PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXXVIII.

PART I.

LONDON:
PRINTED BY RICHARD TAYLOR, RED LION COURT, FLEET STREET;
AND SOLD BY G. AND W. NICOL, PALL MALL, BOOKSELLERS TO THE ROYAL SOCIETY.
MDCCCXXVIII.

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APPENDIX.

PHILOSOPHICAL TRANSACTIONS.

I. *Experiments to ascertain the ratio of the magnetic forces acting on a needle suspended horizontally, in Paris and in London. By Captain* EDWARD SABINE, *of the Royal Artillery, Secretary of the Royal Society.*

Read June 21, 1827.

THE magnetic needles employed in these experiments were cylinders of 0,16 inch diameter, and 2,4 inches in length, pointed at the ends: they were suspended by a single silk fibre of rather more than five inches in length. The box in which they were inclosed, as a protection from the weather, was of wood, having at the bottom a graduated circle in ivory, rather exceeding in diameter the length of the needles, and over the centre of which the silk fibre was suspended. The bottom of the box being rendered horizontal by means of foot screws, and shown to be so by an unattached spirit level, the zeros of the circle were placed in the direction of the magnetic meridian, and a needle was suspended in a horizontal position. Another needle was then employed to draw it 50 or 60 degrees from its natural direction; on the removal of which, the suspended needle resumed its direction in the ordinary process of vibration. The registry of the vibrations was commenced when the arc had diminished to 30°, and continued until it was reduced to below 5°: the method of registering the vibration will be best understood by a reference to the Tables at the close, and is too simple to require further explanation. The number of vibrations made by each needle between the arcs of 30° and 5° was usually from 300 to 400; and the time in which these were performed varied, in the different needles, from 12 to 16 minutes: the mean time of performing 100 vibrations between the specified arcs is the result deduced for each experiment.

Four of the needles, Nos. IV, VIII, X, and XI, with an apparatus in duplicate, were sent to me in the summer of 1826 by Professor HANSTEEN of Christiania, to be employed in obtaining the comparative magnetic intensity in different parts of Great Britain. Shortly after their arrival, an opportunity occurred of sending two of the needles, Nos. IV and XI, with an apparatus, to Captain BASIL HALL, in Edinburgh; by whom, assisted by Lieut. ROBERT CRAIGIE, of the Royal Navy, the experiments numbered 12 to 16 in the subjoined tables were made, in February 1827; and the needles returned, so as to be included in the comparative experiments between Paris and London.

The two remaining needles, marked A and B, making six in all, were made, at my request, by Mr. DOLLOND, in the autumn of 1826, of the same size and form as those sent me by Professor HANSTEEN.

On the 3rd of December 1826, being about seven weeks before I expected to leave England for Paris, I made the experiments 1 to 4, with needles A and B, VIII and X, in the garden of the Horticultural Society at Chiswick; and after an interval of six weeks, repeated, with the same needles, at Shernfold Park near Tunbridge Wells, on the 15th of January, the experiments 5 to 8, to ascertain that their magnetism had sustained no change. On the 30th of January, fifteen days only after this second trial, three of the needles, No. VIII, A, and B, (No. X having been accidentally mislaid on that day,) were employed in the garden of the Royal Observatory at Paris, in the experiments numbered 9 to 11; and on the 14th of March, Nos. X and XI (which last had been returned by Captain HALL from Edinburgh), and the needles A and B repeated, were employed in the experiments numbered 17 to 20; in which observations I had the pleasure of being assisted by Mr. WILLIAM RITCHIE, rector of Tain Academy in Scotland.

An opportunity occurring, Nos. VIII, X, and XI, were sent to England early in April, and the experiments numbered 21 to 24 made with those three needles and, with No. IV (sent by Captain HALL to London, but which had not been forwarded to me in Paris), in the garden of the Horticultural Society at Chiswick, on the 23rd of April, by Captain CHAPMAN of the Royal Artillery, who kindly undertook this trouble at my request; and having done so, returned them again to me at Paris.

By Professor HANSTEEN's recommendation, the four needles which he had sent me were kept at all times separate from each other; the two which Mr. Dollond made had been on the contrary kept together in a small ivory case; the needles being placed parallel, but not touching, the north pole of the one being opposed to the south pole of the other, but not connected. Being desirous of ascertaining the effect which separation might have on the magnetism of these needles (A and B), they were removed from each other after the experiments of the 14th of March, and kept apart until the 30th of April; when they were again tried in the garden of the Observatory at Paris, in experiments 25 and 26, and their time of vibration was found the same as before. Nos. VIII and XI, which had arrived from Captain Chapman, were tried on the same day, Experiments 27 and 28, and Nos. IV and X, which arrived a few days after, on the 10th of May, in the experiments 29 and 30. Finally, on my return to England in June, the needles were again taken to the garden at Chiswick, and the experiments 31 to 34 made on the 11th of June.

The place of observation in the garden at Chiswick was near the middle of the Arboretum; and in the garden of the Observatory at Paris, in the Cabinet of M. Arago, specially constructed for magnetic observations, which he kindly permitted me to occupy for the purpose.

The Tables at the close contain the full details of the temperatures and the hours of the day at which the several experiments were made. It will be seen that the variations of temperature included at each station were very considerable; but care was taken that the mean temperature of the several experiments with each needle should, in most cases at least, approach the same amount at London and at Paris:

With Needle IV the mean temp. at London was	54,5	and at Paris	62
With Needle VIII	50	. . . .	52,5
With Needle X	40,5	. . . .	59
With Needle XI	54,5	. . . .	66,5
With Needle A	55	. . . .	54
With Needle B	54,5	. . . .	53

Still the preponderance of high temperatures was at Paris; and it is expedient therefore to reduce the several results to a nearer accord with what they would have been, had they been all made at the same temperature. I avail myself for this purpose of a formula for the reduction of different temperatures, which Professor Hansteen has derived from experiments made with a cylinder precisely similar in all respects to those which he sent to me. Supposing the time of n vibrations in the temperature t to be T seconds, and in the temperature t' to be T' seconds, $T = T' \left[1 - 0{,}000165\ (t' - t)\right]$, the temperature being expressed in degrees of Fahrenheit. It is possible that this reduction may not be strictly correct for all cylinders of the same shape and make as that from whence it was originally derived; but it may at least be confidently presumed, that the results obtained by such cylinders being corrected by it, will more nearly approach a strict relation to each other, than when no attempt is made to counteract the effect of differences of temperature: and that, viewing the small ultimate amount to be compensated in the present case, this formula may be considered as being quite sufficient for the purpose.

The following Table presents in one view the results obtained with each needle at the different stations at which they were tried.

Needle.	LONDON.					PARIS.				
	Date.	Therm.	Time of Vibration.	Reduction to 40°.	Corrected Time of Vibration.	Date.	Therm.	Time of Vibration.	Reduction to 40°.	Corrected Time of Vibration.
		°	s	s	s		°	s	s	s
IV	Apr. 23, 1827, 1 P.M.	40	341,69	0,00	341,69	May 10, 1827, 5½ P.M.	62	331,12	−1,20	329,92
	June 11, 1827, 2½ P.M.	69	343,21	−1,64	341,57					
	Mean......	...	....	....	341,63	Mean......	...	....	....	329,92
VIII	Dec. 3, 1826, 2½ P.M.	41	275,85	−0,05	275,80	Jan. 30, 1827, 11½ A.M.	28	267,22	+0,53	267,75
	Apr. 23, 1827, 2 P.M.	40	276,44	0,00	276,44	Apr. 30, 1827, 5½ P.M.	77	268,76	−1,64	267,12
	June 4, 1827, 1½ P.M.	69	278,02	−1,33	276,69					
	Mean......	...	....	....	276,31	Mean......	...	....	....	267,435
X	Dec. 3, 1826, 2 P.M.	41	329,63	−0,05	329,58	Mar. 14, 1827, 1½ P.M.	56	319,17	−0,84	318,33
	Apr. 23, 1827, 2½ P.M.	40	330,86	0,00	330,86	May 10, 1827, 5 P.M.	62	320,38	−1,16	319,22
	Mean......	...	....	....	330,22	Mean......	...	....	....	318,775
XI	Apr. 23, 1827, 3 P.M.	40	313,98	0,00	313,98	Mar. 14, 1827, 2½ P.M.	56	304,13	−0,80	303,33
	June 11, 1827, 3½ P.M.	69	315,37	−1,53	313,84	Apr. 30, 1827, 5 P.M.	77	304,73	−1,86	302,87
	Mean......	...	....	....	313,91	Mean......	...	....	....	303,10
A	Dec. 3, 1826, 3½ P.M.	41	247,03	−0,05	246,98	Jan. 30, 1827, Noon.	28	238,95	+0,48	239,43
	June 11, 1827, 4 P.M.	69	250,07	−1,20	248,87	Mar. 14, 1827, 2½ P.M.	56	240,73	−0,63	240,10
						Apr. 30, 1827, 3½ P.M.	77	241,20	−1,47	239,73
	Mean......	...	....	....	247,925	Mean......	...	....	....	239,573
B	Dec. 3, 1826, 3 P.M.	41	345,94	−0,05	345,89	Jan. 30, 1827, 1 P.M.	28	331,85	+0,66	332,51
	June 15, 1827, 3½ P.M.	68	349,16	−1,59	347,57	Mar. 14, 1827, 3 P.M.	56	337,21	−0,88	336,33
						Apr. 30, 1827, 3 P.M.	77	338,01	−2,06	335,95
	Mean......	...	....	....	346,73	Mean......	...	....	....	334,93

From the results in the preceding Table it appears that when the horizontal intensity in London is taken as unity, the same intensity in Paris is shown by the several cylinders to be as follows:

By Needle IV = 1,0732
By Needle VIII = 1,0675
By Needle X = 1,0726
By Needle XI = 1,0723
By Needle A = 1,0709
By Needle B = 1,0717

Mean.... 1,07137 or 1,0714.

From the very careful observations which are regularly made on the dip of the needle at the Royal Observatory at Paris, the mean dip corresponding to the period when these experiments were made is known to have been 67° 58′. In assuming the dip at the same period at London to have been 69° 45′, which is allowing a diminution of 3′ per annum since it was observed in 1821 to be 70° 04′, (Phil. Trans. for 1822, Art. I.) we cannot fail to be sufficiently near the truth for the present purpose. The horizontal intensity at Paris being then as 1,0714, to unity at London, it results that the absolute intensity of terrestrial magnetism was greater at London than at Paris at the period of these experiments by about eleven parts in a thousand.

The experiments of Captain Hall and Lieut. Craigie at Edinburgh with Nos. IV and XI give the following results:

Needle.	EDINBURGH.					LONDON.	
	Date.	Temp.	Time of Vibration.	Reduction to 40°.	Corrected Time of Vibⁿ.		Corrected Time of Vibⁿ.
		°	s	s	s		s
No. IV	Feb. 15, 1827.	32	350,47	+0,46	350,93	Vibrations in London at 40° page 4.	341,63
No. XI	Feb. 15, 1827.	32	321,07	+0,43	321,50	Vibrations in London at 40° page 4.	313,91

Whence the horizontal intensity at Edinburgh, when the same intensity at London is taken as unity, is by

No. IV = 0,9477
No. XI = 0,9534

And by a mean of the two Needles, 0,9505.

In the Horticultural Society's Garden at Chiswick, near London: December 3d, 1826.

Observer, Captain SABINE. Therm. 41°. Chron. MOLYNEUX 407. Rate, nearly Mean Time.

EXP. 1. NEEDLE VIII. Hour 2½ P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	260 Vib^{ns}. in
	m s		m s	m s
0	40 29,6	260	52 27,6	11 58
10	40 57,6	270	52 55,2	11 57,6
20	41 25,2	280	53 22,8	11 57,6
30	41 53,2	290	53 50,4	11 57,2
40	42 20,8	300	54 17,6	11 56,8
50	42 48,8	310	54 45,6	11 56,8
60	43 16,4	320	55 12,8	11 56,4
80	44 12			
100	45 07,2			
120	46 02,8			
140	46 57,6			
160	47 52,8			
180	48 47,6			
200	49 42,8			
220	50 38			
240	51 32,4			

Mean....11 57,2

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

275,85 sec.

EXP. 2. NEEDLE X. Hour 2 P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	200 Vib^{ns}. in
	m s		m s	m s
0	8 56	200	19 56,4	11 00,4
10	9 29,2	210	20 29,2	11 00
20	10 02,8	220	21 02	10 59,2
30	10 35,6	230	21 34,8	10 59,2
40	11 08,8	240	22 08	10 59,2
50	11 42,4	250	22 40,8	10 58,4
60	12 15,2	260	23 13,6	10 58,4
80	13 21,2			
100	14 27,2			
120	15 32,8			
140	16 38,8			
160	17 44,8			
180	18 50,4			

Mean....10 59,26

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

329,63 sec.

EXP. 3. NEEDLE A. Hour 3½ P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns}. in
	m s		m s	m s
0	40 43,2	300	53 05,2	12 22
10	41 08,4	310	53 30	12 21,6
20	41 33,2	320	53 54,8	12 21,6
30	41 58,4	330	54 19,2	12 20,8
40	42 23,2	340	54 44	12 20,8
50	42 48	350	55 08,4	12 20,4
60	43 12,8	360	55 33,2	12 20,4
80	44 02,8			
100	44 52			
120	45 41,6			
140	46 31,2			
160	47 20,4			
180	48 09,6			
200	48 59,2			
220	49 48,4			
240	50 37,6			
260	51 26,8			
280	52 16			

Mean....12 21,09

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

247,03 sec.

EXP. 4. NEEDLE B. Hour 3 P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	200 Vib^{ns}. in
	m s		m s	m s
0	14 33,6	200	26 06,8	11 33,2
10	15 08,8	210	26 41,6	11 32,8
20	15 43,6	220	27 16	11 32,4
30	16 18,4	230	27 50	11 31,6
40	16 53,2	240	28 24,4	11 31,2
50	17 28	250	28 59,2	11 31,2
60	18 02,8	260	29 33,6	11 30,8
80	19 12			
100	20 21,2			
120	21 30,4			
140	22 39,6			
160	23 48,8			
180	24 58,4			

Mean....11 31,89

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

345,94 sec.

In the grounds of Shernfold Park, Frant, Sussex: January 15th, 1827.

Observer, Captain Sabine. Therm. 38°. Chron. Molyneux 407. Rate, Mean Time.

Exp. 5. Needle VIII. Hour 2¼ P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns. in
	m s		m s	m s
0	31 13,6	300	44 58	13 44,4
10	31 41,6	310	45 25,2	13 43,6
20	32 09,2	320	45 52,6	13 43,4
30	32 37,2	330	46 20	13 42,8
40	33 05,2	340	46 47,6	13 42,4
50	33 32,2	350	47 14,2	13 42
60	34 00,8	360	47 42,8	13 42
80	34 55,2			
100	35 50			
120	36 45,2			
140	37 40,4			
160	38 35,2			
180	39 29,6			
200	40 24,4			
220	41 19,6			
240	42 14,4			
260	43 09,2			
280	44 04			

Mean 13 42,94

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

274,31 sec.

Exp. 6. Needle X. Hour 1¼ P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns. in
	m s		m s	m s
0	43 28,8	300	59 54	16 25,2
10	44 02	310	00 26,4	16 24,4
20	44 35,2	320	00 59,6	16 24,4
30	45 08,4	330	01 32	16 23,6
40	45 41,2	340	02 04,4	16 23,2
50	46 14,4	350	02 37,2	16 22,8
60	46 47,2	360	03 10	16 22,8
80	47 53,2			
100	48 58,8			
120	50 04,4			
140	51 10			
160	52 15,2			
180	53 21,2			
200	54 26,8			
220	55 32			
240	56 37,2			
260	57 42,8			
280	58 48,4			

Mean 16 23,77

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

327,92 sec.

Exp. 7. Needle A. Hour 3¼ P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns. in
	m s		m s	m s
0	30 06	300	42 24	12 18
10	30 31,6	310	42 48,8	12 17,2
20	30 56	320	43 12,8	12 16,8
30	31 20,8	330	43 37,6	12 16,8
40	31 45,6	340	44 02	12 16,4
50	32 10,4	350	44 26,4	12 16
60	32 35,2	360	44 50,8	12 15,6
80	33 24,8			
100	34 14			
120	35 03,2			
140	35 52			
160	36 41,2			
180	37 30			
200	38 19,2			
220	39 08			
240	39 57,2			
260	40 46			
280	41 35,2			

Mean 12 16,69

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

245,56 sec.

Exp. 8. Needle B. Hour 4 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns. in
	m s		m s	m s
0	2 32,8	300	19 47,6	17 14,8
10	3 07,6	310	20 21,6	17 14
20	3 42,4	320	20 56	17 13,6
30	4 17,2	330	21 30,4	17 13,2
40	4 52	340	22 05,2	17 13,2
50	5 26,8	350	22 39,2	17 12,4
60	6 01,2	360	23 13,2	17 12
80	7 10,4			
100	8 19,2			
120	9 28,4			
140	10 37,2			
160	11 46,4			
180	12 55,2			
200	14 04,4			
220	15 12,8			
240	16 21,2			
260	17 30			
280	18 39,2			

Mean 17 13,31

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

344,44 sec.

In the Garden of the Observatory at Paris: January 30th, 1827.

Observer, Captain SABINE. Therm. 28°. Chron. MOLYNEUX, No. 407. Rate, Mean Time.

EXP. 9. NEEDLE VIII. Hour 11¼.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	15 47,2	300	29 09,6	13 22,4
10	16 14	310	29 36,4	13 22,4
20	16 41,2	320	30 03,2	13 22
30	17 08	330	30 29,6	13 21,6
40	17 35,2	340	30 56	13 20,8
50	18 01,6	350	31 23,2	13 21,6
60	18 28,8	360	31 49,6	13 20,8
80	19 22,4			
100	20 16			
120	21 09,6			
140	22 03,2			
160	22 56,8			
180	23 50			
200	24 43,6			
220	25 37,2			
240	26 30,4			
260	27 23,2			
280	28 16,8			

Mean....13 21,66

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

267,22 sec.

EXP. 10. NEEDLE A. Hour Noon.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	14 15,6	300	26 13,2	11 57,6
10	14 39,6	310	26 37,2	11 57,6
20	15 04	320	27 00,8	11 56,8
30	15 28	330	27 24,8	11 56,8
40	15 52	340	27 48,8	11 56,8
50	16 16	350	28 12,4	11 56,4
60	16 40,4	360	28 36,4	11 56
80	17 28,8			
100	18 16			
120	19 03,6			
140	19 51,6			
160	20 39,6			
180	21 27,6			
200	22 15,2			
220	23 02,8			
240	23 50,4			
260	24 38,4			
280	25 26			

Mean....11 56,86

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

238,95 sec.

EXP. 11. NEEDLE B. Hour 12 to 1 P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	43 49,6	300	00 26,8	16 37,2
10	44 23,6	310	01 00	16 36,4
20	44 56,8	320	01 32,8	16 36
30	45 30,4	330	02 05,6	16 35,2
40	46 04	340	02 39,2	16 35,2
50	46 37,2	350	03 12	16 34,8
60	47 10,8	360	03 44,8	16 34
80	48 17,6			
100	49 24			
120	50 30,4			
140	51 36,8			
160	52 43,2			
180	53 49			
200	54 55,6			
220	56 02			
240	57 08			
260	58 14,4			
280	59 20,4			

Mean....16 35,54

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

331,85 sec.

Edinburgh: February 15th, 1827.

Observers, Captain **Basil Hall** and Lieut. **Robert Craigie**, R.N. Therm. 32°. Barom. 30,00.
Chron. gaining 1^{s},5 per diem.

Exp. 12. Needle IV.

Vib^{ns}.	Time.		Vib^{ns}.	Time.	
	m	s		m	s
0	8	47,5	300	26	18,9
10	9	23,5			
20	9	58,5			
30	10	34			
40	11	09,5			
50	11	45,5			
60	12	19,5			
80	13	29,8			
100	14	59,7			
120	15	50,0			
140	16	59,5			
160	18	09,5			
180	19	19,5			
200	20	29,5			
220	21	39,5			
240	22	49,8			
260	23	59,2			
280	25	09,0			

300 Vibrations in 17^{m} 31^{s},4.

Whence the Mean Time of 100 Vibrations in Arcs between 30° and 5°

350,47 sec.

Exp. 13. Needle IV.

Vib^{ns}.	Time.		Vib^{ns}.	Time.	
	m	s		m	s
0	33	59,5	290	50	55,5
10	34	35,5			
20	35	11,0			
30	35	45,5			
40	36	20,7			
50	36	56,0			
70	38	06,5			
90	39	16,5			
110	40	26,5			
130	41	37,0			
150	42	46,5			
170	43	57,0			
190	45	06,5			
210	46	16,5			
230	47	26,0			
250	48	36,5			
270	49	46,0			

290 Vibrations in 16^{m} 56^{s}.

Whence the Mean Time of 100 Vibrations in Arcs between 30° and 5°

350,35 sec.

Exp. 14. Needle IV.

Vib^{ns}.	Time.		Vib^{ns}.	Time.	
	m	s		m	s
0	4	24	300	21	55,8
20	5	35			
40	6	45,5			
60	7	55,8			
80	9	06,5			
100	10	16,5			
120	11	26,5			
140	12	36,8			
160	13	46,8			
180	14	56,5			
200	16	06,5			
220	17	16,5			
240	18	26,5			
260	19	35,9			
280	20	46,0			

300 Vibrations in 17^{m} 31^{s},8.

Whence the Mean Time of 100 Vibrations in Arcs between 30° and 5°

350,6 sec.

Exp. 15. Needle XI.

Vib^{ns}.	Time.		Vib^{ns}.	Time.		300 Vib^{ns} in	
	m	s		m	s	m	s
0	47	31,0	300	63	26	16	05
10	48	03,5	310	64	08	16	04,5
20	48	36,0	320	64	40	16	04
30	49	08,5	330	65	12	16	03,5
40	49	41,0	340	65	44	16	03
50	50	13,5	350	66	16	16	02,5
60	50	45,5	360	66	47,5	16	02
80	51	50,2					
100	52	54,8					
120	53	58,8					
140	55	03,5					
160	56	07,5					
180	57	12,0					
200	58	16,2					
220	59	20,0					
240	60	24,0					
260	61	28,0					
280	61	32,0					

Mean 16 03,5

Whence the Mean Time of 100 Vibrations in Arcs between 30° and 5°

321,17 sec.

Exp. 16. Needle XI.

Vib^{ns}.	Time.		Vib^{ns}.	Time.		300 Vib^{ns} in	
	m	s		m	s	m	s
0	16	52,5	300	32	57	16	04,5
10	17	25,0	310	33	29	16	04
20	17	57,5	320	34	00,2	16	02,7
30	18	30,0	330	34	33	16	03
40	19	02,5	340	35	04,8	16	02,3
50	19	35,0	350	35	37,0	16	02
60	20	07,3	360	36	09,0	16	01,7
80	21	11,7					
100	22	16					
120	23	20					
140	24	24,5					
160	25	29					
180	26	33					
200	27	37					
220	28	41,2					
240	29	45					
260	30	49					
280	31	53,2					

Mean 16 02,9

Whence the Mean Time of 100 Vibrations in Arcs between 30° and 5°

320,97 sec.

In the Garden of the Observatory at Paris: March 14th, 1827.

Observers, Captain Sabine and Mr. Ritchie. Therm. 56°. Chron. Molyneux, No. 407. Rate, Mean Time.

Exp. 17. Needle X. Hour 1 to 2 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	31 13,6	300	47 12,4	15 58,8
10	31 46	310	47 44	15 58
20	32 18,4	320	48 16	15 57,6
30	32 50,4	330	48 48	15 57,6
40	33 22,4	340	49 19,6	15 57,2
50	33 54,8	350	49 51,6	15 56,8
60	34 26,8	360	50 23,2	15 56,4
80	35 30,8			
100	36 34,8			
120	37 38,8			
140	38 42,8			
160	39 46,4			
180	40 50			
200	41 54			
220	42 58			
240	44 01,6			
260	45 05,2			
280	46 08,8			

Mean 15 57,5

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

319,17 sec.

Exp. 18. Needle XI. Hour 2 to 3 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	59 17,2	300	14 31,2	15 14
10	59 48	310	15 01,2	15 13,2
20	00 18,8	320	15 31,6	15 12,8
30	00 49,6	330	16 01,6	15 12
40	01 20,4	340	16 32	15 11,6
50	01 50,8	350	17 02,4	15 11,6
60	02 21,2	360	17 32,8	15 11,6
80	03 22,4			
100	04 23,6			
120	05 24,8			
140	06 25,2			
160	07 26			
180	08 26,8			
200	09 27,6			
220	10 28,4			
240	11 28,8			
260	12 29,6			
280	13 30,4			

Mean 15 12,4

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

304,13 sec.

Exp. 19. Needle A. Hour 2 to 3 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	26 54	300	38 57,2	12 03,2
10	27 18,2	310	39 21,2	12 03
20	27 42,8	320	39 45,2	12 02,4
30	28 07,2	330	40 09,2	12 02
40	28 31,2	340	40 33,2	12 02
50	28 55,6	350	40 57,2	12 01,6
60	29 20	360	41 21,2	12 01,2
80	30 08,4			
100	30 56,8			
120	31 44,8			
140	32 32,8			
160	33 21,2			
180	34 09,2			
200	34 57,2			
220	35 45,2			
240	36 33,2			
260	37 21,2			
280	38 09,2			

Mean 12 02,2

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

240,73 sec.

Exp. 20. Needle B. Hour 3 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	51 52	300	08 45,2	16 53,2
10	52 26	310	09 18,4	16 52,4
20	53 00,6	320	09 52,4	16 51,8
30	53 34,4	330	10 26	16 51,6
40	54 08,4	340	10 59,6	16 51,2
50	54 42,8	350	11 33,6	16 50,8
60	55 16,4	360	12 06,8	16 50,4
80	56 24			
100	57 31,6			
120	58 39,6			
140	59 46,8			
160	00 54			
180	02 01,6			
200	03 08,8			
220	04 16			
240	05 23,2			
260	06 30,8			
280	07 37,6			

Mean 16 51,63

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

337,21 sec.

In the Garden of the Horticultural Society, at Chiswick, near London: April 23d, 1827.

Observer, Captain Chapman, R.A. Therm. 40°.

Exp. 21. Needle IV. Hour 1 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	27 32	300	44 37	17 05
10	28 06	310	45 11	17 05
20	28 40	320	45 45	17 05
30	29 15	330	46 20	17 05
40	29 49	340	46 54,5	17 05,5
50	30 23	350	47 28	17 05
60	30 57	360	48 02	17 05
80	32 07			
100	33 15			
120	34 23,5			
140	35 31			
160	36 39			
180	37 49			
200	38 57			
220	40 05			
240	41 13			
260	42 21			
280	43 29,5			

Mean 17 05,07

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

341,69 sec.

Exp. 22. Needle VIII. Hour 2 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	7 32	300	21 21	13 49
10	8 00	310	21 49	13 49
20	8 27	320	22 16	13 49
30	8 55	330	22 45	13 50
40	9 23	340	23 13	13 50
50	9 51	350	23 40	13 49
60	10 18			
80	11 14			
100	12 09			
120	13 04			
140	14 00			
160	14 56			
180	15 51			
200	16 46			
220	17 41,5			
240	18 36			
260	19 32			
280	20 27			

Mean 13 49,33

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

276,44 sec.

Exp. 23. Needle X. Hour 2 to 3 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	38 26	300	54 59	16 33
10	38 58	310	55 32	16 34
20	39 32,5	320	56 05	16 32,5
30	40 05	330	56 38	16 33
40	40 39	340	57 11	16 32
50	41 11,5	350	57 44	16 32,5
60	41 46	360	58 17	16 31
80	42 52,5			
100	43 58			
120	45 05			
140	46 10,5			
160	47 17			
180	48 23			
200	49 29,5			
220	50 35,5			
240	51 42			
260	52 48			
280	53 53,5			

Mean 16 32,57

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

330,86 sec.

Exp. 24. Needle XI. Hour 3 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	4 09	300	19 51	15 42
10	4 40	310	20 22	15 42
20	5 11,5	320	20 54	15 42,5
30	5 44	330	21 26	15 42
40	6 15	340	21 57	15 42
50	6 47	350	22 29	15 42
60	7 18	360	22 59	15 41
80	8 21			
100	9 24			
120	10 27			
140	11 30,5			
160	12 33			
180	13 35			
200	14 38			
220	15 40,5			
240	16 44			
260	17 46			
280	18 49,5			

Mean 15 41,93

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

313,98 sec.

In the Garden of the Observatory at Paris: April 30th, 1827.

Observer, Captain SABINE. Therm. 77°. Chron. MOLYNEUX No. 407. Rate, Mean Time.

EXP. 25. NEEDLE A. Hour 3½ P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	33 29,2	300	45 33,6	12 04,4
10	33 53,6	310	45 58	12 04,4
20	34 18	320	46 22	12 04
30	34 42,8	330	46 46	12 03,2
40	35 07,2	340	47 10,4	12 03,2
50	35 31,2	350	47 34,4	12 03,2
60	35 55,6	360	47 58,4	12 02,8
120	38 20,4			
180	40 44,8			
240	43 09,2			

Mean....12 03,6

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

241,2 sec.

EXP. 26. NEEDLE B. Hour 3 P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	1 41,6	300	18 37,2	16 55,6
10	2 16	310	19 41,2	16 55,2
20	2 50,4	320	19 45,2	16 54,8
30	3 24,8	330	20 18,8	16 54
40	3 58,8	340	20 52,4	16 53,6
50	4 33,2	350	21 26,0	16 52,8
60	5 07,2	360	22 00,4	16 52,2
100	7 22,8			
140	9 37,6			
180	11 52,8			
220	14 07,6			
280	17 30			

Mean....16 54,03

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

338,01 sec.

EXP. 27. NEEDLE XI. Hour 5 P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	350 Vib^{ns} in
	m s		m s	m s
0	58 43,2	350	16 31,2	17 48
10	59 14,4	360	17 01,6	17 47,2
20	59 45,2	370	17 32	17 46,8
30	00 16	380	18 02,4	17 46,4
40	00 46,8	390	18 32,8	17 46
50	01 17,2	400	19 03,2	17 46
60	01 48	410	19 33,6	17 45,6
120	04 51,2			
180	07 54,4			
200	08 55,2			
220	09 56			
240	10 57,2			
260	11 58			
280	12 58,8			
300	14 00			
320	15 00,8			
340	16 01,2			

Mean....17 46,57

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

304,734 sec.

EXP. 28. NEEDLE VIII. Hour 5½ P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	31 21,2	300	44 48,4	13 27,2
10	31 48	310	45 15,2	13 27,2
20	32 15,6	320	45 42	13 26,4
30	32 42,8	330	46 09,2	13 26,4
40	33 10	340	46 35,6	13 25,6
50	33 36,8	350	47 02,4	13 25,6
60	34 04	360	47 29,6	13 25,6
80	34 58			
100	35 51,6			
120	36 45,2			
140	37 39,3			
160	38 32,8			
180	39 26,4			
200	— —			
220	41 13,6			
240	42 07			
260	43 01,2			
280	43 54,4			

Mean....13 26,286

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

268,76 sec.

In the Garden of the Observatory at Paris: May 10th, 1827.

Observer, Captain Sabine. Therm. 62°. Chron. Molyneux No. 407. Rate, Mean Time.

Exp. 29. Needle X. Hour 5 P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	10 52,4	300	26 55,2	16 02,8
10	11 25,2	310	27 27,2	16 02
20	11 57,6	320	27 59,2	16 01,6
30	12 30	330	28 30,8	16 00,8
40	13 02,4	340	29 02,8	16 00,4
50	13 34,4	350	29 34,8	16 00,4
60	14 06,8	360	30 06,8	16 00
80	15 11,2			
100	16 15,2			
120	17 19,2			
140	18 23,2			
160	19 27,2			
180	20 31,6			
200	21 35,6			
220	22 39,6			
240	23 43,6			
260	24 47,2			
280	25 51,2			

Mean....16 01,14

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

320,38 sec.

Exp. 30. Needle IV. Hour 5½ P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	39 57,2	300	56 32	16 34,8
10	40 31,2	310	57 04,8	16 33,6
20	41 04,4	320	57 38	16 33,6
30	41 38	330	58 11,2	16 33,2
40	42 11,2	340	58 44,4	16 33,2
50	42 44,4	350	59 17,2	16 32,8
60	43 18	360	59 50,4	16 32,4
80	44 25,2			
100	45 31,2			
120	46 37,2			
140	47 43,6			
160	48 49,6			
180	49 56			
200	51 02,4			
220	52 08			
240	53 14			
260	54 20			
280	55 26			

Mean....16 33,37

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

331,12 sec.

In the Garden of the Horticultural Society at Chiswick: June 11th, 1827.

Observer, Captain Sabine. Therm. 69°. Chron. Molyneux No. 407. Rate, Mean Time nearly.

Exp. 31. Needle IV. Hour 3½ P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	45 04,6	300	62 15,2	17 11,6
10	45 39,6	310	62 49,6	17 10
20	46 14	320	63 23,6	17 09,6
30	46 48,4	330	63 57,6	17 09,2
40	47 23,4	340	64 32	17 08,6
50	47 57,6	350	65 06,8	17 09,2
60	48 32	360	65 41,2	17 09,2
80	49 41,2			
100	50 50			
120	— —			
140	53 07,6			
160	— —			
180	55 24,8			
200	56 33,2			
220	57 41,6			
240	58 50			
260	59 58,4			
280	61 05,6			

Mean....17 09,63

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

343,21 sec.

Exp. 32. Needle VIII. Hour 1½ P.M.

Vibns.	Time.	Vibns.	Time.	300 Vibns in
	m s		m s	m s
0	44 43,2	300	58 38	13 54,8
10	45 11,6	310	59 06	13 54,4
20	45 39,6	320	59 34,4	13 54,8
30	46 07,6	330	60 01,6	13 54
40	46 35,6	340	60 29,6	13 54
50	47 03,6	350	60 56,8	13 53,2
60	47 31,6	360	61 24,8	13 53,2
80	48 27,6			
100	— —			
120	50 18,8			
140	51 14,4			
160	52 10,4			
180	53 05,6			
200	54 01,2			
220	54 56,8			
240	55 52,4			
260	56 48			
280	57 43,2			

Mean....13 54,06

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

278,02 sec.

In the Garden of the Horticultural Society at Chiswick, near London: June 11th, 1827.

Observer, Captain Sabine. Therm. 69°. Chron. Molyneux No. 407. Rate, Mean Time nearly.

Exp. 33. Needle XI. Hour $3\frac{1}{2}$ P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	21 00,4	300	36 48	15 47,6
10	21 32,4	310	37 19,2	15 46,8
20	22 04,4	320	37 50,8	15 46,4
30	22 36	330	38 22,4	15 46,4
40	23 08	340	38 53,6	15 45,6
50	23 39,6	350	39 24,8	15 45,2
60	24 11,2	360	39 56	15 44,8
80	25 14,8			
100	26 18			
120	27 21			
140	28 24,4			
160	29 27,6			
180	30 30,4			
200	31 33,2			
220	32 36,4			
240	33 39,6			
260	34 42,4			
280	35 45,2			

Mean....15 46,11

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

315,37 sec.

Exp. 34. Needle A. Hour 4 P.M.

Vib^{ns}.	Time.	Vib^{ns}.	Time.	300 Vib^{ns} in
	m s		m s	m s
0	48 57,2	300	01 28,8	12 31,6
10	49 22,4	310	01 53,6	12 31,2
20	49 48	320	02 18,4	12 30,4
30	49 13,2	330	02 43,2	12 30
40	50 38,8	340	03 08,4	12 29,6
50	51 03,6	350	03 43,2	12 29,6
60	51 29,2	360	03 58,4	12 29,2
80	52 19,2			
100	53 09,2			
120	53 59,2			
140	54 49,2			
160	55 39,2			
180	56 29,2			
200	57 18,8			
220	58 08,8			
240	58 58,8			
260	59 48,8			
280	00 38,8			

Mean....12 30,23

Whence the Mean Time of 100 Vibrations between the Arcs of 30° and 5°

250,07 sec.

II. *On the resistance of fluids to bodies passing through them.* *By* JAS. WALKER, *Esq. F.R.S.E.* *Communicated by* DAVIES GILBERT, *Esq. M.P. V.P.R.S.*

Read May 31, 1827.

THE principal object of this Paper is to explain a mode which I have taken to measure the resistance of fluids to bodies passing through them. It is, I believe, new; and being more simple and less subject to error than any yet adopted, I have thought it my duty to offer it to the Royal Society, together with the results of the experiments I have made up to the present time. I intend to continue the experiments in a boat which is building for the purpose, with some improvement in the machine, during the ensuing summer, the only season in which it can well be done, nearly a perfect calm being necessary for making them with accuracy. The machinery is of very easy construction, and the description of it may, I hope, lead others to follow the example, and to prosecute the inquiry in the same manner with surfaces of various forms and sizes.

The resistance of fluids has long formed an interesting subject, and has lately acquired a new importance from the introduction of steam in navigation, rendering the ratio between power and velocity essentially necessary to be known. The comparison of canals with rail-roads, to which public attention has of late been much directed, depends also chiefly upon the ratio between the resistance and velocity by each of those modes of conveyance. A question connected with this latter subject, to which my attention has been professionally called, led me to make the experiments I am about to detail.

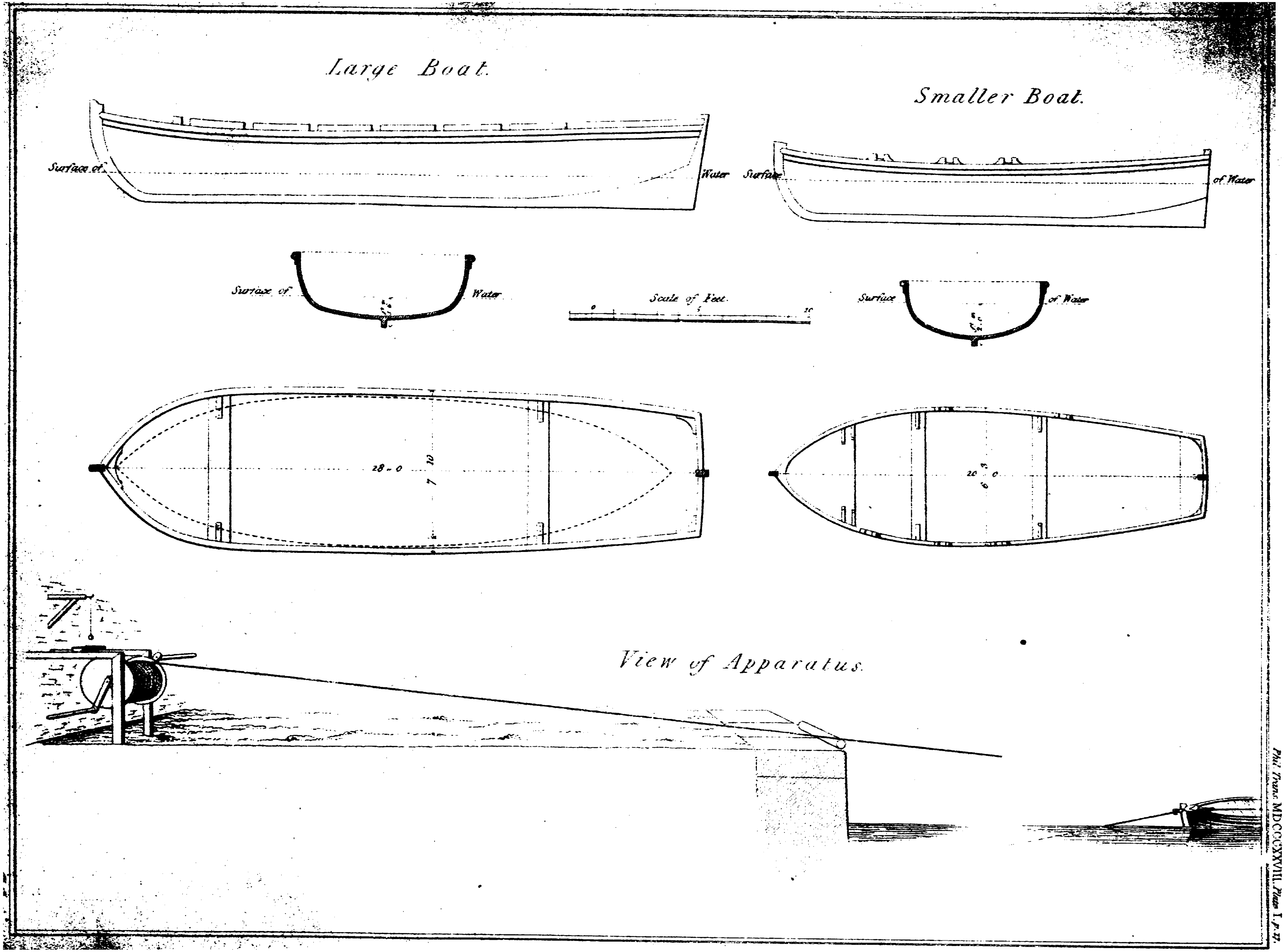
It has been demonstrated and proved in the most satisfactory manner, by various experiments, that the resistance from friction to a carriage upon a road or rail-road is the same at all velocities. I know, therefore, that the same strain upon a waggon which has the effect of moving it upon a rail-road at the rate of one mile per hour, will (after the inertia is overcome) be indicated at any other velocity at which the power is made to move; but I have not found any theory or experiment by which, after knowing the strain upon a boat moving at the rate of two miles per hour, I have been able to fix satisfactorily the strain that is exerted upon it when moving at the rate of four miles per hour.

The resistance of the fluid *per se* increases in the duplicate ratio of the velocity.—Experiment has amply confirmed this theory in the abstract; but there are other elements of resistance caused by viscidity, by friction, by the accumulation of the water in front and the depression towards the stern of the boat, for which our ignorance of the laws which govern the internal motion of the fluid has prevented any correct theory from being suggested; and the experiments, from their disagreement, and from the way in which they have been made, have not done much to supply the defect.

The most important experiments upon this subject are those of the French Academy in 1776 and 1778, conducted by Bossut and others, and those that were made by the London Society for the Improvement of Naval Architecture between 1793 and 1798.

The French experiments of 1776 were made by means of boxes six feet in length (French measure), one foot wide, and two feet deep, or by the models of ships, of the same length, and nineteen inches wide; the depth of immersion varied from seven to sixteen inches; the velocity and resistance were calculated by the time of passing over fifty feet with uniform velocity. The motion was communicated by means of a silken cord two lines and a half in diameter, one end of which was attached to the float, while the other end was passed under a pulley or sheave, and then over another sheave at the height of seventy-six feet, when the weights were fastened to it.

The moving power does not appear in any case to have exceeded twenty-four pounds, nor the velocity two miles and a half per hour; and with those velocities the friction was considered so small as scarcely to be sensible. The general result was, that the resistance is in the duplicate ratio of the velocity; but the small velocities, the short distance, the friction of the sheaves, and the varying friction of the line dragged through the water, as well as the small sizes of the bodies themselves, have appeared to me objections to the application of the results of these experiments, especially to larger bodies and to higher velocities.



Large Boat.

Smaller Boat.

View of Apparatus.

The principal object of the experiments which were made by **Bossut** and **Condorcet** in 1778, was to ascertain the difference of resistance to bodies of different forms: they appear to have been made with great care, but with machinery of nearly the same description as those of 1776, and subject, as far as respects what I had in view, to the same objections as the former ones; only that the bodies were somewhat different in size, some of them being two feet and others four feet wide, with two feet depth of immersion.

