

XLII. *Observations for determining the Length of a Degree of Latitude in the Provinces of Maryland and Pennsylvania, in North America, by Messieurs Charles Mason and Jeremiah Dixon.*

Read Nov. 24, 1768. **I**N this work, the first thing to be considered was, how to continue a right line : and this was done by setting up marks with the assistance of an equal altitude or transit instrument (for it was contrived so as to serve either purpose at pleasure), made by Mr. John Bird, of the same construction with that described by M. Le Monnier, in the preface to the single volume of the French *Histoire Celeste*.

The cylindrical ends of the cross axis of the telescope were laid in two angles of the supporters, which rose perpendicularly from a horizontal bar, that was fastened firmly to the upper part of the vertical axis. The axis of the telescope was set truly horizontal, by a spirit level hung on its cylindrical ends.

The brass frame, which receives the vertical axis, was screwed to a post fixed in the ground, in the direction of the line which was to be continued.

When the vertical wire in the telescope was brought to bisect any mark, it was kept in that direction, by confining firmly, between two pushing screws, a horizontal arm that projected from a collar that surrounded the vertical axis; and, to prove that a small shock would not alter its position, a small pressure

pressure was applied against one of the supporters, which being removed, it was carefully noted, whether the wire returned again to bisect the mark.

At every station (or mark) the telescope was turned two or three times after the mark was fixed in the line, to prove that the said mark was truly set.—In general, the distances between the marks did not exceed a mile, nor were they less than half a one.

The telescope magnified about 25 times. Three or four marks were always left standing, and on a little rising ground they would all be seen in a right line, the vertical wire in the telescope bisecting their centers without sensible error.

The marks made use of in continuing the lines were concentric circles of black and white, painted upon both sides of a board 14 inches square. This board moved in mortices made in two posts, which were drove into the ground; and, when the center of the said mark was brought, by means of signals, into the line, it was fastened by wedges to the posts.

By means of a plummet, a peg was driven into the ground, and a notch cut in it, under the center of the said mark, in order to secure the line.

In the evening, when we left off, a mark was placed before, and two or three left behind us; and in the morning the instrument was again set up in the same place, to prove that the marks were not moved.

The tremour of the air (caused by the sun's rays) was often very great; and, to avoid any error that might arise from the fluttering of the marks, we intermitted our operations sometimes for five or six hours

in a day, and were often obliged to make use of the morning or evening twilight.

In the continuation of the line, a person was left at the mark, behind the instrument, till another mark was set forward, to prove with a plummet that its center was not moved.

The vifo cut through the woods, in this work, was about eight or nine yards wide, and, in general, seen about two miles, beautifully terminating to the eye in a point.

The zenith distances of the stars, for determining the celestial arc, answering to the interval of the parallels of the northernmost and southernmost points of the lines, were made with an excellent sector of six foot radius, constructed by Mr. John Bird.

In the course of the work, for dividing the provinces of Maryland and Pennsylvania, the following lines were traced out, that offered themselves for determining the length of a degree of latitude.

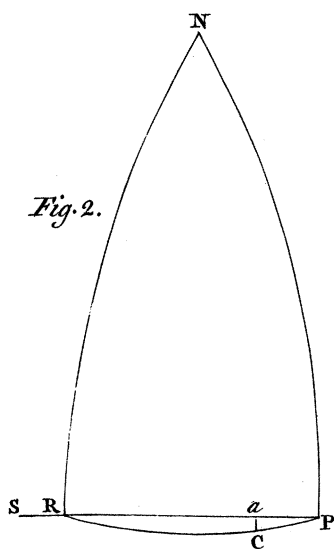
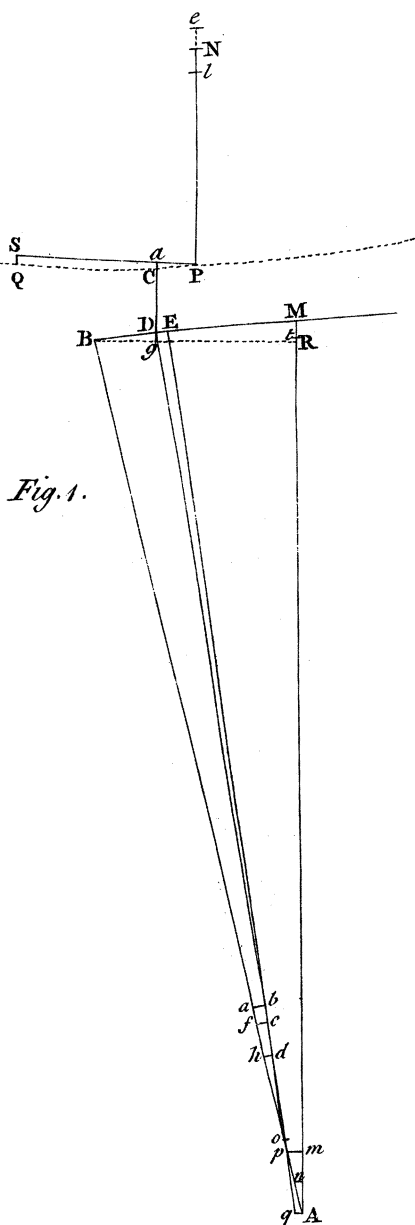
In the following fig. let N represent the northernmost point, and A the most southern of the said lines. Beginning at N, a meridian was traced from N to

P. = 14 ^{m.} 64 ^{ch.} 8. ^{lin.} In this line there were some hills, which were measured horizontally with a level, but the plains were measured with a chain.

PC = 2 ^{m.} 79 ^{ch.} 27; ^{lin.} C being in the parallel of latitude with P, which was determined by the sector.

DC a meridian = 5 ^{m.} 2 ^{ch.} 43, ^{lin.} in which are three or four small ascents and descents.

The



The points B D E and M are in a right line.
 $BD = 22 \overset{\text{cha.}}{51}$, and the angle $CDM = 86^\circ 32 \frac{1}{7}'$
 nearly. Hence,

B is fouth of $D = 1 \overset{\text{ch.}}{36} \overset{\text{lin.}}{= D g.}$

The line $AB = 81 \overset{\text{m.}}{78} \overset{\text{ch.}}{31} \overset{\text{lin.}}{}$, in which is one gentle
 rifing hill, about half a mile over; all the reft of the
 line is an entire level or plain.

Thefe measurements, expreffed in English statute
 miles and parts of the fame, were made with a chain,
 eftablifhed from a brafs statute yard, which was
 proved and corrected, in the courfe of the work, by
 another statute chain (kept only for that purpofe) made
 from the faid brafs yard. They were only defigned
 for dividing the provinces of Maryland and Penfyl-
 vania: the fame lines were re-meafured afterwards
 with wooden rectangular levels, for the purpofe of
 determining the length of a degree of latitude, as will
 appear in the fequel of this work.

The point C was placed in the parallel of latitude of
 P, thus. Let N (fee TAB. XIII. fig. 2.) represent the
 north pole of the terreftrial globe; P and R two places
 lying in the fame parallel of latitude RCP; PR an
 arch of a great circle $= 10'$ joining the faid points; and
 PN, RN two meridians. PN or the complement
 of the latitude of P being $= 50^\circ 16' 42''$, the angle
 NPR or the azimuth of the great circle PR was
 found by calculation to be $89^\circ 55' 51''$. The going
 of the clock being found by equal altitudes of ftars,
 the times were computed when the fame or other
 ftars would pafs the azimuth of the line PR; and, at
 the time computed for any ftar, the interfection of
 the crofs wires of the tranfit instrument being brought
 to

to cover the star, the telescope was turned down to the horizon, and a land-mark was fixed up at the distance of about half a mile, answering to the intersection of the wires. In like manner, by other stars, several other marks were fixed up, and the mean of all was taken. In this direction the line PR was continued; and though it was at first intended to extend it only to R , to the distance of $10'$ of a great circle, it was in fact prolonged somewhat further, to S , PS being $= 12,312$ miles, or $10' 45''$ of a great circle. Now PC being $= 2,991$ miles, or $2' 37''$ of a great circle, the angle NPC is $= 89^\circ 58' 55''$; from whence $NPS = 89^\circ 55' 51''$ being subtracted, there remains the angle SPC or $aPC = 3' 4''$, whence aC , or the distance of the parallel PCR at C , south of a , should be $14,1$ feet. But it having been made a rule, in dividing the provinces of Pennsylvania and Maryland, to trace out the parallels of latitude by the observations taken with the astronomical sector only, the sector was put up at P and S successively (see fig. 1.) and the zenith distances of the stars Capella α Lyræ, and others, were observed at both places; whence the point S was concluded to be 43 yards or 129 feet $= SQ$ more northerly than P ; and thence it was found by calculation, that the parallel of latitude PQ at the point C should be $45\frac{1}{2}$ feet, $= aC$ distant from the great circle PS , and to the south of the same; and the point C was placed accordingly, by laying off $45\frac{1}{2}$ feet $= aC$, at right angles, to the line Pa from the point a towards the south.

aC found by the sector, being $45\frac{1}{2}$ feet, and found by the azimuth of the line PS being $14,1$ feet only, it

it follows, that had the position of the point C been determined by the latter method, instead of the former, it would have been placed 31,4 feet more to the northward than it was found by the sector; and, in consequence, the length of the degree of latitude would have come out 21 feet longer. But the difference is so small, that it only serves to confirm the exactness of the work, and renders it unnecessary to enter into any consideration, which of the two methods ought to be preferred.

The meridians NP, CD, and AM, were found by celestial observations. The method of proceeding was as follows:

To find the meridian AM, and the angle that the line AB makes with the said meridian.

The equal altitude instrument being set up at the point A, with its vertical axis over the said point, equal altitudes of stars were observed for finding the motion of the clock. The time was next computed when some northern stars would pass the meridian by the clock, at which instant (shewn by the clock) the vertical wire in the telescope was brought to bisect the star; and, the vertical axis of the instrument remaining fixed, the telescope was turned down in the same azimuth to the horizon, and a candle placed opposite to the vertical wire, as a point in the meridian.

And the time of stars passing an azimuth in the direction of the line AB, for determining the angle BAM, was found by bringing the vertical wire in the telescope to bisect a candle placed (about $1\frac{1}{4}$ mile from A) in the line AB; the telescope was then elevated to the star, and the time when it passed the said vertical wire taken.

The

The observations for determining the meridian A M, and the angle that the line A B makes with the said meridian, were as follows :

1766.		Time per clock.				Sum.				Half Sum.				} equal altitudes α Cygni.	star passed the meridian per clock. star's apparent right ascension.	clock too fast for sidereal time.				
October.		h	'	"	h	'	"	h	'	"	h	'	"							
h_2	... 11	19	51	27	21	17	10+	41	11	23+	20	35	41½+							
		52	49—		18	35+		11	24		35	42								
		54	13		19	56		11	23		35	41½								
Mean												—		20	35	42				
														20	33	30				
														2	12					

O . . . 12		20	0	16	21	10	22::	. . . . .	. . . . .	equal altitudes α Cygni.		
		1	42	11	47—	41	13	29—	20	36	44½	
		3	15	13	14		13	30		36	45	
Mean										star passed per clock.		
										star's apparent right ascension.		
										clock too fast for sidereal time.		

22 20 13 α Ursa major } passed an azimuth in the direction of the line A B.
23 26 β Ursa major

1766.		Time per clock.		Sum.		Half Sum.	
h	'	h	'	h	'	h	'
October.							
2 . . . 13	19 50 41	21 22 12 +	41 15 33 —	20 37 46½	} equal altitudes α Cygni.		
	51 58	23 35½	15 33½	37 47 —			
	53 20½	24 52	15 33	37 46½			
Mean				= 20 37 46½		star passed per clock.	
				20 33 30		star's apparent right ascension.	
				<u>4 16½</u>		Clock too fast. Hence the clock gained of sidereal time the last 24 ^h . . . 62".	

