Fig. 69.

2. *Or thus, by the Rule.*

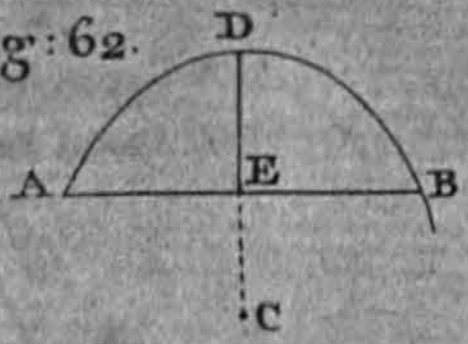
Set the depth 18 on MD, to the length 85 on B; and againſt the breadth 54.4 on A, is the content 38.7 on B.

SCHOL.

It may be obſerved, that many of the rules laid down here for gauging, are only approximations; being contrived for eaſe and expedition; and come pretty near the truth in moſt caſes. For to what purpoſe can it be to make uſe of long and laborious rules and calculations, ſuited to certain particular figures; when we do not know that any veſſels we deal with have theſe figures. If we ſhould gauge a cask as a paraboloid, which happens to be a parabolic ſpindle; we ſhould make a great miſtake. Therefore it is better in mechanical things to uſe mechanical rules; and judge from the apparent curvature of the veſſel, what rule to uſe, and how to apply it.

FINIS.

Fig: 62.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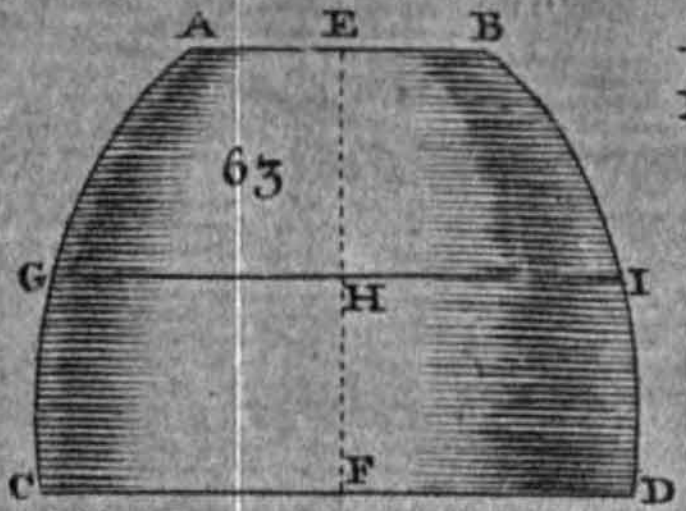
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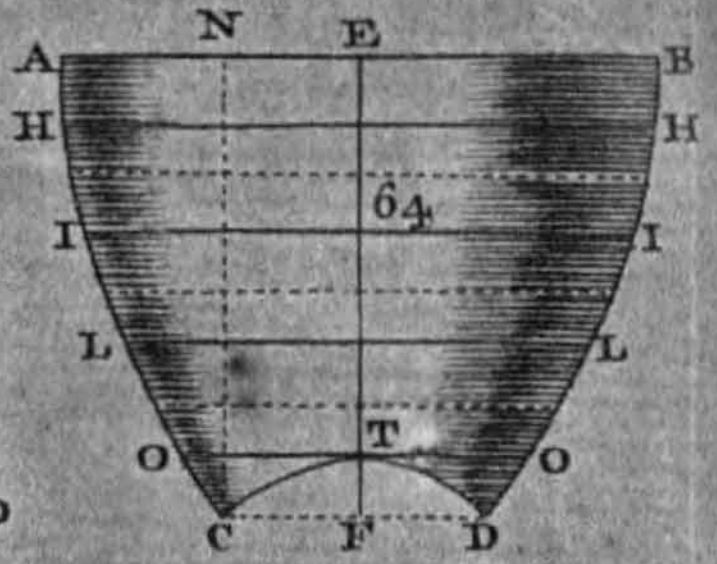
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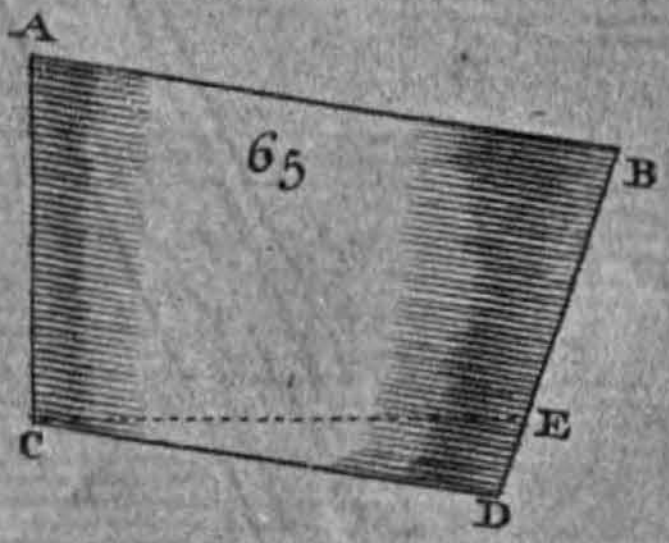
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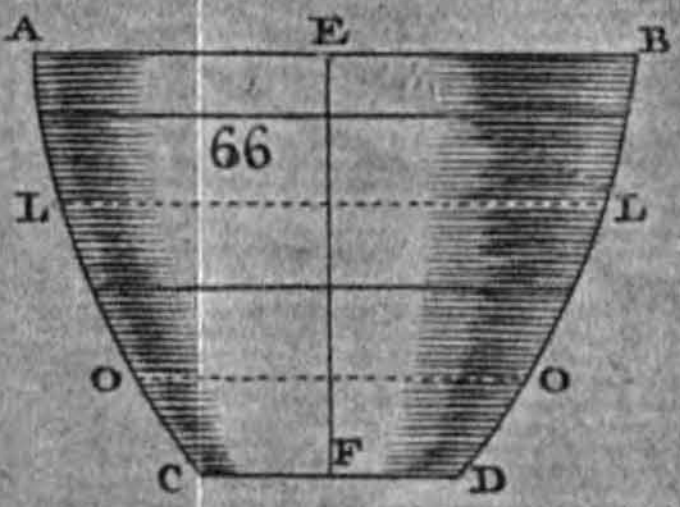
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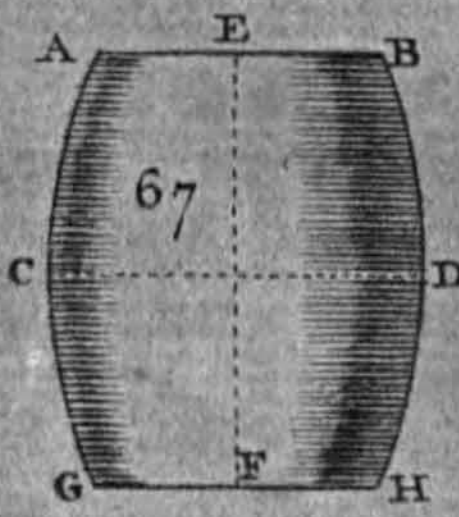
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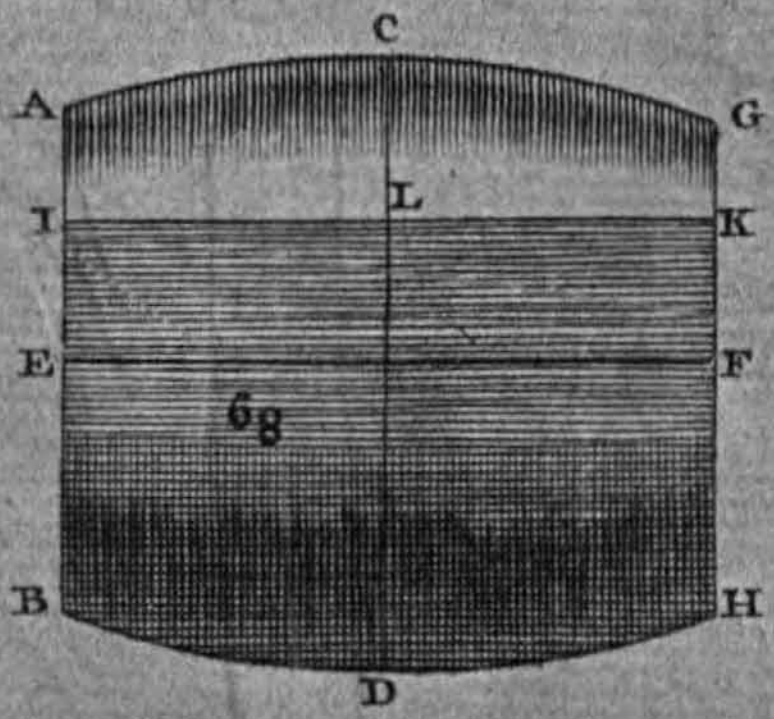
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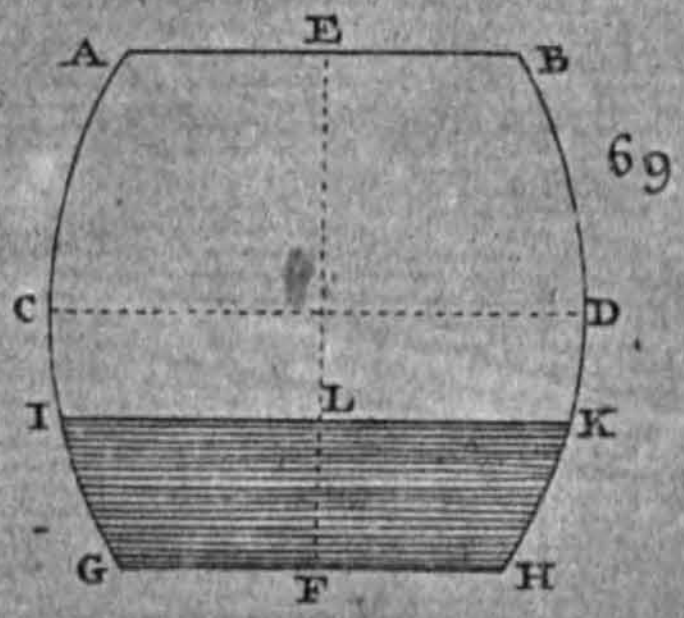
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THE ART OF SURVEYING, OR MEASURING LAND.

