.

Here it may be obſerved, that the Diſtance between X and Y, thus found, is the Length of an Arc of a great Circle of the Earth between theſe two Stations, and not the ſtraight Line, or ſhorteſt Diſtance. The Chord of that Arc is the true Diſtance to be uſed in Surveying. Therefore inſtead of X Y meaſured by two Latidudes, take its Chord, which is twice the Sine of half the Arc. The Proportions between the following Arcs and their Chords were found by the Tables of natural Sines by ſaying, As the

the Radius of the Tables, is to the natural Sine of half the given Arc, ſo is the Radius of the Earth to a fourth Number; which doubled, is the Chord required. If X Y therefore is found by two Latitudes to be $69\frac{1}{2}$ Engliſh Miles, the Chord of that Arc, or ſhorteſt Diſtance between X and Y is only 69 Miles and 150 Yards: if the Arc is $34\frac{3}{4}$ Miles, its Chord is $34\frac{3}{4}$ Miles and 80 Yards: if the Arc is 20 Miles, its Chord will be $19\frac{3}{4}$ Miles and 264 Yards nearly. If the Arc meaſured is leſs than twenty Miles, its Chord may be reckoned the ſame with the Arc.

If, in Practice, it ſhall happen that Y cannot be ſeen from X; or that, becauſe of their Diſtance, both Points cannot be included in the ſame Draught; in theſe Caſes, to avoid the Trouble and Loſs of Time in finding the Latitude of another Place inſtead of X, pitch on ſome other Station nearer Y, as S, whoſe Diſtance and Direction from X is determined on the Draught, and where Y can be ſeen: find its Latitude, by letting fall the Perpendicular S b on the true Meridian drawn through X; and b X meaſured on the Scale and reduced to geometrical Miles, will be the Difference of Latitude between X and S: which added to, or ſubtracted from, the Latitude of X (as S is northward or ſouthward of it) will be the Latitude of S. Then, having the Latitude of S and of Y, find their Diſtance, as before directed.

To find how much the Sun's Declination, at any Place, differs from the Declination in the Table.

Judge, as near as you can, what the Difference of Longitude is, in Time, between the Place of Obſervation, and the Place for which the Table of Declination is calculated. Then, ſubtract the Declination for the Day of Obſervation, and for the Day next following, from each other, and the Remainder will be the Variation of Declination for one Day, or 24 Hours; and allow a twenty-fourth Part of that Variation for every Hour between your Meridian and the Meridian of the Table of Declination. For Example: ſuppoſe the Variation of the Sun's Declination in 24 Hours, is found by the Table to be ten Minutes; and the Longitude of the Place of Obſervation, from the Place for which the Table of Declination is calculated, is 45 Degrees, or 3 Hours; then ſtate the Proportion thus,

As

As 24 Hours : is to 10′ : : so is 3 Hours : to 1′, 15″. Which 1′, 15″ is to be added to, or subtracted from, the Declination in the Table, according to the Circumstances following.

When the Sun's Declination is increasing: if you are eastward of the Meridian of the Table, the Remainder must be subtracted from the Declination in the Table: but if you are westward of the Meridian of the Table, it must be added, to give the Sun's Declination at the Place of Observation.

When the Sun's Declination is decreasing: if you are eastward of the Meridian of the Table, the Remainder must be added to the Declination in the Table: if you are westward, it must be subtracted from it, to give the Declination at the Place of Observation.

Within three, or four, Days of the Solstices, an Error of 30, or 40 Degrees in the Longitude of the Places, will make no sensible Error in the Sun's Declination: but when the Sun is within 10 Degrees of the Equinoxes, to be sufficiently exact in the Declination, the Longitude should be known to half an Hour, or 8 Degrees.

A sure and ready Way to find, whether the Sun's Declination, or Zenith Distance is to be added or subtracted, to produce the Latitude.

Let it be observed, that if the Sun's Place in the Eclyptic is transferred to the Earth, or, marked by a Point on the Meridian of a Place; then, the Sun's Meridian Zenith Distance, obtained by the Quadrant, is equal to the Distance of that Point from the Place of Observation: and therefore, when the Distance of the Sun (or the Point which represents it) from the Equator, is known, the Distance of the Place of Observation from the Equator will likewise be known.

PLATE I. FIG. IV.

If therefore a Circle N E P Q is made by Hand, representing a Meridian on the Earth, and a Line E Q, for the Equator, drawn through the Middle of it; then a Point S, representing the Sun's Place, marked by Guess on the Circle;

Circle; but on the North, or South Side of the Equator-line, as the Sun's Declination is North or South; and another Point Z, for the Place of Obſervation, North from S, if the Sun is South at Mid-day; but South of S, if the Sun is North at Mid-day: then by inſpecting that Figure, it will be eaſy to ſee whether the Declination, or Zenith Diſtance, is to be added or ſubtracted from each other, to give Z E, the Latitude, or Diſtance of the Place from the Equator. In this Caſe, it is obvious, that the Declination S E muſt be added to Z S the Zenith Diſtance, to give Z E the Diſtance of the Place from the Equator. Again, let s be the Sun's Place, then Z s is the Zenith Diſtance, from which s E muſt be ſubtracted to give Z E the Diſtance from the Equator. Again, if s is the Sun's Place, and z the Place of Obſervation, the Sun being ſuppoſed North at Mid-day; then z s is the Zenith Diſtance, to which s E, the Declination, muſt be added, to give z E, the Diſtance of z from the Equator. If z falls between s and E, then the Zenith Diſtance muſt be ſubtracted from the Declination to give the Latitude: as will be manifeſt by marking the Points properly on the Figure.

PROB. III.

To find the Latitude of a Place which is inacceſſible.

Firſt find the Variation of the Needle; then, by the Direction of the Needle, pitch on a convenient Place which bears due Eaſt, or due Weſt, from the inacceſſible Place whoſe Latitude is required; there find the Latitude, and that will be the Latitude of the other likewiſe: for both are in the ſame Parallel.

The nearer the Place of Obſervation is to the other, the more exactly will the Latitudes agree; becauſe they will be leſs affected by any Inaccuracy in the Bearing by the Needle.

A TABLE

A TABLE of the Refraction of the Heavenly Bodies in Altitude.

App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.
° ′	′ ″	° ′	′ ″	° ′	′ ″	° ′	′ ″	° ′	′ ″
0. 0	33. 0	3. 30	13. 6	7. 40	6. 45	13. 0	4. 3	27. 0	1. 51
5	32. 10	3. 40	12. 40	7. 50	6. 37	13. 20	3. 57	28.	1. 47
10	31. 22	3. 50	12. 15	8. 0	6. 29	13. 40	3. 51	29.	1. 42
15	30. 35	4. 0	11. 51	8. 10	6. 22	14. 0	3. 45	30.	1. 38
20	29. 50	4. 10	11. 29	8. 20	6. 15	14. 20	3. 40	31.	1. 35
30	28. 22	4. 20	11. 8	8. 30	6. 8	14. 40	3. 35	32.	1. 31
32	28. 5	4. 30	10. 48	8. 40	6. 1	15. 0	3. 30	33.	1. 28
36	27. 30	4. 40	10. 29	8. 50	5. 55	15. 30	3. 24	34.	1. 24
40	27. 0	4. 50	10. 11	9. 0	5. 48	16. 0	3. 17	35.	1. 21
50	25. 42	5. 0	9. 54	9. 10	5. 42	16. 30	3. 10	36.	1. 18
1. 0	24. 29	5. 10	9. 38	9. 20	5. 36	17. 0	3. 4	37.	1. 16
1. 10	23. 20	5. 20	9. 23	9. 30	5. 31	17. 30	2. 59	38.	1. 13
1. 20	22. 15	5. 30	9. 8	9. 40	5. 25	18. 0	2. 54	39.	1. 10
1. 30	21. 15	5. 40	8. 54	9. 50	5. 20	18. 30	2. 49	40.	1. 8
1. 40	20. 18	5. 50	8. 41	10. 0	5. 15	19. 0	2. 44	41.	1. 5
1. 50	19. 25	6. 0	8. 28	10. 15	5. 7	19. 30	2. 39	42.	1. 3
2. 0	18. 35	6. 10	8. 15	10. 30	5. 0	20. 0	2. 35	43.	1. 1
2. 10	17. 48	6. 20	8. 3	10. 45	4. 53	20. 30	2. 31	44.	59
2. 20	17. 4	6. 30	7. 51	11. 0	4. 47	21. 0	2. 27	45.	57
2. 30	16. 24	6. 40	7. 40	11. 15	4. 40	21. 30	2. 24	46.	55
2. 40	15. 45	6. 50	7. 30	11. 30	4. 34	22. 0	2. 20	47.	53
2. 50	15. 9	7. 0	7. 20	11. 45	4. 29	23. 0	2. 14	48.	51
3. 0	14. 36	7. 10	7. 11	12. 0	4. 23	24. 0	2. 7	49.	49
3. 10	14. 4	7. 20	7. 2	12. 20	4. 16	25. 0	2. 2	50.	48
3. 20	13. 34	7. 30	6. 53	12. 40	4. 9	26. 0	1. 56	51.	46
52.	44	59.	34	67.	24	75.	15	83.	7
53.	43	60.	33	68.	23	76.	14	84.	6
54.	41	61.	32	69.	22	77.	13	85.	5
55.	40	62.	30	70.	21	78.	12	86.	4
56.	38	63.	29	71.	19	79.	11	87.	3
57.	37	64.	28	72.	18	80.	10	88.	2
58.	35	65.	26	73.	17	81.	9	89.	1
		66.	25	74.	16	82.	8	90.	0

A TABLE of the Depreſſion, or Dip, of the Horizon of the Sea.

Height of the Eye above the Sea in Feet.	Depreſſion of the Horizon of the Sea. ′ ″	Height of the Eye above the Sea in Feet.	Depreſſion of the Horizon of the Sea. ′ ″	Height of the Eye above the Sea in Feet.	Depreſſion of the Horizon of the Sea. ′ ″
1	0. 57	12	3. 18	35	5. 39
2	1. 21	14	3. 34	40	6. 2
3	1. 39	16	3. 49	45	6. 24
4	1. 55	18	4. 3	50	6. 44
5	2. 8	20	4. 16	60	7. 23
6	2. 20	22	4. 28	70	7. 59
7	2. 31	24	4. 40	80	8. 32
8	2. 42	26	4. 52	90	9. 3
9	2. 52	28	5. 3	100	9. 33
10	3. 1	30	5. 14		

PROB. IV.

Having the Diſtances of three Points, A, B *and* C, *either in a ſtraight Line, or forming a Triangle; at any Station* S, *without the Triangle, to find its Diſtance from theſe Points.*

PLATE I. FIG. V.

BY PROTRACTION.

At S, with a Theodolite, or Hadley's Sextant, take the Angles A S C and C S B: then, making A B (the Side which ſubtends the greateſt Angle, and is oppoſite to the middlemoſt Point) the Baſe; at B, make the Angle A B D equal to the Angle A S C, and lying on that Side of A B which is fartheſt from S; and at A, make the Angle B A D equal to C S B, interſecting A D in D; draw a Circle paſſing through the three Points

Points A, D, B, and it will alſo paſs through S: draw out the Line C D, and it will cut the Circle in S, the Point of Station required.

Demonſtration. The Angles A S D and A B D are equal, for they ſtand in the ſame Segment A S B D (Eucl. B. III. Prop. 21.) A S D is therefore equal to the firſt obſerved Angle. In the ſame manner, B S D and B A D are equal, for they ſtand in the ſame Segment D A S B; and D S B is therefore equal to the other obſerved Angle; and S the Point of Station, and S A, S C, S B, the Diſtances required.

BY CALCULATION.

1. In the Triangle A B C, the Sides being known, the Angles are found by Trig. Sol. 4. Page 3.

2. In the Triangle A B D, the Side A B is given by Suppoſition; and the Angles D A B and D B A equal, reſpectively, to the correſponding obſerved Angles; therefore the Angle at D is alſo known: from thence (by Trig. Sol. 1.) find the Side A D. Then,

3. In the Triangle C A D, the Sides C A and A D are known, and the included Angle C A D (which is what B A D wants of B A C) from thence (by Trig. Sol. 3.) find A C D. Then,

4. In the Triangle A S C, two Angles A S C and A C S, and the Side A C oppoſite to one of them, are known; from thence (by Trig. Sol. 1.) A S may be found. In the ſame manner may S B or S C be found.

If the Point C is on the other Side of A B, towards S, or in the Line A B, it is obvious that S may be found in the ſame manner; the ſame Protraction, and Calculation, ſerving for each of theſe Caſes.

FIG. VI.

If it ſhall happen that the Points C and D fall ſo near each other, that in protracting, C D is produced with Uncertainty, which will happen when the Point C lies beyond A B; and the obſerved Angle A S C is nearly equal to the Angle A B C, and the other obſerved Angle C S B is nearly equal to the Angle C A B. In which Caſe take the Point C on the Side of A B which is next to S, as at K: or, ſhift your Station nearer to, or farther from C, and find the Poſition of that Station, and then its Diſtance from S. Or, on C B, make the Angle C B D equal to the obſerved Angle A S C, and the Angle B C D equal to the Supplement to 180° of both the obſerved Angles A S B; then the Interſection of theſe Sides will be the Point D: draw a Circle paſſing though the Points B, C, D, and A D produced, will cut that Circle in S, the Point of Station required. For,

B S D C being a quadrilateral Figure inſcribed in a Circle, B S D is the Supplement of B C D to 180° (by Eucl. B. III. Prop. 22.) and by Conſtruction equal to the two obſerved Angles: and A S C and D B C being equal, as ſtanding on the ſame Arc D C; A S C muſt be the firſt obſerved Angle, and C S B (the Remainder of A S B) the other; and S therefore the Point of Station.

Here it may be obſerved, that the Diſtance of an Object found in this manner by Hadley's Sextant, is the real aerial Diſtance in a ſtraight Line from the Eye to the Object; but it is the level Diſtance that is neceſſary in ſurveying. If the Object therefore is on a Hill, or Eminence, that is near, and of conſiderable Height, it will be greater than is required in ſurveying, as the Hypothenuſe of a right-angled Triangle is greater than the Baſe. To find the level Diſtance, or Diſtance of a Point within the Baſe of the Hill, right below the Object on the Top of it; pitch on ſome remarkable thing that lies below, and in a Line with the Object, and take the Angle with that inſtead of the Object on the Hill.

PROB.

PROB. V.

Having the Distances of three Points A, B *and* C, *that form a Triangle, at any Station* S, *in the Direction of one of the Sides, to find its Distance from these Points.*

FIG. VII.

BY PROTRACTION.

Take the Angle A S B with an Instrument; subtract that Angle from C A B, and the Remainder will be the Angle A B S; for C A B is the external Angle of the Triangle A B S, and therefore (by Eucl. B. I. Prop. 32.) is equal to A S B and A B S taken together. Then, at B, on the Side B A, draw the Angle A B S; produce C A, and it will intersect B S in S, the Point of Station; and S A, S C, S B will be the Distances required.

BY CALCULATION.

In the Triangle A B S, the Angle at S is found by Observation; the Angle B A S is the Supplement of C A B to 180°, and therefore the Angle A B S is also known: that is, in the Triangle A B S, all the Angles and a Side are known; from thence the other two Sides S A and S B are found by Trig. Sol. 1.

PROB. VI.

Having the Distances of three Points A, B *and* C, *forming a Triangle; at any Station* S, *within the Triangle, to find its Distance from these Points.*

FIG VIII.

BY PROTRACTION.

Make any one of the Sides, suppose A B, the Base: take with an Instrument the Angles A S C and C S B, which the two other Sides subtend: at

 B make

B make the Angle A B D (lying without the Base of the Triangle) equal to the Supplement of A S C to 180°; and the Angle B A D equal to the Supplement of C S B: these Sides produced, will intersect in D. Draw a Circle passing through the three Points A, D and B; join C D, and it will intersect the Circle in S, the Point of Station; and S A, S C, S B will be the Distances required.

Demonstration. The Angles A S D and A B D are equal, for they stand in the same Segment A S B D (Eucl. B. III. Prop. 21.) therefore A S C, the Supplement of A S D, is also the Supplement of A B D; and, by Construction equal to the first observed Angle. Again, B S D and B A D are equal, for they stand in the same Segment B S A D; and B S C, the Supplement of B S D, is also the Supplement of B A D; and therefore, by Construction, equal to the other observed Angle; and S the Point of Station; and S A, S B, S C, the Distances required.

BY CALCULATION.

1. In the Triangle A B D, the Angles B A D and A B D are known, being respectively Supplements of the observed Angles A S C and B S C; and therefore their Supplement A D B is known; and the Side A B opposite to one of them: from thence (by Trig. Sol. 1.) find the Side A D. Then,

2. In the Triangle C A D, the Sides A C and A D are known, and the included Angle C A D (equal to C A B and B A D together) from thenee find the Angle A C D, by Trig. Sol. 3.

3. In the Triangle A C S, the Angles at C and S are known, and the Side A C, opposite to one of them; from thence (by Trig. Sol. 1.) find A S and C S.

PLATE I. FIG. IX.

If the Point of Station is in any of the Sides, as at S in the Side A B; take the Angle which one of the other Sides, suppose A C, subtends there; and on any Part of A B, as D, make the Angle A D E equal to the observed Angle A S C: through C, draw the Line C S parallel to D E cutting

cutting A B in S, and S will be the Point of Station. For C S and D E being parallel, the Angles A S C and A D E are equal (Eucl. B. I. Prop. 29.) A S C is therefore the obſerved Angle, and S the Point of Station.

On account of the great Utility of theſe laſt Problems in Surveying, I ſhall ſhew a general, and more ready Method, of finding, by Protraction, the Point of Station S, in the three principal Caſes foregoing; communicated by Capt. *John Campbel* of his Majeſty's Navy.

1. *When the obſerved Angle* A S B *is leſs than* 90 *Degrees.* From the Points A and B draw the Angles B A m and A B M, lying towards S, each equal to the Complement of the obſerved Angle A S B, and the Interſection of the Lines A m, B M, will be the Center m of the Circle A S B. From the Extremities of either of the other Sides of the Triangle A B C, as B C, draw the Angles B C n and C B N, each equal to the Complement of the obſerved Angle C S B, and the Lines C n, B N, will interſect each other in n, the Center of the Circle C S B; and the Point of Interſection of theſe two Circles ſhall be the required Station S. For,

The Angle A S B being leſs than a Right-Angle, the Line A B will divide the Circle A M S B into two unequal Segments, in the greateſt of which (A M S B) S muſt ſtand (Eucl. B. III. Prop. 31.) and therefore the Center, m, which is always in the greateſt Segment, will be on the ſame Side of A B that S is. Alſo, in the Triangle m A B, the Angles A B m and B A M together, are the Supplement of the Angle A m B to two Right-Angles; but A B m and B A m are (by Conſtruction) the Supplement of twice A S B to two Right-Angles; A m B is therefore double the Angle A S B; and ſtanding on the ſame Arc (by Eucl. B. III. Prop. 30.) S muſt be in the Circumference of the Circle A S B.

In the ſame Manner it may be ſhewn that S is in the Circumference of the Circle C S B, and therefore it muſt be in their Interſection.

2. *When the obſerved Angle* A S B (Fig. 19.) *is more than* 90 *Degrees:* Then ſubtract 90 from it, and make the Angles at A and B each equal to the Remainder; and to lie on the Side of A B, which is fartheſt from S;

and m, the Point of Interſection of theſe two Lines will be the Center of a Circle, which will paſs through A, B and S. For, the Angle A S B being more than 90 Degrees, the Line A B will divide the Circle into two unequal Segments, in the leaſt of which (A S B) the Point of Station S muſt be; and the Center m, therefore, on the Side of A B oppoſite to S. Alſo, the Angle m A B = m B A = (by Conſtruction) to the difference between A S B and a Right-Angle: alſo the Angle n C B = n B C = $\overline{\text{C S B}-90^{\circ}}$.

The Point of Station S found inſtrumentally.

The Point S may be readily laid down on a Draught, by drawing on a looſe tranſparent Paper indefinite Right-lines S A, S B, S C, at Angles equal to thoſe obſerved; which being placed on the Draught ſo as each Line may paſs over, or coincide with, its reſpective Object, the angular Point S will then coincide with the Place of Obſervation. Or,

Provide a graduated Semicircle of Braſs, about 6 Inches in Diameter, having three Radij with chamfered Edges, each about 20 Inches long, (or as long as it may be judged the Diſtance of the Stations from the three given Objects may require) one of which Radij to be a Continuation of the Diameter that paſſes through the Beginning of the Degrees on the Semicircle, but immoveably fixed to it, the other two moveable round the Center, ſo as to be ſet and ſcrewed faſt to the Semicircle at any Angle. In the Center let there be a ſmall Socket, or Hole, to admit a Pin for marking the central Point on the Draught. When the ſloped Edges of the two moveable Radij are ſet and ſcrewed faſt to the Semicircle, at the reſpective Degrees and Minutes of the two obſerved Angles, and the whole Inſtrument moved on the Draught until the Edges of the three Radij are made to lie along the three ſtaſimetric Points, each touching its reſpective Point, the Center of the Semicircle will then be in the Point of Station S; which may be marked on the Draught, through the Socket, with a Pin. Such an Inſtrument as this may be called a *Station-pointer*; and would be found convenient for finding the Point of Station readily and accurately, except when the given Objects were near; when the Breadth of the Arch, of the Radij, and of the Braſs about the Center of the Semicircle might hinder the Points to be ſeen, or the Radij to be placed ſo as to comprehend a very ſmall Angle between them.

PROB.

PROB. VII.

Having the Diſtance and Poſition of two Points A *and* B; *at two Stations,* S *and* s, *to find the Diſtance of theſe Stations from each other, and from the given Points.*

PLATE I. FIG. X.

1. At S, take the Angles A S s and B S s; and at s, take the Angles A s S and B s S. Then,

2. Making S s any length, ſuppoſe 10, take it from a Scale of equal parts, and draw it on Paper: and at S and s, protract the reſpective obſerved Angles, and the Points A and B will be determined in Proportion to the aſſumed Length of S s. Then, taking the protracted Length of A B from the Scale, ſay,

As the protracted Length of A B,
Is to the aſſumed Length of S s,
So is the true Length of A B,
To the true Diſtance of S *and* s.

3. The Diſtance S s being thus found, and the Angles at S and s obſerved, the Diſtances S A, S B and s A, s B, may be taken from the proper Scale, after a new Protraction; or calculated, as in Prob. I.

PROB. VIII.

Having the Diſtance and magnetic Bearing of two Points, A *and* B *protracted; at any Station* S, *(not very oblique to* A B) *to find its Diſtance from theſe Points, by the Needle.*

PLATE I. FIG. XI.

At S, with a good magnetic Needle, take the Bearings of A and B, in Degrees and Parts of a Degree: then, from theſe Points draw out their respective Bearings in the opposite Direction, towards S: that is, if A bears exactly North; draw a Line from the Point A exactly South; if it bears East 10, or 20 Degrees southward, draw the Line West 10, or 20 Degrees northward, and so for any other Bearing. Draw the opposite Bearing of B in the same manner; and S, the Intersection of these two Lines, will be the Point of Station; and S A, S B, the Distances required.

This is an easy and ready way of finding the Distance of any Station, from two Places whose Distance has been accurately determined before; and will be found convenient very often in the Course of a Survey; and sufficiently exact on most Occasions; provided the Places, A and B, are not very remote from the Station, nor the Intersection of their Bearings too oblique. If the Needle is good, a Distance of 20 Miles is not to be reckoned too far, when the Angle subtended by the two Places is not less than 50 Degrees, nor more than 140.

CHAP. IV.

Of the Examination of Surveying Instruments.

THE Accuracy of geometrical Mensuration depends so much on the Accuracy of the Instruments made use of in it, that it is a very necessary Qualification in a Surveyor to be capable of examining and adjusting them. Some Instruments are made in such a Manner, without any Necessity, and as if it were on purpose, that it is very troublesome to find whether all their Parts are exact or not; and for that Reason Surveyors are too apt to take them on Trust, without Examination: but this often creates more Trouble in their Business, and occasions Errors which they can neither account for, nor correct. If Surveyors were more cautious, Instrument-makers would become more careful.

How to examine the Accuracy of a Theodolite.

PLATE I. FIG. XII.

1. On a Level about a Mile or two long, such as the Margin of a Lake, or the High-water Mark along a well-sheltered Sand, when the Sea has been smooth

ſmooth a little before, ſet three upright Pales * A, B, C, exactly in a Line; and about half a Mile, or a Mile from each other. If it can be done, let the Line run exactly on ſome remarkable Part of a diſtant Object.

2. Set the Theodolite horizontal, with its Center right over the Hole B, where the middle Pole ſtood: ſet the Index at 0 Degrees, and turn the Theodolite till, through the Teleſcope, you ſee the Pole A at the vertical Wire; then ſcrew the Inſtrument faſt in that Poſition. Next turn the Index to 90, and remark ſome diſtant Object exactly at the vertical Wire of the Teleſcope: if no ſuch Object is to be ſeen, ſet up a Pole D in that Direction half a Mile off, or as far as it can be ſeen.

3. Then ſet the Index at 0 Deg. again, and turn the Inſtrument till you ſee the Pole C, through the Teleſcope exactly at the vertical Wire: ſcrew the Inſtrument faſt in that Poſition; turn the Index to 90; look through the Teleſcope; and if the Object, or Pole, D, is exactly at the vertical Wire, then is the Index right centered, and the graduated Circle exactly divided into four Quadrants; for the Line D B, ſtanding on the right Line A C, makes the Angles on each Side, A B D and C B D, equal. But, if the Object is not ſeen exactly at the vertical Wire, obſerve how much it is over, or falls ſhort of it, and half that Difference is the Error of the Diviſion at 90 †.

4. To find if the Graduations of each Quadrant are right: Apply the Beginning of the Diviſions of the vernier Scale, to the Beginning of each Degree of the Theodolite; and if the End of the Diviſions of the Vernier reaches the reſpective Degree preciſely in each Application, then the Graduations of the Theodolite are right; otherwiſe one, or more, are wrong. If each Degree is ſubdivided, theſe Subdiviſions may be examined in the ſame manner. This is a very eaſy and nice way of examining the Graduations of any Inſtrument that has a vernier Scale on it.