22 21 16 α Ursa major } passed an azimuth in the direction of the line A B.
 22 24 21 β Ursa major }

The apparent right ascension of α Ursa major	. . . . .	22 49 8
The clock will be too fast, when this star will be on the meridian	. . . . .	4 22 —
α Ursa will be on the meridian per clock	. . . . .	22 53 30 —
In like manner I find that γ Ursa major will be on the meridian per clock	. . . . .	23 45 55½
And the pole * at	. . . . .	0 50 27

At the instant when the clock shewed 22^h 53' 30", the vertical wire was brought to bisect the star α Ursa major; and then the vertical axis was made fast (the level shewing the horizontal position of the axis of the telescope and the line of collimation being just), the telescope was then brought down to the horizon, and by means of a candle seen through a small hole in a board, a mark, at the distance of 21 42^{lin.}, was placed in a line with the said vertical wire.

1766. October.	Time per clock.			Sum.			Half Sum.		
	h	'	"	h	'	"	h	'	"
22 15	19	52	14+	21	23	47	41	18	42½
23 15	53	22½		25	10		18	42½	
24 15	54	55½		26	28		18	42+	
							20	39	21+
							33	30	
							5	51+	
							clock too fast.		

22 31 56 ♂ Urfa minor passed the line A B.
2 4 18 β Urfa minor passed ditto.

24 ... 16	20	0	17	21	17	24	41	20	32	20	40	16	} equal altitudes \approx Cygni.
		1	41		18	51½		20	32½		40	16+	
		3	8		20	16		20	33		40	16½	
<hr/>													
20 40 16+													
20 33 30													
<hr/>													
6 46+													
<hr/>													
clock too fast.													

22 23 46 α Urfa major passed the line A B.
22 26 45½ β Urfa major passed ditto.
22 32 45 ♂ Urfa minor passed ditto.

	Time per clock.			Sum.			Half Sum.		
	h	'	"	h	'	"	h	'	"
1766.									
October.									
24... 16	23	41	16	0	19	46	0	3	18½
	43	51½			22	46		3	19—
	46	51			25	22		3	19
				Mean	=	0	3	19	* passed the meridian per clock.
						23	56	22	*'s apparent A R.
						6	57—		

} equal altitude of α Andromeda.

the clock too fast. Hence by the going of the clock, in the interval between α Cygni and α Andromeda passing the meridian.

At	{	0 53	0	the Pole *	will be on the meridian.
		2 58	41	β Urfa minor	will be on ditto.
At	{	0 53	0	{ by the clock, the vertical wire was brought to the Pole * as usual; and, by means of a candle at the distance of a mile, a mark was placed, which fell, as near as could be judged, on the mark placed the 14th instant.	
At		2 5	10	β Urfa minor	passed the line A B.
		2 58	41	the wire was brought to β Urfa minor	for finding a meridian as before; and, by means of a candle at the distance of a mile, a mark was placed, which fell 3 inches east of that placed the 14th.

N. B. In this last observation the axis of the telescope was turned end for end; that is, the telescope itself was turned upside down. This proved the ends of the cylinder to be good.

2 . . . 17 In the evening, by means of a candle placed behind a board, with a small hole in it over the mark placed the 13th infant, the line was extended to the marks at a mile distance, and there a mark placed, which fell $\frac{1}{4}$ of an inch east of the mark placed the 14th infant.

From the whole, there are six observations, all within the space of about 3 inches, at the distance of a mile : The mean was taken as a point in the meridian, north of the point A.

At this meridian point m , we laid off the line mp , at right angles to the meridian A, m, M , and, by a candle being placed at a , in the right line AB (about $1\frac{1}{4}$ miles from A), another candle was advanced along the line mp , till the vertical wire in the telescope bisected both candles : Under the candle, at the intersection of mp , with AB , viz. at p , a mark was placed in the ground.

The ground between m , and p , being made smooth (it was level as a floor by nature) the distance mp , was measured twice, and found to be 5 chains, 14 feet, and $\frac{1}{2}$ of an inch.

With this same chain the distance $m A$ was measured = 80 chains exactly.

For the Angle BAM, by celestial measure.

	h		'		"	
The AR of the meridian when α Urfa major passed an azimuth in the direction of the line AB.	}	22	16	53, 8	by observations made October 12.	
		22	16	55, 1	D° on the 13.	
		22	16	54, 7	D° on the 16.	
Mean		22	16	54 5	=	334 13 38
AR of α Urfa major	162 16 54
Angle at the Pole =	171 56 44

AR's of the meridian when β Urfa minor passed { 1 58 7, 8 by observations made October 14.
the direction of the line AB. 1 58 14, 2 D° on the 15.
1 58 7, 1 D° on the 16.

Mean of the first and last = 1 58 7, 5 = 29 31 52
AR of β Urfa minor 222 53 30

Angle of the Pole

Now having the distance of the \ast s from the Pole, the angles at the Pole, and the latitude of the point A, per
spherics, we find the star's azimuth from the north = the angle B A M.

And for the said Angle by terrestrial measurement. As A M: Rad :: $p m$:

Tangent Angle $p A m$. = the Angle B A M. = 3 43 40
Angle per α Urfa major 3 43 25
D° per β Urfa minor 3 43 25

Mean 3 43 30 = Angle B A M.

In the same manner as the point m , in the meridian from A was found, points in the meridian, north of P and N, were also found; and having two points given, with them a right line was extended as follows; first N P. in a line with N ϵ .—At N the equal altitude instrument was set up, and the vertical wire in the telescope was brought to bisect the mark at ϵ ; and there the vertical axis made fast. The spirit level shewing the axis of the telescope to be horizontal.

The vertical axis being well secured, the telescope part is taken off the supporters, and turned to point to the southward (carefully taking off, and putting it on the supporters so as not to move the axis); then on the farthest rising ground that could be seen, another mark was placed at l , in a right line with the vertical wire. A mark being left at N, the instrument is taken, and set up three or four feet south of the mark l , and having brought the vertical wire in the telescope in a right line with the marks at l , and N, the vertical axis is then made fast as before, the telescope immediately turned, and a third mark placed to the southward; and so the operation was continued.

In

In the same manner the lines PS, CD, AB, and AE were traced out; and, to prove that by this method a right line may be extended, we shall here give the result of continuing the lines AB and AE. A and D being two points between which a right line was to be drawn.

The point n was known to be nearly in the line AD. At A and n marks were placed, and 3 or 4 feet north of n (which was $\frac{1}{4}$ of a mile from A), the instrument was set up; then, in the same manner as above, the vertical wire in the telescope was brought in a line with A and n , and the vertical axis made fast; the telescope was then turned to point to the northward, and a third mark placed, &c. &c. In this manner the line A n was continued to B.

Having continued the line to B, it fell $22\frac{1}{2}$ ^{chs.} ^{lin.} west of the point D: we then returned and laid off eastward off-sets from the line AB, at every fifth mile from A, proportional to the distance from A, and at the end of every off-set placed a post, in order to form the line AD.

Off-sets were measured very correct at $\left\{ \begin{array}{l} \text{about } 10\frac{1}{2} \text{ miles} \dots\dots = ab. \\ \text{the } 10^{\text{th}} \text{ mile} \dots\dots = fc. \\ \text{about the } 9^{\text{th}} \text{ do} \dots\dots = bd. \end{array} \right\}$ and at the 3 points, b, c, d , three

marks were placed. At b the instrument was set up, to see if the 3 marks were placed in a right line; when it appeared they were not exactly so; but, on moving the middle one $\frac{1}{2}$ an inch east, they then made a right line.

In this direction we continued the lines b, c, d , to A, which fell 2 feet 2 inches west of the point A, at q . The distance A q being so small a quantity (gradually rising) in ten miles, we thought it would be superfluous to change the direction, and therefore returned to the point b , and extended the line northward, proceeding in the same manner as before.

Having continued the line to E, it fell 16 feet 9 inches east of the point D.

Hence the off-sets from this line to the true line AD, are as shewn by the Table B. And as we passed by the off-set posts made from AB, we measured the distance of this line AE from the said off-set posts, which were as given in the Table D.

TABLE B.

Miles from
point A. Feet Inches

0	2	2	} to the eastward.
5	1	0	
10	0	2.2	} to the westward, to give the true line A D.
15	1	4	
20	2	6	
25	3	8	
30	4	10	
35	5	11	
40	7	1	
45	8	3	
50	9	5	
55	10	6	
60	11	8	
65	12	10	
70	14	0	
75	15	2	
80	16	4	
82	16	9	

TABLE D.

Miles from
point A. Feet Inches

0	2	2	} eastward.
5	0	10	
10	0	0	} the distance of the off-set posts, west from the line A E.
15	0	4	
20	4	8	
25	7	4	
30	8	3	
35	7	6	
40	8	5	
45	9	6	
50	10	11	
55	11	1	
60	10	6	
65	11	7	
70	12	11	
75	15	7	
80	16	7	
82	16	9	

From these Tables we have the difference of the results of the two lines A B and A E; that is, the off-set posts from the line A B, which form the true line A D: And the off-set posts from the line (A E) traced last, that also form the said line A D, will be distant from each other, at every fifth mile, as follows:

Miles

Miles from
point A. Feet Inches

0	0	0
5	0	2
10	0	2.2
15	1	0
20	2	2
25	3	8
30	3	5
35	1	7
40	1	4
45	1	3
50	1	6
55	0	7
60	1	2
65	1	3
70	1	1
75	0	5
80	0	3
82	0	0

This is a sufficient proof that the line A B is the arch of a great circle; but, as a farther confirmation that no error could arise, we observed at different points in the line the right ascensions of the meridian when the star δ Urfæ minoris passed an azimuth corresponding to the direction of the line, being in the upper part of its circle. The method of proceeding was in the same manner, as described before, for finding the angle B A M.

OBSERVATIONS for determining the right Ascensions of the Meridian, when δ Urfæ Minoris passed the Line A B.

June 25, 1764, we began at the point A, to trace the line A B; and the weather being so cloudy prevented our making any one observation till July 10, though we attended every night. By this time we had continued the line 20 miles from A,

1764. Time per watch.

	h	'	"	h	'	"
δ ... 10	15	49	0	17	5	10
	55	0		17	12	17
	16	2	8	18	3	

} equal altitudes of Antares. Hence the * passed the meridian per watch at
A R of Antares 16 33 36
 16 15 1
Watch too fast for fiducial time 0 18 35
P P

20 Miles from A.	1764. July.	Time per watch.				
	h ' " h ' "	19	29	26	20	15 36
δ . . . 10	34 18	21	40			
	40 21	26	30			
		equal alt. α Aquilæ.				Hence * passed at . . . 19 57 58
		Right ascenf. of α Aquilæ				19 39 18
		Watch too fast				0 18 40
		22 44 45	δ Urfæ minoris passed an azimuth in the direction of the line A B.			
		— 18 44	watch too fast when the * passed the line.			
		22 26 1	= the right ascension of the meridian, when δ Urfæ minoris passed the line A B.			

27	18 10 45	19 45 4	} equal altitude α Lyræ.	Hence * passed at . . 18 59 0
	11 54	46 10		Right ascension = . . 18 28 58
	12 56	47 11		
				Watch too fast . . . 0 30 2
43 Miles from A.	20 33 58	21 30 50	} equal alt. α Cygni.	Hence * passed at . . . 21 3 58
	35 33	32 23		Right ascension . . . 20 33 25
	37 3	33 58		
				Watch too fast . . . 0 30 33
	22 57 36	δ Urfæ minoris passed the direction of the line A B.		
	— 31 1	watch too fast at this time.		
	22 26 35	= the right ascension of the meridian when δ Urfæ minoris passed the line A B.		

1764.	Time per clock.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										</
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22 26 28 = the right ascension of the meridian when ♀ Urfæ minoris passed the line A B.

August.										
11 Miles from A.	18	47	25	19	0	0	equal alt. of α Lyræ.	Hence * passed at . . . 19 12 42 its right ascension . . . 18 28 58	Watch too fast 0 43 44	
	48	24		37	0					
	49	33		38	0					
	20	42	45	21	50	48				equal alt. α Cygni.
	44	8		52	12					
	45	30		53	30		equal alt. α Cygni.	Hence * passed at 21 18 9 its right ascension 20 33 25	Watch too fast 0 44 44	
	23	12	48	♂ Urfæ minoris passed the direction of the line A B.						
	—	45	30	= watch too fast.						

22 27 9 = the right ascension of the meridian, when ♀ Urfæ minoris passed the direction of the line A B.