CONTAINING,

I. The Work to be Perform'd in the Field, as taking all neceſſary Dimenſions and Meaſures.

II. Concerning Protracting, Reducing, Caſting up, and Dividing.

III. Meaſuring inacceſſible Heights, and Diſtances.

Diſce ſed a doctis, indoctos ipſe docebo. CATO.

LONDON:

Printed for J. NOURSE, in the Strand; and Bookſeller in Ordinary to his MAJESTY.

MDCCLXX.

THE PREFACE.

THE Art of Surveying is of great antiquity; and it has been ſaid, that it was firſt found out in Egypt. For when the Nile, by its frequent inundations, overflowed the country, and deſtroyed all the boundaries of mens eſtates, or buried them under the ſlime and mud; they were neceſſitated to ſeek out ſome methods or other, whereby to ſet out to every man his due quantity of ground; that it might be reſtored to him without loſs. And as this happened very often, they were under a neceſſity of ſtudying this art, for preſerving the limits and extent of their lands and poſſeſſions.

But though the knowledge of ſuch an art muſt be neceſſary on this occaſion, and accordingly made uſe of for that purpoſe; yet it might be found out ſooner. For without doubt, the Art of Surveying had been known, ever ſince there had been any ſuch thing as the dividing of lands. For as there could be no ſetting out, or making any diviſion of lands, without taking the meaſures of the whole, and of the ſeveral parts; ſo as ſoon as that happened, muſt the way of meaſuring be known; and thus we meet with a man meaſuring Jeruſalem, Zechariah, ch. 2. And the ſame neceſſity that cauſed men to divide the land into ſhares, at the ſame time forced them to ſeek for methods to reduce them to an equality, and to find the proportion between one part and another. And thus the firſt dividing

ding of the land of Egypt *among the people, gave riſe firſt to Surveying and Geometry.*

It has been objected, that the ſurveying of land makes the poor tanants to have dear bargains, and occaſions things to ſell dear and grow ſcarce; and therefore land ought not to be meaſured. But then a man muſt be kept ignorant of his property, in other caſes as well as this. Does a man's knowledge abridge his conſcience? We often ſee that men, by over-eſtimating their eſtates, let their tenants hard penny-worths, being ignorant of the true quantity of ground they let, for the want of ſurveying. But every man, in any ſort of buſineſs, will always make the beſt he can of his goods. And muſt every man have the liberty to make the beſt of his own, and only the owners of land tied from it? Now the Art of Surveying teaches how to give every man his due, and to do juſtice to every body, to the landlord as well as the tenant, to the buyer as well as the ſeller; by ſhewing the true meaſure and quantity of the land. Therefore Surveying is a neceſſary and uſeful Art, which not only gives the true quantity, but ſhews rules for laying down maps and drafts of an eſtate; which exhibits to view every field, and every object therein, in their proper ſituations; which is a uſeful invention.

Many large volumes have been writ concerning the Art of Surveying, by which it has been drawn out to an unneceſſary length. For the whole of it is founded upon the ſimpleſt principles of Geometry, which are eaſily learned, and cannot need ſuch long and tedious explications; for ſuch methods only confound the reader. For no ſubject ought to be treated more voluminouſly, than there is real difficulty in it; which is not the found in this Art. It is a good old maxim, μακρὸν ἕλκειν μέγα κακὸν, and ought always to be obſerved. For by ſpinning out things in long diſcourſes, the reader is loſt in a miſt of words. But this perplexity is avoided

ed, in treating the subject in a concise way, and going no farther than the subject leads.

In the following Book, you have a verbal description of the instruments used in Surveying. For it is not worth the while to give any Cuts of them; a sight of them being more instructive than any figure can be. In Sect. I. *you have an account of all the work that is to be done out of doors; with proper Rules to proceed by.* Sect. II. *teaches how to plot, reduce, cast up, and divide any parcel of land. And lastly,* Sect. III. *shews the methods of taking heights and distances, both accessible and inaccessible; which is a curious and useful subject, and very necessary to be known.*

I have omitted nothing belonging to this Art, and have treated of every thing in as concise a manner, and yet as clearly, as the subject would admit of. And so I take my leave of the reader, wishing he may meet with all the satisfaction he expects.

W. Emerson.

SURVEYING.

SURVEYING, or *measuring Land*, is the art of finding the content of any field, or parcel of land; which is always expressed in acres and decimal parts; or perhaps in acres, roods and perches. This sort of measuring differs from others, as it is concerned in nothing but measuring parcels of the earth's surface, which are large figures; and whose measures are taken in chains and decimal parts; whereas the dimensions in other ways of measuring are taken, and cast up, in inches, feet, yards, &c.

The instruments used in surveying are of several sorts. 1. Those for measuring angles; as the *Theodolite, plain table, semicircle, circumferentor, Geodetical staff, infallible*, &c. 2. For measuring distances; as the *wheel*, or *perambulator*, the *chain*, &c. 3. For levelling; as the *water level, spirit level*, &c. 4. For making draughts upon paper; as *scales, line of chords, protractor, reducing scale, compasses, parallel ruler*, &c. 5. For marks, &c. as *arrows, station staves, streamers*, &c.

The Theodolite.

This is a brass circle, 12 or 14 inches diameter; its circumference is divided into 360 degrees; it has two sights upon it, fixt at the beginning of the degrees; and also a moveable index, with two sights, which moves about the center. The whole is to be fixt upon a three legged staff, with a ball and socket. To some of these instruments are fitted telescopic sights; which makes it one of the

beſt inſtruments for taking angles. And ſometimes them have a card and compaſs, with a needle playing round the center, which in ſome caſes is very uſeful.

The plain Table.

This is a flat board or table, the bigneſs of a ſheet of paper; fitted into a frame going round its edges, which frame is to keep the ſheet of paper faſt on the table, for uſing in the field. The edge is graduated into degrees, from a braſs center in the middle of the table; by means of which it may be uſed without a paper. It has a looſe index with two ſights, being ſighted both back and forward; and upon this index is a tangent line for taking heights. The index is made to turn upon any given point, againſt a pin, or the point of a pair of compaſſes placed therein, as a center; and in taking angles, this center muſt be the braſs center. The ſtreight edge of the index is called the *fiducial edge*.

The uſe of this inſtrument is to draw the plot or figure of any field or parcel of land upon a paper, in the field. For when the work in the field is finiſhed, you have the exact form of the ground upon the paper on the plain table. This is a proper inſtrument for ſurveying ſmall incloſures, and of great diſpatch; but not ſo good for large eſtates, by reaſon the paper upon the table will contract in dry weather, and expand in moiſt weather. And therefore if one part be drawn when it is dry, and another when it is moiſt, the field will be diſtorted, and the parts out of proportion.

The under ſide of the frame is divided into equal parts, and may be turned upſide down upon occaſion.

Circum-

Circumferentor.

This is a parallelogram, eight inches long and four broad, made of box or brass, its edge graduated or divided into degrees; to this belongs an index with sights forward and backward. It may also be made in form of a circle eight inches diameter.

To this belongs a box and needle; and therefore it is the fittest instrument for mapping a harbour, and for drawing the position of rocks, sands, shoals, soundings, &c. And proper for measuring a county, if it be made large.

Semicircle.

This is a large semicircle divided into degrees, having sights placed at the beginning or edge. It has a moveable index with sights back and forward, moving about the center. To this is fixed a box and needle; it is the same as half a Theodolite. It is fitted to a ball and socket, and set upon a three leg'd staff, like all the rest.

Geodetical Staff.

This is an instrument with two legs, having sights upon them, opening upon a brass center-pin, like the legs of a pair of compasses; each leg is a foot and half long, or more. There is a long ruler, called the *Graduator*, which turns upon a pin in the end of one of the legs, and goes thro' the end of the other leg. This ruler is graduated with a line of chords, answerable to the length of the legs, which is the radius. As the instrument is opened, the moveable leg, running along the graduator, shews to what angle the instrument is opened. And when it is open, it appears in form of an isosceles triangle; and may be opened to a right angle, or something more; and then the graduator will be

the

the hypothenuſe. This is an excellent inſtrument for taking angles.

Infallible.

This is an inſtrument not very common; it is a flat board, or a plate of copper or braſs, a foot ſquare. On the middle or thereabouts is fixed a perpendicular pin, on which is ſcrew'd an index with two ſights. The table or plate is to be covered with a paper, which muſt be folded at the ends under the inſtrument, and ſcrew'd faſt at every corner, by four plates fixt underneath the table. Then the index muſt be put upon the pin, which will come thro' the paper.

This inſtrument is very ſimple, and very eaſily made, and differs nothing from the plain table, but only that it is ungraduated; and the index always turns upon the fixt pin. When it is uſed in the field, it muſt be placed on a three legged ſtaff, being a ſtaff with three legs opening outward, to ſtand on the ground in any poſition you will. All theſe inſtruments are for taking angles or draughts.

Wheel, or Perambulator.

The wheel to meaſure diſtances, is $2\frac{3}{4}$ yards in circumference, but ought rather to be $5\frac{1}{2}$ yards about, or a ſtatute pole. It conſiſts of clockwork, and on the face has two hands or pointers, to ſhew the diſtance run. The wheel runs between two cheeks, in a frame of wood; by taking hold of the frame it is driven forward, and by the motions of the hands, and diviſions on the face, is ſhewn how many yards, poles, furlongs or miles, you have gone. One hand goes round in half a mile, and the other in 12 miles.

This inſtrument is very uſeful for meaſuring roads, rivers, and all level ground.

Chain

Chain.

There are ſeveral ſorts of chains, but *Gunter's Chain* is the beſt for meaſuring land; its length is 4 poles or 22 yards; and is divided into 100 links; and at every 10 links there is a piece of braſs, with figures or tails for diſtinction; by theſe, the links are eaſily reckoned.

In meaſuring towns, a chain of 50 feet and 50 links is the moſt commodious.

Water Level.

This is a round tube made of wood or braſs, about three feet long; the ends of it are turned up ſquare; in which are cloſe cemented two glaſs tubes perpendicularly. The tube is to be almoſt quite filled with water. There are two ſights fixt to this machine; and often teleſcopic ſights, for great diſtances. When it is fixt level on a three legged ſtaff, the water will riſe to equal heights in both the glaſs tubes, where proper marks or diviſions are made to ſhew it.

The uſe of theſe is to find a true level, for conveying water, draining fens, &c.

Spirit Level.

A ſpirit level, or air level, is a cylindrical glaſs tube, very near filled with ſpirit of wine, wanting only a drop, and then ſealed. On this, ſights are fixt, which ſhould be teleſcopic ſights. When the ſights are placed level or horizontal, the bubble or drop of air will be in the middle; but when it is not level, the bubble will go to the higher end.