* To place a Pole upright; ſtand ſtraight up with your Feet cloſe together; put one End of the Pole between your Toes, and take the other up along your Breaſt and Chin, and in that Poſture preſs it down with both Hands till it ſtands firm.

† By a proper Application of the above Principles, the Graduation of Inſtruments, large or ſmall, may be rendered as accurate as the Materials made uſe of will admit, and the leaſt Degree of Inaccuracy in them readily diſcoverable; as could be eaſily ſhewn, were this a Place for it.

To find if the Wire of the Telescope is exactly vertical: hang up a Plumb-line at some Distance; set the Theodolite level; look through the Telescope to the Plumb-line when at rest, and if the upright Wire moves exactly along the Plumb-line when the Telescope is elevated or depressed, then is the Wire exactly vertical. If the Wire crosses the Plumb-line in any Part, turn it by the proper Screws, or Pins, till you get it exact.

Cautions in taking Angles with a Theodolite.

1. Spread the Legs that support it pretty wide, and thrust them firm in the Ground, especially on Sand, or soft Ground; that they may not yield, or sink unequally during the Observations.

2. Set it level; otherwise the Angles will not be precise.

3. Screw the Ball firm in the Socket, that in turning the Index, the Diameter of the Theodolite may not vary from the Object it was directed to; which, without Care in the Observer, or in the Structure of the Instrument, will happen frequently.

4 The Angles should be taken twice over, and read off by different Persons.

5. It would often prevent Mistakes in Angles, and contribute to Dispatch, if a Theodolite was provided with two Telescopes, one above its Plane, and the other below it; the lower one to move round only when the Circumference of the Theodolite was turned; by which Means it would be readily seen through this Telescope when the Diameter shifted from the Direction of the Object it was fixed at. Also if these Telescopes shewed Objects erect; and in their natural Position, instead of being reversed and inverted; and if the Telescopes magnified more than they commonly do. It would likewise be an Advantage if the Vernier was made to give every Minute of a Degree, in place of four or five, as in most Theodolites.

Of Hadley's *Sextant.*

This Instrument may be used with great Advantage in Maritim Surveys, on most Occasions; being more portable, more readily applied to the taking

of

of Angles, and generally more accurately and minutely divided than Theodolites are: an Obſerver is leſs liable to Miſtakes with it; and, which is a very material Advantage, he can take Angles with it at Sea, as well as on Land. There are two Inconveniences attending the Uſe of it; one is, that ſmall, or obſcure Objects, eſpecially if the Ground riſes beyond them, cannot be eaſily perceived in the Glaſſes: the other is, that no Angle above 120 Degrees can be taken by it at once, and that ſometimes there are not proper intervening Objects for dividing a larger Angle into two *.

A Braſs Sextant of nine Inches Radius, though it does not admit of Back-obſervations, will be found as convenient a Size as any for a Surveyor. It ſhould be provided with a ſmall Teleſcope, that can be taken off and put on at Pleaſure, for obſerving celeſtial Bodies; and with a Tube for terreſtrial Objects, which is better than a thin Plate of Braſs with Holes in it. There ſhould likewiſe be a Screw at the End of the Index, to bring the two Objects exactly to one another, after they have been firſt brought near by the Hand; and if a Staff with a Ball and Socket is fitted to it, and a Belt to ſupport the whole, it will be found a great Eaſe to the Obſerver. The Teleſcope and Tube ſhould be ſo contrived, as to be raiſed occaſionally as high as the Middle of the tranſparent Part of the Horizon-glaſs, for obſerving Objects that are bright enough to be ſeen by Reflection from it.

Each of the Glaſſes belonging to the Sextant ſhould have its two Surfaces perfect Planes, and parallel to one another; and the Index and Horizon-glaſſes ſhould ſtand perpendicular to the Plane of the Inſtrument. Theſe Particulars of the Glaſſes ought to be carefully attended to, and adjuſted by the Inſtrument-maker, before he gives the Sextant out of his Hand: for though Defects in the Glaſſes may be detected by proper Examination, yet the want of Paralleliſm and Plainneſs cannot be corrected without new Glaſſes; and, to adjuſt the Inclination, is troubleſome to young Practitioners. The firſt thing however which a Beginner ſhould learn is, the eaſieſt way of holding the Sextant for making Obſervations, and of bringing the reflected

* Any Angle may be taken by the Back-obſervation, by one experienced in this manner of obſerving; but the Back-obſervation is too difficult and troubleſome to be recommended in general to all Practitioners; and requires a Sextant or Octant of at leaſt 16 Inches Radius, to have ſufficient Room for the Back-vanes, which is an inconvenient Size for Land Surveys.

Image

Image and Object near each other by moving the Index. Tho' this requires Practice more than Precept, the following Directions may be found serviceable at first.

How to hold the Sextant for taking Angles.

Whether the Sextant is to be held vertically, or horizontally with its Face uppermost, it should be supported chiefly with the Right-hand, and the Index governed by the Left, in the following Manner. For horizontal Angles; hold the Instrument horizontally, with the Face uppermost, and place the Thumb of the Right-hand against the Edge of the curved Part on which the Sight-vane stands, but so as not to touch the Index when it is set at o, or the Beginning of the Degrees; and extend your Fingers across the Back of the Instrument, so as to lay hold of the opposite Edge of the additional Part on which the Horizon-glass stands, placing the Fore-finger on one Side, the two next Fingers on the other Side of the greatest Swelling, and the Point of the little Finger against the Back of the Instrument. When there is no Staff and Belt, horizontal Angles are easiest taken sitting with the right Ancle on the left Knee, and the right Elbow supported by the right Knee. The Index may be managed by placing the Thumb of the left Hand against the outer Edge of the graduated Arch, and keeping the End of the Index betwixt the two first Fingers: or by taking the End of the Index between the Fore-finger and Thumb, and resting the other Fingers against the middle Bar, or against the Far-side of the Instrument, as a very little Practice will direct.

For taking vertical Angles: hold the Sextant in a vertical Position, with the Thumb and Fingers of the Right-hand, as before, for horizontal Angles; or as the Form of the Swelling at the Horizon-vane enables you to take the surest Hold; rest the Extremity of the Arch against your Breast, and that will enable you to manage the Index more easily with your Left-hand.

When Angles are to be taken with the Instrument inverted, or with the Face below, then it must be held and supported chiefly by the Left-hand, and the Right reserved for governing the Index, in the following Manner. Hold the Sextant horizontal, with its Face downward: place the Thumb of your Left-hand on the Center-plate at the Back of the Index-glass; the three

three firſt Fingers above the Center-part, and the Inſide of the little Finger againſt the Edge of it; and when the Eye is applied to the Sight-vane, preſs the Edge of that Side againſt your Forehead: take care that the little Finger, by being too low, does not intercept the Sight of any of the Objects.

In all Obſervations, the Sextant ſhould be held in a Plane paſſing through the Eye of the Obſerver and the two Objects whoſe angular Diſtance is to be found.

How to examine the Glaſſes of a Sextant.

To find whether the two Surfaces of any one of the reflecting Glaſſes are parallel: apply your Eye at one End of it, and obſerve the Image of ſome diſtant Object reflected very obliquely from it; if that Image appears ſingle and well defined about the Edges, it is a Proof that the Surfaces are parallel: on the contrary, if the Edge of the reflected Image appears miſted, as if it threw a Shadow from it, or ſeparated like two Edges, it is a Proof that the two Surfaces of the Glaſs are inclined to each other. If the Image in the Speculum, particularly the Sun, is viewed through a ſmall Teleſcope, the Examination will be more perfect.

To find whether the Surface of a reflecting Glaſs is a perfect Plane. Chuſe two diſtant Objects as nearly on a Level as can be had: hold the Sextant horizontal, with your Eye at the Sight-vane, view the Left-hand Object directly through the tranſparent Part of the Horizon-glaſs, and move the Index till the reflected Image of the other is ſeen below it in the ſilvered Part; make the two Images unite juſt at the Line of Separation: then turn the Sextant round ſlowly in its own Plane, ſo as to make the united Images move along the Line of Separation of the Horizon-glaſs: if the Images continue united, without receding from each other, or varying their reſpective Poſition, the reflecting Surface is then ſufficiently plane.

To find if the reflecting Glaſſes are perpendicular to the Plane of the Sextant. Move the Index near the Middle of the Arch of the Sextant; apply your Eye obliquely near one End of the reflecting Glaſs, ſo as to ſee Part of the Arch of the Sextant by Reflection, and Part of it by direct Viſion: if the two Parts of the Arch form one uniform Curve, without

appearing

appearing in the leaſt above or below each other, then is the Glaſs perpendicular to the Plane of the Sextant. If the Image of the Arch ſeen by Reflection is higher than the Arch ſeen directly, then the Glaſs inclines forward; in which Caſe, ſlacken the fore-adjuſting Screw of the Glaſs, and ſcrew in the back one. If that Part of the Arch ſeen directly is higher than its Image ſeen by Reflection, then the Glaſs leans backward, and the back-adjuſting Screw muſt be ſlackened, and the fore one ſcrewed in. Be careful, in all Caſes where one Screw draws, or puſhes againſt another, to ſlacken one of them before you ſcrew up the other.

To find if the two Surfaces of a red or darkening Glaſs, are parallel and perfectly plane. This muſt be done by means of the Sun when it is near the Meridian, in the following Manner. Hold the Sextant vertically, and direct the Sight to ſome Object in the Horizon, or between you and the Sky, under the Sun; turn down the red Glaſs, and move the Index till the reflected Image of the Sun is in Contact with the Object ſeen directly: fix then the Index, and turn the red Glaſs round in its ſquare Frame; view the Sun's Image and Object immediately, and if the Sun's Image is neither raiſed nor depreſſed, but continues in Contact with the Object below, as before, then the Surfaces of the darkening Glaſs are true.

How to obſerve the horizontal Angle, or angular Diſtance, between two Objects.

Firſt adjuſt the Sextant, and if the Objects are not ſmall, pitch on a ſharp Top, or Corner, or ſome ſmall diſtinct Part in each to obſerve; then having ſet the Index to 0 Deg. hold the Sextant horizontally, as above directed, and as nearly in a Plane paſſing through the two Objects as you can; direct the Sight through the Tube to the Left-hand Object, till it is ſeen directly through the tranſparent Part of the Horizon-glaſs: keeping that Object ſtill in Sight there, move the Index till the other Object is ſeen by Reflection in the ſilvered Part of the Horizon-glaſs; then bring both Objects together by the Index, and by the Inclination of the Plane of the Sextant when neceſſary, till they unite as one, or appear to join in one vertical Line, in the Middle of the Line which divides the tranſparent and reflecting Parts of the Horizon-glaſs: the two Objects thus coinciding, or one appearing directly below the other, the Index then ſhews on the Limb the Angle which the two

Objects ſubtend at the naked Eye. This Angle is always double the Inclination of the Planes of the two reflecting Glaſſes to one another; and therefore every Degree and Minute the Index is *actually* moved from o, to bring the two Objects together, the Angle ſubtended by them at the Eye will be twice that Number of Degrees and Minutes; and is accordingly numbered ſo on the Arch of the Sextant; which is really an Arc of 60 Degrees only, but graduated into 120°. As this has been demonſtrated in ſeveral Books and Pamphlets, it is needleſs to inſiſt on it here.

The Angle found in this Manner between two Objects that are *near* the Obſerver, is not preciſe; and may be reckoned exact only when the Objects are above half a Mile off. For, to get the Angle truly exact, the Objects ſhould be viewed from the Center of the Index-glaſs, and not where the Sight-vane is placed; therefore, except the Objects are ſo remote that the Diſtance between the Index-glaſs and Sight-vane vaniſhes, or is as nothing compared to it, the Angle will not be quite exact. This Inaccuracy in the Angle between near Objects is called the *Paralax* of the Inſtrument; and is the Angle which the Diſtance between the Index-glaſs and Sight-vane ſubtends at any near Object. It is ſo ſmall, that a Surveyor will ſeldom have Occaſion to regard it: but if it ſhall happen that great Accuracy is required, let him chuſe a diſtant Object exactly in a Line with each of the near ones, and take the Angles between *them* and that will be the true Angle between the near Objects. Or, obſerve the Angle between near Objects, when the Sextant has been firſt properly adjuſted by a diſtant Object; then adjuſt it by the Left-hand Object, which will bring the Index on the Arch of Exceſs beyond o Degrees: add that Exceſs to the Angle found between the Objects, and the Sum will be the true Angle between them. If one of the Objects is near, and the other diſtant, and no remote Object to be found in a Line with the near one; adjuſt the Sextant to the near Object, and then take the Angle between them, and the Error of Paralax will be removed.

How to obſerve the Altitude of the Sun on the Sea, or on Shore at the Edge of the Sea.

Adjuſt the Sextant by the Horizon (as is afterwards directed:) raiſe the Teleſcope, or Tube, as high as the Middle of the tranſparent Part of the

Horizon-glaſs; ſet the Index to o Degrees; turn in the darkening-glaſſes, or only one of them if the Sun is not very bright; turn your Face directly to the Sun; hold the Sextant in a vertical Poſition, with its Plane paſſing as near through the Sun's Center and the neareſt Part of the Horizon as you can, and direct the Sight to that Part of the Horizon; then move the Index from o on the Limb, till you ſee the red Image of the Sun come down toward the Horizon. If there is any Difficulty in finding that red Image, it is either becauſe the Sun is obſcured by a Cloud, or becauſe the Sextant is not in a vertical Plane that paſſes through the Sun, which muſt be diſcovered by glancing at the Sun with your naked Eye, and in the latter Caſe, by turning your Body more directly to the Sun. Having brought the Sun's Image almoſt down to the Horizon, then, with your Left-hand, ſwing the Sextant backward and forward, from one Hand to the other, and the Image of the Sun will ſeem to deſcribe the Arch of a Circle convex to the Horizon: move the Index till the lower Edge of the Image juſt grazes on the Horizon; when it is at the loweſt Point of the Arch apparently deſcribed, then ſtop the Index, and mark down the Degrees and Minutes ſhewn on the Limb; which call The *obſerved Altitude.* When this is corrected by the Sun's Semidiameter, the Dip of the Horizon, the Refraction, and the Index-error, if there is any, it will give the true Altitude of the Sun's Center.

How to take an horizontal Angle between two Objects with the Sextant inverted.

To obſerve in this Manner: ſet the Index at o, and hold the Inſtrument as above directed; direct the Sight to the Left-hand Object till it is ſeen through the tranſparent Part of the Horizon-glaſs, and you will likewiſe perceive its reflected Image in the ſilvered Part: then advance the Index, and at the ſame time keep the reflected Image in Sight, by turning your Body and the Sextant toward the Right-hand, till you ſee the other Object through the tranſparent Part; make them join in the Middle of the Line of Separation of the Horizon-glaſs, and the Index will ſhew the Angle on the Limb.

This Method of obſerving will be often convenient, becauſe, after a little Practice, an Angle may be taken more readily this way than with the Face of of the Sextant uppermoſt; and alſo becauſe the fainteſt Object may often be found by direct viſion through the tranſparent Part of the Glaſs, when it could not be ſo eaſily found by Reflection.

How to adjuſt the Horizon-glaſs for Obſervation, by a horizontal Line.

To adjuſt the Horizon-glaſs is, to make it parallel to the Index-glaſs when the Pointer of the Vernier is placed at o, or the Beginning of the Degrees. This is the moſt important Adjuſtment of all for an Obſerver; and ſhould be done every Time one begins to make any Obſervations. The horizontal Lines fitteſt for this Operation are, the Horizon of the Sea, which is the leaſt; and the Roof, or upper Part of the Wall of a large well-built Houſe above half a Mile diſtant.

To adjuſt by the Horizon of the Sea, or any other horizontal Line: turn the Index, till the Pointer of the Vernier ſtands exactly at o on the Limb, and fix the Index there: hold the Sextant in a vertical Poſition, and obſerve whether the Edge of the Sea-horizon (or other horizontal Line) ſeen in the ſilvered Part of the Glaſs, makes one continued Line with the Edge of the Sea ſeen in the tranſparent Part: if it does not, and the Line appears broken, or one Part of it above the other, bring them into one ſtraight Line by turning the adjuſting Lever at the Back of the Horizon-glaſs; then fix the Lever by the Button-ſcrew in the Middle of it, and the Horizon-glaſs is adjuſted, or parallel to the Index-glaſs.

To find the Error of this Adjuſtment: move the Index a little from its Place; hold the Sextant in a vertical Poſition as before, and turn the Index till the Line of the Sea-horizon (or other horizontal Line) ſeen in the ſilvered Part of the Horizon-glaſs joins exactly in one ſtraight Line with the Edge of the Sea ſeen through the tranſparent Part: then the Number of Minutes by which o on the Vernier differs from o on the Limb is the Error of the Adjuſtment; and muſt be allowed for in all the Angles taken with this Adjuſtment, in the following Manner. If the Pointer, or o on the Vernier, ſtands on the quadrantal Arch, or to the Left-hand of o on the Limb, then this Error is to be ſubtracted from the Angle ſhewn on the Limb by the

Index; but if o on the Vernier ſtands on the Arch of Exceſs, or to the Right of o on the Limb, then the Error of the Adjuſtment is to be added to the Angle ſhewn on the Limb.

To verify the Error of Adjuſtment found by this, or any other Method: ſet the Index ſo as to ſhew the exact Error found, and to ſhew it on the quadrantal Arch, if that Error is to be ſubtracted, but on the Arch of Exceſs, if the Error is to be added. Then fix the Index, and directing the Sight to ſome diſtant Object, take notice whether the direct and reflected Images perfectly coincide or not: if they do, the Index Error is truly determined; if not, it muſt be corrected by the Method proper for it.

When the Index is moved from you, to bring an Image and Object together, it will give a different Angle from that ſame Angle taken by moving the Index towards you. This, probably, is occaſioned by the Index bending or ſtarting a little by the Preſſure of the Hand. To correct this, when great Accuracy is required, take the Angles two or three times over each Way, and the Medium of all will be the true Angle.

How to adjuſt the Horizon-glaſs by a ſtraight vertical Line.

The Lines fitteſt for this are, the upright Corner of a Houſe, or a Pole ſet upright in the Ground, at leaſt half a Mile off.

Bring the Pointer of the Vernier to o on the Limb; hold the Plane of the Sextant horizontal; view the vertical Line in the Middle of the tranſparent Part of the Horizon-glaſs, and its Image in the reflecting Part, and turn the Lever till both make one continued Line, neither appearing to the Left, or Right of the other; then ſcrew the Horizon-lever faſt, and the Horizon-glaſs is adjuſted.

To find the Error of this Adjuſtment: move the Index out of its Place; then ſet the Vernier again to o on the Limb; hold the Plane of the Sextant horizontal; view the vertical Line directly through the tranſparent Part of the Horizon-glaſs, and its Image in the reflecting Part: if they make one continued Line, there is no Error; if they do not make one continued Line,

move

move the Index a little to one Side or the other till they do so, and the Number of Minutes by which the Pointer of the Vernier differs from o on the Limb, is the Error of this Adjustment; which is to be subtracted from each Angle taken, if the Pointer stands on the quadrantal Arch, and added when it is on the Arch of Excess. In reading off the Minutes on the Arch of Excess, remember to take their Compliment to 30, in Place of what the Vernier shews.

To adjust the Horizon-glass by the Sun.

Set the Pointer of the Vernier to o on the Limb; hold the Sextant horizontal; raise the Telescope, or Tube, as high as the Middle of the transparent Part of the Horizon-glass; use a smoked, or red Glass to defend the Eye, and slip a Screen of Pastboard nine Inches square, with a Hole in the Middle, over the End of the Telescope, to keep the Face from being scorched; then view the Sun and its Image both through the transparent Part of the Horizon-glass, and by the Lever make them cover each other exactly, so as to appear as one Object; screw the Lever fast, and the Horizon-glass is adjusted.

The Adjustment may be made in the same Manner by the Moon, or a Star, without a Darkening-glass or Screen.

To find the Error of this Adjustment; move the Index a little from its former Place at o; then, by the Index, make the two Images cover one another exactly as before; and the Number of Minutes by which the Pointer of the Vernier differs from o on the Limb, is the Error of Adjustment, and must be allowed for as above.

Another, and rather a nicer, Manner of adjusting by the Sun.

Set the Pointer of the Vernier to o on the Limb; hold the Quadrant horizontally, with the darkening Glass and Screen to defend your Eye and Face; measure the Diameter of the Sun, first on the quadrantal Arch, and next on the Arch of Excess; or with the Index, first on the Left-hand of o on the Limb, and then on the Right of it. If these two Diameters are equal, then is the Horizon-glass adjusted: if the Diameters are unequal, turn the Horizon-lever a little one way or the other, till upon measuring them again they are found equal: or, which is equivalent, and often more convenient, when the Error is small; mark the Difference between the two Diameters, and make Allowance of half that Difference in each Angle observed on the Limb, adding or subtracting it as before directed. In reading off the odd Minutes on the Arch of Excess, remember to take the Compliment to 30 of what the Vernier shews.

The Diameter of the Sun is measured thus. Set the Pointer of the Vernier at o; hold the Sextant horizontally; by the Index bring the reflected Image in external Contact with the direct Image; note the Degrees and Minutes of the Pointer from o; then bring them in Contact on the opposite Side of the direct Image, and note the Degree and Minutes; see whether the Diameter on the quadrantal Arch, or the Diameter on the Arch of Excess, is greatest; mark the Difference, and reserve the half of it for Use, if you do not correct the Error by the Lever.

The Adjustment may be made pretty exact by taking two Diameters of a straight-sided Land-object in the same Manner.

How to adjust the Sextant by any remarkable Land-object at a Distance.

It will often happen on a Survey, that no straight Line, either vertical or horizontal, nor no celestial Body, can be seen to adjust by. In this Case, pitch on some small remarkable Object at a Distance, as the tapering Top of a Hill, or Rock, or a small Hummoc, or Chimney-head, or detached Branch of a Tree, for this Purpose. To adjust by such an Object, set the Index to o; hold the Sextant horizontal; view the Object through the transparent Part, and its Image in the reflecting Part, of the Horizon-glass; and by the Lever, bring the Image directly below the Object in the Middle of the Line of Separation, so as neither appears to one Hand of the other, but that if a vertical Line is imagined to be drawn through any Point of the Image, it would pass through that same Point of the Object; then screw the

the Lever faſt, and the Horizon-glaſs is adjuſted. This Method of adjuſting may be ſufficient for common Purpoſes, but is not ſo very exact as the other Methods.

How to examine the Angle of the Sextant.

The Angle of the Sextant, meaſured by the Arc of the Limb comprehended between 0 and 120 may be verified, firſt, by adjuſting the Glaſſes as before directed, and then taking, at one Station, five or ſix horizontal Angles, comprehending a whole Circle round; add theſe Angles together, and if their Sum amounts to 360 Degrees exactly, the Angle of the Sextant and its Graduations may be concluded to be exact. The Objects that form theſe Angles muſt be very remarkable and ſharp, and all of the ſame apparent Height, to prevent Miſtakes in taking them; otherwiſe Inaccuracy in the Obſerver may be imputed to the Inſtrument.

Another way of examining the Angle of the Sextant is, by ſetting perpendicular in a level Ground three Poles, or Staves, between four and five Feet high, with Flags flying at each, ſo as to form a Triangle, whoſe greateſt Angle is leſs than 120 Degrees; let the Diſtance of the Poles from one another be half a Mile, or as much farther as they can be ſeen diſtinctly. After adjuſting the Sextant, take the three Angles of the Triangle very exactly, keeping the Center of the Sextant exactly on the Center of the Staff you obſerve at; and if the Sum of the Angles amounts preciſely to 180 Degrees, the Sextant may be con cluded to be good. The ſeveralGraduations, and their Subdiviſions, may be examined by the Vernier, as directed for the Theodolite.

How to examine the Accuracy of the two quadrantal Radij of an aſtronomical Quadrant.

PLATE I. FIG. XIII.

1. On a level Line ſet two Poles, A and B, perpendicular in the Ground, about a Mile, or more, from one another; let a Flag fly at the Top of each, to render them more conſpicuous; and let the Poles appear on ſome remarkable ſharp Part (C) of a remote Object; the farther the Object is, the better.

2. Put

2. Put the Quadrant on its Stand at B, with its Plane ſet horizontal, either by a ſpirit Level laid on it, or by a Carpenter's Level, and its Center right above the Hole where the Pole ſtood, and in the Poſition as at b. If the Stand cannot ſupport it horizontally, lay the Quadrant ſteady on a firm Table. Then, with the Index at o Deg. look through the Teleſcope, and turn the Quadrant till you ſee the Object C exactly at the Interſection of the Wires. Let the Quadrant be kept firm in that Poſition, and turn the Index to 90, and obſerve through the Teleſcope what Object the Interſection of the Wires bears on : if it bears on nothing remarkable, ſet up a Pole and Flag D, in that Direction, as far off as can be ſeen.

3. With the Index at 90, turn the Quadrant on its Center a Quarter round, till it is in the Poſition a, ſo that you ſee the Pole A through the Teleſcope at the Interſection of the Wires. Then keeping the Quadrant firm in that Poſition, turn the Index to o Deg. and if through the Teleſcope you ſee the Object D, exactly at the Interſection of the Wires, then the two Radij of the Quadrant, drawn through o and 90, are preciſely at right Angles, and the Axis of the Teleſcope parallel to the Radius it is faſtened to. If the Object D, does not appear exactly at the Interſection of the Wires, but on one Side of it; then half its Diſtance from the Interſection is the Error of the Quadrant; and is either in the Angle of the two Radij, or in the Axis of the Teleſcope, which is a Line ſuppoſed drawn through the Center of the Eye-glaſs and the Interſection of the Croſs-wires. It is much more likely to be in the Teleſcope than in the quadrantal Radij; and therefore to correct it, the Wires in the Teleſcope muſt be ſhifted by their proper Screws, half the Diſtance between the Object and Interſection of the Wires; and the Quadrant examined over again as before. If it is not right on this ſecond Examination, correct the Wire over again by the Screws, and examin the Quadrant a third Time; and if the Object D, and the Interſection of the Wires ſtill diſagree, conclude the Error to be in the Angle of the Radij between o and 90. Mark how much that Error is, and by it correct all future Obſervations. This Method is liable to a little Inaccuracy, if the Plane of the Quadrant is not made exactly horizontal.