The models which the London Society used for their experiments, so far as they have been published, were of various lengths, but all one foot broad and one foot deep; and either sunk considerably under the surface, and held there by bars attached to a floating body, or sunk until their upper surfaces were just level with the water. These were dragged across the water in the Greenland (now the Commercial) Dock, by means of a line passed under a sheave to the top of a triangle of poles, or shear legs, sixty feet high, thence through a system of pulleys, from which the box that contained the weight was suspended.

The friction and rigidity of this machinery and line were important, when the small size of the body to be moved is considered;—it appears that it amounted in most cases to thrice the calculated resistance of the body. A very small error in deducting for this must have been fatal to the accuracy of the experiment; and although every pains appear to have been taken to ascertain the deduction to be made, it is extremely difficult to get at it in all cases with the necessary correctness. It does not appear that the friction between the water and the rope was taken into account: this alone, in so great a length, must have been considerable; and not only so, but varying in extent in the same experiment, as the line became shorter, and different also in each experiment, according to the velocity.

My object has been to get rid of the liability to error from the above causes, and to show at one view the amount of all the resistances opposed to the body under different velocities: but to show those resistances without mixing them with the friction of the line through the water, or of the machinery.

The accompanying drawing will give a correct idea of the plan I took. The experiments were made in the middle of the East India Import Dock, which is 1410 feet in length, 560 feet wide, and 24 feet deep; so that there was no resistance from the sides or bottom of the dock. A spring weighing-machine was fixed near the bow of the boat, the dial laid horizontally, so as to be easily seen by a person on board; one end of a line three-eighths of an inch in diameter was attached to the hook of the spring, the other end was carried ashore and attached to a reel or barrel three feet in diameter, the frame of which was firmly fixed in the ground, and the handles of sufficient length for the necessary number of men to turn the barrel. The velocities were calculated from the time of passing through 176 yards, or one-tenth of a mile; but to obtain uniform velocity, the boat was at each experiment drawn over twice the length, and the 176 yards taken in the middle of the distance by two marks upon the line. The time between the two marks coming to the edge of the dock was carefully noted by a person stationed there for the purpose. Three persons at least were on board the boat;—one to read off the strain shown upon the dial every two seconds, one to write them down, and a third to steady the boat. An exact uniformity of motion by the men at the handles was obtained, after a little practice, by means of a pendulum varying in length (as a quick or slow motion was required) hung up in sight of the men, by the oscillations of which they regulated the revolution of the handles.

It will easily be seen, that although the men who worked the barrel had to overcome the resistance arising from friction of the line through the water, and of the bearings of the barrel, the weights or strain marked by the hand or index of the dial on board the boat measured the resistances to the boat only.

The experiments in the Table A were made in a full built boat loaded with two tons two cwt., exclusive of the men. The length of the boat upon the surface of the water was eighteen feet six inches; the breadth, six feet; the depth of immersion, two feet; the whole depth of the boat being three feet, leaving one foot above water, and the greatest immersed cross section nine feet.

The experiments in Table B were made in the same boat as those of Table A, with about two tons of ballast.

'Column 1. is the number of seconds employed in passing 176 yards, or one-tenth of a mile.—Column 2. the velocity per hour expressed in miles and decimals of a mile.—Column 3. the actual measure of resistance or strain shown upon the dial of the machine.—And Column 4. the resistance calculated upon the ratio of the square, taking one of the experiments as a standard.

Table A.

Number of Experiments.	1. Seconds in passing 176 yards.	2. Miles and decimals per hour.	3. Actual resistance in pounds.	4. Calculated resistance in pounds, taking No. 5. as standard.
1	124	2,903	15,75	15,04
2	85	4,235	39,50	32,01
3	146	2,465	10,00	10,85
4	140	2,571	11,00	11,80
5	145	2,483	11,00	11,00 standard
6	140	2,571	12,00	11,80
7	120	3,000	14,00	16,06
8	120	3,000	14,00	16,06

Table B.

Number of Experiments.	1. Seconds in passing 176 yards.	2. Miles and decimals per hour.	3. Actual resistance in pounds.	4. Calculated resistance in pounds, taking No. 4. as standard.
1	79	4,557	44,85	38,59
2	80	4,500	40,32	37,64
3	93	3,871	28,07	27,85
4	94	3,830	27,26	27,26 standard
5	78	4,165	49,34	39,59
6	141	2,553	10,03	12,12
7	142	2,535	9,47	11,94
8	142	2,535	9,52	11,94
9	142	2,535	10,10	11,94
10	143	2,517	9,23	11,78

As a number of the above velocities are nearly the same, I have averaged the results. The average resistance of Nos. 7, 8 and 10 (low velocities), is 9,41 pounds: the corresponding velocity, 2,529 miles. The average resistance of Nos. 1 and 2 (high velocities), is 42,59 pounds: the velocity, 4,529 miles per hour. The resistance calculated in the duplicate ratio of the velocities would be 38,11 pounds in place of 42,59.—Again, the same low velocities, Nos. 7, 8 and 10, compared with No. 3 (velocity 3,871), would give, by calculation, a resistance 22,04, while the actual resistance was 28,07.

The experiments in Table C were made in a boat twenty-eight feet in length (See the drawing); but being light, and more exposed to the action of the wind, the smaller boat already described was afterwards substituted.

Table C.

Number of Experiments.	1. Seconds in passing 176 yards.	2. Miles and Decimals per hour.	3. Actual resistance in pounds.	4. Calculated resistance in pounds, taking No. 1. as standard.
1	162	2,222	13,08	13,08 standard
2	187	1,925	11,00	9,82
3	89	4,045	47,26	43,34
4	87	4,138	49,50	45,35
5	137	2,609	18,10	18,02

A few experiments were also made in a small Thames wherry, the distance 80 yards. The average velocity of four of these experiments was 106 yards per minute, or 3,60 miles per hour; resistance 10,4 pounds: and of four others, the velocity was 160 yards per minute, or 5,5 miles per hour; and the resistance 29 pounds; while the ratio of the square of the preceding four experiments would have given 24,27 pounds.

The smaller excess beyond the calculated resistance in the larger boat and the wherry, as compared with the other boat, I consider to have been owing to the form of the bow of those boats causing less heaping of the water in front of them.

In almost every experiment, therefore, the resistance shows an increase amounting to the square of the velocity; but where the velocity is considerable, the resistance follows a still higher ratio, and this in open water. In narrow canals the increase must be considerably greater.

The excess beyond the square is to be attributed in a great degree to the raising of the water at the bow in high velocities, and to the depression at the stern. This does not take place until the velocity is considerable; and in the low velocities of the French experiments it could not be so important.

The boats which I used were taken without any previous preparation; my object being to collect all the resistances to a boat in the ordinary state when in use; and the results have satisfied me, that, as respects the comparison of canal navigation with rail-roads, the rapid increase of resistance upon water brings the rail-road to a par with it at a lower velocity, than if the resistance upon canals were as the squares of the velocities, as hitherto calculated.

If, with a speed of two miles and a half per hour, thirty tons upon a canal be equal to seven tons and a half upon a level rail-road, a speed of five miles per hour would, upon the principle of the square, bring the rail-road and canal to an equality; while the result of the experiments makes the two modes of conveyance equal, considerably under four miles per hour, and gives the rail-road the decided preference at all higher velocities.

It will be observed, from the manner in which former experiments have been made, that the weights employed have been in proportion to the resistance; that is at least to the square of the velocity. The way in which I made the experiments, required a weight or power at least in the ratio of the cube. Thus if the weight put into the scale in the former experiments produced a velocity 1, a weight 4 produced a velocity 2; while in my experiments, if one man at the wheel produced a velocity 1, eight men (even without regarding the excess beyond the commonly received theory) were required to produce a velocity 2. The cause is evident; and would scarcely deserve mentioning, but that it affords a simple way of removing the confusion I have heard and seen expressed on the subject of the ratio of the square and the cube. As the weight 4 descended in the scale with twice the velocity, the expense of power per second was as 8, or as the cube; but the distance (50 or 96 feet) being performed in half the number of seconds, brought the quantity of power exerted to pass through the given distance back to 4. And in my case, as one man overcame the resistance 1, four men would be required to overcome the resistance 4 with the same velocity: but the velocity being twice the former velocity, it required twice the power, or eight men; the distance was, however, gone over in half the time, so that the expense of power, by doubling the velocity, was only as 4 to 1, as in former experiments. So in overcoming the friction upon a road or rail-road, if a fixed engine of one-horse power move a waggon upon a level road one mile per hour, a two-horse power, acting through a wheel and pinion, or otherwise, will be required to double the speed, although the friction at all velocities is uniform: and *cæteris paribus*, the quantity of power required for moving a given weight a fixed distance upon land, is the same at all velocities; while upon water the quantity increases considerably beyond the square of the velocity.

The following statements with velocities at two and four miles per hour upon a road and upon water, show at one view the whole of the points.

Land Experiments.

Velocity per hour	2 miles
Distance passed over	2 miles
Power of engine required	1-horse
Time occupied	1 hour
Quantity of mechanic power expended	1

Water Experiments.

Velocity per hour	2 miles
Distance passed over	2 miles
Power of engine required	1-horse
Time occupied	1 hour
Quantity of mechanic power expended	1

Land Experiments.		*Water Experiments.*	
Velocity per hour	4 miles	Velocity per hour	4 miles
Distance passed over	2 miles	Distance passed over	2 miles
Power of engine required	2-horse	Power of engine required	8-horse by theory, more by experiment
Time occupied	½ hour	Time occupied	½ hour
Quantity of mechanic power expended	1	Quantity of mechanic power expended	4 by theory, more by experiment

But the most remarkable difference between the experiments I have made, and the others to which I have referred, is the absolute measure of resistance. By the French experiments, a square foot with a velocity 1,854 mile per hour, had a resistance of 7,25 pounds. My experiments with a midship section of nine feet superficial, and the same velocity, make the resistance eleven pounds, or only 1,22 per foot superficial. The difference between a flat opposing surface and the form of the boats I used, will account in part for this great variation: but on comparing another experiment of Bossut's, in which the front or prow is an angle of 96°, I found the resistance nine pounds per foot, with a velocity under two miles and one-third per hour; which exceeds my experiments in fully as great a proportion as the former: I am therefore disposed to think that much of the difference is to be ascribed to the way in which the experiments have heretofore been made, although it is certainly difficult to suppose so very great a disagreement from that cause alone. I have proved the accuracy of the weighing-machine I used; and the mode of making the experiments is so simple, that I think there is little room for error. I can only promise to take advantage of the approaching season, and to communicate without prejudice the results of any experiments I may make in confirmation or correction of what I have already done.

III. *On the corrections in the elements of* DELAMBRE'S *Solar Tables required by the observations made at the Royal Observatory, Greenwich. By* GEORGE BIDDELL AIRY, *Esq. M.A., Fellow of Trinity College Cambridge, and Lucasian Professor of Mathematics in the University of Cambridge. Communicated by* JOHN FREDERICK WILLIAM HERSCHEL, *Esq. V.P.R.S.*

Read December 6, 1827.

THE attention of the Board of Longitude having been directed to the state of the Solar Tables used in the construction of the Nautical Almanac, the Astronomer Royal was requested to furnish the Board with a comparison of the computed and observed Right Ascensions of the Sun since the erection of the new transit instrument at Greenwich: and I was desired to examine the discrepancies with a view to the discovery of the errors in the elements of the tables. The papers containing this comparison I received at the beginning of June last; and in the last summer, as soon as other engagements permitted, I undertook the laborious work of examining the discordances. The corrections of the elements determined by these calculations agree in general with those that have been obtained from other observations; but in one particular, and that an important one, there is a very remarkable difference. The results of such an inquiry will perhaps be acceptable to the Royal Society; and the singularity of the conclusion which I have mentioned, will make it necessary for me to describe the manner in which I have obtained it.

The number of observations from which this comparison is made is 1212, commencing on July 30, 1816, and terminating on December 30, 1826. The only interruption of any importance is one of about three months, from February 4, to May 22, 1825. These do not include all that are given in the Greenwich Observations, but only those which are likely to have been least affected by irregularities of the clock, &c. in consequence of the observation of standard stars at no great interval. As far as the end of 1820 the observations are reduced by Dr. Maskelyne's catalogue; after that time they are reduced by Mr. Pond's catalogue of 1820, in which the right ascensions of the stars are increased $0'',31$, of time. Though there is sometimes a disagreement in the errors for consecutive days amounting to three or four tenths of a second of time, (undoubtedly produced partly by the errors of observation and partly by those in the calculation of the Nautical Almanac,) yet when the skill of the observers and the excellence of the instrument are considered, I believe it will be allowed that this mass of observations is equal to any that has been used for the purpose of correcting the tables.

A slight inspection of these errors was sufficient to indicate that a correction of the epochs of the sun's longitude and of the longitude of the perigee, with perhaps an alteration of the equation of the centre, would bring the calculated place for any one year sufficiently near to the observed place; and with these corrections only I commenced my calculations. But, upon comparing the discrepancies for different years, I found that there was certainly some other source of irregularity; and such could be found only in the erroneous mass assigned to some of the planets. The masses of Venus and Mars being the only ones which produce any sensible effect on the Earth's motion, and which can be measured in no other way, I supposed them subject to error, and with these five assumed corrections the greatest part of the calculations has been made. A more critical examination showed that there was an error in the assigned mass of the moon; but the rapidity of variation of the lunar inequality allowed me to determine this correction by a more simple process.

Suppose now O to be the observed error of the tables, the sun's observed place being reduced by Dr. Maskelyne's catalogue; e the error of Maskelyne's place of the equinox in Æ, or the quantity by which the right ascensions of all the stars in his catalogue ought to be increased, both expressed in seconds of time. Then $O-e$ is the real error of the tables in Æ. After January 1st, 1821, when the observations are reduced by Mr. Pond's catalogue, in which the right ascensions are increased by ,31 of time, the error of the tables is $O+,31-e$. The corresponding errors in longitude, expressed in seconds of space, are $15 \sec 23° 28' \times \cos^2 \text{dec} \times \overline{O-e}$; and $15 \sec 23° 28' \times \cos^2 \text{dec} \times \overline{O+,31-e}$. Now if the proper corrections were applied to the elements of the tables, the sum of the quantity just found, and the alteration produced in the longitude by those corrections, would, if the observations were accurate, be nothing; and if there be no constant cause of error in the observations, upon adding a great number of quantities thus formed, the errors may be expected nearly to destroy each other, and the sum may be assumed equal to nothing. Let X be the number of seconds of space by which the epoch of the sun's longitude ought to be increased; Y the increase in seconds of the epoch of the longitude of perigee: Z the increase which must be made in the greatest equation of the centre: suppose the mass of Venus to be increased in the ratio of $1 : 1 + V$, and that of Mars in the ratio of $1 : 1 + M$. Then $X - Y$ is the increase of the mean anomaly. Now the tables contain the alteration in the equation of the centre for an increase of 10′ in the mean anomaly, and for a diminution of 17″,177 in the greatest equation of the centre. The sun's true longitude then being taken from the Nautical Almanac, and his true anomaly found by subtracting the longitude of the perigee, the mean anomaly corresponding was found in the tables, and the alterations of the equation of the centre for + 10′ in mean anomaly and − 17″,177 in the greatest equation were taken out: call them *a* and *b*. By the alteration of epochs and of the equation of the centre, the tabular longitude would be increased by $X + \frac{a \times (X-Y)}{600} - \frac{bZ}{17{,}177}$. The perturbations of Venus and Mars are increased each by a constant to make them always positive; (DELAMBRE has not mentioned the values of the constants, but they appear to be respectively 16″6, and 6″,5; they are subtracted from the equation of the centre): call these *c* and *d*, and let *f* and *g* be the tabular perturbations. Then the real perturbations are $f - c$ and $g - d$; and by increasing the masses of Venus and Mars, the sun's tabular longitude would be increased by $V\,(f - c)$ and $M\,(g - d)$. If then we neglect for the present the lunar equation, which we may do, since every group of equations will comprehend several lunations, we shall have a series of equations similar to the following, each of which is true excepting the errors of observation;

$$0 = 15 \sec 23^\circ 28' \times \cos^2 \mathrm{decl} \times \overline{\odot - e} + X + \frac{a(X-Y)}{600} - \frac{bZ}{17{,}177} + V(f-c) + M(g-d).$$

Dividing this by 15 sec 23° 28′, and putting $\frac{X}{15 \sec 23^\circ 28'} = x$, $\frac{X-Y}{600 \times 15 \times \sec 23^\circ 28'}$

$= y, \frac{-\mathrm{Z}}{17{,}177 \times 15 \times \sec 23^\circ 28'} = z, \frac{\mathrm{V}}{15 \sec 23^\circ 28'} = v, \frac{\mathrm{M}}{15 \sec 23^\circ 28'} = m$, the equation becomes

$$0 = \cos^2 \text{decl} \times \overline{\odot - e} + x + ay + bz + v(f-c) + m(g-d).$$

The equations thus formed were to be divided into groups of two kinds: one kind in which the coefficient of one of the unknown quantities was large, another in which it was small or negative: and by subtracting the sum of one group from the sum of the other, an equation would be obtained in which the coefficient of that quantity would certainly be large, and in which the other coefficients probably would not be large. As there was some uncertainty respecting the values of c and d, it appeared desirable to eliminate them from all the equations but one: this was done by dividing the equations into groups of equal numbers and subtracting one from the other. Thus the equations were divided into eleven groups containing 606 equations, in which the value of a was positive or $> -3{,}8$; and eleven groups containing 606 equations, in which a was negative and $< -3{,}8$; their difference gave this equation:

$$(\beta)\ldots 0 = +85{,}484 - e \times 9{,}382 + y \times 15048{,}9 - z \times 368{,}58 + v \times 1026{,}7 + m \times 598{,}4.$$

They were again divided into eleven groups containing 606 equations, in which the value of b was positive and $> 2{,}5$; and eleven groups containing 606 equations, in which b was $< 2{,}5$ or negative: their difference gave

$$(\gamma)\ldots 0 = -22{,}785 - e \times 13{,}832 - y \times 174{,}5 + z \times 13319{,}28 + v \times 517{,}3 + m \times 636{,}0.$$

They were then divided into thirteen groups of 606 equations, in which the value of f exceeded 15,4; and thirteen groups of 606 equations, in which f was less than 15,4: their difference gave

$$(\delta)\ldots 0 = +61{,}465 - e \times 1{,}536 + y \times 2905{,}7 + z \times 95{,}50 + v \times 6655{,}1 + m \times 223{,}2.$$

Similarly, they were divided into nine groups of 606 equations, in which g exceeded 6,3; and nine groups in which g was smaller: from their difference

$$(\epsilon)\ldots 0 = +65{,}860 + e \times 6{,}678 + y \times 5706{,}9 + z \times 3944{,}46 + v \times 439{,}9 + m \times 2307{,}2.$$

Lastly, by adding together all the equations,

$$(\alpha)\ldots 0 = -177{,}278 - e \times 1118{,}282 + (x - vc - md) \times 1212 - y \times 1744{,}3$$
$$+ z \times 1418{,}96 + v \times 19319{,}1 + m \times 7519{,}8.$$

As it was probable that the epoch of the sun's longitude ought to be altered, it was to be expected that the secular motion of the tables was incorrect. I had supposed, however, that this error might be neglected in the investigations, and that the results would be sufficiently accurate for the mean time of the observations: but an examination of the groups showed that this was not the case. The equations in which the coefficients of x and those of y were alternately positive and negative, as well as those in which the coefficients of v were alternately great and small, were distributed with tolerable uniformity over the several years. But it was not so with those in which the coefficients of m were alternately large and small. A single group in which the coefficients of m were large, extended over nearly two years at the beginning of the period of the observations, and comprehended 219 observations. The equation then (ϵ) intended to have the coefficient of m large, would be of the same nature as if the sum of the equations for several years were subtracted from the sum of the equations for several years previous; and would therefore be much affected by the error in the secular motion. This was taken into account in the following manner: let S be the number of seconds of space by which the secular motion ought to be increased; and let X now represent the correction of the epoch for 1816. Then in q years after 1816 the tabular longitude would have been greater, had the secular motion been correct, by $\frac{q\mathrm{S}}{100}$; and in r years by $\frac{r\mathrm{S}}{100}$. If in this interval N observations had been made, distributed almost uniformly over the interval, the sum of all the increments of the tabular longitude would have been nearly $\frac{\mathrm{N}}{2}\left(\frac{q\mathrm{S}}{100}+\frac{r\mathrm{S}}{100}\right)=\frac{\mathrm{S}}{200}\cdot\mathrm{N}(q+r)$ in seconds of space. By this quantity the errors of the tables (in the original equations containing X, Y, &c.) ought to be increased: and therefore, in the equations containing x, y, &c. they ought to be increased by $\frac{\mathrm{S}}{3000\,.\,\sec 23^\circ\,28'}\times\mathrm{N}(q+r)$. Let $\frac{\mathrm{S}}{3000\,.\,\sec 23^\circ\,28'}=p$: then the first term of each group, (in which N is the number of equations, and q and r the years and fractions of years from the beginning of 1816 to the first and last observation respectively, of that group,) must be increased by $p\times\mathrm{N}(q+r)$. Applying this to all the groups, it is found that (α) ought to be increased by $+\,14051\,.p$; (β) by $-\,220\,.p$; (γ) by $+\,393\,.p$; (δ) by $-\,241\,.p$; and (ϵ) by $-\,3817\,.p$.

Solving the equations thus augmented, we find

$$\begin{array}{rl}
x - vc - md = & {,}37718 + e \times {,}9696 - p \times 24{,}182 \\
y = & -{,}0043027 + e \times {,}000964 - p \times {,}0697 \\
z = & {,}0029488 + e \times {,}001419 - p \times {,}1278 \\
v = & -{,}006674 + e \times {,}000049 - p \times {,}0004 \\
m = & -{,}021682 - e \times {,}00775 + p \times 2{,}042
\end{array}$$

And (supposing $c = 16{,}6$, $d = 6{,}5$), $x = {,}12547 + e \times {,}9200 - p \times 10{,}915$; whence

$$\begin{array}{rl}
X = & +\ 2{,}0518 + e \times 15{,}045 - S \times {,}05458 \\
Y = & +\ 44{,}2690 + e \times 5{,}589 + S \times {,}1545 \\
Z = & -\ {,}8283 - e \times {,}399 + S \times {,}01096 \\
V = & -\ {,}1091 + e \times {,}0008 - S \times {,}000002 \\
M = & -\ {,}3546 - e \times {,}1267 + S \times {,}01021
\end{array}$$

in which X, Y, Z, and S are expressed in seconds of space, and *e* in seconds of time.

The Astronomer Royal, in his latest catalogue, has made $e = 0'',20$. To determine S we have the following data. From the researches of M. BURCKHARDT (Conn. des Tems, 1816,) it appears that the correction of the epoch in 1783, using MASKELYNE's catalogue, was $0'',25$: in 1801, $0'',8$. And from the expression above for X it appears that the correction, using MASKELYNE's catalogue, was + 2,05 in 1816 + 5,458 years, or in the middle of 1821. The comparison of this with the correction for 1783 gives $S = 4'',7$: the comparison with that for 1801 gives $S = 6'',1$. Now if there be in the sun's motion any inequality of long period, the value of S which is wanted here is not the real increase of mean secular motion, but that which, independent of the inequalities taken into account in the tables, but including all others, applies to the period of the observations. I have therefore taken $S = 6'',0$. After these substitutions I find that

The epoch for 1816 ought to be increased by $4'',734$; or, more exactly, free from any uncertainty respecting the value of S, the epoch for 1821,5 ought to be increased by $5'',061$.

The epoch of the perigee ought to be increased by $46'',3$.

(These epochs are to be measured from the equinoxial point adopted by Mr. POND in his catalogue of 1826.)

The greatest equation of the centre ought to be diminished by 0″,84.

The mass of Venus ought to be reduced in the proportion of 10000 : 8911, or 9 : 8 nearly.

The mass of Mars ought to be reduced in the proportion of 10000 : 6813, or 22 : 15 nearly.

Hitherto I have not considered the possible error in the coefficient of the lunar equation. The variations of this equation are so much more rapid than any of the others, that the other corrections may be determined independently of it, and it can be determined independently of them, and even without reducing the errors to errors of longitude. I have merely arranged the observed errors in Æ from the middle of 1816 to the end of 1820 in two groups, one comprehending all the observations between new moon and full, and the other all the observations between full moon and new; from each group I have found a mean, and have taken the difference of the means. The same has been done from the beginning of 1821 to the end of 1826. Thus, to the end of 1820,

Mean of 248 errors between new moon and full = − ,0825.
Mean of 265 errors between full moon and new = − ,1609.
Excess of the former + ,0784 in seconds of time.

After 1820.

Mean of 374 errors between new moon and full = −, 4493.
Mean of 325 errors between full moon and new = − ,5445.
Excess of the former + ,0952.
Mean of the whole ,0881 in seconds of time, equivalent to 1″,322 of space.

To find the alteration which this requires in the coefficient of the lunar equation, suppose k to be that alteration: then the correction to the sun's longitude would be very nearly k × sin diff. long. of sun and moon. Now in the number of observations that we have taken, we may suppose that the difference of longitudes of the sun and moon has had different values between 0° and 360° without any remarkable preponderance of any particular values. To reduce this to calculation, suppose while the angle increased from o to π,

n observations were made at the intervals $\frac{\pi}{n}$: then we must find the mean of the quantities $k \sin \frac{\pi}{n}$, $k \sin \frac{2\pi}{n}$, &c. up to $k \sin \pi$: in other words we must find the value of $\frac{k}{n} \Sigma \sin \frac{x\pi}{n}$. Now $\Sigma \sin \frac{x\pi}{n} = -\frac{\cos \overline{x - \frac{1}{2}} \cdot \frac{\pi}{n}}{2 \sin \frac{\pi}{2n}}$: which from $x = 1$ to $x = n + 1$ is $\frac{2 \cos \frac{\pi}{2n}}{2 \sin \frac{\pi}{2n}} = \frac{1}{\tan \frac{\pi}{2n}}$: and the mean $= \frac{2k}{2n \tan \frac{\pi}{2n}}$, which when n is very great becomes nearly $= \frac{2k}{\pi}$. This then is the mean quantity by which the longitudes between new moon and full, so far as they depend on this equation, are too great, and similarly $\frac{2k}{\pi}$ is the mean quantity by which the longitudes between full moon and new are too small. Taking the difference then, $\frac{4k}{\pi} =$ difference of mean errors $= 1'',322$; whence $k = 1'',04$. And since the sun's longitude, as far as it depends on this, is too great between new moon and full, at which time the lunar equation increases the longitude, it follows that the coefficient of the lunar equation ought to be diminished by $1'',04$. The coefficient in **Delambre**'s tables is $7'',5$: hence, if the moon's parallax be not altered, the quotient of the moon's mass by the moon's mass + the earth's mass is to be diminished in the ratio of 29 : 25 nearly.

If these deductions could be relied on, we should have

Mass of Venus $= \frac{1}{401211} \times$ that of the Sun.

Mass of Mars $= \frac{1}{3734602} \times$ that of the Sun.

Mass of the Moon $= \frac{1}{80,4} \times$ that of the Earth.

And the limits of the errors of **Delambre**'s tables, roughly estimated, would be as follows,

Error in epoch for 1830		$-5'',6$
Greatest error from error in place of perigee . . .	$\pm 1'',5$	
Greatest error from error in greatest equation of centre	$\pm 0\ ,8$	
Greatest error from the combination of these		$\pm 1\ ,7$

Greatest error from error in mass of Venus	± 1″,5
Greatest error from error in mass of Mars	± 1 ,9
Greatest error from error in mass of the Moon	± 1 ,0
Greatest possible negative error	− 11″,7
Greatest possible positive error	+ 0″,5

I shall now compare these results with those which have been found from an examination of some of Dr. MASKELYNE's observations.

In the Connaissance des Tems for 1816, M. BURCKHARDT has given the results of a comparison of DELAMBRE's tables with nearly four thousand of MASKELYNE's observations, extending from 1774 to 1810. The following are his most important conclusions.

1st. The correction of the epoch in 1801 was + 0″,8. In 1783, + 0″,25. In 1752, − 3″,0. The latter was found from 310 of BRADLEY's observations, and the result seems doubtful, from the uncertainty of the reductions.

2nd. The correction of the longitude of the perigee in 1783 was + 25″; in 1801 it was − 2″,7. If these places of the perigee be used, the variable part of aberration is not to be applied, in order to find the sun's apparent place.

3rd. The correction of the greatest equation of the centre in 1783 was − 0″,84; and in 1801, − 1″,23.

4th. The coefficient of the lunar equation to be diminished from 7″,5 to 6″,8.

5th. The mass of Venus to be diminished $\frac{1}{9}$th.

6th. The mass of Mars to be diminished $\frac{1}{80}$th: which produces an almost insensible effect on the sun's longitude.

The general agreement of my conclusions with those of M. BURCKHARDT is highly satisfactory. The correction of the equation of the centre and the diminution of the mass of Venus are absolutely the same: the diminution of the coefficient of the lunar equation differs very little. In the diminution of the mass of Mars there is a sensible difference: and though my equation for *m* is not so favourable for its exact determination as those for *y*, *z*, and *v*, yet I am inclined to think that M. BURCKHARDT's diminution is not sufficient. The slight disagreement in the increase of secular motion deduced from the comparison of my correction of the epoch with the two given by M. Burckhardt, (a correction which in general is liable to less uncertainty than any other,) seems to show that there is still some very small inequality in the sun's motion not included in the tables.

But our deductions as to the correction of the place of the perigee do not present the same agreement. It must be observed that the variable part of aberration is included in the longitude given by M. Burckhardt's corrected perigee. Now the effect of this variable part is the same as if the longitude of the perigee were increased by $10'',1$. Consequently M. Burckhardt's correction of the perigee ought to be diminished by $10'',1$. Thus we have,

Correction of perigee in 1783, $+\ 14'',9$
Correction of perigee in 1801, $-\ 12'',8$
Correction of perigee in 1821, $+\ 46'',3$

The motion of the perigee then appears to be of the most irregular kind. Of the accuracy of the correction for 1816, as established by Mr. Pond's observations, there can be no doubt. Independently of the very great care which has been used, by systematic checks on every part of the operations, to insure accuracy in the numerical calculations, it is sufficient to glance at the discrepancies of the observed and calculated Æ, in order to see that the longitude of the perigee must be increased. The negative errors of the tables are invariably greatest in summer. The necessity of diminishing the masses of Venus and Mars, and even of diminishing the equation of the centre, is not evident till the equations are formed: but the error and the kind of error in the place of the perigee will never be doubted by any one who has seen the observations. The equation also (β) in which the coefficient of y is large, is very favourable for its exact determination.

I can see only two ways in which this singular irregularity can be accounted for. One is by supposing that the term in the motion of the perigee which depends on the square of the time is incorrectly calculated. I have too much confidence in the accuracy of the results in the Mécanique Celeste to suppose there the existence of an error sufficiently great. The other is by supposing some yet undiscovered inequality of the form $a \,.\, \sin(b\,\theta + c)$ where θ is the sun's mean longitude and b a coefficient differing very little from unity. This I suspect to be the true cause of the discordance of theory and observation.

The corrections which I have stated as the result of this examination differ in some degree from those deduced in the Phil. Trans. for 1827, p. 65, &c. from Mr. South's observations. The smallness of the number of observations there used, and the rejection of any alteration of the planetary perturbations, are sufficient to account for this difference.

G. B. Airy.

Trinity College, Cambridge,
Oct. 3rd, 1827.

POSTSCRIPT.

I have the satisfaction of stating to the Royal Society, that since the communication of the paper above, my conjecture with regard to the origin of one of the irregularities noticed in it has been completely verified. Upon examination of the planetary theory, I find that in consequence of the action of Venus, the Earth's motion in longitude is affected with an inequality for which the expression, taking the mass of Venus as determined in this paper, is

$$2'',6 \times \sin\left\{8 \times \text{mean long. Venus} - 13 \times \text{mean long. Earth} + 39^\circ\ 57'\right\}.$$

The period of this inequality is about 240 years. This term accounts completely for the difference in the secular motions given by the comparison of the epochs of 1783 and 1821, and by that of the epochs of 1801 and 1821. From the known relations of terms in the investigations of physical astronomy, it will be seen that there must be in the expression for the Earth's longitude, terms, probably sensible, of the forms

$$A \,.\, \sin\left\{8 \times \text{mean long. Venus} - 12 \times \text{mean long. Earth} + B\right\},$$

and

$$C \,.\, \sin\left\{14 \times \text{mean long. Earth} - 8 \times \text{mean long. Venus} + D\right\};$$

and these may account for the alteration of the equation of the centre, and the irregular motion of the perigee. The earth's latitude also must be affected with similar terms. I have been prevented from calculating these terms, and from extending the former so as to include the parts depending on the secular variations of the elements, and even from examining some parts so carefully as I could wish, by the excessive labour attending these investigations. The term calculated is of the 5th order; and I believe it may be fairly stated that the labour of the calculation is twenty times as great as for the long inequality of Saturn, and far greater than for any term hitherto treated of. I shall resume the investigations as soon as I have sufficient leisure and spirits: and I propose then to lay before the Society a more detailed account of the calculation.

G. B. AIRY.

Trinity College,
December 16th, 1827.

Erratum in the Paper on Mr. SOUTH'S *observations.*

In the Phil. Trans. for 1827, page 69, line 16,—*for* 1^s 30°, 4^s 30°, 7^s 30°, 10^s 30°,—*read* 1^s 15°, 4^s 15°, 7^s 15°, 10^s 15°. This error has not affected the calculations.

IV. *Experiments to determine the difference in the length of the seconds pendulum in London and in Paris. By Captain* EDWARD SABINE, *of the Royal Artillery, Secretary of the Royal Society. Communicated by* THOMAS YOUNG, M.D., *Foreign Secretary to the Royal Society, and Secretary to the Board of Longitude.*

Read November 15, 1827.

THE length of the pendulum vibrating seconds having been measured in London by the method and apparatus of KATER, and in Paris by those of BORDA and BIOT, and the standards of linear measure of the two countries having been referred respectively to those measurements for future verification, an endeavour was made by M. ARAGO in 1817 and 1818, at the instance of the Bureau des Longitudes, to bring the lengths so measured into direct comparison with each other, by ascertaining, by means of invariable pendulums conveyed intermediately between Paris and London, the difference of length that actually exists between the pendulums at those places; which difference ought also to be that between the absolute measurements.

From a summary account of the proceedings on that occasion, published at the close of the 3rd volume of the Base du Système Métrique, we learn that from certain accidental causes therein noticed, the rates of the pendulums employed were not obtained with sufficient precision to make the result conclusive.

By the indulgence of the Duke of Wellington, Master General of the Ordnance, the leave of absence from my regiment, under which I had completed my former pendulum experiments, was continued whilst I should have the means of employing myself usefully. No better mode of doing so presented itself, with such means as were within my command, than to carry into effect a purpose which had been deemed of sufficient importance to have been recommended by the Bureau des Longitudes, and undertaken by M. ARAGO.

M. SCHUMACHER had requested me to procure for him an invariable pendulum similar to those I had employed in my own experiments, and to ascertain its rate at Mr. BROWNE's house in London, before it should be sent to him at Altona. Having communicated to M. SCHUMACHER my wish to use this pendulum in the comparison between London and Paris, I received his most ready consent; although it would occasion a delay of some months in the period of the pendulum's reaching him. My intention being also known to the Board of Longitude, I obtained permission to employ a pendulum belonging to the Board, which had been made at the same time as M. SCHUMACHER's, to replace the one formerly lent to Captain HALL, and since supplied at the request of the Russian Government, to Captain LÜTKE of the Russian Navy, on a scientific voyage to the Pacific. The Board's pendulum was marked No. 7, and M. SCHUMACHER's No. 8. Each was accompanied by an iron tripod stand, and the usual apparatus of agate planes, thermometers, &c.: and with M. SCHUMACHER's was a tripod stand of oak, designed to support the clock used in the observation of coincidences. The tripod stands of the clock and pendulums were in all respects similar to those I had used in my former experiments, which renders a particular description of them here unnecessary. The instruments were forwarded to me at Paris by Mr. JONES their maker, early in the year, so as to be in readiness to commence the experiments when the spring should be sufficiently advanced; and by the good offices of M. ARAGO they passed the Custom-house at Calais with no other inconvenience than a short delay.

From the moment that my intention was known at Paris, the utmost desire was shown by the gentlemen of the Royal Observatory to afford me every possible facility and accommodation. The Salle de la Méridienne, in which M. BIOT's experiments had been made, was placed at my disposal; and one of the pendulum stands was established, as near as its shape would permit, to the very spot in which his measurement had been made. A clock which had been previously used in pendulum experiments was supplied for the observation of coincidences; and its daily rate was ascertained with the necessary exactness by M. MATHIEU, by comparing it at intervals of twelve hours with the transit clock of the Observatory. Having assured myself by trial on the 27th of April that all parts of the apparatus were in order to commence, the dispositions being in every particular the same as those I had adopted in my former experiments, and the weather having apparently set in mild and steady, the observations were begun on the following day.

No. I. of the Tables forming an Appendix to this Paper, contains an account of the daily rate of the clock used in observing coincidences, from the 27th of April to the 10th of May inclusive, and is given precisely as I received it from M. Mathieu. In Table II. are contained the particulars of thirteen distinct determinations of the rate of pendulum No. 8 obtained by the method of coincidences. In twelve of these the knife edge of the pendulum rested on its own agate planes, and in the thirteenth experiment on those belonging to No. 7. The planes were numbered according to the pendulums to which they belonged. Of the thirteen determinations, four were obtained by M. Mathieu, four by M. Nicollet, three by myself, one conjointly by M. Nicollet and M. Savary, and one conjointly by M. Savary and myself. Corrected for the arcs of vibration and for the buoyancy of the air, and reduced to a common temperature of 58° Fahr., being the mean of all the temperatures at which they were made, the results were as follows :

Experiment 1.	M. Mathieu	85922,12 Vibrations.
Experiment 2.	Captain Sabine	85922,40 Vibrations.
Experiment 3.	M. Nicollet	85922,33 Vibrations.
Experiment 4.	M. Mathieu	85922,28 Vibrations.
Experiment 5.	M. Nicollet	85922,56 Vibrations.
Experiment 6.	Captain Sabine	85922,54 Vibrations.
Experiment 7.	M. Mathieu	85921,51 Vibrations.
Experiment 8.	M. Nicollet	85921,81 Vibrations.
Experiment 9.	Captain Sabine	85921,95 Vibrations.
Experiment 10.	M. Mathieu	85921,88 Vibrations.
Experiment 11.	MM. Nicollet and Savary	85921,90 Vibrations.
Experiment 12.	M. Savary and Captain Sabine	85921,91 Vibrations.
Experiment 13.	M. Nicollet	85922,65 Vibrations.

Table III. contains the particulars of thirteen determinations of the rate of pendulum No. 7, obtained also by the method of coincidences. In eleven of these the knife edge rested on the planes of No. 8, and in the two others on its own planes. In addition to the gentlemen who favoured me with their cooperation in the experiments with the pendulum No. 8, I had the pleasure of being joined in those with this pendulum by Captains Freycinet and

Duperrey; whose voyages round the world, specially devoted to the sciences, have done so much honour to their country and to themselves, and have contributed so largely to the extension of pendulum experiments in particular. Of the thirteen determinations,—six were obtained by M. Mathieu, three by M. Nicollet, one by M. Savary, one by Captain Freycinet, one by Captain Duperrey, and one by myself. Corrected for the arcs and for the buoyancy of the air, and reduced to a common temperature of 60° Fahr., being the mean temperature at which they were made, the results are as follows:

Experiment 1.	M. Mathieu	85933,81 Vibrations.
Experiment 2.	M. Nicollet	85934,15 Vibrations.
Experiment 3.	Captain Sabine	85934,09 Vibrations.
Experiment 4.	M. Mathieu	85933,93 Vibrations.
Experiment 5.	M. Mathieu	85934,14 Vibrations.
Experiment 6.	Captain Duperrey . . .	85934,40 Vibrations.
Experiment 7.	M. Mathieu	85933,92 Vibrations.
Experiment 8.	M. Nicollet	85934,19 Vibrations.
Experiment 9.	Captain Freycinet . . .	85934,21 Vibrations.
Experiment 10.	M. Mathieu	85933,96 Vibrations.
Experiment 11.	M. Nicollet	85934,30 Vibrations.
Experiment 12.	M. Mathieu	85934,77 Vibrations.
Experiment 13.	M. Savary	85934,83 Vibrations.

Whilst each of the pendulums was thus in its turn employed in the observation of coincidences, a series of experiments was at the same time carrying on with the other to ascertain its rate by means of a journeyman clock or counter; the second tripod stand being placed for that purpose on the opposite side of the room. This method was employed by Captains Freycinet and Duperrey in the pendulum experiments made during their voyages; and though inferior to that of coincidences in the approximation and accordance of individual results, there appears no reason to doubt that by sufficiently multiplying the observations it would conduct to the same mean determination. In the present case five results only were obtained with No. 8, and a like number with No. 7. Those with No. 8, although exhibiting discordances with each other exceeding two seconds in amount, afford a mean approaching within three tenths of a second of that furnished by the coincidences. The particulars of these are given in Table V, and of those with pendulum No. 7 in Table IV. The whole of these experiments were conducted by M. Mathieu, assisted either by M. Nicollet, M. Savary, or myself, as two observers are requisite in this method. The planes of No. 7 were used throughout, except in the last experiment with pendulum No. 8. The thermometer, and the arc by which the amplitude of vibration was registered, were carefully compared, and found to agree with those used in the experiments by the other method. Each comparison of the clock and counter entered in the Tables is a mean of eleven observations. The several results with each pendulum corrected for the arc and for the buoyancy of the atmosphere, and reduced to the same common temperature respectively as those obtained by the coincidences, are as follows:

Pendulum No. 8.	*Pendulum No.* 7.
Experiment 1. 85920,87 Vibrations.	Experiment 1. 85933,49 Vibrations.
Experiment 2. 85921,15 Vibrations.	Experiment 2. 85932,86 Vibrations.
Experiment 3. 85921,34 Vibrations.	Experiment 3. 85931,88 Vibrations.
Experiment 4. 85922,73 Vibrations.	Experiment 4. 85933,01 Vibrations.
Experiment 5. 85923,18 Vibrations.	Experiment 5. 85932,92 Vibrations.

It appears then as the mean result of eighteen distinct experiments with each pendulum,—thirteen obtained by the method of coincidences, and five by the counter,—that the pendulum No. 8 would perform 85922,06 vibrations at 58° Fahr., and pendulum No. 7, 85933,83 vibrations at 60° Fahr., in twenty-four hours of mean solar time, in a vacuum, at the spot in which M. Biot measured the length of the seconds pendulum at Paris.

Early in September, the pendulums and stands having been conveyed from Paris to London by water, as the least expensive mode of transport and that in which the pendulums were least likely to be injured, and the summer temperature having lowered to nearly the same average as during the period of observation at Paris, the comparative experiments in Portland Place were commenced. Mr. Browne's absence from London at that season of the year having deprived me of the valuable assistance I have been accustomed to receive from him on similar occasions, in his very exact determination of the daily rate of his clocks, I employed for that purpose a small transit instrument of my own, placed in a temporary observatory which Mr. Browne has built on the top of his house. With this instrument the rate of Mr. Browne's clock by Molyneux was determined between the 12th and 23rd of September as is shown in Tables VI, VII, and VIII; and the rate of his clock by Cumming, with which the coincidences were observed, was obtained by the morning and evening comparisons with Molyneux entered in Table IX. It will be seen by this table that the difference in the time shown by the two clocks between the 12th and 21st of September never exceeded 29^s,9 or fell short of 29^s,7: an additional instance of the steady going of those clocks, of which so many former proofs are on record. The comparisons in this Table afford also a very satisfactory presumption that a detached pendulum vibrating in front of the pendulum of a clock, as in the observation of coincidences, has no perceptible influence on the going of the clock: the detached pendulum in this case was kept in almost continual vibration, as may be seen by Tables X. and XI. between the morning and evening comparisons, and was always at rest between the evening and the morning: the effect of its motion on the clock, if indeed there was any effect at all, was perfectly insensible. The transit observations give reason to conclude that the trifling gain of Cumming on Molyneux on the 21st, 22nd, and 23rd of September, by which their difference was gradually increased to 30^s,6 at 10 P.M. on the 23rd September, was an increase in the rate of Cumming rather than a diminution in that of Molyneux; and it is accordingly so considered in the daily rate of Cumming deduced in Table IX. from the comparisons with Molyneux.