1764.	Time per watch.	
August.	h ' " "	
♄ . . . 27	18 54 38 19 58 50 } equal altitudes α Lyræ.	
	55 40 59 54 }	
	56 44 20 0 57 }	
		Hence the * passed merid. per watch . . . 19 27 47
		Right ascension of α Lyræ 18 28 58
		Watch too fast 0 58 49
Here we were 80 miles from A.	21 6 32 21 54 46 } equal alt. α Cygni.	h ' " "
	8 4 56 25 }	
	9 44 58 2 }	Hence passed at 21 22 31
		*'s right ascension 20 33 25
		Watch too fast 0 59 6
	23 25 55 δ Urfæ minoris passed the direction of the line AB.	
	— 50 21 watch too fast.	

22 26 34 = the right ascension of the meridian when δ Uræ minoris passed the line A B.

Most of these equal altitudes were observed per Mr. Dixon, I judging the time by the watch, which had only the hour and minute hands; therefore the seconds must not be expected as from a good clock, nor does the problem require it, as the star δ Ursaë minoris changed its azimuth very slowly.—The passage of the star δ Ursaë minoris over the line A B was in general taken by myself.

The A R of meridian when } 22 26 O I } by observations made on the 15th and 16th of October, 1766, at the point A.
 & Uræ minoris passed A B. } 22 25 54 I }

Whether the small effects of the aberration and nutation of the star δ *Ursæ minoris*, at the different times, will add to or diminish from the correspondence of these numbers, I have not determined; the above being sufficient for the purpose intended: for if the direction of the line had been changed any quantity of note, it would have caused a much greater difference in the right ascensions of the meridians, when the star passed the line, than any we here find,

The following are observations for determining the celestial arch between the points A and N. — Those marked with dots and *, thus, . . * . . were made by Mr. Dixon.

1766. We fet up the sector at the point A, in the middle of a west line, drawn between Cape Hinlopen
 October. and Chefopeak Bay, and made the following observations.
 8

N. B. Each revolution of the micrometer = 52"

PLANE OF THE SECTOR EAST.

*'s names.	Nearest point on the sector.	Points on the micrometer.	Diff. between the points on the micrometer.	Apparent zen. distances.	
	°	'	°	"	°
γ Andromedæ	2	45—	{ 5 31— 6 10	0	31,3 2 44 28,7 North.
β Persei	1	35—	{ 7 8 7 14	0	6,0 1 34 54,0 N.
δ D°	8	35—	{ 7 32+ 9 13+ 6 16	1	25,0 8 33 35,0 N.
Capella	7	15+	{ 4 39— 3 24— 2 22½	1	21,3 7 16 21,3 N.
β Aurigæ	6	25+	{ 1 10 1 0½	1	3,2 6 26 3,2 N.
Castor	6	5—		0	9,5 6 4 50,5 South;

*'s Names.	Nearest point on the sector.	Points on the micrometer.	Diff. between the points on the mi- crometer.	Apparent zen. distances.
1766. October.				
24 9	Cloudy.			
2 10	α Lyrae	0 5+	0 2	19,0 0 7 19,0 North.
	γ Cygni	1 5-	1 7,7	1 3 53,3 N.
	α D°	6 0-	0 4,7	0 5 59 55,3 N.
	γ Andromedæ	2 45-	0 30,0	0 2 44 30,0 N.
...*	β Persei	1 35-	0 6,5	1 34 53,5 N.
	δ D°	8 35-	1 25,5	8 33 34,5 N.
	Capella	7 15+	1 20,0	7 16 20,0 N.
	β Aurigæ	6 25+	1 4,0	6 26 4,0 N.
	Castor	6 5-	0 9,5	6 4 50,5 N.
2 11	α Lyrae	0 5+	2 20,7	0 7 20,7 N.
	δ Cygni	6 5+	1 51,0	6 6 51,0 N.
	γ D°	1 5+	1 8,0	1 3 52,0 N.

		*'s Names.	Nearest point on the sector.	Points on the micrometer.	Diff. between the points on the mi- crometer.			Apparent zen. distances.		
			°	'	°	'	°	'	"	
1766.	October.									
○	12	♂ Perfei	8	35—	{ 1 43 3 26	1	27,0	8	33	33,0
		Capella	7	15+	{ 6 28 4 50	1	22,0	7	16	22,0
		β Aurigæ	6	25+	{ 1 33+ 0 21+	1	4,0	6	26	4,0
		Castor	6	5—	{ 15 37½ 15 29½	0	8,0	6	4	52,0

TURNED THE SECTOR PLANE WEST.

♂	13	γ Andromedæ	2	45—	{ 6 2+ 5 29½	0	24,8	2	44	35,2
		β Perfei	1	35+	{ 5 43 5 44—	0	0,7	1	35	0,7
		δ D°	8	35—	{ 6 2½ 4 24	1	22,5	8	33	37,5
		Capella	7	15+	{ 7 4½ 8 40	1	27,5	7	16	27,5

*'s Names. Nearest point on the sector. Points on the micrometer. Diff. between the points on the micrometer. Apparent zen. distances.

1766. October.

14	α Lyræ	0	5+	{ 14 12 16 49	2	21,0	0	7	21,0
	α Cygni	6	0	{ 13 16 13 16	0	0,0	6	0	0,0
	γ Andromedæ	2	45—	{ 2 46 2 22	0	24,0	2	44	36,0
	β Persei	1	35+	{ 2 5— 2 5+	0	0,6	1	35	0,6
	δ D°	8	35—	{ 3 27+ 2 0—	1	19,6	8	33	40,4
	Capella	7	15+	{ 1 50+ 3 36	1	29,7	7	16	29,7
	β Aurigæ	6	25+	{ 2 51 4 18½	1	11,5	6	26	11,5
	Castor	6	5—	{ 7 17 7 29	0	12,0	6	4	48,0

* * * * *

15	α Lyræ	0	5+	{ 3 33 6 20—	2	22,7	2	7	22,7
	δ Cygni	6	5+	{ 6 18 8 32	1	58,0	6	6	58,0
	γ D°	1	5—	{ 7 4 5 43—	1	5,3	1	3	54,7
	α D°	6	0+	{ 6 36+ 6 37½	0	1,2	6	0	1,2
	Andromedæ	2	45—	{ 6 40½ 6 16	0	24,5	2	44	35,5
	β Persei	1	35+	{ 5 48— 5 48—	0	0,0	1	35	0,0

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Diff. between the
points on the mi-
crometer. Apparent zra.
distances.

Nearest point
on the factor. micrometer.

*'s Name.

1766. October.

15	♂ Persei	8 35—	{ 8 2 6 24	1 22,0	8 33 38,0
	Capella	7 15+	{ 7 21½ 9 5	1 27,5	7 16 27,5
	♂ Aurigæ	6 25+	{ 9 25— 10 44½	1 11,8	6 26 11,8
	Castor	6 5—	{ 12 45+ 13 6	0 12,7	6 4 47,3

16	α Lyrae	0 5+	{ 4 48+ 7 35	2 22,7	0 7 22,7
	♂ Cygni	6 5+	{ 2 20½ 4 32—	1 55,2	6 6 55,2
	γ D°	1 5—	{ 0 25 17 12½	1 4,5	1 3 55,5
	α D°	6 0+	{ 0 8½ 0 9	0 0,5	6 0 0,5
	γ Andromedæ	2 45—	{ 4 31½ 4 3½	0 28,0	2 44 32,0
	β Persei	7 35+	{ 3 25 3 25	0 0,0	1 35 0,0
	♂ D°	8 35—	{ 4 4 2 24½	1 23,5	8 33 36,5
	Capella	7 15+	{ 1 20— 3 5	1 29,3	7 16 29,3
	β Aurigæ	6 25+	{ 5 29½ 6 48	1 10,5	6 26 10,5
	Castor	6 5—	{ 8 5 8 15½	0 10,5	6 4 49,5

.....

*'s Names.	Nearest point on the factor.	Points on the micrometer.	Diff. between the points on the mi- crometer.			Apparent zen. distances.		
	°	'		'	"	°	'	"
17 α Lyræ	0	5+	{ 5 18— 8 5	2	23,3	0	7	23,3
γ Cygni	1	5—	{ 8 1½ 6 41½ 6 48½	1	4,0	1	3	56,0
α D°	6	0—	{ 6 48 6 48	0	0,5	5	59	59,5
Capella	7	15+	{ 8 43 10 26½	1	27,5	7	16	27,5
β Aurigæ	6	25+	{ 10 39— 12 6	1	11,3	6	26	11,3
Castor	6	5—	{ 12 14— 12 25+	0	11,6	6	4	48,4

18 { α Lyræ	0	5+	{ 6 49 9 38+	2	25,3	0	7	25,3
γ Cygni	6	5+	{ 7 45— 10 8	1	59,3	6	6	59,3
γ D°	1	5—	{ 5 15 4 3	1	4,0	1	3	56,0
α D°	6	0+	{ 16 47— 16 49	0	2,3	6	0	2,3

[300]

THE RESULT OF THESE

Star's zenith distance at the point A.

PLANE OF THE

In the tent east.

	α Lyrae.	δ Cygni.	γ Cygni.	α Cygni.	γ Androm.
	D. o ' "	D. o ' "	D. o ' "	D. o ' "	D. o ' "
1766. Oct.	10 0 7 19,0	11 6 6 51,0	10 1 3 52,3	11 6 0 5,5	8 2 44 28,7
	11 0 7 20,7	11 6 6 51,0	11 1 3 52,0	12 6 0 3,5	10 2 44 30,0
	12 0 7 22,0	12 6 6 51,0	12 1 3 51,0		11 2 44 30,7
					12 2 44 27,6
Mean 11 11	0 7 20,57	6 6 51,0	1 3 51,7	6 0 4,50	2 44 29,25
Aberration	— 17,11	— 18,40	— 17,33	— 17,75	— 4,08
Nutation --	+ 6,12	+ 4,14	+ 2,92	+ 2,25	— 7,53
Precess. Oct. 11, 1764.	0,0	0,0	0,0	0,0	0,0
Refract. ---	+ 0,12	+ 6,11	+ 1,06	+ 6,0	+ 2,75
Mean zen. dist. the 11th Oct.	0 7 9,70	6 6 42,85	1 3 38,42	5 59 55,0	2 44 20,39

PLANE OF THE

October.

14	0 7 21,0	15 6 6 58,0	15 1 3 54,7	14 6 0 0,0	13 2 44 35,2
15	0 7 22,7		16 1 3 55,5	15 6 0 1,2	14 44 36,0
16	0 7 22,7		17 1 3 56,0	16 6 0 0,5	15 44 35,5
17	0 7 23,3	18 6 6 59,3	18 1 3 56,0	17 5 59 59,5	16 - - - -
	-----			18 6 0 2,3	
Mean - - - -	0 7 22,42	6 6 58,65	1 3 55,55	6 0 0,70	2 44 35,57
Aberration	— 16,74	— 18,31	— 17,40	— 17,93	— 4 79
Nutation --	+ 6,12	+ 4,14	+ 2,92	+ 2,25	— 7,53
Precess. ---	— 0,03	— 0,14	— 0,18	— 0,19	— 0,19
Refract. ---	+ 0,12	+ 6,11	+ 1,06	+ 6,0	+ 2,75
Mean zen. dist. Oct. 11, 1766.	0 7 11,89	6 6 50,45	1 3 41,95	5 59 50,83	2 44 25,84
D° plane east	0 7 9,70	6 6 42,85	1 3 38,42	5 59 55,0	2 44 20,39
Mean zen. dist. Oct. 11, 1766, at the point A.	0 7 10,79	6 6 46,65	1 3 40,18	5 59 52,92	2 44 23,10

OBSERVATIONS, AS FOLLOWS:

SECTOR EAST.