How

How to examine and adjust an astronomical Quadrant.

1. Set up the Quadrant on the Margin of a Lake, close to the Edge of the Water, so that the Center of the Quadrant is just over the Water: (or, in a well-sheltered Bay when the Sea is smooth, right over the High-water Mark) set one Side of the Quadrant perpendicular by the Plummet; and measure the Height of the Center of the Telescope above the Surface of of the Water (or above the High-water Mark) in Inches and Parts of an Inch.

2. About half a Mile off (but not above a Mile) set a Pole straight up in in the Edge of the Lake (or on the High-water Mark) with a conspicuous sliding Cross-piece on it: let one Edge of the Cross-piece be set as high above the Surface of the Water (or High-water Mark) as the Center of the Telescope was, and about 2 Inches higher, if the Distance of the Stations is half a Mile; 4½ Inches higher if ¾ of a Mile, and 8 Inches higher if their Distance is one Mile; for the Height of the Tangent above the Surface of the Earth in these Arcs *.

3. Set the Index of the Quadrant to 0 Degrees, or exactly to the horizontal Radius, and direct the Telescope to the Pole: if, while the vertical Wire runs along the Pole, the horizontal Wire runs exactly along that Edge of the Cross-piece which was set as high as the Center of the Telescope, the Quadrant and Telescope are right. If the horizontal Wire does not coincide

* The Height of a Tangent to the Extremity of any small Arc above the other Extremity of that Arc, is a third Proportional to the Diameter of the Earth and the Length of the Arc. For, imagine a Diameter drawn to one End of the Arc, and produced till it meets a Tangent drawn to the other End; then, by Eucl. B. III. Prop. 36. the Rectangle of the Diameter (in this Case the same with the Secant) and produced Part is equal to the Square of the Tangent. If the Diameter is called d, the produced Part p, the Tangent t, and the Arc a; the two equal Rectangles will be expressed thus $d \times p = t \times t$: and because a small Arc and its Tangent are so nearly equal, that one may be assumed for the other; in place of $t \times t$, substitute $a \times a$, and it will be $d \times p = a \times a$. When two Rectangles are equal, their Sides are reciprocally proportional (Eucl. B. VI. Prop. 14.) therefore $d : a :: a : p$; that is, as the Diameter is to any small Arc, suppose one Minute, so is that Arc to the Height of the Tangent above it. By this Proportion the Numbers in the Text were found, supposing the Diameter of the Earth to be 41798117 Feet.

in that Manner, ſhift it by the proper Screws till it does ſo, and the quadrantal Angle and Axis of the Teleſcope will then be right.

The Screws for ſhifting the Wires are on the Teleſcope, at the common Focus of the Object and Eye-glaſs. If you ſee the Edge of the Croſs-piece below the horizontal Wire, eaſe the upper Screw, and ſcrew in the lower one *; if the Edge of the Croſs-piece appears above the horizontal Wire, eaſe the lower Screw, and ſcrew in the upper one, till the horizontal Wire coincides with the Edge of the Croſs-piece; and the Axis of the Teleſcope is then right.

This Adjuſtment may be verified, by placing the Quadrant where the Pole ſtood, and the Pole where the Center of the Quadrant was, and the Axis of the Teleſcope, and the Edge of the Croſs-piece, at the ſame Height above the Surface of the Water as at firſt; then make the Radius of the Quadrant perpendicular by the Plummet, ſet the Index to 0 Degrees, look through the Teleſcope, and if the horizontal Wire and Edge of the Croſs-piece coincide again, the Angle of the Quadrant and Axis of the Teleſcope are certainly right. If any Difference is perceived, move the horizontal Wire, by its Screws, half that Difference, and it will be rectified.

The Graduations of a Quadrant may be examined in the ſame Manner as thoſe of the Theodolite above mentioned, by applying the Vernier to the ſeveral Degrees, and Parts of a Degree.

How to adjuſt Bird'*s twelve-inch Quadrant, as made before the Year* 1751.

For performing this, there are three principal Parts to be adjuſted, 1. The Pillar is to be ſet perpendicular to the Horizon. 2. One Side of the Quadrant is to be ſet perpendicular. 3. The Axis of the Teleſcope, or Line of Sight, is to be made parallel to the horizontal Radius of the Quadrant.

* As the Teleſcope inverts Objects, what appears below the horizontal Wire is really above it, and therefore, ſcrewing in the lower Screw, which puſhes up the Wire, will bring it nearer the Object. The contrary is true of the upper Screw.

1. *To set the Pillar perpendicular.*

1. Set the Brass Pedestal on a firm Support. An iron-bound Cask, with a Free-stone, or thick Slate, kept on purpose to cover the Top of it, is as good and convenient for a Surveyor as any thing. Then hang the Quadrant on the Pillar, and by the Spirit-level and Screws in the Feet, the Pillar may be set perpendicular in the following Manner. Turn the Quadrant till the upper Side is parallel to two opposite Feet, and with one Hand unscrew that Screw of the Foot toward which the Buble inclines, and, at the same time, with the other Hand screw in the opposite Screw, till the Buble rests equally between the two Marks, or Scratches, on the glass Tube: then turn the Quadrant, horizontally, half round; and if the Buble does not rest exactly between the Scratches as before, by unscrewing that Screw towards which the Buble inclines, and at the same screwing in the other, make the Buble move over half the Space in the Tube by which they differ, and remember toward which End it inclines. Then turn the Quadrant one Quarter round, till its upper Side is parallel to the other two Feet; and if the Buble does not rest in the same Place, with respect to the Scratches, as it did before, make it do so by the Screws in the Feet; and then bring it equally between the Scratches, by lowering that End of the Tube toward which the Buble stood, or raising the other End. For doing this, there are three Screws at each End of the Tube. To lower one End, slacken the right and left, or pushing, Screws, and screw in the Middle Screw, till the Buble rests equally between the two Scratches: then the Pillar and Level are right, or nearly so. To prove if they are exact, or to make them so, if they are not; begin the same Process over again, by first turning the Quadrant half round, and if the Buble rests not equally between the Scratches, move it half the Difference by the Screws in the Feet; and then quarter round, and adjusting the Level first so far by the Screws in the Feet, and next by raising or lowering one End of the Tube as before directed; till you get the Buble to stand in the same Part of the Glass when the Quadrant is turned half round and quarter round; and the Pillar and Level will then be right.

Let it be adverted here, that in turning the Screws of the Feet, the Feet themselves will be apt to shift insensibly on the Support; which, if not prevented, will render this Part of the Adjuſtment troubleſome and tedious. To guard againſt this, ſmall Grooves, or Furrows, the Width of the Screw-ends ſhould be ſunk a little in the Stone, or Support, and the Screws placed in theſe Grooves; or ſome other equivalent Contrivance to keep the Feet from ſhifting.

2. *To make one Side of the Quadrant perpendicular.*

This is done by making the Plumb-line hang firſt over the fine Point at the Arrow-head, on the center Plate; and next to cover the other fine Point on the Arch below.

It is made to hang over the upper Point, by ſcrewing the elaſtic Bit of Braſs (over which the Wire of the Plummet goes) out, or in, by its upper Screw-nail. It is made to hang over the lower Point, by the adjuſting Screw within the Quadrant, which is turned by a round brotched Braſs-button on its Head.

The Plummet ſhould be made to hang in a ſmall Cup, or Veſſel, filled with Water, to make it more ſteady, and reſt ſooner: and if the Veſſel is faſtened by an Arm to the Pillar of the Pedeſtal, ſo as to move round along with the Quadrant, it will be the more convenient.

The Plumb-line ſhould be made to hang very near the Plane of the Quadrant, at the lower Arrow, but not to touch it: which is done by preſſing with the Hand the elaſtic Bit of Braſs before mentioned, a little backward or forward.

3. *To adjuſt the Teleſcope, or to make its Axis horizontal, when the Index is at 90 Degrees.*

Set the Index to 90, keeping the Plummet and Level right: then direct the Teleſcope to ſome diſtant Object above a Mile off, (but the farther the better) till you ſee a remarkable Part of it exactly at the horizontal Wire: then take off the Quadrant from the Pillar, by unſcrewing the two large Iron-ſcrews; and invert the Quadrant, by ſcrewing it on again with the

Arch

Arch uppermoſt: then ſcrew to the Arch of the Quadrant a crooked Bit of Braſs, with a Notch in it, as near the Arrow as you can, and hang the Plummet over that Bit of Braſs, moving it to one Side or the other, till the Line covers the Point on the Arch; and if it does not then cover the Point on the Center-plate alſo, make it do ſo by the Screws in the Feet: then look through the Teleſcope; and if the horizontal Wire cuts the ſame Part of the Object it did before Inverſion, the Teleſcope is right. If the Object appears higher or lower, the Wire in the Teleſcope muſt be moved half the Difference, by the two Steel-ſcrews near the Eye-end of the Teleſcope: if the Object appears higher than the horizontal Wire, eaſe the lower Screw, and ſcrew in the upper one; if the Object appears below, eaſe the upper Screw, and ſcrew in the lower one; till the horizontal Wire cuts the diſtant Object at half the Difference it did before inverting it: then it is adjuſted for Obſervation.

The Wire in the Teleſcope that is applied to the Limb of the Sun, in taking its Altitude, ought to be exactly horizontal when the Plane of the Quadrant is perpendicular. To find if it is ſo: adjuſt the Quadrant by the Level and Plummet, as before directed; then point rhe Teleſcope to ſome ſmall diſtinct Object at a Diſtance, as the Top of a Rock, a Chimney-head, &c. and remark a particular Part of it which the Wire croſſes: turn the Quadrant a little about gently, towards one Side; and if all Parts of the Wire paſs over the ſame Part of the Object, the Wire is truly horizontal. But if one End of the Wire croſſes the Object higher, or lower, than the other, preſs the two ſmall Screws that govern the Wire between your Finger and Thumb, and at the ſame Time turn them ſide-wiſe, but in oppoſite Directions, till, upon looking again, and turning the Quadrant, you find all Parts of the Wire paſs over the ſame Part of the Object; then it is truly horizontal.

Theſe Adjuſtments may ſeem difficult and tedious at firſt; but they are neceſſary: and by practiſing two or three Times within Doors, till a right way of handling the ſeveral Parts of the Quadrant becomes familiar, they will be found much eaſier than may at firſt be imagined.

When

When a Quadrant of this Sort, made by a good Artiſt, has been firſt verified and adjuſted, the ſimpleſt and eaſieſt way of examining a Theodolite or *Hadley*'s Quadrant is, firſt to take an Angle between any two ſmart Objects with the verified Quadrant, and then with the Inſtrument under Examination; and if they differ, to aſcribe it to the latter.

How to examine a magnetic Needle.

Firſt ſet the Box level; by raiſing, or lowering, one Side of it, till each End of the Needle, when it plays from Side to Side, runs along the Circumference of the graduated Circle in the Box; and both Ends of the Needle, when at reſt, point equally high on it. Then turn the Box gently, till one End of the Needle reſts at the Beginning of the Graduations exactly, and if the other End points exactly to 180°, the oppoſite Graduation, the Needle is ſo far right centered. Next turn the Box 90 Degrees round, and if the Ends of the Needle then point preciſely to the oppoſite Degrees, then the Needle is truly centered. Each Degree may be tried in the ſame Manner.

Obſerve likewiſe if the Cap in the Center of the Needle is ſmall and tapering in the Inſide, or large and ſpherical: if it is a Portion of a large Sphere, the Point of the Steeple will be apt to reſt on different Parts of it, and by that Means vary the Center of the Needle, and cauſe it to point wrong.

CHAP.

CHAP. V.

Meridional Problems by the Stars; and Variation of the magnetic Needle by the Sun.

How to fix a meridian Line by a Star, when it can be ſeen at its greateſt Elongation on each Side of the Pole.

PROVIDE two Plummets. Let one hang from a fixt Point: let the other hang over a Rod, ſupported horizontally about 6 or 8 Feet above the Ground, or Floor in a Houſe, and ſo as to ſlide occaſionally along the Rod: let the moveable Plummet hang four or five Feet northward of the fixt one. Some time before the Star is at its greateſt Elongation, follow it, in its Motion, with the moveable Plummet, ſo as a Perſon a little behind the fixt Plummet may always ſee both in one, and juſt touching the Star. When the Star becomes ſtationary, or moves not beyond the moveable Plummet, ſet up a Light on a Staff, by Signals, about half a Mile off, preciſely in the Direction of both the Plummets. Near twelve Hours afterwards, when the Star comes towards its greateſt Elongation on the other Side of the Pole, with your Eye a Foot or two behind the fixt Plummet, follow it with the moveable Plummet, till you perceive it ſtationary as before: mark the Direction of the Plummets then by a Light put up preciſely in that Line: take the Angle between the Places of the two Lights with *Hadley*'s Quadrant, or a good Theodolite, the Center of the Inſtrument at the fixt Plummet; and a Pole ſet up in Day-light, biſſecting that Angle, will be exactly in the Meridian ſeen from the fixt Plummet.

This Obſervation will be more accurate if the Eye is ſteadied by viewing the Plumb-lines and Star through a ſmall Slit in a Plate of Braſs ſtuck upright on a Stool, or on the Top of a Chair-back.

This Problem depends on no former Obſervations whatever: and as there is nothing in the Operation, or Inſtruments, to affect its Accuracy, but what any one may eaſily guard againſt, it may be reckoned the ſureſt Foundation for all ſubſequent celeſtial Obſervations that require an exact Meridian Line. The only Diſadvantage is, that it cannot be performed but in Winter, and when the Stars may be ſeen for 12 Hours together; which requires the Night to be about 15 Hours long.

How to fix a Meridian-line by two circumpolar Stars that have the same Right-ascension; or differ precisely 180 *Degrees.*

Pitch on two Stars that do not set, and whose Right-ascensions are the same, or exactly 180 Degrees different; take them in the same vertical Circle by a Plumb-line, and at the same Time let a Light be set up in that Direction, half a Mile, or a Mile off, and the Light and Plummet will be exactly in the Meridian.

In order to place a distant Light exactly in the Direction of the Plumb-line and Stars, proceed in the following Manner. Any Night before the Observation is to be made, when the two Stars appear to the Eye to be in a vertical Position, set up a Staff in the Place near which you would have the Plummet to hang; and placing your Eye at that Staff, direct an Assistant to set another Staff upright in the Ground, 30 or 40 Yards off, as near in a Line with the Stars as you can. Next Day, set the two Staffs in the same Places; and in their Direction, at the Distance of a Mile, or half a Mile northward, cut a small Hole in the Ground, for the Place where the Light is to stand at Night; and mark the Hole so, that a Person sent there at Night may find it.

Then chuse a calm Night, if the Observation is to be made without Doors; (if it is Moon-light, so much the better) and half an Hour before the Stars appear near the same Vertical, have a lighted Lanthorn ready tied to the Top of a Pole, and set upright in the distant Hole marked for it the Night before; and the Light will then be very near the Meridian, seen from the Place marked for the Plummet. At the same Time, let another Pole, or Rod, 6 or 8 Feet long, be supported horizontally where the Plummet is to hang, six or seven Feet from the Ground, and hang the Plumb line over it, so as to slip easily along it either to one Hand or the other, as there may be Occasion (or tie a Staff firmly across the Top of a Pole six or seven Feet long; fix the Pole in the Ground, and make the Plumb-line hang over the Cross-staff.) Let the Weight at the End of the Line be pretty heavy, and swing in a Tub of Water, so as it may not shake by a small Motion of the Air. Then shift the Plumb-line to one Hand, or the other, till one Side of the Line, when at Reſt, cuts the Star which is neareſt the Pole of the World, and the Middle of the Light together: as that Star moves, continue moving the Plumb-line along the Rod, ſo as to keep it always on the Light and Star, till the other Star comes to the ſame Side of the Plumb-line alſo; and then the Plummet and Light will be exactly in the Meridian.

There are not two remarkable Stars near the North Pole, with the ſame Right-aſcenſion preciſely, or juſt a Semicircle's Difference: but there are three Stars that are very nearly ſo, viz. the Pole-ſtar, ε in Urſa Major, and γ in Caſiopeia. If either of the two laſt, particularly ε, are taken in the ſame Vertical with the Pole-ſtar, they will then be ſo very near the Meridian, that no greater Exactneſs need be deſired for any Purpoſe in Surveying. At London γ is about 1′ Weſt of the Meridian then; and ε much nearer it, on the Weſt Side likewiſe. Stars towards the S. Pole proper for this Obſervation are, γ, in the Head of the Croſs; α, in the Foot of the Croſs; and α, in the Head of the Phenix.

How to find a Meridian-line by a circumpolar Star, when it is at its greateſt Elongation from the Pole.

1. Find the Latitude of the Place in which you are to obſerve the Star.

2. Pitch on a Star whoſe Declination is known, and calculate its Azimuth from the North (or elevated Pole) when its Elongation from the Pole is greateſt.

3. Find at what Time it will be on the Meridian the Afternoon you are to obſerve; and ſix Hours after that, it will be at its greateſt Elongation.

4. At that Time, as near as you can, by a Plummet, as before directed, ſet up a Light half a Mile, or a Mile off, in the Direction of the Plumb-line and Star, and mark the Place of the Light in the Ground, and alſo of the Plumb-line.

5. Next Day ſet up a Pole where the Light ſtood, with a Flag flying at it. Then with a Theodolite, or *Hadley*'s Quadrant, ſet the Index to the Degree

and Minute of the Star's Azimuth from the North, found before; direct, by waving to one Hand or the other, an Assistant to set up a Staff on the same Side of the Pole with a Flag as the Pole of the World was from it, so as at the Plumb-line these two Lines may make an Angle equal to the Azimuth of the Star, and the Plumb-line and Staff will then be in the Meridian.

When any Star is descending, it is on the West-side of the Pole of the World; while it ascends, it is on the East-side of it.

The Pole of the World is always between the Pole-star and Ursa-major: so that when Ursa-major is W. or E. of the Pole-star, the Pole of the World is W. or E. of it likewise.

To find the Azimuth of a Star from the elevated Pole, when it is at its greatest Elongation, use the following Proportion.

As Radius
Is to the Co-sine of the Latitude of the Place,
So is the Co-tangent of the Star's Distance from the Pole,
To the Co-tangent of its Azimuth from the Meridian.

On the N. Side of the Equator, the Pole-star is the most convenient for this Observation; for the Time when it* is at its greatest Elongation from the Pole, may be known sufficiently near by the Eye; by observing when ε in Ursa-major and γ in Casiopeia appear to be in a horizontal Line, or parallel to the Horizon; for that is the Time. Or, the Time may be found more precisely by making fast a small Piece of Wood along the Plumb-line when extended, with a Cross-piece at right Angles to the Top of the upright Piece, like the Letter T; when the Plummet is at Rest, and both Stars are seen touching the upper Edge of the Cross-piece, then they are both horizontal. It is another Conveniency in making use of this Star, that it changes its Azimuth much slower than other Stars, and therefore affords more Time to take its Direction exact.

On the South-side of the Equator, the Head of the Cross is the most convenient for this Observation, being nearest to the S. Pole; and the Time of its greatest Elongation when it appears in a horizontal Line with the Foot of the

the Crofs, or the Head of the Phenix; the Pole of the World is between it and the laft of thefe Stars.

To find when any Star will come to the Meridian, either in the South or North. Find the Star's right Afcenfion, in Time, from the moft correct Tables, alfo the Sun's right Afcenfion for the Day and Place propofed; their Difference will fhew the Difference between their Times of coming on the Meridian in the South, or South of the Pole; which will be after Noon if the Sun's right Afcenfion is leaft, but before Noon if greateft. Eleven Hours 58 Minutes after the Star has been on the Meridian South of the Pole, it will come to the Meridian North of it, or below the Pole.

Given the Latitude of the Place, and the Declinations and right Afcenfions of two Stars in the fame vertical Line; to find the horizontal Diftance of that Vertical from the Meridian; the Time one of the Stars will take to come from the Vertical to the Meridian; and the precife Time of the Obfervation.

CASE I.

When the two Stars are northward of the Zenith.

PLATE I. FIG. XV.

Let Z P O be a Meridian, Z the Place of Obfervation, H O its Horizon, and Z V a vertical Circle paffing through two known Stars, s and S; P the Pole, E Q the Equator, P s D and P S d Circles of Declination (or right Afcenfion) paffing through thefe Stars: then is Z P the co. latitude of the Place, P s and P S the co. declination of the two Stars refpectively, and the Angle s P S the neareft Diftance of their Circles of right Afcenfion; V O the Arc of the Horizon between the vertical Circle and the Meridian; and d Q the Arc of the Equator between the Star S and the Meridian. When, in the Triangle P Z s, the Angles P Z s and s P Z (meafured by the Arcs V O and d E) are found, the Problem is folved.

SOLUTION.

1. Begin with the oblique-angled Triangle P s S; in which are given two Sides P s and P S, the co. declinations of the two Stars respectively, and the included Angle S P s; which Angle is the Difference of their right Ascensions when it is less than 180 Degrees; but if their Difference is more than 180°, then the Angle S P s is equal to the lesser Right-ascension added to what the greater wants of 360 Degrees. From hence find the Angle S s P by the following Proportions.

As Radius
Is to the co. sine of the given Angle (S P s)
So is the Tan. of the Side opposite the required Ang. (P S)
To the Tan. of an Angle, which call M.

M. is like the Side opposite the Angle sought, if the given Angle is acute; but unlike that Side, if the given Angle is obtuse *.

Take the Difference between the Side (P s) adjacent the required Angle and M; call it N. Then,

Sine N : Sine M : : Tan. of the given Angle (S P s) : Tan. of the required Angle (S s P) which is like the given Angle if M is less than the Side (P s) adjacent to the required Angle; but unlike the given Angle if M is greater than P s.

2. Next in the oblique-angled Triangle P s Z there are given two Sides, P Z the co. latitude of the Place of Observation; P s, the co. declination of the Star s; and the Angle P s Z opposite to one of them, which is the Supplement of P s S (last found) to 180°: from thence find the Angle P Z s opposite the other Side, by the following Proportion.

Sine of P Z : *Sine* P s Z : : *Sine* P s : *Sine* P Z s. *either acute or obtuse.*

This Angle P Z s, measured by the Arc of the Horizon V O, is therefore equal to the horizontal Distance of the Vertical of the two Stars from the Meridian.

* Two Arcs, or Angles, are said to be like, or of the same Kind, when both are less than 90°, or both more than 90° : but are said to be unlike, when one is greater and the other less than 90°: and are made like, or unlike, to another, by taking the Supplement to 180° of the Arc, or Angle, produced in the Proportion, in place of what the Proportion brings out.

Meridian. Let the Direction of the Vertical be taken by a Plumb-line and distant Light, as before directed, or by two Plumb-lines, and marked on the Ground. Next Day, the Degrees and Minutes in the Arc V O may be added to it by *Hadley*'s Quadrant, and a Pole set up there, which will be in the Direction of the Meridian from the Pumb-line.

3. Last, in the same Triangle P s Z, find the Angle s P Z between the given Sides, by the following Proportions.

As Radius
Is to the Tan. of the given Angle (P s Z)
So is the co. s. of the adjacent Side (P s)
To the co. t. of M.

M is acute, if the given Angle and its adjacent Side are like; but obtuse, if the given Angle and the adjacent Side are unlike.

As the co. t. of the Side adjacent to the given Angle (P s)
Is to the co. t. of the other Side (P Z)
So is the co. s. M
To the co. s. of an Angle, which call N.

N is like the Side opposite the given Angle, if that Angle is acute; but unlike the Side opposite the given Angle, if that Angle is obtuse.

Then the required Angle s P Z is either equal to the Sum or Difference of M and N, as the given Sides are like or unlike.

The Angle s P Z, thus found, added to s P S, and their Sum subtracted from 180° will leave the Angle d P Q, or the Arc d Q that measures it, which is the Arc of the Equator the Star S must pass over in coming from the Vertical, Z V, to the Meridian. Which converted into Time, and measured by a Clock, or Watch, beginning to reckon the precise Moment that a Plumb-line cuts both Stars, will shew the Hour, Minute, and Second that S is on the Meridian.

Find, by the right Ascension of the Star and Sun, at what Time that Star should come to the Meridian in the North the Night of the Observation; subtract from it the Time the Star takes from the Vertical to the Meridian, and the Remainder, corrected by the Sun's Equation, will be the Time when the two Stars were in the same Vertical.

The

The lowest of the two Stars comes soonest to the Meridian below the Pole; the highest of them comes soonest to that Part of the Meridian which is above the Pole.

The nearer in Time one of the Stars is to the Meridian when the Observation is made, it is the better: for then an ordinary Watch will serve to measure the Time sufficiently exact. It is still more advantageous if one of them is above the Pole when the other is below it.

The nearer one of the Stars is to the Pole, and the farther the other is from it, the more exact will this Observation be; because the Change of the Vertical will be the sooner perceived. For this Reason, in North Latitudes, Stars northward of the Zenith are preferable to those that are southward of it.

If the two Stars are past the Meridian when they are observed in the same Vertical, then the Arc d Q gives the Time S took to come from the Meridian to the Vertical; and must be added to the Time when that Star was on the Meridian to give the Time of the Observation: and the Arc of the Horizon V O must be marked on the Ground on the Side of the Vertical contrary to what it would have been in the foregoing Supposition; that is, eastward *below* the Pole, and westward *above* it.

When two Stars come to the vertical Line near the Meridian, it may be difficult to judge on which Side of it they are at that Time; for determining this, the following Rules may serve.

The right Ascension of two Stars may be either each *less*, or each *more* than 180 Degrees, or *one more* and the *other less*.

When the right Ascension of each of the Stars is *either less*, *or more*, than 180 Degrees, they will come to the same Vertical on the *East-side* of the Meridian when the Star with the *greatest* right Ascension is the *lowest*; but on the *West* Side of the Meridian when it is *highest*.