In Tables X. and XI. are contained the particulars of twelve results obtained with pendulum No. 7, and of ten with pendulum No. 8, all by the method of coincidences; the pendulums being used at the same spot in which Captain Kater's measurement of the length of the seconds pendulum was made. The agate planes of No. 8 were employed as at Paris in the greater part of the experiments; the two last with each pendulum being the only experiments in which the planes of No. 7 were used. The thermometer was the same as at Paris, and suspended precisely at the same distance below the knife edge. The arc for noting the amplitude of vibration was also the same. Of the twelve experiments with pendulum No. 7, two were made by M. Quetelet of Brussels (who has since undertaken a series of pendulum experiments at the principal cities of the Netherlands), and the remainder by myself. Of the ten with pendulum No. 8, two were made by M. Quetelet, one by Captain Chapman of the Royal Artillery, and the others by myself. I had greatly to regret the absence from London of Mr. Baily, and of Captain Beaufort, R.N., Fellows of the Royal Society, who had otherwise promised me their co-operation. The results corrected for the arcs of vibration and for the buoyancy of the atmosphere, and reduced to a common temperature of 63° Fahr., being the mean at which they were made, are as follows:

Pendulum No. 7.	Experiment 1.	Captain Sabine.	85944,61 vibrations.
	Experiment 2.	Captain Sabine.	85944,48 vibrations.
	Experiment 3.	Captain Sabine.	85944,55 vibrations.
	Experiment 4.	Captain Sabine.	85944,64 vibrations.
	Experiment 5.	Captain Sabine.	85944,55 vibrations.
	Experiment 6.	Captain Sabine.	85944,63 vibrations.
	Experiment 7.	Captain Sabine.	85944,41 vibrations.
	Experiment 8.	Captain Sabine.	85944,72 vibrations.
	Experiment 9.	M. Quetelet.	85944,79 vibrations.
	Experiment 10.	Captain Sabine.	85944,60 vibrations.
	Experiment 11.	M. Quetelet.	85944,71 vibrations.
	Experiment 12.	Captain Sabine.	85944,50 vibrations.

Pendulum No. 8.	Experiment 1.	Captain Sabine.	85932,05 vibrations.
	Experiment 2.	Captain Sabine.	85932,09 vibrations.
	Experiment 3.	Captain Sabine.	85932,04 vibrations.
	Experiment 4.	Captain Sabine.	85932,00 vibrations.
	Experiment 5.	M. Quetelet.	85932,17 vibrations.
	Experiment 6.	M. Quetelet.	85932,29 vibrations.
	Experiment 7.	Captain Sabine.	85932,13 vibrations.
	Experiment 8.	Captain Sabine.	85931,93 vibrations.
	Experiment 9.	Captain Sabine.	85931,84 vibrations.
	Experiment 10.	Captain Chapman.	85931,85 vibrations.

It appears then, by these experiments, that the pendulum No. 7 would make 85944,60 vibrations at 63° FAHR., and the pendulum No. 8, 85932,04 at 63°, in 24 hours of mean solar time, in a vacuum, at the spot in which Captain KATER measured the length of the seconds pendulum in London.

We have, therefore, for pendulum No. 7, 85933,83 vibrations at 60° FAHR. in Paris, and 85944,60 vibrations at 63° in London; and for pendulum No. 8, 85922,06 vibrations at 58° at Paris, and 85932,04 vibrations at 63° in London.

Employing 0,421 of a vibration per diem as the equivalent to one degree of FAHRENHEIT'S scale (according to the result of the experiments made with two similar pendulums, of which the particulars are related in the volume of my former pendulum experiments, pages 198—208), and reducing the vibrations in Paris and in London to a common temperature of 60°, we have

	For Pendulum No. 7.	*For Pendulum No.* 8.
In Paris	85933,83	85921,22
In London	85945,80	85933,30
Whence the accelerations	12,03	12,08

The mean acceleration is 12,05.—Such is the result obtained by taking into account the experiments made by means of the counter as well as those by the observation of coincidences; and with the agate planes belonging to No. 7, as well as with those belonging to No. 8: that is to say, all the experiments made with either pendulum.

Should we confine ourselves to that portion of the experiments alone in which the method of coincidences was followed and the planes of No. 8 employed, we obtain as the mean of eleven distinct results in Paris and ten in London with pendulum No. 7, twelve in Paris and seven in London with pendulum No. 8, an acceleration of 11,93 vibrations. Finally, therefore, if we regard in round numbers 12 seconds as the acceleration between Paris and London, we are warranted by these experiments in considering one tenth of a second, per diem, as the limit of probable error, and that it is extremely unlikely that the error should amount to two tenths of a second.

The length of the seconds pendulum in Mr. BROWNE's house in London, by KATER's measurement, is 39,13908; and in the Salle de la Méridienne in the Observatory at Paris, by BIOT's measurement, 39,12843. The difference of these two numbers is ,01065, corresponding to an acceleration of 11,76 seconds. The difference in the length of the seconds pendulum in London and in Paris, equivalent to an acceleration of 12 seconds, is ,01088. Captain KATER's measurement in London, transferred to Paris by means of an acceleration of 12 seconds, would make the pendulum in Paris 39,12820, instead of 39,12843, the determination of M. BIOT: and M. BIOT's measurement, transferred in like manner to London, would make its pendulum 39,13931, instead of 39,13908 as measured by KATER.

It is fitting that I should notice the original measurement of the length of the seconds pendulum in the Observatory at Paris, made in 1792 by M. BORDA. The result he obtained was 39,12776; but as his experiments were made in the basement story of the Observatory, which is two stories lower than the Salle de la Méridienne, a compensation of ,00012, equivalent to something more than 30 feet, may be supposed to place M. BORDA's result in fair comparison with M. BIOT's. Thus reduced, M. BORDA's result becomes 39,12764 for the Salle de la Méridienne.

Without the slightest intention of deciding between authorities, each of whom is deservedly held in such high respect,—and viewing indeed the very small differences in the three determinations as evidencing, in a remarkable manner, the ingenuity of the respective methods, and the experimental skill by which each was obtained,—it may be remarked in conclusion, that if a mean be taken for the Observatory at Paris, between the measurements of BORDA, BIOT, and KATER, (the latter transferred to Paris by means of the intermediate acceleration of 12 seconds,) the determination of KATER will be found to hold very nearly the middle line between the other two; approaching nearer by ,00011 (equivalent to somewhat more than one-tenth of a vibration per diem) to the measurement of BIOT than to that of BORDA.

TABLE I.—Paris.—Comparaisons de l'Horloge qui a servi aux Expériences du Pendule Invariable avec l'Horloge Sidérale qui est à côté de la Lunette Méridienne.

Année 1827.		Epoques moyennes des Comparaisons		Marche diurne de l'horloge sidérale.	Intervalles entre les Comparaisons				Retard de l'horloge sur le tems moyen	
		à l'horloge d'expérience.	à l'horloge sidérale.		à l'horloge sidérale.	en tems sidéral.	en tems moyen.	à l'horloge. d'expérience.	entre les compar.	en 24h moyennes
		h m s	h m s	s	h m s	h m s	h m s	h m s	m s	m s
Avril 27.	Matin	8 54 42,00	23 46 42,65	+0,23	12 24 · 6,66	12 24 6,54	12 22 4,64	12 20 16,00	1 48,64	3 31,33
	Soir	9 14 58,00	12 10 49,31							
28.	Matin	7 34 29,00	22 33 33,31	+0,23	14 18 24,90	14 18 24,77	14 16 4,14	14 13 59,33	2 4,81	3 30,45
	Soir	9 48 28,33	12 51 58,21							
29.	Matin	6 05 17,33	21 11 22,05	—0,26	12 16 5,14	12 16 5,27	12 14 4,68	12 12 17,67	1 47,01	3 30,42
	Soir	6 17 35,00	9 27 27,19							
30.	Matin	5 59 55,00	21 13 25,58	—0,13	12 18 5,44	12 18 5,51	12 16 4,59	12 14 17,00	1 47,59	3 30,99
	Soir	6 14 12,00	9 31 31,02							
Mai 1.	Matin	6 43 27,00	22 04 39,15	—0,25	11 39 59,63	11 39 59,75	11 38 5,07	11 36 23,00	1 42,07	3 31,06
	Soir	6 19 50,00	9 44 38,78							
2.	Matin	6 02 10,33	21 30 37,88	—0,35	12 27 7,79	12 27 7,97	12 25 5,57	12 23 16,67	1 48,90	3 30,46
	Soir	6 25 27,00	9 57 45,67							
3.	Matin	6 34 44,00	22 10 49,41	—0,28	11 45 58,44	11 45 58,58	11 44 2,92	11 42 20,10	1 42,82	3 30,29
	Soir	6 17 04,10	9 56 47,85							
4.	Matin	6 17 22,67	22 00 50,93	—0,13	12 5 2,79	12 5 2,85	12 3 4,07	12 1 18,33	1 45,74	3 30,58
	Soir	6 18 41,00	10 05 53,72							
5.	Matin	6 22 59,00	22 13 57,05	0,00	10 23 46,11	10 23 46,11	10 22 3,92	10 20 33,00	1 30,92	3 30,46
	Soir	4 43 32,00	8 37 43,16							
7.	Matin	7 33 04,33	23 39 21,22	+0,08	12 18 6,06	12 18 6,02	12 16 5,10	12 14 17,67	1 47,43	3 30,16
	Soir	7 47 22,00	11 57 27,28							
8.	Matin	8 17 35,00	0 31 34,09	+0,12	12 13 4,30	12 13 4,24	12 11 4,14	12 9 17,33	1 46,81	3 30,38
	Soir	8 26 52,33	12 44 38,39							
10.	Matin	6 09 07,00	22 37 22,65	+0,12	13 46 20,10	13 46 20,03	13 44 4,66	13 42 4,00	2 0,66	3 30,66
	Soir	7 51 11,00	12 23 42,76							

La marche diurne de l'horloge sidérale a été obtenue par les passages des étoiles au méridien. Je me suis particulièrement attaché à observer les passages de jour. La veille du jour où l'on a commencé les expériences du pendule, le 26 avril, j'avais trouvé par 4 étoiles le retard absolu de l'horloge sidérale sur le temps sidéral. Je l'ai ensuite déterminé le 27 par 9 etoiles, le 28 par 8 étoiles, le 29 par 8 étoiles, le 30 par 2 étoiles, le 1er mai par 4 étoiles, le 2 par 8 etoiles, le 3 par 3 étoiles, le 4 par 6 étoiles. Des retards absolus obtenus chaque jour j'ai conclu la marche diurne du 27 avril au 4 mai. Les petites irregularités que l'on remarque dans les avances ou retards diurnes tiennent aux changemens de température qui ont été très sensibles. Le ciel s'est couvert le Samedi 5 mai, je n'ai pu revoir des étoiles que le 9: j'en ai observé 4 qui m'ont servi à conclure la marche diurne pour le 5, le 7, le 8, et le 10. Les nombres que j'ai adoptés pour ces quatre jours sont d'ailleurs confirmés par les passages du soleil au méridien.

TABLE II.

Paris.—Coincidences observed with the Invariable Pendulum No. 8.

EXP. 1. April 28th A.M. Clock making 86189,55 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}759^{mm},40.\ \text{Th. } 12°,9\ \text{Cent.}\\ 759\ \ ,00.\ \text{Th. } 13\ ,8\ \text{Cent.}\end{array}\right\}$ $759^{mm},20$. Th. 13°,35. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of			Arc of Vibration.
		Disapp.	Re-app.	Coincidence.	
°		m s	m s	h m s	°
53,5	1	57 37	57 40	7 57 38,5	1,00
53,7	2	08 08	08 15	8 08 11,5	0,94
53,8	3	18 39	18 47	8 18 43	0,88
	4	29 11	29 18	8 29 14,5	0,82
53,9	5	39 41	39 49	8 39 45	0,78
	6	50 13	50 20	8 50 16,5	0,74
	7	00 45	00 52	9 00 48,5	....
54,2	8	11 14	11 26	9 11 20	0,63
	9	......	......	....	....
	10	32 22	32 27	9 32 22,5	0,58
	11	42 52	43 01	9 42 56,5	0,52
	12	53 26	53 31	9 53 28,5	0,48
55,1	13	04 00	04 16	10 04 08	0,46
55,1	14	14 30	14 46	10 14 38	0,43
55,3	15	25 03	25 13	10 25 08	0,40
	16	35 36	35 44	10 35 40	0,38
	17	46 07	46 19	10 46 13	0,36
55,8	18	56 39	56 49	10 56 44	0,33

Intervals between Coincidences.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Pendulum.		
	Vibrations.	Vibrations.	+	
1—16	632,1	630,1	0,72	85917,60
2—17	632,1	630,1	0,64	85917,52
3—18	632,07	630,07	0,56	85917,42
Mean ; Vibrations at 54°,49 FAHR.				85917,51
Reduction to 58° FAHR.				—1,47
Correction for buoyancy				+6,08
Vibrations in vacuo at 58° FAHR.				85922,12

EXP. 2. April 28th Noon. Clock making 86189,55 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}758^{mm},90.\ \text{Th. } 13°,8\ \text{Cent.}\\ 757\ \ ,68.\ \text{Th. } 14\ ,4\ \text{Cent.}\end{array}\right\}$ $758^{mm},29$. Th. 14°,1. Planes No. 8. Therm. No. 4.

Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of			Arc of Vibration.
		Disapp.	Re-app.	Coincidence.	
°		m s	m s	h m s	°
56,1	1	25 07	25 11	11 25 09	0,91
	2	35 36	35 43	11 35 39,5	0,86
	3	46 07	46 14	11 46 10,5	0,81
56,3	5	07 05	07 17	12 07 11	0,70
56,8	13	31 14	31 26	13 31 20	0,41
	14	41 42	42 00	13 41 51	0,38
	15	52 20	52 29	13 52 24,5	0,36
56,7	16	02 49	03 00	14 02 54,5	0,33

Intervals between Coincidences.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Pendulum.		
	Vibrations.	Vibrations.	+	
1—14	630,92	628,92	0,65	85917,01
2—15	631,15	629,15	0,57	85917,03
3—16	631,08	629,08	0,51	85916,95
Mean ; Vibrations at 56°,475 FAHR.				85916,99
Reduction to 58° FAHR.				—0,64
Correction for buoyancy				+6,05
Vibrations in vacuo at 58° FAHR.				85922,40

Table II. (Continued.)

Exp. 3. April 28th P.M. Clock making 86189,55 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}757^{mm},68.\ \text{Th. } 14°,4\ \text{Cent.}\\757\ \ ,00.\ \text{Th. } 14\ ,3\ \text{Cent.}\end{array}\right\}$ $757^{mm},34$. Th. 14°,35. Planes No. 8. Therm. No. 4.

Observer, M. Nicollet.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
56,7	1	16 01	16 04	14 16 02,5	0,98
	2	26 29	26 34	14 26 31,5	0,94
	3	36 57	37 03	14 37 00	0,88
	4	47 25	47 37	14 47 31	0,81
56,4	5	57 54	58 05	14 57 59,5	0,78
	6	08 25	08 35	15 08 30	0,72
	7	18 55	19 06	15 19 00,5	0,67
	8	29 28	29 37	15 29 32,5	0,63
56,4	9	39 59	40 08	15 40 03,5	0,59
	10	50 27	50 38	15 50 32,5	0,56
	11	01 02	01 10	16 01 06	0,52
	12	11 29	11 39	16 11 34	....
56,4	13	22 04	22 13	16 22 08,5	0,47
	14	32 32	32 43	16 32 37,5	....
	15	43 05	43 17	16 43 11	0,39
	16	53 35	53 48	16 53 41,5	0,38
	17	04 06	04 20	17 04 13	0,36
56,4	18	14 40	14 50	17 14 45	0,34

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	630,6	628,6	0,70	85916,92
2—17	630,77	628,77	0,64	85916,94
3—18	631,0	629,0	0,57	85916,95
Mean; Vibrations at 56°,46 Fahr.				85916,94
Reduction to 58° Fahr.				—0,65
Correction for buoyancy				+6,04
Vibrations in vacuo at 58° Fahr.				85922,33

Exp. 4. April 29th A.M. Clock making 86189,58 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}758^{mm},60.\ \text{Th. } 13°,3\ \text{Cent.}\\759\ \ ,25.\ \text{Th. } 14\ ,0\ \text{Cent.}\end{array}\right\}$ $758^{mm},92$. Th. 13°,65. Planes No. 8. Therm No. 4.

Observer, M. Mathieu.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
54,3	1	18 04	18 06	6 18 05	1,00
54,4	2	28 32	28 36	6 28 34	0,94
54,4	3	39 04	39 09	6 39 06,5	0,88
54,5	4	49 35	49 39	6 49 37	0,83
54,6	5	00 05	00 12	7 00 08,5	0,78
	6	......	......	....	....
54,8	7	21 09	21 15	7 21 12	0,69
	8	31 37	31 47	7 31 42	0,66
	9	42 09	42 19	7 42 14	0,61
	10	52 42	52 49	7 52 45,5	0,57
55,0	11	03 11	03 22	8 03 16,5	0,54
55,1	12	13 47	13 56	8 13 51,5	0,50
55,3	13	24 20	24 27	8 24 23,5	0,47
	14	......	......	....	....
55,7	15	45 26	45 33	8 45 29,5	0,41
55,8	16	55 57	56 05	8 56 01	0,39
56,0	17	06 30	06 36	9 06 33	0,37
56,0	18	17 00	17 08	9 17 04	0,36

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	631,73	629,73	0,74	85917,48
2—17	631,93	629,93	0,65	85917,47
3—18	631,83	629,83	0,59	85917,37
Mean; Vibrations at 55°,07 Fahr.				85917,44
Reduction to 58° Fahr.				—1,23
Correction for buoyancy				+6,07
Vibrations in vacuo at 58° Fahr.				85922,28

TABLE II. (Continued.)

EXP. 5. April 29th A.M. Clock making 86189,58 Vibrations in a Mean Solar Day.

Barom. {759^{mm},30. Th. 14°,0 Cent. / 759 ,10. Th. 14 ,9 Cent.} 759^{mm},20. Th. 14°,45. Planes No. 8. Therm. No. 4.

Observer, M. NICOLLET.

Therm.	No. of Coincid.	Times of Disapp.		Re-app.		Coincidence.			Arc of Vibration.
°		m	s	m	s	h	m	s	°
56,3	1	37	12	37	13	9	37	12,5	1,05
	2	47	40	47	42	9	47	41	1,00
	3	58	07	58	12	9	58	09,5	0,92
	4	08	37	08	42	10	08	39,5	0,86
56,6	5	19	06	19	12	10	19	09	0,81
	6	......		......		....			....
	7	40	06	40	15	10	40	10,5	0,70
	8	......		......		....			....
56,8	9	01	09	01	19	11	01	14	0,60
	10	......		......		....			....
	11	22	08	22	18	11	22	13	0,52
	12	32	42	32	50	11	32	46	....
	13	43	11	43	22	11	43	16,5	0,46
	14	53	43	53	54	11	53	48,5	0,42
57,2	15	04	14	04	25	12	04	19,5	0,40
	16	14	46	14	57	12	14	51,5	0,38
	17	25	16	25	28	12	25	22	0,36
	18	35	48	35	59	12	35	53,5	0,32
	19	......		......		....			....
57,6	20	56	48	57	04	12	56	56	0,30
	21	07	20	07	34	13	07	27	0,26
57,7	22	17	48	18	08	13	17	58	0,25

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—20	630,71	628,71	0,66	85916,96
2—21	630,84	628,84	0,57	85916,93
3—22	630,97	628,97	0,48	85916,88
Mean; Vibrations at 57°,03 FAHR.				85916,92
Reduction to 58° FAHR.				—0,41
Correction for buoyancy				+6,05
Vibrations in vacuo at 58° FAHR.				85922,56

EXP. 6. April 29th P.M. Clock making 86189,58 Vibrations in a Mean Solar Day.

Barom. 758^{mm},84. Th. 14°,9 Cent. Planes No. 8. Therm No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.		Re-app.		Coincidence.			Arc of Vibration.
°		m	s	m	s	h	m	s	°
587,	1	37	51	37	54	1	37	52,5	1,02
	2	48	19	48	23	1	48	21	0,94
	3	58	46	58	52	1	58	49	0,88
	4	09	12	09	23	2	09	17,5	0,82
	5	19	40	19	53	2	19	46,5	0,78
	6	30	10	30	23	2	30	16,5	0,71
57,2	7	40	40	40	55	2	40	47,5	0,67
	8	51	07	51	25	2	51	16	0,62
	9	01	38	01	57	3	01	47,5	0,58
	10	12	09	12	28	3	12	18,5	....
	11	22	40	22	58	3	22	49	....
	12	33	12	33	31	3	33	21,5	....
57,0	13	43	47	43	57	3	43	52	0,48
	14	54	12	54	35	3	54	23,5	....
	15	......		......		....			....
	16	15	17	15	33	4	15	25	0,38
	17	25	46	26	06	4	25	56	0,35
57,1	18	36	16	37	38	4	36	27	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	630,167	628,167	0,74	85916,80
2—17	630,467	628,467	0,63	85916,81
3—18	630,533	628,533	0,55	85916,75
Mean; Vibrations at 57°,275 FAHR.				85916,79
Reduction to 58° FAHR.				—0,30
Correction for buoyancy				+6,05
Vibrations in vacuo at 58° FAHR.				85922,54

TABLE II. (Continued.)

EXP. 7. April 30th A.M. Clock making 86189,01 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{matrix} 760^{mm},00. \text{ Th. } 13°,8 \text{ Cent.} \\ 760 \quad ,20. \text{ Th. } 14 ,3 \text{ Cent.} \end{matrix}\right\}$ 760^{mm},10. Th. 14°,15. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
55,3	1	02 10	02 12	6 02 11	1,02
55,4	2	12 40	12 42	6 12 41	0,96
55,5	3	23 09	23 12	6 23 10,5	0,91
55,5	4	33 39	33 43	6 33 41	0,86
55,6	5	44 07	44 13	6 44 10	0,80
55,6	6	54 35	54 45	6 54 40	0,75
55,7	7	05 06	05 15	7 05 10,5	0 70
55,7	8	15 36	15 45	7 15 40,5	0,66
55,8	9	26 07	26 15	7 26 11	0,62
55,9	10	36 37	36 47	7 36 42	0,58
56,0	11	47 08	47 20	7 47 14	0,53
56,0	12	57 38	57 51	7 57 44,5	0,50
56,0	13	08 09	08 21	8 08 15	0,48
56,1	14	18 39	18 54	8 18 46,5	0,44
56,1	15	29 09	29 26	8 29 17,5	0,41
56,2	16	39 41	39 58	8 39 49,5	0,39
56,2	17	50 13	50 30	8 50 21,5	0,37
56,4	18	00 43	01 01	9 00 52	0,35

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	630,57	628,57	0,75	85916,37
2—17	630,7	628,7	0,67	85916,37
3—18	630,77	628,77	0,60	85916,32
Mean; Vibrations at 55°,83 FAHR.				85916,35
Reduction to 58° FAHR.				—0,91
Correction for buoyancy				+6,07
Vibrations in vacuo at 58° FAHR. .				85921,51

EXP. 8. April 30th A.M. Clock making 86189,01 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{matrix} 760^{mm},20. \text{ Th. } 14°,3 \text{ Cent.} \\ 760 \quad ,02. \text{ Th. } 15 ,1 \text{ Cent.} \end{matrix}\right\}$ 760^{mm},11. Th. 14°,7. Planes No. 8. Therm. No. 4.

Observer, M. NICOLLET.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
56,6	1	26 33	26 36	9 26 34,5	0,98
	2	37 02	37 06	9 37 04	0,93
	3	47 29	47 36	9 47 32,5	0,86
	4	57 57	58 04	9 58 00,5	0,81
57,0	5	08 27	08 34	10 08 30,5	0,76
	6	18 56	19 05	10 19 00,5	0,70
	7	29 25	29 34	10 29 29,5	0,66
57,6	8	39 55	40 05	10 40 00	0,60
	9	50 24	50 35	10 50 29,5	0,57
57,7	10	00 54	01 06	11 01 00	0,53
	11	11 22	11 37	11 11 29,5	0,50
	12	21 55	22 07	11 22 01	0,46
	13	......	.....	....	....
58,0	14	42 57	43 11	11 43 04	0,42
	15	53 26	53 38	11 53 32	0,37
	16	03 56	04 10	12 04 03	0,36
	17	14 23	14 43	12 14 33	0,34
58,1	18	24 54	25 15	12 25 04,5	0,31

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	629,9	627,9	0,67	85916,01
2—17	629,9	627,9	0,61	85915,95
3—18	630,13	628,13	0,52	85915,94
Mean: Vibrations at 57°,5 FAHR.				85915,97
Reduction to 58° FAHR.				—0,21
Correction for buoyancy				+6,05
Vibrations in vacuo at 58° FAHR.				85921,81

TABLE II. (Continued.)

EXP. 9. April 30th P.M. Clock making 86189,01 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}760^{\text{mm}},00.\ \text{Th. } 15^\circ,2\text{ Cent.}\\ 759\quad ,08.\ \text{Th. } 14\ ,3\text{ Cent.}\end{array}\right\}$ 759^{mm},54. Th. 14°,75. Planes No. 8. Therm. No. 4.

Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of			Arc of Vibration.	Intervals between Coincidences.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.		Nos.	Clock.	Pendulum.		
°		m s	m s	h m s	°		Vibrations.	Vibrations.	+	
58,5	1	41 40	41 45	0 41 42,5	0,90	1—16	629,77	627,77	0,59	85915,77
	2	52 08	52 13	0 52 10,5	0,83	2—17	630,00	628,00	0,50	85915,88
	3	02 37	02 42	1 02 39,5	0,78	3—18	630,17	628,17	0,44	85915,90
	4	13 04	13 12	1 13 08	0,74					
	5	23 32	23 42	1 23 37	0,68	Mean; Vibrations at 58°,15 FAHR.				85915,85
	16	19 00	19 18	3 19 09	0,34					
	17	29 31	29 50	3 29 40,5	0,32	Reduction to 58° FAHR.				+0,06
57,8	18	40 02	40 22	3 40 12	0,29	Correction for buoyancy				+6,04
						Vibrations in vacuo at 58° FAHR. .				85921,95

EXP. 10. May 1st A.M. Clock making 86188,94 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}760^{\text{mm}},00.\ \text{Th. } 14^\circ,5\text{ Cent.}\\ 760\quad ,00.\ \text{Th. } 14\ ,8\text{ Cent.}\end{array}\right\}$ 760^{mm},00. Th. 14°,65. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of			Arc of Vibration.	Intervals between Coincidences.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.		Nos.	Clock.	Pendulum.		
°		m s	m s	h m s	°		Vibrations.	Vibrations.	+	
56,6	1	30 22	30 25	6 30 23,5	1,00	1—16	630,6	628,6	0,72	85916,30
56,7	2	40 51	40 54	6 40 52,5	0,93	2—17	630,8	628,8	0,61	85916,27
56,8	3	51 19	51 23	6 51 21	0,88	3—18	631,0	629,0	0,55	85916,29
56,9	4	01 48	01 53	7 01 50,5	0,82					
56,9	5	12 17	12 24	7 12 20,5	0,77	Mean; Vibrations at 56°,89 FAHR.				85916,29
56,9	6	22 46	22 55	7 22 50,5	0,72					
56,9	7	33 14	33 25	7 33 19,5	0,68	Reduction to 58° FAHR.				−0,47
56,9	8	43 46	43 57	7 43 51,5	0,63	Correction for buoyancy				+6,06
	9	......	......	....	....					
56,9	10	04 47	04 59	8 04 53	0,55	Vibrations in vacuo at 58° FAHR. .				85921,88
56,9	11	15 18	15 30	8 15 24	0,51					
	12	......	......	....	....					
56,8	13	36 19	36 36	8 36 27,5	0,46					
56,8	14	46 51	47 09	8 47 00	0,42					
56,9	15	57 22	57 39	8 57 30,5	0,39					
57,0	16	07 54	08 11	9 08 02,5	0,37					
57,1	17	18 24	18 45	9 18 34,5	0,34					
57,3	18	28 56	29 16	9 29 06	0,32					

TABLE II. (Continued.)

EXP. 11. May 1st A.M. Clock making 86188,94 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}760^{mm},00.\ \text{Th. } 14°,8 \text{ Cent.}\\ 759\ \ \ \ ,36.\ \text{Th. } 15\ ,3 \text{ Cent.}\end{array}\right\}$ 759^{mm},68. Th. 15°,05. Planes No. 8. Therm. No. 4.

Observers: 1—9, M. NICOLLET; 12—18, M. SAVARY.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
	1	32 49	32 50	9 32 49,9	1,02
57,8	2	43 16	43 21	9 43 18,5	0,95
	3	53 44	53 49	9 53 46,5	0,90
57,8	4	04 11	04 18	10 04 14,5	0,84
	5	14 40	14 48	10 14 44	0,78
57,9	6	25 10	25 19	10 25 14,5	0,72
58,0	7	35 38	35 48	10 35 43	0,68
58,2	9	56 38	56 47	10 56 42,5	0,58
58,5	12	28 04	28 18	11 28 11	0,48
	13	38 33	38 48	11 38 40,5	0,44
58,8	15	59 34	59 48	11 59 41	0,40
	16	10 04	10 18	12 10 11	0,37
	17	20 33	20 49	12 20 41	0,34
58,9	18	31 03	31 19	12 31 11	0,33

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibration in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	629,43	627,43	0,74	85915,82
2—17	629,50	627,50	0,63	85915,73
3—18	629,63	627,63	0,58	85915,74
Mean; Vibrations at 58°,24 FAHR.				85915,76
Reduction to 58° FAHR.				+0,10
Correction for buoyancy				+6,04
Vibrations in vacuo at 58° FAHR.				85921,90

EXP. 12. May 1st P.M. Clock making 86188,94 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}759^{mm},35.\ \text{Th. } 15°,7 \text{ Cent.}\\ 758\ \ \ \ ,50.\ \text{Th. } 14\ ,5 \text{ Cent.}\end{array}\right\}$ 758^{mm},92. Th. 15°,1. Planes No. 8. Therm. No. 4.

Observers: 1—15, M. SAVARY; 16—18, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
58,9	1	03 02	03 05	1 03 03,5	0,92
58,9	2	13 29	13 32	1 13 30,5	0,87
	3	23 57	24 03	1 24 00	0,80
	4	34 26	34 31	1 34 28,5	0,75
58,8	5	44 53	44 59	1 44 56	0,70
	6	55 21	55 28	1 55 24,5	0,67
	7	05 50	05 58	2 05 54	0,62
58,7	8	16 18	16 27	2 16 22,5	0,59
	9	26 50	26 57	2 26 53,5	0,56
58,7	10	37 18	37 28	2 37 23	0,52
	11	47 47	47 59	2 47 53	0,49
	12	58 17	58 28	2 58 22,5	0,46
58,6	13	08 45	08 57	3 08 51	0,44
	14	19 12	19 30	3 19 21	0,39
	15	29 43	30 00	3 29 51,5	0,38
58,6	16	40 11	40 31	3 40 21	0,34
	17	50 42	51 00	3 50 51	0,32
58,5	18	01 10	01 32	4 01 21	0,30

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	629,17	627,17	0,60	85915,58
2—17	629,37	627,37	0,54	85915,58
3—18	629,40	627,40	0,45	85915,51
Mean; Vibrations at 58°,71 FAHR.				85915,56
Reduction to 58° FAHR.				+0,30
Correction for buoyancy				+6,05
Vibrations in vacuo at 58° FAHR.				85921,91

TABLE II. (Continued.)

EXP. 13. May 8th A.M. Clock making 86189,62 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}751^{mm},60.\ \text{Th. }15^{\circ}\text{ Cent.}\\ 752\ \ \ ,56.\ \text{Th. }15\text{ Cent.}\end{array}\right\}$ 752^{mm},58. Th. 15°. Planes No. 7. Therm. No. 4.

Observer, M. NICOLLET.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
57,4	1	17 55	18 01	8 17 58	0,94
57,3	2	28 22	28 32	8 28 27	0,88
57,2	3	38 51	39 01	8 38 56	0,82
57,3	4	49 23	49 33	8 49 28	0,76
57,3	5	00 55	01 04	9 00 59,5	0,70
57,3	6	10 24	10 36	9 10 30	0,66
57,3	11	02 56	03 13	10 03 04,5	0,46
57,3	15	44 55	45 20	10 45 07,5	0,37
57,3	16	55 29	55 50	10 55 39,5	0,34
57,3	17	06 00	06 22	11 06 11	0,32
57,3	18	16 30	16 55	11 16 42,5	0,30

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	630,77	628,77	0,62	85916,96
2—17	630,93	628,93	0,55	85916,95
3—18	631,11	629,11	0,47	85916,95
Mean; Vibrations at 57°,3 FAHR.				85916,95
Reduction to 58° FAHR.				—0,29
Correction for buoyancy				+5,99
Vibrations in vacuo at 58° FAHR.				85922,65

TABLE III.

Paris.—Coincidences observed with the Invariable Pendulum No. 7.

EXP. 1. May 2nd A.M. Clock making 86189,54 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}758^{mm},60.\ \text{Th. }14^{\circ},8\text{ Cent.}\\ 758\ \ \ ,60.\ \text{Th. }15\ ,2\text{ Cent.}\end{array}\right\}$ 758^{mm},60. Th. 15°. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
57,0	1	54 07	54 09	5 54 08	1,00
57,1	2	05 03	05 05	6 05 04	0,95
57,1	3	16 00	16 04	6 16 02	0,89
57,2	4	26 57	27 03	6 27 00	0,83
57,2	5	37 57	38 03	6 38 00	0,78
57,3	6	48 56	49 03	6 48 59,5	0,72
57,3	7	59 56	00 03	6 59 59,5	0,68
57,4	8	10 54	11 02	7 10 58	0,63
57,4	9	21 52	22 02	7 21 57	0,59
57,5	10	32 51	33 02	7 32 56,5	0,56
57,5	11	43 50	44 02	7 43 56	0,52
57,5	12	54 50	55 04	7 54 57	0,49
57,6	13	05 50	06 05	8 05 57,5	0,47
57,6	14	16 50	17 06	8 16 58	0,43
57,7	15	27 50	28 07	8 27 58,5	0,40
57,8	16	38 51	39 08	8 38 59,5	0,38
57,9	17	49 51	50 07	8 49 59	0,36
58,1	18	00 49	01 08	9 00 58,5	0,33

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	659,43	657,43	0,72	85928,84
2—17	659,67	657,67	0,65	85928,87
3—18	659,77	657,77	0,57	85928,83
Mean; Vibrations at 57°,45 FAHR.				85928,85
Reduction to 60° FAHR.				—1,07
Correction for buoyancy				+6,03
Vibrations in vacuo at 60° FAHR.				85933,81

TABLE III. (Continued.)

EXP. 2. May 2nd A.M. Clock making 86189,54 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}758^{mm},60.\ \text{Th. } 14°,8 \text{ Cent.}\\ 757\ \ \ ,52.\ \text{Th. } 16\ ,0 \text{ Cent.}\end{array}\right\}$ 758^{mm},06. Th. 15°,4. Planes No. 8. Therm. No. 4.

Observer, M. NICOLLET.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
	1	36 13	36 21	9 36 17	0,88
58,5	2	47 11	47 20	9 47 15,5	0,82
	3	58 09	58 18	9 58 13,5	0,77
	4	09 06	09 06	10 09 11	0,72
58,9	5	20 04	20 14	10 20 09	0,66
	6	31 03	31 13	10 31 08	0,62
	7	42 01	42 11	10 42 06	0,56
59,0	8	52 58	53 12	10 53 05	0,52
59,1	11	25 52	26 15	11 26 03,5	0,44
	13	47 53	48 14	11 48 03,5	0,42
	15	09 53	10 14	12 10 03,5	0,33
59,6	16	20 52	21 14	12 21 03	0,30
	17	31 54	32 13	12 32 03,5	0,28
59,6	18	42 53	43 14	12 43 03,5	0,26

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	659,07	657,07	0,53	85928,51
2—17	659,20	657,20	0,45	85928,49
3—18	659,33	657,33	0,40	85928,50
Mean; Vibrations at 59°,12 FAHR.				85928,50
Reduction to 60° FAHR.				—0,37
Correction for buoyancy				+6,02
Vibrations in vacuo at 60° FAHR.				85934,15

EXP. 3. May 2nd P.M. Clock making 86189,54 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}757^{mm},52.\ \text{Th. } 16°,0 \text{ Cent.}\\ 756\ \ \ ,50.\ \text{Th. } 15\ ,8 \text{ Cent.}\end{array}\right\}$ 757^{mm},01. Th. 15°,9. Planes No. 8. Therm. No. 4.

Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
59,4	1	04 41	04 44	2 04 42,5	0,91
	2	15 36	15 43	2 15 39,5	0,84
59,2	3	26 34	26 41	2 26 37,5	0,79
	4	37 29	37 40	2 37 34,5	0,74
59,1	7	10 24	10 34	3 10 29	0,59
	9	32 22	32 33	3 32 27,5	0,53
59,1	10	43 21	43 34	3 43 27,5	0,50
	11	54 21	54 31	3 54 26	0,47
	12	05 19	05 30	4 05 24,5	0,42
59,1	13	16 17	16 29	4 16 23	0,38
	14	27 17	27 31	4 27 24	0,36
	15	38 15	38 33	4 38 24	0,34
59,1	16	49 14	49 31	4 49 22,5	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—14	658,58	656,58	0,61	85928,41
2—15	658,81	656,81	0,53	85928,43
3—16	658,89	656,89	0,47	85928,41
Mean; Vibrations at 59°,17 FAHR.				85928,42
Reduction to 60° FAHR.				— 0,35
Correction for buoyancy				+6,02
Vibrations in vacuo at 60° FAHR.				85934,09

TABLE III. (Continued.)

EXP. 4. May 3rd A.M. Clock making 86189,71 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}756^{mm},50.\ \text{Th. }15^{\circ},2\text{ Cent.}\\ 756\quad ,95.\ \text{Th. }15\ ,5\text{ Cent.}\end{array}\right\}$ $756^{mm},72$. Th. 15°,35. Planes No. 8. Therm. No. 8.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
57,8	1	53 20	53 22	5 53 21	1,00
57,9	2	04 16	04 19	6 04 17,5	0,95
57,9	3	15 12	15 17	6 15 14,5	0,89
57,9	4	26 08	26 15	6 26 11,5	0,83
57,9	5	37 07	37 13	6 37 10	0,78
58,0	6	48 03	48 11	6 48 07	0,72
	7	......	......	....	....
	8	09 59	10 11	7 10 05	0,60
58,1	9	20 56	21 08	7 21 02	0,58
	10	31 56	32 08	7 32 02	0,55
58,2	11	42 55	43 08	7 43 01,5	0,51
	12	53 55	54 08	7 54 01,5	0,49
	13	04 54	05 08	8 05 02	0,45
58,4	14	15 53	16 07	8 16 00	0,42
58,4	15	26 53	27 07	8 27 00	0,39
58,5	16	37 53	38 07	8 38 00	0,37
58,6	17	48 52	49 07	8 48 59,5	0,34
58,8	18	59 52	00 06	8 59 59	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	658,6	656,6	0,71	85928,70
2—17	658,8	656,8	0,63	85928,67
3—18	658,97	656,97	0,56	85928,68

Mean; Vibrations at 58°,19 FAHR.	85928,68
Reduction to 60° FAHR.	—0,76
Correction for buoyancy	+6,01
Vibrations in vacuo at 60° FAHR.	85933,93

EXP. 5. May 3rd A.M. Clock making 86189,71 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}757^{mm},00.\ \text{Th. }15^{\circ},5\text{ Cent.}\\ 756\quad ,45.\ \text{Th. }16\ ,1\text{ Cent.}\end{array}\right\}$ $756^{mm},72$. Th. 15°,8. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
59,0	1	06 49	06 51	9 06 50	1,00
59,0	2	17 45	17 49	9 17 47	0,96
59,1	3	28 41	28 47	9 28 44	0,91
59,2	4	39 37	39 42	9 39 39,5	0,84
59,3	5	50 34	50 40	9 50 37	0,80
	6	01 30	01 35	10 01 32,5	0,74
	7	12 26	12 33	10 12 29,5	0,69
59,4	8	23 22	23 31	10 23 26,5	0,63
	9	......	......	....	....
59,4	10	45 20	45 28	10 45 24	0,56
59,4	11	56 16	56 27	10 56 21,5	0,52
59,4	12	07 16	07 26	11 07 21	0,48
59,6	13	18 14	18 26	11 18 20	0,47
	14	......	......	....	....
59,7	15	40 11	40 24	11 40 17,5	0,38
59,8	16	51 08	51 25	11 51 16,5	0,36
59,9	17	02 09	02 25	12 02 17	0,34
60,0	18	13 08	13 24	12 13 16	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	657,77	655,77	0,70	85928,34
2—17	658,00	656,00	0,64	85928,38
3—18	658,13	656,13	0,58	85928,38

Mean; Vibrations at 59°,44 FAHR.	85928,37
Reduction to 60° FAHR.	—0,23
Correction for buoyancy	+6,00
Vibrations in vacuo at 60° FAHR.	85934,14

TABLE III. (Continued.)

EXP. 6. May 3rd P.M. Clock making 86189,71 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}756^{mm},45.\ \text{Th. } 16°,1\ \text{Cent.}\\ 756\ \ \ \ ,60.\ \text{Th. } 16\ ,2\ \text{Cent.}\end{array}\right\}$ 756^{mm},52. Th. 16°,15. Planes No. 8. Therm. No. 4.