1766. D. Oa.	β Perfei.				δ Perfei.				Capella.				β Aurigæ.				Castor.			
	°	'	"		°	'	"		°	'	"		°	'	"		°	'	"	
8	1	34	54,0		8	8	33	35,0	8	7	16	21,3	8	6	26	3,2	8	6	4	50,5
10	1	34	53,5		10	8	33	34,5	10	7	16	20,0	10	6	26	4,0	10	6	4	50,5
11	1	34	55,7		11	8	33	33,0	11	7	16	20,3	11	6	26	4,0	11	6	4	49,5
12	1	34	55,0		12	8	33	33,0	12	7	16	22,0	12	6	26	4,0	12	6	4	52,0
<hr/>																				
	1	34	54,55		8	33	34,17		7	16	20,90		6	26	3,80		6	4	50,62	
	—		1,09		+		2,0		+		5,48		+		6,55		—		3,52	
	—		8,27		—		8,40		—		7,85		—		7,15		+		4,70	
			0,0				0,0				0,0				0,0				0,0	
	+		1,58		+		8,55		+		7,26		+		6,43		+		6,08	
<hr/>																				
	1	34	46,77		8	33	36,32		7	16	25,79		6	26	9,63		6	4	57,88	

SECTOR WEST.

October.

13	1	35	0,7	13	8	33	37,5	13	7	16	27,5		14	6	26	11,5	14	6	4	48,0	
14		35	0,6	14		33	40,4	14		16	29,7		15	26	11,8		15		4	47,3	
15		35	0,0	15		33	38,0	15		16	27,5		16	26	10,5		16		4	49,5	
16		35	0,0	16		33	36,5	16		16	29,3		17	26	11,3		17		4	48,4	
										17	16	27,5		17		26	11,3	17		4	48,4
<hr/>																					
	1	35	0,33		8	33	38,10		7	16	28,30		6	26	11,28		6	4	48,30		
	—		1,79		+		1,20		+		4,98		+		6,22		—		3,75		
	—		8,27		—		8,46		—		7,85		—		7,15		+		4,70		
	—		0,16		—		0,14		—		0,07		—		0,02		—		0,10		
	+		1,58		+		8,55		+		7,26		+		6,43		+		6,08		
<hr/>																					
	1	34	51,69		8	33	39,31		7	16	32,62		6	26	16,76		6	4	55,23		
	1	34	46,77		8	33	36,32		7	16	25,79		6	26	9,63		6	4	57,88		
<hr/>																					
	1	34	49,23		8	33	37,82		7	16	29,20		6	26	13,20		6	4	56,56		

1766.
December.

24 11 Set up the sector at the point N, in the forks of the river Brandiwine, in Pennsylvania, and made the following observations.

*'s Names.	Nearest point on the sector.	Points on the micrometer.	Diff. between the points on the mi- crometer.	Apparent zen. distances.
γ Andromedæ	0 1 15+	{ 5 20 $\frac{1}{2}$ 4 18—	0 54,8	1 15 54,8 North.
β Persei	0 5+	{ 4 46+ 3 18	1 20,3	0 6 20,3 N.
δ D°	7 5+	{ 4 8 4 6	0 2,0	7 5 2,0 N.
Capella	5 50—	{ 5 35 8 17	2 18,0	5 47 42,0 N.
☉ 14 Cloudy.				
γ Andromedæ	1 15+	{ 7 32 6 29	0 55,0	1 15 55,0 N.
β Persei	0 5+	{ 8 3 6 25	1 21,7	0 6 21,7 N.
δ D°	7 5+	{ 6 27 6 24	0 3,0	7 5 3,0 N.
....*				
Capella	5 50—	{ 4 46 $\frac{1}{2}$ 7 29 $\frac{1}{2}$	2 19,0	5 47 41,0 N.
β Aurigæ	4 55+	{ 9 20 $\frac{1}{2}$ 6 29 $\frac{1}{2}$	2 27,0	4 57 27,0 N.
Castor	7 35—	{ 9 14 $\frac{1}{2}$ 7 35	1 23,5	7 33 36,5 South.

*'s Names.	Nearest point on the factor.	Points on the micrometer.	Diff. between the points on the micrometer.	Apparent zen. distances.
δ 16 γ Andromedæ	1 15+	{ 9 37— 8 33	0 55.7	1 15 55.7 North.
β Perfei	0 5+	{ 7 45½ 6 16½	1 21.0	0 6 21.0
δ D°	7 5+	{ 5 21½ 5 19½	0 2.0	7 5 2.0
Capella	5 50—	{ 7 11 9 46—	2 18.7	5 47 41.3
β Aurigæ	4 55+	{ 9 39 6 47+	2 27.7	4 57 27.7
Castor	7 35—	{ 6 34½ 5 5—	1 21.8	7 33 38.2
γ 17 α Lyræ	1 20+	{ 5 44— 7 42—	1 42.0	1 21 42.0 South.
γ 18 Cloudy.				
γ 19 α Lyræ	1 20+	{ 5 1½ 7 1	1 43.5	1 21 43.5
{ β Perfei	0 5+	{ 8 42½ 7 14+	1 20.2	0 6 20.2
....*....	7 5+	{ 7 4 7 0	0 3.7	7 5 3.7
Capella	5 50—	{ 5 42½ 8 22½	2 16.0	5 47 44.0
β Aurigæ	4 55+	{ 8 6+ 5 15	2 27.3	4 57 27.3
Castor	7 35—	{ 4 45+ 3 16	1 21.3	7 53 38.7

*'s Names. Nearest point on the horizon. Points on the micrometer. Diff. between the points on the micrometer. Apparent zen. distances.

h	20	Cloudy.	.	.	.	"	"	"	"
☉	...*	21	α Lyrae	...	20+	{	3 2 5 0—	1 41,7	1 21 41,7

TURNED THE SECTOR PLANE WEST.

☉	21	β Persei	...	...	0	5+	{	6 4+ 7 42	1 29,7	0 6 29,7
		δ D°	...	...	7	5+	{	7 50— 8 8	0 10,3	7 5 10,3
		Capella	...	...	{	5 45+	{	4 5— 7 25½	2 56,8	5 47 56,8
		β Aurigæ	...	...	5	50—	{	4 5— 1 33½	2 7,2	5 47 52,8
		Castor	...	...	4	55+	{	7 0— 9 51	2 35,3	4 57 35,3
			...	...	7	35—	{	10 0+ 11 38+	1 30	7 33 30,0
☽	22	Cloudy.								
☽	23	D°								
☽	24	α Lyrae	...	...	1	20+	{	6 44— 5 0—	1 36,0	1 21 36,0
		γ Andromedæ	...	...	1	15+	{	4 41— 6 1½	1 4,8	1 16 4,8
		β Persei	...	...	0	5+	{	4 16½— 6 3—	1 30,2	0 6 30,2
...	...	δ D°	...	...	7	5+	{	6 16½— 6 27	0 10,5	7 5 10,5

		N ^o s Names.	Nearest point on the sector.	Points on the micrometer.	Diff. between the points on the micrometer.	Apparent size. distances.
1766. Decemb.						
24	♂	Capella	5 50—	{ 9 19— 6 47 6 2	2 7,7	5 47 52,3
...		β Aurigæ	4 55+	{ 9 1 6 31+	2 35,0	4 57 35,0
		Castor	7 35—	{ 8 16½	1 29,2	7 33 30,8
25		Cloudy.				
26	♀	D°				
27	h	α Lyræ	1 20+	{ 5 13+ 3 22	1 35,3	1 21 35,3
		γ Andromedæ	1 15+	{ 8 19 9 31	1 4,0	1 16 4,0
		β Persei	0 5+	{ 9 17½ 11 3	1 29,5	0 6 29,5
		δ	7 5+	{ 12 16+ 12 26	0 9,7	7 5 9,7
		Capella	5 50—	{ 6 32 4 7	2 9,0	5 47 51,0
28	γ	Andromedæ	1 15+	{ 4 14— 5 26—	1 3,7	1 16 3,7
	β	Persei	0 5+	{ 2 42½ 4 27	1 28,5	0 6 28,5
	β	Aurigæ	4 55+	{ 8 14— 11 13+	2 35,6	4 57 35,6
				R r		

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PLANE

PLANE OF THE

1766. December.	α Lyræ.	γ Androm.	β Persei.
	° ' "	° ' "	° ' "
 13	1 15 54,8	13 0 6 20,3
	..... 15	1 15 55,0	15 0 6 21,7
	..... 16	1 15 55,7	16 0 6 21,0
17	1 21 42,0	.....	.....
19	1 21 43,5	.....	19 0 6 20,2
21	1 21 41,7	.....	.....

Mean	1 21 42,40	1 15 55,17	0 6 20,80
Aberration	+ 2,20	— 11,76	— 9,20
Deviation	— 5,66	— 7,60	— 8,19
Precess.	+ 0,48	— 3,12	— 2,64
Refraction	+ 1,36	+ 1,26	+ 0,10

Mean zen. dist. Oct. 11, 1766	1 21 40,78	1 15 33,95	0 6 0,87
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PLANE OF THE

1766. December.	21 0 6 29,7
	24 1 21 36,0	24 1 16 4,8	24 6 30,2
27	21 35,3	27 16 4,0	27 6 29,5
	..... 28	16 3,7	28 6 28,5

Mean	1 21 35,65	1 16 4,17	0 6 29,48
Aberration	+ 0,15	— 11,63	— 9,56
Deviation	— 5,66	— 7,60	— 8,19
Precess.	+ 0,53	— 3,76	— 3,05
Refraction	+ 1,36	+ 1,26	+ 0,10

Mean zen. dist. Oct. 11, 1766	1 21 32,03	1 15 42,44	0 6 8,78
D° Plane East	1 21 40,78	1 15 33,95	0 6 0,87

True mean zen. dist. 11 Oct. 1766, at the point N. D° at the point A.	1 21 36,42	1 15 38,19	0 6 4,87
	0 7 10,79	2 44 23,10	1 34 49,23

Difference	1 28 47,21	1 28 44,91	1 28 44,40
	28 44,91		
	44,40		
	43,98		
	45,09		
	44,34		

Mean
= 1 28 44,99 = the true celestial arch between the points N and A.

SECTOR EAST.

♄ Perfei.			Capella.			♂ Aurigæ.			Castor.		
°	'	"	°	'	"	°	'	"	°	'	"
13	7	5 2,0	13	5 47 42,0							
15		5 3,0	15	47 41,0	15	4 57 27,0			15	7 33 36,5	
16		5 2,0	16	47 41,3	16	57 27,7			16	7 33 38,2	
		
19		5 3,7	19	47 44,0	19	57 27,3			19	33 38,7	
		

7	5	2,67	5 47 42,08	4 57 27,33	7 33 37,80
—		8,61	— 3,20	— 0,60	— 3,78
—		8,26	— 7,52	— 6,75	+ 4,20
—		2,26	— 0,95	— 0,29	— 1,25
+		7,08	+ 5,80	+ 4,95	+ 7,55

7	4	50,62	5 47 36,21	4 57 24,64	7 33 44,52
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SECTOR WEST.

21	7	5 10,3	21	5 47 52,8	21	4 57 35,3	21	7 33 30,0
24	7	5 10,5	24	5 47 52,3	24	57 35,0	24	33 30,8
27		5 9,7	27	47 51,0		.....		.....
		.....		.....	28	57 35,6		.....

7	5	10,17	5 47 52,03	4 57 35,30	7 33 30,40
—		9,37	— 4,24	— 1,60	— 3,52
—		8,26	— 7,52	— 6,75	+ 4,20
—		2,56	— 1,09	— 0,32	— 1,36
+		7,08	+ 5,80	+ 4,95	+ 7,55

7	4	57,06	5 47 44,98	4 57 31,58	7 33 37,27
7	4	50,62	5 47 36,21	4 57 24,64	7 33 44,52

7	4	53,84	5 47 40,60	4 57 28,11	7 33 40,90
8	33	37,82	7 16 29,20	6 26 13,20	6 4 56,56

1	28	43,98	1 28 48,60	1 28 45,09	1 28 44,34
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this being a
little wide of
the rest is
left out.

R r e

The following are Observations made at the Points N, and near P, in the Year 1764 :
But the Length of Time between these, and those made at A, being near three Years —
probably the Set made at N, in December 1766, may be best to be used in determining
the Length of a Degree of Latitude.

STAR'S ZENITH DISTANCES.

SECTOR IN THE TENT, PLANE EAST.