In the beſt ſort, this cylindric glaſs tube, with the bubble, is fixt upon the tube of an aſtronomical teleſcope, two or three feet long; and ſo adjuſted,

juſted, that when the bubble is in the middle, the object or mark, ſeen through the teleſcope, is exactly level with it. And there is a proper apparatus with ſcrews to ſet the whole level; which is known by the bubble being in the middle.

Scales.

The ſcales or rulers ought to have ſeveral lines of equal parts upon them; ſome greater, ſome leſſer, to ſuit all caſes, particularly diagonal ſcales, which ſhew the diviſion of 1 into a hundred parts. Thus, we muſt have a ſcale of a chain in an inch, a chain in $\frac{3}{4}$ of an inch, in $\frac{1}{2}$ an inch, &c. By theſe we draw a field, or a *map* or *plan*, called alſo a *plot* or *plat*.

There are alſo ſcales made that one may prick off the diſtances by the edge.

Line of Chords, Protractor, reducing Scale, Compaſſes, parallel Ruler.

Theſe are ſo well known, that they need no deſcription. The chords, and protractor, are for laying down angles; the reducing ſcale, for increaſing or diminiſhing a plan or map; the compaſſes, for ſetting off diſtances; and the parallel ruler, for drawing parallel lines. As to the reducing ſcale, it turns on a center pin, nearer one end than the other. On this are ſeveral lines of equal parts running both ways from the center; and in certain given proportions.

There is alſo an inſtrument made with two drawing pens, ſo that tracing one of them over the draught, the other will, on a clean paper, delineate it anew, in a leſs or bigger form; being a very expeditious inſtrument.

Arrow

Arrows.

These are ten ſmall ſticks, about a foot or half a yard long, and ſharp at one end, to ſtick in the ground at the end of every chain, in meaſuring. They may be tipt or piled with iron at bottom; and coloured blue and red near the top, to make them viſible.

Station Staves, and Streamers.

These are long poles to be ſet up in the angles of a field, or in other remarkable places. If they be far off, they have moveable vanes or ſtreamers placed on them, to be ſlid up and down; or tied to their tops. And theſe vanes or marks may be white, or coloured red or blue, to make them viſible at great diſtances.

Some of theſe poles are divided into links, for meaſuring offſets readily.

The Field Book.

As it is not poſſible to ſurvey any great quantity of ground without noting down the particulars; therefore you muſt have in the field a little book, called the *Field Book*, in which to write your ſtations, offſets, angles, lines, obſervations, &c. This book you may divide into columns, as you think convenient, as will beſt ſuit your occaſions: for there are hardly two perſons that have the ſame method for their field notes; however, it ought to be contrived in the eaſieſt and moſt intelligible manner; for any method, that lays a burden upon the memory, is imperfect, and not fit to be practiſed.

This

This book may be contrived after the followi manner. Make three columns, the middle one for the angles (mark'd <), ſtations (mark'd ⊙), t diſtances meaſured, and bearings, &c. The two columns on the left and right, are for the offsets on the left and right, againſt their reſpective diſtances in the ſecond column; and for ſuch remarks as occur. Draw a line under the work at the en of every ſtation; that the workings at the ſeveral ſtations may not confound one another.

Note, in ſurveying with the plain table, you need no field book; the whole work being deſcribed upon it, except offsets which may be ſet thereon, as they happen.

The FIELD BOOK.

Offsets and remarks on the left.	Stations.	Offsets and remarks on the right.
	⊙ 1	
.12	< 113° 15	
	00	.26 Thomſon's hedge begins.
	56	touch the hedge
	4.13	.34
.32 a croſs hedge	6.09	.41 a tree
	8.00	.00
	⊙ 2	
	< 87 43	
	.00	.00
	1.80	Gutter changes
.87 houſe corner	3.15	
	4.82	.27 a pond
	⊙ 3	
	64 15	
a gate	0.84	.5
	2.75	.15
	4.11	.29 a gate
.88 a brook	5.28	
18 foot path	5.92	.15
	6.00	00
15 hedge corner	7.54	
	9.20	28 a ſpring.

Explanation.

⊙ 1 is the firſt ſtation, and the < there is 113 15. On the right an offset .26 or 26 links, where Thomſon's hedge begins; meaſuring to .56 we touch the hedge. At 4.13 an offset of 34. At 6.09 an offset .41 at a tree. At 8.00 no offset. On the left, at firſt an off-ſet .12; at 6.09 an offset .32 where there is a croſs hedge. And ſo for the reſt of the ſtations.

1. A

1. *A Table of Long Meaſures.*

7·92 inch	1 link						
12	$1\frac{17}{33}$	1 foot					
36	$4\frac{6}{11}$	3	1 yard				
198	25	$16\frac{1}{2}$	$5\frac{1}{2}$	1 pole			
792	100	66	22	4	1 chain		
7920	1000	660	220	40	10	1 furl.	
63360	8000	5280	1760	320	80	8	1 mile

2. *A Table of Square Meaſures.*

9 feet	1 yard					
$272\frac{1}{4}$	$30\frac{1}{4}$	1 perch				
4356	484	16	1 chain			
10890	1210	40	$2\frac{1}{2}$	1 rood		
43560	4840	160	10	4	1 acre	
27878400	3097600	102400	6400	2560	640	1 mile

In theſe Tables, each perpendicular column is of one denomination throughout. And all the lateral ones are equal, but of different denominations.

Note, a pole and perch is the ſame thing, and a ſquare chain is called a rape in the North, being the tenth part of an acre.

SECT.

Fig.

SECT. I.

The Practice of SURVEYING, *containing the Work to be done in the Field.*

PROB. I.

To take an angle BAC, *or measure the quantity of it in degrees.* 1.

SET up two ſtation ſtaves perpendicular, in ſome parts of the lines AB, AC, as at B and C; and put thereon ſome viſible marks, large enough to be ſeen from A. Then plant the inſtrument in the angular point A, or as near it as poſſible. Then,

1. For an inſtrument with a paper upon it, as the plane table, and infallible. Screw the table faſt; then direct the index to one mark as B, and turning it about, till thro' the ſights you ſee B, then draw the line AB by the edge of the index. Then direct the index to the other mark C, and turning it about till you ſee it thro' the ſights, then draw the line AC by the edge of the index. Then you have the angle BAC upon the paper. Here the edge of the index muſt be kept all the while upon the point A.

2. For inſtruments with two fixt ſights, and a moveable index, as the theodelite, ſemicircle, geodetical ſtaff, &c. direct the fixt ſights along one of the lines AB, turning the inſtrument about, till thro' the ſights you ſee the mark B, there ſcrew faſt the inſtrument. Then direct the moveable index along the other line AC, and move it about,

Fig. 1. till thro' the ſights you ſee the mark C. Then the degrees cut by the index, upon the graduated limb of the inſtrument, ſhews the quantity of the angle; which ſet down in the field book. If the angle be obtuſe, you muſt take it by back ſights; cauſing *b*, *c* to lye on the other ſide of A.

3. By an inſtrument with a needle. Place the inſtrument ſo, that the north end of the needle may hang directly over the flower-de-luce. Then direct the ſights to one mark as B, and note the degrees cut by the needle. Then direct the ſights to the other mark C, and note again what degrees are cut by the needle. For their ſum or difference (as the caſe is) will be the quantity of the angle BAC; which ſet down.

If either mark cannot be ſeen from A, as in the caſe of hills, trees, &c. ſet up a new mark in ſome place between, from whence both A and the other may be ſeen. And to place it in the line, ſhift it to the right and left, till both A and the other mark appear through the ſights, both forward and backward; and that is the place of the new mark, which may be uſed inſtead of the other.

Note, if ſeveral angles are to be taken at one point as A; take them all from one and the ſame line as AB. For by this means, there will be leſs danger of committing any error.

SCHOL.

There is alſo a way to take an angle in the field by the chain only; which is this. Take a chain length along both ſides AB and AC, as A*b* and A*c*; then meaſure the diſtance *bc* between *b* and *c*, and write it down. Then the angle A may be found by plain trigonometry; for it will be as A*b* : radius :: ſo $\frac{1}{2}$ *bc* : S. $\frac{1}{2}$ the angle A. Or find $\frac{1}{2}$*bc* in the table of natural ſines, and it ſhews half the angle BAC.

But

But this method being ſubject to errors, ought Fig.
not to be practiſed, but in caſe of neceſſity, or for
want of proper inſtruments.

PROB. II.

To meaſure a right line, or any diſtance, upon the ground.

1. Let AB be the diſtance to be meaſured. Set 2.
up ſtaves with marks upon them, at A, B and C.
Then the leader of the chain muſt take the ten
arrows in his left hand, and take hold of the end
of the chain with his right hand, by putting his
hand into the ring. Then let him go from A to-
wards B, drawing the chain after him; and as he
goes, let him take an arrow into his right hand
ready to ſtrike down. The follower muſt ſtand at
A, having hold of the other end of the chain in his
right hand; and cauſe the leader to go always along
the right line AB, till he comes at the ſtretch of
the chain; then the follower muſt hold his end
cloſe to A, and the leader, ſtretching the chain
ſtreight, muſt prick the arrow upright into the
ground, at the very end of the chain. Then he
muſt go forward, and take another arrow into his
right hand; and when the follower comes to the
arrow ſticking in the ground, he muſt ſet the end
of the chain cloſe to it, and take it up with his
right hand; whilſt the leader, at the ſame time,
pulls the chain ſtreight, and pricks in another ar-
row; and then proceeds as before; and whilſt the
follower is going, he muſt put the arrow into his
left hand. Thus at the end of every chain, the
leader puts down an arrow, and the follower takes
one up. And thus they go on, till they come at
B, the end of the line; and then the follower muſt
reckon his arrows, for there will be ſo many chains;

Fig. 2. and if any thing to ſpare, ſee how many odd link reaches from the laſt arrow to B; and ſet all down the chains in whole numbers, and the links in decimals.

If all the arrows are gone before the leader gets to the end at B, he muſt come back for the ten arrows; and the follower muſt ſet his toe at the place where the laſt ſtick or arrow was; till the leader, pulling the chain ſtreight, puts in another ſtick; and then proceed. In great diſtances, you will have the arrows to change ſeveral times; then you muſt note the number of changes, which will be eaſieſt done thus. Put 20 ſmall ſtones in your pocket, and at every change of the arrows (that is, at every 10 chains) remove a ſtone into another pocket. And at laſt, counting the ſtones removed, you will have the number of changes; where 8 changes make a mile. And then the whole length muſt be ſet down in the field book.