Observer, Captain DUPERREY.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
60,0	1	30 44	30 48	12 30 46	0,90
60,2	2	41 40	41 44	12 41 42	0,84
	3	52 35	52 42	12 52 38,5	0,78
	4	03 32	03 40	13 03 36	0,72
	5	14 30	14 37	13 14 33,5	0,68
	6	......	......	....	....
60,1	7	36 25	36 34	13 36 29,5	0,60
	8	47 22	47 32	13 47 27	0,57
	9	58 21	58 31	13 58 26	0,52
	10	......	......	....	....
60,2	11	20 19	20 28	14 20 23,5	0,45
	12	31 16	31 27	14 31 21,5	0,42
	13	......	......	....	....
	14	53 12	53 27	14 53 19,5	0,38
59,7	15	04 11	04 27	15 04 19	0,35
	16	15 10	15 26	15 15 18	0,32
	17	26 10	26 26	15 26 18	0,30
59,7	18	37 08	37 26	15 37 17	0,30

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	658,13	656,13	0,57	85928,37
2—17	658,40	656,40	0,49	85928,41
3—18	658,57	656,57	0,44	85928,40
Mean ; Vibrations at 60°,05 FAHR.				85928,39
Reduction to 60° FAHR.				+0,02
Correction for buoyancy				+5,99
Vibrations in vacuo at 60° FAHR.				85934,40

EXP. 7. May 4th A.M. Clock making 86189,42 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}757^{mm},15.\ \text{Th. } 15°,3\ \text{Cent.}\\ 757\ \ \ \ ,10.\ \text{Th. } 15\ ,4\ \text{Cent.}\end{array}\right\}$ 757^{mm},12. Th. 15°,35. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
57,8	1	08 41	08 44	6 08 42,5	1,01
57,9	2	19 38	19 41	6 19 39,5	0,96
57,9	3	30 35	30 40	6 30 37,5	0,90
57,9	4	41 33	41 40	6 41 36,5	0,84
57,9	5	52 31	52 39	6 52 35	0,79
57,9	6	03 30	03 38	7 03 34	0,72
57,9	7	14 29	14 38	7 14 33,5	0,68
58,0	8	25 28	25 38	7 25 33	0,63
	9	......	......	....	....
	10	......	......	....	....
58,0	11	58 26	58 38	7 58 32	0,52
58,0	12	09 24	09 37	8 09 30,5	0,49
58,0	13	20 23	20 37	8 20 30	0,46
58,1	14	31 25	31 38	8 31 31	0,43
58,2	15	42 25	42 39	8 42 32	0,40
58,2	16	53 26	53 40	8 53 33	0,37
58,3	17	04 27	04 40	9 04 33,5	0,34
	18	15 27	15 41	9 15 34	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	659,37	657,37	0,72	85928,71
2—17	659,60	657,60	0,64	85928,72
3—18	659,77	657,77	0,57	85928,71
Mean ; Vibrations at 58° FAHR...				85928,71
Reduction to 60° FAHR.				—0,84
Correction for buoyancy				+6,05
Vibrations in vacuo at 60° FAHR.				85933,92

TABLE III. (Continued.)

EXP. 8. May 4th A.M. Clock making 86189,42 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}757^{mm},10.\ \text{Th. }15°,3\text{ Cent.}\\ 756\ \ \ ,22.\ \text{Th. }16\ ,1\text{ Cent.}\end{array}\right\}$ $756^{mm},66$. Th. 15°,7. Planes No. 8. Therm. No. 4.

Observer, M. NICOLLET.

Therm.	No. of Coincid.	Times of			Arc of Vibration.
		Disapp.	Re-app.	Coincidence.	
°		m s	m s	h m s	°
58,6	1	25 47	25 47	9 25 47	1,02
	2	36 42	36 44	9 36 43	0,96
	3	47 36	47 41	9 47 38	0,88
59,0	4	58 33	58 40	9 58 36,5	0,82
59,1	5	09 29	09 37	10 09 33	0,77
	6	20	......	....	....
	7	31 21	31 33	10 31 27	....
	8	42	......	....	....
59,5	9	53 21	53 31	10 53 27	0,58
	10	......	......	....	....
59,8	11	15 16	15 32	11 15 24	0,50
59,9	12	26 18	26 31	11 26 24,5	0,47
60,0	13	37 17	37 29	11 37 23	0,44
	14	......	......	....	....
	15	59 14	59 26	11 59 20	0,40
60,1	16	10 13	10 28	12 10 20,5	0,36
	17	21 10	21 28	12 21 19	0,34
60,1	18	32 09	32 28	12 32 18,5	0,32

Intervals between Coincidences.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Pendulum.		
	Vibrations.	Vibrations.	+	
1—16	658,23	656,23	0,72	85928,26
2—17	658,40	656,40	0,64	85928,26
3—18	658,70	656,70	0,55	85928,27
Mean; Vibrations at 59°,85 FAHR.				85928,26
Reduction to 60° FAHR.				—0,06
Correction for buoyancy				+5,99
Vibrations in vacuo at 60° FAHR.				85934,19

EXP. 9. May 4th P.M. Clock making 86189,42 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}756^{mm},4.\ \text{Th. }16°,3\text{ Cent.}\\ 755\ \ \ ,1.\ \text{Th. }16\ ,3\text{ Cent.}\end{array}\right\}$ $755^{mm},75$. Th. 16°,3. Planes No. 8. Therm. No. 4.

Observer, Captain FREYCINET.

Therm.	No. of Coincid.	Times of			Arc of Vibration.
		Disapp.	Re-app.	Coincidence.	
°		m s	m s	h m s	°
60,1	1	18 00	18 09	1 18 04,5	0,78
60,0	2	28 58	29 08	1 29 03	0,73
60,0	3	39 50	40 07	1 39 58,5	0,69
60,0	4	50 52	51 05	1 50 58,5	0,65
60,0	5	01 50	02 05	2 01 57,5	0,62
60,0	6	12 48	13 01	2 12 54,5	0,55
60,0	7	23 45	24 01	2 23 53	0,52
60,0	8	34 45	35 00	2 34 52,5	0,49
60,0	9	45 44	46 01	2 45 52,5	0,46
60,0	10	56 42	56 59	2 56 50,5	0,42
60,0	11	07 42	07 59	3 07 50,5	0,41
59,9	12	18 40	18 59	3 18 49,5	0,38
59,9	13	29 40	29 59	3 29 49,5	0,36
59,9	14	40 40	40 57	3 40 48,5	0,33
59,9	15	51 38	51 59	3 51 48,5	0,30
	16	......	......	....	....
59,8	17	13 39	13 56	4 13 47,5	0,28
59,8	18	24 38	24 55	4 24 46,5	0,28
59,8	19	35 36	35 54	4 35 45	0,25

Intervals between Coincidences.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Pendulum.		
	Vibrations.	Vibrations.	+	
1—17	658,94	656,94	0,43	85928,25
2—18	658,97	656,97	0,39	85928,23
3—19	659,16	657,16	0,33	85928,25
Mean; Vibrations at 59°,95 FAHR.				85928,24
Reduction to 60° FAHR.				—0,02
Correction for buoyancy				+5,99
Vibrations in vacuo at 60° FAHR.				85934,21

TABLE III. (Continued.)

EXP. 10. May 5th A.M. Clock making 86189,54 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}753^{mm},35.\ \text{Th. } 15^{\circ},9\ \text{Cent.}\\ 753\ \ ,30.\ \text{Th. } 16\ ,3\ \text{Cent.}\end{array}\right\}$ 753^{mm},32. Th. 16°,1. Planes No. 8. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
58,8	1	13 43	13 44	6 13 43,5	1,02
58,9	2	24 37	24 39	6 24 38	0,96
59,0	3	35 32	35 35	6 35 33,5	0,89
59,0	4	46 29	46 33	6 46 31	0,83
59,0	5	57 26	57 31	6 57 28,5	0,78
59,1	6	08 22	08 29	7 08 25,5	0,72
59,2	7	19 20	19 27	7 19 23,5	0,68
	8	......	......	....	....
59,3	9	41 15	41 24	7 41 19,5	0,59
59,4	10	52 13	52 24	7 52 18,5	0,56
59,4	11	03 11	03 22	8 03 16,5	0,52
59,4	12	14 10	14 21	8 14 15,5	0,49
	13	......	......	....	....
59,6	14	36 08	36 18	8 36 13	0,42
59,8	15	47 06	47 17	8 47 11,5	0,39
59,9	16	58 05	58 17	8 58 11	0,37
60,0	17	09 03	09 15	9 09 09	0,36
60,1	18	20 02	20 14	9 20 08	0,33

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	657,83	655,83	0,73	85928,23
2—17	658,07	656,07	0,66	85928,26
3—18	658,30	656,30	0,57	85928,25
Mean; Vibrations at 59°,37 FAHR.				85928,25
Reduction to 60° FAHR.				—0,26
Correction for buoyancy				+5,97
Vibrations in vacuo at 60° FAHR.				85933,96

EXP. 11. May 5th A.M. Clock making 86189,54 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}753^{mm},30.\ \text{Th. } 15^{\circ},9\ \text{Cent.}\\ 752\ \ ,80.\ \text{Th. } 16,\ 3\ \text{Cent.}\end{array}\right\}$ 753^{mm},05. Th. 16°,1. Planes No. 8. Therm. No. 4.

Observer, M. NICOLLET.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.	Arc of Vibration.
°		m s	m s	h m s	°
60,3	1	34 05	34 06	9 34 05,5	1,02
60,4	2	45 02	45 05	9 45 03,5	0,94
60,4	3	55 54	56 01	9 55 57,5	0,88
60,5	4	06 51	06 58	10 06 54,5	0,83
60,9	7	39 39	39 49	10 39 44	0,68
60,9	8	50 36	50 47	10 50 41,5	0,62
60,9	9	01 33	01 45	11 01 39	0,58
60,8	10	12 31	12 43	11 12 37	0,55
60,8	11	23 29	23 41	11 23 35	0,51
60,4	16	18 21	18 35	12 18 28	0,38
60,4	17	29 20	29 34	12 29 27	0,36
	18	40 19	40 34	12 40 26,5	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	657,5	655,5	0,74	85928,10
2—17	657,57	655,57	0,64	85928,04
3—18	657,93	655,93	0,55	85928,09
Mean; Vibrations at 60°,61 FAHR.				85928,08
Reduction to 60° FAHR.				+0,26
Correction for buoyancy				+5,96
Vibrations in vacuo at 60° FAHR.				85934,30

TABLE III. (continued.)

EXP. 12. May 7th A.M. Clock making 86189,84 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}748^{mm},90.\ \text{Th. } 15°,6\ \text{Cent.}\\749\ \ ,00.\ \text{Th. } 16\ ,0\ \text{Cent.}\end{array}\right\}$ 748^{mm},95. Th. 15°,8. Planes No. 7. Therm. No. 4.

Observer, M. MATHIEU.

Therm.	No. of Coincid.	Times of Disapp.		Times of Re-app.		Times of Coincidence.			Arc of Vibration.
°		m	s	m	s	h	m	s	°
58,4	1	24	01	24	03	7	24	02	1,00
58,5	2	34	57	35	02	7	34	59,5	0,94
58,7	3	45	54	46	01	7	45	57,5	0,89
58,9	4	56	52	56	59	7	56	55,5	0,82
59,1	7	29	50	29	57	8	29	53,5	0,68
59,2	8	40	50	40	58	8	40	54	0,62
59,3	9	51	48	51	57	8	51	52,5	0,58
59,4	10	02	48	02	56	9	02	52	0,53
59,4	11	13	46	13	56	9	13	51	0,50
59,5	12	24	43	24	57	9	24	50	0,47
59,6	13	35	43	35	57	9	35	50	0,45
59,8	14	46	44	46	58	9	46	51	0,42
59,9	15	57	44	57	59	9	57	51,5	0,38
59,8	16	08	45	09	02	10	08	53,5	0,36
59,3	18	30	45	31	03	10	30	54	0,32

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—16	659,43	657,43	0,70	85929,12
3—18	659,74	657,74	0,59	85929,15
Mean; Vibrations at 59°,25 FAHR.				85929,13
Reduction to 60° FAHR.				—0,31
Correction for buoyancy				+5,95
Vibrations in vacuo at 60° FAHR.				85934,77

EXP. 13. May 7th A.M. Clock making 86189,84 Vibrations in a Mean Solar Day.

Barom. $\left\{\begin{array}{l}749^{mm},00.\ \text{Th. } 16°,0\ \text{Cent.}\\749\ \ ,10.\ \text{Th. } 16\ ,2\ \text{Cent.}\end{array}\right\}$ 749^{mm},05. Th. 16°,1. Planes No. 7. Therm. No. 4.

Observer, M. SAVARY.

Therm.	No. of Coincid.	Times of Disapp.		Times of Re-app.		Times of Coincidence.			Arc of Vibration.
°		m	s	m	s	h	m	s	°
59,4	1	43	14	43	14	10	43	14	1,02
59,5	2	54	07	54	12	10	54	09,5	0,96
59,5	3	05	03	05	11	11	05	07	0,88
59,5	4	15	59	16	10	11	16	04,5	0,83
59,5	5	26	59	27	08	11	27	03,5	0,76
59,5	6	37	57	38	07	11	38	02	0,70
59,9	7	48	55	49	05	11	49	00	0,66
60,0	8	59	54	00	04	11	59	59	0,63
60,0	9	10	53	11	03	12	10	58	0,58
60,0	10	21	51	22	03	12	21	57	0,53
60,0	11	32	51	33	04	12	32	57,5	0,49
60,0	12	43	49	44	07	12	43	58	0,46
59,7	13	54	49	55	06	12	54	57,5	0,42
59,3	14	05	48	06	08	13	05	58	0,40
59,3	15	16	50	17	08	13	16	59	0,37
59,3	16	27	52	28	08	13	28	00	0,35
59,3	17	38	53	39	11	13	39	02	0,33

Intervals between Coincidences. Nos.	Clock.	Pendulum.	Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Vibrations.	Vibrations.	+	
1—15	658,93	656,93	0,73	85928,95
2—16	659,32	657,32	0,65	85929,03
3—17	659,64	657,64	0,56	85929,06
Mean; Vibrations at 59°,73 FAHR.				85929,01
Reduction to 60° FAHR.				—0,11
Correction for buoyancy				+5,93
Vibrations in vacuo at 60° FAHR.				85934,83

TABLE IV.

Paris.—Rate of the Invariable Pendulum No. 7, obtained by the Counter.

EXP. 1. April 29th, 1827. Clock making 86189,58 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.	
	Clock.	Counter.			Merc.	Therm.
	h m	h m s	°	Fahr.	mm	Cent.
1	11 07	3 50 01,536	1,10	57,4	759,30	14,2
2	11 37	4 19 56,218	0,88	....	759,25	14,5
3	12 07	4 49 50,709	0,76	58,0	759,25	14,6
4	12 37	5 19 45,277	0,64	58,0	759,25	14,8
5	13 07	5 49 39,700	0,55	58,0	759,25	14,8
6	13 37	6 19 34,282	0,47	58,0	759,25	14,8
7	14 07	6 49 28,791	0,40	57,8	759,00	14,6
8	15 07	7 49 17,891	0,30	57,3	758,80	14,5
9	16 07	8 49 06,973	0,24	57,2	758,80	14,5
			Mean....	57,71	759,13	14,6

Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Counter.		
	h m	Vibrations.	Vibrations.	
1—8	4 0	14356,355	0,70	85929,04
1—9	5 0	17945,437	0,62	85928,94
2—8	3 30	12561,673	0,49	85927,91
2—9	4 30	16150,755	0,45	85928,01
3—9	4 0	14356,264	0,37	85928,15
Mean; Vibrations at 57°,71 FAHR.				85928,41
Reduction to 60° FAHR.				−0,96
Correction for buoyancy				+6,04
Vibrations in vacuo at 60° FAHR. .				85933,49

EXP. 2. April 30th, 1827. Clock making 86189,01 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.	
	Clock.	Counter.			Merc.	Therm.
	h m	h m s	°	Fahr.	mm	Cent.
1	8 15	0 30 19,9	1,01	56,0	760,15	14,1
2	9 15	1 30 08,864	0,71	56,6	......	....
3	10 25	2 39 56,182	0,50	57,6	......	....
4	11 25	3 39 45,309	0,38	58,2	760,20	15,0
5	12 15	4 29 36,091	0,30	58,5	......	....
6	13 25	5 39 23,418	0,21	58,8	759,85	15,1
			Mean....	57,62	760,07	14,73

Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Counter.		
	h m	Vibrations.	Vibrations.	
1—5	4 0	14356,191	0,63	85927,42
1—6	5 10	18543,518	0,51	85927,78
2—5	3 0	10767,227	0,39	85927,86
2—6	4 10	14954,554	0,31	85928,18
Mean; Vibrations at 57°,62 FAHR.				85927,81
Reduction to 60° FAHR.				−1,00
Correction for buoyancy				+6,05
Vibrations in vacuo at 60° FAHR.				85932,86

TABLE IV. (Continued.)

EXP. 3. May 1st, 1827. Clock making 86188,94 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observers, MM. MATHIEU and SABINE.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.	
	Clock.	Counter.			Merc.	Therm.
	h m	h m s	°	Fahr.	mm	Cent.
1	9 14	1 03 23,836	1,00	57,1	760,00	14,8
2	9 49	1 38 17,600	0,80	57,9	......	......
3	10 19	2 08 11,991	0,68	58,3	......	......
4	11 34	3 22 58,164	0,47	59,0	......	......
5	13 14	5 02 40,002	0,28	59,1	......	......
6	14 14	6 02 29,018	0,20	59,1	......	......
		Mean		58,42	760,00	14,8

Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Counter.		
	h m	Vibrations.	Vibrations.	
1—5	4 0	14356,166	0,59	85927,17
1—6	5 0	17945,182	0,49	85926,94
2—5	3 25	12262,402	0,44	85925,93
2—6	4 25	15851,418	0,35	85925,95
Mean; Vibrations at 58°,42 FAHR.				85926,50
Reduction to 60° FAHR.				—0,66
Correction for buoyancy				+6,04
Vibrations in vacuo at 60° FAHR.				85931,88

EXP. 4. May 8th, 1827. Clock making 86189,62 Vibrations in a Mean Solar Day.
Planes No. 8. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.	
	Clock.	Counter.			Merc.	Therm.
	h m	h m s	°	Fahr.	mm	Cent.
1	7 53	0 24 20,600	1,01	57,5	751,60	15,0
2	8 53	1 24 09,736	0,77	57,7	......	......
3	9 53	2 23 58,736	0,60	57,8	......	......
4	10 53	3 23 47,778	0,48	57,8	......	......
5	11 53	4 23 36,827	0,38	57,7	......	......
6	12 53	5 23 25,909	0,30	57,7	752,85	15,8
		Mean....		57,7	752,22	15,4

Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Counter.		
	h m	Vibrations.	Vibrations.	
1—5	4 0	14356,227	0,73	85928,37
1—6	5 0	17945,309	0,63	85928,38
2—5	3 0	10767,091	0,52	85927,48
2—6	4 0	14356,173	0,44	85927,74
Mean; Vibrations at 57°,7 FAHR.				85927,99
Reduction to 60° FAHR.				—0,97
Correction for buoyancy				+5,99
Vibrations in vacuo at 60° FAHR.				85933,01

TABLE IV. (Continued.)

EXP. 5. May 10th, 1827. Clock making 86189,36 Vibrations in a Mean Solar Day.
Planes No. 8. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.	
	Clock.	Counter.			Merc.	Therm.
	h m	h m s	°	Fahr.	mm	Cent.
1	5 58	0 43 12,982	1,00	57,3	751,25	14,6
2	6 58	1 43 02,054	0,78	57,4	......	......
3	7 58	2 42 51,209	0,60	58,3	......	......
4	8 58	3 42 40,091	0,44	59,0	......	......
5	9 58	4 42 29,209	0,33	59,6	......	......
6	10 58	5 42 18,164	0,22	60,0	750,30	16,0
Mean....				58,6	750,77	15,3

Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Counter.		
	h m	Vibrations.	Vibrations.	
1—5	4 0	14356,227	0,66	85928,04
1—6	5 0	17945,182	0,52	85927,38
2—5	3 0	10767,155	0,47	85927,71
2—6	4 0	14356,110	0,36	85927,02
Mean; Vibrations at 58°,6 FAHR.				85927,54
Reduction to 60° FAHR.				—0,59
Correction for buoyancy				+5,97
Vibrations in vacuo at 60° FAHR.				85932,92

TABLE V.

Paris.—Rate of the Invariable Pendulum No. 8, obtained by the Counter.

EXP. 1. May 2nd, 1827. Clock making 86189,54 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.	
	Clock.	Counter.			Merc.	Therm.
	h m	h m s	°	Fahr.	mm	Cent.
1	9 08	0 56 12,218	1,00	58,5	758,60	15,2
2	10 08	1 56 00,745	0,71	59,0	......	......
3	11 23	3 10 46,218	0,49	59,4	......	......
4	12 13	4 01 36,773	0,37	60,0	......	......
5	13 08	4 55 26,173	0,28	60,0	......	......
6	14 08	5 55 14,673	0,20	59,8	757,15	15,8
Mean....				59,45	757,87	15,5

Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
Nos.	Clock.	Counter.		
	h m	Vibrations.	Vibrations.	
1—5	4 0	14353,955	0,59	85914,49
1—6	5 0	17942,455	0,50	85914,46
2—5	3 0	10765,428	0,37	85913,99
2—6	4 0	14353,928	0,30	85914,04
Mean; Vibrations at 59°,45 FAHR.				85914,25
Reduction to 58° FAHR.				+0,61
Correction for buoyancy				+6,01
Vibrations in vacuo at 58° FAHR.				85920,87

TABLE V. (Continued.)

EXP. 2. May 3rd, 1827. Clock making 86189,71 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.		Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Clock.	Counter.			Merc.	Therm.	Nos.	Clock.	Counter.		
	h m	h m s	°	Fahr.	mm	Cent.		h m	Vibrations.	Vibrations.	
1	9 33	0 18 35,100	1,00	59,8	757,00	15,5	1—5	4 0	14353,845	0,59	85914,02
2	10 33	1 18 23,745	0,70	59,8	......	......	1—6	5 0	17942,689	0,50	85915,75
3	11 33	2 18 12,011	0,50	60,0	......	......	2—5	3 0	10765,200	0,36	85912,33
4	12 33	3 18 00,718	0,37	60,2	......	......	2—6	4 0	14354,044	0,29	85914,90
5	13 33	4 17 48,945	0,28	60,2	......	......					
6	14 33	5 17 37,789	0,20	60,1	755,65	16,1	Mean; Vibrations at 60°,17 FAHR.				85914,25
			Mean	60,17	756,32	15,8	Reduction to 58° FAHR.				+0,91
							Correction for buoyancy				+5,99
							Vibrations in vacuo at 58° FAHR.				85921,15

EXP. 3. May 4th, 1827. Clock making 86189,42 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.		Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Clock.	Counter.			Merc.	Therm.	Nos.	Clock.	Counter.		
	h m	h m s	°	Fahr.	mm	Cent.		h m	Vibrations.	Vibrations.	
1	8 46	0 41 57,873	1,00	58,5	757,30	15,2	1—5	4 0	14353,936	0,58	85914,26
2	9 46	1 41 46,363	0,70	59,4	......	......	1—6	5 30	19736,872	0,47	85915,03
3	10 48	2 43 34,364	0,50	59,9	......	......	2—5	3 0	10765,443	0,35	85913,95
4	11 46	3 41 23,589	0,36	60,3	......	......	2—6	4 30	16148,382	0,27	85915,00
5	12 46	4 41 11,809	0,27	60,6	......	......					
6	14 16	6 10 54,745	0,18	60,4	......	......	Mean; Vibrations at 59°,85 FAHR.				85914,56
			Mean	59,85	757,30	15,2	Reduction to 58° FAHR.				+0,78
							Correction for buoyancy				+6,00
							Vibrations in vacuo at 58° FAHR.				85921,34

TABLE V. (Continued.)

EXP. 4. May 5th, 1827. Clock making 86189,54 Vibrations in a Mean Solar Day.
Planes No. 7. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.		Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Clock.	Counter.			Merc.	Therm.	Nos.	Clock.	Counter.		
	h m	h m s	°	Fahr.	mm	Cent.		h m	Vibrations.	Vibrations.	
1	8 08	0 33 25,382	1,00	59,9	753,50	16,0	1—5	4 00	14354,145	0,60	85915,64
2	9 28	1 53 09,909	0,62	60,5	......	......	1—6	5 00	17942,482	0,50	85914,60
3	10 08	2 33 02,464	0,50	61,0	......	......	2—5	2 40	9569,618	0,32	85917,08
4	11 08	3 32 50,855	0,38	61,3	......	......	2—6	3 40	13157,955	0,26	85915,24
5	12 08	4 32 39,527	0,29	60,9	......	......					
6	13 08	5 32 27,864	0,21	60,6	752,60	16,4	Mean; Vibrations at 60°,7 FAHR.				85915,64
		Mean		60,7	753,05	16,2	Reduction to 58° FAHR.				+1,13
							Correction for buoyancy				+5,96
							Vibrations in vacuo at 58° FAHR.				85922,73

EXP. 5. May 7th, 1827. Clock making 86189,84 Vibrations in a Mean Solar Day.
Planes No. 8. Therm. No. 3. Observer, M. MATHIEU.

No. of Comparisons.	Comparisons.		Arc of Vibration.	Temp.	Barometer.		Intervals between Comparisons.			Correction for Arc.	Corrected Vibrations in 24 Hours Mean Solar Time.
	Clock.	Counter.			Merc.	Therm.	Nos.	Clock.	Counter.		
	h m	h m s	°	Fahr.	mm	Cent.		h m	Vibrations.	Vibrations.	
1	8 18	0 10 31,182	1,00	59,2	748,90	15,6	1—4	4 10	14952,454	0,59	85917,19
2	9 18	1 10 19,782	0,70	60,0	......	......	1—5	5 00	17942,745	0,49	85916,13
3	11 18	3 09 56,955	0,38	59,9	......	......	2—4	3 10	11363,854	0,36	85916,88
4	12 28	4 19 43,636	0,28	60,4	......	......	2—5	4 00	14354,145	0,29	85915,63
5	13 18	5 09 33,927	0,20	59,9	749,00	16,0					
							Mean; Vibrations at 59°,88 FAHR.				85916,46
		Mean		59,88	748,95	15,8	Reduction to 58° FAHR.				+0,79
							Correction for buoyancy				+5,93
							Vibrations in vacuo at 58° FAHR.				85923,18

TABLE VI.—Transits observed in London.

1827.	Stars.	Wires Observed.					Mean.		
		1st.	2d.	Meridian.	4th.	5th.	By Chronometer.	By MOLYNEUX.	By CUMMING.
		m s	m s	h m s	m s	m s	h m s	h m s	h m s
Sept. 12	γ Aquilæ ...	13 40,4	14 04	8 14 28	14 51,2	15 15,2	8 14 27,8	8 13 41,58	8 14 11,38
	α Aquilæ ...	17 58,8	18 22	8 18 45,6	19 08,8	19 32,8	8 18 45,6	8 17 59,35	8 18 29,15
	α Cygni ...	10 48,4	11 21,2	9 11 53,6	12 26,4	13 59,6	9 11 53,8	9 11 07,36	9 11 37,16
	ε Pegasi ...	11 00,4	11 24,4	10 11 48	12 12	12 36	10 11 48,13	10 11 01,5	10 11 31,3
	Capella...	37 49,2	38 22,4	17 38 56	39 29,2	40 02,8	17 38 55,93	17 38 08,5	17 38 38,3
	Rigel......	....	....	17............	41 28,8	....	17 41 05,2	17 40 17,76	17 40 47,56
13	α Lyræ......	2 52,4	3 22,8	7 3 52,4	4 22	4 51,6	7 3 52,27	7 03 03,3	7 03 33,1
	γ Aquilæ ...	9 48,4	10 11,6	8 10 35,2	10 59,2	11 22,4	8 10 35,33	8 09 46,11	8 10 15,91
	α Aquilæ ...	14 06,4	14 30	8 14 53,2	15 16,8	15 40,4	8 14 53,33	8 14 04,1	8 14 33,9
	α Cygni ...	6 55,6	7 28,8	9 08 01,6	8 34	9 06,8	9 08 01,4	9 07 12,05	9 07 41,9
14	Sun's 1st L.	54 30	54 53,6	23 55 17,6	55 40,8	56 04	23 56 21,32	23 55 29,92	23 55 59,72
	Sun's 2d L.	56 38,4	57 02	23 57 25,2	57 49,2	58 12,4			
15	Sun's 1st L.	....	....	23 54 59,6	55 22,8	55 46,4	23 56 03,73	23 55 09,13	23 55 38,93
	Sun's 2d L.	56 20,8	56 44,8	23 57 08	57 31,6	57 54,8			
	γ Draconis	16 30,8	17 08	6 17 45,6	18 22,8	19 00,4	6 17 45,53	6 16 49,73	6 17 19,53
16	Sun's 1st L.	53 56	54 19,6	23 54 42,8	55 06	55 29,2	23 55 46,75	23 54 48,65	23 55 18,5
	Sun's 2d L.	56 04	56 27,6	23 56 50,8	57 14	....			
17	Sun's 1st L.	53 37,2	54 00,4	23 54 24	54 47,2	55 10,4	23 55 28	23 54 27,7	23 54 57,45
	Sun's 2d L.	55 45,6	56 00,2	23 56 32	56 55,2	57 18,8			
18	Sun's 1st L.	53 19,2	53 42,8	23 54 06	54 29,6	54 52,8	23 55 10,16	23 54 06,56	23 54 36,36
	Sun's 2d L.	55 27,2	55 50,8	23 56 14	56 37,6	57 01,2			
	Capella...	....	15 07,2	17 15 40,8	16 13,6	16 47,2	17 15 40,53	17 14 34,33	17 15 04,23
	Rigel ...	....	17 26	17 17 49,6	18 13,2	18 36,4	17 17 49,6	17 16 43,4	17 17 13,3
	α Orionis...	56 32,8	56 56,4	17 57 20	57 43,6	58 07,6	17 57 20,07	17 56 13,8	17 56 43,7
19	Sun's 1st L.	....	53 24,4	23 53 48	54 11,6	54 34,8	23 54 52,55	23 53 45,65	23 54 15,55
	Sun's 2d L.	55 10	55 34	23 55 57,2	56 20,4	56 43,6			
	γ Draconis	....	....	6 02 14,8	2 51,6	....	6 02 14,6	6 01 06,7	6 01 36,6
	α Lyræ......	39 36,4	40 06,4	6 40 36	41 05,6	41 35,6	6 40 36	6 39 28,1	6 39 58
20	α Cygni ...	39 48,4	40 20,8	8 40 53,6	41 26,4	41 59,2	8 40 53,67	8 39 41,07	8 40 10,87
	α Orionis...	48 49,2	49 12,4	17 49 36,4	49 59,2	50 23,2	17 48 36,13	17 48 22,53	17 48 52,43
22	Sun's 1st L.	....	....	23 52 57,6	....	....	23 54 01,6	23 52 43,4	23 53 13,5
	Sun's 2d L.	....	....	23 55 05,6	....	....			
	α Lyræ......	28 00	28 29,6	6 28 59,6	29 29,6	29 59,2	6 28 59,6	6 27 40,8	6 28 11
	γ Aquilæ...	34 56	35 19,6	7 35 42,8	36 06,8	36 30,4	7 35 43,07	7 34 24,2	7 34 54,4
	α Aquilæ...	39 13,6	39 37,2	7 40 00,8	40 24,8	40 48,4	7 40 00,93	7 38 42,03	7 39 12,23
	α Cygni ...	32 03,2	32 36,4	8 33 09,2	33 41,6	34 14	8 33 08,93	8 31 49,98	8 32 20,18
	ε Pegasi ...	32 16	32 40	9 33 03,6	33 26,8	33 50,8	9 33 03,47	9 31 44,42	9 32 14,62
	α Orionis...	....	....	17 41 50	42 13,6	42 37,6	17 41 50,07	17 40 30,07	17 41 00,47
23	γ Draconis	45 31,2	46 08	5 46 45,2	47 22,8	48 00,4	5 46 45,47	5 45 24,07	5 45 54,77
	α Lyræ......	24 07,6	24 37,6	6 25 06,8	25 36,4	26 06,4	6 25 06,93	6 23 45,43	6 24 16,13
	γ Aquilæ...	31 03,2	31 26,4	7 31 50,4	32 14	32 38	7 31 50,4	7 30 28,8	7 30 59,5
	α Aquilæ...	35 20,4	35 44,2	7 36 07,6	36 31,6	36 55,2	7 36 07,77	7 34 46,17	7 35 16,87
	α Cygni ...	....	28 42,8	8 29 15,6	29 48,8	30 21,2	8 29 15,7	8 27 54,1	8 28 24,7
	ε Pegasi ...	....	....	9............	....	29 58	9 28 10,4	9 27 48,73	9 28 19,33

TABLE VII.

Rate of MOLYNEUX deduced from the preceding Transits of Stars.

Stars.	Dates.	Clock's Loss on Sidereal Time.	Difference between Sidereal and Solar Time.	Clock's Gain on Solar Time.	Interval of Days.	Clock's daily Gain on Solar Time.
	September.	m s	m s	s		s
γ Aquilæ	12 to 22	39 17,38	39 19,1	1,72	10	0,17
”	12 to 23	43 12,78	43 15,01	2,23	11	0,22
”	13 to 22	35 21,91	35 23,19	1,28	9	0,14
”	13 to 23	39 17,31	39 19,1	1,79	10	0,18
α Aquilæ	12 to 22	39 17,32	39 19,1	1,78	10	0,18
”	12 to 23	43 13,18	43 15,01	1,83	11	0,17
”	13 to 22	35 22,08	35 23,19	1,11	9	0,12
”	13 to 23	39 17,93	39 19,1	1,17	10	0,12
α Cygni	12 to 20	31 26,29	31 27,28	0,99	8	0,12
”	12 to 22	39 17,38	39 19,1	1,72	10	0,17
”	12 to 23	43 13,26	43 15,01	1,75	11	0,16
”	13 to 20	27 30,98	27 31,37	0,39	7	0,06
”	13 to 22	35 22,07	35 23,19	1,12	9	0,12
”	13 to 23	39 17,95	39 19,1	1,15	10	0,12
”	20 to 23	11 46,97	11 47,73	0,76	3	0,25
ι Pegasi	12 to 22	39 17,08	39 19,1	2,02	10	0,20
”	12 to 23	43 12,77	43 15,01	2,34	11	0,21
Capella	12 to 18	23 34,17	23 35,46	1,29	6	0,21
Rigel	12 to 18	23 34,36	23 35,46	1,10	6	0,18
α Lyræ	13 to 19	23 35,2	23 35,46	0,26	6	0,04
”	13 to 22	35 22,5	35 23,19	0,69	9	0,08
”	13 to 23	39 17,87	39 19,1	1,23	10	0,12
”	19 to 23	15 42,67	15 43,64	0,97	4	0,24
γ Draconis	15 to 19	15 43,03	15 43,64	0,61	4	0,15
”	15 to 23	31 25,66	31 27,28	1,62	8	0,20
”	19 to 23	15 42,63	15 43,64	1,01	4	0,25
α Orionis	18 to 22	15 43,73	15 43,64	—0,09	4	—0,02
					Mean daily Gain......	0,15

TABLE VIII.

Rate of MOLYNEUX deduced from Transits of the Sun.

1827.	Sun's Transit by MOLYNEUX.	Mean Time of Apparent Noon.	MOLYNEUX Slow.	Rate of MOLYNEUX deduced.								
				Dates.	Int^s	Daily Gain.	Dates.	Int^s	Daily Gain.	Dates.	Int^s	Daily Gain.
Sept.	h m s	h m s	s	September.	Days	s	September.	Days	s	September.	Days	s
14	23 55 29,92	23 55 40,2	10,28	14 to 15	1	0,21	15 to 17	2	0,28	16 to 22	6	0,06
15	23 55 09,13	23 55 19,2	10,07	„ 16	2	0,36	„ 18	3	0,22	17 to 18	1	−0,14
16	23 54 48,65	23 54 58,2	9,55	„ 17	3	0,26	„ 19	4	0,14	„ 19	2	−0,02
17	23 54 27,7	23 54 37,2	9,50	„ 18	4	0,16	„ 22	7	0,13	„ 22	5	0,06
18	23 54 06,56	23 54 16,2	9,64	„ 19	5	0,15	16 to 17	1	0,05	18 to 19	1	−0,09
19	23 53 45,65	23 53 55,2	9,55	„ 22	8	0,14	„ 18	2	−0,04	„ 22	4	0,11
22	23 52 43,4	23 52 52,6	9,20	15 to 16	1	0,52	„ 19	3	0,00	19 to 22	3	0,12
				Mean daily Rate.						Gaining 0,13.		

Mean daily Rate of MOLYNEUX finally concluded, gaining 0,15 s from the 12th to the 23rd of Sept.

TABLE IX.

Comparisons of MOLYNEUX and CUMMING, Sept. 12th to Sept. 23rd.

Sept.		s	Sept.		s
12;	7 P.M. CUMMING Fast of MOLYNEUX	29,8	18;	7 P.M. CUMMING Fast of MOLYNEUX	29,8
13;	5 A.M.	29,8	19;	5 A.M.	29,9
—	7 P.M.	29,8	—	6 P.M.	29,9
14;	7 A.M.	29,9	20;	7 A.M.	29,85
—	8 P.M.	29,8	—	9 P.M.	29,85
15;	8 A.M.	29,8	21;	5 A.M.	29,9
—	6 P.M.	29,8	—	10 P.M.	29,95
16;	5 A.M.	29,8	22;	10 P.M.	30,2
—	6 P.M.	29,8	23;	5 A.M.	30,4
17;	6 P.M.	29,7	—	10 P.M.	30,6

Rate of CUMMING deduced:
- Sept. 12th P.M. to Sept. 20th P.M. gaining 0,18 s per diem.
- Sept. 20th P.M. to Sept. 21st P.M. gaining 0,28 per diem.
- Sept. 21st P.M. to Sept. 23d P.M. gaining 0,38 per diem.

TABLE X.

London.—Coincidences observed with the Invariable Pendulum No. 7.

EXP. 1. September 13th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 29°,96. Planes No. 8. Therm. No. 4. Observer, CAPTAIN SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 63°,85 FAHR.
63,7	1	44 29	44 33	6 44 31	6 50 43,7			373,7	85938,27
	2	50 41	50 46	6 50 43,5		0,87	0,49		
63,8	3	56 54	56 59	6 56 56,5					
63,9	33	03 43	03 52	10 03 47,5	10 10 02,0				
	34	09 58	10 06	10 10 02		0,28			
64,0	35	16 12	16 19	10 16 16,5					
Reduction to 63° FAHR.									+0,36
Correction for buoyancy									+5,98
Vibrations in vacuo at 63° FAHR.									85944,61

EXP. 2. September 13th Noon. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,00. Planes No. 8. Therm. No. 4. Observer, CAPTAIN SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 64°,2 FAHR.
64,1	1	35 52	35 55	10 35 53,5	10 42 06,7			373,5	85937,99
	2	42 05	42 08	10 42 06,5		0,83	0,47		
64,2	3	48 18	48 22	10 48 20					
64,2	31	42 34	42 41	1 42 37,5	1 48 51,7				
	32	48 48	48 56	1 48 52		0,29			
64,3	33	55 01	55 10	1 55 05,5					
Reduction to 63° FAHR.									+0,50
Correction for Buoyancy									+5,99
Vibrations in vacuo at 63° FAHR.									85944,48

TABLE X. (Continued.)

EXP. 3. September 13th P.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,05. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	°	s	s	At 64°,2 FAHR.
64,3	1	16 20	16 24	2 16 22					
	2	22 33	22 36	2 22 34,5	2 22 34,7	0,85			
64,3	3	28 46	28 49	2 28 47,5			0,51	373,52	85938,05
64,1	30	16 48	16 58	5 16 53					
	31	23 00	23 11	5 23 05,5	5 23 06,7	0,31			
64,1	32	29 16	29 27	5 29 21,5					
				Reduction to 63° FAHR.					+0,50
				Correction for buoyancy					+6,00
				Vibrations in vacuo at 63° FAHR.					85944,55

EXP. 4. September 14th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,25. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	°	s	s	At 63°,25 FAHR.
63,1	1	10 42	10 44	7 10 43					
	2	16 55	16 58	7 16 56,5	7 16 56,5	0,80			
63,2	3	23 08	23 12	7 23 10					
63,3	29	05 06	05 15	10 05 10,5			0,47	373,89	85938,49
	30	11 21	11 30	10 11 25,5	10 11 25,33	0,30			
63,4	31	17 37	17 43	10 17 40					
				Reduction to 63° FAHR.					+0,10
				Correction for buoyancy					+6,05
				Vibrations in vacuo at 63° FAHR.					85944,64

TABLE X. (Continued.)

EXP. 5. September 14th Noon. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,22. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.		Mean Interval.*	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	° s		s	At 63°,725 FAHR.
63,4	1	28 45	28 48	10 28 46,5	10 35 00	0,86	0,53	373,62	85938,21
	2	34 58	35 02	10 35 00					
63,7	3	41 12	41 15	10 41 13,5					
63,8	29	23 04	23 11	1 23 07,5	1 29 21,33	0,32			
	30	29 19	29 24	1 29 21,5					
64,0	31	35 30	35 40	1 35 35					
Reduction to 63° FAHR.									+0,30
Correction for buoyancy									+6,04
Vibrations in vacuo at 63° FAHR.									85944,55

EXP. 6. September 14th P.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,20. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Mean Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	° s		s	At 63°,975 FAHR.
64,0	1	44 22	44 25	1 44 23,5	1 50 36	0,87	0,65	373,51	85938,19
	2	50 35	50 37	1 50 36					
64,1	3	56 47	56 50	1 56 48,5					
63,9	28	32 24	32 31	4 32 27,5	4 38 40,83	0,42			
	29	38 36	38 45	4 38 40,5					
63,9	30	44 50	44 59	4 44 54,5					
Reduction to 63° FAHR.									+0,41
Correction for buoyancy									+6,03
Vibrations in vacuo at 63° FAHR.									85944,63

TABLE X. (Continued.)

EXP. 7. September 15th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,30. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 64°,025 FAHR.
63,6	1	50 24	50 26	10 50 25					
	2	56 37	56 40	10 56 38,5	10 56 38,5	0,83			
64,0	3	02 50	02 54	11 02 52			0,47	373,45	85937,93
64,2	30	50 54	50 59	1 50 56,5					
	31	57 05	57 12	1 57 08,5	1 57 08,63	0,30			
64,3	32	03 18	03 24	2 03 21					
Reduction to 63° FAHR.									+0,43
Correction for buoyancy									+6,05
Vibrations in vacuo at 63° FAHR.									85944,41

EXP. 8. September 19th P.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,19. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 64°,05 FAHR.
64,1	1	18 12	18 16	1 18 14					
	2	24 25	24 29	1 24 27	1 24 27,17	0,97			
64,1	3	30 39	30 42	1 30 40,5			0,81	373,433	85938,25
64,0	21	22 40	22 45	3 22 42,5					
	22	28 53	28 58	3 28 55,5	3 28 55,83	0,475			
64,0	23	35 06	35 13	3 35 09,5					
Reduction to 63° FAHR.									+0,44
Correction for buoyancy									+6,03
Vibrations in vacuo at 63° FAHR.									85944,72

TABLE X. (Continued.)

EXP. 9. September 20th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 29°,79. Planes No. 8. Therm. No. 4. Observer, M. QUETELET.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	°	s	s	At 61°,95 FAHR.
61,6	1	16 37	16 42	7 16 39,5					
61,6	2	22 49	22 56	7 22 52,5	7 22 52,5	0,96			
61,7	3	29 02	29 09	7 29 05,5			0,64	374,37	85939,26
62,1	31	23 47	23 53	11 23 50					
62,2	32	30 00	30 07	11 30 03,5	11 30 03,67	0,34			
62,5	33	36 14	36 21	11 36 17,5					
								Reduction to 63° FAHR.	−0,44
								Correction for buoyancy	+5,97
								Vibrations in vacuo at 63° FAHR.	85944,79

EXP. 10. September 20th P.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 29°,78. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	°	s	s	At 62°,25 FAHR.
62,0	1	2 29	2 32	1 02 30,5					
	2	8 42	8 46	1 08 44	1 08 44,17	0,94			
62,2	3	14 56	15 00	1 14 58					
62,3	23	19 35	19 43	3 19 39			0,71	374,08	85938,95
	24	25 50	25 57	3 25 53,5	3 25 53,67	0,41			
62,5	25	32 04	32 13	3 32 08,5					
								Reduction to 63° FAHR.	−0,31
								Correction for buoyancy	+5,96
								Vibrations in vacuo at 63° FAHR.	85944,60

TABLE X. (Continued.)