1764.	γ Andromedæ.			β Persei.			α Persei.			δ Persei.			
		o	'	"		o	'	"			o	'	"
January.	17	1	15	0,0	0	5	40	0	.....	7	4	29,5
	19	.....	.....	.....	0	5	39,6	.....	.....	7	4	31,0
	20	1	15	2,2	0	5	39,0	9	3	47,0	7	4	30,2
	21	1	15	1,3	0	5	37,5	9	3	49,7	7	4	30,8
	22	1	15	1,2	0	5	38,0	.....	.....	7	4	31,0
Mean, January	20	1	15	1,2	0	5	38,8	9	3	48,3	7	4	30,5
Aberration declin.	—	—	10,0	—	—	9,1	—	11,4	—	—	10,4	—	
Deviation D°	—	—	3,3	—	—	5,7	—	6,2	—	—	6,7	—	
Precess. fr. 1 Jan. 1764.	—	—	1,0	—	—	0,8	—	0,7	—	—	0,7	—	
Refraction	+	+	1,4	+	+	0,1	+	10,5	+	+	8,3	+	
Observatory S° of Tent	+	+	0,3	+	+	0,3	+	0,3	+	+	0,3	+	
Mean zen. dist. 1 Jan. 1764		1	14	48,6	0	5	23,6	9	3	40,8	7	4	21,3

SECTOR IN THE OBSERVATORY, PLANE WEST.

January	26	1	15	4,7	0	5	41,7	...	...	7	4	32,8	
24	27	1	15	5,7	0	5	41,0	9	3	57,0	
	28	1	15	4,5	0	5	44,0	9	3	57,5	7	4	33,0
	29	1	15	5,5	0	5	44,0	9	3	55,3	7	4	32,7
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Mean, January	27½	1	15	5,1	0	5	42,7	9	3	56,6	7	4	32,8
Aberration in Declin.	—	—	—	9,0	—	—	8,6	—	11,1	—	—	10,3	—
Deviation D°	—	—	—	3,3	—	—	5,7	—	6,2	—	—	6,7	—
Precess. from 1 Jan. 1764	—	—	—	1,3	—	—	1,1	—	1,0	—	—	0,9	—
Refraction	+	+	+	1,4	+	+	0,1	+	10,5	+	+	8,3	+
<hr/>													
Mean zen. dist. 1 Jan. 1764		1	14	52,9	0	5	27,4	9	3	48,8	7	4	23,2
D° Plane East		1	14	48,6	0	5	23,6	9	3	40,8	7	4	21,3
True zen. dist. at the point N, 1 Jan. 1764.	}	1	14	50,8	0	5	25,5	9	3	44,8	7	4	22,2
Precess. to Oct. 11, 1766		+		49,45			40,56	...	...	+		34,61	+
<hr/>													
Reduced to Oct. 11, 1766		1	15	40,25	0	6	6,06	...	...		7	4	56,81

* Z. DIST. AT THE POINT N.

PLANE WEST.

		Capella			β Aurigæ.			Castor			α Lyrae.		
		o	'	"	o	'	"			Jan.	o	'	"
1764.	27	5	47	46,8	28	4	57	38,4	.....	27	1	21	57,5
	28	5	47	47,0	29	4	57	36,4	.....	28	1	21	57,0
January.	29	47	46,7		Feb. 2.	57	38,0		.....			
February.	2	47	47,8					Feb.	.....		1	21	57,3
	3	47	44,7					3	7 33	6,6	Ab.	—	9,5
		.....			5	4	57	36,8	5	7 33	4,8	Dev.	— 9,4
		.....			6	4	57	36,2	6	7 33	5,5	Prec.	+ 0,2
		.....						8	33	6,8	Refr.	+	1,5
												
		.....									Feb.	1	21 40,1
												
		.....									11	1 22	3,8
		.....									13	1 22	1,3
Mean	30	5	47	46,6	1	4	57	37,2	5½	7 33	5,9	12	1 22 2,5
Aberration in Declin.		—	7,4		—	—	5,7		—	—	0,6	—	13,0
Deviation		—	8,8		—	—	9,2		+	9,1		—	9,4
Precess. from 1 Jan. 1764		—	0,4		—	—	0,1		—	0,7		+	0,3
Refraction		+	6,7		+	—	5,8		+	8,8		+	1,5
Mean zen. dist. 1 Jan. 1764		5	47	36,7		4	57	28,0		7 33	22,5		1 21 41,9
													1 21 40,1
												Mean	1 21 41,0

PLANE EAST.

FERNER ERG.										Feb.		
February		.....		Feb.		.....		.....		16	1 22	8,2
		.....		18		4 57 35,7		.....			.....	.....
20		5 47 39,0		20		4 57 34,7		20 7 33 7,3		20	1 22	16,5
21		5 47 38,7		21		57 35,0		21 7 33 6,3		21	1 22	8,8
22		47 38,0		22		57 35,2		22 33 5,7		22	1 22	9,8
										26	1 22	10,8
Mean	21	5 47	38,6	21	4 57	35,2	21	7 33	6,4	22	1 22	9,6
Aberration	—	8,0	—	6,9	+	0,5	—	14,8				
Deviation	—	8,8	—	9,2	+	9,1	—	9,4				
Precess. from 1 Jan.	—	0,7	—	0,2	—	0,95	+	0,35				
Refraction	+	6,7	+	5,8	+	8,8	+	1,5				
Mean zen. dist. 1 Jan. 1764		5 47	27,8		4 57	24,7		7 33	23,8		1 21	47,3
D° Plane West		5 47	36,7		4 57	28,0		7 33	22,5		1 21	41,0
True zen. dist. at the point } N, 1 Jan. 1764	}	5 47	32,3		4 57	26,3		7 33	23 1		1 21	44,2
Precess. to Oct. 11, 1766		+	14,56	+	4,28	+	18,97	—	7,03			
		5 47	46,86		4 57	30,58		7 33	42,07		1 21	37,17

Stars Zenith Distances observed at a Point 7 chains 91 links North of P.

PLANE EAST.

		Capella.		α Lyræ.		δ Cygni.		γ Cygni.		α Cygni.	
		o' "	May	o' "	May	o' "	May	o' "	May	o' "	May
1764. May.	7	6 0 29,8	6	1 9 10,5	13	4 50 6,3	13	0 12 59,5	10	4 43 0,8	
	8	6 0 28,3	7	9 10,0	Ab.	14,9	—	15,0	11	4 42 58,2	
	9	6 0 29,0	9	10,5	Dev.	8,74	—	8,1	12	43 2,7	
	13	6 0 30,0	11	9,0	Prec.	3,05	+	4,0	13	43 0,0	
			12	10,0	Ref.	5,6	+	0,2	11½		
			13	7,7							
						4 50 32,5		0 12 40,6			
Mean of the 1st fett		10 6 0 29,3	10	1 9 9,6	May					mean 4 43 0,4	
Aberration		— 1,5	—	12,3	19	4 50 8,0	19	0 13 0,0	Ab.	+	16,5
Nutation		— 9,0	—	9,4	20	4 50 9,0	20	12 58,0	Dev.	+	7,6
Precess. fr. 1 Jan. 1764		— 1,9	+	1,1	23	50 11,3	23	12 57,0	Prec.	—	4,5
Refract.		+ 7,0	+	1,2	25	50 9,6	25	12 56,0	Refr.	+	5,5
True zen. dist. 1 Jan. 1764.		6 0 23,9	1 8 50,2								
					22	4 50 9,5	22	0 12 57,75	mean	4 43 25,5	
					Ab.	13,2	—	13,5	May		
					Nut.	8,74	—	8,1	19	4 43 1,0	
					Prec.	3,25	+	4,3	20	43 1,5	
					Refr.	5,6	+	0,2	23	43 0,5	
									25	43 2,3	
					mean	4 50 33,8		0 12 40,6			
					Mean of the above.	4 4 32,5		0 12 40,6	22	mean 4 43 1,3	
									Ab.	+	14,9
									Nut.	+	7,6
									Prec.	—	4,8
									Refr.	+	5,5
True zen. dist. 1 Jan. 1764, from the mean of all the five observations.						4 50 33,15		0 12 40,60			

May α Lyræ.

19	1 9 4,3
23	9 3,8
25	9 3,7

Mean of the 2d fett	22 1 9 4,3
Aberration	— 9,5
Nutation	— 9,4
Precess.	+
Refraction	+
Mean	1 8 47,7
Mean above	8 50,2
Mean of all the observat. 1 Jan. 1764	1 8 49,0

		22	mean	4 43 24,5
			Mean of the above	25,4
True zen. dist. 1 Jan. 1764, from the mean of all the observations				4 43 25,0

Star's Zenith Distances observed at a Point 7 chains 91 links North of P.

PLANE WEST.

1764.	Capella.	α Lyrae.	δ Cygni.	γ Cygni.	α Cygni.
May \odot	28 6 0 32,7	27 1 08 59,0	27 4 50 14,8	26 0 12 52,6	26 4 48 4,3
June	1 0 32,3	28 8 59,5	28 4 50 51,0	27 12 51,0	27 43 4,2
	5 0 31,7	June 3 8 58,0	June 3 50 15,0	28 June 12 51,0	28 June 43 4,0
		4 8 59,8	4 50 15,3	3 12 51,0	3 43 7,5
		6 8 58,2	5 50 16,8	4 12 50,3	4 43 5,4
		7 8 57,3	6 50 16,3	5 12 49,8	5 43 6,5
		8 8 57,3	8 50 18,0	6 12 50,0	6 43 7,8
				7 12 49,0	7 43 8,0
				8 12 48,0	8 43 8,3
Mean	1 6 0 32,2	3 1 8 58,4	3 4 50 15,9	3 0 12 50,3	3 4 43 6,2
Aberration	+ 1,4	— 6,3	+ 10,4	— 11,3	+ 12,8
Nutation	— 9,0	— 9,4	+ 8,74	— 8,1	+ 7,6
Precess. from 1 Jan. 1764	— 2,2	+ 1,1	— 3,40	+ 4,6	— 5,2
Refraction	+ 7,0	+ 1,2	+ 5,6	+ 0,2	+ 5,5
Mean zen. dist. 1 Jan. 1764 at a point 7 ch. 91 lin.	6 0 29,4	1 8 45,0	4 50 37,24	0 12 35,7	4 43 26,9
Do. Plane East	0 23,9	1 8 49,0	4 50 33,15	0 12 40,60	4 43 25,0
True zen. dist. 1 Jan. 1764 at a point 7 cha. 91 lin. North of P	6 0 26,60	1 8 47,00	4 50 35,19	0 12 38,20	4 43 25,95
Precess. to 11 Oct. 1766	+ 14,56	— 7,03	+ 23,03	— 30,75	+ 34,59
True zen. dist. 11 Oct. 1766	6 0 41,16	1 8 39,97	4 50 58,22	0 12 7,45	4 44 0,54
Do. at the point A	7 16. 29,20	+ 7 10,79	6 6 46,65	1 3 40,18	5 59 52,92
Difference	1 15 48,04 15 50,76 48,43 47,63 52,38	1 15 50,76	1 15 48,43	1 15 47,63	1 15 52,38
	Arches by different Stars				
Mean	1 15 49,45 = the celestial arch between the point 7 cha. 91 lin. N. of P and the point A				

Remarks on re-measuring the Lines with two rectangular Levels, or measuring Frames.

The levels used in this work were, each, 20 feet in length, and 4 feet in height. They were made of pine, an inch thick, and in form of a rectangle; the breadth of the bottom board was $7\frac{1}{2}$ inches, that of the top = 3 inches, of the ends = $4\frac{1}{2}$ inches, and the bottom and top were strengthened with boards firmly fixed to them at right angles. The joints were secured with plates of iron, and the ends were plated with brass. The plumb lines used in setting them level, were = 3 feet and 2 inches in length, and hung in the middle of the levels, being secured in a tube from the wind, in the manner of carpenters levels; wherefore we called these by the same name.

When the plumb-line bisected a point at the bottom, the ends were perpendicular.

Where the ground was not horizontal, or there were logs, &c. to pass over, one end of the level was raised by a winch and pulley.