When

When the right Ascension of one of the Stars is more than 180 *Degrees, and that of the other less.*

If the right ascension of the highest is less than 180°, but greater than the Excess of the other's right Ascension above 180°, then they come to the Vertical on the *East Side* of the Meridian. But if the right Ascension of the higher Star is less than that Excess, they come to the Vertical on the *West Side* of the Meridian.

If the right Ascension of the higher Star is *more* than 180 Degrees, and that Excess is *less* than the right Ascension of the lower Star, then they come to the Vertical on the *West Side* of the Meridian; but if the Excess of the higher Star's right Ascension above 180° is *more* than the right Ascension of the lower Star, then they come to the same Vertical on the *East Side* of the Meridian.

CASE II.

When the two Stars are in the same Vertical southward of the Zenith.

PLATE I. FIG. XVI.

When two Stars are observed in the same vertical Line *southward* of the Zenith (or toward the depressed Pole) the Operations and Solutions are nearly the same as in Case 1. For let P Z O be a Meridian, Z the Place of Observation, O H its Horizon, Z V a vertical Circle passing through the two Stars S and s; P the Pole, Q E the Equator, P D and P d two Circles of Declination (or right Ascension) passing through the two Stars respectively: then is Z P the co. latitude of the Place, P S and P s the co. declination of the two Stars respectively, the Angle S P s the Difference of their right Ascensions, the Angle S Z Q (or O V the Arc of the Horizon which measures it) the Distance of the Vertical from the Meridian; the Angle s P Z (or d Q which measures it) the Arc of the Equator, which s must pass over from the Vertical to the Meridian, which converted into Time, and measured by a Watch, will shew when s is on the Meridian;

3 and

and ſubtracted from the calculated Time that the Star ſhould come to the Meridian, will (when corrected by the Sun's Equation) give the true Time of the Obſervation: S P s is the Triangle to begin the Solution with; and in the Triangle s P Z, the Angles s P Z and s Z P, when found, will give the Solution of the Problem, as in Caſe 1. For the Supplement of s Z P to 180° is the Angle V Z O (or its Meaſure O V) the horizontal Diſtance of the Vertical from the Meridian; the Angle s P Z (or its Meaſure d Q) is the equatorial Diſtance of the Vertical from the Meridian: for all which the Solution in Caſe 1. properly applied, will ſerve.

On the South Side of the Zenith, when the *higheſt* of the two Stars has the *leaſt* right Aſcenſion, they come to the ſame Vertical on the *Eaſt Side* of the Meridian; but when the higheſt Star has the *greateſt* right Aſcenſion, they come to the ſame Vertical on the *Weſt* Side of the Meridian.

How to fix a Meridian-line by the Equality of the Time of Aſcent and Deſcent of a circumpolar Star toward the Meridian.

For performing this Problem it is neceſſary to have a good Clock, or a good Watch, in the Room where the Obſervation is made, or in a Room adjoining to it. The Clock-caſe ſhould be ſet perpendicular by a Plummet, and the Back of it ſcrewed firm to wooden Wedges, or to Holdfaſts of Iron, driven tight in a Brick, or Stone Wall; or to an upright maſſy Poſt, or Beam, ſet two or three Feet into the Ground below, and ſupported higher up by inclining Stays on two or three Sides: for if a Clock is not fixed firm, but ſet up againſt an ordinary Wainſcoting, or is liable to any Shake by Perſons walking on the Floor, it will never be made to go exactly. There ſhould likewiſe be ſome Contrivance to prevent the lengthening or ſhortening of the Pendulum by Heat and Cold. When the Clock has been placed perpendicular and immoveable, then it muſt be exactly regulated to keep equal Time, which may be done in the following Manner.

Take notice of any Star that will be hid from your Sight, any Time of the Night, by a Chimney-head, the Corner of a Houſe, or a Poſt ſet firm in the Ground for that Purpoſe. Make a ſmall Hole in a Window-ſhutter, or a Door, or in a thin Plate of Metal fixed in either of them, through which

which the Star may be ſeen. A little before the Star will be hid, ſtop your Clock, or Watch, with the Second-hand at 60; write down the Hour and Minute at which it was ſtopt; continue looking to the Star through the Hole; and the Inſtant the Star diſappears behind the Chimney-head, or other Object, ſet the Clock or Watch agoing. If a Watch is made uſe of, it may be held in your own Hand, with your Finger at the Stopper, while you look to the Star through the Hole. If it is a Clock, you muſt have an Aſſiſtant ready to let go the Pendulum the Moment you call out, *Now.* Next Night, about the ſame Time, look through the ſame Hole, and watch the coming of the ſame Star toward the ſame Object, and the Moment it diſappears, ſtop the Clock, or Watch, till you write down the Hour, Minute, and Second at which it was ſtopt; and if the Time between the two Obſervations ſhewn by it, amounts preciſely to 23 Hours, 56 Minutes, 4 Seconds, the Clock, or Watch has kept Time exactly. If the Time ſhewn by it is more than that, then it goes ſo much faſter in a Day than it ought to do: if the Time ſhewn is leſs than that, then it goes ſo much ſlower than it ſhould do to keep equal Time: and the Error in a Day ſhould be noted down, ſo as to be allowed for afterwards, in caſe the Clock or Watch cannot be brought preciſely to equal Time, but may fall ſhort, or exceed it, by a certain Number of Seconds each Day. If there is Time enough, it is better to let ſeveral Days, or a Week, intervene between the two Obſervations, and for each Day elapſed, to allow 3 Minutes 56 Seconds for the Acceleration of the Star's Revolution. That is, if the Clock or Watch goes equally, the Star will diſappear behind the Object 3 Minutes 56 Seconds ſooner the ſecond Night, or in one Day, than it did the firſt; in two Days, it will diſappear 7 Minutes 52 Seconds ſooner; the fourth Night (or in three Days) 11 Minutes 48 Seconds ſooner by the Clock or Watch than the firſt Night; and ſo in Proportion for any Number of Days; or, a little more preciſely, according to the following Table.

Days.	M.	S.	3ds.
1.	3..	55..	54
2.	7..	51..	48
3.	11..	47..	42
4.	15..	43..	36
5.	19..	39..	30
6.	23..	35..	24
7.	27..	31..	18
8.	31..	27..	12
9.	35..	23..	6
10.	39..	19..	—

When the Clock has been exactly regulated to go equal Time, then pitch on a Star which does not ſet, and is neither very near the Pole, nor too far from it. If it is very near, it will change its Vertical ſlowly, and the preciſe Time of its coming to it will not be ſo eaſily diſtinguiſhed: if it is too far from the Pole, it will come to the higheſt Part of its diurnal Circle, too near the Zenith to be obſerved accurately at the Plumb-line. Some Star in the great Bear may be the moſt convenient. Hang two Plummets with heavy Bobs, ſwinging in Water, near a large open Window, or Door, facing the North, and as nearly in the Direction of the Meridian as you can; let the Plumb-line next your Eye be fixt, and the other moveable at pleaſure from one Hand to the other. The Eye ſhould not be too near the fixt Line, nor the fartheſt Line of too ſmall a Size; for then they will appear miſted, tranſparent and ill-defined, and the preciſe Time of the Star's Appulſe will not be known; but the Diſtance of the Eye and the Thickneſs of the Lines ſhould, by previous Trial, be ſuited to diſtinct Viſion. Stop the Clock at any Hour, with the Minute and Second Hands at 60, and write down the Hour they point out. Near the Time that the Star comes in the Direction of both Plumb-lines, let an Aſſiſtant hold back the Pendulum of the Clock, ſo as to be ready to let it go when you call to him: keep both Plumb-lines in one from your Eye, and the Moment the Star touches one Side of them, call out, *Now*; that your Aſſiſtant may immediately let go the Pendulum of the Clock. Take care the Plummets be not ſhifted in the leaſt; and, near twelve Hours afterward, when the Star next approaches near to the Direction of the Plumb-lines, take them in one from your Eye, and let your Aſſiſtant watch the Second-hand of the Clock, counting each Second audibly by the Beats; and the Moment you ſee the Star at the ſame Side of the Plumb-lines as in the firſt Obſervation, call out, *Now*: your Aſſiſtant muſt immediately call out the laſt ſecond he counted, ſo as you may know it and mark it down, while he looks to the Minute and notes it down; then write down the Hour, Minutes and Seconds all together. In the ſame Manner, near twelve Hours thereafter, when the Star approaches near to the Plumb-lines on the other Side of its diurnal Circle, take the Plumb-lines in one with your Eye; let your Aſſiſtant count the Seconds by the Beats of the

 Clock,

Clock, and the Moment the Star touches the ſame Side of the Plumb-line as before, call out, *Now*; that he may repeat, audibly, the Second he counted laſt, which you muſt note down, while he looks the Minute, and notes it down. If the Time of the Star's Aſcent on one Side of the Plumb-lines is exactly equal to the Time of its Deſcent on the other, then the Plumb-lines hang preciſely in the Meridian. If theſe Times are unequal, ſhift the moveable Plummet a little toward that Side where the Star took the longeſt Time; and begin the ſame Operations again, and continue them till you find the Star takes equal Time on each Side of the Plumb-lines.

In Obſervations of this kind, where the Time is required to be known, it may be managed without an Aſſiſtant, after ſome Practice. For one may catch the Second from the Clock by his Eye a little before the Time of Obſervation, and continue counting the Seconds or Beats by the Ear, while his Eye watches the Star; and the Inſtant it is hid, he ſhould repeat the laſt Second till he ſees the Minute on the Clock, and then write down both together. Or, begin to count the Seconds by the Ear from the Moment of the Obſervation, till you can ſee the Time ſhewn by the Clock, from which ſubtract the Number of Seconds you counted, and you will have the Time of the Obſervation according to the Clock.

If the Pendulum of the Clock is contrived to keep of an equal Length, notwithſtanding the Variations of Heat and Cold; if it is not wuond up between the Obſervations, or does not ſtop in the Time of winding; and if it is well regulated immediately before the Obſervations begin, and again verified by the diurnal Revolution of a Star when they are over; a very exact Meridian Line may be found this way. But ſuch Clocks are rarely to be met with; the Operation is often tedious; and is practicable only in Winter, and when the Sun does not ſet later than about half an Hour after four; for the Stars are ſeldom ſeen in Winter diſtinctly, till the Sun is near an Hour and a half ſet.

In this Operation, a Watch is managed much in the ſame Manner as a Clock; only, when it is to be ſtopt during the Obſervation, the Obſerver may do it himſelf, by holding the Watch in both Hands, with his Finger at the Stopper. When the Time is to be noted without ſtopping the Watch, then, near the Appulſe of the Star to the Plumb-lines, an Aſſiſtant muſt count the Seconds by the Motion of the Second-hand; and, when the Obſerver calls out, *Now*, muſt repeat audibly the laſt Second he counted, that the Obſerver may note it down, while the Aſſiſtant looks to and notes the Minute.

Though other Methods of finding a Meridian-line than thoſe above, except the laſt, have been generally practiſed and recommended by Aſtronomers, yet it will be evident to Theoriſts, eſpecially ſuch as are accuſtomed to celeſtial Obſervations, that when the Places of the Stars are exactly known, this important Problem may be performed more eaſily, and with more Certainty, by means of a Plummet, *which adjuſts itſelf*, than by any other Inſtruments, or Obſervations whatever on the Sun. For it is well known, that in ſolar Obſervations, the Air, the Object, the Inſtruments, the Obſerver, may each occaſion ſome Inaccuracy, which the moſt Expert cannot altogether avoid; but they are either quite removed, or eaſily prevented, in our way, by the moſt inexperienced Performer.

The polar Diſtances and right Aſcenſions of theſe ſix Stars in 1770, were as follows: + ſignifies increaſing, — decreaſing.

	Char. and Mag.	Diſtance from the Pole.	Variation in 10 Years.	R. Aſcenſion in Degrees.	Increaſes in 10 Years.	R. Aſcenſion in Time.	Increaſes in 10 Years.
Northern Stars.		D. M. S.	′ ″	D. M. S.	′ ″	H. M. S.	′ ″
Pole Star	α. 2	0. 1. 56	—3. 17	10. 44. 0	25. 0	0. 42. 56	3. 17
Firſt in Tail of the G. Bear	ε. 2	32. 47. 0	+3. 17	190. 45. 5	7. 0	12. 43. 0	0. 27
Middle of Caſiopeia's Chair	γ. 3	30. 32. 20	—3. 17	10. 27. 16	9. 0	0. 41. 48	0. 35
Southern Stars.							
Head of the Croſs . . .	γ. 2	19. 9. 0	—3. 18	184. 29. 42	8. 3	12. 19. 0	0. 40
Foot of the Croſs	α. 1	28. 10. 0	+3. 20	183. 29. 0	8. 3	12. 14. 0	0. 32
Head of the Phenix . .	α. 2	46. 30. 0	+3. 20	3. 43. 15	7. 30	0. 15. 0	0. 30

PROB.

How to find the Sun's Amplitude at Rising, or Setting, and from thence the Variation of the magnetic Needle.

Make the Needle level with the graduated Circle in the Box. Then, when the Sun's lower Edge is a Semidiameter above the Horizon, take the Bearing of its Center (from the N. or S. which ever is nearest) through the Sights, making the Thread bissect the Sun's Disk, and that subtracted from 90°, will be the Sun's magnetic Amplitude, or Distance from the E. or W. Points by the Needle.

Next, calculate the Sun's true Amplitude for that Day, by the following Proportion.

As the co-sine of the Latitude,
Is to Radius,
So is the Sine of the Sun's Declination at Setting or Rising,
To the Sine of his Amplitude from the W. or E.

Which will be N. or S. as the Sun's Declination is N. or S: and the Distance in Degrees and Minutes between the true E. or W. and the magnetic, is the Variation of the Needle.

An easy and sure way to prevent Mistakes, which the Unexperienced are liable to in this Calculation is, to draw a Circle by Hand, representing the visible Boundary of the Horizon, and on it to mark the several Data by Guess; then by inspecting the Figure it will easily appear how the Variation is to be found, whether by Addition or Subtraction, and on which Side of the North it lies. For Example:

PLATE I. FIG. XIV.

Suppose the Variation was sought at Sun-setting. Draw by Hand a Circle N W S E, to represent your visible Horizon: in the Middle of it mark the Point C, for your Station: from C, draw the Line C W, to represent the true West; then on the North or South Side of that Line, according as the Sun set northward or southward of the true West, draw the

Line

Line C ⊙, repreſenting the Direction of the Sun's Center at ſetting, and another Line C w, for the magnetic Weſt, either on the North or South Side of ⊙, as it was obſerved to be, and at its judged Diſtance. Then by obſerving the Situation of theſe Lines, it will eaſily occur whether the magnetic Amplitude and true Amplitude are to be added, or ſubtracted, to give the Variation; and on which Side of the true North the Variation lies. In the preſent Suppoſition, w ⊙ is the magnetic Amplitude, and ⊙ W the true Amplitude; ⊙ W therefore muſt be ſubtracted from ⊙ w to give w W the Diſtance of the one from the other: and n, the magnetic N. 90 Deg. from w, muſt be weſtward of N, the true North.

This Method is ſufficiently exact for finding the Variation; but it is not exact enough for fixing a preciſe meridian Line: becauſe of the Uncertainty of the Refraction, and of the Sun's Center: but if the Sun aſcends, or deſcends, with little Obliquity, the Error then will be very little.

How to find the Sun's Azimuth, and from thence to find the Variation of the Needle.

Firſt let the Latitude of the Place be exactly found. Next let the Quadrant be carefully adjuſted for Obſervation. Then, two or three Hours before or after Mid-day, take the Altitude of the Sun's Center as exactly as poſſible, making the vertical Wire of the Teleſcope biſſect the Sun's Diſk; and, without altering the Plane of the Quadrant in the leaſt, move the Teleſcope vertically till you ſee ſome diſtant ſharp Object on the Land, exactly at the vertical Wire; and that Object will be in the Direction of the Sun's Azimuth when the Altitude of its Center was taken. If no ſuch Object is to be ſeen, let a Pole be ſet up in that Direction, about half a Mile off, or as far as can be ſeen eaſily.

Next calculate the Sun's Azimuth by the following Rule.

Add the Complement of the Latitude, the Complement of the Altitude, and the Complement of the Sun's Declination to 90° together, and take the half of that Sum, and note it down: ſubtract the Complement of the Declination from the half Sum, and take the Remainder; then take the Complement

plement arithmetical * of the Sines of the Complement of the Altitude, and of the Complement of the Latitude, and add them together, and to them add the Sines of the forementioned half Sum and Remainder: half the Sum of these four Logarithms is the co. sine of half the Azimuth required. Therefore find by the Tables what Angle that co. sine answers to; double that Angle, and that will be the Sun's Azimuth from the North.

If the Sun's Declination is S. in *North Latitude*, or N. in *South Latitude*; in place of taking the Complement of the Declination to 90°, add 90° to it, and proceed as before.

In South Latitudes the Azimuth is found in the same Manner; only, the Sun's Azimuth is found from the S.

Then, to find the Variation, place your Needle below the Center of the Quadrant, set it level, and find how many Degrees the Pole, or Object, in the Sun's Azimuth, bears from the North by the Needle; and the Difference between that and the Azimuth found by Calculation, is the Variation of the Needle sought.

If the Sun ascends, or descends with little Obliquity, a Meridian Line may be fixed pretty exactly this way, because a small Inaccuracy in the Altitude of the Sun's Center will not be sensible in the Azimuth. But when the Sun does not rise high on the Meridian, this Method is not to be relied on when great Exactness is necessary; for then every Inaccuracy in Latitude Altitude, and Refraction, occasions severally a greater Error in the Azimuth. To mark the Meridian-line on the Ground, place the Center of a Theodolite, or *Hadley*'s Quadrant, where the Center of the Quadrant was when the Sun's Altitude was taken, and putting the Index to the Degree and Minute of the Azimuth, direct (by waving your Hat towards one Side, or the other) a Pole to be set up, making an Angle with the former Pole placed in the Azimuth, equal to the Sun's Azimuth found; and that

* The Complement arithmetical of a Logarithm is found thus: begin at the Left-hand of the Logarithm, and subtract each Figure from 9, and the last Figure from 10, setting down the several Remainders in a Line; and that Number will be the arithmetical Complement required.

last-

laſt-placed Pole will be in the Meridian, ſeen from the Center of the Quadrant.

N. B. The Sun's Declination in the Tables muſt be corrected by the Variation ariſing from the Difference of the Time between your Meridian and that of the Tables; and alſo for the Variation of Declination for the Hours before, or after Noon, at which the Sun's Altitude was taken.

The two laſt Problems are conſtructed and explained in every Treatiſe of Navigation; it is therefore needleſs to be more particular here.

MARITIM SURVEYING.

PART II.

Of the Procedure and Operations in ſurveying Sea-coaſts, according to their various Circumſtances.

CHAP. I.

How to form a ſtaſimetric Scheme of Points, by which the Diſtances along the Coaſt may be determined.

IN order to ſurvey a Bay, Harbour, River, or any Part of the Sea-coaſt, with ſufficient Accuracy and Expedition, three principal things are requiſite. The firſt is, to meaſure a *fundamental Baſe-line:* the ſecond, to form a *ſtaſimetric Scheme* of Points, by which other Diſtances along the Coaſt may be determined: the third is, to delineate on Paper *a Figure ſimilar to the propoſed Coaſt.* The ſeveral Methods of finding the Length of a Baſe-line having been explained in Part 1. Chap. 3. the next is, how to form the *ſtaſimetric Scheme*; which may be done in the following Manner.

PLATE II. FIG. I.

1. Having firſt taken a general View of the Place to be ſurveyed from an Eminence, in order to find out proper Objects for the Scheme, and to plan

in your Mind the Procedure of the Survey; pitch on the ſmooth Sand X Y for a fundamental Baſe-line, as near the Middle of the Harbour, or Part to be ſurveyed, as can be had conveniently: on it meaſure the ſtraight Line X Y with a Pole, or Chain, as directed p. 4; mark its Extremities on the Ground, and write the Number of Poles, or Chains, in a Field-book prepared for the Purpoſe.

2. At X, with a Theodolite, take the Angles, that ſome of the moſt conſpicuous and ſharpeſt Objects (ſuch as Steeples, Towers, remarkable Tops of Hills, &c.) on each Side of the Bay, make with the Baſe-line; as Y X A, Y X B, Y X C, Y X D: and as many other Parts along the Coaſt as are diſtinctly ſeen, and may be judged convenient. If there are no remarkable Objects to be ſeen that are ſmall enough, cauſe Turrets, or Signals, of Stone or Turf, to be built for that Purpoſe, on the moſt convenient Hills or Eminences. Alſo, at Y, take the Angles X Y A, X Y B, &c. then take the Bearing of X from Y, with a good magnetic Needle and Sights: write theſe Angles diſtinctly in the Field-book, together with the Name, or Deſcription, of each Object, and the Part of it which you obſerve, ſo that they may be known again when needed, or when you go to them: write down likewiſe, on which Side of the Baſe-line each Object lies, whether on the right or left, when you look towards the fartheſt End of it.

3. Near the Middle of a Sheet of large Paper (ſo as there may be room for laying the Protractor, and drawing out the Angles) draw the magnetic Meridian right up and down. In a convenient Part of that Line, mark a Point X, to repreſent one Extremity of the Baſe-line; and at X, make an Angle with the Meridian equal to the Bearing of Y from it. On that Bearing ſet off the Length of X Y, in Miles and Parts of a Mile, taken from a Scale of equal Parts, not leſs than an Inch to a Mile.

4. From X and Y on the Paper, protract carefully, with a large Protractor, the ſeveral Angles written in the Field-book; and alſo calculate trigonometrically the moſt material Diſtances: judge of the Accuracy of the Protraction by its Agreement with the Calculation; and if any of them differ, protract, or calculate theſe again till the Error is corrected, and the Points repreſenting the ſeveral Objects are marked in their proper Poſitions and Diſtances on the Paper.

5. To

5. To verify these protracted Distances, go to any of the Objects, as D, take the Bearing of X and Y, to find if they agree with the Protraction; if so, then take the Angle X D Y, add it to the two other Angles of that Triangle, and if their Sum is 180 precisely, then is the Position of D exact: there also take the Bearings, by the Needle, of the other Objects; and if their Bearings from you agree with their Bearings from D on the Paper, then your several Operations have been rightly performed, and the stasimetric Scheme is exact. If the Bearing of any of the Objects by the Needle differs from that of its representative Point on the Paper, take the Angles of that Object again from the two Extremities of the Base-line, and protract them anew, till you discover the Error, and find all agree: then, and no sooner, should you proceed to delineate the Coast-line on the Paper.

Note 1. Very high Mountains, whose Tops are often hid in Clouds, are on that account not so convenient Objects for a stasimetric Scheme, as Hills of a more moderate Height, which may be seen more frequently.

Note 2. As the Use of this stasimetric Scheme is for finding the Distances of other Parts along the Coast, by one or other of the longimetrical Problems in Part 1. therefore great Care ought to be taken to get the Distances and Positions of the Points in it exact: wherefore if any of the Objects lies too oblique to the Base-line, or is too far from it, to have its Distance determined precisely; let *one* of the Angles only be taken at the Base-line, and the other from one of the Objects whose Distance is ascertained, and makes a more direct Intersection with it.

Note 3. If no level Sand can be had within the Bay, or Harbour, for a Base-line; then a smooth Plane near it, on either Side, may be measured, and the Distances of the Objects on each Side of the Bay deduced trigonometrically from thence.

Note 4. If no Plane fit for a Base-line is in, or near, the Harbour to be surveyed, and if it is but a few Miles in Extent; then the Distance of Objects properly situated may be measured by the Velocity of Sound (as above directed) and that Distance made a Base-line, from which the stasimetric Scheme may be deduced.

Note 5. If the Bay, or River is above eight Miles in Extent, and no sufficient Plane in, or near it; then take the Latitudes of two remarkable Hills, or Objects, at least 15 Miles asunder, and not above 45 Degrees from the Meridian; from thence find their Distance in Miles and Parts of a Mile (by Prob. 2. page 12.) make that the Base-line, and from thence calculate and protract the Distances in the stasimetric Scheme.

The Form of a Field-book.

Measured in a straight Line on the Sand on the S. Side of the Entry of Great-Harbour, from X (at the High-water Mark of White-point) to Y (at the Edge of the Grass on Green-point) 416 Chains, 25 Links; each Chain 60 Feet long, and each Link one Foot; amounting to $4\frac{1}{2}$ Miles and 408 Yards more.

At X, (by the Needle) Y bears — W. $18\frac{1}{2}$° N.

Angles taken at X, *on the Side* X Y. Y *bearing* W. $18\frac{1}{2}$°. N.

			Deg.	Min.
Right Side.	a	Signal on Flat-hill - - - - - - - - - -	23	24
	b	Steple of New-church, and Point of a Clay-cliff about a Mile beyond it - - - - -	36	15
	c d	Sharp Rock on Black-head, and north End of a Spring-tide Rock near the Middle of the Bay	41	48
Left Side.	e	Castle-strong, W. Corner - - - - - -	9	15
	f	Low rocky Point N. of that Castle - - -	11	54
	g	E. Gavel of Wood-house - - - - - -	134	50

Angles taken at Y, *on the Side* X Y, X *bearing* E $18\frac{1}{2}$°. S.

			Deg.	Min.
Left Side.	a	Signal on Flat-hill - - - - - - - - - -	64	40
	b	Steeple of New-church - - - - - - -	57	22
	c	Sharp Rock on Black-head - - - - - -	95	16
Right Side.		Hillock near Sandy-point, and Point of a high rocky Cliff, supposed three Miles off - -	38	27
		W. Gavel of Cot-house - - - - - - - -	134	15
	e	Castle-strong, W. Corner - - - - - - -	163	10
	g	E. Gavel of Wood-house - - - - - - -	18	49
		Ben-more Hill, the westmost and most tapering Top; also a breaking Shoal about a League off	165	51

In

In taking the Angles at Y, take the ſame Part of each Object which was done at X; and before protracting, prefix the ſame ſmall Letters to the Names of the ſame Places, or Objects. Theſe Letters ſerve to mark the ſeveral Directions of the Angles in protracting, ſo that the Interſection of the correſponding Sides may be more readily found on the Paper.