EXP. 11. September 22nd A.M. Clock making 86400,38 Vibrations in a Mean Solar Day.
Barom. 29°,58. Planes No. 7. Therm. No. 4. Observer, M. QUETELET.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	° s		s	At 61°,95 FAHR.
	1	*....	*....	*......	7 25 42,5				
61,9	2	*....	*....	*......		1,00	0,74		
	3	*....	*....	*......					
61,9	29	14 00	14 08	10 14 04	10 20 17,67			374,113	85939,22
62,0	30	20 12	20 22	10 20 17		0,40			
62,0	31	26 27	26 37	10 26 32					
(* Particulars mislaid.)					Reduction to 63° FAHR.				−0,44
					Correction for buoyancy				+5,93
					Vibrations in vacuo at 63° FAHR.				85944,71

EXP. 12. September 22nd P.M. Clock making 86400,38 Vibrations in a Mean Solar Day.
Barom. 29°,57. Planes No. 7. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of			Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.				
°		m s	m s	h m s	° s		s	At 61°,95 FAHR.
61,8	1	01 41	01 42	12 01 41,5............	1,18	0,99	373,74	85939,01
62,1	26	37 21	37 29	2 37 25	0,44			
				Reduction to 63° FAHR.				−0,44
				Correction for buoyancy				+5,93
				Vibrations in vacuo at 63° FAHR.				85944,50

TABLE XI.

London.—Coincidences observed with the Invariable Pendulum No. 8.

EXP. 1. September 16th Noon. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,34. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	° s		s	At 64°,9 FAHR.
64,5	1	16 23	16 27	11 16 25	11 22 28	0,82	0,42	363,48	85925,20
	2	22 26	22 29	11 22 27,5					
64,9	3	28 30	28 33	11 28 31,5					
65,0	33	30 12	30 19	2 30 15,5	2 36 19,33	0,25			
	34	36 15	36 23	2 36 19					
65,2	35	42 19	42 28	2 42 23,5					
Reduction to 63° FAHR.									+0,80
Correction for buoyancy									+6,05
Vibrations in vacuo at 63° FAHR.									85932,05

EXP. 2. September 17th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,36. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app	Coincidence.					
°		m s	m s	h m s	h m s	° s		s	At 64°,65 FAHR.
64,3	1	16 32	16 36	7 16 34	7 22 37,17	0,93	0,54	363,53	85925,36
	2	22 35	22 39	7 22 37					
64,6	3	28 39	28 42	7 28 40,5					
64,7	34	36 26	36 35	10 36 30,5	10 42 33,67	0,30			
	35	42 30	42 38	10 42 34					
65,0	36	48 33	48 40	10 48 36,5					
Reduction to 63° FAHR.									+0,69
Correction for buoyancy									+6,04
Vibrations in vacuo at 63° FAHR.									85932,09

TABLE XI. (Continued.)

EXP. 3. September 17th P.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,34. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.	Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	° s	s	at 65°,1 FAHR.
65,0	1	56 48	56 51	12 56 49,5				
	2	02 50	02 53	1 02 51,5	1 02 51,67	0,92		
65,0	3	08 52	08 56	1 08 54				
65,2	30	52 21	52 28	3 52 24,5		0,56	363,32	85925,12
	31	58 24	58 32	3 58 28	3 58 28	0,32		
65,2	32	04 28	04 35	4 04 31,5				
Reduction to 63° FAHR.								+0,88
Correction for buoyancy								+6,04
Vibrations in vacuo at 63° FAHR.								85932,04

EXP. 4. September 18th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,27. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of Disapp.	Times of Re-app.	Times of Coincidence.		Arc and Correction.	Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
°		m s	m s	h m s	h m s	° s	s	at 64°,775 FAHR.
64,5	1	00 31	00 36	8 00 33,5				
	2	06 34	06 39	8 06 36,5	8 06 36,67	0,89		
64,7	3	12 38	12 42	8 12 40				
64,9	31	02 14	02 19	11 02 16,5		0,50	363,44	85925,22
	32	08 17	08 23	11 08 20	11 08 20	0,30		
65,0	33	14 21	14 26	11 14 23,5				
Reduction to 63° FAHR.								+0,74
Correction for buoyancy								+6,04
Vibrations in vacuo at 63° FAHR.								85932,00

Table XI. (Continued.)

Exp. 5. September 18th P.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,24. Planes No. 8. Therm. No. 4. Observer, M. Quetelet.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 65°,91 Fahr.
65,9	1	10 35	10 40	1 10 37,5					
65,9	2	16 37	16 42	1 16 39,5					
66,0	3	22 40	22 44	1 22 42	1 22 42	0,95			
66,0	4	28 42	28 47	1 28 44,5					
	5	34 44	34 49	1 34 46,5					
65,8	30	06 03	06 10	4 06 06,5			0,64	363,124	85924,92
65,9	31	12 05	12 12	4 12 08,5					
65,9	32	18 08	18 16	4 18 12	4 18 12,6	0,35			
65,9	33	24 12	24 20	4 24 16					
65,9	34	30 16	30 24	4 30 20					
Reduction to 63° Fahr.									+1,22
Correction for buoyancy									+6,03
Vibrations in vacuo at 63° Fahr.									85932,17

Exp. 6. September 19th A.M. Clock making 86400,18 Vibrations in a Mean Solar Day.
Barom. 30°,20. Planes No. 8. Therm. No. 4. Observer, M. Quetelet.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 64°,17 Fahr.
64,0	1	19 47	19 53	8 19 50					
64,1	2	25 49	25 55	8 25 52	8 25 52,5	0,85			
64,1	3	31 53	31 58	8 31 55,5					
64,2	34	39 52	40 04	11 39 58			0,44	363,91	85925,78
64,3	35	45 56	46 06	11 46 01	11 46 01,67	0,25			
64,3	36	52 00	52 12	11 52 06					
Reduction to 63° Fahr.									+0,49
Correction for buoyancy									+6,02
Vibrations in vacuo at 63° Fahr.									85932,29

TABLE XI. (Continued.)

EXP. 7. September 21st A.M. Clock making 86400,28 Vibrations in a Mean Solar Day.
Barom. 29°,84. Planes No. 8. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	s	s	At 61°,85 FAHR.
61,6	1	35 51	35 52	10 35 51,5	10 41 55,17			364,11	85926,62
	2	41 55	41 56	10 41 55,5		1,07	0,92		
61,8	3	47 57	48 00	10 47 58,5					
62,0	23	49 18	49 25	12 49 21,5	12 55 25,67				
	24	55 23	55 28	12 55 25,5		0,47			
62,0	25	01 27	01 33	13 01 30					
Reduction to 63° FAHR.									−0,48
Correction for buoyancy									+5,99
Vibrations in vacuo at 63° FAHR.									85932,13

EXP. 8. September 23rd A.M. Clock making 86400,38 Vibrations in a Mean Solar Day.
Barom. 29°,55. Planes No. 7. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of			Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.				
°		m s	m s	h m s	°	s	s	At 60°,3 FAHR.
60,2	1	59 45	59 50	5 59 47,5	1,18	0,86	364,485	85927,12
60,4	34	20 11	20 20	9 20 15,5	0,35			
Reduction to 63° FAHR.								−1,13
Correction for buoyancy								+5,94
Vibrations in vacuo at 63° FAHR.								85931,93

EXP. 9. September 23rd A.M. Clock making 86400,38 Vibrations in a Mean Solar Day.
Barom. 29°,55. Planes No. 7. Therm. No. 4. Observer, Captain SABINE.

Therm.	No. of Coincid.	Times of			Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.				
°		m s	m s	h m s	°	s	s	At 60°,5 FAHR.
60,4	1	28 37	28 40	9 28 38,5	1,00	0,71	364,464	85926,95
60,7	29	18 40	18 47	12 18 43,5	0,37			
Reduction to 63° FAHR.								−1,05
Correction for buoyancy								+5,94
Vibrations in vacuo at 63° FAHR.								85931,84

TABLE XI. (Continued.)

EXP. 10. September 23rd P.M. Clock making 86400,38 Vibrations in a Mean Solar Day.
Barom. 29°,57. Planes No. 7. Therm. No. 4. Observer, Captain CHAPMAN, R.A.

Therm.	No. of Coincid.	Times of				Arc and Correction.		Mean Interval.	Corrected Vibrations in 24 Hours Mean Solar Time.
		Disapp.	Re-app.	Coincidence.					
°		m s	m s	h m s	h m s	°	'	s	At 61°,37 FAHR.
60,9	1	44 04	44 10	1 44 07					
	2	50 07	50 13	1 50 10	1 50 10,5	1,01			
61,4	3	56 11	56 17	1 56 14					
61,4	35	10 24	10 41	5 10 32,5			0,61	364,265	85926,60
	36	16 31	16 42	5 16 36,5	5 16 35,5	0,28			
61,4	37	22 32	22 43	5 22 37,5					
Reduction to 63° FAHR.									−0,68
Correction for buoyancy									+5,93
Vibrations in vacuo at 63° FAHR.									85931,85

POSTSCRIPT.

The expenses attendant on the conveyance of the pendulums and apparatus from London to Paris, and from Paris back to London, amounting to 26*l.* 15*s.* were defrayed by the Board of Longitude; with whom the papers have been deposited, containing the original entries of the several observations recorded in this paper.

In the account of my pendulum experiments made within the tropics and in the arctic circle, printed at the expense of the Board of Longitude, the rate of the clock with which the pendulums were compared was obtained at five stations, viz. at Bahia, Maranham, Trinidad, Jamaica, and New York, by means of a small repeating circle of six inches diameter, belonging to the Board of Longitude. The correct value of the divisions of the level of this instrument having been ascertained by Captain KATER since the publication of that volume, see Phil. Trans. 1827, Art. IX., the observations made with it at the stations above mentioned have been recomputed: whence it appears that at Bahia the astronomical clock was losing *less* by 0ˢ,09 per diem,—at Maranham *more* by 0ˢ,01 per diem,—at Trinidad *less* by 0ˢ,04 per diem,—at Jamaica *more* by 0ˢ,08 per diem,—and at New York *more* by 0ˢ,05 per diem,—

during the coincidences at each station, than was previously supposed. The length of the seconds pendulum at those stations requires consequently the following corrections, viz.

Bahia;	+ ·00008
Maranham;	— ·00001
Trinidad;	+ ·00004
Jamaica;	— ·00007
New York;	— ·00004

I am also indebted to Captain Kater for the discovery of the two following inaccuracies, which I gladly avail myself of the present opportunity to correct. "In the Table of results with the detached pendulums, the mean of the vibrations of pendulums 3 and 4 at New York should be 86117,98 instead of 86118,48; and at Hammerfest 86220,96 instead of 86221,46; and the resulting seconds pendulums, respectively, 39,10109 instead of 39,10153, and 39,19468 instead of 39,19512."

None of these corrections are of sufficient magnitude to be sensible in the deductions by any of the modes in which the observed pendulums are combined or applied in the volume alluded to; but, for the convenience of those persons who may have occasion to employ the results as data in other deductions, the following corrected Table is subjoined:

St. Thomas;	Latitude 0° 24′,7 N;	Pendulum	39,02074 inches.
Maranham;	2 31,6 S;		39,01213
Ascension;	7 55,2 S;		39,02410
Sierra Leone;	8 29,6 N;		39,01997
Trinidad;	10 38,9 N;		39,01888
Bahia;	12 59,3 S;		39,02433
Jamaica;	17 56,1 N;		39,03503
New York;	40 42,7 N;		39,10120
London;	51 31,1 N;		39,13929
Drontheim;	63 26,0 N;		39,17456
Hammerfest;	70 40,1 N;		39,19475
Greenland;	74 32,3 N;		39,20335
Spitzbergen;	79 49,9 N;		39,21469

V. *On the measurement of high temperatures. By* JAMES PRINSEP, *Esq. Assay Master of the Mint at Benares. Communicated by* PETER MARK ROGET, *M.D. Secretary of the Royal Society.*

Read December 13, 1827.

IF all the experiments had been recorded, which at different times must undoubtedly have been made on the subject of Pyrometry, by those engaged in operations requiring the accurate management of fire, the catalogue would consist principally of abortive attempts, if not of decided failures. The efforts to obtain exact measurements of high temperatures have probably been abandoned, partly from the occurrence of unforeseen difficulties, partly from the uncertainty of the results obtained: such, at least, appears to be the only way of accounting for the blank presented in this interesting and practically important branch of chemical knowledge.

In the admeasurement of the lower portions of the scale of temperature, and the determination of the proper methods of graduation, and the laws of expansion, gaseous tension, &c. a great degree of accuracy has been introduced. To the extent of the boiling point of mercury, indeed, we have tolerably exact values of the dilatation of metals and fluids; and by Messrs. DULONG and PETIT's experiments, the table has been extended to the irregularities of the thermometric indications of several substances, compared with the supposed uniform expansion of air, or of any other gas in a dry state.

But with respect to the measure of heat produced by furnaces, until Mr. DANIELL recently took up the subject, we only find upon record the invention of Mr. WEDGWOOD's pyrometer; an instrument the indications of which are assumed in every chemical work as authority for some doctrines relative to the scale of temperature, which savour of the marvellous; and for others, which a slight practical acquaintance with metals and crucibles must at all times have proved to be fallacious. As an example of the latter, I will only adduce the instance of the fusing point of copper, which, in Mr. WEDGWOOD's table, is placed, on the authority of Mr. ALCHORNE, considerably below that of silver; whereas if a crucible containing the two metals in a state of purity be carefully heated, the silver may be seen to flow round the copper some little time before the latter yields to the fire.

When I assert that so little progress has been made in pyrometry, however, I must be understood to refer only to the absolute measurement of high temperatures; for which purpose Mr. WEDGWOOD himself never considered his instrument qualified, although it was well adapted to the practical purpose of ascertaining deviations from a regulated heat required in any process of the arts. In this branch of the subject we may no doubt find numerous contrivances on record, which the ingenuity of different artists has at different times suggested. Most igneous operations, however, such as enamelling, assaying, foundry, &c. furnish tests of themselves on which the workman can generally place all the confidence he requires.

It is needless to describe the devices invented to indicate the mere comparative heat of fires: the principle of most of them consists in making a bar of some metal traverse the middle of the furnace, and act, by its elongation or otherwise, upon a convenient piece of mechanism outside. I have myself long made use of such a bar, carrying at one extremity an index on the compensation principle, made of silver and gold: and I only advert to it here that I may take the opportunity of noticing a curious circumstance brought to light by its constant use during five years.

The heat communicated to this compound index can never have much exceeded the melting point of lead, or about 700° FAHR., and yet the surface of the gold has gradually become perfectly discoloured, and apparently penetrated by the silver, in the same manner as would have been produced by mercury at a common temperature. This effect commenced on the edges of the slip of metal, and has now advanced nearly over the whole surface of the gold, giving it the appearance, under the microscope, of being studded over with hard tubercles of a leaden colour. The golden yellow, where it is not yet thoroughly changed, has become green like that of an alloy of gold and silver. The impregnation has extended to a considerable depth in the gold, and consequently the index has become less and less sensible to changes of temperature. But I should remark, that at the fixed end of the plate, where a piece of platina foil had been joined, to strengthen and support the index, no discoloration has taken effect, the platina covering seeming to shelter the gold from the argentine vapours. I should also remark, that the two metals were originally quite pure, and were united without any alloy, by simply laying an ingot of silver over one of gold, and heating the two until the former just began to melt; the compound ingot was then laminated.

Mr. Faraday has shown that mercury emits vapour capable of amalgamating with gold at very low temperatures. The circumstance just described tends to prove that silver does the same while yet in a solid state, and below the lowest red heat visible in the dark. I unfortunately omitted to keep any note of the original weight of the bar, and am therefore unable to say whether any sensible diminution has taken place.

To return from this digression.—In the Journal of the Royal Institution, vol. xi. Mr. Daniell has described an ingenious instrument, with which he measured the fusing points of many metals, and which has served to remove many of the anomalies of our so long undisputed catalogues. It may, however, be urged against his pyrometer, that platina has a smaller dilatation than every other metal, which is again diminished by the expansibility of the inclosing case of black-lead; and, moreover, that plumbago is acknowledged to be a very bad conductor of heat, and is liable to lose its shape. There does not appear by Mr. Daniell's account, to have been a desirable accordance in the result of different trials, excepting in the two experiments upon the fusing point of silver.

In the present day such a laudable jealousy of invention exists among scientific men, that it would be dangerous, even in this remote part of the world, to pass over any thing connected with my subject, lest I should be suspected of plagiarism in what I may hereafter offer as my own. I should therefore notice that Dr. Ure has recommended an air thermometer made of platina; but I cannot learn whether his plan has ever been carried into effect*. Sir James Hall has also announced that he has found a means of measuring furnace heat; and the world will no doubt receive it with the confidence due to the ingenuity of the illustrious inventor.

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* I find since, that the instruments have been made for sale; but I have seen no statements of experiments made with them.

The mind often speculates upon such subjects without bringing its crude ideas into practical form. I have at one time thought that the light, and consequently heat, of a fire might be admirably measured by the eye, with the intervention of a series of thin plates of coloured glass or talc; the number necessary to obscure the light being the indication of the heat.

It would be difficult, without actual trial, to estimate the objections to a photometer of this kind, from which doubtless some useful observations might arise: the intense heat of the oxy-hydrogen blowpipe, the fusion of platina, and other refractory metals, might thus be roughly estimated. The dark brown mica is well adapted for the construction of such an instrument, which might be made of one or two hundred thin laminæ pasted on card frames. The eye should be protected from extraneous light by means of a dark tube during observation.

After trying various plans, I have at last fixed upon one which appears to have superior claims to accuracy; and possesses the great advantage of being identifiable at any time and in any part of the world.

The fusing points of pure metals are determinate and unchangeable; they also comprehend nearly the whole scale of temperature; the unoxidable, or noble metals, alone embrace a range from the low melting point of silver to the high ignition of platina. There are, it is true, only three fixed points in this scale; but as many intermediate links may be made as are required, by alloying the three metals together in different proportions. When such a series has been once prepared, the heat of any furnace may be expressed by the alloy of least fusibility which it is capable of melting. Besides the unity of determinations which such a pyrometer would give, several other advantages might be enumerated:—the smallness of the apparatus; nothing more being necessary than a little cupel, containing in separate cells eight or ten pyrometric alloys, each of the size of a pin's head;—the indestructibility of the specimens; since those melted in one experiment would need only to be flattened under the hammer to be again ready for action;—and the facility of notation; since three letters with the decimal of the alloy would express the maximum heat: thus, pyrom. S .3 G might be used for an alloy of 0.7 silver with 0.3 gold, and G .23 P would express gold containing 23 per cent. of platina.

Having thus explained the principles of my proposed pyrometer, I proceed to describe the circumstances worthy of notice which occurred in the preparation of the alloys.

As gold melts at a heat not very much above silver, I assumed only ten degrees between them, measuring each by a successive addition in the alloy of 10 per cent of gold to the pure silver; the tenth degree being, of course, measured by pure gold. These alloys are easily made, and require no comment: in accurate researches they may be further subdivided, using always the decimal notation.

From the fusion of pure gold to that of pure platina, I assumed 100 degrees, adding one per cent of the latter metal to the alloy which measured each successive degree. Now, it is hardly to be supposed that the progress of these hypothetical degrees represent equable increments of heat; they will however, as I before observed, always indicate the same intensity; and their absolute value, as a matter rather of speculative than of practical interest, is to be sought by other expedients, such as the expansion of a platina bar, &c. in co-operation with the pyrometric cupel. I shall hereafter have to show how this has been practised in measuring the melting point of silver.

It was as long ago as the year 1821 when I made up the first twenty alloys of platina and gold; the metals were in a state of purity, and the proportions were adjusted to less than the thousandth part of the unit of each specimen, which weighed precisely 15 grains troy. The metals were fused in a powerful forge, supported on a small bone-ash cupel, and inclosed in an earthern crucible. The access of air was prevented as far as possible, and in some cases the metal was wrapped in paper to prevent the separation of small particles. I am thus particular in describing minutely the process of fusion, because some unexpected circumstances presented themselves in the fused buttons, which I believe have not hitherto been observed. Upon examining the specimens on their return from the fire, some were found to have gained considerably in weight; these were always more or less brittle under the hammer: others returned of the same weight as at first; and some few had even lost slightly in weight, and these, especially the latter, proved perfectly malleable. They were also of a brighter colour, and more deeply crystallized on the surface with the curiously knotted retiform indentations so peculiar to the alloys of platina.

I cannot here refrain from indulging in a few remarks upon the cause of this phænomenon. Neither gold nor platina, alone, were known to have the faculty of absorbing oxygen at high temperatures; and yet I could attribute the increase to nothing else, as carbon in many cases was not present, and the cupel exhibited no trace of being acted upon; excepting now and then where a paper covering had been employed, when the phosphate of lime had assumed, under the metallic button, a beautiful bright blue colour, resembling that of phosphate of iron. I soon satisfied myself that no carbon had been absorbed, by submitting a portion of the suspected metal to solution in nitro-muriatic acid. Neither could I obtain traces of silex, nor of any other earth; although M. Boussingault has observed that platina may even be readily fused by combining it with silex, which is effected by heating the metal in a crucible lined with wood charcoal: the metal in such case becomes brittle, and gains about one per cent in weight; but the silex is regularly discoverable by its forming a jelly on solution in aqua regia, which was by no means the case in my experiments. I am rather inclined therefore to believe, although unable to confirm the supposition for want of due examination, that the increase of weight must be attributed to oxygen, as has been proved by Mr. Lucas to be the case with regard to silver and copper. But the former of these metals gives out, at the moment of its becoming solid, the oxygen absorbed while it was in a liquid state: and copper, when quite brittle from the presence (as is supposed) of oxygen, may be restored to its malleable state by what is technically called poling; that is, by bringing carbon in contact with the melted metal: whereas when I remelted one of the platina alloys in an envelope of leather, it gained additional weight, and became more brittle than before.—The subject must be left for future examination.

The following Table will explain more fully the effect to which I have alluded. I have continued the series of alloys up to 70 per cent of platina, but that and the previous specimen were not fused in the highest forge heat. G .55 P. was only half melted by the intense heat capable of fusing the cupel of Gualior clay in which it was supported.

Alloys of Platina and Gold.

No.	Proportions of		Heat employed.	Colour of the Alloy.	Specific Gravity.	Weight of fused bead.	Malleability.
	Gold.	Platina.					
0	100	0	hottest part of assay furnace.	Bright orange, a cast redder; inclining to a buff or yellow ochre; then growing paler; cream-yellow and wood-brown; then acquiring a dingy-purplish tint like tarnished silver, and gradually losing the buff tint until it has nearly the bright steel colour of platina.	19·36	1000	Perfectly malleable.
1	99	1·			18·4	1001·4	Rather brittle.
2	98	2			19·0	1001	Ditto.
3	97	3			19·0	1000	Ditto.
4	96	4	ditto remelted.		19·8	1004	Not very perfectly fused.
5	95	5	forge.		19·1	1008·5	Brittle.
6	94	6	,,		18·6	1001	Rather so on edges.
7	93	7	,,		18·7	1014·5	Very brittle.
8	92	8	,,		19·5	1000	Quite malleable.
9	91	9	,,		19·4	1000	Quite malleable.
10	90	10	,,		18·7	1005	Brittle.
11	89	11	,,		19·0	1003	Brittle.
12	88	12	,,		19·4	1000	Quite malleable.
13	87	13	,,		18·8	1013	Very brittle.
14	86	14	,,		18·6	1000	Malleable.
15	85	15	,,		20·0	1000	Quite malleable.
16	84	16	,,		19·1	1004	Brittle on edges.
17	83	17	,,		19·2	1003	Ditto.
18	82	18	,,		20·5	990?	Perfectly malleable.
19	81	19	,,		20·9	996	Ditto.
20	80	20	bone-ash cupel melted.		18·9	1000·2	Not entirely.
21	75	25			20·9	992	Malleable.
22	70	30	,,		20·0	994	Not quite malleable.
23	65	35	,,		19·9	990	Perfectly malleable.
24	60	40	,,		19·0	1000·2	Cracks on edges and blisters.
25	55	45	,,		18·9	1000·3	Ditto, ditto, and brittle.
26	50	50	,,		20·0	1000	Rather brittle.
27	45	55	Gualior clay. crucible melted.		..	1000·3	Brittle, but not fused.
28	40	60			..	991	Not fused.
29	30	70			..	1000	Platina wires only agglutinated or soldered together by the gold.

Note 1.—The first four specimens were melted under an assay muffle: they were wrapped in paper, and the bone ash cupels were all stained under the metallic beads of a fine azure blue (query, phosphate of iron?).

2.—The beads melted in a forge, when suffered to cool gradually, were all crystallized deeply: the colour of the brittle beads was duller than that of the malleable ones.

3.—No. 7 was remelted inclosed in leather: it gained an additional six-tenths per cent, and was more brittle than before. This is unfavourable to the oxygen hypothesis.

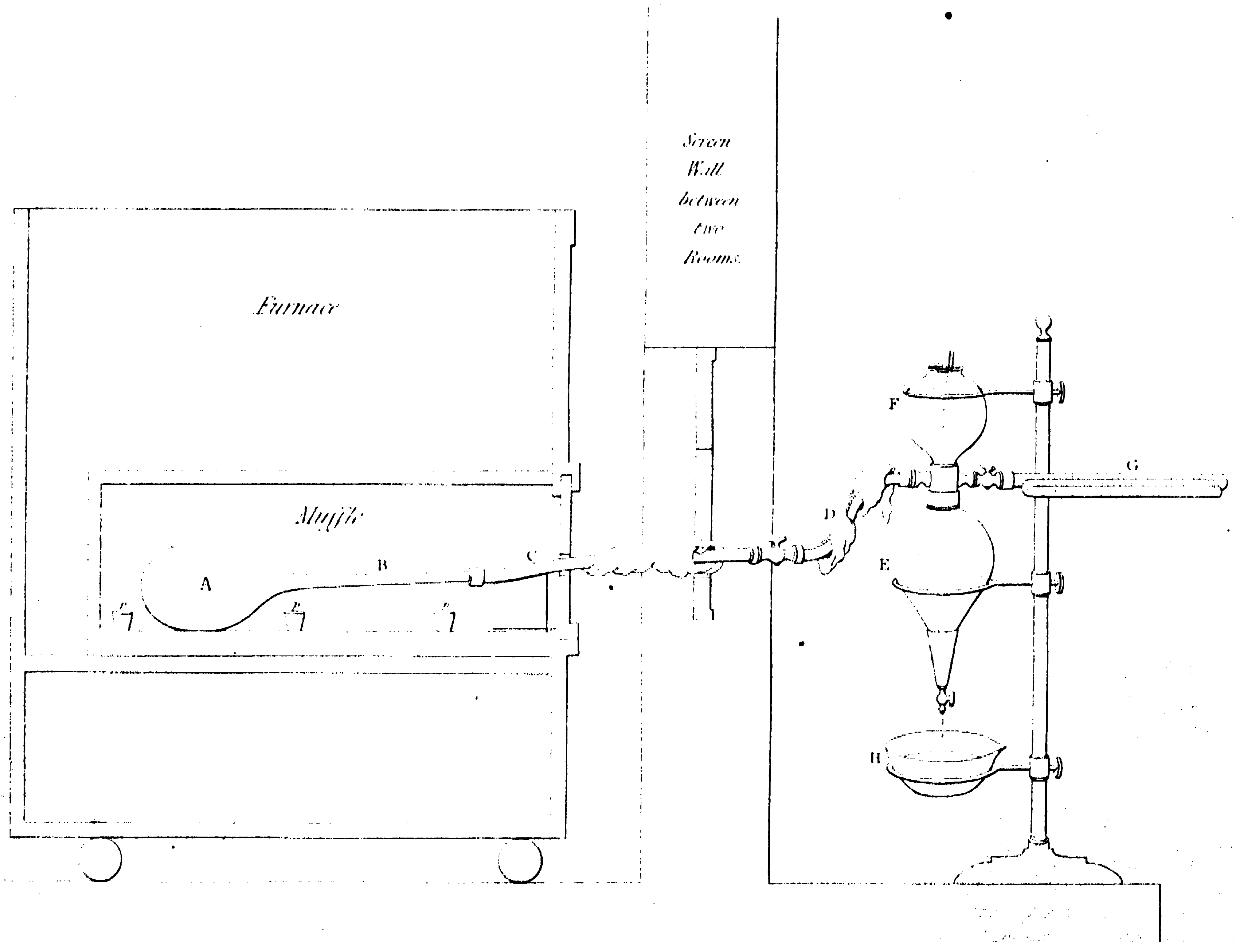
4.—The specific gravities were taken after hammering and annealing; but they cannot be depended upon, on account of the small bulk of the specimens, and the cracks on their edges: they are, however, the mean of two separate experiments made at distant periods; and prove, in a general way, that the brittle were of less specific weight than the malleable beads.

I shall now proceed to mention a few trials made with my pyrometric alloys in different furnaces and in different parts of the same furnace. The disparity of heat is greater than might have been supposed: and where, as in assaying the precious metals, so much depends upon the temperature at which the operation is performed, it would be useful to know every difference in this respect obtaining in various countries, and its effect upon the quality or standard of bullion.

	Maximum alloy melted.
Muffle of an assay furnace; front;	S .0 G
Muffle of an assay furnace; middle; average	S .3 G
Muffle of an assay furnace; behind; average	S .5 G
The Calcutta charcoal is better than that of Benares, and frequently heats the muffle to	G .04 P
Calcutta silver-melting furnaces of the English construction (specimens inclosed in an iron melting-pot)	G .075 P
Calcutta open native furnace	G .06 P
Calcutta blast furnace for melting musters	G .20 P
Black lead table furnace without chimney	G .08 P
Apex of condensed air blowpipe flame	G .20 P
Melting point of copper by two trials under a muffle	G .03 P
Melting of cast iron, about	G .30 P
Highest heat of a forge with the charcoal of Benares	G .55 P

The above examples are sufficient to show the use of this simple instrument as an indicator of heat. I lay no stress upon the melting points of copper or iron, because I have no opportunity of trying them on a large scale. The instrument is well adapted for measuring the relative force of different fuel;—of pit-coal, charcoal, wood, &c.; a point, in this country especially, where woods vary so much in texture, of no inconsiderable interest. In conclusion, I may notice that some ingenuity is necessary in the contrivance of a box to hold and pre-

Fig. 1.



Section of the Golden Bulb Thermometer   Scale 1½ inch to a foot.

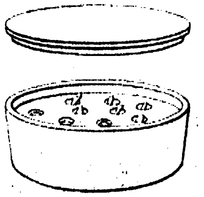


Fig. 2.   Pyrometer Cupel.

serve the specimens separate; and that the alloys of silver and gold lose in weight by long exposure to heat: they are however easily replaced; and the little musters need never be thrown away, as the gold may always be again purified. The platina alloys are very durable.

Having explained the means which I had provided for ascertaining the relative heat of a furnace, I turn to the more interesting portion of my experiments on pyrometric subjects; namely, the determination by means of an air thermometer of the absolute temperature at which pure silver enters into fusion. And here I pass over many fruitless endeavours made with cast iron retorts *, filled with azote to prevent oxidation, and proceed at once to the description of the apparatus which at last satisfied my expectations, and furnished the results presently to be enumerated.

In Plate II. fig. 1. the complete apparatus is displayed at the moment of an experiment. A, represents a retort or bulb of pure gold, weighing about 6500 grains troy, and containing nearly ten cubic inches of air. B, is a tube also of pure gold, which at its outer end is firmly united by a small gold collar to a similar tube, C, of pure silver; the bore of the latter tube is larger than that of the gold; but to prevent any undue influence from the unequal heating of the air contained in them both, and to confine the operation entirely to the gold bulb, the two tubes are plugged by wires of the same metals, so as to leave a very minute crevice for the air to pass. The outer part of the tube C is kept cool with a wet towel, to protect the stopcocks and flexible tube D. The tube D completes the communication of the air bulb with the glass reservoir E, which is intended as a substitute for an inconvenient length of

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* These experiments only furnished me with one fact new to myself; namely, that cast iron acquires a permanent increase of bulk by each successive heating: for the cubic contents of the retort used, as determined by the weight of pure mercury contained at the temperature of 80°, were as follows:

Before the first experiment...............	9.13 cubic inches.
After the first fire	9.64
After three fires	10.16

And the augmentation, which is more remarkable, exceeds the dilatation due to the temperature to which it was exposed; for as iron expands .0105 in 180 degrees, the increase of bulk upon 10 cubic inches should be $.105 \times 3 = .315$ at 1800° Fahr., or near the melting point of silver: whence it may be concluded that the dilatation of iron is not equable, as has been also proved by Messrs. Dulong and Petit.

graduated tube. This reservoir is nearly filled with olive oil, and is furnished with a safety tube and bulb F into which the oil rises when the air of A begins to flow, and a stopcock below, for the purpose of restoring the equilibrium of pressure by drawing out a portion of the oil. In the collar of the reservoir E, however, there is another stopcock aperture, leading into a graduated glass tube, G, in which a small bubble of oil is made to traverse. As this tube was very accurately divided into two-hundredths of a cubic inch, and may be read off to a tenth of that quantity, the equilibrium is capable of very delicate adjustment.

The furnace, as the figure exhibits, was situated in an adjoining apartment, so as to screen the exterior apparatus entirely from the heat. A small thermometer in F, however, serves to note any small change of temperature in the reservoir.

The furnace and muffle need no description, being of the ordinary assay construction. *p*, *p*, *p*, are little pyrometer cupels containing alloys of silver and gold, as mentioned in the former part of this paper.

Fig. 2. represents one of these pyrometer cupels with the lid raised, showing three of the alloys melted, and the rest retaining their form.

Every part of the instrument was ultimately rendered perfectly air-tight. But the first twelve experiments were rejected on account of minute leakage, which was at length entirely overcome; and several more were excluded on the suspicion of the air within the bulb not being thoroughly deprived of moisture, which desideratum was at last considered to be attained after frequently replenishing it with fresh air from a mercurial gasometer, where it had been exposed for days and even weeks to the drying action of concentrated sulphuric acid.

The absolute temperature, as must be evident from the construction of the instrument, is to be deduced from the measured volume of air expelled from the heated gold bulb; which volume again is to be found by the weight of the oil drawn from the reservoir, together with the adjustment of the bubble of oil in the graduated glass tube. The necessary calculation, however, embraces several corrections: some of them of minor effect and of known and certain influence,—as the formulæ for barometric and thermometric change; specific gravity of the oil, &c.;—others, which affect materially the results, and are by no means so certain in their power: these are the dilatation of gold at high temperatures, and the absolute law of gaseous expansion. The close agreement of M. Gay-Lussac's and Mr. Dalton's expressions for the expansion of gas between the fusing and the boiling point of water (0.375 and 0.376 in 180° Fahr.) leaves, it is true, but little room for hesitation in the adoption of the term 0.675 for 180 degrees. But as the tables of the dilatation of metals only give that of gold up to the boiling point of water, I may be wrong in assuming an equable rate of increase for greater heat: and it is therefore as much to provide against alterations in these points by future experimentalists, as from an earnest desire to conceal nothing which may affect my general conclusions, that I venture to trouble the Society with a detail of the data on which the several calculations are made. By this means, too, the following tables will speak for themselves, without the necessity of continual explanation.

First Series.

1. The tubes of silver and gold not plugged.
2. The contents, or interior volume of the gold bulb and tube, were found equal to 9.989 cubic inches, at the rate of 252.397 grains of pure water to the cubic inch at 80° Fahr.: but as the minus expansion of the portion of air in the gold tube, due to its not being heated to the full heat of the bulb, was rather more than balanced by the plus expansion of the air in the silver tube, the volume is estimated at 10 cubic inches.
3. The specific gravity of the oil found to be .91 at 80° Fahr.

Date.	Oil expelled.	Barometer		Thermometer		Adjustment of the Index.	No. of Exper.	Notes made at the time.
		before.	after.	before.	after.			
	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
May 29	1744·1	29·55	·48	90·	97·	+·005	1	Small square muffle furnace.—Silver not melted.
30	1726·0	29·40	·40	95·	93·6	+·028	2	Ditto. About the same heat, or rather hotter;—silver not melted.
June 1	1611·0	29·36	·35	94·5	100·5	—·043	3	Black's table furnace with muffle; bright-red heat, or orange.—Silver not at all affected.
4	1757·5	29·43	·40	93·3	94·5	+·010	4	Ditto.—Could not raise sufficient heat to fuse silver with the large muffle in.
5	1786·2	29·46	·43	87·	87·	—·011	5	Same furnace with narrower muffle.—A silver wire held over the bulb barely melted.
6	1753·5	29·31	·33	91·	94·8	—·023	6	Same furnace—heat not full. (Several subsequent experiments were rendered imperfect by a minute leakage where the gold and silver tubes were joined: this was remedied by adding solder.)
10	1810·0	29·315	·31	94·2	96·	+·025	7	Large assay furnace. Heat = S.4 G. (The next experiments were faulty from leakage, and it became necessary to cut off and replace the tip of the gold tube. The contents were now 10·062; or, allowing roughly for the portion less influenced by the heat, 10·03.)
July 1	1814·0	29·36	·43	90·	90·	+·040	8	Large assay furnace; bright orange heat: expansion continuing,—doubtful whether moisture was not present.
9	518·5	29·29	·29	84·1	86·	+·055	9	In boiling water.
10	1829·5	29·275	·27	86·5	84·5	+·062	10	Large furnace. Full melting heat.

SECOND SERIES.

1. The silver tube was now plugged with a wire whose cubic measure was 0·611 inch. This, projecting a little way into the gold tube, diminished the latter about 0·03 inch.
2. The volume of the gold tube being 0·415 inch, requires, now that there is no counterbalancing effect produced by the air of the silver tube, a correction to be introduced for its not sharing the full heat of the bulb itself in the furnace. I have thus experimentally estimated this correction, dividing the tube into four compartments:

the first containing	0·185;	heated, say to		1200°,	yields expansion		0·647
the second	—	·120	—	—	1100	— —	·394
the third	—	·080	—	—	1000	— —	·246
the fourth	—	·030	—	—	900	— —	·086
						Sum....	1·373

·415 heated all to 1600° would yield....1·785

The quantity of cold air expelled from the tube proportionate to 1·785 is 0·319
and for 1·373 is 0·290
leaving a difference 0·029

which is to be deducted from the residual gas in every experiment; or, as it comes to the same thing, may be deducted from the contents of the bulb and tube at once. 10·062 — ·03 + ·029 =10·003. Therefore 10,000 may be safely used as the volume of air during the present series.

3. The specific gravity at the beginning and end of these experiments was
24th of September at 88°....·9111. 11th of July at 82°....·9125
And the latter estimation is used for the temperature of 80°; to which, in the following series, the weight of the oil expelled is always reduced.

Date.	Oil expelled.	Barometer		Thermometer		Adjustment of the Index.	No. of Exper.	Notes made at the time.
		before.	after.	before.	after.			
	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
July 14 15	1789·	29·25	·35	83·3	89·	+·012	11	Large furnace always used. Full melting heat.—Apparatus placed in the cold muffle the preceding evening.
	1590·	29·25	·35	83·8	87·	....	12	Same experiment. At a full red heat.
16	1738·2	29·28	·38	91·	89·7	—·030	13	Oil allowed to remain in the safety tube under a pressure of three inches during the night; so that a small portion of air might have been absorbed by it.
17	1805·	29·38	·375	89·8	92·5	+·068	14	Good experiment. When cooled down, the index returned almost precisely to the original point.
19	1801·	29·28	·39	90·	89·9	+·033	15	Fresh air from the gasometer. Hot fire.
20	489·	29·37	·37	90·	91·	—·021	16	In boiling water—whole tube submerged.
21	1808·7	29·32	·34	88·5	88·	+·035	17	Hot fire. Henceforward the instrument was put suddenly into the muffle when heated to the necessary pitch.
24	1809·6	29·27	·282	91·	88·2	+·005	18	Moderate fire.
24	1816·2	29·28	·27	91·8	94·9	+·018	19	Second fire—rather hotter than the last.
25	1821·9	29·28	·32	88·2	90·9	—·060	20	
27	1814·	29·24	·27	85·4	88·2	—·012	21	
28	1836·2	29·29	·285	85·7	88·8	+·019	22	Hot fire.
29	1843·4	29·26	·28	83·8	83·9	+·069	23	Before this experiment the gold bulb had been inadvertently filled with the damp air of the room.—hygr. 91°.
29	1787·2	29·29	·27	86·6	91·	+·033	24	Dry air from the gasometer—low heat.
31	1813·4	29·20	·21	82·9	83·6	·000	25	Silver-melting heat.
Aug. 2	1816·7	29·436	·442	82·	85·	+·025	26	Full heat.
3	1795·7	29·405	·43	83·7	86·5	+·010	27	Silver not melted close to the bulb.
5	1820·	29·41	·44	83·	85·5	—·008	28	A hotter fire.
7	1823·3	29·45	·455	83·	84·3	+·028	29	Ditto.
9	1821·6	29·475	·474	89·	91·4	·000	30	Fully the melting point of silver—air fresh from the gasometer.

Although the foregoing series of experiments exhibits as much uniformity as could possibly be expected in a subject so liable to unavoidable irregularities, still I felt anxious to get rid altogether of the small correction allowed for the imperfect heating of the tube. With this view I re-opened the tubes, and fitted in the thick gold wire mentioned on a former occasion. The interior volume was now reduced to 9.7615 cubic inches: and by the trial in boiling water, this appears to be most correctly the influential volume.

THIRD SERIES.

Date.	Oil expelled.	Barometer		Thermometer		Adjustment of the Index.	No. of Exper.	Notes made at the time.
		before.	after.	before.	after.			
Aug.	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
17	455·9	29·40	·402	87·8	87·5	·000	31	In boiling water. Instrument in a very perfect state.
18	1736·3	29·43	·451	84·3	85·1	+·025	32	Large furnace; a little hotter than silver fusion.
20	1735·6	29·472	·480	83·	86·1	+·051	33	A minute portion of atmospheric air had previously been admitted to the dry air of the oil reservoir. Good experiment.
21	1786·8	29·486	·500	81·9	86·	—·170	34	Full muffle heat.
23	1695·5	29·43	·44	82·	86·3	—·012	35	Small furnace. Bright orange heat; silver not melted.
25	..	..	..	..	..	....	36	Back of the gold bulb melted at a temperature of about S .9 G. There had been a little silver solder applied to the part which gave way.

After this accident I endeavoured to render the bulb again serviceable by patching on a new bottom with as little solder as possible. In effecting the junction, I had reason to fear that a small portion of borax got into the interior of the instrument, and injured the subsequent experiments; and, as accidents seldom come singly, I was also perplexed by a few drops of oil having oozed down the tubes into the bulb, and, being suddenly converted into permanent gas, producing an excess in the quantity of oil driven from the reservoir. In four experiments the excess was about 150 grains, and the cause was evident during the process of cooling; but it was difficult to estimate the exact amount of new gas generated.

The contents of the repaired bulb were 7.666.

FOURTH SERIES.

Date.	Oil expelled.	Barometer		Thermometer		Adjustment of the Index.	No. of Exper.	Notes made at the time.
		before.	after.	before.	after.			
	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
Sept. 6	1841·1	29·575	·580	86·3	88·7	—·002	37	A hot fire.
7	1813·5	29·55	·56	86·9	91·1	+·035	38	Moderate and regular.
7	1923·3	29·592	·58	91·	94·8	+·072	39	Very hot fire. The solder on the bottom of the bulb had evidently run, but no leakage ensued.
8	1848·4	29·54	·54	88·	91·6	+·028	40	A regular fire.
9	1842·7	29·58	·59	87·	89·7	+·037	41	Below the ordinary heat.
11	1900·8	29·49	·49	87·	91·	+·040	42	Hot fire—Quere, any air generated.
13	1867·8	29·38	·398	87·	88·5	·000	43	Solder had partially fused. No leakage.
14	1859·5	29·47	·47	88·2	91·1	+·015	44	A good experiment.
14	1852·5	29·48	·48	89·2	92·9	+·065	45	Fresh air from the gasometer. No leakage; fire rather hot.
17	859·2	29·41	·40	87·	89·	+·024?	46	In boiling water.—This extraordinary anomaly seemed to be caused by an exceedingly minute infiltration of aqueous vapour, through the new joint; but on examination with a condensing air syringe, there did not appear any leakage. The longer the bulb remained in the water, the more gas came over; and when the instrument was again submitted to the furnace, the oil expelled amounted only to 1200 and 1300 grains, proving that some leakage existed which was not perceptible at a low temperature. With this experiment the whole series was brought to a conclusion.