The level being set, a short staff was drove into the ground (very near and opposite the plumb-line), in the top of which moved a thin plate of iron, about 12 inches long; at the ends of which were points, which were directed to the intersections of lines, drawn on the board that covered the plumb-line. By bringing the points in a line with one of the said intersections, if the level was by accident moved, it might be discovered, and brought again to its place.

A level being thus marked, the end of the other was brought in contact with it, and marked in the same manner, before the first was moved; the first was then taken up, and set before the last. And so the operation was continued. Mr. Dixon attended one plumb-line and staff, and I the other. The measure was carried on in a strait line, and in the proper direction, by pointing the levels to the farthest part of the vista that could be seen; this was readily and accurately done, on account of their lengths. The levels were frequently compared with the brass standard, of 5 feet, provided for that purpose, and the difference was noted between 8 times the brass standard, and the length of the two levels taken together; as may be seen in the 3d and 4th columns of the following table. This difference serves for reducing the measure taken with the levels, to what it would have been if it had been taken with the brass standard itself; see column 6th. For facilitating this comparison of the levels with the brass standard, pieces of brass were fixed into the bottom boards of the levels, on each of which was drawn a faint line. And one tenth of an inch at the end of the brass standard being divided into ten parts or hundredths of an inch, the difference between eight times the brass standard, and the two levels joined together, was with the help of a magnifying glass of a short focus, determined to great accuracy. Moreover, the brass standard being liable to alter with the changes of heat and cold, a further correction becomes necessary on that account, in order

order to reduce the measures to the temperature of 62° of Fahrenheit's thermometer, which is the term to which the former operations of this kind have been reduced. For this purpose, the rate of expansion of brass is taken from Mr. Smeaton's experiments, made with a pyrometer of his invention (see Philos. Transf. Vol. XLVIII. Part II.) which is $\frac{2 \cdot 3 \cdot 2}{100000}$ th of an inch upon a length of one foot for a variation of 180° of Fahrenheit's thermometer; whence the expansion answering to four times the length of the brass standard, or 20 feet, or the length of one level, would be $\frac{4 \cdot 6 \cdot 4}{100000}$ th of an inch for the same difference of the thermometer; and $\frac{2 \cdot 5 \cdot 8}{100000}$ th of an inch for 1° of the same thermometer. Therefore, in order to find the correction of column 7th, the constant quantity, .00258 was multiplied by the difference of 62, and the degree of the height of the thermometer; and that product, again multiplied by the number of levels measured, gave the correction required in inches and decimal parts of an inch; which was additive or subtractive, according as the thermometer was higher or lower than 62 degrees.

In the following Process, the

- 1 and 2 Columns contain the time of the day, M signifying morning, A afternoon.
- 3 - - - the height of the thermometer at D°.
- 4 - - - the quantity, in hundreth parts of an inch, that the two levels, taken together, were more or less than eight times the brass standard, or 40 feet.
- 5 - - - the number of levels measured between the times, that the levels themselves were measured with the brass standard.
- 6 - - - the corrections, or quantity in inches, to be added to, or subtracted from, the number of levels measured each day, arising from the levels being more or less than the brass standard.
- 7 - - - the correction, or quantity arising from the thermometer in inches.

Began, at the point N, to re-measure the lines with two rectangular levels, 20 feet each in length.

1768	1	2	3	4	5	6	7
February	h						
♂ 23	10	M	52	+,12	203	+12,18	- 4,97
	3	A	53	+,12			
		The breadth of Brandywine the 1st time		}	8,18	+ 0,49	} - 0,47
		D° a 2d, where we crossed			12,20	+ 0,73	

1768	1	2	3	4	5	6	7	
February	b							
		D° a third time			9.87	+ 0.39	— 0.20	
24	9	M	54	+ .08				
	1½	A	44	+ .12	325	+ 16.25	— 13.41	
	5		39	+ .32 ::				
25								
26	9½	M	40	+ .12				
	4½	A	45	+ .11	247	+ 14.08	— 12.42	
27								Rain.
28								
29	8½	M	40	+ .08	80			Rain in the afternoon.
						+ 3.20	— 0.41	
March	1							
	9½	M	32	+ .23				
	4½	A	42	+ .21	320	+ 35.20	— 20.64	
2	8½	M	32	+ .20				
	1	A	51	+ .10	200	+ 15.10	— 10.58	
	5½		48	+ .115	170	+ 9.09	— 5.48	
3	8½	M	40	+ .185				
	2	A	48	+ .125	230	+ 17.82	— 10.68	
	5		43	+ .145	120	+ 8.10	— 4.33	
4	8½	M	31	+ .19				
	2	A	38	+ .16	200	+ 17.50	— 14.19	
	5½		30	+ .185	150	+ 12.90	— 10.83	
5	8	M	27	+ .18				
	1	A	41	+ .12	220	+ 16.50	— 15.80	
	5½		29	+ .165	120	+ 8.40	— 8.36	
6								
7	8½	M	28	+ .155				
	2	A	38	+ .09	250	+ 15.37	— 18.70	Very dry winds with frost.
	5¾		36	+ .105	90	+ 4.41	— 5.80	
8	8	M	36	+ .103				
	1½	A	52	— .037	230	+ 3.8	— 10.68	
	5½		45	+ .06	170	— 1.02	— 5.92	

1768
March

	1	2	3	4	5	6	7
9	8 $\frac{1}{4}$ 2 5 $\frac{1}{2}$	M A	51 66 52	+ ,065 — , 11 + ,015	270 110	— 3,10 — 2,58	— 2,44 — 0,85
10	8 $\frac{3}{4}$ 0 $\frac{1}{2}$	M A	58 61	— ,01 — ,03	179,2	— 1,79	— 1,15

Here subtract 4 inches, for going round the corner of a barn

This reached the point P.

Hence NP = 3914,45 levels + 199 02 inches — 178,40 inches = 78290 72 feet.

Began at the Point C.

2	11	11	M	60	— ,04	137,15	— 2 74	— 0,71	Rain.
h	12	9 1 5 $\frac{1}{2}$	M A	52 58 53	+ ,07 + ,01 + ,08	108 156	+ 2,16 + 3,51	— 1,95 — 2,61	
Q	13								
24	17	Began where we left off, on the 12th instant, to measure as before.							
	10	M	34	+ ,09	132	+ 5,94	— 8,51		
	2	A	40	+ ,09	144	+ 6,12	— 8,91		
	5		36	+ ,08					
	18	8 $\frac{1}{2}$ 2 5 $\frac{1}{2}$	M A	36 42 35	+ ,085 + ,03 + ,073	264 156	+ 7,65 + 4,06	— 15,66 — 9,45	
	19	9	M Noon	36 31	+ ,115 + ,145	233,35	+ 14,93	— 17,15	

This reached the point D.

Hence CD = 1330,50 levels + 41,63 inches — 64,95 inches = 26608,06 feet.

From D to g = 1 chain, and 36 links found before; = 89,76 feet.

Q	20	Sent to Philadelphia, about 40 miles distant, for tents, &c.							
24	24	Began at the point B, to measure the line AB.							
	1 $\frac{1}{2}$	M.	49	— ,08	132	— 5,28	— 4,42		
2	25	.....						
h	26	Noon 6	57 A	— ,05 43	211,05	+ 1,58	— 6,53		
Q	27								

1768		1	2	3	4	5	6	7	
March		h							
D	28								Snow.
♂	29	8 2 5½	M A	40 47 40	+ ,19 + ,09 + ,11	264 264	+ ,18,48 + ,13, 2	—12,60 —12,60	Compared two thermometers ; they agreed within one division.
♀	30	8½ 2½ 6¼	M A	38 61 45	+ ,14 + ,025 + ,10	288 192	+11,95 + 5,95	— 9,28 — 4,46	
♂	31	8½ 2 6½	M A	45 62½ 49	+ ,15 + ,105 + ,17	204 192	+12,85 +13,15	— 4,21 — 2,97	By accident one of the thermom. was broke.
April									
♀	1	8 2 6	M A	39 52 35	+ ,195 + ,19 + ,19	324 204	+31,10 +19,38	—13,79 — 9,73	
♂	2	9 2½ 6¼	M A	40 46 37	+ ,18 + ,14 + ,15	228 168	+18,24 +12,18	—11,17 — 8,88	
⊙	3								
D	4	9½ 3 6	M A	38 51 36	+ ,04 + ,12 + ,13	312 192	+12,48 +12,00	—14,08 — 9,16	Snow in the evening.
♂	5								Snow.
♀	6	8½ 3 6¼	M A	37 51 38	+ ,14 + ,13 + ,13	228 204	+15,39 +13,26	—10,58 —10,70	
Crossed Bohemia river obliquely =						33,875	+ 2,21		
♂	7								Snow all day, and frost at night.
♀	8	11 6¼	M A	37 40	+ ,23 + ,155	396	+38,02	—24,01	

1768 April		1	2	3	4	5	6	7
Q	9	9 2 6	M A	44 57 51	+ ,165 co + ,02	192 204	+ 7,96 + 1,02	— 5,69 — 4,21

○ 10

D	11	9 2½ 6½	M A	59 66 59	— ,017 — ,16 — ,10	288 228	— 12,81 — 14,82	+ 0,37 + 0,29
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8	12	8 3 6	M A	47 70 60	— ,02 — ,14 — ,03	348 156	— 13,92 — 6,63	— 3,14 + 1,21
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8	13	9 1 6	M A	64 76 64	— ,08 — ,105 — ,07	240 156	— 11,16 — 6,86	+ 4,95 + 3,22
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4	14	8½ 4½	M A	53 53	— ,02 00	396	— 1,98	— 9,19
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2	15	9	M	45	+ ,18	264	+ 23,76	— 11,57
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Rain in the afternoon : this day we passed through water, two feet deep, for half a mile.

h	16	8 4	M A	46 56	+ ,20 + ,205	396	+ 39,99	— 11,23
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○	17	8½	M	52	+ ,11½	264	+ 6,20	— 1,70
D	18	Noon 6½	A	67 58	— ,02 — ,01	192	— 1,44	+ 0,24

8	19	8½ 3	M A	53 74	+ ,01 — ,075	444 132	— 9,50	+ 2,23
			after 3 ^h aft.					

8	20	8½ 2½ 6½	M A	57 78 61	+ ,025 — ,065 — ,02	312 216	— 3,12 — 4,54	+ 4,43 + 4,18
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1768 April		1 A	2	3	4	5	6	7	
4	21	8½ 1½	M A	52 75	+ ,06 + ,02	264			
			aft. 1½ A			132	+ 7.92	+ 1.53	Left off in a swamp of water 18 inches deep.
8	22 }								Rain day and night.
h	23 }								
⊙	24								Rain till 11 ^h A.M.
h	25 }								Swamps so full of water we could not proceed.
h	26 }								
8	27	10 5½	M A	73 72	00 — ,035	420	— 3.78	+ 11.38	
4	28	8½ 6	M A	54 61½	— ,03 — ,02	396	— 4.95	— 4.09	
8	29	...	...	...	...	...	...	...
h	30	7 2 6	M A	60 76 73	+ ,19 + ,11 + ,11	336 108	+ 25.20 + 5.94	+ 5.20 + 3.47	
May									
⊙	1								
h	2	8½ 6½	M A	54 56	+ ,05 + ,09	384	+ 13.44	— 6.93	
h	3	10 3 6½	M A	61 82 75½	+ ,115 + ,02 + ,075	288 108	+ 9.79 + 2.59	+ 7.06 + 4.74	This day we found the diff. between the 42d and 43d mile posts 3 levels and 6 feet more than usual between 2 mile posts.
8	4	12½	M	79	+ ,115	228	+ 13.11	+ 10.00	Thunderstorm all the morning: passed the main branch of Choptank.