CHAP. II.

Examples of the Procedure in ſurveying Sea-coaſts, under the moſt common Circumſtances.

EXAMPLE I.

How to ſurvey a Bay, Harbour, or River, and to delineate the Coaſt-line on Paper.

PLATE II. FIG. I.

IN this Operation it will ſave much Time and Trouble, if the Surveyor has been accuſtomed to eſtimate, by the Eye, ſmall Diſtances, ſuch as a Mile, half a Mile, a Quarter, and 200 Yards, ſomething near the Truth. This Dexterity may be acquired, ſufficiently exact for the Purpoſe it is to ſerve, by frequently viewing with Attention ſuch Diſtances when actually meaſured, and comparing other Diſtances with the Ideas of theſe in the Memory; eſpecially when the Nature of the Ground compared, and the Darkneſs, or Clearneſs of the Weather, are nearly the ſame.

Firſt, form a ſtaſimetric Scheme of Points, as above delineated; and that the Points may be more diſtinct, and the Paper not incumbered with a Number of unneceſſary Lines, transfer the magnetic Meridian, and the ſeveral aſcertained Points in the Scheme, to a convenient Part of a large Sheet of clean Paper (or of ſeveral Sheets paſted together) ſo as there may be Room on it to contain and protract the reſt of the Coaſt: then draw a ſmall Black-lead Circle, or Dots, round each of theſe Points to render them more apparent, and write near each the Name of the Object it repreſents. Next, divide the Paper all over into ſmall Squares, by Black-lead Lines about an Inch aſunder, drawn parallel, and perpendicular, to the magnetic Meridian.

These Parallels serve for laying the Protractor North or South, East or West by the Eye readily, in any Point from whence a magnetic Bearing is to be drawn. If one Direction only of any other sharp Object has been taken, draw it out likewise from the Station at which it was observed; and write its Name along that Line, with a (D:) before it, to signify that it is the Direction of that Object; or an (L:) if it is the Limit of any Head, or Point. If Fig. 1. is the Harbour, the new stasimetric Scheme will then look as in Plate II. Fig. 2.

In the next Place; With this Scheme of Points and angular Directions, go to any Station on the Shore whose Place is marked on the Paper, as X, and there, with a good magnetic Needle, take the Bearing of a from it; draw it on the Scheme from X, the corresponding Point there, and judge its Distance as near as you can; take that Distance in your Compasses from the same Scale of equal Parts by which X Y was laid down; mark its Extent from X on the Bearing-line, and trace with the Point of your Compasses on the Paper the Curvature of the Coast between X and a, as exactly as you can: take also the Bearing of b from X, and draw it on the Paper. Next go to Y; at it take by the Needle the Direction of b, draw it on the Paper, and it will intersect the other Direction taken at X in b; trace the apparent Curvature between Y and b: take also the Bearing of a, and that drawn out will intersect its former Direction from X in the true Place of a; sketch the Curvature between a and b, and black-lead the whole from Y to X, which will finish that Part of the Coast-line. Next take the Bearing of c from Y, draw it out on the Scheme, and on that Line mark its judged Distance, and with your Compasses trace on the Paper the Curvature of the Coast between them. At c intersect that Bearing by the Bearing of C, or D, and correct that Part of the Curvature which is next c, and pencil the Tracing between c and Y: then take the Bearing of d, draw it on the Scheme, mark its judged Distance on that Bearing, and trace the Curvature between c and d with your Compasses: take also the Bearing of g, draw it on the Paper, and mark it so as to be found again when you come to g. At d take the Bearing of D, to intersect the former Bearing from c in d; correct the Curvature between them, and pencil it. Take also the Bearing of e, mark its judged Distance, and trace the Curve between them: at e, by the Bearing of D, intersect its Bearing from d, correct the Curvature, and pencil as before. In the same Manner, fix by magnetic Intersections the

the Points f and g, and trace the Curvature and Windings of the Coaſt between them. But becauſe the Point h is more in the Way of Ships ſailing up the Bay than any of the former Parts between c and h, its Poſition ſhould be determined in the exacteſt Manner. Therefore at h, with a Theodelite, or Hadley's Quadrant, take the Angles A h B, B h C, and from thence (by Longim. Prob. 3.) find the Point of Station h; which will give its true Place independent of the former Stations. Next draw the magnetic Bearings of the Points i, k, l, m, n; interſect theſe Lines by the Bearing of C taken at each of them; delineate the Curvatures between them, and the Coaſt-line of the Bay will be ſo far finiſhed. In this Manner proceed along the whole Shore of the Harbour, *firſt* fixing the Place you ſtand on by Interſections of the Needle; but at proper Diſtances, and Parts that are of Conſequence to Navigation, let theſe be determined by two Angles taken more accurately, and protracted by one or other of the longimetrical Problems in Part I.

If all the Stations along a Coaſt are determined by magnetic Interſections, the natural Defects of the Needle will, in Time, produce ſenſible Errors. If all the Stations are determined by the Angles between three Objects (according to a Longim. Prob. in Part 1.) though that in Strictneſs is the moſt exact Way, yet it would be much more tedious, confuſe the Draught with a Multitude of interſecting Lines and Arches, and anſwer no Purpoſe in Navigation better, nor in any Reſpect render a Draught more ſerviceable than if only ſome of the moſt material Stations, and principal Projections of the Coaſt here and there, were ſo determined, and the intermediate Parts found by Interſections of the Needle.

If, at any Part of the Coaſt, two, or three of the neceſſary ſtaſimetric Objects cannot be ſeen, becauſe of interpoſing Hills; or are not in a convenient Poſition for determining the Station wanted; go to ſome Eminence near that Station, from whence the Objects may be ſeen more advantageouſly, find the Point of Station on that Eminence by one of the longimetrical Problems in Part 1. protract it on the Paper, and by it, with one or two of the other Objects, find the Station wanted on the Coaſt.

If at any Station, the Angle between two Hills, or Objects, is wanted, but interpoſing Eminences, or other Objects, hinder one of them to be ſeen; in that Caſe, go to the Top of the interpoſing Eminence till you ſee the Hill and Station from it, and exactly in a Line with them ſet up two Poles; and the Angle between any of the Poles and the other Object, or Hill, taken at the Station, will be the ſame with the Angle between the two Hills. Thus may the Angle, or Bearing of any Objects, be found from a Place where they cannot be ſeen, which will be neceſſary or convenient on many Occaſions.

Mountains, Rocks, and Stones, are frequently endowed with a magnetical Quality, which diſturbs the Polarity of a Needle, and, if not adverted to, will create much Trouble. To prevent this, it is neceſſary to carry two Needles always along with you, and to ſet both down at each Station, beyond the Reach of each others Influence; if they both agree in the Bearing of the ſame remote Object, it may be concluded that they are not diſturbed by Magnetiſm.

At every Station take Care to inſert, and to diſtinguiſh in the Draught, the Appearances and Nature of the neighbouring Parts of the Coaſt, ſuch as rocky Cliffs, graſſy Cliffs, ſandy Shores, rocky Shores, &c. and remarkable Hills, Houſes, Trees, &c. but eſpecialy ſuch as may ſerve for Landmarks to direct Ships through Channels, or to avoid Rocks and Shoals. The Hills and Houſes ought to be repreſented in ſuch Proſpects as will enable Sailors to know them when they are ſeen from the Sea, without regarding much the Diverſity of Perſpective which this will occaſion in the ſame Draught; for Uniformity ought always to give Place to Utility.

If the Survey is to be carried on without the Harbour, along the Coaſt on each Side, it may be continued on the Foundation laid before, and by the ſame Procedure, to as great a Diſtance as the ſtaſimetric Objects can be eaſily ſeen, and while the Angles they ſubtend are not too acute to be relied on, or protracted with Certainty. Before this happens, it will be neceſſary to pitch on other ſtaſimetric Objects as you go along the Coaſt, to determine their Diſtances carefully by one of the longimetric Problems, and make theſe ſupply the Places of ſuch of the former as are too remote; and by theſe laſt, others ſtill farther along may be determined, to ſerve the ſame Purpoſe to a greater Extent. But let it be adverted here, that if too long a Series of Triangles is continued from one Baſe-line, the unavoidable Imperfection of Inſtruments,

ſtruments, Obſervations, and Protraction, will, in Time, produce very ſenſible Errors: therefore it is adviſeable to break off the Series at proper Diſtances, and to lay a new Foundation by meaſuring another Baſe-line, and proceeding by it as at firſt. When this is done, remember that two Objects, or Points, in the firſt Draught, at a proper Diſtance and Poſition, be likewiſe included in the ſecond; that by theſe Points the two Draughts may be eaſily joined together, and make one Map when it is needful.

When the Coaſt of a Bay, Harbour, or River is ſurveyed, or any conſiderable Part of it, then find the Diſtance and Extent of all the Rocks, Sand-banks and Shoals that lie near it; obſerve Leading-marks to them; and Land-marks for avoiding them; ſound the Depth of the Water to, round, and from each; and alſo along the Shore, as near to it as Veſſels can, or ought to ſail. Alſo ſound particularly the ſeveral Places of Anchorage, and take Land-marks, or Bearings for finding them, and inſert an Anchor in the proper Part of the Draught, for pointing them out more readily. Inſert alſo the Time of High-water on the Days of new and full Moon, the ordinary Riſe of ſpring and neap Tides, the Direction of the Stream of Flood, and what Irregularities may be obſerved in theſe, both within and without the Harbour.

EXAMPLE II.

How to ſurvey an Iſland.

CASE 1. *If the Iſland has ſeveral conſpicuous Hills in it:* firſt meaſure a Baſe-line on a Plane, or by two Latitudes. 2. On that Baſe-line form a ſtaſimetric Scheme of Points, as was explained in Part II. Chap. 1. § 3. Survey and delineate the Coaſt of the Iſland as directed for a Harbour in the laſt Example.

PLATE III. FIG. I.

CASE 2. *If the Iſland is but a few Miles long, and has but one remarkable Hill, or Object in it;* as A, which may be ſeen from all, or moſt Parts of the Coaſt: by one of the longimetrical Problems in Part I. find the Diſtance of any of the Points, or Heads, in the Iſland (ſuppoſe B) from A. At B, take the magnetic Bearing of A, in Degrees and Parts of a Degree; lay down that Diſtance on Paper according to the Bearing obſerved; and draw black-lead Lines all over the Paper, parallel and perpendicular to the magnetic Meridian, about an Inch from one another. At B, with a Theodolite, or Hadley's Quadrant, take the Angles A B C and A B F; write them down firſt in your Field-book, and then draw them out from the Point B: alſo take the Bearing of a and b by the Needle; judge of their Diſtances from B; draw them, and ſketch the Curve of the Coaſt between you and them. Then go to C; there take the Angles A C B, A C D; write them down; add A B C and A C B together, ſubtract their Sum from 180°, and the Remainder will be the Angle B A C; draw that Angle from the Point A, and it will interſect the Side B C in the Point of Station C. At C, take the Bearing of a, and that will interſect its former Bearing from B in the corrected Place of a: then ſketch the Curvature between C and B, and pencil it. Next draw the Angle A C D; at D, take the Angles A D C, A D E; the former added to A C D and ſubtracted from 180° will leave the Angle C A D; draw that Angle, and it will interſect the Side C D in the Station D: ſketch and pencil the Curve between C and D. Then draw the Angle A D E, and the Bearing D c; fix the Point E by the Angle at E, and finiſh the Bay between D and E as before. Go on in this Way from Point to Point round the Iſland, till the whole is finiſhed, remembering to inſert remarkable Cliffs, Houſes, or other Objects at each Station.

If at any Point, as G, or H, A cannot be ſeen; take the Direction of A from that Point, by ſetting two Poles exactly in a Line between them, as mentioned in Page 72, and take the Angle between one of the Poles and the other viſible Object. By ſuch a Procedure as this, the Circumference of any Iſland will be found to meet on Paper, without arbitrary Alterations.

When an Iſland is ſmall, and great Exactneſs unneceſſary; if the firſt Diſtance, or Baſe-line, is true, and long enough, all the other Diſtances may be got ſufficiently exact by Interſections of a good Needle, without any other Inſtrument to take the Angles.

When

When one Side, or Part, of the Iſland is delineated on the Paper, then find the Diſtance and Dimenſions of the ſeveral Rocks, Sand-banks, Shoals and Ledges along it; ſound the Depth of the Water towards and round each of them, and take Leading-marks on them, and Land-marks for avoiding them: ſound alſo along each Part of the Coaſt after it is delineated, as near the Shore as Veſſels can, or ought to ſail; and when the whole Coaſt is finiſhed, ſound round it a Mile, or more, from the Land.

EXAMPLE III.

How to proceed in ſurveying an extenſive Coaſt.

CASE 1. If the Coaſt extends northward, or ſouthward, take, carefully, the Latitudes of two remarkable Hills, or Promontories along the Coaſt, as near the true Meridian as they can be found, and as far from each other as can be ſeen diſtinctly: ſuppoſe 20, 30, or 40 Miles. From their Difference of Latitude, Bearings and Variation of the Needle, find their Diſtance in Miles and Parts of a Mile (by longim. Prob. 2. p. 12.) make the Chord of that Arc, or Diſtance, the Baſe-line, and by it form a ſtaſimetric Scheme of Points; one, or two of them, repreſenting remarkable and ſharp Objects. If one, or more, of the Objects lie off the Coaſt at Sea, it will be a Conveniency; for there will be fewer Objects to intercept the Sight of theſe. When the ſtaſimetric Scheme is verified, and transferred to ſome Sheets of clean Paper, and a Number of magnetic Meridians, and eaſt-and-weſt Lines, drawn over it, then begin to ſurvey and delineate the Coaſt, as directed in Example II.

It will ſometimes happen that no one proper Object is to be ſeen from *both* Ends of ſo long a Baſe-line, with which to form a ſtaſimetric Scheme; but if any remarkable intermediate Object, properly ſituated, is ſeen at one End of the Baſe-line, and the other End ſeen at *that* Object, its Diſtance may be found with equal, or rather more Accuracy, by taking one Angle of the Triangle, formed by the Baſe-line and Object, at that End of the Baſe-line where it is ſeen, and the other Angle at the Object; thence the third Angle is found; and the Diſtance of the Object. Theſe three determined Diſtances will be ſufficient for finding all other Diſtances between the two Extremities of the Base-line; and also for determining other ſtaſimetric Objects neceſſary for continuing the Survey far beyond theſe Extremities.

Let it be obſerved, that if the Quadrant with which the Latitudes of the two Places were found, and the Obſervations, are good, a Baſe-line of 30, or 40 Miles meaſured in that Manner, is more to be relied on than ſuch a Diſtance determined by a Baſe-line of three or four Miles meaſured on a Plane: becauſe it is rare to find Planes ſo long without ſome ſenſible Irregularities in them; and more rare to meet with two ſo remote Objects ſharp enough for taking the Angles at each End of ſuch a Baſe-line with Preciſion. Theſe two Sources of Inaccuracy may occaſion a greater Error in a Diſtance of 20, or 30 Miles, than can be ſuppoſed when the Latitudes are carefully taken with a good Quadrant.

When the Survey has been continued by a Train of ſtaſimetric Triangles a conſiderable Length beyond the Baſe-line, it will then be proper to diſcontinue the Procedure on that Foundation, and to meaſure a new Baſe-line; either on a level Plane, or by two Latitudes, as before; taking Care to have two determined Points common to both Draughts, for connecting them into one.

If the Inſtrument with which the Angles are taken does not give them minutely enough; or if the Objects that form the ſtaſimetric Triangles are not ſharp enough, Errors may be expected, and will undoubtedly become ſenſible in a long-continued Series of Triangles. How far they have actually taken Place in the Draught may be diſcovered by comparing the obſerved Bearings of diſtant Hills or Head-lands, whoſe Poſitions have been determined by former Obſervations, with their Bearings in the Draught: or, by comparing ſuch moderate Diſtances as one can judge of by the Eye, with their protracted Diſtances on the Paper.

When a conſiderable Length of the Coaſt has been ſurveyed, the Soundings marked near it, and all the Rocks, Shoals, Banks, remarkable Hills, Buildings, Groves of Trees, and other Diſtinctions of the Coaſt inſerted and expreſſed in the Draught; then ſail along it, ſix, eight or ten Leagues from

 the

the Land, according as it can be ſeen diſtinctly; ſound the Depth of the Water, obſerve the Setting of Tides and Currents, and ſketch Views of the Coaſt as you ſail, inſerting in them the Names of the moſt material Hills, Heads, Entries of Rivers, Harbours, &c. ſo that Seamen may know, by the Eye, where the principal Places on the Coaſt lie, and how to ſteer for them.

CASE 2. *If the Coaſt to be ſurveyed extends eaſtward, or weſtward*; chuſe a remarkable Hill, or Head, near the Coaſt, and another Hill, or remarkable Object up the Country, northward or ſouthward; find their Diſtance by meaſuring a Plane, or by the Latitudes, and make that Diſtance the Baſe-line; from thence form a ſtaſimetric Scheme of Points; and with it proceed to ſurvey and delineate the Coaſt as before directed.

If any Part of a Coaſt that extends eaſtward or weſtward is ſo circumſtanced, as neither to have in it a level Plane fit to be meaſured, nor any Hill or remarkable Object up the Country, or lying off the Coaſt, far enough diſtant to become a Baſe-line by taking their Latitudes: in that Caſe, build a Wall or Turret, of Earth or Stone, on the moſt conſpicuous Part of the Shore; and another Turret three or four Miles from it up the Country, and ſo large as to be ſeen five or ſix Miles off, or farther: meaſure the Diſtance of the two Turrets by the Velocity of Sound, and make that a Baſe-line from whence to determine trigonometrically the Diſtance of the other Stations and Signals ſet up along the Coaſt for that Purpoſe: from theſe laſt, find other Diſtances: then, if you meet with no Plane fit to be meaſured, nor any remarkable Hill or Object, at a ſufficient Diſtance and Poſition for determining a new Baſe-line by the Latitudes; meaſure a new Baſe-line by Sound, and proceed as before. Such a Caſe as this is very rare; but when it happens, a good portable Teleſcope, or Spy-glaſs, will be found convenient, and ſhould be provided accordingly.

That the maritim Survey of a Kingdom, or large Tract of Continent, may be carried on with Expedition and Accuracy together, it is neceſſary one Superintendant, or Head-ſurveyor, expert in Theory and Practice, ſhould have two Aſſiſtants under him, who are capable of executing his Orders. *Their* Duty is, to conform to his Directions diligently and faithfully, as far as can be done; to omit no Part of the Coaſt, nor neglect any Rocks, Shoals,

Shoals, Channels, Tides, or neceſſary Soundings; to be at Pains to get Information concerning them from the Inhabitants, or Pilots, wherever they come, but to inſert nothing in their Draughts but what has been actually examined by themſelves; to keep a daily Journal of their Operations, Obſervations, and likewiſe of what Informations they may receive from others that have not been examined by themſelves.

The *Head-ſurveyor's* Duty is, to plan and direct the Procedure of the whole Survey; to order the Veſſel, Boats and Men on the Service when and where he ſees it neceſſary; to chuſe proper Planes and Diſtances for meaſuring fundamental Baſe-lines; to ſee the Menſuration, or celeſtial Obſervations himſelf; to pitch on proper Objects for the ſtaſimetric Scheme; and ſee the Angles taken that determine their Diſtances; to inſpect the Calculations and Protraction; to verify the Scheme when protracted; to cauſe a clean Copy of it to be made out for himſelf, and one for each of the Aſſiſtants; to ſend one of them to ſurvey on one Side, or towards one End of the Baſe-line; another on the other Side or End of it, and himſelf to remain with the Veſſel that attends the Survey, and to ſurvey in that Neighbourhood; to examine their ſeveral Performances when they return to the Veſſel; to compare the moſt material Diſtances in their Draughts with the Obſervations by which they were determined; to point out Miſtakes, or Defects, and cauſe them to be corrected; to inſert the ſeveral Obſervations, Meaſurements, Deſcriptions, and Sailing-directions regularly in a Book; to join the ſeveral Parts of the Coaſt, as they are compleated, into one Draught; and when that is of a ſufficient Extent, to cauſe a clean, diſtinct Copy to be made of it aboard: then to ſail in the Veſſel to the next ſtationary Harbour; to cauſe Soundings, and uſeful Views of the Coaſt to be taken by the Way, and ſuch remarkable Objects on Land to be inſerted in the Draught, as may have been omitted by the Aſſiſtants. There will be no great Advantage in having more than two Aſſiſtants under one Superintendant; for this would often occaſion either Delays in waiting for one or other of them before the Scene of Operation could be ſhifted; or elſe a ſuperficial Inſpection of their Performances.

Toward the End of Harveſt, when the Days are turning ſhort, and bad Weather may be expected more frequently, a Survey will be ſooner diſpatched, if the Examination of Shoals and Sand-banks, that lie at a Diſtance from

from the Land, is poſtponed till the End of the following Spring; and the Survey of the Coaſt *only*, and the Soundings near it, or of Rivers and narrow Arms of the Sea, are taken in the Winter and Spring Seaſons.

Though in general it is better that a conſiderable Part of a Coaſt be ſurveyed before the Soundings are taken near it, yet often both may be diſpatched together with ſufficient Exactneſs; by making an Eye-ſketch of the ſmall Bays and Windings of the Coaſt as you go from Point to Point in a Boat to determine their Diſtances, taking the Soundings by the Way, and inſerting them in the correſponding Parts of the Sketch as near as you can judge; and at the ſame Time marking down the Direction of the Boat, or on what Object her Head is kept, in ſailing or rowing from Place to Place; and the Bearing of one or two Objects when the principal Soundings were taken: when that Part of the Coaſt is ſurveyed, theſe Soundings may then be transferred to the Draught by the Bearings, and by the Direction in which the Boat was ſteered. If any Shoals are met with, take Marks on them, or two contiguous Angles by *Hadley*'s Quadrant, and examine them more particularly afterward, when the Survey of the adjacent Part of the Coaſt is finiſhed.

EXAMPLE IV.

How to proceed in ſurveying a large Cluſter of Iſlands.

PLATE III. FIG. II.

Pitch on two remarkable tapering Hills, Rocks or other Objects, at a competent Diſtance, as A and B, as near North, or South, of each other as you can; and if a Line connecting them runs about the Middle of the Cluſter it is the better. Find the Diſtance of A and B, either by meaſuring a ſtraight Line on a Plane, or by their Latitudes, and make that the Baſe-line: ſelect amongſt the other Iſlands one, or more, remarkable Objects on each Side of the Baſe-line; as C and D; of theſe form and verify a ſtaſimetric Scheme, as before directed. With this Scheme go to one of the Iſlands, and by longim. Prob. 4, or 7, find the Diſtance of two proper Parts, or Points in it; make that a Baſe-line for ſurveying it, as explained in Example 2. Do the ſame for each Iſland, ſounding the Channels between them, and obſerving the Setting and Strength of the ſeveral Streams of Tide as you paſs and re-paſs, taking Notes of all and inſerting them in the Draught at the Time they are obſerved. When all the Iſlands are ſurveyed and Channels ſounded, and every neceſſary Particular is inſerted in the Draught, then ſail round the whole, between four and ten Leagues from the Land, and ſound the Depth at that Diſtance, and draw Views of the Land as you ſail.

If the Iſlands extend northward and ſouthward in a narrow Chain, (as in Fig. 3.) and are ſo ſmall, or ſo uneven, that no ſufficient Baſe-line, for the whole, can be meaſured on either of them; then find by their Latitudes the Diſtance of two of the moſt conſpicuous Hills, or Rocks, that are ſituated along one Side of the Cluſter, and at a ſufficient Diſtance from each other, as A and B. At A and B with *Hadley*'s Sextant, or a Theodolite, take the Angles B A C, B A D, A B C, A B D, and from thence and the Side A B, find the Places of C and D any two remarkable Objects on the other Side of the Cluſter of Iſlands, which may make the Angle B A C and A B D as near to right Angles as may be conveniently had. From any three of theſe Points the Poſition of a Place on any of the Iſlands may be found; or by Interſections of the Needle from *two* advantageouſly ſituated; and each Iſland delineated ſeparately, as before directed.

CHAP. III.

Examples of the Procedure in ſurveying Sea-coaſts under unfavourable Circumſtances.

EXAMPLE I.

How to ſurvey ſmall Iſlands that extend Eaſt or Weſt in a long narrow Train.

PLATE III. FIG. IV.

IF the Iſlands are ſmall, and extend eaſtward or weſtward in a long narrow Train, as Fig. 4. then no ſufficient Baſe-line will be found either by meaſuring a Plane; or by the Latitudes of any two Iſlands: in that Caſe, if the whole Extent of the Iſlands is not above 12 or 15 Miles, a Baſe-line may

may be meaſured by the Velocity of Sound, a ſtaſimetric Scheme protracted from thence for determining the Diſtances of the ſeveral Iſlands from one another, and each ſurveyed ſeparately, as before directed. But if the Iſlands extend above 15 Miles in Length, ſuch a Procedure will not be found ſufficiently exact, becauſe a Diſtance cannot be meaſured by Sound with Preciſion: then the following Method is more to be relied on.