In going from A to B, the leader muſt always keep his eye on the mark at B, and keep in the line AB, ſo as to cover the mark at B from the follower.

At the end of the line AB, and at the end of every change, count all the arrows in both parcels, to ſee if they both make ten; if they do not, one has been dropt, and the diſtance muſt be meaſured over again.

2. In meaſuring to or from any hedge, you muſt account 5 links, from the roots of the quicks, on that ſide where the gutter is; and that will be the boundary; but in walls, the outſide is the boundary.

3. When the mark at B cannot be ſeen from A, then ſet up a mark in ſome place between, from which both A and B may be ſeen; and this place may be found, by the inſtrument, placing it there, and removing it, till A and B both appear through the

the ſights backward and forward. And if one will not do, ſet up two or three marks after the ſame manner. Fig. 2.

4. If the diſtance be very great, as amounting to ſeveral miles, then the eaſieſt way is to meaſure with the wheel; in which there are ſeveral indexes, ſhewing how many miles, furlongs, &c. have been paſſed over. But this is not ſo exact as the chain.

5. Great diſtances alſo may be meaſured expeditiouſly, by the firing of great guns in a dark night; and obſerving with a watch or a pundulum vibrating ſeconds, how many ſeconds there are between the flaſh, and the report of the gun. For that number of ſeconds multiplied into 1142, gives the number of feet in the diſtance. But this is not ſo exact as the former methods.

6. If the line you meaſure is not horizontal, but riſes or falls; and you want the horizontal length. Then with a quadrant, you muſt take the elevation or depreſſion of that line; and then the horizontal length may be found by trigonometry.

Or in deſcents, or going down a ſteep place, you may find the horizontal level thus. At the top, ſtretch out as much of the chain as you can horizontally, and let a ſtone fall from that point of the chain, and where it falls, ſet that point of the chain; and ſtretch out another part of it horizontally, from which let fall another ſtone, which will ſhew another place to hold at again horizontally; and proceed thus to the bottom. Then the ſum of all theſe parts of the chain is the horizontal line.

Fig.

PROB. III.

To meaſure offsets, and find their ſituation upon a right line.

3. Let AB be any right line, and *Aegh* a crooked hedge; *co*, *de*, *fg*, *Bh*, &c. ſeveral offsets, to be meaſured. From every angle or ſenſible bend of the hedge, as *e*, *g*, &c. let perpendiculars be ſuppoſed to fall on the line AB, as at *c*, *d*, *f*, &c. which points may be taken near enough, by the eye, if the offsets are not very large; but if they are, it muſt be done by the inſtrument. To this end, you muſt have a croſs line upon your index, perpendicular to the viſual ray. Then as you meaſure along the line AB, when you come at *c*, ſet down the length *Ac*, and meaſure the offset *co*; and to know when you are at the point *c*, place your inſtrument about *c*, and look thro' the ſights to A and B, and if you can ſee both A and B, looking back and forward, then you are in the line; if not, the inſtrument muſt be removed till you can ſee both. The inſtrument ſtanding thus, look along the croſs line on the index, and if it run directly to *e*, then *c* is the point where the offset falls; but if it point not to *e*, the inſtrument muſt be removed back or forward in the line AB, till it does; whilſt the ſights ſtill point to A and B.

Proceeding forward, find the points *d* and *f*, &c. in the ſame manner, where the offsets *de*, *fg*, &c. fall; and meaſure the offsets as you go along. And care muſt be taken to go in the line AB; and that at each point *d* or *f*, the ſights may point to A and B, at the ſame time that the croſs line points to *e* or *g*. Then all muſt be ſet down in the field book, as you meaſured them; that is, both the diſtances

along

along the ſtationary line, and the correſponding Fig. 3.
offſets, which will be as follows.

	left hand.
⊙ A	° ′
Ac = 1.94	.37 = co
Ad = 3.42	.23 = de
Af = 4.17	.81 = fg
AB = 4.45	.47 = Bb

Cor. *After the ſame manner, if* Aegb *be an irregular curve; erect* 3, 4 *or* 5 *(equidiſtant) ordinates or offſets, at* c, d, f, &c: *and meaſure the baſe* AB, *and the offſets as before.*

PROB. IV.

To draw a ſtreight line, on the ground, from one place A, *to another* B.

1. Take a long cord, and faſten one end at A, 4.
and carry the other end towards B; if it will reach thither, ſtrain it right, and faſten it at B. Then either pin down the cord, to the ground; or elſe, which is better, make a trench along the line with a ſharp ſpade, and that will be your line.

2. If the cord will not reach to B; let ſome body draw the cord ſtreight towards B, which ſuppoſe will reach to C; and there let him hold a ſtake upright; and moving it to and fro, ſet it at laſt, that A, C and B may hide one another, when ſeen from A or B; then A, C and B will be in a right line. And after this manner ſet one length after another, till you come at B.

3. If there happen to be any hill or riſing ground 5.
in the way, that one place cannot be ſeen from the other; then perhaps, a very long pole may be ſet up in one of the places, and be ſeen at the other; and then proceed as before. But if this cannot be done,

Fig. 5. done, ſet up two or more ſtakes in the way, as C, D, &c. and let them be ſo placed by trials, that C ſeen from A, ſhall cover D; and D ſeen from C ſhall cover B or the next ſtake, and ſo on to the laſt *And note*, in directing one another, no words muſt be uſed, but only ſigns of the hand; for it is ſuppoſed to be too far off, to hear any directions.

But if you have an inſtrument with back ſights as well as fore ſights, fix your inſtrument ſo between A and B, that you may ſee both of them, through back ſight and fore ſight, and there you muſt place a ſtake as at C; but if A and B cannot both be ſeen from C, ſet it by gueſs, and another D alſo by gueſs, and ſo on. Then try them, and ſhift them, till A and D appears from C; and C and B from D, &c. by back ſight and fore ſight; and then they are all in a line.

PROB. V.

To raiſe a perpendicular upon a line AB, *at a given point* A, *upon the ground.*

6. Take a ſquare, or rather a graduated inſtrument with ſights, and placing it at A, direct the ſights of the inſtrument, or the ſide of the ſquare along AB, and fix the inſtrument. Then turn the ſights to 90 degrees, and look thro' them along the line AD, and let ſome perſon ſet a ſtake forward, as at D. Then DA is perpendicular to AB. If you uſe a ſquare, you muſt look along the other ſide of the ſquare, to find a point, as D.

Or thus.

Set off 40 links from A to B, and 50 links from B to D, ſo that 30 links may juſt reach from D to A. Then DA is perpendicular to AB.

For

For then the triangle BAD is right angled at A, Fig. 6.
and the square of the hypothenuse BD is equal to the sum of the squares of the two sides, BA, AD.

PROB. VI.

To let fall a perpendicular from a given point D, upon any line AB, upon the ground.

Set an instrument somewhere about A, in the line AB; and a mark at B; then directing the sights along AB, fix the instrument. Then turn the index to 90 degrees, and if you see D thro' the sights, you are in the perpendicular. If not, move the instrument back and forward in the line AB, till you can see D, with the index set to 90 degrees; the instrument having the position before described; that is, directed to B; then DA is a perpendicular. This may be done in a few trials. 6.

A square will perform the same thing; moving one side along AB, till the other side point to D, as at A.

PROB. VII.

To lay down a given angle on the ground, as CAB.

Set up a stake somewhere in the line AB, as at B; then place an instrument at A, and direct the sights at the beginning of the degrees, to B; then fixing the instrument, set the index to the degrees of the given angle; as DAE, and looking along the index AD, cause some assistant to set up a stake in the line ADC, as at C; then the angle CAB will be that required. 7.

By an instrument with two legs; set it to the given angle, and placing it at A, direct one leg AE along the line AB, to the stake at B, and set up another

Fig. 7. another ſtake in the line AC, as at C, in the direction of the other leg AD.

PROB. VIII.

Thro' a given point C, *to drawn a line paral* *a given line* AB, *on the ground.*

8. Meaſure the neareſt diſtance of the given point C from the line AB; and at a convenient diſtance from A, as at B, raiſe the perpendicular BD to the line AB. Set the length AC from B along the perpendicular to D, and draw CD, which will be parallel to AB.

Or thus.

Take any ſtation B in the line AB; and with a proper inſtrument, meaſure the angle ABC. Then, by the laſt Prob. lay down the angle BCD equal to ABC; draw CD, which will be parallel to AB.

Or at any point A in the line AB, take the angle CAB; then going to C, ſet off the ſame angle ECD, to D; E being in the line CA.

Otherwiſe thus.

Set up a ſtake at C, and another at any place as A, in the line AB. And let two obſervers hang up two lines and plummets at D and B. Then let the obſerver at B take notice when the ſun, or ſome ſtar (agreed on between them) comes in the line BA; and at that inſtant give notice to his correſpondent at D, to ſet his line and plummet ſo, that D and C may be in a line with the ſun or the ſame ſtar. And then CD is parallel to AB. It will be beſt for the obſerver at D, to keep his line and plummet always in a line with C, and the ſun or ſtar.

PROB.

Fig.

PROB. IX.

To measure the horizontal base of a Hill, as BC.

BAD be a horizontal line, CA a perpendi- 9.
from the top, BC the slope or side of the hill. Set proper marks up, and with a proper instrument, take the elevation, that is, the angle ABC or ACB; and one being given the other is known. Then measure with a chain the side CB. And it will be, as rad : BC : : S. angle BCA : to BA.

If the hill has different declivities in several places, take the angles in these several places, and the side of each part as before. Then find the base of each, by the same operation; and the sum of all is the whole base.

All this may be done by rule and compass, by laying down the triangle BAC, or the several parts thereof.

If there be likewise a descent on the other side, as CD; you may find the part AD in the same manner as before. Or proceed thus, take the angles at B and D, and subtract their sum from 180 gives the angle BCD; or the angle BCD itself may be measured; and measuring either side of the hill as BC, then, as S. angle D : BC : : S. angle BCD : BD the whole base.

Cor. *By the same method the height of the hill* CA *may be found. For it will be, as radius* : BC : : *S. angle* ABC : *to* CA.

PROB.

Fig.

PROB. X.

To reduce a field to fewer ſides in the field, w[here] an angle is very obtuſe, or when one of the ſi[des] very ſhort.