It now remains to convert the data afforded by the foregoing table into degrees of the common thermometer. A single example will suffice to explain the process of this simple though somewhat lengthy calculation: and the table No. II. which follows, will set forth the fundamental data whence the results of each experiment are deduced.

One or two corrections,—for the expansion of the glass reservoir, and for the minute quantity of air contained in the exterior part of the apparatus,—are omitted in the calculation, as hardly appreciable: the temperature of the air in E (fig. 1.) may not always have been given with accuracy, as the thermometer was unavoidably suspended in F. No error on this head could exceed a single degree, as the screen wall effectually kept off the influence of the furnace, or equalized it on all objects connected with the apparatus outside.

TABLE II.

No. of experiment.	Volume of air expelled after all corrections.	Dimensions of heated gold bulb.	Expansion converted into degrees at ·375 per 180°.	Temperature of air.	Heat of the furnace.	Heat by Pyrometric cupels.	Notes.
	cubic inch.	cubic inch.	deg.	deg.	deg.		
1	7·472	10·410	1492	90	1582	none	Orange heat.
2	7·559	10·430	1578	95	1673	none	Bright orange.
3	7·106	10·370	1239	95	1334	none	Bright red heat, rather orange.
4	7·643	10·442	1644	94	1738	none	Bright orange—not quite melting silver.
5	7·775	10·465	1771	90	1861	S	Silver wire melted.
6	7·620	10·440	1627	91	1718	S	Perhaps a little less.
7	7·901	10·480	1917	94	2011	S .4 G	
8	7·978	10·470	2011	90	2101	none?	Damp air
9	2·300	10·032	144	84	228	. . . .	Ditto (These three rejected.)
10	8·057	10·499	2112	86	2198	S .2 G	Ditto
11	7·717	10·460	1727	84	1811	S	
12	6·876	10·350	1110	84	1194	. . . .	Full red heat.
13	7·566	10·430	1579	91	1670	S .1 G	Rejected.—Some air oozed out in night?
14	7·859	10·475	1863	90	1953	S .2 G?	Pyrometer cupel not employed, but put down by estimation.
15	7·851	10·475	1863	90	1953	S .3 G	Fresh air.
16	2·100	10·030	128	88	216	. . . .	Doubtful to what the excess can be attributed.
17	7·911	10·480	1930	88	2018	S .2 G?	
18	7·915	10·480	1934	90	2024	S .2 G	Pyrometer cupel at back of bulb S .3 G.
19	7·830	10·470	1835	92	1927	S .1 G?	
20	7·810	10·470	1812	88	1900	S .1 G?	
21	7·836	10·470	1845	85	1930	S .1 G	
22	7·936	10·490	1959	86	2045	S .3 G	Pyrometer; behind S .4 G, in front S .2 G.
23	8·094	10·500	2166	84	2250	S .2 G	Damp air.—Rejected.
24	7·712	10·460	1713	87	1800	S	Dry air. Fire proved dull.
25	7·864	10·475	1875	83	1958	S	Behind, S 0.15 G.
26	7·838	10·470	1792	82	1874	S .1 G	
27	7·769	10·465	1773	84	1857	S	Hardly so high.
28	7·863	10·475	1875	83	1958	S .2 G	
29	7·923	10·490	1945	83	2028	S .2 G	
30	7·866	10·475	1877	89	1966	S .1 G	
31	1·979	9·792	124·3	87·7	212	. . . .	The whole bulb and tube submerged in boiling water.
32	7·518	10·190	1701	88	1789	S	Perhaps these three are all a little too low; for the part of the bulb next the tube must have been less heated than the rest, and no allowance is made: the difference however must be very small.
33	7·538	10·190	1721	86	1807	S	
34	7·524	10·190	1708	86	1794	none	
38	7·819	10·121	2015	89	2104	S	From the uncertainty attending this series of experiments, it is better at once to reject the resulting temperatures. In Nos. 39 and 42 gas was evidently generated: and upon breaking up the instrument the interior of the tubes was found coated with oil, and the glaze of borax.
39	8·360	10·172	2993	95	3088	S	
40	7·989	10·1[illegible]0	2261	91	2352	S	
41	7·993	10·150	2268	90	2358	S	
42	8·218	10·170	2674	91	2765	S .4 G	
43	8·088	10·158	2426	88	2514	S .7 G	
44	8·037	10·154	2339	88	2427	S .2 G	
45	8·042	10·156	2348	89	2437	S .25 G	

The average results may be thus expressed:

Full red heat . . .	1200	
Orange heat . . .	1650	
Silver melts	1830	Daniell . . 2233°. Wedgwood 4717°.
Silver with $\frac{1}{10}$ gold .	1920	
Silver with $\frac{1}{4}$ gold, say	2050	

Example of the calculation of temperature from TABLE I.

On the 27th July 1826—twenty-first experiment.

	Weight of oil at temperature 80°, 1814·0 grains . . . . log.		3·2586373
	Correction for barometer $\left\{\begin{matrix}29^\circ{\cdot}24\\29\ {\cdot}27\end{matrix}\right\}$ . . . . difference of logarithms +		·0004453
	Correction for thermometer $\left\{\begin{matrix}85^\circ{\cdot}4\\88\ {\cdot}2\end{matrix}\right\}$ log. vol. air $\left.\begin{matrix}{\cdot}9763879\\{\cdot}9737043\end{matrix}\right\}$ diff. −		·0026836
	Constant for specific gravity of oil = ·9125 . . . . $\bar{1}$·9602329 Constant for grains of water per cubic inch = 252·397 . . 2·4020842 . . . −		2·3623171
Results,	Correct volume of air expelled at 85°·4 = 7·8358 cub. in.		0·8940819
	Volume of bulb	10·0000	
	Residual gas in the heated bulb	2·1642	0·3352974
	Correction for change of barometric pressure . . . . −		·0004453
	Correct residual gas	2·1620	0·3348521
	Expansion of gold at 1950° on 10 cub. in. = ·470		1·0199467
			1·
	Therefore as 2·1620 : 10·47 : : 10 : volume of gas, if all were heated =	48·428	. . . . 1·6850946
	deduct	10·000	
Results,	Quantity of expansion, cubic inches	38·428	1·5846478
	Constant for gaseous expansion 0·375 . . . . $\bar{1}$·5740313 Constant for 180° Fahr. . . . . 2·2552725		1·6812412
		1844·6	. . . . 3·2658890
	+	85·4	
	Temperature of the furnace in degrees of Fahr.	1930·0°	

I have now brought these experiments to a conclusion, and believe that they are sufficiently trustworthy to warrant a reduction in the tabular melting point of pure silver of at least 400 degrees below the determination of Mr. Daniell, while they indisputably prove the superiority of that gentleman's thermometric table as contrasted with that of Mr. Wedgwood.

That the air thermometer cannot be expected to give indications perfectly accordant, those who have kept registers of the manometer of the sympiesometer will be ready to grant. At high temperatures, also, a very small difference in the quantity of air ejected produces a considerable change in the corresponding heat; and the air thermometer has the disadvantage of becoming less sensible with every increase of heat; for the portion which is expelled from the hot bulb must necessarily be cooled to a known point before it can be measured. The substitution of a reservoir of oil or mercury in the place of a mere graduated tube is essential, where the instrument is to be suddenly thrust into the fire, as the rapid motion of a bubble of liquid in a tube would either, if oil, leave it as a film lining the tube, or if mercury, break a passage for the air by the side of it. The reservoir employed by me was equal to a tube fifty feet long, and of the same bore as the adjusting tube G.

To obviate the uncertainty of the increase of the bulb A, I constructed an apparatus for submitting the dilatation of gold and other metals to actual measurement: but as I have not yet concluded my experiments, I shall reserve them for a separate communication.

VI. *On Captain* Parry's *and Lieutenant* Foster's *experiments on the velocity of sound. By Dr.* Gerard Moll, *Professor of Natural Philosophy in the University of Utrecht. Communicated by Captain* Henry Kater, *V.P.R.S.*

Read January 17, 1828.

DURING Captain Parry's winter residence at Port Bowen, in 1824—1825, experiments were instituted on the velocity of sound. As, probably, investigations of that sort will not frequently be made at such low temperatures, it appears not uninteresting to compare the results obtained, with the theoretical formula of the late lamented Laplace, and also with other experiments made under different circumstances. With this view I caused my assistant M. Simons to make the calculations of which I am about to render an account.

Captain Parry's and Lieut. Foster's experiments were made at Port Bowen, in 73° 13′ 39″ N. and 88° 54′ 55″ W. of Greenwich. The distance of the brass six-pounder from the station of the observers was trigonometrically determined by Captain Parry to be 12892,96 English feet, and by Lieut. Foster 12892,82 feet; the mean being 12892,89 feet. Time was measured by pocket chronometers held close to the observers' ears. The direction of the gun was S. 71° 48′ E. The table of the experiments is repeated, to avoid the necessity of reference.

Date.	Barom.	Therm.	Wind.		Weather.	No. of guns fired.	Interval in Seconds between the Flash and Report.			Rate of travelling per 1″ in feet.
			Direction.	Force.			Parry.	Foster.	Mean.	
1824.	Engl. inch.	Fahr.					″	″	″	
Novemb. 24	29,841	— 7°	E.S.F.	light	overcast	5	12,3525	12,430	12,3912	1040,49
December 8	29,561	— 9	N.N.E.	squally	very clear	6	12,331	12,5266	12,4288	1037,34
1825.										
January 10	30,268	—37	E.S.E.	light	clear	4	12,5889	12,4700	12,5290	1029,01
February 7	29,647	—24,5	N.E.	light	very clear	6	12,639	12,6167	12,6278	1020,99
17	29,598	—18		calm	overcast	6	12,372	12,440	12,406	1039,25
21	29,735	—37,5		calm	overcast	6	12,8167	12,7067	12,7617	1010,28
March 2	30,398	—38,5	easterly	light	overcast	6	12,640	12,780	12,710	1014,39
22	30,258	—21,5	westerly	light	clear, and fine	6	12,400	12,7167	12,5583	1026,64
June 3	30,118	+33,5	easterly	light	very clear	6	11,7333	11,744	11,7387	1098,32
4	30,102	+35	S.E.	strong	clear	6	11,5889	11,4733	11,5311	1118,10

As it is suggested by the observers themselves, that the experiment of the 4th of June was influenced by a strong wind, blowing in the direction of the base, I shall not take the result of that day into the account. From the mean of all the other observations, we have the velocity of sound in one second equal to 1035,19 English feet, at a barometric pressure of 29,936 English inches, the temperature being — 17°,72 Fahr.

Laplace's theoretical formula, for the computation of the velocity of sound, is

$$V = \sqrt{\frac{gp}{D}} \times \sqrt{\frac{c'}{c}} \text{ *}$$

V being that velocity.
p the barometric pressure.
D the density of the air.
$\frac{c'}{c}$ the ratio between the specific heat of air, at a constant pressure and at a constant volume.

Taking the French metre equal to 39,38255 English inches [†], as results from English and French comparisons, we have 1035,19 feet = 315,4597826 metres; 29,936 inches = 0,76013 metres; — 17°,72 Fahr. = —27°,1 Centig.

According to Biot's and Arago's experiments, and taking the dilatation of mercury by heat as determined by Dulong and Petit, we have the weight of a cube centimetre of mercury at 0° Centig. 13,596152 grammes. The same philosophers found the weight of a cube centimetre of dry atmospheric air, under a pressure of 760 millimetres, and at a temperature of 0° Centig., at Paris, in latitude 48° 50′ 14″, equal to 0,001299541 grammes. To compute from these data the weight of a cube centimetre of atmospheric air at Port Bowen at the temperature of 0° Centig., and the pressure of 760 millimetres, we must multiply the number 0,001299541 by the ratio of the intensity of gravity at Paris and at Port Bowen.

Let the intensity of gravity at Port Bowen be g, the latitude $l = 73° 13′ 39″$;

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[*] Laplace, Annales de Chimie et de Physique T. III. p. 238. Poisson sur la vitesse du son, Annales de Chimie et de Physique Mai 1823, p. 5.

[†] I found afterwards that it had been better to have adopted Captain Kater's comparison of the metre with English inches, as given in the Phil. Trans. for 1818, p. 103.

at Paris g', the latitude $l = 48° 50' 14''$; and in latitude 45° (g); g' being equal to 9,8088 metres: We have then

$$g = (g)\,(1-0{,}002837\cos 2\,l)\,;\ \text{and}\ g' = (g)\,(1-0{,}002837\cos 2\,l')\colon$$

$$\frac{g}{g'} = \frac{1-0{,}002837\cos 2\,l}{1-0{,}002837\cos 2\,l'} = \frac{1{,}002364503}{1{,}000378864}\,;$$

$$\text{and}\ g = g'\left\{\frac{1{,}002364503}{1{,}000378864}\right\} = 9{,}8088\left\{\frac{1{,}002364503}{1{,}000378864}\right\}.$$

Thus the weight of a cube centimetre of dry air, at a pressure of 760 millimetres, and at the temperature 0° Centig., is at Port Bowen

$$\frac{0^{\text{v}}{,}001299541\times 1{,}002364503}{1{,}000378864} = 0{,}0013021206\ \text{grammes};$$

and the density of the air at Port Bowen, under a pressure of 760 millimetres, and in temperature 0°,0, is

$$\frac{0{,}0013021206}{13{,}596152} = \frac{1}{10441{,}545}$$

Consequently at an atmospheric pressure p, and temperature t, the density of air, at Port Bowen, is

$$D = \frac{p}{10441{,}545\times 0{,}760\,(1+0{,}00375\,t)}\ ;\ \text{and as}\ t = -27^\circ{,}62,$$

$$D = \frac{p}{10441{,}545\times 0{,}760\,(1-0{,}00375\times 27{,}62)}.$$

According to the experiments of Messrs. GAY-LUSSAC and WELTER, the ratio between the specific heat of air, under a constant pressure, and that under a constant volume, $\frac{c'}{c} = 1{,}3748$.

Substituting the above values in the formula

$$V = \sqrt{\frac{gp}{D}} \times \sqrt{\frac{c'}{c}}\quad \text{we have}$$

$$V = \sqrt{9{,}82827\times 10441{,}55\times 0{,}760\times 0{,}896425}\ \times\ \sqrt{1{,}3748}$$

$$= 310{,}0305696\ \text{metr.} = 1017{,}72\ \text{English feet.}$$

The general result of Captain PARRY's and Lieut. FOSTER's experiments gives for the velocity of sound . . . . 315,426 metr. = 1035,19 feet.
The theoretical calculation gives . . . . 310,031 metr. = 1017,72 feet.

Difference between calculation and experiment . . . . 5,395 metr. = 17,47 feet.

Now, if we take the mean of the experiments made at Port Bowen the 17th and 21st February 1825, when the weather was calm, we have the velocity by experiment, 1024,765 feet = 312,249446 metr., at a barometric pressure of 0,75328 metr., and a temperature of −27°,75 FAHR., or −33°,2 Centig.

Thus we have $D = \frac{p}{0{,}760 \times 0{,}8755 \times 10441{,}55}$; which being substituted in the foregoing expression, we have the velocity of sound,

$$V = \sqrt{9{,}82827 \times 10441{,}55 \times 0{,}8755 \times 0{,}76} \times \sqrt{1{,}3748} = 306{,}39072 \text{ metr.}$$

The velocity by experiment . . . . = 312,249446 metr.

Difference between computation and experiment, on the 17th and 21st February 1825 . . . = 5,858726 metr.

Again, comparing the experiments of the 22nd March and 3d June with theory, we may hope to have some compensation for the effect of wind. On the 22nd March the wind was westerly, and on the 3d June easterly. Both experiments were made at a temperature comparatively high. The velocity of sound was, by the mean of the experiments of these two days, 1062,48 English feet, or 323,741284 metr. The barometric pressure was 30,188 inches, or 0,76653 metr. The temperature was +6° FAHR., or −14°,4 Centig.

Calculating with these data, we have the velocity of sound, on the 22nd March and 3d June, by theory . . . . 318,488009 metr.
By the experiments . . . . 323,741284 metr.

Difference by the experiments of 3d June and 22nd March . . . . 5,253275 metr.
Difference by the experiments of 17th and 22nd February . . . . 5,858726 metr.
Difference by all the experiments but the last . . . 5,395 metr. or 17,47 feet.

In the experiments which I made with Dr. Van Beek, and which are recorded in the Phil. Trans. for 1824, we had the following differences between calculation and experiment.

By the experiments of 27th June, 1823, difference 4,92 metr. = 16,147 feet.
By the experiments of 28th June, 1823, difference 4,24 metr. = 13,916 feet.

The final inference to be drawn appears, that in those high latitudes, the uncertainty of the data on which the calculations are founded, is somewhat greater than at higher temperatures. Laplace himself says of these differences, "qu'elles paraissent être dans les limites des petites erreurs dont cette expérience, et les élémens de calcul, dont j'ai fait usage, sont encore susceptibles."

Perhaps it might occur to some, that Captain Parry and Lieut. Foster ought to have observed the hygrometer; but I think the objection unfounded. I believe it may be shown, that even supposing the air saturated with aqueous vapour, it could, at those low temperatures, have no influence on the velocity of sound.

Let the tension of aqueous vapour in the atmosphere be T. According to M. Gay-Lussac's experiments, the density of aqueous vapour is $\frac{10}{16}$ of the density of dry air. Thus we have

$$D = \frac{p - \frac{3}{8}\,T}{10441{,}55 \times 0{,}76\,(1 + 0{,}00375\,t)}$$

which being substituted in the theoretical formula, it becomes

$$V' = \sqrt{\frac{g\,.\,p\,.\,10441{,}55 \times 0{,}76\,(1 + 0{,}00375\,t)}{p - \frac{3}{8}\,T}} \times \sqrt{\frac{c'}{c}}$$

We calculated Captain Parry's and Lieut. Foster's experiments by the formula

$$V = \sqrt{10441{,}55\,.\,g\,.\,0{,}76\,(1 + 0{,}00375\,t)} \times \sqrt{\frac{c'}{c}}$$

thus we have

$$V' = V\,.\,\sqrt{\frac{p}{p - \frac{3}{8}\,T}}.$$

Now supposing the degrees of the centesimal thermometer under 100° or the boiling point to be N, and T_N the tension of aqueous vapour at that temperature, in a space saturated with moisture; we have, by a formula deduced by M. Biot from M. Dalton's experiments*

$$\text{Log. } T_N = \bar{1}.8819493 - 0{,}01537271116\ N - 0{,}0000673241\ N^2 + 0{,}00000003377\ N^3$$

Captain Parry's experiments were made at the temperatures of $-27°$, $-33°$, and $-14°$ Centig. Thus we must successively take N equal to 127, 133, and 114; and calculating on those several suppositions, we have the tension of aqueous vapour, at

$-27°$ C. .... $0{,}000816121 = T$
$-33°$ C. .... $0{,}000542991 = T'$
$-14°$ C. .... $0{,}002010982 = T''$

The general result of all Captain Parry's experiments, at a temperature of $-27°$ Centig. and barometric pressure of 0,76013 metr., was $V = 310{,}0305696$ metres.

we have $T = 0{,}00081621$; $\frac{3}{8}\ T = 0{,}000306045375$; $p - \frac{3}{8}\ T = 0{,}759823954625$ metr.

and thus $V' = 310{,}0304696 \text{ metr.} \times \sqrt{\frac{0{,}76013}{0{,}759824}} = 310{,}0929624$ metr.

Thus, even supposing that the air in Captain Parry's and Lieut. Foster's experiments was as moist as possible, the difference in the velocity of sound at such low temperatures could be only 0,0623921 metr., or about 2 inches $\frac{4}{10}$.

Calculating on the same supposition, the experiments of the 17th and 21st February, and of the 22nd March and the 3d of June 1825; and supposing the air as moist as can be: we have, for the 17th and 21st of February 1825,

$$V' = 306{,}43213 \text{ metr.}$$

and thus the velocity altered by 0,04141 metr. or about $1\frac{7}{10}$ inch in 1''.

For the experiments of the 22nd March and the 3d June 1825, the difference is somewhat greater. For we have then

$$V' = 318{,}64481 \text{ metr.}$$

and the velocity is altered by 0,156801 metr. or $6\frac{2}{10}$ inches.

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* Biot, Traité de Physique, T. I. p. 277.

At all events, the effect produced by moisture, under the circumstances in which the experiments at Port Bowen were made, is so trifling, that it may safely be neglected altogether.

I shall now proceed to compare the experiments of the northern navigators with those of Dr. Van Beek and myself, and shall reduce for that purpose the Port Bowen experiments to what they would have been at the temperature of 0° C. or 32° F.

Taking V'' as the velocity of sound at 0° C., and D the density of air at that temperature, we have

$$V'' = \sqrt{\frac{g \cdot p}{D}} \times \sqrt{\frac{c'}{c}}$$

Let V be the velocity at a temperature t, we have again

$$V = \sqrt{\frac{g\,p\,(1+0{,}00375\,t)}{D}} \times \sqrt{\frac{c'}{c}}$$

wherefore

$$V'' = \frac{V}{\sqrt{1+0{,}00375\,t}}$$

The mean of Captain Parry's and Lieut. Foster's experiments, excepting those of the 4th of June 1825, give

$$V = 315{,}42597826 \text{ metr.}; \text{ the temperature } t = -27^\circ{,}62 \text{ Centig.}$$

Whence V''	= 333,15 metr.
In the same manner, calculating V'' for the experiments of the 17th and 21st of February 1825, we have	333,71
And for those of the 22nd of March and 3d of June . . .	332,85
Dr. Van Beek's and my experiments give	332,05
Messrs. Stampfer and Von Myrbach in 1822 in Germany .	333,25
Messrs. Arago, Mathieu and Biot, in France	331,05
Mr. Benzenberg in Germany	333,70
Messrs. Epinoza and Bauza in Chili	356,14
Dr. Olinthus Gregory in England	335,14
The French Academicians in 1738	332,93

Thus the differences between Captain Parry's experiments and ours, when both are reduced to the same temperature of 0° is $1^{m}\cdot 1$, $1^{m}\cdot 7$, and $0^{m}\cdot 8$. These differences will be deemed very small, if we consider, that between our own experiments the difference was 0,66 metr., and that between those of the members of the French Board of Longitude, there were still more considerable differences.

These results on the whole appear very satisfactory; and the near agreement of experiments, made under circumstances so widely different, must lead us to suspect that whatever difference still remains between the results of computation and observation, must be ascribed, in a great measure, to some imperfection of the theoretical formula, and not to any fault or neglect of the observers.

Another conclusion may be fairly drawn from the coincidence of the results obtained by Captain Parry and his friend, with those of many other observers. I mean the great accuracy with which Captain Parry's proceedings were conducted. Our own experiments were made under every favourable circumstance; in the middle of summer, in a place where nothing was wanted which could give ease and comfort to the observers. Captain Parry and Lieut. Foster operated in a dreary climate, partly in a polar winter, far from every thing which could make their task easy, and above all at a temperature of which it is frightful to think. Besides this, Captain Parry had many other important matters at the time committed to his care. Our observations, and those of many other observers, were a party of pleasure; theirs, a painful drudgery. And still with every thing thus in our favour, provided with all the means which we could think of, we could do no better than he did in the most inhospitable climate of the globe. It appears that Captain Parry's experiments are as accurate as those of any other observer. This equality I should consider as a proof of superiority, considering the peculiar circumstances under which the experiments at Port Bowen were made.

VII. *An account of a series of experiments made with a view to the construction of an achromatic telescope with a fluid concave lens, instead of the usual lens of flint glass. In a letter addressed to* Davies Gilbert, *Esq. M.P. President of the Royal Society. By* Peter Barlow, *Esq. F.R.S. &c.*

Read January 17, 1828.

YOU are aware that I have been for some time engaged in a set of experiments directed to the construction of achromatic fluid telescopes, and that I have succeeded in constructing, by the aid of Messrs. Gilbert, two instruments of that description, the one of 3 inches aperture and the other of 6 inches. You are aware also that it was my intention to have laid these before the members of the Board of Longitude; and if the construction had met with their approbation, I hoped they might have been disposed to have ordered a like instrument (but upon a scale much exceeding anything yet attempted), the construction of which it would have given me great pleasure to have superintended.

It is, however, doubtful whether I shall be able at present to pursue the experiments*; and I wish therefore to place on record the progress I have made, the results which have been obtained, and the ultimate object I had in view; and I am in hopes this communication may not be thought undeserving a place in the Philosophical Transactions.

These experiments may perhaps date their origin from an attempt on the part of the opticians above referred to, to submit to actual practice the rules and principles laid down by Mr. Herschel, in the Phil. Trans. for 1821, Art. XVII., for the construction of aplanatic object-glasses. These experiments led to others, which I have described in the Phil. Trans. for 1827, Art. XV. In following out the latter, I saw a strong practical instance of the great difficulty of obtaining flint glass of sufficient size and purity for astronomical telescopes; and this led me to consider the practicability of substituting a fluid for the

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* Since this paper was read, my letter has been presented to the Board of Longitude, and the experiments are in progress.

flint lens. Dr. BLAIR many years back had projected the construction of fluid object-glasses, and is said to have succeeded in making very perfect telescopes of that description. His view, however, in these constructions was not the same as mine; because with him it was still necessary to retain the flint lens; his only object being to destroy what has been named the secondary spectrum, due to a want of proportionality between the coloured spaces of the spectrums of flint and plate, or crown glass, as compared with their respective refractive indices; whereas my design was to dispense altogether with the flint glass, by substituting in its place a fluid medium of the requisite refractive and dispersive power.

A great number of fluids may be thus employed; and the first business was to determine amongst the many, that which seemed best suited for the purpose. With this view I undertook the examination of the properties of various oils, acids, &c. and was ultimately led to try the sulphuret of carbon, which at once appeared to claim a preference, and to possess nearly every requisite I could desire; having a refractive index about equal to that of the best flint glass, with a dispersive power more than double, perfectly colourless, beautifully transparent, and, although very expansible, possessing the same, or very nearly indeed the same, optical properties*, when hermetically sealed, under all temperatures to which it is likely to be exposed for astronomical purposes, —unless indeed it should be found that direct observations on the solar disc in some extreme cases are inadmissible. Its high dispersive power also gives it an advantage which no glass ever made, or likely to be made, can possess; although the fixed nature of the latter material may probably always give it a preference in the construction of telescopes: and I wish clearly to be understood, not as proposing to supplant the use of flint glass in these instruments, but simply to supply its place by a valuable substitute, in cases where it cannot be obtained sufficiently large and pure; or where it can only be obtained at an expense which must always limit the possession of a powerful astronomical telescope, to a small number of individuals and to public bodies.

Having, as above stated, selected my fluid, my next object was to determine

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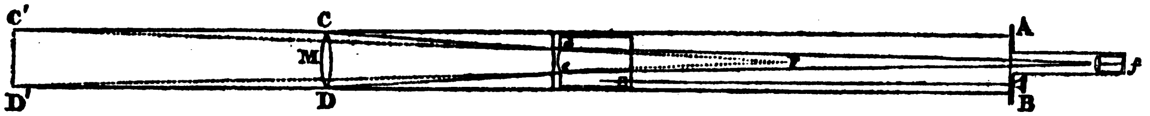
* It may be proper to state that, between the temperature of 31° in February and 84° in August, and again at 31° in December or November, I found no appreciable difference in the index or in the focal length of the telescope. The fluid has even been put in a state of ebullition by the application of red hot iron; and in a very few minutes has become transparent, and the focus remained either exactly or very nearly the same.

the best means of confining it, which after several trials was satisfactorily accomplished; and I now at once attempted a telescope of 6 inches aperture and 7 feet in length: but after several unsuccessful experiments, arising from unforeseen difficulties, I laid it by, and undertook one of 3 inches aperture. I was here more fortunate, having with this instrument in its rude experimental form, without any adaptation or selection of glasses, separated a great number of double stars of that class which Sir W. HERSCHEL has pointed out as tests of a good 3½-inch refractor. I can see with it the small star in Polaris with a power of 46; and with the higher powers several stars which are said to require a good telescope; as for example, 70 p Ophiuchi, 39 Bootis, the quadruple star ε Lyræ, ζ Aquarii, α Herculis, &c. Encouraged by my success on this instrument, I again attempted the 6-inch object-glass, with a different manner of adjusting and securing the lenses; and the result of my endeavours I consider to be perfectly demonstrable of the practicability of the construction, allowance being made for the imperfections of a first attempt, at a novel construction, on a considerable scale, and which professes only to prove the applicability of the principle, and not the completion of the experiment. With this instrument the small star in Polaris is so distinct and brilliant with a power of 143, that its transit might be taken with the utmost certainty. The small stars in α Lyræ, Aldebaran, Rigel, ε Bootis, &c. are very distinctly exhibited; amongst the larger close double stars, Castor and γ Leonis are well defined with a power of 300; and amongst the smaller double stars I may mention ω Aurigæ, 52 Orionis, ζ Orionis, and a variety of others of the same class. The belts and double ring of Saturn are well exhibited with a power of 150; and the belts and satellites of Jupiter are very tolerably defined with the same power, but will not bear a higher power than about 200, in his present situation, which is certainly not favourable: in both cases the discs of the planets are satisfactorily white, and belts and shadows well marked; but in Jupiter, and perhaps in both, there is some uncorrected colour round the edge of the disc. Of this however I shall speak again after describing the principle of the construction.

In the usual construction of achromatic telescopes, the two or three lenses composing the object-glass, are brought into immediate contact; and in the fluid telescope proposed by Dr. BLAIR the construction was the same, the fluid having been inclosed in the object-glass itself. Nor could any change in this arrangement in either case be introduced with advantage, because the dispersive ratio between the glasses in the former instance, and between the glass and fluid in the latter, is too close to admit of bringing the concave correcting medium far enough back to be of any sensible advantage. The case, however, is very different with the sulphuret of carbon. The dispersive ratio here varies (according to the glass employed) between the limits 299 and 334; which circumstance has enabled me to place the fluid correcting lens at a distance from the plate lens equal to half its focal length; and I might carry it still further back, and yet possess sufficient dispersive power to render the object-glass achromatic. Moreover, by this means the fluid lens, which is the most difficult part of the construction, is reduced to one-half, or to less than one-half, of the size of the plate lens; consequently, to construct a telescope of ten or twelve inches aperture involves no greater difficulty in the manipulation, than in making a telescope of the usual description of five or six inches aperture, except in the simple plate lens itself: and, what will be thought perhaps of greater importance, a telescope of this kind of ten or twelve feet length will be equivalent in its focal power to one of sixteen or twenty feet. We may therefore, by this means, shorten the tube several feet, and yet possess a focal power more considerable than could be conveniently given to it on the usual principle of construction. This will be better understood from the annexed diagram.



In this figure, A, B, C, D represent the tube of the 6-inch telescope, C, D the plate object-glass, F the first focus of rays, *d e* the fluid concave lens, distant from the former 24 inches. The focal length M F being 48 inches, the diameter of the fluid lens is consequently as 48 : 6 :: 24 : 3 inches. The resulting compound focus is 62·5 inches: it is obvious, therefore, that the rays *d f*, *e f* arrive at the focus under the same convergency and with the same light, as if they proceeded from a lens of 6 inches diameter placed at a distance beyond the object glass C, D, (as C′ D′) determined by producing these rays till they meet the sides of the tube produced in C′ D′, viz. at 62·5 inches beyond the fluid lens. Hence, it is obvious, the rays will converge as they would do from an object-glass C′ D′ of the usual kind with a focus of 10 feet 5 inches.

We have thus, therefore, shortened the tube 38·5 inches, or have at least the advantage of a focus 38·5 inches longer than our tube; and the same principle may be carried much further, so as to reduce the usual length of refracting telescopes nearly one-third without increasing the aberration in the first glass, beyond the least that can possibly belong to a telescope of the usual kind of the whole length. It should moreover be observed, that the adjustment for focus may be made either in the usual way, or by a slight movement of the fluid lens, as in the Gregorian reflector by means of the small speculum; in the latter case the eye-piece is fixed, which may probably be convenient for astronomical purposes, in consequence of the great delicacy of the adjustment.

Besides the above advantages attending this principle of construction, I am willing to hope that another very important one (which I have not however been able at present practically to demonstrate) may still be effected; namely, the reduction of what has been termed the secondary spectrum, either to zero or to a very inconsiderable amount. In order to examine the practicability of this object, let us first consider the two lenses in contact, and inquire into the conditions requisite for uniting the violet, the red, and the mean ray, which latter may be accounted that on the confine of the violet and red sides of the spectrum. Let the focal length of the mean ray in the plate lens be f, and the length of the focus beyond f, viz. the red side of the spectrum, be r, its whole focus being $f + r$; let f', r' and of course $f' + r'$ denote the same in the correcting fluid lens: then, in order that the red ray may coincide with the mean ray, we must have

$$\frac{1}{f} - \frac{1}{f'} = \frac{1}{f+r} - \frac{1}{f'+r}$$

Now $$\frac{1}{f+r} = \frac{1}{f} - \frac{r}{f(f+r)}$$

and $$\frac{1}{f'+r'} = \frac{1}{f'} - \frac{r'}{f'(f'+r')}$$

therefore, when $\frac{1}{f} - \frac{1}{f'} = \frac{1}{f+r} - \frac{1}{f'+r'}$

we must have $$\frac{r}{f(f+r)} = \frac{r'}{f'(f'+r')}$$

and therefore, $f : f' : : \frac{r}{f-r} : \frac{r'}{f'+r'}$

That is, the mean focal lengths must be to each other as the red part of the focus divided by the whole focal length of the red ray, or, as the dispersive powers for this side of the spectrum, in each lens.

In the same way, if we denote by v and v' the length of the violet part of each focus; then to have the violet and the mean ray coincide, we must have

$$\frac{1}{f} - \frac{1}{f'} = \frac{1}{f-v} - \frac{1}{f'-v'},$$

and as before, we shall find that this can only take place when

$$\frac{v}{f(f-v)} = \frac{v'}{f'(f'-v')} : \text{ or when } f : f' : : \frac{v}{f-v} : \frac{v'}{f'-v'};$$

Hence, in order to unite these three colours, the conditions must be that

$$\frac{r}{f+r} : \frac{v}{f-v} : : \frac{r'}{f'+r'} : \frac{v'}{f'-v'}.$$

But as f, r and v, in one case, and f', r' and v', in the other, are dependent and proportional in each respective focus, if these proportions do not arise from the natural properties of the two media, they cannot be produced by art, while the lenses are in contact; but in any case where the violet side of the correcting or concave lens exceeds that of the red in a greater proportion than the violet exceeds the red in the convex lens, and if the dispersive ratio be so great as to admit of the lenses being sufficiently opened from each other, then such a distance may be found as shall produce the above proportion; and hence unite these three rays in one common focus, or at least approximate towards this result.

Let the distance of the lenses be d, and let the plate focus remain as before f, then the negative focus must be reduced till $\frac{(f-d)^2}{ff'}$ = dispersion[*].

Conceive this length to be found, which may still be denoted by f', and r' and v' may also denote the same as before, the ratio $\frac{r'}{f'-r'}$ to $\frac{v'}{f'-v'}$ will likewise still remain the same.

But the coloured focus of the plate lens remaining the same as before, while the mean focus is changed from f to $f-d$; we must now, in order to unite the three rays, have

$$\frac{r}{f-d+r} : \frac{v}{f-d-v} : : \frac{r'}{f'+r'} : \frac{v'}{f'-v'}$$

The two latter terms remaining in the same ratio, while the two former may be varied at pleasure by changing the value of d; which will have no effect on the ratio of the latter terms, although the actual value of f', r' and v', must necessarily vary for every change in the value of d.

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[*] Phil. Trans. 1827, Art. XV.

Let the constant ratio of the latter terms be $m : n$; then we have to find d, such that,

$$\frac{r}{f-d+r} : \frac{v}{f-v-v} :: m : n; \text{ or, } \frac{nr}{f-d+r} = \frac{mv}{f-d-v};$$

which reduced, gives $d = \frac{mvf + mvr - nrf + nvr}{mv - nr}$.

If now a', a'', a''' be taken to denote the refractive indices of the red, green, and violet ray in the front lens, we shall find f, r and v, to be to each other as 1, $\frac{a''-a'}{a'}$, and $\frac{a'''-a''}{a'''}$; and substituting these proportional values for the above letters, our expression becomes

$$d = f a'' \left\{ \frac{m(a'''-a'')-n(a''-a')}{m a'(a'''-a'')-n a'''(a''-a')} \right\}$$

In like manner, if α', α'', α''' be taken to denote the refractive indices of the red, green, and violet ray in the correcting lens, then we shall find

$$\frac{r'}{f'+r'} : \frac{v'}{f'-v'} :: m : n :: \alpha''-\alpha' : \alpha'''-\alpha''$$

Which latter may therefore be substituted for m and n.

The formula then becomes

$$d = f a'' \left\{ \frac{(\alpha''-\alpha')(a'''-a'')-(\alpha'''-\alpha'')(a''-a')}{(\alpha''-\alpha')(a'''-a'')a'-(\alpha'''-\alpha'')(a''-a')a'''} \right\}$$

an expression for the distance in terms of the indices and focus only.

In plate glass, according to Fraunhofer, $a' = {\cdot}515$, $a'' = {\cdot}525$, and $a''' = {\cdot}535$. Which values being substituted, give

$$d = f \left\{ \frac{(\alpha''-\alpha')-(\alpha'''-\alpha'')}{{\cdot}981(\alpha''-\alpha')-1{\cdot}019(\alpha'''-\alpha'')} \right\}$$

In flint glass, from the same authority, $\alpha' = {\cdot}602$, $\alpha'' = {\cdot}620$, $\alpha''' = {\cdot}640$. Which numbers being substituted, give $d = {\cdot}734 f$. An impracticable distance in this case, because the dispersive power of flint glass is not great enough to correct the plate lens when so far removed.

If these indices had been ·602, ·621, and ·640, then we should find $d = 0$, or the lenses ought then to be in contact. A change therefore of ·001 in the index of the green ray, changes the distances of the lenses from nothing to nearly three-fourths of the whole focus of the plate; consequently, the determination of the proper distance to combine the three colours, when the media are such as to admit of it, depends upon the most delicate determination of the indices of the red, green, and violet rays; but these being so determined, and the dispersive power of the medium being great enough, the most complete union may be effected.

Whether the sulphuret of carbon fall within this limit or not, I am not at present able to say. I have attempted to find the indices of the different colours by means of a prism; but it is extremely difficult to determine the limits of the different shades, and perhaps after all the best way is by actual experiment on the telescope itself. Fearful in the beginning of advancing too far in opening the lenses, the first experiment was made with the fluid at a very inconsiderable distance behind the plate, and the quantity of uncorrected colour was very great. I next tried a distance of 18 inches, and the uncorrected colour was considerably less than before, but still too great. With this distance the experiment was witnessed by Captain KATER. I next opened the lenses 24 inches, and at this distance the experiment was witnessed by Professor AIRY, who still detected some uncorrected colour, which, however, is not sensible to my eye till the telescope is applied with a high power to Jupiter, Venus, or some bright star; neither was this defect felt in any sensible degree by Mr. SOUTH or Captain BEAUFORT, who were also present.

From the gradual diminution of the outstanding purple by opening the lenses from contact to 24 inches, I suspect with a distance of 32 inches, (which is perhaps the most I can venture upon with a focus of 48 inches for my plate,) that the red would be outstanding, and if so the proper point must be between these limits.

This, however, remains to be verified by experiment; should it be effected, we may enumerate the advantages of this telescope as follow:

1. It renders us independent of flint glass.
2. It enables us to increase the aperture of the telescope to a very considerable extent.
3. It gives us all the light, field, and focal power of a telescope of one and a half times at least, probably of twice the length of the tube.
4. It is presumed that further experiments may enable us to find such a distance for the lenses as shall reduce what has been termed the secondary spectrum, (inseparable from the usual construction,) either to zero or to an inconsiderable amount.

VIII. *A catalogue of nebulæ and clusters of stars in the southern hemisphere, observed at Paramatta in New South Wales, by* James Dunlop, *Esq. In a letter addressed to Sir* Thomas Makdougall Brisbane, *Bart. K.C.B. late Governor of New South Wales. Presented to the Royal Society by* John Frederick William Herschel, *Esq. Vice President.*

Read December 20, 1827.

THE following nebulæ and clusters of stars in the southern hemisphere were observed by me at my house in Paramatta, situated about 6″ of a degree south and about $1^s.78$ of time east of the Brisbane Observatory. The observations were made in the open air, with an excellent 9-feet reflecting telescope, the clear aperture of the large mirror being nine inches. This telescope was occasionally fitted up as a meridian telescope, with a strong iron axis firmly attached to the lower side of the tube nearly opposite the cell of the large mirror, and the ends of the axis rested in brass Y's, which were screwed to blocks of wood let into the ground about 18 inches, and projecting about 4 inches above the ground; one end of the axis carried a brass semicircle divided into half degrees and read off by a vernier to minutes. The position and index error of the instrument were ascertained by the passage of known stars. The eye end of the telescope was raised or lowered by a cord over a pulley attached to a strong wooden post let into the ground about two feet: with this apparatus I have observed a sweep of eight or ten degrees in breadth with very little deviation of the instrument from the plane of the meridian, and the tremor was very little even with a considerable magnifying power. I made drawings or representations of a great number of the nebulæ and clusters at the time of observation, several of which are annexed to this paper; and also very correct drawings of the Nebulæ major and minor, together with a representation of the milky nebulosity surrounding the star η Robur Caroli. The places of the small stars in the Nebulæ major and minor, and also those accompanying the η Robur Caroli, I ascertained by the mural circle in the year 1825, at which time I was preparing to commence a general survey of the southern hemisphere. These stars being laid down upon the chart, enabled me to delineate the nebulosity very accurately.

The nebulæ are arranged in the order of their south polar distances to the nearest minute for 1827, and in zones for each degree in the order of their right ascension. The column on the right hand shows the number of times the object has been observed.

The reductions and arrangement have been principally made since my return to Europe; and I trust this catalogue of the nebulæ will be found an acceptable addition to that knowledge which the Brisbane observatory has been the means of putting the world in possession of, respecting that important and hitherto but little known portion of the heavens.

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
1	4	13	0	12	14	A very small faint round nebula, about 12″ diameter, with a very minute star south following dist. 1′	1
2	0	33	6	15	41	A faint nebula, about 1½′ long, irregular figure, rather branched. This is involved in the margin of the Nebula minor	1
3	0	41	8	15	59	A small round nebula, about 12″ diameter	1
4	0	42	19	15	56	A faint round nebula, about 30″ diameter	1
5	0	47	12	15	46	A small faint nebula, about 10″ or 12″ diameter	1
6	0	47	39	15	36	A faint nebula, about 20″ diameter	1
7	1	9	32	15	46	A faint round nebula, 35″ diameter, with a small star near the south margin, but not involved	1
8	1	10	23	15	48	A small oval nebula, about 10″ diameter	1
9	1	12	37	15	44	A faint nebula, about 1½′ diameter, of an irregular round figure	2
10	1	13	43	15	51	An elliptical nebula, about 1′ long and 40″ broad, with three minute stars in it	1

Fig. 1.