Pitch on the moſt remarkable Head, Hill, or Object that is to be found near the Middle of the Range of Iſlands, as X: find its Latitude, and the Variation of the Needle there. Then five or ſix Leagues northward, or ſouthward of X, anchor a Veſſel, as at V: on a prefixed Day, let the Latitude of the Veſſel be taken aboard with *Hadley*'s Quadrant, as exactly as poſſible: and at the ſame Time, while the Veſſel remains ſteady in the ſame Place, let the Angles X V C, X V D, be alſo taken with *Hadley*'s Sextant, and as many more Angles between them as there are remarkable Objects to be ſeen. About Mid-day, while the Sun's Altitude is taking on board, let one Aſſiſtant at X find the magnetic Bearing of the Veſſel from thence; and alſo ſet up a Pole half a Mile, or a Quarter of a Mile from it, exactly in the Direction of the Veſſel; and let the Place of the Pole be marked on the Ground, for future Uſe. Let two other Aſſiſtants be ſtationed one at A, and the other at B, four or five Miles on each Side of X, and there mark the Direction of the Veſſel from them at Mid-day, by Poles in the Ground as was done at X, ſo that the Angles V X A, V X B and X B V, X A V, may be taken afterwards at Leiſure, though the Veſſel is removed. Find the Diſtance of X V (by longim. Prob. 2.) make that the Baſe-line; on it protract the ſeveral Angles obſerved on Shore, and aboard, and form a ſtaſimetric Scheme of Points; in which the Stations X, V, A, B, will be determined; and alſo one Direction of C and D, and of the other Objects obſerved at V. From the Angles which two, or three of theſe Objects ſubtend, the Diſtances of the other Iſlands, or of any Station in them, may be found, and each Iſland ſurveyed ſeparately.

If the whole Extent of the Iſlands cannot be included in the Angles taken at V, the ſame Operations muſt be begun again where the former ended, and the reſt of the Iſlands ſurveyed in the ſame Manner.

EXAMPLE II.

How to proceed in surveying a Coast covered with Wood, or Bushes, so that in-land Objects cannot be seen from the Shore.

PLATE III. FIG. V.

Case 1. *If it is a River, Bay, or Habour*; find stasimetric Objects on the Side opposite to that which you are to delineate, and by these determine your stationary Distances by two Angles, or by Intersections of the magnetic Needle.

Case 2. *If it is an open Coast, that has no Land opposite to it near enough.* 1. Measure a Base-line on a Plane, or by two Latitudes, and from thence find the Distances of three remarkable in-land Hills, or Objects, as Y, R, W, that may be seen from a Boat at Sea, over the Trees; and protract a stasimetric Scheme on Paper including these three Objects. If three remarkable Objects cannot be had; two conveniently situated for magnetic Intersections along the Coast will serve.

2. Prepare eight Poles, each with a flag flying at its Top for Signals; two of the Flags white, two red, two yellow, or striped, and two black: the white to represent one of the stasimetric Objects, the red another, the yellow or striped a third, as shall be agreed on between the Surveyor and his Assistant; the black any new stasimetric Object, whose Place may be found necessary to be determined as the Survey goes on. Let these Colours be written on the stasimetric Scheme, each at the Point, or Object, signified by it; and a Copy of the Scheme given to the Assistant to direct him, and prevent Mistakes; together with four of the Signals, each of a different Colour; the other four are to be carried along with the Surveyor.

3. At the first Point, or Station on Shore, whose Distance is to be determined, as A, let the Surveyor set up a Signal of a Colour indicating what stasimetric Object is to be first observed, as Y, or yellow. Then the Assistant must go off in a Boat to X, as far from the Shore as to see the stasimetric Objects over the Trees, and take that Signal in a Line with the Object it denotes, keeping the Boat steady at Anchor in that Place, and putting up

up a Signal of the same Colour with the Surveyor's, to signify that the Boat is then in the right Place. Let the Surveyor then take exactly the magnetic Direction of the Signal X in the Boat; which will also be the Direction of his Station B from the indicated stasimetric Object Y. Let it be drawn out on the Paper from its proper Point Y, and a Signal of another Colour R, set up in the Place of the former, to signify to the Assistant to move the Boat till he takes that Signal in a Line with the Object R it represents; and there let the Assistant, when ready, put up the like Signal at Z, and keep the Boat at rest till the Surveyor has taken its magnetic Direction, and drawn it on the Paper; which will intersect the former Direction in the Point of Station A, on the Shore.

4. Let the Surveyor then take the magnetic Direction of the next Point of Land B, along the Shore; draw it on the Paper; estimate its Distance by the Eye; mark that Distance on the Line of Direction; sketch with the Point of his Compasses the Figure of the Curvature of the Coast between the two Points A and B; take down his Signal and wave it, for a Sign to the Boat to move towards the next Point B, on the Coast.

5 When the Surveyor comes to that Point, let him put up a Signal W, or White, intimating what stasimetric Object the Assistant is to take in a Line with it; which when he has done, let the Assistant set up the like Signal in the Boat, and keep it steady at Anchor till its Bearing is taken on the Shore; which will intersect the Line of Direction taken at A the first Station, in the corrected Distance of B the second Station: let the Curve of the Coast between them be also corrected, and drawn with Black-lead, and the Coast-line between these two Points of Land will be finished.

Let the Distance of the next Point C be determined, and the Coast-line sketched, in the same Manner; and go on thus till the stasimetric Objects can be seen by the Surveyor on Shore, when there will be no Occasion for the Boat.

If any of the stasimetric Objects shall happen to be hid from the Assistant's Sight by interposing Hills; he must then first set up the Surveyor's Signal, and above it set up that Colour which points out some other stasimetric Object that is seen: which when the Surveyor observes, he must set up another Signal of the same Colour above his former one; and then take the Direction of the Signals in the Boat; which will be the Direction of his Station from the Object represented by the uppermost Colour.

When any of the stasimetric Objects begins to disappear, or to be too remote, or oblique, for Accuracy; then, when the Surveyor is at a proper Station, the Assistant must set up the black Signal; to signify that the Place of a new stasimetric Object is to be determined. The Bearing of the black Signal taken when the Boat is at Rest, and drawn out from the Surveyor's Point of Station, in the opposite Direction, will be one Direction of the new stasimetric Object. When the Surveyor comes to another Station proper for another Intersection, the black Signal must be set up again by the Assistant: and when the Boat is at Rest, the Surveyor is to take its magnetic Direction, which will intersect the former in the Place of the new stasimetric Object; which must continue to be pointed out thereafter by the black Signal; till, by Agreement, it shall be changed for another Colour, that the black Colour may be again reserved for another new Object, in case it shall be necessary.

As the Assistant goes along the Shore in the Boat, he may, at the same Time sound the Depths of the Water, and mark them on an Eye-sketch of the Coast; or insert them by their Bearings from the Stations, and other remarkable Parts of the Coast.

For this Manner of Surveying, it is necessary that the Assistant should be tolerably acquainted with the Business, that he may be capable of making a proper Choice of Objects, and Stations for determining their Distances.

This Method of surveying a Coast is sometimes necessary; and though not so exact as when the Angles can be taken with a Theodolite, or *Hadley*'s Quadrant; yet when the stasimetric Objects are advantageously situated, and the Coast so surveyed is not very extensive, it will be found sufficiently exact for the Purposes of Navigation. If any particular Part of such a Coast requires great Exactness, then three Assistants, and three Boats, must be employed at the same Time; each must have the same Sort of Signals, and they must take the Surveyor's Signal bearing on three different stasimetric

Objects at once; by which Means he may take the Angles between them by a Theodolite, or by *Hadley*'s Quadrant, which will be the same with the Angles between the three stasimetric Objects; and from thence may find the Place of Station precisely, by longim. Prob. 4.

If there is any Stream of Tide, or Breeze of Wind, where the Boat lies, it will not be kept steady by one Anchor only, but must be made to ride by two, in order to continue in the same Place while the Surveyor makes his Observations on Shore.

EXAMPLE III.

How to survey a Coast, without going ashore on it.

There are some Coasts where it is impracticable to land for a continued Swell and Surf on the Shore; and others, where the Barbarity of the Inhabitants renders it unsafe; the Survey of such Places must be made altogether at Sea; and may be done in the following Manner.

CASE I. *If the Coast extends northward and southward.*

1. Find the Variation of the Compass.

2. Chuse two remarkable tapering Hills, or other sharp Objects, 20 or 30 Miles asunder, and as near the same Meridian as they can be had; but so situated, that by sailing along the Coast or into a Bay, or River, one of them may be taken in a Line with the other, so that their mutual Bearing may be exactly taken with a good amplitude Compass.

3. The Variation being found, bring a Ship to an Anchor right East, or West, from each Hill or Object, on different Days, and there observe their Latitudes with *Hadley*'s Quadrant; which will be the Latitudes of the two Hills respectively.

4. From these Latitudes and their Bearing, find the Distance of the two Hills, by longim. Prob. 2. and protract a stasimetric Scheme, in which these two Points will be given.

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5. In a rowing Boat of 8 or 10 Oars, and in moderate Weather, go as near to ſome remarkable projecting Point, or Promontory, as you can with Safety; there anchor your Boat, and with an amplitude Compaſs, conſtructed and balanced ſo as to be as little affected by the Motion of the Boat as poſſible, take the Bearing of the two ſtaſimetric Objects; draw theſe out from their correſponding Points on the Scheme, in the oppoſite Direction, and their Interſection will be the Place of the Boat. Take the Bearing of ſome remarkable Part of the Point, or Promontory next you; judge its Diſtance as near as you can; draw that Bearing on the Paper from the Point found for the Boat's Place; and on it mark the eſtimated Diſtance of the obſerved Part of the Point or Promontory; which will be one Point in the Coaſt to be ſurveyed, and ſufficiently exact for the Purpoſes of Navigation; the Error being only what may ariſe from eſtimating a Diſtance that is not above a quarter or half a Mile off.

6. In the Boat, take the Bearing of the next Point along the Coaſt, from the Point or Promontory determined; draw it on the Paper; mark its eſtimated Diſtance on that Line; and with the Point of your Compaſſes trace on the Paper the Figure of the Coaſt between theſe two Points of Land.

7. Go to the Point laſt obſerved, as near as you can; take its Bearing from one of the ſtaſimetric Objects, which will interſect the Line of Direction from the firſt Place of Anchorage in the corrected Diſtance of the ſecond Point along the Coaſt; correct alſo the Figure of the Coaſt, and pencil it; and laſtly inſert remarkable Objects on the Land, and Diverſities of the Coaſt between the Points, together with the Rocks obſerved, and Soundings taken by the Way. Take the Bearing of the third Point, mark its eſtimated Diſtance, ſketch the Curve of the Coaſt, and correct both when you are at that Point as before; and go on in this Manner, from Point to Point, till the whole is finiſhed.

Though this Method of Surveying is leſs perfect than any of the other Methods, yet if the Card of the Compaſs can be made to ſtand at Reſt in the Boat, either by Art, or the Smoothneſs of the Sea, a Draught of a Coaſt may be made in this Manner, or of Bays or Harbours in it, which will give a diſtinct Notion of them, and prove a pretty good Direction to Shipping, either along the Coaſt, or into theſe Bays or Harbours.

CASE 2. If the Coaſt extends eaſtward and weſtward, then two ſtaſimetric Objects muſt be choſen, which lie about N E or S W from each other, and alſo their Bearing and Latitudes found, in order to find their Diſtance, and form a ſtaſimetric Scheme for carrying on the Survey in the ſame Manner as before.

EXAMPLE IV.

From a Veſſel at Anchor in the Mouth of a Harbour, how to ſketch the Harbour ſpeedily, as far as can be ſeen.

Suppoſe Fig. 6. in Plate iii. is the Harbour, and the Veſſel at V: take the Bearing of any remarkable Part D, right up the Harbour; gueſs as near as you can to its Diſtance; draw out the Bearing on Paper, and by a convenient Scale mark on it that judged Diſtance. In the ſame Manner, mark a Point for the Bearing and judged Diſtance of C: then draw between C and D on the Paper, the Curvature, or Windings of the Coaſt, as they appear to the Eye. Next take the Bearings and judged Diſtance of the Point B, and draw the Irregularities of the Coaſt from B to C, and to F. Do the other Side of the Harbour from A to D and to G in the ſame Manner, and the Figure on the Paper will have an apparent Reſemblance to the Harbour, exhibit its Dimenſions ſomething near the Truth, and ſhew the true Courſe into it, if there are no unperceived Rocks or Shoals in the Way. Next, inſert in the Draught the moſt remarkable Appearances of the Coaſt, the Houſes, Hills, Trees, Forts, &c. and ſuch Rocks or Shoals as can be ſeen while you remain there. In ſailing to or from the Harbour, the Lay of the Coaſt, on one, or both Sides of the Entry; and within the Harbour from B to C, and from A to E, may be corrected by the Bearings.

This Method of ſketching a Bay, or Harbour, though far from being exact, will give ſuch an Idea of it as may be of Service on ſome Occaſions; and therefore ſhould not be neglected when there is no Opportunity of doing it more exactly.

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EXAMPLE V.

How to make a serviceable Draught of a Harbour by a Compass, or magnetic Needle, only.

PLATE II. FIG. I.

Go to some Eminence where the whole, or a great Part, of the Harbour may be seen, and select two conspicuous sharp Objects, as tapering Hills, Steeples, Chimney-heads, &c. as A and C, at a competent Distance from each other, and conveniently situated for a base Line; (if no such sharp Objects are to be found, put up Signals on the Hills, or Eminences;) take their Bearing in Degrees, and Parts of a Degree by the Needle, or Compass, which should be provided with Sights, and graduated for that Purpose; and estimate by the Eye the Distance of C from A, as near as you can judge. At A and C take the Bearing of B, and of any other remarkable Object D, on the other Side of the Harbour; and from these Data protract a stasimetric Scheme on Paper, wherein the Points A, B, C, D, will have the same magnetic Directions and proportional Distances as the Object they represent.

With this Scheme go to any adjacent Point of Land in the Harbour, as X; there set down your Compass, or Needle; take the magnetic Directions of two of the stasimetric Objects that are most advantageously situated; draw them out from their respective Points on the Scheme, and their Intersection will be the Point of Station X. At X take the Bearing of the next Point Y; guess its Distance from you; take that Distance from the Scale; mark it on the Bearing-line, and trace on the Paper with the Point of your Compasses the Curve of the Coast between X and Y; take also the Bearing of a and b, and of such Rocks and Shoals as may be seen along the Coast, and draw them on the Paper. Then go to Y; there take the Bearing of A, or of any other of the stasimetric Objects that may make a more direct Intersection; draw out its Direction, and its Intersection with X Y will be the corrected Place of Y. By the Bearing of b and of a, correct likewise their Positions; then the Curve of the Coast between X and Y may be traced with Black-lead more exactly, and remarkable Houses, Trees, &c. inserted,

and

and the Diverſities of the Coaſt between X and Y marked. Proceed in the ſame Manner from Point to Point till the whole Coaſt-line of the Harbour is delineated. If any more ſtaſimetric Objects become neceſſary, let their Places be determined by magnetic Interſections drawn from two of the former Objects.

Next, by Interſections of the Needle taken on Land, or of the Compaſs on Sea, find the Places and Extent of the ſeveral Rocks, Shoals and Sandbanks in and near the Harbour, take Marks for avoiding them, and ſound the Depth of the Water round them, and in other Parts of the Harbour; and mark the beſt Anchorage.

Such a Draught as this of a Bay or Harbour neither requires much Skill nor Time to execute; and though not exact in the Diſtances, exhibits a juſt Repreſentation of the Place; and will be found ſufficient for directing Veſſels in and out without a Pilot, if the Channel is not *very* intricate.

EXAMPLE VI.

How to ſketch a Coaſt in ſailing along it.

1. Prepare a Sheet of large Paper, with parallel Black-lead Lines and Perpendiculars croſſing them all over, as in a ſtaſimetric Scheme. Prepare alſo, in a Book, an *Obſervation Table*, in which is to be wrote diſtinctly and regularly, the ſeveral celeſtial Obſervations, Bearings, Diſtances meaſured by the Log-line, Rocks, Shoals, Soundings, Overfalls, Races of Tide, and other Remarks that may be made along the Coaſt. The Table may conſiſt of ſeven or eight Columns, diſpoſed in the following Order.

OBSERVATIONS IN NAVIGATING THE COAST OF ———

SKETCH I.

From Cape ——— to the Point ———, being ——— Miles measured by the Log. The Course from Station I. *to* II. *being* S¼ W.

Year, Mon. and Day.	Mer. Alt. of the Sun.	Bearings at Station I.	Time and Distances sailed from St. I.	Bearings and Soundings taken at these Distances.	Bearing of Rocks, Shoals, Overfalls, and their estimated Distances, when in a Line with Points or Heads on the Coast.	Remarks on the Tides, and on the Nature and Dimensions of the Rocks, Shoals and Anchorage.
	D. M.		H. M. Mi.	Fath.	Points and Heads Mi.	
1774 Jan.		A W. 17°N. a W. 22 S.	1 20 ¼ 11 45 4	A N. 5° W. b W. 20 S. } 21	c, and Rock. W. 7° N. 2½ d, and Hill. S. 19° W.	This Rock dries at low Water, and seemed 100 Yards in Length from N E. to S W. a Leading-mark to it is,

2. Let four expert Persons be appointed; one to take the Bearings exactly with an Amplitude Compass; one to oversee the Running-out of the Log-line, and to keep an Account of the Ship's Way, so as to be able readily to tell the Distance she has run, when required; the third to attend the heaving of the Lead; to write down the Soundings, and the Bearings of one or two Heads, Points, or remarkable Parts of the Coast taken at each Depth: the fourth, a Draughtsman, to draw out the necessary Bearings and Distances, and to delineate the Figure and Windings of the Coast at the several Stations, and to correct their Forms and Dimensions while the Ship is sailing along the Land.

3. Begin to take the Sketch, if it can be done, off some remarkable Promontory, or Point, that extends farther out than the rest of the Coast, and may intercept and turn off the principal Stream of Tide, so that there may be

be little Stream where the Ship's Way is to be firſt meaſured by the Log. Bring the Ship as near the Point as can be done with Safety; there drop Anchor, if the Depth of the Water and the Ground are proper for it; if they are not, make the Ship *lie to* as ſteadily as poſſible.

4. On a convenient Part of the prepared Paper make a *Dot* to repreſent the Place of the Ship; draw a ſmall Black-lead Circle round the Dot to make it more conſpicuous, and mark it with N° I. for the firſt Station. Then take the Bearing of the Point, or Promontory you lie off; draw it out with a Protractor from the Dot; eſtimate its Diſtance by the Eye as exactly as you can; take that Diſtance from a proper Scale of equal Parts, mark it on the Bearing-line with a Dot, and with the capital Letter A. Next take the Bearing of the fartheſt Point, or Promontory, which is ſeen diſtinctly, and is intended for the Limit of the firſt Sketch; draw it out from N° I; eſtimate its Diſtance by the Eye; take it from the Scale, and mark it on the Bearing-line with a Dot and with the capital Letter B. Take alſo the Bearings, and eſtimate the Diſtances, of all the Points, Heads, Inlets of Rivers or Harbours, Rocks, Corners or Heads of Bays, that are ſeen between the two Points A and B; draw them out and mark them with the ſmall Letters a, b, c, &c. as far as they are ſeen with any Diſtinctneſs.

5. Sketch faintly (ſo as it may be eaſily rubbed out when it is to be corrected afterward) the Figure of the Coaſt between the ſeveral Dots; as from A to a, from a to b, from b to c, &c. as far as two or three Miles; or only as far toward B as you have a diſtinct Sight of the Bays, Irregularities, and Dimenſions of the ſeveral Parts of the Coaſt, and let the reſt be ſketched as you ſail paſt them, after their Diſtances have been corrected by the Ship's Run meaſured by the Log.

6. Look for ſome conſpicuous tapering Hill, Building, Steeple, or Grove of Trees, up the Country, and ſeveral Miles diſtant from the Shore, and ſituated as far along the Coaſt toward B, or beyond it, as can be found; take the Bearing of that Hill, or Object exactly, draw it on the Paper; and when another Bearing of it is taken at a proper known Diſtance from the Station I, its Poſition will then be determined on the Draught by the Interſection of theſe two Bearings, and will ſerve for correcting, or determining the Diſtances of Points, Promontories, Bays, &c. along the Coaſt.

7. While the Ship lies at Station I. off A, let the Latitude be obferved, if there is an Opportunity, either by the Sun or Stars. Then get the Ship under Way, and fail in a ftraight Line for the fecond Station off B; meafure the Ship's *Run* carefully by the Log, and keep an Account of the Time by a Watch as you fail; that when you are off any of the Heads, Points or Openings marked with the fmall alphabetical Letters, their Diftance may be known more exactly and corrected: Correct alfo, by the Way, the Figures and Dimenfions of thofe Parts of the Coaft which were imperfectly feen and fketched at N° I. Alfo, found the Depth of the Water by the Way, and at each Sounding take the Bearing of the firft Point A, or of the laft Point B, and of one or more of the Heads, or Points on the Coaft; and likewife of the inland Hill, or other Object, in order to determine afterward the Places of the feveral Soundings, and to difcover whether the Ship is carried out of the ftraight Courfe by Streams of Tide, Currents, or Lee-way, and to correct that Deviation. Let fuch Rocks, Shoals, Overfalls, or remarkable Streams of Tide as are met with, have two or three Bearings taken of them when they appear in a Line with any of the Points, Heads, or Iflands in the Draught, and their Extent eftimated by the Eye; and all wrote in a Book, to be inferted in the Draught more correctly afterward; and if there is an Opportunity, to be more particularly examined another Time.

8. When the Ship has got to the Head, or Point B, the Limit of the firft Sketch, drop Anchor; or bring the Veffel *to*, as at N° I.; write at the Top of the *Obfervation Table* the Diftance between A and B, as meafured by the Log; and write in the Table all the intermediate Diftances fo meafured; and likewife the Obfervations, Bearings, Times of them, Diftances, Soundings, and Remarks; all of which muft be referved for future Ufe, when the Sketch undergoes another Correction.

9. At Station II. take the Bearing of the inland Hill, or Object, one Direction of which was drawn out from the firft Station, and thefe two Bearings will interfect in the Place of the Hill; which will then ferve to correct the Pofition of fome Parts between the firft and fecond Stations, and to determine by Interfections the Pofition of Heads, Points, and other Parts of the Coaft between the fecond and third Station; and verify, or correct, their Pofitions meafured by the Log.

Take

Take also the Bearing of the Top of some other conspicuous inland Hill, or Object, situated farther along the Coast, the Position of which must be determined afterward by another Bearing taken at a proper Distance; and *that* Hill will then serve for the same Use between Station III. and IV. as the other Hill does between Station II. and III. Then take the Bearing of the Point, or Head, B, next you; estimate its Distance, and mark it on the Paper in the Bearing-line with a Dot, and N° II. for the second Station, or Beginning of the second Sketch; also the Bearing of a distant Point or Promontory, for the other End of it; estimate its Distance by the Eye, draw it out from N° II, and mark it with a Dot and the capital Letter C. Then take Bearings of all the Heads, Points, Inlets, &c. between B and C, estimate their Distances, and mark them on the Bearings, and sketch the Figure of the Coast between the Points, and proceed as was directed at Station I. till the whole is finished in the same Manner. This however is but a rough imperfect Sketch, and must be corrected at more Leisure, by drawing the whole anew on clean Paper from the Distances and Observations in the Observation-Table.

10. If the Coast lies northward and southward; observe the Latitudes of the Heads, Points, or Inlets, at every 20 or 30 Miles Distance, if it can be done; and by these let the principal Distances be a second Time corrected. If the Coast lies nearly East and West, the Distance cannot be corrected by Latitudes, and therefore frequent Observations of the Sun are unnecessary.

11. When you are obliged to leave off the Work for want of Day-light, or by bad Weather, do it as near some Head, or remarkable Part of the Coast as you can; take Bearings, or Marks, on the Place you left off at, that it may be easily found when you want to begin again.

12. If the Coast navigated is a *Strait*, or the Mouth of a River, where the Land on each Side can be seen; at each Station on one Side, take the Bearings of remarkable Heads, Points, Islands, Hills, &c. on the opposite Side, and let that be *one* Direction by which their Positions and Distances are determined.

A Coast sketched in the above Manner may contain many good Harbours or Bays, which are not to be perceived in sailing along it. If there is an Opportunity,

Opportunity, the Ship ſhould go into ſome of them, until a Delineation was made of them, and the Entrance ſounded in and out; which would render the Sketch of the Coaſt of much more Service.

CHAP. IV.

Rocks and Shoals determined and deſcribed. Tides and Soundings. Tides deſcribed. Harbours deſcribed. Copying and reducing Draughts. Neceſſary Inſtruments.

SECTION I.

How to determine the Diſtance and Extent of Rocks, Sand-banks, and Shoals, lying off a Coaſt that has been ſurveyed; and how to avoid them by the approximating Angle.

TO determine their Diſtance; anchor a Veſſel at one End of the Rock, Sand-bank, or Shoal; and in the Veſſel, with *Hadley*'s Quadrant, take the Angles between three Objects on Shore, whoſe Diſtances from one another are known, and (by longim. Prob. Page 18.) find the Diſtance of the Veſſel from theſe Objects, which will give that End of the Rock or Shoal.

Or, anchor a Boat at one End of the Rock, or Shoal, and take the Angles on Shore from two Stations whoſe Diſtance is known, and (by longim. Prob. Page 10.) find the Diſtance of the Boat.

To find the Extent of the Rock, Sand-bank or Shoal; if its Extent is ſmall, it may be eſtimated by the Eye ſufficiently near: if large, the other Extremity muſt be determined in the ſame Manner, by the Angles taken on Shore; or rather, by one Angle taken on Shore, and that Direction interſected by a magnetic Bearing at the other End before determined.

When a Coaſt has been firſt carefully ſurveyed, the Diſtance of Rocks, Shoals, and Sand-banks may be found with ſufficient Exactneſs by two Bearings of ſome diſtinct Part of them taken on Shore with a good magnetic

 Needle;

Needle; provided the Stations are not at ſuch a Diſtance, or Poſition, from each other as to make too oblique an Interſection.

If the Shoal lies ſo far from the Coaſt eaſtward or weſtward that the Land cannot be ſeen at it; in moderate Weather, anchor a Veſſel at the Shoal, and two Boats with their Sails looſe at a proper Diſtance and Poſition from each other, between the Shoal and Land, and ſo as the Boats may be ſeen from the Shoal, and the Land ſeen from the Boats. Let an Obſerver in each Boat take the Angles between three known Objects on Land with *Hadley*'s Quadrant; and another Obſerver in the Veſſel at the Shoal, take the Bearing of the two Boats as exactly as poſſible with a Compaſs. By the firſt Angles the Diſtance of the Boats from the Land, and from each other, will be found; and by the Bearings, the Diſtance of the Shoal from the Boats, and of Conſequence from the Land, will likewiſe be determined.