10. Let DEFKCBAD be any field, which here conſiſts of ſeven ſides. Then,

1. Suppoſe ABC is a very obtuſe angle or bending, which we want to take way. Produce the longer ſide of the angle CB to cut the ſide AD (adjoining to the other ſide), at G; then take the point I, ſo that it may divide the line GA, in the ſame proportion, as B divides GC; that is, ſo that GI may be to GA, as GB to GC. And as GA is in this caſe very ſhort, this may be done by the eye exact enough, for the moſt part, or as exactly as the two points A and B can be determined. Then draw the line CI, and leaving out the angles B and A, the two lines CB, BA are reduced to one CH, and the field conſiſts of one ſide leſs than before. And the ſame may be done with the angle FED, by producing FE till it cut AD, and finding the point Q as I was found before.

2. Suppoſe ED a very ſhort ſide. Stand at D the end of the ſhort ſide, and obſerve, directly over the angle F (the next but one), ſome very remote object, as a houſe, tree, mountain, ſun, moon, ſtar, cloud, &c. Then immediately remove along AD, till you ſee the ſame object directly over E; at that place Q, put in a ſtake or ſome mark. Then leave out the angles E, D, and take Q inſtead thereof. And the two ſides FE and ED are reduced to one FQ, which takes away another ſide of the field. And the ſame thing may be done with the ſide BA, by obſerving the ſame remote object from A over C, and from I over B.

The

The reason of this process is this; the lines AC Fig.
and IB are parallel; and the lines DF and QF are 10.
parallel; and therefore the triangle CBA is equal
to CIA; and the triangle FED is equal to FQD.

2. *This method is very useful, when we meet with a field with crooked hedges, by reducing it to fewer sides.*

For by this means we have the same quantity of ground, and fewer hedges. For the lines CI and FQ take in as much as they leave out.

SCHOL.

When any side of a field is very irregular, you may draw a strait line instead of it, which shall take in as much ground in some places, as it leaves out in others; and so does not alter the quantity of it. And this way of giving and taking, shortens the work; and such a liner may be drawn as exactly by the eye, in most cases, as the boundaries themselves can be ascertained.

PROB. XI.

To survey a triangular field ABC.

1. *By the Chain.*

Set up station staves at the angles A, B and C. 11.
Then measure with the chain from A to C; and when you come at P, where the perpendicular BP falls, set up a stake there. And the point P is easily found, for as you go along from A, set your instrument where you think the perpendicular will be, then look thro' the sights back and forward, to see that you be in the line AC; that done, look thro' the cross line upon your index, and if you see the vertex B, then you are at the place P, where the perpendicular falls. But if B does not appear,

you

Fig. you muſt move back or forward in the line AB,
11. till B can be ſeen along the croſs line, as at P. Then having meaſured AC, and ſet it down, go to P and meaſure the perpendicular PB, and ſet it down likewiſe. And thus you have the baſe and perpendicular, which is ſufficient for finding the content.

Or meaſure all the three ſides AC, CB, BA, ſeverally, with the chain; and note them down. Then the triangle may be laid down, and the content caſt up by Sect. II.

2 *By taking one or more angles.*

Meaſure two ſides AC and CB, and the angle included ACB; by which the triangle may be deſcribed.

Or meaſure one ſide AC, and two angles A and C, then the third angle B will be known.

Or, if you cannot get the angle C; take any point D in the baſe AC, where take the angle ADB, and meaſure AC and DB; and then it may be caſt up by Sect. II.

PROB. XII.

To ſurvey a field in form of a trapezium.

1. *By the chain.*

12. Set up ſtation ſtaves with marks or ſtreamers, at all the corners A, B, C, and D. Then chooſe one of the diagonals AC or DB to meaſure, let it be DB; it ought to be ſuch a one, as that you can ſee the mark at B from D, or the mark at D from B; and likewiſe the marks at A and C from the diagonal DB; and likewiſe the perpendiculars AF and CG ſhould fall within the figure.

Begin at D, and meaſure along the diagonal DB in a right line, till you come at the place of the perpen-

perpendicular AF, which will be known, by look- Fig.
ing backward and forward thro' the sights to D and 12.
B; and then looking along the cross line to see A;
removing the instrument, till A can be seen. Then
at F put in a stake. Then measure forward, and
find the place G of the other perpendicular GC as
before; and put in another stake at G. Then mea-
sure to the end B, and set down the length DB.
Then go to F or to A, and measure the perpendi-
cular FA, and set it down. Lastly, go to G, and
measure the perpendicular GC, and set it down,
with the rest. And by these the content will be
found.

Diagonal DB — 8.97
1 Perp. AF — 3.18
2 Perp. GC — 4.80

Otherwise, by the Chain.

Draw a rude draught of the field to imitate it
upon paper; and having set up marks at all the
corners, draw a diagonal as DB upon your draught.
Then begin at any angle D, and measure all the
sides round about to D again; and then the diago-
nal DB; and set them all down as they are mea-
sured, upon the correspondent lines of your draught.
Then from these measures, the field may be laid
down upon paper, and the content found, by Sect.
II.

In measuring this way, it is best to take the short-
est diagonal.

Otherwise, by the Chain.

Marks being set up at A, B, C and D. Find the 13.
intersection E of the diagonals AC, DB; thus,
place the staff and index at E, and if you can see
D and B forward and backward, and also A and C
forward and backward, thro' the sights, then E is
the intersection sought. But if not, remove the

staff

Fig. 13. ſtaff, till you can ſee them all; which is ſoon done by a few trials. Then meaſure the lines in this order, AE, EC, CB, BE, ED, and DA (for proof), with the chain. And write their lengths on their proper lines, in a rude draught of the field. From theſe meaſures, the field may be laid down, and the content found, by Sect. II.

In all theſe methods, there is no occaſion for any inſtrument (beſides the chain), but an index with two ſights and a croſs line, and a ſtaff to ſet it on; whoſe uſe is to make you go ſtrait, by trying foreſight and back ſight; and for finding the perpendiculars, when they are required.

2. *By taking an Angle.*

Having ſet up marks at all the corners; find the interſection E, of the diagonals in the field, as in the laſt method. Then fixing the inſtrument at E, take any one of the angles at E, as AEB, and ſet it down. Then meaſure the diagonals AC and BD, and ſet them down. Then by theſe, the content will be found, by Sect. II.

Angle AEB,	66°	20′
AC,	7.	54
DB,	6.	17

Or thus, by taking ſeveral Angles.

Make a rude draught of the field upon paper, and draw one diagonal as DB, which meaſure and ſet down in the draught. Then with the inſtrument, take the quantity of the angles, DCB, CDB, and ADB, DAB; and ſome other angle or ſide for proof; and ſet all theſe angles down in the draught. Then by means of theſe, the field may be laid down on paper, and meaſured.

Note, it does not ſignify whether your eye draught be true or falſe, provided all the lines lay but in their

their right poſition; for the conſtruction at laſt will make all right. Fig. 13.

SCHOLIUM.

As the ſurveying a triangle and a trapezium, is the foundation of ſurveying all other ſorts of figures, I have been very particular in ſhewing different methods. For all plane figures muſt be divided into triangles and trapeziums before they can be meaſured; and therefore the learner ought to have a good notion of theſe.

PROB. XIII.

To ſurvey any field by the chain only.

Let ABDF be the field propoſed. Set up ſtation ſtaves, or any long ſticks, with marks or ſtreamers on them, in every corner of the field; pieces of white or red rags will do well enough, if they can but be ſeen, the breadth of the field. And as you walk over the field, conſider how it may moſt commodiouſly be divided into triangles or trapeziums, ſo as to be eaſieſt meaſured. It muſt be ſo divided, that you may ſee from one end to the other, of any diagonal of a trapezium, or baſe of a triangle; and likewiſe ſee the tops of the perpendiculars, which muſt fall within the figure. Here the field is divided into two trapeziums FCDE and FCBG, and a triangle BGA. Here we might have divided the field into the two trapeziums ABCG and GFEC, and the triangle ECD; and a great many other ways. 14.

Having ſet out the parts of the field, as you deſign to meaſure them; begin at any part as FEDC, and meaſure along the diagonal FD, till you come at the perpendiculars IC and HE, which I have ſhewn how to find in the laſt Prob. there put ſtakes

Fig. 14. in. When the diagonal FD is meaſured, and ſet down, go to E and meaſure EH, and then IC, and ſet them down; and then you have the firſt trapezium.

Being at C, meaſure along the diagonal CG of the trapezium CFGB, till you come at the perpendiculars LB, KF, to ſet marks, whoſe places are found as before; then meaſure to the end, and ſet down the diagonal; then go to F, and meaſure the perpendicular FK, and then LB, and ſet them down. So you have the ſecond trapezium.

Being at B, meaſure along the baſe BG to the perpendicular NA, and put in a ſtake at N. Then meaſure to G, and ſet down the baſe BG, and laſtly, meaſure the perpendicular AN, and ſet it down; ſo you have the triangle BGA.

The reſult of the work.

1. *Trapezium.*

The diagonal	—	11.88
1 perpendicular	——	3.54
2 perpendicular	— —	2.52

2. *Trapezium.*

The diagonal	— —	12.00
1 perpendicular	—	4.47
2 perpendicular	—	3.72

Triangle.

Baſe	— —	10.56
Perpendicular	—	3.32

In meaſuring any of the lines, take care to go very ſtrait; otherwiſe the perpendiculars will be either too ſhort or too long, by going out of the line. But when the perpendiculars are near together, as HE, IC, the going out of the line cauſes little error; becauſe one gains what the other loſes.

When

When the perpendiculars are not very long, the places where the perpendiculars fall may be taken true enough by the eye, without an index; for a ſmall error in the place, makes no ſenſible difference in the length. Fig. 14.

Otherwiſe thus.

Let ABCDE be a field; from any angle of the field as D (from which all, or moſt of, the other angles may be ſeen), ſuppoſe lines drawn to the other angles, as A and B; which will divide the whole field into triangles; and marks being placed at theſe angles; take an eye draft of the field, thus divided into triangles. Then meaſure all the ſides of every triangle, and ſet them down in the draft, along their reſpective lines. Thus, meaſure DE, EA, AD, in the triangle ADE; then DB, BA, in the triangle ABD, then BC, CD in the triangle BDC. Having got all theſe meaſures, every triangle may be drawn upon paper one by one, and ſo the whole field will be laid down. And your rough draft will inform you, how to join the triangles together. 15.

If the other angles cannot be ſeen from any angle, then you muſt take a point about the middle of the field as F, from which all the angles A, B, C, D, E, can be ſeen. And ſetting up marks at theſe angles, and ſuppoſing lines drawn to them all from F, take a rough draught of the field as uſual. Then meaſure all the ſides of every triangle one by one, and write down their lengths, as you meaſure them, along their correſpondent ſides in the draft. And then they may be all laid down on paper as before. 16.