1768 May		1 h	2	3	4	5	6	7
24	5	8 2 5½	M A	70½ 86 72	+,115 +,02 +,09	264 132	+ 8,97 + 3,63	+10,90 + 5,79
2	6	9½ 4	M A aft. 4 ^h	66 63 A	+,14 +,155	324 72	+29 11	+ 2,55
h	7	8 3	M A	60 74	+,185 +,065	408	+ 25,5	+ 5,26
o	8							
2	9	7½ 4½	M A	63 85	+ 03 -,095	528	- 8,69	+16,35
2	10	8½ 7	M A	61 68	+,005 +,01	372	+ 1,49	+ 2,40
2	11	9½ 6½	M A	70 72	+,111 +,06	528	+22,44	+12,26
								Rain in the night and morning.
24	12	7 2 6½	M A	54½ 67 68	+,23 +,03 +,015	264 276	+17,16 + 3,03	- 0,68 + 3,92
								Rain last night.
2	13	8½ 3	M A aft. 3 ^h	68 75 A	+,10 -,025	300 96	+ 7,33	+ 9,71
h	14	10½ 3	M A	66 74½	+,145 +,14	264	+18,74	+ 5,45
o	15							
2	16	7½ 3½	M A aft. 3½ ^h	57 81 A	+,19 -,02	384 144	+22,44	+ 9,53
2	17	8½ 3	M A aft. 3 ^h	66 87 A	+,12 -,085	384 144	+ 4,75	+19,75

1768 May		1	2	3	4	5	6	7	
8	18	8½ 1	M A	67 90	+,085 +,14	144	+ 8,13	+ 6,13	Passed through Marthy Hope, water 4 or 5 feet deep.
24	19	9½ 3	M A	69 86	+,15 +,075	264	+14,78	+10,55	
8	20	8 3	M A	69 93 aft. 3 ^h A	+,17 +,04	276 168	+23,31	+21,76	Great. dew. for 4 morn- ings past.
h	21	9 4	M A	73 86	+,08 —,01	360	+ 6,30	+16,25	Great dew.
0	22								
D	23								Rain.
8	24	7 3	M A	50 75 aft. 3 ^h A	+,35 +,21	480 180	+92,40	+ 0,85	
8	25	9½ 4	M A	59 56	+,28 +,34	396	+61,38	— 4,59	Rain last night and this morn- ing. Passed through water part of the day.
24	26	9½ 5½	M A	58 53	+,38 +,36	528	+97,68	— 8,85	Rain last night and part this day, the levels continually wet.
8	27	8 3¼	M A	65 79 aft. 3¼ ^h A	+,18 +,14	396 264	+52,80	+17,02	Dry weather.
h	28								
0	29								
D	30								

1768 May	1 h	2	3	4	5	6	7	
d	3 ¹	8 $\frac{1}{4}$ 3 $\frac{1}{2}$	M A	79 90	+ ,01 — ,12	376	—10,34	+21,82
								Very dry weather for 3 days past.

This reach'd to the North side of the river Nanticoke, near to the 7th mile post; here we left a mark.

24 June 2	Passed over the river Nanticoke, and began at the 6th mile post from the point A.							
	8	M	84	+ ,075	300			
	2 $\frac{1}{2}$	A	74	+ ,08				
		aft. 2 $\frac{1}{2}$ ^h	A		228	+20,59	+23,15	

♀	3	9	M	76	+ ,155	396		
		3	A	85	+ ,02			
			aft. 3 ^h	A		264	+29,04	+31,50

h	4	6 $\frac{1}{4}$ 1	M A	64 82	+ ,213 00	398,875	+21,15	+11,32
								At the point A.

○	5							
D	6	Began at the 6th mile post, and measured Northward through the swamp of Nanticoke.						
		7 $\frac{1}{2}$	M	67	+ ,12	230	+10,12	} to the river 6,83
		2	A	77	+ ,055			
		Cross the river to the mark left the 31st of May.				34,67	+ 1,54	

This finished the line A B.
Hence AB = 21696,47 levels + 892,34 inches + 94,51 inches = 43401,64 feet. { The breadth of the rivers was found by measuring a base, and taking angles with a Hadley's quadrant.

Note. The reckoning was kept by stretching a rope in the line to be measured (in general) = 12 levels, which was often proved : and it was almost impossible that an error could arise ; as we always began the rope with the same level, and ended it with the other ; the rope not being removed till the last level was set.

The person that stretched the rope, sometimes Mr. Dixon, and sometimes myself, kept the account of the number of ropes measured : though the mile posts in the lines AB and DC were sufficient for that purpose, as the lines had been so often measured before.

In the line NP there were no mile posts, but two or three intermediate marks, which we found to agree in a general law with the levels.

Supposing the levels exactly = 20 feet each ; then in the line NP a mile per chain measure = a mile and 9,44 feet by the levels ; and in the line CD a mile per chain measure = a mile and 9,86 feet by the levels.

In the line AB, what the levels make more than the chain, between the mile posts. is as follows.

Miles from the point A.	Diff. in feet.	Miles from the point A.	Diff. in feet.	
81	$14\frac{1}{2}$ }	43	74 }	<div> Here appears to be an error of one chain = 66 feet, in the chain measure, as observed before. <p>P. 318.</p> </div>
80		42		
78		40	16	
76	25	39	8	
75	14	38	$14-$	
72	43	37	14	
70	$32\frac{1}{2}$	36	$14\frac{1}{2}$	
66	61	35	14	
65	$15-$	34	$14\frac{1}{2}$	
63	$33+$	33	$14\frac{1}{2}$	
61	$33\frac{1}{2}$	28	$79\frac{1}{2}$	
60	$16\frac{1}{2}$	27	15	
59	$15\frac{1}{2}$	25	32	
58	$16\frac{1}{2}$	24	$20\frac{1}{2}$	
57	$14\frac{1}{2}$	23	14	
56	15	22	$11\frac{1}{2}$	
55	13	21	$12\frac{1}{2}$	
54	$12\frac{1}{2}$	19	22	
53	$10\frac{1}{2}$	18	$14\frac{1}{2}$	
52	$12\frac{1}{2}$	15	29	
51	11	13	$14\frac{1}{2}$	
50	13	12	5	
49	11	10	$11\frac{1}{2}$	
48	$9\frac{1}{2}$	9	8	
47	$9\frac{1}{2}$	8	$7\frac{1}{2}$	
45	$17\frac{1}{2}$	6	14	
44	7	4	23	
43	$9\frac{1}{2}$	2	13	
		0	$21\frac{1}{2}$	

We took notice of these differences as we measured from B to A, always finding the miles greater by the chain measure, by the quantity above, which shews that the chain was continually extending itself by use; as we had direct proof of, being obliged to contract it every day, and re-adjust it to its proper length by means of the standard chain.

To find the Latitude of the Point N.

	♄ Persei			α Capella			β Aurigæ			Castor			α Lyreæ.		
True observed zenith dist. reduced to 1 Jan. 1764.	7	4	22,2	5	47	32,3	4	57	26,3	7	33	23,1	1	21	44,2
Stars decl. by Dr. Bradley.	47	0	40,0	45	43	53,0	44	53	44,2	32	22	56,8	38	34	34,0
Latitude by the different stars.	39	56	17,8	56	20,7		56	17,9		56	19,9		56	18,2	
			20,7												
			17,9												
			19,9												
			18,2												
Mean =	39	56	18,9	= the latitude of the point N.											
Arch between N and A =	1	28	44,9												
	38	27	34	= the latitude of the point A.											
	39	11	56	= the mean latitude.											

Cha. Mason.
Jere. Dixon.

The Length of a Degree of Latitude in the Province of Maryland and Pennsylvania, deduced from the foregoing Operations; by the Astronomer Royal.

THE difference of latitude of the points N and A, or the amplitude of the celestial arch, answering to the distance between the parallels of latitude passing through N and A, has been found by the sector, page 306, to be $1^{\circ} 28' 45'', 0$. The terrestrial measure of the distance of the said parallels is next to be found. This is composed of the sum of the lines NP, CD, Dg, and AR, the last mentioned line being the reduction of AB to a meridian line passing through A: therefore BR expresses a parallel of latitude passing through B. Let Bt be an arch of a great circle drawn perpendicular to the meridian line, AR produced: The triangle BA t, on account of the smallness of its sides with respect to the radius of the earth, and the smallness of the angle BA t $= 3^{\circ} 43' 30''$ may be taken for a plane rectilinear triangle, in what follows, without any sensible error, as will appear to any one who makes the trial. Therefore it will be, by proportion, as radius is to the cosine of the angle BA t $= 3^{\circ} 43' 30''$ so is AB $= 434011,6$ English feet, to At $= 433094,6$ English feet. But this is to be lessened by the small quantity Rt, or the distance of the parallel circle BR from the great circle

T t 2

B t,

Bt, which is to a third proportional to the diameter of the earth and the line B R, as the tangent of the latitude of the point B, to the radius. Whence $Rt = 15,8$ feet which subtracted from A t just found =

433094,6 leaves	AR =	433078,8 feet
To which add {	NP =	78290.7
as found before {	CD =	26608 0
	Dg =	89.7

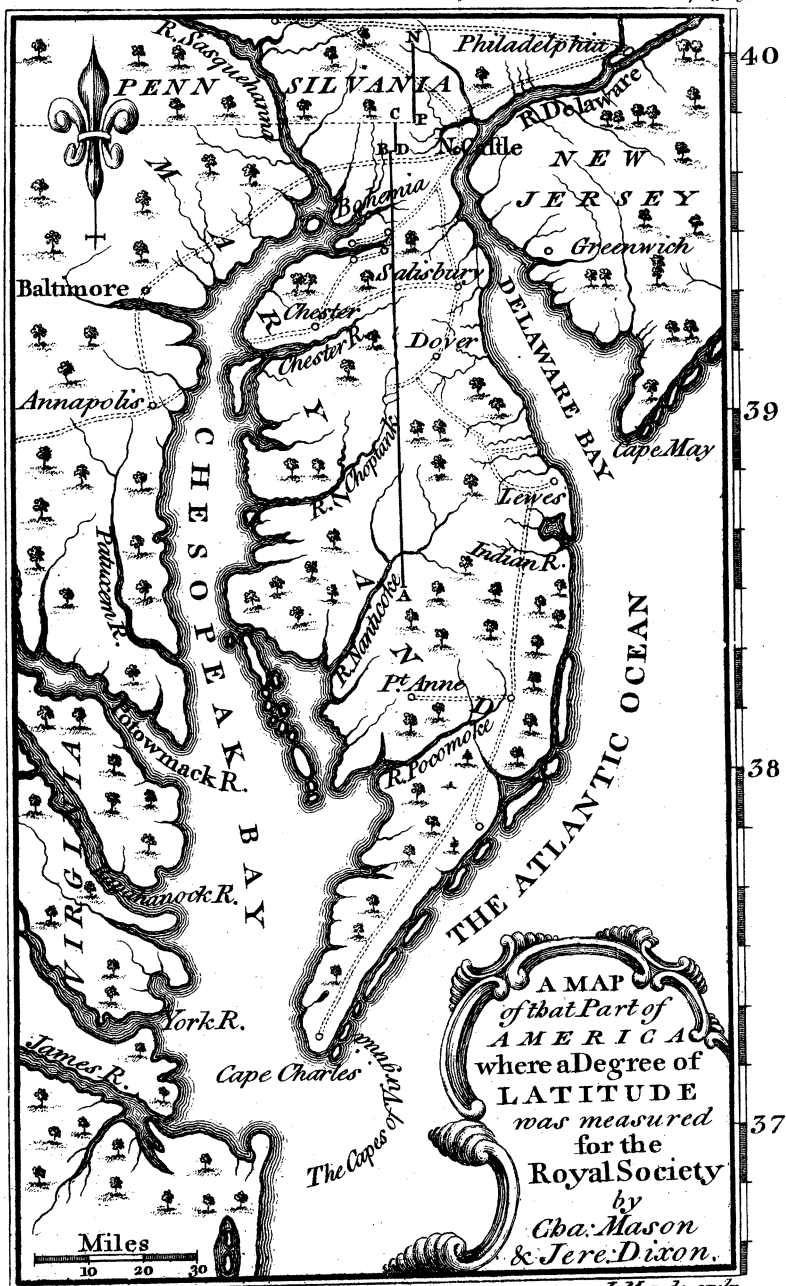
The sum is = 538067 feet

= an arch of meridian intercepted between the parallels of latitude passing through the points N and A, answering to the celestial arch $1^{\circ} 28' 45''$.