The Diſtance of the Shoal from any one of the Boats may likewiſe be meaſured by the Velocity of Sound, by appointing two or three Guns to be fired from the Veſſel when a Signal is made, as directed in Long. Oper. 3.

If Boats, or ſmall Veſſels, cannot anchor within Sight of the Land, and, at the ſame Time, be ſeen at the Shoal; then ſail from the Shoal towards the Land with a leading Wind, meaſure the Ship's Run carefully with a Log-line, and when the Land is ſeen diſtinctly, there drop anchor; and find your Diſtance from it by *Hadley*'s Quadrant; and the Diſtance run from the Shoal, added to the Diſtance of the Land (and reduced to one Direction, if neceſſary) will give the Diſtance and Poſition of the Shoal from the Land nearly. If the Shoal lies North or South from the Coaſt, its Diſtance may be found by the Latitude, and the Ship's Courſe in ſailing towards the Land.

At every Rock, Shoal and Sand-bank, Marks ought to be taken on the Land, for avoiding them. In doing this, chuſe ſuch Objects only as are remarkable and ſtriking, which a ſtranger to the Coaſt may readily diſtinguiſh; and not ſuch as are ſmall, or faint, which none but a Perſon particularly acquainted in the Place can find out. If no ſuch diſtinct Land-marks can be found for directing Veſſels paſt them; then they may be avoided by the *Approximating Angle*, taken in the following Manner. On the Out-ſide of ſuch Rock or Shoal, with *Hadley*'s Sextant obſerve carefully the Angle which two

remarkable

remarkable Objects on the Land, at a proper Distance and Situation, subtend; take also their Bearings by the Compass; and write all down for future Use. And while at any other Time, in sailing towards that Shoal, the Angle between these two Objects is found *less* than the approximating Angle, you are certainly without the Shoal; and also without all Rocks or Shoals lying within a Circle that may be supposed to pass through the two Objects on Land, and the Point where the approximating Angle was taken. For all Angles *in* the Periphery of that Circle, which the two Objects subtend, are equal; the Angles *within* the Periphery, greater than these; and the Angles *without* it, less. Euc. iii. 21. The Bearings will shew when you are a moderate Distance from it on either Side.

To find out Shoals that may be along any Coast: in blowing Weather, go to the Top of a Hill, Cliff, or Eminence, and observe where the Sea appears rougher, or the Waves break more, than in other Parts, for there the Water is shallowest; except the Roughness arises from a Stream of Tide going against the Wind; or two Streams meeting each other. Take Land-marks, or the Bearing of the Breakers, from one, or two, remarkable Places, and that will direct you to the Shoal in a Boat afterwards, when the Weather is moderate.

Or, in a Calm, observe just after Slack-water, where a grey Stream, or Ripple on the Surface, first begins; and at the smooth Edge of that Ripple the shallowest Water will be found.

Breakers are often seen in calm Weather, before a Gale of Wind, where the Water is shallower than in the neighbouring Parts; though there may be a sufficient Depth where the Breakers rise.

SECTION II.

Circumstances to be taken Notice of in describing Rocks, Shoals and Sand-banks.

It may not be unnecessary first to caution a Surveyor against taking his Accounts of Rocks, Shoals, Tides, or Harbours, solely from the Information of others, without examining them himself: for there are few to be met with who have been careful and circumstantial enough in their Observations; and

and ſome who will affirm for Fact, as if grounded on actual Obſervation, what is only a vague Opinion long entertained on uncertain Authority. Even profeſſed Pilots are often ſatisfied with knowing how to avoid Dangers by keeping at a ſufficient Diſtance from them, or in the common Channel, without troubling themſelves about farther Particulars. Information ſhould be made Uſe of, but only as a Direction for farther Inquiry, and to facilitate your own Search and Examination. In deſcribing Rocks, Banks, and Shoals,

1. Take Notice how far they lie from ſome remarkable Head, or Part, of the neareſt Land; and how they bear from that and from ſome other conſpicuous Part of the Coaſt.

2. How far they extend in Length, and in what Direction.

3. What Land-marks lead directly on them.

4. At what Time of the Tide they begin to dry, or are covered.

5. The leaſt Water on the Shoal.

6. How they are to be avoided on each Side.

7. The approximating Angle, if diſtinct Land-marks are not to be found.

SECTION III.

Affections of Tides relative to the Soundings.

As the perpendicular Riſe of ſpring and neap Tides varies ſenſibly according to the Diſtance and Poſition of the Moon with Reſpect to the Earth; and of the Earth and Moon with Reſpect to the Sun, and alſo by Winds and Weather; the Depths of the Water proper to be inſerted in Draughts of the Sea-coaſt, ſeem to be ſuch only as are taken at low Water in ordinary Spring-tides; and not ſuch as are found when the Tides are affected by extraordinary Cauſes. Ordinary Spring-tides may be reckoned, ſuch as happen in moderate Weather, on the third Day after new or full Moon, when ſhe is at her mean Diſtance from the Earth, and the Sun not near the Equinoxes.

It would be extremely tedious to wait for low Water Spring-tide, to take all the neceſſary Soundings. Therefore, that the Depths proper to be marked may be known, whatever Time they are taken, let the perpendicular Riſe, or Fall, of the Water, in moderate Weather, on the third, or fourth Day after Full or Change, and after Quarter Moon, be firſt found by Experiment; and then the Depth at low Water ordinary Spring-tide may be known ſufficiently near, by making the following Allowances at the Time each Depth is taken.

If the Depth is taken at High-water Spring-tide, then deduct the full Riſe of ordinary Spring-tide from the Depth found, and the Remainder will be the Depth to be inſerted in the Draught.

Spring-tide, at the	1ſt Hour before and after High-water, deduct	$\frac{11}{12}$	of the full Riſe of ordinary Spring-tide.
	2d Hour before and after High-water, deduct	$\frac{3}{4}$	
	3d Hour before and after High-water, deduct	$\frac{1}{2}$	
	4th Hour before and after High-water, deduct	$\frac{1}{4}$	
	5th Hour before and after High-water, deduct	$\frac{1}{12}$	
	6th Hour, or about Low-water, deduct	0	

If the Depth is taken at High-water Neap-tide, from each Depth deduct $\frac{4}{5}$ths of the full Riſe of Spring-tide, or the whole Riſe except one fifth Part.

Neap-tide, at the	1ſt Hour before and after High-water, deduct	$\frac{4}{5}$	of the full Riſe of Spring-tide.
	2d Hour before and after High-water, deduct	$\frac{3}{4}$	
	3d Hour before and after High-water, deduct	$\frac{1}{2}$	
	4th Hour before and after High-water, deduct	$\frac{1}{4}$	
	5th Hour before and after High-water, deduct	$\frac{1}{5}$	
	6th Hour, or about Low-water, deduct	$\frac{1}{5}$	

Theſe Allowances are not given as quite preciſe, for they will vary a little from ſeveral Cauſes; but as a general Rule, which will be found ſufficiently exact on moſt Occaſions. Shoals and Channels that have leſs than four Fathoms, and are much in the Way of Shipping, require to be ſounded at low Water Spring-tide, that the Depth of the Water there may be more preciſe.

That the Depths to be marked may be known with more Exactneſs, let it be obſerved, that when the Moon is in the Perigea, or leaſt Diſtance from the Earth, then the perpendicular Riſe of ſpring and neap Tides are about one eighth more than ordinary; and that about the Equinoxes, the full Riſe is about one tenth more, from that Cauſe alſo: that when the Moon is in the Apogea, or at her greateſt Diſtance from the Earth, then the Tides are proportionally leſs than ordinary: ſo that ſometimes the greateſt neap Tides may riſe as high as the leaſt ſpring Tides. But theſe and other Affections of the Tides have not yet been ſo minutely inquired into as they deſerve. Hard Gales of Wind in any Place, eſpecially if it blows in the Direction of the Flood, ſwells the Tide to an uncommon Height: Storms at a Diſtance, are found ſometimes to occaſion an extraordinary Riſe of the Water in Places where the Gale is not felt: and two Streams of Tide running round an Iſland, make the Tide riſe higher near their Meeting than it does in other neighbouring Parts.

Where the Depth at low Water is above five Fathoms, there a Foot or two, more or leſs, is of no great Conſequence; and therefore it is ſufficient if the Deduction from the Riſe of ſpring Tide is in Proportion to the Time of the Tide: that is, at high Water, deduct the full Riſe; at quarter Ebb, three Quarters; at half Ebb, or Flood, half the Riſe; and at three Quarters Ebb, or one Quarter Flood, deduct one Quarter of the full Riſe from each Depth found.

The beſt Way to find the exact Time of high Water on the full and change Days is, in moderate Weather, when the Sea is ſmooth; then, about three Hours before high Water, mark the Place on the Shore to which the Tide reaches, and write down the Hour and Minute you obſerved it: on the Ebb, watch till the Tide falls to the ſame Mark on the Shore, and ſee what Hour and Minute it is then; and to the Time between the two Obſervations add two Minutes for each Hour, on Account of the Acceleration of the Tide, and half that Sum, added to the Time of the firſt Obſervation, will be the true Time of high Water that Day.

SECTION IV.

Circumſtances to be taken Notice of in deſcribing Tides.

1. Obſerve the Time of high water on the full or change Day of the Moon. Let it be expreſſed in Hours and Minutes, not as is commonly

done, by the Bearing of the Moon, which ſerves no uſeful Purpoſe whatever, but always occaſions an unneceſſary Reduction of Time, and Points of the Compaſs, into one another.

2. Obſerve the perpendicular Riſe of the Tide on the third, or fourth Day, after new or full Moon; and at different Seaſons of the Year; and when the Moon is in the Perigea and Apogea.

3. Obſerve the Direction of the Streams of Flood and Ebb, near the Coaſt, and at a Diſtance from it; the Irregularities, or Variations of their Direction; and at what Time of the Tide on the Shore, the Stream in the Offing begins to turn.

4. Obſerve the greateſt Velocity of the Stream at ſpring and neap Tides, off the Coaſt, and in Channels; meaſured by a Log-line heaved from a Boat or Ship at Anchor; or by driving with the Stream, in a Calm, a known Diſtance.

5. In ſpeaking of irregular Tides, do not ſay, it flows 9, or 8 Hours, and ebbs 3, or 4 (as is often done) when you mean only, that the Stream runs 9, or 8 Hours one Way, and 3, or 4 the other; for that creates Confuſion, and ſometimes Miſtakes. While the Tide riſes, and then only, it is Flood; and only while it falls, is it Ebb; in whatever Direction theſe Streams run. Therefore always expreſs ſuch an Irregularity in the Stream, by the Time it *runs* in one Direction, and the Time in the other.

SECTION V.

Circumſtances to be taken Notice of in deſcribing Harbours.

1. Obſerve if they are well ſheltered, or, on what Quarter they are expoſed.

2. The Depth of the Water, and Nature of the Ground in the Anchorage.

3. What Number of Ships they are capable of containing eaſily; and of what Size, or Draught of Water.

4. In what Part to anchor; and the Land-marks, or Bearings for it.

5. How the Entry may be diſtinguiſhed at a Diſtance, or how to fall in with it coming from Sea.

6. How to avoid Rocks and Shoals in the Way to a Harbour; or ſailing to the Anchorage.

7. If there is a Sufficiency of freſh Water, and where it is; and what Proviſions the Place affords.

8. In unknown Places, obſerve what Forts, or Batteries are in them; what their Strength is; and how near a large Ship may get to them: or, in what Parts of the Harbour, Forts, or Batteries, may be advantageouſly erected, either for Defence, or Attack.

SECTION VI.

How to copy a Draught exactly.

Pin clean Paper over the Draught to be copied, ſo as they may not ſhift: hang, or hold, them up before a Window, or the Glaſs of a Chariot, and the Drawing will appear through the clean Paper, and may be traced on it with a black-lead Pencil, and afterwards with Ink.

Or, rub the Back of the Draught, or as much of it as may be neceſſary, over with Charcoal; lay the rubbed Side on clean Paper, and pin them together, and lay both on a Table, the Draught uppermoſt, and with a ſmooth-pointed Tracer, of Braſs, Ivory or Steel, not very ſharp, trace exactly all the Coaſt-line firſt, and then other Parts, and the Under-paper will retain the Impreſſion diſtinctly. If the Charcoal ſtains other Parts of the Under-paper, it will rub out by the Crumb of Loaf-bread, after the Tracing is inked.

If, in the Copy, you want the true Meridian right up and down on the Paper, inſtead of the Magnetic: draw the true Meridian firſt on the Middle of the original Draught; then in a proper Part of the clean Paper (before it is pinned to the other) draw a Line right up and down; and pin them together ſo, that the Line on the clean Sheet may lie exactly under, or over

over (according to the Manner of copying) the true Meridian drawn on the Original; then trace the one from the other.

SECTION VII.

How to reduce a Draught to a ſmaller Scale.

A Pantagraph is by far the eaſieſt and moſt expeditious Inſtrument for diminiſhing Draughts with Accuracy: but, when one of a ſufficient Size for large Draughts cannot be got, either of the following Methods will ſerve.

With Black-lead draw the large Draught all over with Croſs-lines, forming exact Squares: draw the clean Paper for the Copy alſo over with the ſame Number of Squares; but their Sides ſmaller, in Proportion to the intended Size of the Scale; ſuch as one half, one fourth, &c. of the Length of the other: diſtinguiſh, by a ſtronger Line, and mark with a Figure, every fifth or ſixth Row of Squares in both, ſo that the ſeveral correſponding Squares may be more readily perceived: then, in each of the ſmall Squares, draw, by the Eye, a Curve ſimilar to that which is in the correſponding larger Square, till the whole is copied.

Or; draw a Black-lead Line from End to End of the large Draught, in any Direction, as A B (Plate III. Fig 7.) by its proper Scale divide that Line into any Number of Miles, or half Miles; at each Diviſion raiſe Perpendiculars, and draw them out to the Coaſt-line, and mark them 1, 2, 3, &c. at each End.

On a proper Part of the Paper for the ſmall Draught, draw a Black-lead Line right up and down on the Paper, for the Meridian; and another Line making the ſame Angle with it, as the divided Line in the large Draught does with its Meridian, and in the ſame Poſition as a b (Fig. 8.) make a b the half, the fourth, &c. of A B, according to the intended Diminution of the Scale; divide it into the ſame Number of Miles, or half Miles, by its proper Scale, as the other is; at each Diviſion raiſe Perpendiculars, draw them out a ſufficient Length, and mark them at each End, 1, 2, 3, &c. as in the other, that the correſponding Perpendiculars may be readily found.

Meaſure

Meaſure on its proper Scale the Length of the firſt Perpendicular on A B, in Miles and Parts of a Mile: take the ſame Number of Miles and Parts from the ſmall Scale, and ſet it from 1 to 1, in the ſmall Figure, and mark it with a Dot: do the ſame in every other Perpendicular, and ſo many Points of the Coaſt in the ſmall Figure will be found.

Then, between every two extreme Dots in the ſmall Figure, ſketch by the Eye the correſponding Curve of the large Coaſt, and both Figures will be ſimilar in every Reſpect. Hills, Rocks and other Objects may be drawn in the ſame Manner.

There are proportional Compaſſes and Compaſſes with three Legs made, by which ſmall Draughts may be diminiſhed; but they do not anſwer ſo conveniently for very large Draughts.

SECTION VIII.

Inſtruments and other Neceſſaries for taking a Survey of the Sea-coaſt.

A good aſtronomical Quadrant 14 Inches Radius of *Bird*'s Conſtruction; with a Pirn of fine Silver-wire for the Plummet.

A *Hadley*'s Octant, 18 Inches Radius.

A *Hadley*'s Sextant of Braſs, 9 Inches Radius.

A Bell-metal Theodolite, with a ſpirit Level, Needle and two Teleſcopes: the Objects to be ſeen direct through the Teleſcope, not inverted.

A Caſe of good Pocket-inſtruments.

A Braſs-ſcale 3 Feet long, with various Lines of equal Parts on it.

A Wooden-ruler 5 Feet long.

A beam-compaſs of Wood two Feet long and ¾ broad, divided from the Center Point along a chamfered Edge into Inches and eights of an Inch.

A *Gunter*'s Scale 2 Feet long; and one a Foot long.

A Braſs

A Braſs circular Protractor 12 Inches Diameter, with an Index and Pricker to mark the Degrees and Minutes on the Paper; the graduated Edge ſilvered. Another 5 Inches Diameter; and another ſemicircular, 3 Inches Diameter.

A meaſuring Pole 30 Feet long, divided into Feet; and conſiſting of two Pieces that may be joined together End-ways, and taken aſunder at Pleaſure.

A ſtraight Mahogany-pole, preciſely 6 Feet long, divided into Feet and Inches; the two extreme Feet into Decimals of an Inch.

Two Iron-chains, each 60 Feet long; each Link a Foot, and the Thickneſs of a Quill; with braſs Marks at every tenth Link.

Four Iron-Reels, with Stakes and Lines, ſuch as Gardeners uſe.

Three wooden Poles, each 10 Feet long, and $1\frac{1}{2}$ Inches Diameter; 12 Poles, each 6 Feet long and one Inch Diameter: all pointed with Iron on a Socket, ſo as to pierce the Ground eaſily and ſtand firm in it.

Thirty cylindrical Iron-pins, ſharpened at one End, for piercing the Ground at the End of each Chain, or Meaſuring-pole; each about 8 Inches long and half an Inch Diameter.

Two Canvaſs-pockets for holding theſe Pins, with Strings for tying them round the Waſte of the Meaſurers.

A good amplitude Compaſs.

A magnetic Needle, with an agat Cape, Braſs graduated Circle, and a Lever, in a ſquare wooden Box, with jointed Sights to lie within the Box when ſhut.

A Pocket-compaſs, with an agat Cape.

A Ship's-compaſs, for taking Bearings in the Boat; the Depth of the Box equal to the Diameter of the Card, ſo as not to touch the Glaſs above, nor the Bottom below with any Motion; and the Angle of the Cape a Right-angle.

A good portable refracting Teleſcope, of *Doland*'s Conſtruction.

A Caſe

A Caſe of Leather, divided Length-ways by Paſteboard into two Apartments, 2 Feet 1 Inch long, and 18 Inches broad; for holding the original Draught, ſpare Paper, Scales and Protractors, and ſecuring them from Rain and Salt-water: alſo a ſmall Drawing-broad, the Size of the Caſe, with Leather Straps and Buckles, for carrying both together over a Man's Shoulder.

A Draught-cover, 2 Feet long, and 18 Inches broad, made of Paſteboard covered with Oil-cloth, like the Cover of a Book, for laying the original Draught in, that it may ſlip eaſily in and out of the Leather Caſe without Injury.

A good Stop-watch, that ſhews Seconds.

A Two-foot reflecting Teleſcope, for obſerving Eclipſes of Jupiter's Satellites, or of the Moon, when neceſſary to find the Longitude.

A large Drawing-table, 7 Feet long, and 5 Feet broad, with a round Moulding along the Edge of one Side and one End, to keep the Paper ſmooth when drawn over the Table to reach the Top of the Draught. The Board, when not in Uſe, to come aſunder in two Leaves, one of the Leaves $1\frac{1}{2}$ Inch broader than the other: when in Uſe, to be faſtened together on the under Side by two Hooks, one near each End; and to be ſupported by a Frame, or by a long three-legged Stool at each End; with a looſe Poſt, or Pillar, under that Side where the Drawer commonly ſits, that the Board may not warp, or bend, by his Weight when leaning on it: the Parts of the Frame, or Stools, to be made and marked ſo as to be eaſily taken to Pieces, or joined, occaſionally.

A Folio Obſervation-book of 4 Quires medium Paper, ruled at the Top for a running Title; and for a local Title; a two-inch Margin on the left Side of each Page; and and two Columns on the Right: the firſt half an Inch, for Degrees and Minutes, the other one Inch, for magnetic Bearings.

A Folio Journal-book, of 3 Quires medium Paper, ruled at the Top; with a two-inch Margin, and a ſmall Column for the Days of the Month on the left Side of each Page.

A View-book, of half a Quire imperial Paper, opening Length-ways to the Extent of two Sheets, and twelve Inches broad; the Leaves pasted and guarded in the Middle.

Memorandum-books, each of 6 Sheets Demy-paper, with red Leather Covers.

East India, or such other large Paper, for the original Draughts; that may bear to be often folded without cutting.

Imperial Paper for the Draughts.

Transparent Paper, for copying Parts of a Draught readily for occasional Service.

Writing Paper.

Cartridge Paper, for covering up a clean Draught while it is making out.

Quills, Crow-quills; Cake-ink, Indian-ink; Hair-pencils, some of the smallest, and some of a middling Size; Black-lead Pencils, some of which flat; Charcoal, for copying a Draught by tracing it on a Table; Penknives.

A Survey-boat, or six-oar'd Cutter, 24 Feet from Stem to Stern, 7 Feet 3 Inches broad, and 2 Feet 11 Inches deep, with Wash-boards, Masts, Sails, &c. and two Graplings, a larger and a less; the larger to have a Block made fast to the Ring for running 40 or 50 Fathoms of Rope through, in order to moor the Cutter off the Shore or Rocks, and haul her in or out at Pleasure. Also an Awning of painted Canvass to sleep under where it is not safe landing. Such a Boat will carry, of King's Allowance, one Week's Beer, and two Weeks Provisions (Water and Firing excpted) of all other Kinds for eight Persons; together with a Tent, Bed-cloths and cooking Vessels; and is fit for rowing as well as sailing, if made light.

A Captain's Tent and Marki, with a Bed and Bedding to serve two Persons.

A Vessel about 120 Tons Burden, pretty broad in the Beam, and full in the Bows; and of such a Mould as to draw little Water, and to take the Ground easily;

easily; with a Cabbin 12 Feet in the Floor, well lighted, and fit to hold the above-mentioned Drawing-table. Her Complement of Men (besides the Surveyor, his Assistant and two Servants) to be a Master, a Purser, a Mate, a Midshipman, a Carpenter, a Sail-maker, a Boatswain, a Cook, fourteen able Seamen before the Mast, and a Pilot for the Coast. A larger Vessel cannot go into small Creeks, which will often retard the Service, and be found very inconvenient on a Survey: a Vessel much less, cannot keep Sea well, nor carry Provisions and other Stores sufficient for the Season; which is likewise a Disadvantage. In hot sickly Climates, and Countries where Seamen cannot be got easily, a greater Number of Hands will be necessary, and likewise a Surgeon. If the Surveyor has two Assistants under his Direction, that both may be employed at the same Time, another six-oar'd Cutter, with six Hands more, will be necessary: and, if the Coast has many Shoals, Sand-banks, or Bar-harbours along it, or few Harbours that are accessible at all Times of the Tide, a Pilot for each Boat, who is minutely acquainted with the Coast, will also be necessary, to guard against Misfortunes, and for finding out the Shoals and Channels more readily.

CHAP. V.

SEC. 1. To find the Longitude by an Eclipse of one of Jupiter's Satellites. 2. To continue a Meridian through a Kingdom. 3. To trace a Parallel of Latitude through a Kingdom.

SECTION I.

How to observe an Eclipse of Jupiter's Satellites, in order to find the Longitude of the Place of Observation.

THE most exact Survey of a Coast cannot be reckoned complete, till its Longitude from some other noted Place is known: and the most careful Surveys, if they extend far eastward, or westward, will require to be corrected by an Observation of the Longitude. It is therefore a necessary Part of a Surveyor's Business to understand how this Problem is to be performed.

For determining the Longitude of one Place from another on Land, Eclipses of Jupiter's Satellites, especially of the first, are found to be the most advantageous celestial Appearance. If the Hour, Minute and Second when any such Eclipse happens is observed in two Places, the Difference of these Times, converted into Degrees, Minutes and Seconds of a Circle, will give the Distance of their Meridians, or the Longitude of one Place from the other. Or, if the precise Time of an Immersion, or Emersion at one Place is known by Calculation, and found by Observation at any other, their Difference of Longitude will then be known. There are Tables published annually, in the nautical Almanack, of the Time at Greenwich, when Jupiter's Satellites will be eclipsed: if therefore the Time in another Place, when such Eclipse happens, especially of the first Satellite, is found by Observation, their Difference of Longitude will be then known.

To find the precise Time of the Day at which an Immersion, or Emersion of a Satellite is observed, four principal Operations are necessary. 1. *To find an exact Meridian-line*, so that by it a Clock, or Watch, may be set either to apparent or to mean Time at the Place of Observation. 2. *To regulate the Clock or Watch*, so as they may keep equal Time: or, to find the Error of their Going, that proper Allowance may be made for it. 3. *To set the Clock, or Watch, to mean or equal Time by the Meridian-line.* 4. *To observe, and note, the precise Moment when the Eclipse begins, or ends.*

1. *To find an exact Meridian Line.* For doing this, see several Ways by the Stars (Part 1. Beginning at Page 47.) which are more to be depended on than any Observations of the Sun, if the Observer is not provided with the best Instruments and a convenient Observatory.

2. *To regulate a Clock, or Watch, so that they may keep equal Time*; or to find how much they go fast or slow, that Allowance may be made for it. The most simple and certain Test of equal Time is, the diurnal Rotation of the Earth on its Axis: or, which results from it, the apparent daily Revolution of the fixt Stars round the Axis of the Earth. By that, therefore, let your Clock, or Watch, be regulated, as directed in Merid. Prob. Page 56.

3. When

3. When the Clock, or Watch, is regulated to go equally, or the Error of their Going is found; *then let them be ſet to the mean Time* * *of the Day by the Meridian-line*, in the following Manner.