Note, the fewer triangles there are, the ſooner they are meaſured; and therefore it is ſooneſt done, when the field is divided into triangles from ſome angle, as in the former method. For the leaſt number of triangles, any field can be divided into, is

Fig. 16. leſs by 2 than the number of ſides of the figure, when the diviſions run from an angle; and the diagonals leſs by 3. But when the diviſion is made from a point within; the number of triangles, and number of lines, is equal to the number of ſides.

For proof of the work, ſome line or diagonal, ſhould be meaſured over and above.

If you have not a rough draft, meaſure round the field, AB, BC, CD, &c. and ſet them down in a table. Then meaſure the diagonals AD, BD, which ſet down in a table; or meaſure FA, FB, FC, &c. and ſet down. But take notice what way you go about the field.

PROB. XIV.

To ſurvey any field by the plain table.

15. Set up marks at every corner of the field, ABCDE, except the corner, where you take your ſtation. Therefore chooſe ſuch an angle for your ſtation, from which you can ſee all the other angles. Then put a clean ſheet of paper upon your table and fix it at the angle D, ſo that the needle, if it have one, may hang juſt over the flower-de-luce. Then apply the index to D, and direct the ſights to E, and by the edge of the index, draw the obſcure line DE upon the paper; meaſure DE, and ſet it off (from your ſcale) from D to E. Then turn the index about, till thro' the ſights you can ſee A, the ſide of the index ſtill being at D. Then draw the line DA; meaſure the diſtance, and ſet it from D to A. In like manner direct the ſights to B, C, &c. and draw lines upon your paper; and meaſure the diſtances DB, DC, &c. and ſet them from D to B, C, &c. upon the paper. Laſtly, draw the ſides of the field DE, EA, AB, BC and CD; ſo your draught is finiſhed.

Other-

Fig. 16.

Otherwiſe thus.

When there is no angle from which all the reſt can be ſeen, take a ſtation in the middle of the field, as at F; from whence all the angles can be ſeen. Then ſet up marks at every corner, and plant the table at F; and turn it about till the needle hangs over the flower-de-luce, and there fix it. Then place the index on the point F, and direct the ſights to A, and draw an obſcure line by the edge of the index upon the paper. Then direct the ſights to B (ſtill keeping the edge of the index cloſe to F), and draw a line. In like manner direct the ſights to C, D and E, and draw lines to C, D, E. Then meaſure all the diſtances, in this order FA, BF, FC, DF, FE; and with your compaſſes ſet the diſtances on their proper lines from F to C, D, E; and laſtly, draw the boundaries of the field AB, BC, CD, DE, EA.

Or thus, by going round the field.

15. Suppoſe ABCDE a wood or pool of water. Plant the table at A, and chuſing a point on the paper near the edge as A, lay the index upon A, and direct the ſights to E, and draw a black line as AE; then meaſure the diſtance AE, and ſet it from A to E on your paper. Then the table remaining fixt, turn the index about, and direct the ſights from A to B, and draw a line as AB; meaſure the diſtance AB, and ſet from A to B on the paper.

Then remove the table to B, and lay the index upon the line BA, and turn the table about, till thro' the ſights you ſee the mark A. Then fix it, and direct the ſights from B to C, and draw the line BC; then meaſure it, and ſet it from B to C on the paper.

Then remove the table to C, and laying the index on the line CB, turn the table about, till you ſee the mark B; then direct the ſights from C to D,

Fig. 15. and draw a line CD on the paper; meaſure CD, and ſet it from C to D. In like manner remove to D and draw DE, and then to E and draw EA. Obſerving at every new ſtation, to lay the index upon the line laſt drawn, and turn the table about, till the index point to the laſt ſtation. For by this means the table is always placed in the very ſame ſituation, at every new ſtation; ſo that all the lines on the table will then be parallel to the reſpective lines in the field. Having thus drawn all the ſides of the field upon your paper, the draft is finiſhed.

Therefore to prove your work, when you are come to any new ſtation, and has fixt the table; turn the index to any former ſtation, or to any angle of the field, or to any known object; and it will paſs thro' the ſame point in the table that repreſents it, if the work is right; and if it do not, there is ſome error committed, which muſt be rectified. Therefore let all your marks ſtand to the laſt, to obſerve by.

Care muſt be taken, that the table be not moved out of its place, till the work at any one ſtation be quite finiſhed. Therefore obſerve at firſt, what object the index points to, when laid upon ſome certain line on your table; for it muſt point to the ſame object at laſt, when laid on the ſame line.

When any very large champion field is thus to be meaſured, it would require the paper to be often changed; to prevent this, uſe the following method. Place the table at every angle, and draw lines as before directed; and meaſure the ſides, but do not ſet the meaſured diſtances upon theſe lines, but only write down the length upon every line. Therefore theſe lines may be drawn as long or as ſhort as you will; and therefore need not run off the table. And when this comes to be laid down, you muſt make all the angles equal to thoſe on the table, and all the ſides of ſuch length as is written upon them,

taken

taken from a proper ſcale; ſo you ſhall have the true plan of the field. Fig. 15.

When a field has many ſides, the method of meaſuring round about it, with the plane table, will be ſubject to errors, by reaſon there are ſo many angles to be taken, and always from different lines, which multiplies the error.

PROB. XV.

To ſurvey a field with the infallible.

Firſt, from a point within it, or at any angle, as ſuppoſe at S. Set up marks at all the corners of the field, as at A, B, C, D, &c. and having aſſumed the ſtation S, there fix the inſtrument PQ, with the paper of obſervation upon it. Then direct the index to the angle A, and from the center of the inſtrument draw by its edge the line 1, the ſame way the angle A lies from S. Then meaſure the diſtance SA, and write that diſtance on the line 1. Then direct the index to B, draw the line 2 from the center of the inſtrument, the ſame way that B lies from S; and meaſure the length SB, and write its length on the line 2 upon the paper. In the ſame manner, the inſtrument ſtill remaining fixt, direct the index ſucceſſively to all the angles C, D, E, F, G; and draw as many lines 3, 4, 5, 6, 7, by its edge, upon the paper; and write thereon their reſpective diſtances SC, SD, &c. meaſured with the chain. Thus we find SA 16.20, SB 10.12, SC 14.68, SD 12.90, SE 7.25, SF 8.84, and SG 14.65. Then all the lines 1, 2, 3, &c. will be parallel to the lines SA, SB, SC, &c. of the field. And the work is ready for lying down. And the proceſs had been the ſame, if the ſtation had been in any angle. 17. 18.

Fig. 18. 19.

Otherwiſe, by going round the field.

Place the inſtrument at any angle A, and direct the index to B, and from the center of the paper draw the line 1, the ſame way from the center that B lies from A. Screw the index faſt upon the line 1, and remove to B, and as you go, meaſure AB, and write its length on the line 1. Then fix the inſtrument at B, and turn it round till the index (by backſight) point to A; there ſcrew the table faſt, and direct the index to C, and draw the line 2 by its edge upon the paper, to lie the ſame way from the center, that C lies from B. Then ſcrew faſt the index to the line 2, and remove to C, and as you go along meaſure the ſide BC, and write its length on the line 2. Fix the inſtrument at C, and turn it round till the index point backward to B; then turn the index to D, and by its edge draw the line 3, and ſcrew it faſt. After this manner proceed to all the angles D, E, F, G; always obſerving, to fix the index upon the line laſt drawn, and when you come at the next angle, to fix the inſtrument, that the index may point backward to the laſt ſtation, and then direct the index to the next ſtation; and in going along, meaſure each ſide, and ſet it upon its reſpective line in the paper. And note, at the laſt ſtation G, the index ought to point to A if the work be right. Here AB is 13.10, BC 6.18, CD 17.75, DE 10.32, EF 10.45, FG 9.00, GA 8.15. And all the lines 1, 2, 3, &c. will be parallel to the reſpective lines AB, BC, CD, &c.

SCHOLIUM.

I might now ſhew how to ſurvey a field by the theodelite, circumferentor, ſemicircle, geodetical ſtaff, &c. but as theſe inſtruments are purely for taking angles, the method whereof has been ſhewn in the firſt Problem; therefore no particular directions

rections need be given further for that purpoſe. And when theſe inſtruments are fit to be uſed, will be ſhewn in the following Problems, wherein are explained the different methods of ſurveying any field or parcel of ground. Fig. 19.

PROB. XVI.

To ſurvey a Field at one ſtation, by meaſuring ſeveral lines.

Chuſe ſome angle in the field for your ſtation, from whence you can ſee all the reſt of the angles, as at S. Then ſet up ſtation ſtaves or marks at every corner A, B, C, &c. Then placing the inſtrument at S, whether it be a Theodolite, Semicircle, Geodetical ſtaff, &c. it is the ſame thing; direct the fixt ſights to A, and there fix the inſtrument; then direct the index to B, ſo that thro' the ſights you may ſee the mark at B; and the degrees cut by the index, will ſhew the angle ASB, which ſet down in the field book. Then direct the index to C, as before; and the degrees cut will ſhew the angle ASC, which ſet down. In like manner take the angle ASD, and the reſt, if there be more, and ſet all down. And this way is more exact, than taking the angles ASB, BSC, CSD, &c. Fig. 20.

Then with the chain meaſure the ſides and diſtances in this order SA, BS, SC, DS; ſetting them down in the field book, or writing them on the lines in a rude draft of the field.

Or thus, from a point within.

When all the angles cannot be ſeen from any one of the angles of the field; aſſume ſome ſtation S within the field, where the angles can all be ſeen; there place the inſtrument at S, and directing the fixt ſights to A, there fix the inſtrument, and direct the index to B, and turning it round, till thro' the ſights you ſee the mark at B, obſerve the Fig. 21.

Fig. 21. degrees cut by the index, for that is the angle ASB, which ſet down in the field book, or in a rude draft of the field. Then the inſtrument remaining fixt, direct the index to C, and the degrees cut, ſhew the angle ASC. In the ſame manner direct the index to all the other corners D, E of the field; and you will get all the angles about S, meaſured from the firſt line SA, which ſet down. And this is more exact, than taking the angles ASB, BSC, &c. ſingly. But with ſome inſtruments you cannot take the angles quite round from the line SA; and therefore you muſt then take the angles ſeparate, ASB, BSC, CSD, DSE and ESA. And to prove the work, the ſum of all theſe angles ought to be equal to 360 degrees. But if the ſtation S happens to be upon an eminence, the ſum of all theſe angles will be ſomething leſs than 360 degrees.