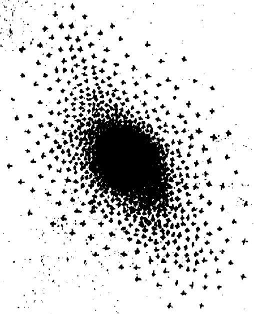


Fig. 2.

Fig. 3.

Fig. 4.

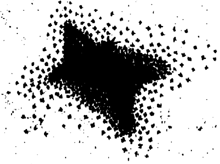


Fig. 5.

Fig. 6.

Fig. 9.

Fig. 10.

Fig. 8.

Fig. 7.

Fig. 11.

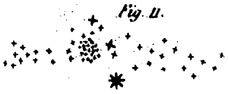


Fig. 13.

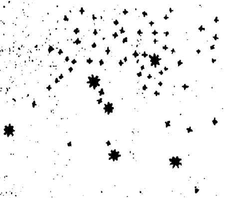


Fig. 15.

Fig. 16.

Fig. 12.

Fig. 17.

Fig. 21.

Fig. 20.

Fig. 18.

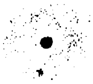


Fig. 22.

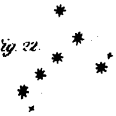
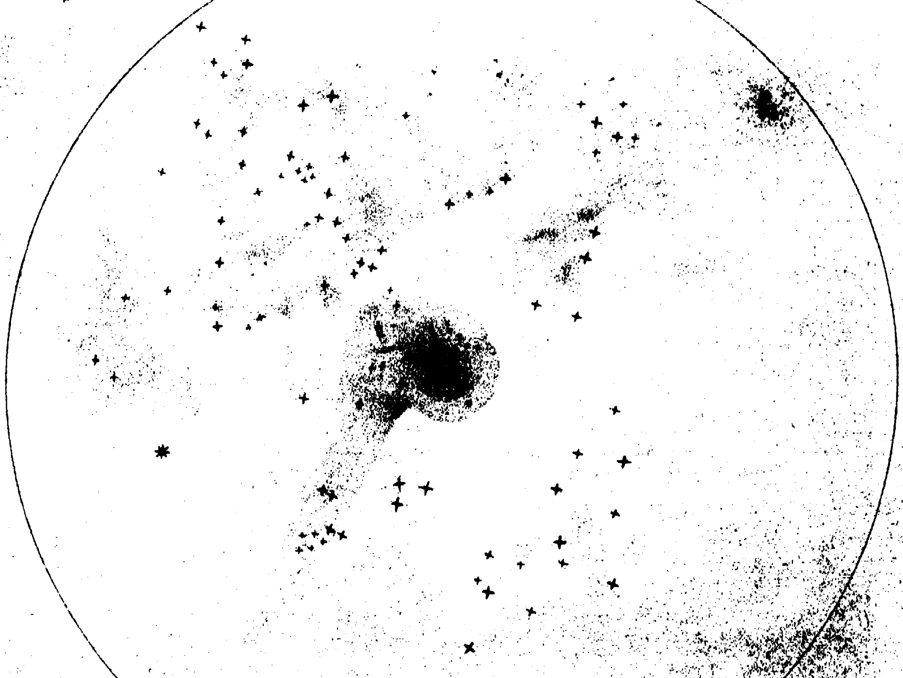


Fig. 19.

Fig. 24.

Fig. 23.

Fig. 14.



No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
11	1	15	57	15	55	A very small round nebula, with a bright point in the centre, which I suspect to be a star	1
12	1	16	30	15	52	A small round nebula, about 8″ diameter	1
13	1	16	38	15	49	A small round nebula, with a bright point in the centre. This is the following of a group of nebulæ	1
14	1	17	0	15	43	A small star in a faint nebula, about 10″ or 12″ diameter	1
15	1	19	53	15	50	A group of very minute stars, in a faint ill-defined rather extended nebula	1
16	1	22	35	15	43	A very faint nebula of a round figure, about 2′ diameter, with a small star in the north margin	1
17	1	26	18	15	32	A faint round nebula, about 2′ diameter, a very little brighter in the middle, with some minute stars in it	1
18	0	16	28	16	59	(47 Toucan, Bode.) This is a beautiful large round nebula, about 8′ diameter, very gradually condensed to the centre. This beautiful globe of light is easily resolvable into stars of a dusky colour. The compression to the centre is very great, and the stars are considerably scattered south preceding and north following.—Figure 1. is a good representation	8
19	0	39	9	16	2	A small faint elliptical nebula.—This is the preceding in a line of small faint nebulæ	1
20	0	39	53	16	8	A faint nebula, 25″ or 30″ diameter. Round figure	1
21	0	40	16	16	0	A small round faint nebula	1
22	0	42	49	16	12	A small faint round nebula.—Rather ill defined	1
23	0	50	22	16	38	A small, but very bright nebula, exceedingly condensed. This is the brightest nebula in the small cloud. I think I perceive two bright nuclei in this body	8
24	0	52	20	16	33	A small faint nebula	1
25	0	53	25	16	54	A pretty large pretty bright nebula, about 2½′ diameter, irregular round figure, resolvable, very slight condensation, not well defined at the edges	7
26	0	54	17	16	38	A small double nebula; the following is very faint	2
27	0	54	37	16	25	A faint elliptical nebula, 2½′ long, and nearly 2′ broad	2
28	0	55	23	16	58	A faint ill-defined small nebula	1
29	0	57	0	16	33	A small round nebula, 10″ diameter, bright at the centre	1
30	0	57	42	16	35	A small round nebula, about 8″ diameter	1
31	0	58	12	16	53	A pretty large unequally bright nebula, about 5′ diameter, round figure, resolvable into stars of mixt magnitudes	5
32	0	59	0	16	42	A small faint nebula	1
33	0	59	3	16	31	A small faint ill-defined nebula	1
34	0	59	40	16	58	A faint elliptical nebula	1
35	1	0	42	16	55	A very small faint nebula, with a small star in the south margin	2

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
36	1	0	43	16	18	A faint ill-defined nebula, about 1½′ diameter	1
37	1	2	30	16	57	A small faint nebula, about 20″ diameter, round	1
38	1	3	40	16	5	A very small oval nebula, a little brighter in the centre; a star of the 8th magnitude south	2
39	1	3	50	16	15	A rather faint nebula, about 2′ long, extended in the direction of the meridian, easily resolvable	2
40	1	4	10	16	31	A small round nebula, with a star in the north side	1
41	1	4	28	16	26	A small faint nebula; many small nebulæ in this place	1
42	1	5	0	16	35	A round well-defined nebula, about 30″ diameter	1
43	1	5	19	16	45	A small round nebula, 8″ diameter, bright at the centre	1
44	1	6	22	16	22	A faint nebula, about 40″ diameter, round figure	1
45	1	7	50	16	20	A small faint nebula	1
46	1	20	0	16	35	A very small faint round nebula	1
47	1	25	11	16	23	A very small round nebula, about 8″ diameter, with a bright point in the centre	1
48	1	26	28	16	9	A faint ill-defined small nebula	1
49	2	28	25	16	1	A small faint nebula, about 12″ diameter, with a bright point in the centre	1
50	0	49	30	17	5	A small faint round nebula	1
51	0	50	37	17	3	A small round nebula	1
52	0	51	0	17	0	A small faint ill-defined nebula. This is the following of a line of small nebulæ	1
53	0	54	30	17	12	A small faint nebula	1
54	0	57	46	17	25	A small round pretty well-defined nebula, 15″ or 20″ diameter	1
55	0	58	28	17	29	A small faint ill-defined nebula	1
56	1	3	15	17	2	A small faint nebula	1
57	1	6	0	17	7	A small faint nebula, about 15″ diameter	1
58	1	7	49	17	9	An extremely faint ill-defined nebula	1
59	1	8	36	17	39	A very small faint nebula, about 10″ diameter	1
60	1	12	32	17	32	A round well-defined nebula, gradually brighter to the centre, about 25″ diameter	1
61	17	0	9	17	3	A rather large faint nebula, of an irregular figure, easily resolvable into very small stars, rich	2
62	0	57	32	18	15	A beautiful bright round nebula, about 4′ diameter, exceedingly condensed. This is a good representation of the 2nd of the Connaissance des Tems in figure, colour, and distance; it is but a very little easier resolved, rather a brighter white, and perhaps more compact and globular. This is a beautiful globe of white light; resolvable: the stars are very little scattered.—Figure 3.	11

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
63	1	7	24	18	49	A small round faint nebula, about 12″ diameter	1
64	2	20	35	18	20	A very small faint nebula, about 10″ diameter, with a minute bright point in the centre	1
65	4	34	37	18	20	An extremely faint nebula, about 15″ diameter	1
66	6	3	52	18	3	An extremely faint round nebula, 30″ or 40″ diameter	1
67	12	11	4	18	24	A star of the 6th magnitude, with a beautiful well-defined milky ray proceeding from it south following; the ray is conical, and the star appears in the point of the cone, and the broad or south following extremity is circular, or rounded off. The ray is about 7′ in length, and nearly 2′ in breadth at the broadest part, near the southern extremity. With the sweeping power this appears like a star with a very faint milky ray south following, the ray gradually spreading in breadth from the star, and rounded off at the broader end. But with a higher power it is not a star with a ray, but a very faint nebula, and the star is not involved or connected with it: I should call it a very faint nebula of a long oval shape, the smaller end towards the star; this is easily resolvable into extremely minute points or stars, but I cannot discover the slightest indications of attraction or condensation towards any part of it. I certainly had not the least suspicion of this object being resolvable when I discovered it with the sweeping power, nor even when I examined it a second time; it is a beautiful object, of a uniform faint light. Figure 2	3
68	16	5	14	18	13	A pretty large rather faint round nebula, about 3½′ or 4′ diameter, a little brighter in the middle. There is a very small nebula on the north preceding side joining the margin of the large nebula	3
69	19	7	—	18	12	(43 Pavonis, Bode's Catalogue.) I cannot find the nebula answering to this place: perhaps there may be a mistake in the right ascension. .	
70	4	4	15	19	57	A small faint nebula, about 25″ long, with a minute star in the southern extremity; a double nebula follows	2
71	4	6	35	19	55	A double nebula, about 35″ diameter; there are two small stars in the preceding of the two	2
72	4	52	25	19	44	A faint nebula, about 20″ diameter	2
73	4	52	42	19	49	A pretty bright round nebula, bright at the centre	3
74	4	53	8	19	53	A small faint nebula	1
75	4	53	30	19	51	A small round well-defined nebula	1
76	4	54	0	19	41	A pretty bright small round nebula	2
77	4	57	35	19	37	A small nebula, with a small star in the south side of it	2
78	4	57	50	19	53	A small faint nebula, about 15″ diameter, with a minute star slightly involved in the south side	1
79	4	59	25	19	55	A small faint nebula, about 12″ diameter	2
80	5	0	8	19	57	A small round nebula, about 10″ or 12″ diameter, well defined	2

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
81	5	1	10	19	59	A faint nebula, 35″ diameter, a small star preceding	2
82	5	2	10	19	51	A small faint nebula, preceding three stars in form of a triangle	1
83	5	10	48	19	40	A pretty large extremely faint nebula, about 5′ long, and 2′ broad, extended north preceding, and south following, resolvable into stars of mixt magnitudes	2
84	5	11	33	19	49	A pretty well-defined small nebula, about 15″ diameter, with a small star rather preceding the centre	2
85	5	16	13	19	48	A very small round nebula, with a bright point exactly in the centre, forming a triangle, with very small stars on the north side	2
86	5	17	10	19	42	An extremely small nebula, 8″ diameter, bright at the centre	2
87	5	21	22	19	49	An extremely faint ray of nebula, about 3′ or 4′ long, and 1′ broad; position south preceding, and north following	2
88	5	21	38	19	59	A small faint nebula, 25″ or 30″ diameter, with two small stars near the south side of it	1
89	5	23	40	19	58	A pretty well-defined round nebula, about 20″ diameter	2
90	5	25	0	19	45	A small round faint nebula, north of a small star	2
91	5	26	23	19	35	A small round nebula, 12″ or 15″ diameter	1
92	5	28	37	19	52	Two very faint round nebulæ; distant 1 diameter, or 30″	1
93	5	28	55	19	58	A very faint nebula, about 30″ diameter	1
94	5	29	29	19	47	An extremely faint small nebula	1
95	5	30	33	19	53	A faint nebula, 30″ diameter: a small star north of the centre	2
96	5	31	38	19	50	A faint round nebula, about 1½ diameter, slightly bright to the centre	2
97	5	33	5	19	47	A round faint nebula, about 15″ diameter	2
98	5	33	22	19	44	A pretty well-defined round nebula, about 30″ diameter	2
99	5	36	30	19	35	A pretty well-defined nebula, 20″ diameter	2
100	5	35	12	19	58	A small round nebula, about 2′ north of a small star	1
101	5	37	5	19	33	A very small ill-defined nebula	1
102	5	38	10	19	47	A faint ill-defined nebula, perhaps 3′ diameter	1
103	5	40	35	19	42	A round well-defined nebula, 30″ diameter, bright at the centre. The preceding of three nebulæ forming a triangle	2
104	5	40	38	19	32	A very small faint nebula, 8″ or 10″ diameter	1
105	5	41	3	19	36	A round well-defined nebula, 25″ diameter	2
106	5	51	10	19	55	A faint elliptical nebula, about 2′ diameter; slightly condensed to the centre	2
107	5	52	20	19	46	A very pretty double nebula, with a star in the preceding side of the largest, and a very small star in the south margin of the smallest nebula	2
108	5	52	32	19	43	A small round faint nebula	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
109	5	52	50	19	40	A small faint nebula	1
110	4	53	5	20	3	A small faint nebula	2
111	4	53	50	20	11	A small round nebula. The preceding of three nebulæ in the form of a triangle	2
112	4	54	2	20	16	A very pretty small double nebula; very nearly equal; distance about 12″ or 15″	2
113	4	54	17	20	5	A small faint nebula, 12″ or 15″ diameter	1
114	4	54	18	20	36	A small round nebula, about 20″ diameter, bright at the centre	2
115	4	59	51	20	6	A small round faint nebula, about 10″ diameter	1
116	5	6	50	20	8	A small round pretty well-defined nebula, bright at the centre	1
117	5	11	30	20	1	A very small nebula, with a small star near the north margin	1
118	5	11	45	20	41	A pretty well-defined small nebula, with a small star south of it	1
119	5	12	25	20	54	A small round pretty well-defined nebula	1
120	5	13	22	20	51	A small round nebula, about 30″ diameter	1
121	5	14	5	20	15	A small round nebula	1
122	5	14	17	20	13	A small nebula, about 20″ diameter, with three smaller nebulæ following, and three pretty bright small stars on the north side	1
123	5	16	3	20	40	A faint ill-defined nebula, 2′ diameter	1
124	5	17	15	20	7	A very small round nebula, about 12″ diameter	2
125	5	18	21	20	19	A small rather well-defined round nebula	1
126	5	18	25	20	1	A very small round nebula, 6″ or 8″ diameter	1
127	5	18	42	20	24	A faint extended nebula, ill defined	2
128	5	19	25	20	0	A small faint nebula, 1′ north of a pretty bright star	1
129	5	19	44	20	37	A pretty large and very ill-defined nebula, of an irregular round figure, with several small stars in it	2
130	5	22	3	20	49	A small round nebula	2
131	5	22	15	20	20	A very faint ill-defined small nebula	1
132	5	22	45	20	56	A small faint confused nebula, rather long	1
133	5	25	57	20	16	A small faint nebula	1
134	5	27	9	20	21	A small faint nebula	1
135	5	27	36	20	25	A small faint round nebula	1
136	5	29	24	20	55	A faint confused pretty large nebula. There are a multitude of small nebulæ in this place	2
137	5	33	40	20	56	A very small faint nebula, about 10″ diameter	1
138	5	34	5	20	4	A small round faint nebula	1
139	5	35	38	20	53	A small faint round nebula	1
140	5	36	13	20	56	A small faint round nebula	1

No.	Æ h m s	S.P.D. ° ′	Description of the Nebulæ and Stars.	No. of Obs.
141	5 37 41	20 0	A faint extended nebula, about 4′ long, very faint towards the extremities, brightest and broadest in the middle. This is in the south following side of a faint cluster of very minute stars	1
142	5 39 30	20 45	(30 Doradûs, Bode) is a pretty large ill-defined nebula, of an irregular branched figure, with a pretty bright small star in the south side of the centre, which gives it the appearance of a nucleus. This is resolvable into very minute stars.—Figure 4. is a very good representation of the nebula resolved. (N.B. The 30 Doradûs is surrounded by a number of nebulæ of considerable magnitudes, nine or ten in number, with the 30 Doradûs in the centre. Figure 5.)	8
143	5 39 44	20 57	A pretty large faint ill-defined nebula, elongated in the direction of the meridian	1
144	5 40 30	20 51	A very small round nebula, bright in the centre	1
145	5 40 55	20 13	This is the centre of a large cluster of extremely minute stars, with many very small nebulæ in it	1
146	5 41 12	20 25	A small faint nebula	1
147	5 41 53	20 41	A pretty bright round or rather oval nebula, 30″ diameter	1
148	5 42 25	20 53	A small faint nebula, 25″ diameter	1
149	5 42 25	20 11	A faint round nebula, about 1′ diameter	1
150	5 43 0	20 6	A well-defined round nebula, small. This precedes a group of nebulæ	2
151	5 43 8	20 45	A faint ill-defined small nebula	1
152	5 43 50	20 1	A cluster of six or seven small nebulæ, forming a square figure 5′ or 6′ diameter, with several minute stars mixt. This is a very pretty group of nebulæ.—Figure 5.	3
153	5 44 10	20 50	A faint small round nebula, 15″ diameter	1
154	5 44 28	20 42	A pretty bright round or rather elliptical nebula, 25″ diameter	1
155	5 46 20	20 5	A very faint elliptical nebula, about 50″ diameter, slightly bright to the centre	1
156	5 48 50	20 4	A very faint ill-defined nebula, 15″ or 20″ diameter	1
157	5 50 10	20 54	A small round nebula, 8″ or 10″ diameter. This is the preceding of three nebulæ forming a triangle	1
158	5 50 46	20 51	A small round well-defined nebula	1
159	5 51 20	20 55	A small round faint nebula	1
160	5 52 54	20 26	A small round pretty well-defined nebula	2
161	5 58 12	20 42	A small faint nebula, 15″ diameter; a small star near the north preceding edge	1
162	5 58 33	20 37	A very faint small nebula	1
163	12 47 40	20 15	A very small round or rather elliptical nebula, 12″ diameter	2
164	12 49 0	20 6	(12 Muscæ, Bode.) This is a pretty bright round nebula, about 4′ diameter, moderately condensed to the centre. This, with the sweeping power, has the appearance of a globe of nebulous matter with very	

No.	Æ	S.P.D.	Description of the Nebulæ and Stars.	No. of Obs.
			small stars in the north following margin. But with a power sufficient to resolve it, the globular appearance vanishes in a very considerable degree; and the brightest and most condensed part is to the preceding side of the centre, with the stars considerably scattered on the north following side. Resolvable into stars of mixt small magnitudes. A small nebula precedes this	5
	h m s	° ′		
165	4 8 34	21 27	An exceedingly faint ill-defined nebula, with several exceedingly minute stars in it	1
166	4 10 0	21 15	A well-defined small elliptical nebula, 12″ long and 8″ broad	1
167	4 54 25	21 32	A pretty bright round well-defined nebula, 15″ diameter	2
168	4 57 3	21 28	A pretty large faint nebula, irregular figure, and irregularly bright in parts	1
169	4 57 40	21 18	A pretty bright pretty large nebula, of an irregular round figure, 5′ diameter; a little brighter in the middle	2
170	5 8 35	21 8	A pretty large faint nebula, irregular figure	1
171	5 10 0	21 56	A very faint round nebula, 25″ diameter	1
172	5 11 27	21 2	A pretty bright round nebula, 40″ diameter. This is preceding and brightest of three nebulæ in a line	2
173	5 14 40	21 7	A small faint nebula, 12″ diameter	1
174	5 16 18	21 41	A very faint ill-defined nebula, with two small stars in it	1
175	5 22 7	21 50	A pretty large rather faint nebula, about 5′ diameter, irregular figure, partly resolvable into stars of mixt magnitudes. The nebulous matter has several seats of attraction, or rather it is a cluster of small nebulæ with strong nebulosity common to all	2
176	5 23 40	21 45	A small faint nebula	1
177	5 27 50	21 1	A small round nebula, 8″ or 10″ diameter	1
178	5 32 7	21 10	A small faint nebula, with a ray proceeding from it, about 6′ or 7′ long; a small star is involved in the preceding extremity of the ray	1
179	5 34 37	21 47	A small faint nebula, about 8″ diameter	1
180	5 36 27	21 48	Three very small nebulæ, forming an obtuse triangle	1
181	5 36 50	21 4	A small faint nebula, 10″ or 12″ diameter	1
182	5 38 2	21 46	A group of very small stars of mixt magnitudes, with several small faint nebulæ, in strong nebulosity, common to all	1
183	5 38 20	21 5	A faint ill-defined nebula, 20″ diameter	1
184	5 41 13	21 0	A very small round nebula, about 8″ diameter	1
185	5 45 37	21 40	A small faint round nebula, preceding a minute double star of the 12th magnitude. Another similar small nebula follows, about 20″ in Æ, and 2′ south in a line with the double star	1
186	5 49 12	21 48	A very small faint nebula	1

No.	AR h m s	S.P.D. ° ′	Description of the Nebulæ and Stars.	No. of Obs.
187	5 50 4	21 46	Two very small faint nebulæ following a small star	1
188	5 51 7	21 29	A curved line of five or six faint small nebulæ, with small stars mixt. This is rich in small stars and nebulæ	1
189	5 52 49	21 46	A very faint round nebula, 30″ diameter. Exceedingly faint	1
190	5 54 17	21 48	Two very small faint nebulæ	1
191	5 54 29	21 45	A pretty bright round nebula, 40″ diameter	1
192	5 56 37	21 28	A minute cluster of very small stars in strong nebulosity	1
193	5 59 0	21 19	A pretty bright round well-defined nebula, 12″ diameter	1
194	5 59 37	21 26	A pretty large faint ill-defined nebula	1
195	6 0 5	21 51	A small pretty bright round nebula, 10″ or 12″ diameter	1
196	6 0 14	21 31	A small round pretty well-defined nebula, 25″ diameter, with a small star north following	1
197	6 2 7	21 33	A small faint round nebula	1
198	6 6 27	21 42	A pretty strong ray of nebula following a small star; but the small star is not involved. The ray is about 2′ long and 50″ broad, with a bright point or nucleus near the preceding extremity.—Figure 6.	2
199	6 8 2	21 52	A faint confused nebula, with two or three bright points in it, which I suspect to be stars	1
200	6 11 34	21 34	A faint nebula, following a pretty bright star	1
201	6 13 30	21 46	A round well-defined small nebula, 20″ diameter, bright at the centre	3
202	6 17 47	21 37	A small faint nebula, about 15″ diameter	1
203	6 21 17	21 53	A small round nebula, 20″ diameter, slightly; a little brighter towards the centre	1
204	12 3 11	21 0	A very faint nebula, about 40″ diameter, with a pretty bright star south following	1
205	3 2 19	22 41	A very faint small nebula, north following, a pretty bright small star; a very minute star is between the bright star and the nebula	1
206	3 15 50	22 50	A faint ill-defined nebula, rather extended in the direction of the meridian, with several exceedingly minute stars in it	1
207	3 18 20	22 25	A faint ill-defined nebula, probably 2′ diameter, of a round figure; a very minute star involved in it	1
208	4 33 7	22 45	A very faint small nebula	1
209	5 6 30	22 14	A very faint round nebula, 45″ diameter, preceding a bright star in the same parallel	1
210	5 14 43	22 25	A small round nebula, rather faint. This is the preceding in a line of nebulæ and small stars, with a star of the 7th magnitude at the north extremity.—Figure 7.	3
211	5 26 42	22 21	A small faint elliptical nebula, about 20″ diameter. This is the preceding in a curved line of six or seven small nebulæ, of unequal magnitudes	4

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
212	5	27	30	22	41	A small faint ill-defined nebula	2
213	5	28	46	22	28	A faint elliptical nebula, about 30″ diameter. This is the following in a curved line of nebula	3
214	5	29	48	22	57	A round small nebula, 12″ or 15″ diameter	2
215	5	30	3	22	34	A round well-defined nebula, about 20″ diameter, bright at the centre	3
216	5	31	12	22	40	A small faint nebula, about 40″ diameter	3
217	5	32	50	22	6	A rather well-defined nebula, 40″ or 50″ diameter	3
218	5	34	22	22	14	A pretty bright round nebula, 30″ diameter, with a minute star slightly involved in the margin	2
219	5	35	40	22	21	A pretty bright round nebula, about 1½′ diameter, bright towards the centre	2
220	5	36	17	22	24	A round faint nebula, about 40″ diameter	1
221	5	46	0	22	50	A faint extended nebula, with a few small stars in it	2
222	5	58	37	22	3	A small round nebula preceding a small star	1
223	6	0	9	22	5	A pretty bright and well-defined small round nebula	1
224	12	26	0	22	32	An exceedingly faint nebula, extended in the direction of the meridian, about 4′ or 5′ in length, with a line or group of very small stars in it	2
225	17	12	50	22	59	A pretty large rather bright round nebula, 3′ or 4′ in diameter, very moderately condensed to the centre, resolvable into extremely minute stars; the stars are more scattered on the south side	3
226	4	39	30	23	14	An extremely small round nebula, pretty well defined; a small star preceding in the same parallel	1
227	4	51	7	23	42	A small faint nebula, 12″ diameter	2
228	4	52	40	23	37	A very faint round nebula, 12″ or 15″ diameter	1
229	4	53	6	23	41	A small round pretty well-defined nebula, 12″ diameter. This is the following of a triangle of very small nebulæ	1
230	4	56	0	23	8	A very faint rather elliptical nebula, about 2′ diameter. This is the preceding and largest of three nebulæ forming a triangle	2
231	4	56	16	23	0	A faint round nebula, 1′ diameter	2
232	4	56	47	23	6	A faint round nebula, about 1½′ diameter	2
233	5	1	40	23	33	A small round well-defined nebula, 10″ or 12″ diameter	1
234	5	3	33	23	12	A round well-defined nebula, about 30″ diameter	1
235	5	3	36	23	25	A small round pretty well-defined nebula	1
236	5	4	33	23	21	A small nebula, 20″ diameter, with a very bright point in the centre	2
237	5	25	7	23	30	A rather large faint nebula, 3′ or 4′ diameter, of an irregular round figure; no central attraction	1
238	5	27	30	23	31	A faint round nebula, about 50″ diameter	1
239	5	32	46	23	23	A pretty large faint nebula, about 2′ diameter, round figure. A number of very small stars on the north side, very faint at the margin	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
240	5	35	3	23	49	A faint round nebula, 25″ or 30″ diameter	1
241	5	36	0	23	0	A large cluster of small stars of mixt magnitudes in strong nebula; irregular extended figure	1
242	5	37	12	23	39	A very faint nebula, 1′ diameter; round figure	1
243	6	9	56	23	34	A very small round well-defined nebula, 10′ diameter	1
244	13	5	0	23	50	A very faint nebula extended north preceding and south following, about 3′ in length, with a minute line of five extremely small stars involved in the nebula, and two minute stars near the north extremity, but not involved	2
245	4	12	6	24	54	A very small faint nebula, 10″ diameter, about 14′ south of a pretty bright small star	1
246	5	4	38	24	51	A pretty well-defined round faint nebula, 25″ diameter; a little brighter at the centre	2
247	5	11	35	24	25	A pretty bright round nebula, 40″ diameter	1
248	5	14	30	24	19	A pretty bright round well-defined nebula, about 30″ diameter, gradually bright to the centre	3
249	6	40	5	24	34	A very small faint ill-defined nebula	1
250	11	43	9	24	20	A very faint small round nebula, about 10″ diameter, with a bright point exactly in the centre. Magnifying power 170	2
251	13	8	0	24	24	An extremely faint small nebula, about 15″ diameter, pretty well defined. A very small star is north preceding, and a very minute south preceding; both very near the nebula, but not involved in it.	2
252	13	20	11	24	44	A very faint nebula, about 25″ diameter. It is very near a star of the 8th magnitude, and near the north following extremity of a crescent of very small stars	2
253	14	35	—	24	10	(3 Circini, Bode) is a line of stars of the 8-9th magnitudes, oblique to the equator, about 1° in length joining a circular line of small stars at the north extremity, with a bright star of the 7th magnitude in the south following extremity.—Figure 8.	3
254	22	26	14	24	57	A very small nebula, 10″ diameter, with a very minute star in the preceding side of it	1
255	22	36	4	24	1	A small faint elliptical nebula in the parallel of the equator, about 25″ long, and 12″ or 15″ broad	1
256	4	46	30	25	39	A small round nebula bright at the centre, 10″ diameter	1
257	9	54	10	25	13	A very small and very faint nebula, about 8″ or 10″ diameter; very feeble at the margin	1
258	10	32	—	25	46	A cluster of extremely small stars, resembling a faint nebula, about 6′ diameter; round figure	1
259	15	3	8	25	5	A small faint round nebula, 25″ or 30″ diameter, sensibly brighter in the middle. A star of the 9th magnitude, 4′ or 5′ south	1
260	15	7	17	25	46	An extremely faint ill-defined nebula, 1½′ or 2′ diameter, irregular round figure, a very little brighter towards the middle	2

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
261	18	49	25	25	35	A very minute double nebula, the distance between them about 15″ of a degree; the largest or following of the two is not more than 10″ diameter; each of them has a small bright point or nucleus	2
262	18	51	30	25	53	A pretty large very faint nebula, about 5′ or 6′ diameter, slightly bright towards the centre; a minute star is north of the nebula, and two stars of the 7th magnitude preceding........................	3
263	21	19	0	25	23	A small faint round nebula, 20″ diameter, a little brighter in the middle, following a group of pretty bright stars.........................	1
264	4	15	13	26	30	A faint round nebula, about 40″ diameter, slightly bright to the centre; this is north preceding θ Rhomboidis........................	2
265	9	5	48	26	1	A very bright round nebula, about 3′ or 4′ diameter, very gradually bright to the centre. This has a fine globular appearance........	1
266	11	40	9	26	8	A very small nebula, very bright immediately at the centre; the bright point is nearly equal in brightness to one of the minute stars north of the nebula. I do not think the bright point is a star, but a very highly condensed nucleus, surrounded by a faint chevelure, not more than 10″ diameter. Another very minute nebula precedes this ...	2
267	11	39	35	26	11	An extremely small round nebula, not more than 5″ diameter, equally and uniformly bright, with a small well-defined planetary disc, with no bright point or condensation to the centre. This is not a small star; the appearance is very different from any of the small stars near it, and it is also very unlike the general appearance of small nebulæ; both of these objects are very singular................	2
268	15	36	8	26	7	A very faint nebula, about 1′ diameter, with a very minute star preceding, and another following; both are involved...............	1
269	16	43	0	26	39	A small round faint nebula, about 15″ diameter, with a minute star near the south side, and four small stars following. The nebula is in the point of a cone formed by the four small stars and itself	2
270	23	41	16	26	59	A faint ray of nebula, about 25″ or 30″ long, with a small star in the centre of it.—Figure 9.	1
271	11	11	36	27	28	A rather bright nebula, about 2½′ or 3′ long and 1′ broad, in the form of a crescent, the convex side preceding; no condensation of the nebulous matter towards any point. This is easily resolvable into many stars of some considerable magnitude, arranged in pretty regular lines, with the nebula remaining, which is also resolvable into extremely minute stars. This is probably two clusters in the same line.—Figure 10.	7
272	12	31	—	27	55	A group of five stars of the 8th or 9th magnitude, with a great number of extremely small stars resembling faint nebulæ, 3′ or 4′ diameter.	1
273	13	34	48	27	57	(201 Centauri, Bode.) This is a curved line of small stars, about 1½′ long, with a star of the 7th magnitude in the north extremity; a group of extremely minute stars on the preceding side of the crescent, and a multitude of very minute stars extended preceding and following.—Figure 11..	7
274	14	19	8	27	39	An exceedingly small very faint round nebula, about 8″ diameter, north	

No.	Æ	S.P.D.	Description of the Nebulæ and Stars.	No. of Obs.
			rather following a star of the 12th magnitude, with a smaller star on the other side	1
	h m s	° ′		
275	14 18 10	27 13	A very small round well-defined nebula, about 15″ diameter, with a bright point in the centre	1
276	15 14 0	27 50	A very small nebula, with a very minute star involved in the north side of it: the star is not central; another small star is distant about 4′ from the nebula	1
277	15 28 9	27 51	A faint extended nebula, about 4′ long and 2′ broad, with a group of seven or eight extremely small stars in it	1
278	16 19 7	27 18	A pretty well-defined small nebula, extended in the parallel of the equator, rather a little south preceding, and north following, about 1½′ long, and 25″ broad, with a star of the 11th or 12th magnitude in the centre. The nebula is nearly equally bright, and the star is in the centre.—Figure 12.	2
279	17 26 0	27 35	A pretty large faint nebula, round figure, about 3′ diameter; very faint at the margin	1
280	19 14 21	27 24	An extremely faint ill-defined nebula, of an irregular figure, rather elongated following: there are two minute stars involved in the preceding side of it	1
281	11 10 16	28 20	A cluster of very small stars, a little elongated preceding and following, about 10′ diameter; the stars are congregated towards the centre, a pretty bright star south, and a double star south following this	4
282	13 42 —	28 57	A group of ten or twelve stars about the 10th magnitude, with a multitude of very small stars, forming an irregular branched figure, 8′ or 10′ long and 6′ broad	1
283	14 47 0	28 59	A group of small stars forming a semicircle, with a line of minute stars joining the extremities	2
284	15 52 8	28 4	A group of twelve or fourteen stars, round figure, 2′ diameter	1
285	15 59 4	28 40	A very faint small round nebula, about 8″ or 10″ diameter; a little brighter in the centre	1
286	16 31 12	28 29	An exceedingly faint very small round nebula, about 12″ diameter, with a minute bright point in the centre. This is south of a star of the 7-8th magnitude, and a nebula follows in the field	1
287	16 35 3	28 32	A faint elliptical nebula, about 25″ diameter, not bright at the centre, and nearly uniform in its light	1
288	21 20 12	28 28	A pretty bright small elliptical nebula, about 20″ long; the brightest part is near the south following extremity. This precedes a small star	1
289	11 29 20	29 16	A pretty large cluster of stars of mixt magnitudes, about 10′ diameter. The greater number of the stars are of a pale white colour. There is a red star near the preceding side; another of the same size and colour near the following side; another small red star near the centre; and a yellow star near the south following extremity, all in the cluster	5

No.	Æ h m s	S.P.D. ° ′	Description of the Nebulæ and Stars.	No. of Obs.
290	11 36 11	29 46	A very faint nebula, round figure, about 1½′ diameter, with two or three very small stars involved in it. There are many similar small stars scattered in the field with a power of 170; the nebulosity is extremely faint. This precedes the 49 Centauri, Bode, which is a star of the 4th or 5th magnitude, and not of the 6th as given in Bode's catalogue	2
291	11 56 9	29 45	A cluster of small stars of mixt magnitudes, irregular figure, about 6′ long and 4′ broad	3
292	12 15 0	29 2	A pretty cluster of extremely small stars, resembling a pretty large faint nebula, about 6′ or 7′ diameter: the compression is very gradual to the centre; a pretty bright star is in the following side of the cluster, round figure	4
293	15 49 5	29 3	A very faint small nebula, about 10″ diameter, with a small star near the south margin, but not involved	1
294	17 42 18	29 4	A very small round nebula, with a small star at the north edge, not involved	1
295	18 54 3	29 45	A pretty large and very bright nebula, 5′ or 6′ diameter, irregular round figure, easily resolved into a cluster of small stars, exceedingly compressed at the centre. The bright part at the centre is occasioned by a group of stars of some considerable magnitude when compared with those of the nebula. I am inclined to think that this may be two clusters in the same line; the bright part is a little south of the centre of the large nebula	5
296	4 42 11	30 40	A faint ill-defined nebula, with a small bright point in the preceding side, which I suspect to be a star; there are several similar small stars in the field	1
297	9 56 0	30 50	A beautiful cluster of stars, arranged in curvilinear lines intersecting each other, about 40′ diameter, extended south preceding, and north following	1
298	10 47 9	30 10	A very faint nebula, of an oblong rectangular figure, extended in the direction of the meridian	1
299	11 22 36	30 14	An extremely faint ray of nebula, about 2′ in length, with a very small star at the following extremity; three pretty bright small stars distant about 1′, and a star of the 7th magnitude south preceding	1
300	12 19 50	30 51	A triangular group of very small stars, about 3′ long, resembling faint nebulæ. A star of the 9th magnitude near the north following extremity	4
301	12 44 —	30 35	(χ Crucis, Bode) is five stars of the 7th magnitude, forming a triangular figure, and a star of the 9th magnitude between the second and third, with a multitude of very small stars on the south side.—Figure 13. is a very correct representation	6
302	14 16 40	30 3	A cluster of small stars of mixt magnitudes, considerably congregated towards the centre, 4′ or 5′ diameter	2
303	15 21 23	30 32	A very small faint nebula, 10″ or 12″ diameter, a little brighter in the middle. A small star precedes this, and a star of the 7th magnitude following	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
304	15	49	—	30	0	(λ Circini, Bode) Lacaille describes this as three small stars in a line with nebula. No particular nebula exists in this place. A group of about twenty stars of mixt magnitudes, forming an irregular figure, about 5′ or 6′ long, answer to the place of the λ. This is in the milky way; and there is no nebula in the group of stars except what is common in the neighbourhood	5
305	17	29	30	30	27	A very small round nebula, with a minute bright point near the following side. The bright point is not in the centre of the nebula, a pretty bright small star following distance 1′ of arc	1
306	4	9	8	31	38	A small round pretty well defined nebula, 10″ or 12″ diameter, slightly bright to the centre, a bright star in the field south following	1
307	4	49	12	31	37	An extremely faint round nebula, 30″ or 40″ diameter	1
308	10	15	48	31	10	A very small round nebula, about 25″ diameter, bright at the centre, nearly in a line between two very small stars. A star of the 6-7th magnitude is south following	1
309	10	38	—	31	13	(η Roboris Caroli, Bode) is a bright star of the 3rd magnitude, surrounded by a multitude of small stars, and pretty strong nebulosity; very similar in its nature to that in Orion, but not so bright. Figure 14. is a very correct representation of it; the circle A B is about 1° and 37′ diameter, with the star η in the centre. I can count twelve or fourteen extremely minute stars surrounding η in the space of about 1′; several of them appear close to the disk: there is a pretty bright small star about the 10th magnitude north following the η, and distant about 1′. The nebulosity is pretty strongly marked; that on the south side is very unequal in brightness, and the different portions of the nebulosity are completely detached, as represented in the figure. There is much nebulosity in this place, and very much extensive nebulosity throughout the Robur Caroli, which is also very rich in small stars	13
310	10	47	0	31	42	A faint nebula, about 1½′ or 2′ diameter, with a small bright star near the preceding side; this is resolvable into exceedingly minute stars	2
311	12	50	30	31	15	A very faint pretty large nebula, about 6′ or 8′ diameter, round figure, resolvable into very minute stars. Several stars of some considerable magnitude appear scattered among the minute stars of the nebula, but they are only the continuation of a branch of small stars which run over the place where the nebula is; the stars in the nebula are very gradually, but not much, compressed to the centre.	4
312	13	16	7	31	38	A pretty large faint nebula, about 5′ diameter, irregular branched figure, resolvable, with considerable compression of the stars towards the central point. This precedes a star of the 7th magnitude, and a group of small stars follow, about 10′ north of the nebula	2
313	14	16	14	31	5	A very minute group of small stars, about 2′ long, extended in the parallel of the equator	1
314	15	9	—	31	29	(16 Circini, Bode) described in the Connaissance des Tems as nebula, with two small stars in it. There are three stars of the 8th magnitude very near each other, forming a triangle, which answers to the place	

No.	AR			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
						of 16 Circini; but there is no nebula accompanying them, neither is there any nebula accompanying any of the stars in this place....	6
	h	m	s	°	′		
315	15	21	30	31	55	A small rather faint nebula, 20″ or 25″ diameter, at the preceding extremity of a line of four or five very small stars	1
316	16	29	6	31	45	A very faint ray of nebula, about 1½′ long, and 15″ or 20″ broad, extended north preceding and south following, with rather a condensation of the nebulous matter near the south following extremity. There is a minute star near the north preceding extremity, but I do not think it is involved in the ray..........................	1
317	17	43	28	31	11	A faint ill-defined round nebula, very faint at the margin, perhaps 1½′ or 2′ diameter	1
318	17	53	—	31	43	A group of eighteen or twenty small stars of nearly equal magnitudes, extended 8′ long, and 4′ broad..............................	1
319	22	7	20	31	58	A very small cluster of very minute stars, resembling a small faint nebula, 2′ diameter	1
320	4	5	7	32	23	A small faint nebula, about 12″ diameter, with three very small stars north of it	3
321	10	27	13	32	37	A very small cluster of very small bright stars; round figure, about 4′ diameter; rich in extremely small stars resembling faint nebula ..	4
322	10	30	7	32	17	A star of the 7th magnitude, involved in faint nebula	1
323	10	59	—	32	16	(5 Centauri, Bode) is a very large cluster of stars about the 9th magnitude, with a red star of the 7—8th magnitude, north following the centre of the cluster. Elliptical figure: the stars are pretty regularly scattered	3
324	11	17	0	32	43	Seven or eight small stars in a line oblique to the equator	1
325	11	32	—	32	19	A cluster of stars in strong milky nebulosity	1
326	16	5	21	32	28	A group of very small stars of an irregular branched figure, 15′ or 20′ diameter. The central part is very thin of stars	4
327	17	48	16	32	26	A very faint nebula, rather extended north, about 30″ or 40″ long ..	1
328	19	15	46	32	41	A small faint nebula, about 20″ diameter, with a minute star in the preceding margin	1
329	21	19	—	32	19	(47 Indi, Bode). This is described as two small stars in nebula. I can find no nebula in this place; but there are three small stars forming an obtuse triangle, which answers to the place of 47 Indi. There is also an angular line of very minute stars, about 1′ in length, following about 2′ or 3′ in time, and 30′ south, which would have a nebulous appearance through a small telescope	4
330	9	22	30	33	46	A faint cluster of small stars of mixed magnitude, with two or three pretty bright stars in it. This answers to 485 Argûs (Bode), and is described as a small star surrounded by nebula. This precedes 492 Argûs, about 3′ in AR, and 3′ or 4′ north of the star, and is probably the object intended; the cluster is about 5′ diameter, irregular figure, no nebula	2