Then say, as $1^{\circ} 28' 45''$; is to $1^{\circ} ::$ so is 538067 feet, to 363763 English feet, which is the length of a degree of latitude in the provinces of Pennsylvania and Maryland. The latitude of the Northernmost point N, was determined from the zenith distances of several stars, see page 323 = $39^{\circ} 56' 19''$ and the latitude of the Southernmost point A = $38^{\circ} 27' 34''$. Therefore the mean latitude expressed in degrees and minutes is $= 39^{\circ} 12'$.

To reduce this measure of a degree to the measure of the Paris toise, it must be premised, that the measure of the French foot was found upon a very accurate comparison, made by Mr. Graham, of the toise of the Royal Academy of Sciences at Paris, with the Royal Society's brass standard, to be to the English foot, as 114 to 107. See Philosophical Transact, Vol. XLII. p. 185. Therefore say as 114 : is to 107 :: so is 363763 the measure of the degree in English feet, to 341427 the measure of the degree in French feet, which divided by 6, the number of feet in a toise, gives the length of the degree = 56904 $\frac{1}{2}$ Paris toises, in the latitude $39^{\circ} 12'$ North.

Such is the length of a degree in this latitude, supposing the five feet brass standard made use of in this measure to have been exactly adjusted to the length of the Royal Society's brass standard. It was really adjusted by Mr. Bird, by his accurate brass scale of equal parts, which he makes such excellent use of in dividing astronomical instruments, and which is just $\frac{1}{10000}$ th part of an inch shorter than the Royal Society's brass standard upon a length of three feet. If one would take notice of so small a difference, the length of a degree just found must be lessened by $\frac{1}{30000}$ th part, or by ten feet, in order to reduce it to the measure of the Royal Society's standard. Since I am treating of such niceties, may it be allowed me to add, that the five feet brass standard having been again compared with Mr. Bird's scale, since its return from North America, appeared both to myself and Mr. Bird to be just $\frac{1}{10000}$ th part of an inch shorter than the scale, upon that side on which the hundredths of an inch are placed at one end, and $\frac{2}{10000}$ ths of an inch shorter than the scale upon the opposite side? which diminution of its length is undoubtedly owing to the small wearing or battering which it has met with in the frequent use that was made of it. But the divided side of the rod having been that which was made use of in measuring the levels, is what is to be regarded in the present case. If one would allow for the wearing of the rod, one may suppose it to have suffered a gradual diminution; and then one must take a mean between its first length, which was the same with Mr. Bird's scale, and its present length, which is $\frac{1}{10000}$ th of an inch shorter; as one may suppose it a medium to have been $\frac{1}{20000}$ th part of an inch shorter than



than Mr. Bird's scale; on which account the length of the degree should be further diminished by $\frac{1}{13500}$ th part, or 3 feet, which added to 10 feet, the correction required on account of the difference of Mr. Bird's scale and the Royal Society's standard, gives 13 feet to be subtracted from the length of the degree calculated above. The whole correction will perhaps be thought scarce deserving of notice, especially as an error of only 1" in the celestial measure would produce an error of no less than 67 feet in the length of the degree. Moreover it is probable that the length of a degree has been already taken 10 or 20 feet too short, by placing the point C too far to the Southward; which would about balance the small correction in question. Therefore, all things being considered, the length of the degree may be stated as given above, viz. = 363763 English feet or 56904 $\frac{1}{2}$ Paris toises. It must, however, be observed, that the accuracy of this reduction into Paris toises depends upon a supposition that the length of the French toise, which is of iron, was laid off by the gentlemen of the Royal Academy of Sciences, upon the brass rod sent over to them for that purpose by Mr. Graham (which was afterwards returned to him); in a room where the heat of the air answered to 62 of Fahrenheit's thermometer, or 15 of Reaumur's, or nearly so, which is probable enough, but is a point that does not appear to have been ascertained. For, on account of the difference of expansion of brass and iron; 2 rods made of those metals, however accurately they may be made of equal lengths at first, will only agree together afterwards in the same temperature of the air in which they were originally adjusted together. It is fortunate that the uncertainty in the present case is but small, since 20° difference of Fahrenheit's thermometer or 10° of Reaumur's produces, according to Mr. Smeaton's experiments, a difference of the expansions of brass and iron of only $\frac{1}{13500}$ th part, which would cause an error of only 27 English feet or about 4 Paris toises in the length of the degree.

It is however to be wished, that the proportion of lengths of the French and English measures might be again ascertained by another careful experiment, in which the temperature of the air, as shewn by the thermometer, might be noted at the time.

[See the Map of the Country, where the foregoing Observations were made, TAB. XIV]

POSTSCRIPT, BY THE ASTRONOMER ROYAL.

HAVING, some time ago, acquainted M. De la Lande, of the Royal Academy of Sciences at Paris, by letter, of this measure of a degree of latitude in North America, and at the same time expressed my doubts about the certainty of reducing it to French measure, from the proportion of the English to the French foot found by Mr. Graham; principally because no notice had been taken of the height of the thermometer at Paris, when the length of the French iron toise was laid off upon the brass rod sent thither by Mr. Graham, whence the proportion of the two measures was afterwards determined by him; and having also mentioned my opinion of the expediency of making another experiment of the proportion of the two measures, in which every necessary circumstance should be noted; and that I might probably request the favour of M. De la Lande to take the trouble to cause a French toise to be made for me, and to see it exactly adjusted to their standard, and then sent to me; he has been pleased to lend me two toises,

toises, which he says are exactly adjusted to the standard of the toise used by Mess. De la Condamine and Bouguer in the measure of the degrees of latitude at Peru, in order to their being compared with the English measure. This comparison has been made by Mr. Bird, with his usual accuracy, while I was present, and also examined the same, since my account of the length of the degree of latitude foregoing was printed; and the result is, that the longest of the two toises (for there is a small difference between them), and which has since been marked with the letter A, is equal to 76,738 inches by Mr. Bird's brass scale of equal parts, and the shortest toise, which is marked B, is = 76,735 inches by the same scale; the height of Fahrenheit's thermometer in the room being 61 degrees. The mean of the lengths of the two toises is therefore = 76,736½ inches by Mr. Bird's scale. But Mr. Bird's scale is $\frac{1}{1000}$ th of an inch upon 3 feet shorter than the Royal Society's brass standard, and consequently $\frac{2.1}{10000}$ th too short for the same upon 76,736½ inches; therefore $\frac{2.1}{10000}$ th of an inch must be subtracted from 76,736½; which leaves 76,7344 for the length of the Paris toise in measures of the Royal Society's brass standard, in the temperature of 61° of Fahrenheit's thermometer. In the temperature of 62° it will be a little shorter; or it may be taken = 76,734 inches in measures of the Royal Society's brass standard. This is $\frac{2.4}{10000}$ th or about $\frac{1}{42}$ d of an inch longer than was determined by Mr. Graham's experiment. Hence it appears, that I was mistaken in supposing, in p. 325, that the uncertainty about the true proportion of the English and French measures was but small, since the error in the former determination now appears to have been $\frac{1}{3157}$ th of the whole, or equivalent to what might have been produced by a difference of 84° of Fahrenheit's thermometer. Whence it arose I cannot pretend to say, neither is it very material to enquire; but the fact is plain, and fully justifies the propriety of repeating the experiment.

I shall now state the length of the degree, measured by Messieurs Mason and Dixon, first in English feet, according to the Royal Society's standard, and then reduced to the French measure by the proportion just established.

From 363763 English feet, the length of the degree found by the 5 feet brass standard, see p. 324, I subtract 10 feet for the difference between Mr. Bird's scale and the Royal Society's standard, and 3 feet for the wearing of the brass rod; and there remain 363750 feet, according to the Royal Society's standard, for the length of the degree. But to this it seems proper to add 21 feet, in order to correct the position of the point C, determined by the sector, which cannot be so certain as that inferred from the azimuth of the line PS. See p. 279. Therefore the true length of the degree, according to the Royal Society's brass standard, in the temperature of 62° of Fahrenheit's thermometer, is 363771 feet, or 68,8960 English statute miles. To reduce this to the measure of the Paris toise, by the proportion above established, say as 76,734 is to 72, so is 363771 to 341328 French feet, or 56888 Paris toises, of the standard of that used in the measure of the degrees of the meridian at Peru.

The method made use of by Mr. Bird, in finding the length of the toises by his scale, was as follows, which may serve as a direction for the like purpose on any future occasion. Two brass pins were drove into a strong deal board 4 inches thick, and longer than the toise; and two brass cheeks were made very square, and the ends brought upon the pins. The toise was then put in between the cheeks, one of which was made to slide so as to be easily brought into contact with the end of the toise, and the other end

at the same time touching the other cheek, the moveable cheek was screwed fast ; and thus the toise was exactly contained between the cheeks without any shake, and it is evident that the interval between the cheeks was exactly equal to the length of the toise. In order to measure this interval, the toise being taken away, very fine lines were drawn with a fine point, at the end of each cheek, upon the brass pins which were in the same plain with the board : then the cheeks were removed, and fine points made at the outer extremity of each line, and this distance being taken between the fine points of a beam compass, was transferred to the scale, and thus the length of the toise was found in measures of the scale, which is divided by a vernier to thousandths of an inch. The toises and brass scale had been left together in the same room, and near one another all the night before, and till the very time of making the comparison of the toises with the scale, in order to be sure that they were all affected with the same degree of heat.

As it may be agreeable to the reader to see the result of the principal measures of degrees of latitude, that have been taken with later instruments and proper accuracy, brought together into one view, the following table is here added.

Length of a degree in Paris toises.	Mean latitude.	Names of the observers.	Years in which the degrees were measured.
57422	66° 20' N	M. de Maupertuis, &c.	1736 and 1737
57074	49 23 N	M. de Maupertuis, &c. and M. Cassini	1739 and 1740
57091	47 40 N	P. Liefganig	1768
57028	45 0 N	M. Cassini	1739 and 1740
57069	44 44 N	P. Beccaria.	1768
56979	43 0 N	Le Pere Boscowich and Le Maire	1752
56888	39 12 N	Mess. Macon and Dixon	1764 to 1768
56750	0 0	M. Bouguer and M. de la Condamine	1736 to 1743
57037	33 18 S	Abbé de La Caille	1752

If this degree be compared with the degree measured at the equator = 56750 toises, in the hypothesis of the earth's being an oblate spheroid, the ratio of the equatorial to the polar diameter will come out as 494 to 493. But, if it be compared with the degree measured in Lapland, in the latitude 66° 20', = 57419 toises (I have subtracted 3 toises, because the toise used in Lapland was $\frac{1}{20}$ th or $\frac{1}{25}$ th of a line less than the toise used in Peru, see M. De la Lande's Astronomy, Article 2107), the ratio of the diameters will be as 142 to 141. The great difference of these results is a fresh proof of what has appeared from the comparison of the measures of the several degrees taken before, either that the figures of the meridians are not accurately elliptical, or that the inequalities of the Earth's surface have a considerable effect in deflecting the plumb-line from its true situation, or both. I had indeed supposed that any deflections of the plumb-line were not to be feared with respect to this particular measure of a degree, at the end of my Introduction to Messieurs Macon and Dixon's account of the same, by arguing

arguing, perhaps too far, from the level disposition of the country through which the degree passes. But the Honourable Mr. Henry Cavendish has since considered this matter more minutely; and having mathematically investigated several rules for finding the attraction of the inequalities of the Earth, has, upon probable suppositions of the distance and height of the Allegany mountains from the degree measured, and the depth and declivity of the Atlantic ocean, computed what alteration might be produced in the length of the degree, from the attraction of the said hills, and the defect of attraction of the Atlantic; and finds the degree may have been diminished by 60 or 100 toises from these causes. He has also found, by similar calculations, that the degrees measured in Italy, and at the Cape of Good Hope, may be very sensibly affected by the attraction of hills, and defect of the attraction of the Mediterranean Sea and Indian Ocean.

The rules, which I used in calculating the ratio of the equatorial diameter to the polar axis, from the North American degree, compared with those measured in Peru and Lapland, are those given by Mr. John Robertson, Librarian to the Royal Society, in his Elements of Navigation, p. 597, as deduced by him from Dr. Letherland's Geometrical Analysis of the problem, which he has also given to the public in the same place, together with some other problems depending upon it, which were necessary to complete the subject.