Having got the angles, meaſure all the diſtances SA, SB, SC, &c. with the chain. And it is quickeſt to meaſure in this order, SA, BS, SC, DS, SE; that is, from the inſtrument to the firſt corner, and back from the ſecond corner to the inſtrument, and ſo on. Still one from the inſtrument, and another to it. Then theſe diſtances muſt all be ſet down in your book or draft.

Otherwiſe, by meaſuring round the field.

22. Take your ſtation, if you can, in an angle or a ſide; let it be at E. Then marks being placed at A, B, C, D; and turning the fixt ſights to A, fix the inſtrument; and direct the index to B, and the degrees cut will ſhew the angle BEA, which note down. Then turn the index to C, and then to D, and note down the degrees cut, which are the angles AEC, AED.

Then meaſure with the chain all the ſides EA, AB, BC, CD, and DE; and ſet them down.

Here

Here if you take all the angles at E ſeparate, the ſum of them all muſt be equal to the angle AED, if the work be right. You muſt note whether the angles at B, C, E, be acute or obtuſe. Fig. 22.

In all theſe methods, care muſt be taken that the inſtrument be not moved out of its place, while you are working; for if it be, your angles will not be true.

PROB. XVII.

To ſurvey a field, by meaſuring but one line, and taking the angles round about.

Let ADF be the field; ſet marks up at all the corners F, A, B, C, D, E; and chuſe ſome ſide, or ſome diagonal or line, to be meaſured, ſuppoſe AF. Then place the inſtrument at F, and take the angles AFB, BFC, CFD, DFE; and note them down. Go to A, and take the angle FAB. In like manner going round the field, take the angles EBC, FCD, FDE; laſtly meaſure FA. Then theſe triangles may be laid down upon paper, one after another, beginning at the triangle FAB. 23.

In like manner any other line, as FB or FC, may be meaſured inſtead of FA; and then the triangle FBC or FCD muſt begin the operation.

Or thus, from a ſtation in the field.

Aſſume the ſtation S, and let FS be meaſured. Place the inſtrument at S, and take all the angles round S, ASB, BSC, CSD, DSE, ESF, and FSA. Then go round the field, and take the angles SAB, SBC, SCD, SDE, SEF, and SFA. From theſe, the field may be laid down, beginning at the triangle SFA. 24.

And any line AS, BS, &c. may be meaſured, inſtead of FS; if AS be meaſured, then the conſtruction muſt begin with the triangle ASB.

Theſe

Fig. Theſe methods are ſubject to errors, eſpecially when the number of ſides is very great.

PROB. XVIII.

To ſurvey a field, by the method of circulation, or going round it.

25. Let ABCDE be the field. In this caſe we muſt reduce the field to as few ſides as we can; and therefore where there are any ſmall bendings, as in crooked hedges, we muſt take offsets by Prob. III. Therefore pitch upon the ſtations, *a*, *b*, *c*, *d*, *e*, as near the hedges as you can conveniently come; and at theſe places ſet up ſtation ſtaves with marks. Begin at ſome angle as *a*, and placing the inſtrument there, take the angle *eab*, which ſet down in the field book. Then meaſure from *a* to *b*; and in going, take the offsets at *a*, and at *f*, *g*, *h*, *i*, and at *b*, and note them down in the field book, and the length *ab*. Then place the inſtrument at *b*, and take the angle *c*, and note it down; and then meaſure from *b* to *c*; and in your way, take the offset at *b*, and where you touch the hedge at *k*, and the offset at *c*; and ſet them down. Then at *c* place your inſtrument, and take the angle *bcd*, which write down; and then meaſure *cd*, taking the offsets at *c* and *d*, which write down. Again place the inſtrument at *d*, and take the angle *cde*, and ſet it down, and the offset at *d*. Then meaſure from *d* to *e*; and as you go, note the point *l* where you touch the hedge, and the offsets at *m* and *e*; and ſet all down. Then ſet the inſtrument at *e*, and take the angle *dea*, and ſet it down, take the offset at *e*, and meaſure from *e* to *a*, being a ſtreight hedge, and take the offset at *a*. Set all down, and your work is finiſhed.

In

In your book you muſt note which are inward, and which are outward angles. And to prove your work, add all the angles together, and the ſum will make twice as many right angles, abating 4, as the field has ſides, if the work be right. Fig. 25.

When there are many angles or ſides in a field, this method is ſubject to errors; therefore it ſhould not be applied, where there are more than 6 ſides; or at leaſt the field ſhould be reduced to that number; for the fewer ſides, the more exact the work will be. For when the number of ſides is very great, the error is multiplied with the number of ſides, becauſe every angle is taken from a different line; and for that reaſon the draught will never cloſe. For when all is laid down the laſt point ſhould fall upon the firſt, for we end where we begun; and when the plan does not anſwer that, it muſt be wrong.

When you cannot get an internal angle conveniently, produce one of the ſides without the field, and take the external angle. And if all the angles be taken externally, the ſum of them all ought to be equal to 4 right angles. And if a ſide cannot be meaſured directly, it may be done by the method of taking inacceſſible diſtances, in the laſt Section.

If you make uſe of the circumferentor for taking angles, you need only place it at every other angle. And tho like for any inſtrument, where a needle is made uſe of.

Otherwiſe, by the needle.

When the number of angles of any piece of ground is very great, the method of circulation, by taking the angles round it, is impracticable, becauſe there is no fixt line to take theſe angles from. In this caſe the needle may be brought in, to our aſſiſtance. And here we have no more to do,

Fig. do, but to go from angle to angle, and take the bearings of all the ſides, or the angles they make with the meridian; and to meaſure the lengths of the ſides.

26. Let ABCDEFGH be ſome thick wood or pool of water, which we cannot ſurvey within. Here we muſt take all the boundaries on the outſide, and reduce it to as few ſides as we can, for greater exactneſs; as in this field, where we have but 5 ſtations; but then we ſhall have the more offsets to be meaſured. Therefore having ſet up marks at *a*, *b*, *c*, *d*, *e*, where we take our ſtations; begin at any one as *a*, and placing the compaſs and needle there, ſo that the needle may hang over the flower-de-luce, take the bearing of the line *ab*, and ſet down what angle it makes with the meridian, and which way it lies in reſpect of E. W. N. or S. Then meaſure the length *ab* to the next ſtation, and in going, take the offsets at *a*, *s*, *t*, and where it touches the corner at B; and ſet all down. Then place the compaſs at *b*, and cauſe the needle to hang over the flower-de-luce; there fix it, and take the bearing, of the next ſtation *c*, or of the line *bc*; and then meaſure *bc*, and then take the offsets at *b*, *f*, *h*, *i*, and where it touches the corner at C; and ſet theſe down. Then place the compaſs at *c*, *d*, and *e* ſucceſſively; and take the bearings of *cd*, *de*, *ea*, as before; and the offsets at *k*, E, *d*, and at *m*, *n*, F, *p*, G; alſo at the corners H and A; and ſet them all down in the field book, and the work is done.

Care muſt by taken, that there be no iron near the needle, for that will make it deviate from the meridian. And the inſtrument need only be placed at every other angle, but then you muſt take the bearings both ways, that is, of both ſides of the incloſed angle, the one forward, the other backward.

When

When the ſurvey is done, if you lay down every diſtance ſingly, and the bearing, upon paper; and from thence get the eaſting, weſting, northing or ſouthing, and put them into diſtinct columns; then the ſum of the eaſtings and of the weſtings muſt be equal. And the ſum of the northings equal to the ſum of the ſouthings; if the work be right. For it is no more than working a traverſe on the land, by plain ſailing, as it is practiſed at ſea. Fig. 26.

Tho' this method is not to be relied on, or uſed, but in caſes of neceſſity, where there is a great number of angles to be taken, by reaſon one cannot take an angle with the needle, to any great exactneſs; yet there is no greater error in taking one angle, than there is in taking 20, becauſe they are all taken from the meridian, and therefore are independent of one another. But if it was poſſible to take an angle as exactly with the needle as with another inſtrument, it would be the beſt inſtrument to ſurvey with. And as it is, it has the advantage of other inſtruments in ſuch caſes where the number of ſides is very great. The main difficulty is, to fix the inſtrument right by help of the needle, by which it is to be placed truly in the meridian; and to help this, the needle muſt be made very long, and be well touched. In uſing other inſtruments, they are fixt, by directing the index to the laſt ſtation, which admits of greater exactneſs. For all inſtruments with a needle, and alſo the plane table, whether it has a needle or not, require at every ſtation to be placed in the ſame poſition, in reſpect to the meridian, thro' all the operations, which is hard to do; for a needle, tho' never ſo good, will not always ſtand at the very ſame point.

PROB.

Fig.

PROB. XIX.

To ſurvey a field at two ſtations meaſuring only one line, which is the ſtationary diſtance.

27 Chooſe two ſtations S and T, in the field, from whence all the angles can be ſeen. Then ſet up ſtation ſtaves there, and at every angle, with ſtreamers of different colours on them. Then place the inſtrument at one ſtation S, and directing the fixt ſights to the other T, there fix the inſtrument; then directing the index ſucceſſively to the ſeveral angles in order, take the angles TSA, TSB, TSC, TSD, TSE, TSF; and number them 1, 2, 3, 4, &c. for diſtinction, and write them all down. And the marks at theſe different angles, ought all to be different, to diſtinguiſh them one from another. Then go to the ſecond ſtation T, and directing the fixt ſights to the firſt ſtation S, fix it there; and directing the index to the ſeveral angles, in the ſame order as before, take the angles STA, STB, STC, STD, STE, STF; and number them, and ſet them all down as before. To take the angles in the ſame order, you ought to know them from one another by the marks; for if you do not know which is which, all your work will be confuſion. And as you go from one ſtation to the other, meaſure the ſtationary diſtance ST. Then if all theſe angles be laid down upon paper, and lines drawn, the correſpondent lines will interſect in the angles or corners of the field A, B, C, &c. Then draw the lines AB, BC, CD, &c.

If the plane table is uſed.

Draw the ſtationary line ST on the table, and ſetting the index to the line ST, direct it to T, and fix the table there; and laying the edge of the index

to

to S, direct it ſucceſſively to all the angles A, B, C, &c. and draw lines from S by the edge of the index. Then go to T, and meaſure the ſtationary diſtance ST, which ſet off upon the table. Lay the index upon the line ST, and direct it to S, and fix the table ſo. Then lay the edge of the index to T, and direct it ſucceſſively to the ſame angles A, B, C, &c. and draw lines from T as before; and note where the correſpondent lines (or thoſe drawn to the ſame angle), interſect; for theſe will be the ſeveral angles of the field. Fig. 27.