In a Room with a large Door, Window, or Opening towards the North, from whence your Meridian-line northward may be ſeen (if the Meridian has been marked toward the North) and another Door, Window, or Opening towards the South, right oppoſite to the other, through which the Sun may be ſeen at Mid-day; hang up two Plumb-lines exactly in the Meridian, as far aſunder as conveniently may be; let the Plummets, or Weights, be as heavy as the Lines will eaſily bear; and make them ſwing in Water, to prevent ſhaking by the Motion of the Air. Stop the Clock, or Watch, preciſely ſo many Minutes and Seconds before, or after twelve, as are equal to the Sun's Equation that Day, which may be found in Equation Tables; and with a ſmoked or tinged Glaſs before your Eye, obſerve when the Center of the Sun comes exactly in a Line with the two Plumb-lines, and that Moment call out, *Now*; that your Aſſiſtant may ſet the Clock, or Watch, agoing immediately. Or, which perhaps is more accurate, ſtop the Clock as many Minutes and Seconds before the Time pointed out by the Equation, as the Center of the Sun takes to move the Length of his Semi-diameter that Day (which may be found in the nautical Almanack) and when the weſtern Edge of the Sun juſt touches the Plumb-line, ſet the Clock, or Watch, agoing, and they will then be ſet to mean or true Time. In moſt Places it will be neceſſary to have a ſmall temporary Room, for an Obſervatory, built on purpoſe; with an Opening toward the North, and another toward the South, that may be ſhut at Pleaſure, to keep out any Draught of Air which would diſturb the Plumb-lines.

* Mean, or equal Time is, the Time ſhewn by a Clock that is ſet right, and goes exactly equal. Or, it is the Time ſhewn by the Sun, corrected by the Equation; or when Allowance is made for the Inequality of the Sun's Motion.

Apparent Time is, the Time ſhewn by the Sun (whether in the Meridian or not) without making any Allowance for the Inequality of the Sun's Motion: this is the Time ſhewn by a good Sun-dial; or found by an Azimuth or Amplitude of the Sun.

Equation of Time is, the Acceleration, or Retardation, of the Sun's Motion; or how much the Sun is too faſt, or too ſlow, of equal Time.

4. To

4. *To observe, and note, the precise Time of the Immersion, or Emersion, of a Satellite:* Two or three Days preceding the Night of the Eclipse, set your Clock, or Watch, to mean Time by the Sun and the Meridian; and, if it can be done, examine its Accuracy, the Day of the Eclipse also; but without altering the Clock, though it has not gone quite exact; for Clocks and Watches often go irregular a little after they have been set back or forward: only, note how much it is less, or more than the mean Time each Day, that proper Allowance may be made in settling the true Time of the Eclipse. Guess as near as you can to your Longitude from Greenwich, and from thence find at what Time the Eclipse may be expected with you: if you are eastward of Greenwich, the nominal Time it will happen with you will be so much later than at Greenwich; if you are westward of Greenwich, the Time with you will be so much sooner, according to the Longitude. An Hour before it is expected, adjust the Telescope * to your Sight, so as to see Jupiter's Belts distinctly. A Quarter of an Hour before the Eclipse is expected (or more, if your Longitude is very uncertain, or if it is any Satellite but the first) sit down to your Telescope; and if it is an Emersion, keep looking towards that Part of Jupiter's Disk on which you find, by the nautical Almanack, it is to happen. But observe, that if your Telescope inverts Objects, the Eclipse will happen on that Part of Jupiter's Disk which is diametrically opposite to that in the Almanack. While you are watching the Appearance of the Satellite, let your Assistant count every Second audibly, by the Beats of the Clock, or by the Motion of the Second-hand of the Watch; and the Instant the Satellite appears, if an Emersion; or the Instant it disappears, if an Immersion, call out, *Stop:* and immediately, the Assistant should repeat the last Second he counted, which the Observer should note down directly, while the Assistant looks to the Minute, and notes it down. Write down likewise what Sort of Telescope you observed with, and its length and magnifying Power: for Eclipses will be perceived somewhat sooner by a good Telescope than by one of a worse kind.

* The Telescopes proper for observing the Eclipses of Jupiter's Satellites are, common refracting Telescopes, from 15 to 20 Feet; reflecting Telescopes of 18 Inches or two Feet; and Telescopes of Mr. *Dollona*'s Construction, with two Object-glasses, from 5 to 10 Feet: or, which are still more convenient, those of $3\frac{1}{2}$ Feet, which he has constructed with three Object-glasses.

An

An experienced Obſerver may count the Seconds by the Beats of the Clock, without an Aſſiſtant; but one unaccuſtomed to theſe Obſervations, by attending to the Time and Satellite together, will be liable to a Miſtake in one, or to Inaccuracy in the other.

If it is the apparent Time of an Immerſion, or Emerſion, that is obſerved, (which is found by ſetting the Clock to Twelve, when the Sun's Center is on the Meridian) it muſt be corrected by the Equation anſwering to the Time of the obſerved Eclipſe, to reduce it to mean Time, to which Eclipſes are calculated in the Almanack; and the Difference between the calculated Time at Greenwich and the equated obſerved Time of the Eclipſe, converted into Degrees and Minutes, will be the Longitude from Greenwich. To convert Time into Degrees and Minutes of a Circle: for every Hour allow 15 Degrees; for every Minute of Time over the Hours, 15 Minutes of a Degree; and for every Second of Time over the Minutes, 15 Seconds of a Degree.

Emerſions are viſible only from the Time of Jupiter's Oppoſition to the Sun, to the Time of his Conjunction: during which Time, he riſes after the Sun ſets. Immerſions are viſible only from his Conjunction to his Oppoſition; during which Time, he riſes before the Sun ſets.

To find when Jupiter is above the Horizon, and to diſtinguiſh him amongſt the Stars; the eaſieſt and readieſt Way is by a celeſtial Globe, as follows. Find his Place in the Ecliptic from an Ephemeris for the Day propoſed; alſo his Latitude, or Diſtance South or North of the Ecliptic; mark that Diſtance on the Globe on a Circle of celeſtial Latitude paſſing through his Place in the Ecliptic. Rectify the Globe for the Latitude of the Place yon are in, and for the Sun's Place at Noon, and ſet the Hour Index to 12; turn the Globe till the Hour Index points out the Hour propoſed; lay a Quadrant of Altitude from the Zenith over the Point marked on the Globe for his Place, and it will ſhew his Height above the Horizon, and likewiſe his Azimuth at that Hour: allow for the Variation of the magnetic Needle, and you will have his Bearing by the Compaſs. By the Altitude and Bearing Jupiter will be eaſily found among the Stars, for he is the largeſt to Appearance of the Stars and Planets, except Venus, who is likewiſe a little brighter than he.

Though

Though an Eclipſe of Jupiter's firſt Satellite is much more to be relied on than the reſt, becauſe the Irregularities of its Motion are better known; yet Eclipſes of the other Satellites ought not to be neglected when there is an Opportunity of obſerving them: becauſe ſuch Eclipſes may be obſerved in ſome other Place; by which the Difference of Longitude of theſe two Places will be as exactly known as by an Eclipſe of the firſt Satellite; and if the Obſervations and Teleſcopes are good, is more to be depended on than any Calculation.

If the Part of Jupiter's Diſk, and the Diſtance from it, at which the Emerſion of a Satellite will happen, are known, that ſeems preferable to an Immerſion; becauſe the Appearance of any luminous body is more inſtantaneous than its Diſappearance.

To find the Longitude of a Place by an Eclipſe of the Moon; a Meridian Line muſt be firſt found; then a Clock, or Watch, regulated to keep equal Time, then ſet to mean or true Time by the Sun in the Meridian, as before directed. Then the preciſe Time noted by a Clock, or Watch, when the Moon's eaſtern Limb touches the Earth's Shadow; alſo the Time when the Shadaw touches ſome remarkable Spots in the Moon's Diſc; and when the Moon's weſtern Edge touches the Shadow at its going off, when the Eclipſe is juſt over: theſe ſeveral Times, compared with correſponding Obſervations in other Places, or with a Calculation, will give the Longitude between theſe Places. But Eclipſes of the Moon are not to be relied on nearer than to three or four Minutes of Time; chiefly from the Difficulty of diſtinguiſhing the Edge of the Shadow preciſely: and therefore Eclipſes of Jupiter's Satellites are to be preferred to lunar Eclipſes, for determining the Longitude of any Place.

SECTION II.

How to continue a Meridian Line through a Kingdom, or large Country.

PLATE III. FIG. IX.

First chuſe ſome remarkable Place from whence to begin the Meridian, as a noted Obſervatory, Church, Caſtle, Hill, &c: if it is near the Middle of the Kingdom, ſo that the Meridian may be continued northward and ſouthward from it, it is the better. Then provide a ſkilful and faithful Aſſiſtant, with two Sets of Inſtruments, one Set for yourſelf, and one for him; and ſix Men, at leaſt, to attend each. Provide alſo two convenient Tents, one for lodging you, and your Attendants and Inſtruments, the other for him, his Attendants and Inſtruments. The Tents will ſerve likewiſe for Signals, and for making Obſervations in, and ſhould therefore be ſo contrived, that a Breadth, or two, of the Cloth at each End, from Top to Bottom, may be laid open occaſionally for obſerving the Stars. The neceſſary Inſtruments are, two Sextants of two Feet Radius, graduated ſo as to be capable of taking horizontal Angles to Parts of a Minute; with a ſpirit Level, and two good Teleſcopes to each, with Croſs-wires in the common Focus of the Glaſſes, and a ſteady Stand to ſupport the Inſtruments horizontally: two good magnetic Needles with Sights; four Plumb-lines, each ſix Feet long, and two Stands for them, one to ſupport two together, about four Feet aſunder; ſix ſtraight ſpiked Poles, each twenty Feet long, with black and white Flags for their Tops, to render them conſpicuous, as they happen to bear on the Sky, or on dark Land; and a Line drawn on one ſquare Side of each, right up and down, for a Plumb-line to be applied to, in order to ſet them perpendicular: if the Plumb-line is hung in a Box, to ſcreen it from the Wind when applied, it would be an Advantage. A Borer, or ſome ſuch Inſtrument, for readily making a Hole in hard Ground for the Poles to ſtand in firmly: in Wind, theſe Poles will need to be ſupported by Ropes from the Top, like a Tent-pole, or by three ſpreading Legs like a Theodolite: twenty ſpiked Poles, each ſix Feet long; a meaſuring Pole, or Chain, with Reels and Lines on them, for meaſuring a ſtraight Line on the Ground.

At the Place where the Meridian is to begin, find an exact Meridian Line, by one of the moſt accurate Methods explained in Part 1. (beginning Page 47.) mark its Extremity by a long Pole ſet perpendicular in the Ground, and a Flag at Top. Continue the Direction of that Part of the Meridian farther, if neceſſary, by taking that Pole, and the Pole or Object you began at in a Line; or by ſetting other upright Poles in the ſame Direction, till you come to the Summit of a Hill, or Eminence, where there is an extenſive View beyond it; there mark a Point in the continued Meridian, by a Pin driven in the Ground, and pitch your Tent over it, ſo that the two

Tent-poles may ſtand parallel to the Meridian, at about the Diſtance of a Foot from it, and not hinder your ſeeing any Objects that are in the Continuation of it. Within the Tent (that your Obſervation may not be diſturbed by the Wind) hang two Plumb-lines on their Stand; and when at Reſt, make them hang exactly in the Meridian backward, or toward the Beginning of the Meridian, by cutting the Object you began at, and one or more of the Poles which continued the Meridian. Stand next behind the other Plumb-line, and, when both are at Reſt, obſerve if they cut any ſmall remarkable Part of a diſtant Object which may be preciſely known when you go to the Object; if ſo, then is that Part of the Object in the Meridian; which may be continued from it as before, by taking it and the Middle of the Tent in a Line, till you come to ſome neighbouring Hill, or Eminence, convenient for pitching the Tent on, and making Obſervations. But if the Plumb-lines do not cut ſuch a ſmall diſtinguiſhable Part of an Object (which indeed will very ſeldom happen) then proceed in the following Manner.

Find out ſome Hill, or Eminence, on one Side of the Direction of the Plumb-lines (the nearer to it the better) and ſo far off as that your Aſſiſtant, at that Eminence, may ſee your Tent, and you may ſee his, when it is pitched on it: if they can juſt be perceived by the naked Eye, it is ſufficient; for then they will be diſtinctly ſeen through the Teleſcopes on the Sextants. Let your Aſſiſtant take the Bearing of the Hill, and of the Direction of the Plumb-lines with the magnetic Needle, and note them down, and theſe will ſerve to direct him nearly to the Hill and Meridian: ſend your Aſſiſtant to the Hill propoſed, with his Tent, Servants and Inſtruments, and let him pitch his Tent on a convenient Part of the Hill, or the neighbourhood of it, where he can ſee your Tent, and you his; and, at the Door of his Tent, ſet up a long Pole, with a conſpicuous Flag at the Top of it, for a Signal to be obſerved through your Teleſcope: ſet you up ſuch another Signal in the Direction of the Meridian, near the Door of your Tent, to be obſerved by him. As ſoon as his Signal is up, ſet your Sextant level, with the Center of it at the Place of the Signal, and take the Angle which his Signal makes with the Meridian, or Direction of the Plumb-lines: write it down, and ſend a Man with it to the Aſſiſtant; when you have done,

done, ſet up your Signal in its Place, with another Flag above the former, to ſignify that you have finiſhed your Obſervation; and let them remain ſo till your Aſſiſtant's Tent is taken down.

When the Aſſiſtant has ſet up his Signal, then he muſt go as near the Direction of the Meridian as he can, by its magnetic Bearing which was taken at the Principal's Tent, and, in that Neighbourhood, find out ſome Eminence, or convenient Place, for the next Station, where his own Tent and the Principal's can be ſeen: there let him ſet up a large Pole and Flag, and two, or more, ſmaller, in a ſtraight Line between it and the Signal at his Tent. Then, at his Tent-ſignal, let him take the Angle with the Sextant, formed by the Line of Poles croſſing the Meridian and the Direction of the Principal's Signal, and write that down. This Angle, and that ſent by the Principal, added together, and ſubtracted from 180° will leave the third Angle of the Triangle. Let him keep in the Direction of the Line of Poles, till he finds by the magnetic Bearing that he is in, or near the Meridian; then let him ſet up the Sextant, and obſerve the Angle between the two Tent-ſignals; if it is equal to the forementioned Remainder, the Center of the Sextant is in the continued Meridian: if the Angle obſerved is greater than that Remainder, the continued Meridian is farther from the Aſſiſtant's Tent than the Center of the Inſtrument; if the obſerved Angle is leſs, the Continuation of the Meridian is between the Inſtrument and the Aſſiſtant's Tent, and the Sextant muſt be ſhifted either one Way or the other, but always in the Direction of the Line of Poles, till this obſerved Angle, and the two formerly obſerved at the Tents, make exactly two Right-angles; then the Point directly below the Center of the Sextant is to be marked by a Pin driven into the Ground, and that will be another Point in the Meridian continued from the firſt Station. If this Place is not convenient for a new Station, he muſt continue the Direction of the Meridian by Poles till he comes to an Eminence, or Place more convenient; there he is to mark a Point with a Pole, and ſetting up another perpendicular Pole at a Diſtance, in a Line with the Principal's Signal, let him order his Tent to be taken down, as a Signal for the Principal to take down his, and to come away with it and with all his other Things. Then, over the Direction of the Meridian found by the Aſſiſtant the Principal muſt pitch his Tent, hang two Plumb-lines within it on the Meridian, and proceed as before to continue it farther.

If a Town, Wood, Building, high Wall, or other Obſtacle, ſhall happen in the Way, ſo as to hinder the Continuation of the meridian Line, as the Wood X in Plate III. Fig. 9. then, before you reach ſuch Obſtacle, on a ſmooth Plane mark off with the Sextant A B a Perpendicular to the Meridian, and meaſure in that Line as great a Length as will extend beyond the Obſtacle, ſo that the Perpendicular B C raiſed on the End of the Meaſurement may fall on one Side of the Obſtacle; and continue B C, if neceſſary, with upright Poles, till you find a ſmooth Plane extending perpendicularly croſs the Direction of the Meridian; on that Plane make C D perpendicular to B C, and meaſure from C to D a Diſtance equal to A B, and D will be a Point in the Meridian continued from A. Then a Perpendicular D E, on the Line C D, will be a Continuation of the original Meridian: by upright Poles placed in theſe two Points, and other Poles in their Direction, it may be continued farther at Pleaſure.

If A B, the Perpendicular, cannot be meaſured exactly, becauſe of the Unevenneſs of the Ground, mark a Line in another Direction, where the Ground is level, as A F, or A G, and take the Angle M A F, or M A G; at F, make the Angle A F C = M A F; and F C will be parallel to M A; or at G, if that is the Direction choſen, make the Angle A G C = M A G, and G C will be parallel to M A. Then in the right-angled Triangle A B F, or A B G, having the Hypothenuſe A F, or A G; and, in the firſt, the Angle A F B, equal to the Supplement of A F C, or, in the other, the Angle A G B = M A G, thence, by Protraction, or Calculation, find the Perpendicular A B, and note it down. At C mark C D a Perpendicular to C B; on it meaſure the Length of A B, and it will terminate in D, a Point in the Meridian M A continued.

If a Perpendicular C D cannot be meaſured exactly, then mark out a Line on either Side of it where the Ground is level, as C H, or C I; take the Angle B C H, or B C I, according to the Direction aſſumed, and from thence, having the Length of the Perpendicular C D = A B, and the Angle D C H = B C H — 90°, or the Angle D C I = 90 — B C I, the Hypothenuſe C H, or C I, may be found: meaſure that on the Ground, and it will terminate in H, or I, a Point in the Meridian M A continued. At H, on C H, make the Angle C H E = M A F; or, at the Point I, the Angle C I E = M A G, and E will be another Point in the Meridian M A continued,

nued. Place perpendicular Poles in theſe two Points, and by them continue the Meridian to ſome Eminence where a diſtant View foreward may be had; there pitch your Tent over the meridian Line, hang up the Plumb-lines in it, and examine your Meridian by the Stars before you proceed farther, in Caſe the meaſuring ſhould have occaſioned any Inaccuracy; correct the Error, if there is any, and then proceed as before, by taking the magnetic Bearing of the Meridian, and of ſome diſtant Eminence on one Side of it, and ſending your Aſſiſtant to pitch his Tent on that Eminence, in order to make the neceſſary Obſervations there, and find out the Direction of the Meridian; and continue the ſame Proceſs till you reach the End of the Territory propoſed.

The Foundation of the foregoing Operations, in getting over Obſtructions, is ſo obvious from the Properties of parallel Lines, that it needs no Explanation to one who is acquainted with the firſt Book of Euclid's Elements. It may however be proper to obſerve, that, if the Meaſurements are not made on ſmooth Planes, with great Care, and the Angles taken and ſet off on the Ground with great Exactneſs, it may make a ſenſible Deviation in the Meridian: and that therefore, after ſuch an Operation, it will generally be expedient to find the Meridian anew by the Stars, and proceed to continue the Direction of it as before. But whether ſuch Obſtructions are met with or not, it will be prudent, every 80, or 100 Miles, to examine the Meridian by the Stars, that if any ſmall Inaccuracy has ariſen, it may not affect the ſubſequent Parts of it.

SECTION III.

How to trace a Parallel of Latitude through a Kingdom.

Provide a good portable Inſtrument for taking the meridian Altitude of the Sun, or a Star, to Parts of a Minute. A Sextant of three Feet Radius, with a convenient Stand to ſupport it, may be ſufficient.

At the Place whoſe Parallel is to be traced, find the Latitude, and an exact meridian Line: ſet off, by Poles placed upright in the Ground, a Perpendicular to the Meridian, and continue that Line about one Degree of Longitude,

Longitude, (ſuppoſe 30 or 40 Miles) till you come to a level Plane extending about one Mile northward, or toward the elevated Pole; there find the Latitude and a meridian Line: on that meridian Line continued through the Plane, meaſure a Diſtance equal to the Difference of the firſt and laſt Latitude (which will be leſs than one Mile) and it will terminate in a Point of the Parallel required. Another Point in it may be marked about the Middle of the Perpendicular to the firſt Meridian: for the Tangent of half a Degree falls very little without the Arc.

At the firſt-mentioned Point in the Parallel, mark off with Poles a Perpendicular to the Meridian as before; continue it 30 or 40 Miles forward till you find another level Plane; there obſerve the Latitude and find a meridian Line: on that Meridian meaſure the Difference of the firſt and laſt Latitudes, and that Meaſurement will terminate in another Point of the Parallel: and the Middle of the Perpendicular to the former Meridian will be a fourth Point. Proceed in the ſame Manner to find other Points as far eaſtward, or weſtward as is neceſſary, and ſtraight Lines on the Ground joining theſe ſeveral Points will mark out on the Ground the Parallel of Latitude of the Place required; or more ſtrictly a Polygon not ſenſibly differing from it.

The Polygon will be ſtill nearer a Circle, if a Perpendicular is continued Eaſt and Weſt from each of the Meridians, and two Points of the Parallel are marked in each of theſe Perpendiculars, one on one Side of the croſſing Meridian, the other on the other Side, and about one third of a degree of Longitude from it.

If it ſhall happen that a ſmooth Plane is not to be had for meaſuring the Difference of the two Latitudes along the Meridian, meaſure a ſtraight Line in any other Direction making an Angle with the Meridian; find that Angle by the Sextant, and you will then have two Sides of a Triangle (the Difference of Latitude and the meaſured Line) and the Angle comprehended between them, to find another Angle, which ſecond Angle obſerved and marked off by a Pole in the Ground will determine the Direction of the third Side; and where it interſects the Meridian will be a Point in the Parallel of Latitude ſought.

The

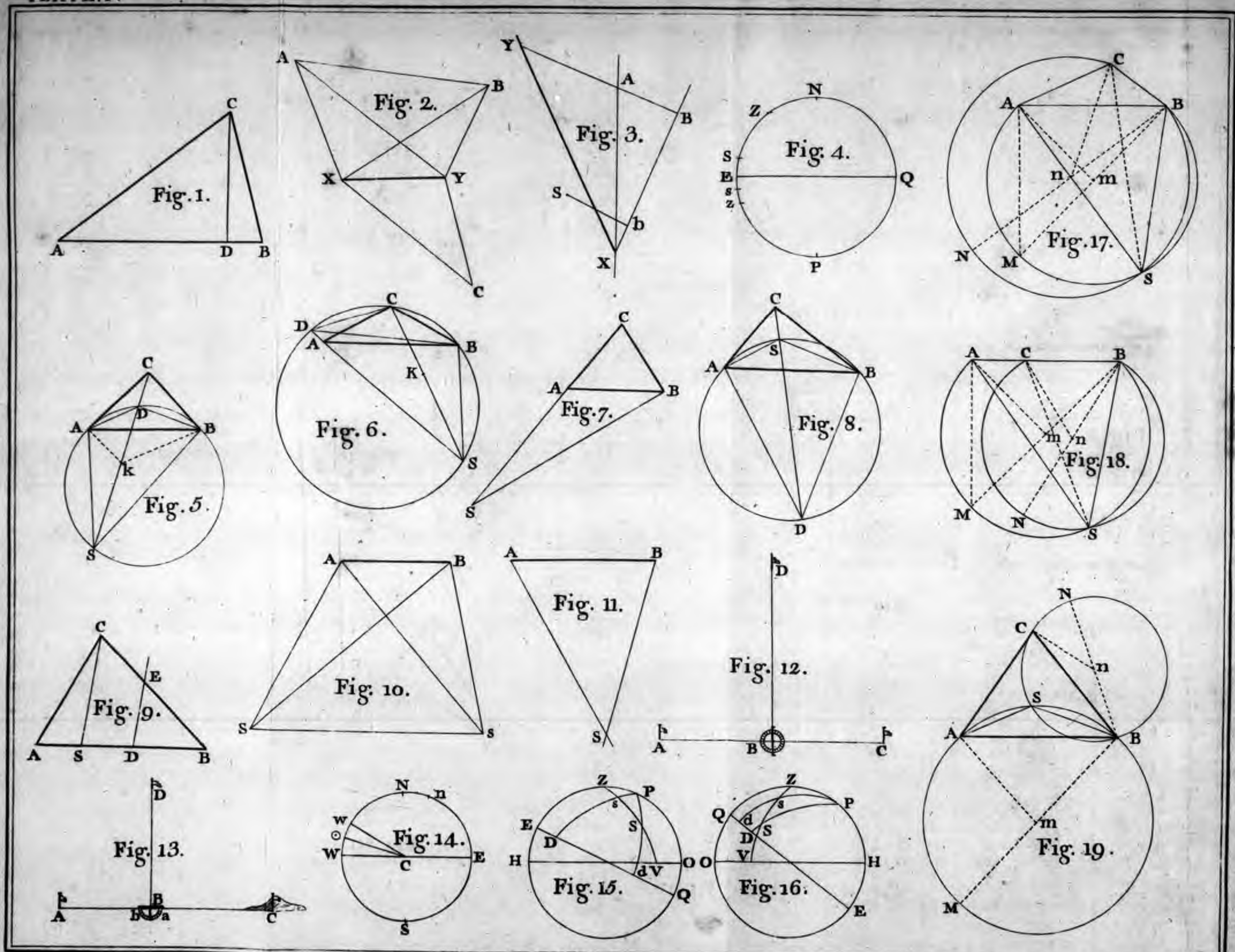
The Exactneſs of this Operation depends chiefly on the Accuracy of the Inſtrument with which the ſeveral Latitudes are taken: the Sextant, therefore ſhould be carefully adjuſted immediately before each Obſervation.

THE END.

ERRATA.

Page 19. Line 22, *after* towards S, *read* as at k.—p. 23. l. 8, *after* A S B, *read* (Fig. 17 and 18.)—p. 27. l. 1, *for* Pales, *read* Poles.—p. 34. l. 16, *for* Horizon, *read* Horizons.—p. 36. l. 16, *after* true Angle, *read* To *prevent* it, the Index ſhould be of a Subſtance not apt to bend, and as broad as the Sextant can conveniently admit of; it ſhould move quite eaſy round the Center; but by means of a ſpring and ſcrew ſhould compreſs the Arch of the Inſtrument with requiſite Firmneſs, and ſo as to ſlide ſmoothly along it when moved.—p. 55. l. *laſt but two*, *for* d Q, *read* D E.—p. 59. l. 22, *for* wuond, *read* wound.—p. 88. l. 16, *for* Objed, *read* Objects.

PLATE. I.



J. Lodge sculp.