The two ſtations S and T may be ſometimes taken in one of the ſides, as in FE; and then there will be fewer angles to take. Or they may be taken out of the field, as at *s* and *t*, as when one is not admitted to come into the ground. And it will ſhorten the work, if one or both ſtations are taken in the production of the ſides of the figure, as here, in AF and DE; and likewiſe if two of the angles fall in the ſame right line, drawn from either ſtation. 28.

Note, the corners of the field thus determined by the interſection of lines, will be trueſt, when they interſect the neareſt to right angles. But when they cut very obliquely as at A, ſuch interſection will not give the point exactly; and therefore it would be better to meaſure one of the lines, as SA or TA. And the error of interſection will be reciprocally as the ſine of the angle SAT, *ceteris paribus*.

If it happen that ſome angle cannot be ſeen from one of the ſtations; then ſet up a ſtake for a mark, in the midway between the ſtation and that angle, to ſtand in a right line; which may ſoon be done by an inſtrument, placed at the ſtake, taking backſight and foreſight. Or take a new ſtation, ſo that the angle or angles wanting, may be ſeen from this and one of the others, and proceed as before.

Fig. 28. Thus a map of the chief places in a town may be made; or any part of a river ſurveyed, &c. by taking two ſtations, on two towers, or two high hills; and thus inacceſſible places may be meaſured by means of ſcaffolds erected, and fixing high poles at the angles, with flags of different colours flying in the air.

But in ſuch caſes, it is beſt to have but a few poles up at once, as half a dozen; and when the places of theſe are determined on the draught, fix them up in freſh places; and ſo as many places as you will, may be determined, by taking a few at a time, and repeating the ſame work.

In uſing the plain table, it ſometime happens that the lines run off the table; in this caſe, move the paper ſo far off the table, that the laſt ſtation may be a little way upon it. Then take a freſh ſheet of paper and glue it to the other, at that ſide with mouth glue, and ſo faſten them down. Then lay a ruler upon that ſtation and the ſtationary line, and prolong it upon the freſh paper. Then lay the index upon the ſtationary line, and turn the table, till thro' the ſights you ſee the laſt ſtation; there fix it, and proceed.

PROB. XX.

By means of ſeveral ſtations, to ſurvey a large common, a river, a part of a country, or any hilly ground.

When all the angles of a field or parcel of ground, or all the objects we want to obſerve, cannot be ſeen from one place; then we muſt take ſo many ſtations, as will ſucceſſively diſcover them all to us.

29. Let ADG be a large common, or part of a country; and A, B, C, D, E, &c. the angles or boundaries of it, or any remarkable objects in the

country,

country, as trees, towers, houſes, mills, &c. Take the ſtations S, T, V, &c. upon ſome hills or eminent places, from which all the angles or objects can be ſeen, and at all the places and ſtations, ſet up long poles with marks. Suppoſe the objects K, L, A, B, C can be ſeen from S; place the inſtrument at S the firſt ſtation, and direct the fixt ſights to the ſecond ſtation T, and there fix the inſtrument. Then take all the angles round S, as TSK, TSL, TSA, TSB, TSC; and meaſure all the diſtances SK, SL, SA, SB, SC, and the ſtationary diſtance ST; and ſet all down. But in the plane table, fix the table and direct the index from S to T, and draw the ſtationary diſtance ST. Then direct ſucceſſively from S to K, L, A, B, C; and draw lines on the table. Then meaſure the diſtances SK, SL, SA, SB, SC, and ST, and ſet them all upon their proper lines. Fig. 29.

Then remove to your ſecond ſtation T, where you can ſee the objects D, E, F, I. Direct the fixt ſights to the former ſtation S, and fix the inſtrument; then take all the angles from ST, as STD, STE, STF, STI; and to the next ſtation STV, and meaſure the diſtances TD, TE, TF, TI, and TV, and ſet all down. Or in the plane table, lay the index on the ſtationary line ST, and keeping it there, turn the table about, till thro' the ſights you ſee the former ſtation S, there fix it. Then direct the index to all the places D, E, F, I, and V; and draw lines, on which ſet the diſtances as before.

Then go to a third ſtation V, where you can ſee the objects G, H. Then placing the inſtrument at V, direct the fixt ſights to T the former ſtation, and fix the inſtrument, and take all the angles from TV, as TVG, TVH, and to the next ſtation, if there be any more; and meaſure

Fig. 29. the diſtances, VG, VH; and ſet all down. But in the plane table, lay the index on the laſt ſtationary line VT, and turn the table about till the former ſtation T appear thro' the ſights, there fix it. Then direct the index ſucceſſively to G and H, and draw lines, on which ſet the meaſured diſtances, VG, VH as before.

And in general when any ſtationary line is drawn on the table, and you come to a new ſtation, lay the index upon that ſtationary line, and turn the table, till thro' the ſights you ſee the ſtation laſt come from, and there ſcrew it faſt, and proceed.

And after this manner, if there be more objects undetermined, you muſt take new ſtations, and ſo proceed, till all is finiſhed.

Then from all theſe angles and diſtances given, the whole work is eaſily laid down by rule and compaſs, and the plan or map deſcribed. But when it is taken by the plain table, it is deſcribed already, by the operations on the table. And if it be a field, lines muſt be drawn from A to B, from B to C, &c.

At every ſtation when the inſtrument is fixt, take care it be not moved out of its place, till all the work at that ſtation be done; which you may know by obſerving ſome remarkable object thro' the fixt ſights; for that object ought always to appear there. Or on the table by drawing a line; or making a mark, by the edge of the index. For then the index being laid to that mark, that object ought always to appear thro' the ſights.

If there be ſome of the objects which cannot be ſeen from any of the former ſtations, then new ſtations muſt be taken from which they can be ſeen. Remembring to take their diſtances, and angles (or poſitions), from ſome of the other ſtations.

If ſome of the objects can be ſeen from two adjoining ſtations, as I from both T and V, then the angles may be taken from both ſtations (ITV and IVT); which will ſave the labour of meaſuring to ſuch objects, the diſtances TI, VI. Fig. 29.

In the plain table, when any ſtation line runs off the table, take off the paper and glue another paper to it with mouth glue; on this produce that ſtation line to its proper length. Then faſten the paper on the table, with the former ſtation near the edge of the table; and laying the index on the new ſtationary line, turn the table about, till you ſee the laſt ſtation come from, thro' the ſights; there fix it and proceed.

It will be proper always to take an eye draught of the field or country, upon paper, before you begin your work. And all your meaſures muſt be written down in this rough draught. Or elſe they muſt be written regularly in a field book on purpoſe.

PROB. XXI.

To ſurvey a lordſhip, or large eſtate of land.

If the eſtate be very large, and contains a great number of fields; it cannot be done by ſurveying all the fields ſingly, and then putting them together; nor can it be done by taking all the angles and boundaries that incloſe it. For in theſe caſes, any ſmall errors will be ſo multiplied as to render it very much diſtorted.

1. Walk over the lordſhip two or three times, in order to get a perfect idea of it, and till you can carry the map of it in your head. And to help your memory, draw an eye draught of it on paper, to guide you, or at leaſt, of the principal parts of it.

Fig. 29. 2. Chooſe two or more eminent places in the eſtate, for your ſtations, from whence you can ſee all the principal parts of it; and the fewer ſtations you have to command the whole, the more exact your work will be; and let theſe ſtations be as far diſtant from one another as poſſible; and they will be fitter for your purpoſe, if theſe ſtationary lines be in or near the boundaries of the ground, and eſpecially if two lines or more proceed from one ſtation.

3. Take what angles, between the ſtations, you think neceſſary, and meaſure the diſtances from ſtation to ſtation, always in a right line; theſe things muſt be done, till you get as many angles and lines as are ſufficient for determining all your points of ſtation. And in meaſuring any of theſe ſtationary diſtances, mark accurately where theſe lines meet with any hedges, ditches, roads, lanes, paths, rivulets, &c. and where any remarkable object is placed, by meaſuring its diſtance from the ſtationary line; and where a perpendicular from it cuts that line. And always mind, in any of theſe obſervations, that you be in a right line, which you will know by taking backſight and foreſight, along your ſtationary line; which you muſt never omit. And thus as you go along any main ſtationary line, take offsets to the ends of all hedges, and to any pond, houſe, mill, bridge, &c. omitting nothing that is remarkable, and all theſe things muſt be noted down, for theſe are your *data*, by which the places of ſuch objects are to be determined upon your plan. And be ſure to ſet marks up at the interſections of all hedges with the ſtationary line, that you may know where to meaſure from, when you come to ſurvey theſe particular fields, which muſt immediately be done, as ſoon as you have meaſured that ſtationary line, whilſt they are freſh in memory. By this means all your ſtationary lines are to be meaſured,

meaſured, and the ſituation of all places adjoining to them determined, which is the firſt grand point to be obtained. I would have you lay down your work upon paper every night, when you go home, that you may ſee how you go on. Fig.

4. As to the inner parts of the eſtate, they muſt be determined in like manner, by new ſtationary lines. For after the main ſtations are determined, and every thing adjoining to them; then the eſtate muſt be ſubdivided into two or three parts by new ſtationary lines; taking inner ſtations at proper places, where you can have the beſt view; and meaſure theſe ſtationary lines as you did the firſt, and all their interſections with hedges, and all offſets to ſuch objects as appear; then you may proceed to ſurvey the adjoining fields, by taking the angles that the ſides make with the ſtationary line, at the interſections, and meaſuring the diſtances to each corner, from the interſections. For every ſtationary line will be a *baſis* to all the future operations; the ſituation of all parts being entirely dependent thereon; and therefore they ſhould be taken as long as poſſible; and are beſt to run along ſome of the hedges or boundaries of one or more fields, or to paſs through ſome of their angles. All things being determined for theſe ſtations, you muſt take more inner ſtations, and continue to divide and ſubdivide; till at laſt you come to ſingle fields; repeating the ſame work for the inner ſtations, as for the outer ones, till all be done. And cloſe the work as oft as you can, and in as few lines as poſſible. And as it may require ſome judgment to chuſe ſtations the moſt conveniently, ſo as to cauſe the leaſt labour; let the ſtationary lines run as far as you can along ſome hedges, thro' as many corners of the fields, and other remarkable points, as you can. And take notice how one field lies by another;