No.	Æ h m s	S.P.D. ° ′	Description of the Nebulæ and Stars.	No. of Obs.
331	5 12 30	33 37	A rather bright nebula about 1′ diameter, very faint at the margin, gradually bright to the centre: a small star north, and another south, both involved in the margin of the nebula. A group of very small stars north	2
332	10 10 6	33 57	A very faint ray of nebula, about 2′ broad, and 6′ or 7′ long, joining two small stars at the south following extremity, which are very slightly involved, but their lustre is not diminished from that of similar small stars in the field. The north extremity also joins a group of small stars, but they are not involved.—Figure 15.......	2
333	14 29 40	33 10	A group of small stars with faint nebula. There is rather a gathering of the nebulous matter, about 10″ diameter, near the north side ...	2
334	15 43 42	33 1	A faint round nebula, about 1½′ diameter, very slightly bright towards the centre. A small star is south, rather preceding the nebula, and ι Normæ is south following	3
335	16 4 52	33 31	A cluster of small stars of mixt magnitudes, congregated into several groups or patches, with a pretty bright star near the centre.......	1
336	16 40 13	33 54	A small faint nebula, about 10″ or 12″ diameter, with a small star involved in the north extremity. This follows a pretty bright small star	2
337	3 7 47	34 5	A very bright round nebula, about 1½′ diameter, pretty well defined and gradually bright to the centre. A small star north following..	2
338	4 16 14	34 28	A pretty large round nebula, about 4′ diameter, moderately and gradually condensed to the centre. A very small star near the following edge, not involved..	2
339	4 28 33	34 52	A small round pretty well defined nebula, bright in the centre, north preceding α Doradûs	1
340	9 8 51	34 48	A very faint round nebula, about 2′ diameter. There are seven or eight very minute stars in the nebula	1
341	12 3 24	34 38	A very small nebula, about 12″ or 15″ diameter, with a very minute star involved in the south side. This nebula is near the preceding extremity of a small crescent of very minute stars: the crescent is not conspicuous	2
342	14 22 24	34 15	A group of small stars of the 11th and 12th magnitude, with a multitude of minute stars mixt, extended south preceding and north following	2
343	15 37 28	34 1	A pretty large faint nebula, with several minute stars in it; round figure, 4′ or 5′ diameter, resolvable..............................	2
344	16 3 5	34 40	An extremely faint pretty large nebula, 5′ or 6′ diameter, with two small stars in the north preceding side, and several very minute stars scattered in it	1
345	17 20 36	34 30	A very small fan-shaped nebula, about 10″ or 12″ long, with a brightish point at the small or south extremity, north of a double star of the 10th magnitude..................................	3
346	17 35 28	34 41	A small round nebula with a bright point in the centre; diameter about 15″..	1

No.	AR			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
347	23	25	36	34	53	A faint round nebula, about 20″ diameter.	1
348	4	1	8	35	23	A very faint nebula, about 35″ diameter. This precedes a group of small stars	1
349	11	42	13	65	13	A pretty large faint nebula, 6′ or 7′ diameter, easily resolvable with slight compression of the stars to the centre, or rather towards the following side of the centre	4
350	14	20	30	35	51	A curved line of small stars, south preceding a star of the 7th magnitude	2
351	14	53	36	35	4	A pretty large cluster of small stars resembling faint nebula, general figure round, south preceding 2 Pyxidis	2
352	14	59	30	35	1	A small round nebula, about 20″ diameter, a little brighter in the centre	1
353	15	38	30	35	34	A rather faint easily resolvable nebula, of an irregular figure, 2′ diameter	1
354	22	29	42	35	34	A small faint round nebula, about 15″ diameter, south following a pretty bright small star	1
355	10	32	8	36	52	A triangular group of small stars resembling faint nebula, with several stars in it of some considerable magnitude	4
356	14	35	40	36	14	A group of eight or ten pretty bright small stars, in the form of a ≺ (the letter Y), about 5′ long, parallel to the equator, with small stars in it resembling faint nebula	3
357	14	15	—	36	17	A very extensive cluster of stars of mixed small magnitudes; the stars appear to be either congregating together in different parts of the cluster, or breaking up; there are several groups already formed, the whole cluster is composed of lines of stars, but no general attraction towards any particular point	1
358	15	47	37	36	55	A pretty large faint nebula, of an irregular figure, about 6′ diameter, very faint	3
359	15	54	10	36	23	Three very minute stars forming a triangle, with a faint round nebula, about 20″ diameter in the centre, but none of the stars are involved in the nebula	
360	15	59	27	36	13	A pretty large cluster of small stars of mixed magnitudes, about 12′ diameter; the stars are considerably congregated towards the centre, extended south preceding and north following	5
361	16	2	—	36	51	A cluster of stars extended south preceding and north following, of various mixed magnitudes, considerably compressed to the centre	1
362	16	11	—	36	57	A space in the milky way, exceedingly rich in small stars	1
363	16	13	5	36	43	A faint cluster of very minute stars, about 2′ diameter, resembling faint nebula	1
364	16	35	12	36	29	A round faint nebula, about 1′ diameter, with three small stars in it; a bright star south of the nebula	1
365	17	4	27	36	1	A very faint small round nebula, about 15″ diameter, with a bright point in the centre. I cannot say there is a gradual condensation of the nebulous matter; the minute point may be a star	1

No.	Æ h	m	s	S.P.D. °	′	Description of the Nebulæ and Stars.	No. of Obs.
366	17	27	10	36	25	A pretty large nebula, extended nearly in the parallel of the equator, brightest and broadest in the middle; a group of very small stars in the middle give it the appearance of a nucleus, but they are not connected with the nebula, but are similar to other small stars in this place which are arranged in groups. The nebula is resolvable into stars	4
367	18	45	11	36	19	An extremely faint nebula, of an irregular figure, 3′ or 4′ diameter, a little brighter in the middle; south following λ Telescopii	1
368	19	21	16	36	35	An extremely faint small round nebula, very difficult to be seen, about 9′ north of a star of the 6-7th magnitude	1
369	3	56	13	37	10	A faint nebula, elliptical in the parallel of the equator, about 30″ long and 12″ broad	1
370	4	25	6	37	59	An extremely faint round nebula, about 15″ diameter, with a small star in the centre. The faint nebula resembling an atmosphere or chevelure; the star is in the centre, a small star south of it has nothing of this nebulous appearance	1
371	8	24	38	37	52	A small faint elliptical nebula, with three minute stars in it. This is near the north following extremity of a crooked line of pretty bright small stars	1
372	9	21	46	37	17	A very faint nebula, of an irregular round figure, about 1′ diameter, very slight condensation *to* the centre	1
373	16	44	34	37	15	A very small round nebula, north preceding ε Aræ, another nebula follows this	1
374	16	45	44	37	27	A very faint nebula, of an irregular round figure, about 2′ diameter, slightly bright towards the centre, easily resolvable into very minute stars, slightly compressed to the centre; this also precedes ε Aræ.	4
375	17	33	30	37	53	A very faint small nebula, about 25″ diameter, round figure, south following a star of the 7th magnitude	1
376	18	4	6	37	44	A pretty bright round nebula, about 1½′ diameter, moderately condensed to the centre; three very small stars involved in the preceding margin	4
377	15	6	53	38	48	A very small faint nebula, 10″ or 12″ diameter, north following a small group or cluster of stars	1
378	16	2	31	38	15	A small faint round nebula, about 10″ diameter, north following two pretty bright stars	1
379	16	11	30	38	32	A small faint round nebula, with a bright centre	2
380	16	13	49	38	52	A pretty large faint nebula, about 6′ diameter, rather elongated in the direction of the meridian; no sensible condensation towards the centre	1
381	17	10	0	38	25	An extremely faint small nebula, about 12″ diameter, with a bright point in the centre	1
382	17	18	16	38	17	A small faint round nebula, about 35″ diameter	1
383	17	37	18	38	26	A small faint nebula, about 30″ diameter, with a small star slightly involved in the preceding margin	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
384	18	16	18	38	50	A very faint ill-defined nebula, very small	1
385	19	28	40	38	32	A faint ray of nebula, about 1½′ long, and 15″ or 20″ broad, extended in the parallel of the equator; a small star precedes it, but is not involved. The following extremity of the ray is the brighter	2
386	10	15	9	39	12	11 Roboris Caroli (Bode). A group of eight or ten pretty bright small stars, with very small stars, about 6′ diameter	2
387	13	12	50	39	53	A very small round nebula, about 10″ diameter, bright immediately at the centre. A star of the 7th magnitude, about 4′ north of it	1
388	13	36	0	39	32	A bright exceedingly well-defined rather elliptical nebula, about 1′ diameter, exceedingly condensed almost to the very edge, and gradually a little brighter to the centre. This is about 6′ north of M Centauri.—I have strong suspicion that this is resolvable into stars	6
389	15	16	34	39	59	A very fine round pretty bright nebula, about 3′ diameter, gradually brighter towards the centre, and well defined at the margin: this is resolvable. With a power of 260 it has a beautiful globular appearance. The stars are considerably scattered on the south side	8
390	16	7	50	39	47	A very small nebula, about 8″ or 10″ diameter, with a very bright nucleus, or else a very minute star in a small nebula. I think the bright point is rather to the north side of the centre. There is a small star preceding, and another following, forming an obtuse triangle with the nebula	2
391	16	22	38	39	22	A very faint small nebula, about 30″ diameter, with two brightish points in it, which I suspect to be exceedingly minute stars	2
392	16	23	23	39	24	A small faint nebula, about 25″ diameter. These two nebulæ are nearly in the same parallel	1
393	16	37	8	39	13	A small faint nebula, 12″ or 15″ diameter, with two small stars slightly involved in the following side	1
394	17	36	23	39	27	A very small round nebula, well defined, about 12″ diameter, a star of the 12th or 14th magnitude near the preceding edge. The star is not involved	1
395	18	17	30	39	53	An extremely faint small round nebula, about 15″ diameter, with two very minute points in it, which I suspect to be stars. The nebula is extremely faint, but pretty well defined	1
396	18	20	50	39	21	A small round faint nebula, with a bright point in the centre, a star of the 7th magnitude following	1
397	9	34	40	40	26	A very small faint round nebula, about 15″ diameter, with two or three exceedingly small stars slightly involved in it, and another small star about 1′ south of it	1
398	13	57	5	40	59	An extremely faint nebula, about 4′ or 5′ long, and 2′ or 3′ broad, elliptical in the parallel of the equator. This is easily resolvable into minute stars, with no sensible condensation or compression towards any point	1
399	15	42	47	40	12	A small faint rather elliptical nebula, about 12″ diameter, with a bright point in the north preceding side of the centre. This precedes a very pretty double star	1

No.	Æ h	 m	 s	S.P.D. °	 ′	Description of the Nebulæ and Stars.	No. of Obs.
400	16	22	48	40	42	A pretty large faint nebula, about 6′ diameter, easily resolvable, round figure, with two rows of small stars following	2
401	16	23	17	40	32	A very faint cluster of small stars, with a branch extended; the head of the cluster is rich in small stars	3
402	17	11	9	40	11	A very fine round cluster of very small stars, slightly compressed to the centre, about 8′ diameter	3
403	17	29	30	40	49	A small round faint nebula, about 25″ diameter, very slightly bright towards the centre; a very small star is near the north edge, but is not involved, and a star of the 6th magnitude preceding	1
404	17	38	20	40	34	A very faint round nebula, about 1′ diameter, following a pretty bright small star	1
405	18	55	24	40	48	A small faint nebula, about 25″ diameter, with a small star preceding it	1
406	21	7	36	40	44	A small round nebula, about 12″ or 15″ diameter, very bright immediately at the centre, resembling a small star surrounded by an atmosphere. This is north following a star of the 6th magnitude	1
407	22	50	55	40	1	A very small faint round nebula, with a bright point in the centre	1
408	0	47	35	41	38	A pretty large rather ill-defined nebula, of a round figure, with a bright point, or small nucleus near the centre; the nebula is extremely faint almost to the very centre. There is a star of the 8th or 9th magnitude near the south preceding side, but not involved	1
409	4	3	56	41	47	A very small and very faint round nebula, about 20″ diameter	2
410	8	6	—	41	26	A curiously arranged group of pretty bright small stars of mixt magnitudes. This answers to the place of 310 Argûs (Bode), and is described by LACAILLE as nebula with five small stars forming the letter T in it. There is no nebulosity in this place. The diameter of the cluster may be about 12′.—Figure 16. is a very good representation of the group	2
411	12	55	30	41	31	A beautiful long nebula, about 10′ long, and 2′ broad, forming an angle with the meridian, about 30° south preceding and north following; the brightest and broadest part is rather nearer the south preceding extremity than the centre, and it gradually diminishes in breadth and brightness towards the extremities, but the breadth is much better defined than the length. A small star near the north, and a smaller star near the south extremity, but neither of them is involved in the nebula. I have strong suspicions that this nebula is resolvable into stars, with very slight compression towards the centre. I have no doubt but it is resolvable. I can see the stars, they are merely points. This is north following the 1st ξ Centauri.—Figure 17.	6
412	16	15	14	41	20	A pretty large round nebula, about 4′ diameter, gradually a little brighter towards the centre. There is a small star on the north, and another on the south side, both involved. This is easily resolved into stars, with slight compression to the centre	4
413	16	29	0	41	35	A cluster of small stars, with a bright star in the preceding side. A very considerable branch or tail proceeds from the north side, which joins a very large cluster	3

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
414	16	45	27	41	32	A very faint ill-defined nebula, about 1½′ or 2′ diameter, with two small stars in it; easily resolvable, with slight compression to the centre.	1
415	17	8	3	41	10	A small nebula, of a long oval figure, with a very small star in the centre, and three stars in a line following	1
416	17	10	15	41	25	A faint ray of nebula extended in the parallel of the equator, about 2½′ or 3′ in length, with two very minute stars in it: this is very feeble and ill-defined. A nebula precedes this	1
417	17	14	0	41	42	A rather faint nebula, of an irregular round figure, 4′ diameter, slightly branched; easily resolvable into stars, with slight compression of the stars to the centre	6
418	17	33	56	41	38	An exceedingly faint nebula, about 2′ long, and 1′ broad, of an irregular figure, with two or three very minute points in it, which I suspect to be small stars.	1
419	17	41	6	41	1	A very faint and very ill-defined small nebula	1
420	17	45	11	41	57	A very small round nebula, with a minute star north of it, but not involved. A nebula follows this	1
421	17	45	23	41	50	A very faint small round nebula	1
422	18	10	20	41	47	A faint round nebula, about 30″ diameter. A pretty large nebula north following this	1
423	18	11	25	41	59	An angular group of extremely small stars resembling a faint nebula, with stars of some considerable magnitude in it; irregular figure, 4′ or 5′ long	3
424	18	16	50	41	23	A very faint small round nebula, with two very minute stars involved in it. This is north following ξ Telescopii, a dusky greenish star of the 5th magnitude	1
425	19	54	13	42	12	A very small faint nebula, about 15″ diameter	1
426	3	38	18	42	8	A very faint nebula, about 1′ diameter, rather elliptical in the parallel of the equator; with a brightish point or condensation of the nebulous matter, a little to the preceding side of the centre	2
427	3	46	45	42	7	A pretty large nebula, round figure, 2′ or 3′ diameter	2
428	3	47	37	42	0	An extremely faint ill-defined small nebula. A pretty large nebula precedes this	1
429	4	3	48	42	34	A very small faint round nebula	1
430	8	54	20	42	3	A group of very small stars of mixed magnitudes, irregular figure, about 3′ diameter	1
431	13	56	—	42	35	A curiously curved line of small stars, of nearly equal magnitudes; two stars of 7th magnitude following	3
432	16	15	—	42	52	A cluster of very small stars following 47 Normæ	1
433	17	26	30	42	48	A round faint pretty well-defined nebula, 10″ or 12″ diameter, south preceding a star of the 7th magnitude	1
434	17	31	0	42	29	A star of the 7th magnitude, accompanied by several small stars. This answers to the place of 68 Aræ (Bode), but there is no nebula	2

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
435	17	31	23	42	37	A very faint small round nebula, very equally faint. A pretty bright small star following, distant about 1′. A star of the 7th magnitude about 7′ south	1
436	18	11	24	42	0	A large faint nebula, of an irregular figure, 4′ or 5′ long; resolvable; mixed magnitudes	2
437	1	1	47	43	4	An extremely faint small nebula; round, with a very minute bright point in the centre	1
438	3	52	7	43	18	A very faint nebula, about 1′ diameter; round figure	1
439	6	29	50	43	23	A faint small nebula, about 20″ diameter, with a very small star in the north preceding side; the nebula is surrounded by six or seven small stars in the form of a circle, about 6′ diameter	1
440	13	16	—	43	26	ω Centauri (Bode) is a beautiful large bright round nebula, about 10′ or 12′ diameter, easily resolvable to the very centre; it is a beautiful globe of stars very gradually and moderately compressed to the centre; the stars are rather scattered preceding and following, and the greatest condensation is rather north of the centre: the stars are of slightly mixed magnitudes, of a white colour. This is the largest bright nebula in the southern hemisphere	8
441	15	32	12	43	32	An exceedingly small faint nebula, 6″ or 8″ diameter, with a very minute star in the following margin, very much resembling a minute double nebula; but the following is a small star	1
442	16	34	50	43	24	Seven or eight small stars in a group, about 1′ diameter, with a minute line of stars on the north side	2
443	17	16	25	43	32	A faint ill-defined small nebula, following a small star	1
444	20	32	20	43	4	A very small ill-defined nebula, with a very small star involved in the south preceding side	1
445	10	9	17	44	29	A pretty large pretty bright round nebula, 4′ or 5′ diameter, very gradually condensed towards the centre, easily resolved into stars; the figure is rather irregular, and the stars are considerably scattered on the south preceding side: the stars are also of slightly mixed magnitudes	5
446	11	3	55	44	21	A very minute star in the centre of a small round nebula, about 15″ diameter; this has very much the appearance of a small star surrounded by an atmosphere. There is a similar small star near the following margin, not involved	2
447	15	8	12	44	52	A very small nebula, with a very minute star involved in the north side; the nebula is about 1′ north of a star of the 9—10th magnitude	1
448	17	42	20	44	7	A very small round faint nebula, about 15″ diameter, very bright immediately at the centre; no star of any considerable magnitude in the field; this is in the milky way, and is very rich in small stars	1
449	19	3	36	44	49	A small faint round nebula, about 15″ diameter, north following a star of the 10th magnitude; two bright stars in the field south	1
450	19	19	24	44	0	A very faint round nebula, about 25″ diameter, south, preceding a star of the 6th magnitude	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No.of Obs.
	h	m	s	°	′		
451	20	12	16	44	37	An extremely small faint elliptical nebula, about 12″ long and 8″ broad, with a small bright point in the following extremity, which may be a star	1
452	5	29	5	45	14	A very faint small ill-defined nebula, with a very minute double star in it	1
453	8	44	0	45	10	A group of ten or twelve pretty bright small stars, south following 409 Argûs	1
454	16	37	23	45	33	A faint nebula, about 4′ or 5′ diameter, irregular round figure, easily resolvable into stars; with stars of larger magnitudes scattered in the preceding side of it	6
455	16	41	20	45	23	An extremely faint ill-defined nebula, easily resolvable into stars; this is in the milky way	1
456	16	49	—	45	31	A very large patch of strong nebula, about 20′ long, and 10′ broad, rich in small and extremely minute stars	2
457	17	23	40	45	22	A beautiful round nebula, about 5′ diameter, with a bright round well-defined disk or nucleus, about 15″ diameter, exactly in the centre; this has the appearance of a planet surrounded by an extremely faint diluted atmosphere; there is a small star involved in the faint atmosphere: the atmosphere is at least 6′ diameter.—Figure 18.	7
458	17	30	51	45	57	A very faint nebula of some considerable extent; extended in the parallel of the equator; resolvable into extremely minute stars	2
459	17	40	20	45	2	A very extremely faint ill-defined nebula, south—following a star of the 7th magnitude	
460	17	45	30	45	54	A very faint nebula, extended about 2¼′ in length, oblique to the equator, with a bright point in each extremity: the northern, I think, is a very small star; but the southern of the two, or the one at the south following extremity, is a small nucleus or condensation of the nebulous matter. This follows 16 Telescopii.—Figure 19.	7
461	17	49	33	45	55	A faint round nebula, about 40″ diameter, gradually a little brighter in the middle	1
462	17	51	17	45	21	A very small faint round nebula, about 12″ diameter; a large nebula north preceding this	1
463	18	3	7	45	47	A small round pretty well-defined nebula, about 8″ or 10″ diameter: a very small star near the following edge, but not involved—preceding σ Telescopii	1
464	18	22	33	45	45	A very fine double nebula, very nearly equal, about 10″ diameter; distance about 17″; position in the parallel of the meridian: a small star follows	1
465	18	38	0	45	7	An extremely faint nebula, rather of a fan shape, with the small end preceding; it may be 3′ broad at the following extremity: there is a very minute bright point (or star) near the small end involved in the nebula	1
466	3	59	5	46	5	A small faint round nebula, about 25″ diameter, a little brighter in the centre: a star of the 10th or 12th magnitude preceding the nebula.	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
467	5	9	25	46	38	An extremely faint nebula, about 50″ diameter, round figure	1
468	9	34	30	46	44	A very faint easily resolvable nebula, extended about 10′ long, and 4′ or 5′ broad: no central condensation	1
469	14	22	15	46	36	An exceedingly faint extended nebula, about 10′ long; rather ill-defined	1
470	16	29	53	46	59	A round nebula, about 3′ diameter, slightly bright to the centre; easily resolvable; gradual central condensation evident	1
471	16	35	35	46	32	A very faint small nebula, about 15″ diameter; another small nebula north of this	2
472	17	11	30	46	45	A faint nebula, about 2′ diameter, rather elongated, slightly bright towards the centre. I suspect this is resolvable: a line of small stars south	1
473	17	55	14	46	22	A very bright round highly condensed nebula, about 3′ diameter. I can resolve a considerable portion round the margin, but the compression is so great near the centre, that it would require a very high power, as well as light, to separate the stars; the stars are rather dusky	5
474	17	58	7	46	31	A small faint elliptical nebula, about 20″ diameter	1
475	23	7	9	46	28	A small faint nebula, rather elongated in the parallel of the equator, about 30″ broad, and 40″ long; there is a pretty bright point situated near the centre of the nebula: a small star precedes it	4
476	23	10	58	46	45	A small faint round nebula, about 30″ diameter: a double nebula follows this	2
477	23	12	40	46	53	Two very small round nebulæ, nearly the same Æ, and differing about 1′ in polar distances	1
478	0	36	23	47	23	A faint ray of nebula, with two very small stars in it	1
479	1	28	15	47	40	A very faint nebula, of a round figure, with two or three minute stars in it near the margin	1
480	3	51	18	47	6	A very faint ill-defined nebula, with two or three very small stars in it, and a small star following	1
481	11	18	0	47	36	A cluster of stars, about 10′ diameter, mixt magnitude. This precedes 25 Centauri (Bode.)	4
482	13	14	44	47	45	A very singular double nebula, about 2½′ long, and 1′ broad, a little unequal: there is a pretty bright small star in the south extremity of the southernmost of the two, resembling a bright nucleus: the northern and rather smaller nebula is faint in the middle, and has the appearance of a condensation of the nebulous matter near each extremity. These two nebulæ are completely distinct from each other, and no connection of the nebulous matters between them. There is a very minute star in the dark space between the preceding extremities of the nebula: they are extended in the parallel of the equator nearly.—Figure 20. is a good representation	7
483	16	28	7	47	3	A cluster of very minute stars, of a round figure, about 4′ diameter, following v Normæ	3
484	16	36	3	47	2	A very small feeble nebula	1

No.	AR			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
485	17	59	18	47	37	A round pretty well-defined faint nebula, about 45″ diameter, north of a triangle of small stars	1
486	18	39	20	47	44	A very singular body resembling a star, with a very faint diluted atmosphere, 8″ or 10″ diameter; it is paler than a star of the same magnitude, and precedes a pretty bright star	2
487	3	11	20	48	14	A pretty bright round nebula, about 1½′ diameter, very bright and condensed to the centre, and very faint at the margin; with a very small star about 1′ north, but not involved	1
488	7	8	48	48	21	An extremely faint small round nebula	1
489	8	40	0	48	43	A very faint nebula, about 6′ diameter, with small stars scattered in it —in the milky way	2
490	8	40	32	48	28	A very large cluster of pretty bright stars, coarsely scattered, about 1° diameter, following a star 5th magnitude, 396 Argûs (Bode.)	2
491	9	7	16	48	55	A very small faint elliptical nebula, about 15″ diameter; a very small star involved in the north extremity	1
492	10	24	47	48	43	A pretty large faint nebula, of an irregular figure, easily resolvable. n. preceding 557 Argûs	1
493	13	35	40	48	35	A very small faint round nebula, about 10″ diameter, gradually a little brighter in the middle; a star of the 7th magnitude north of the nebula	1
494	14	8	7	48	29	A very small faint nebula, south preceding a star of the 10th magnitude	1
495	15	14	30	48	22	An exceedingly faint ray of nebula, about 1′ long, extended in the direction of the meridian: a group of small stars south of the nebula.	1
496	16	28	5	48	35	An extremely small feeble nebula	1
497	16	28	25	48	39	A very small round nebula, about 10″ diameter	1
498	16	29	50	48	25	A very small round nebula, about 12″ or 15″ diameter. These three nebulæ are in the field together, and another small nebula follows, north	1
499	16	42	—	48	25	A cluster of pretty bright stars of mixt small magnitudes, considerably congregated to the centre, about 10′ diameter, with a large branch of very small stars extended on the north side; this is 150 Scorpii (Bode.)	3
500	17	3	18	48	55	A small nebula, about 20″ diameter, round, or rather elliptical, pretty well defined, with a bright point in the centre	1
501	17	37	48	48	41	Two very small stars, with a small nebula between them; both the stars are involved in the nebula, but the nebula is not in a line between the stars	1
502	17	38	0	48	26	A group of small bright stars of nearly equal magnitudes	2
503	17	40	27	48	13	A very small faint elliptical nebula, about 10″ diameter, preceding a very small star, and following a group of stars	1
504	18	9	0	48	36	A small round rather well-defined nebula, about 20″ diameter: a very	

No.	AR h m s	S.P.D ° ′	Description of the Nebulæ and Stars.	No. of Obs.
			small star is involved in the northern margin, and a small star precedes it, distant 1′	1
505	18 33 8	48 35	A small rather elliptical nebula, about 15″ long, with a small bright point preceding the centre	1
506	18 33 13	48 30	A very faint nebula, about 25″ diameter. I suspect a very feeble ray proceeding towards the other nebula, but not connected. This nebula is rather confused and ill-defined	1
507	0 6 50	49 50	A beautiful long nebula, about 25″ in length; position north preceding, and south following, a little brighter towards the middle, but extremely faint and diluted to the extremities. I see several minute points or stars in it, as it were through the nebula: the nebulous matter of the south extremity is extremely rare, and of a delicate bluish hue. This is a beautiful object.—Figure 21.	4
508	5 7 0	49 45	An exceedingly bright, round, well-defined nebula, about 1½′ diameter, exceedingly condensed, almost to the very margin. This is the brightest small nebula that I have seen. I tried several magnifying powers on this beautiful globe; a considerable portion round the margin is resolvable, but the compression to the centre is so great, that I cannot reasonably expect to separate the stars. I compared this with the 68 Conn. des Tems, and this nebula greatly exceeds the 68 in condensation and brightness	5
509	12 15 0	49 32	A very curiously branched group of small stars in the form of an inverted F, about 1° in length: a bright star of the 7th magnitude in the preceding extremity of the figure	1
510	12 38 10	49 44	A faint nebula, about 12″ or 15″ diameter, a little brighter to the centre, very faint at the margin	2
511	12 40 4	49 30	A pretty large faint nebula	1
512	14 18 8	49 16	A very small round nebula, about 14″ diameter, a little brighter in the middle, with a very small star involved in the margin of the nebula	1
513	15 51 0	49 28	A very singular body; it is not larger than a star of the 12th magnitude. With a higher power it has a considerable hairy appearance; it is very different from a star of the same magnitude, and is not dusky, but rather pale; preceding ω Lupi about 6½′ in AR, and 6′ or 7′ north of the star	2
514	16 13 20	49 46	A round cluster of small stars of nearly equal magnitudes, about 12′ diameter, considerably congregated to the centre, not rich in small stars. This answers to the place of 44 Normæ (Bode), but there is no nebula	5
515	16 33 29	49 30	A small faint round nebula, about 10″ diameter, with a bright point or nucleus in the centre	1
516	18 0 55	49 4	A very faint small ill-defined nebula, with two very minute stars in it: they are not near the centre, but involved in the north and south sides: this is north preceding two stars of the 6th magnitude	1
517	18 40 48	49 19	A small faint nebula, rather elongated in the direction of the meridian. The south extremity is brightest and broadest, and about 15″ in length	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
518	22	46	8	49	24	A very faint nebula extended preceding and following, about 1½′ long, and 20″ or 25″ broad; a little brighter in the middle, or rather nearer the north preceding extremity; the south following extremity is very ill defined	2
519	2	27	7	50	4	A faint nebula, of an irregular round figure, about 30″ diameter, north of a bright small star	1
520	16	43	16	50	50	A cluster or group of small stars, about 4′ diameter, with branches extending south preceding, and north following, with considerable compression of the stars towards the centre of the group. This answers to the place of 155 Scorpii (Bode), but there is no nebula	3
521	16	50	0	50	34	Two rows or lines of pretty bright small stars in the parallel of the equator, with a multitude of minute stars resembling faint nebula, 5′ diameter	2
522	17	5	44	50	44	An exceedingly faint nebula, about 1½′ long, and 1′ broad, elliptical in the direction of the meridian, with two or three very small stars in it	4
523	17	40	18	50	58	A small round pretty well-defined nebula, about 10″ diameter	1
524	17	43	4	50	21	An extremely faint nebula, about 40″ diameter, following a pretty bright small star	1
525	17	50	30	50	13	A very small, very faint round nebula, with a pretty bright point, immediately at the centre	1
526	18	8	58	50	52	A small elliptical nebula, about 25″ long, and 15″ broad, preceding a small star	1
527	18	9	30	50	11	A faint round nebula, about 1′ diameter	1
528	18	50	56	50	9	A very small round nebula, about 10″ or 12″ diameter	2
529	22	6	30	50	56	An extremely faint small nebula, 8″ or 10″ diameter. I think there is rather a brightish point in the preceding side; the nebula is south following a pretty bright small star	1
530	0	47	23	51	24	A pretty large faint nebula, irregular round figure, 6′ or 7′ diameter, easily resolvable into exceedingly minute stars, with four or five stars of more considerable magnitude; slight compression of the stars to the centre	3
531	5	0	23	51	55	A long or rather elliptical nebula, about 2′ long, and 50″ broad, a little brighter in the middle, and well defined. There is a group of small stars on the north side	2
532	5	2	50	51	37	An elliptical nebula, about 1½′ long, brightest and broadest in the middle, well defined. The preceding nebula and this, are very similar in appearance and brightness	1
533	5	13	17	51	54	An extremely small faint nebula, with a brightish point near the centre	1
534	5	52	50	51	59	A very small extremely faint nebula, 10″ diameter	1
535	7	45	4	51	59	A pretty large faint nebula, easily resolvable into small stars, or rather a cluster of very small stars, with a small faint nebula near the north preceding side, which is rather difficult to resolve into exceedingly small stars. This is probably two clusters or nebula in the same line; the small nebula is probably three times the distance of the large nebula	5

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
536	16	17	55	51	33	A round nebula, about 1′ diameter, bright immediately at the centre, and very faint from the bright nucleus to the margin. Another observation makes the figure rather elliptical, with a bright nucleus	2
537	17	13	25	51	3	An extremely faint ill-defined nebula, extended in the direction of the meridian, about 4′ or 5′ long, and 35″ broad; the brightest part is near the south following extremity. There are two small stars near the south extremity in a line parallel with the nebula	1
538	17	21	30	51	23	An extremely faint nebula, about 3′ or 4′ diameter, with three minute stars in it	1
539	17	45	20	51	21	A small faint nebula, about 15″ diameter, round, pretty well defined, two bright stars south	1
540	17	54	7	51	36	A very small round nebula, about 14″ diameter, a little brighter to the centre	1
541	18	3	53	51	57	A very small and very faint round nebula, with a bright point exactly in the centre, resembling a very small star surrounded by an atmosphere or burr	2
542	18	12	43	51	54	A small round or rather elliptical nebula, preceding a small star of the 10th magnitude	2
543	18	42	56	51	6	A very small round nebula, 10″ or 12″ diameter, pretty well defined, and sensibly brighter in the centre; in a line between two small stars	3
544	19	15	0	51	24	A very small faint nebula, with a brightish point in the centre	1
545	22	22	0	51	5	Six or eight pretty bright small stars in the form of the letter T, about 4′ long.—Figure 22.	2
546	23	26	12	51	46	An extremely feeble nebula, ill defined; it appears rather elongated oblique to the equator; it is north following a star of the 7th magnitude, and also north of the small stars	1
547	3	17	24	52	13	A small faint round nebula, about 15″ diameter	1
548	3	17	37	52	3	A rather bright round nebula, about 1½′ diameter, gradually condensed to the centre	2
549	5	2	27	52	17	A faint nebula, about 2½′ long, and fully 1′ broad, extended south preceding and north following; a very minute star near each extremity, not involved	2
550	6	40	56	52	46	A very small faint round nebula, with a very small star near the centre. The star is not exactly in the centre	1
551	15	31	12	52	2	Three or four small stars involved in faint nebula. I think there is rather a condensation of the nebulous matter near the following extremity	1
552	15	35	3	52	50	A beautiful round pretty bright nebula, about 2′ diameter, pretty well defined	3
553	16	20	7	52	23	A very faint nebula of a round figure, about 2½′ diameter, with two small stars in it	1
554	16	35	16	52	44	A very fine bright round nebula, 50″ diameter, gradually condensed to the centre	1

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
555	16	53	20	52	17	Two very minute stars involved in a small faint nebula. This precedes a very curious line of small stars	1
556	16	54	35	52	18	A curiously curved line of pretty bright small stars, with many very small stars mixt	3
557	17	38	30	52	59	A small well-defined rather bright nebula, about 20″ diameter; a very small star precedes it, but is not involved; following γ Telescopii	5
558	17	48	0	52	12	A faint nebula, of an irregular round figure, about 2′ diameter, with several extremely small stars in it	1
559	18	53	0	52	2	A singular dark space in the heavens, of an irregular figure, about 1½° long, and 1½° broad; no stars except exceedingly minute stars in the greatest portion of this space. There is a bright star in each side	1
560	19	12	28	52	51	A very small star surrounded with faint nebula like an atmosphere; other stars in the field are not accompanied with this appearance; the nebula is very faint, and the star is very near the centre	1
561	21	27	22	52	45	A small faint round nebula, 10″ or 12″ diameter	1
562	3	37	39	53	14	A pretty large faint round nebula, about 3½′ diameter, gradual slight condensation to the centre, very faint at the margin	2
563	8	6	—	53	12	A large cluster of stars of mixt magnitude, rather extended figure, not rich in very small stars	2
564	9	8	17	53	53	A pretty large faint nebula of a round figure, 6′ or 8′ diameter; the nebulosity is faintly diffused to a considerable extent. There is a small nebula in the north preceding side, which is probably a condensation of the faint diffused nebulous matter; the large nebula is resolvable into stars with nebula remaining	2
565	13	0	17	53	15	A very small and very faint elliptical nebula, north preceding *m* Centauri (Bode); the nebula is in a line between two small stars, and is rather nearer the northern star of the two	1
566	13	4	0	53	10	A very extensive cluster of stars of the 8th and 9th magnitudes, with several stars of the 7th magnitude in it; not rich in very small stars	1
567	17	7	40	53	27	A very faint small ill-defined nebula, with a small star in it, with two small stars south of it, but not involved	1
568	17	28	30	53	6	A very faint cluster of very small stars, resembling faint nebula; the stars are considerably congregated to the centre, irregular round figure	3
569	17	54	14	53	45	A pretty large faint nebula, round figure, 5′ or 6′ diameter, resolvable into very minute stars, with nebula remaining	2
570	18	24	20	53	9	A very faint nebula, with an extremely faint ray or tail, about 4′ long, proceeding from it south rather following; there are two very small stars slightly involved in the head, and also two very minute stars involved near the central line of the ray or tail.—Figure 23.	1
571	18	38	40	53	16	A pretty large faint nebula, ill defined, with a number of stars of small magnitude scattered in it	1
572	18	45	53	53	23	A very small round nebula, with a very minute star in the north side	1
573	18	49	15	53	10	A beautiful bright round nebula, about 3½′ diameter, moderately and	

No.	Æ	S.P.D.	Description of the Nebulæ and Stars.	No. of Obs.
			gradually condensed to the centre. This is resolvable. The moderate condensation, and the blueish colour of the stars which compose it, give it a very soft and pleasant appearance. This is rather difficult to resolve, although the condensation is not very great....	6
	h m s	° ′		
574	3 31 20	54 23	A rather faint, pretty well-defined elliptical nebula, about 1′ long, and 50″ broad, a little brighter to the centre	1
575	5 19 20	54 24	A very small extremely faint nebula, with a bright point or nucleus in the centre	1
576	5 24 19	54 40	A faint small nebula, n. preceding ε Columbæ	1
577	6 35 9	54 29	A very small elliptical nebula, about 15″ or 20″ diameter	1
578	6 42 22	54 11	A pretty bright round nebula, 3′ or 4′ diameter, moderately condensed to the centre. This is resolvable into stars....................	6
579	16 55 23	54 3	An extremely feeble small nebula, ill defined	1
580	17 39 30	54 49	A very faint small nebula, rather extended....................	1
581	17 43 35	54 32	A small round nebula, 10″ diameter, bright at the centre	1
582	18 11 40	54 2	A very minute group of small stars, about 1′ diameter, with a bright star in the centre, and extremely minute stars mixt, resembling faint nebulæ	1
583	18 17 23	54 43	A very small exceedingly faint nebula, with a bright point a little on one side of the centre. The nebula is a very few seconds in diameter	1
584	18 20 0	54 30	A very small nebula, 8″ or 10″ diameter, pretty well defined, bright at the centre	1
585	18 26 52	54 53	A round well-defined nebula, about 45″ diameter, moderately condensed very gradually to the centre	4
586	19 2 47	54 58	A very small nebula, with a bright point near the centre, rather on the south side. I cannot say whether this be a star or not	1
587	19 20 25	54 25	An extremely faint nebula, about 25″ long and 8″ or 10″ broad, elongated in the parallel of the equator	1
588	19 58 30	54 7	A very curious nebula, very faint and well defined, with an exceedingly bright point in the centre, resembling a small star surrounded by an atmosphere about 30″ diameter; the bright point is exactly in the centre, a bright star 12′ or 15′ south	1
589	20 3 7	54 29	A faint ray of nebula, about 30″ or 40″ long, with two very small stars in it; the stars are not in the centre, but nearer the south side....	1
590	0 23 7	55 41	A faint round nebula, about 2′ diameter	1
591	3 25 4	55 36	A very faint small ill-defined nebula	1
592	5 34 32	55 24	A small round pretty well-defined nebula; another similar small nebula north	1
593	5 34 39	55 27	A small round rather well-defined nebula	1
594	5 40 40	55 38	A small faint nebula, with a ray shooting out on the north side......	1
595	17 32 12	55 11	A round faint nebula, about 1′ diameter	1

No.	Æ h m s	S.P.D. ° ′	Description of the Nebulæ and Stars.	No. of Obs.
596	17 33 34	55 5	A faint ray of nebula, about 5′ long and 30″ broad, with three stars in it.—Figure 24	2
597	17 40 0	55 8	A pretty large faint nebula, easily resolvable. This precedes a cluster of stars	1
598	18 30 14	55 46	A very small nebula, with a minute star in the preceding side, a bright star preceding	1
599	0 21 6	56 8	A very faint nebula, about 25″ diameter, rather elliptical. North of η Cælæ sculptoris. There are four small stars south of the nebula in the form of a lozenge	2
600	4 5 56	56 38	An extremely faint ill-defined nebula, rather elongated in the direction of the meridian, gradually a little brighter towards the centre	1
601	5 17 11	56 17	A small round faint nebula, about 12″ diameter, with a bright point in the centre	1
602	14 0 4	56 15	An exceedingly small faint nebula, a very few seconds in diameter, n. preceding 248 Centauri	1
603	15 44 23	56 56	A very small round nebula, north preceding ξ Lupi, which is a very fine double star	1
604	16 42 56	56 33	A very small oval nebula, the north end is rather the brightest and broadest	1
605	17 35 —	56 0	The milky way for several degrees in this place is very beautiful; as seen through the telescope, the small patches of the nebulosity and the alternate dark spaces of the sky very much resemble small cirrocumuli clouds	1
606	18 2 37	56 32	A faint nebula, about 1¼′ long and 30″ or 40″ broad, with a considerable brightness near each end, and faint in the middle, resembling two small nebulæ joined	1
607	18 27 3	56 55	A rather bright well-defined round nebula, about 12″ or 14″ diameter, following a star of the 6th magnitude	2
608	23 50 0	56 29	A faint round nebula, about 2′ diameter, with very slight condensation towards the centre; a double star is north preceding	2
609	8 36 20	57 55	A small round faint nebula. N. of L. Pyxidis	1
610	11 12 —	57 0	A faint nebula, of an irregular figure, extended about 6′ in length	1
611	14 51 8	57 39	A very singular body resembling a star with a burr. The light is equal to that of a star of the 7th and 8th magnitude, and the diameter is not sensibly larger, with various magnifying powers. This has the appearance of a bright nucleus, surrounded by a strong brush of light; and the nebulosity surrounding the bright point has not that softness which nebulæ in general possess. I consider this different from nebulæ in general	4
612	17 30 —	57 47	A cluster of small stars of mixt magnitudes, about 15′ diameter, irregular figure	2
613	18 22 10	57 28	A pretty bright round well-defined nebula, about 1¼′ diameter, gradually condensed to the centre; there is a small star about 1′ south of the nebula	4
614	18 33 24	57 34	A pretty bright round nebula, about 1½′ diameter, very much condensed to the centre	5

No.	Æ			S.P.D.		Description of the Nebulæ and Stars.	No. of Obs.
	h	m	s	°	′		
615	19	8	9	57	28	A very small feeble ill-defined nebula	1
616	6	25	30	58	40	An ill-defined faint nebulosity of some considerable extent, with several small stars scattered in it	1
617	11	10	35	58	12	A very faint pretty large nebula, about 2′ broad and 4′ long, very faint at the edges. The brightest and most condensed part is near the south following extremity; a small star is involved in the north preceding extremity, and there are two small stars near the south extremity, but not involved	2
618	16	9	0	58	25	A very small star of the 14th magnitude, surrounded by a considerable atmosphere or nebulous appearance, about 8″ diameter. The star is perfectly in the centre. There are two small stars of rather larger magnitude, south following	1
619	18	3	30	58	9	A pretty well-defined round nebula, about 2′ diameter, slight condensation to the centre	2
620	19	30	54	58	35	A beautiful large round bright nebula, about 6′ or 7′ diameter, gradually condensed to the centre, easily resolvable	2
621	1	29	6	59	40	A very small round nebula, about 15″ diameter, pretty well defined, bright at the centre	1
622	9	39	0	59	45	A faint elliptical nebula, 2½′ long and 1½′ broad, with a small star involved in the preceding margin	1
623	13	29	54	59	15	A very small and very bright nebula, very much resembling a small star, surrounded by a very strong burr; this is a singular body	2
624	18	46	7	59	18	A very beautiful nebula, with a very bright round well-defined disk or nuclei, about 15″ diameter, surrounded by a gradually decreasing light or chevelure, about 1¼′ diameter; this is exceedingly bright immediately at the centre	4
625	3	13	—	60	—	(This is the place nearly), a round nebula, about 2′ diameter, very bright at the centre, and very faint from the centre to the margin, almost equally faint from the bright nucleus to the margin. There are two pretty bright small stars following the nebula rather north	1
626	7	47	0	60	27	A cluster of small stars, of an irregular round figure, with faint nebula, easily resolvable. The 257 Argûs is south following	1
627	16	51	0	60	11	160 Scorpii (Bode) is a pretty bright round nebula, considerably condensed, and rather suddenly bright at the centre, pretty well defined at the margin	2
628	13	15	3	61	2	185 Centauri (Bode) is a very beautiful round nebula, with an exceedingly bright well-defined planetary disk or nucleus, about 7″ or 8″ diameter, surrounded by a luminous atmosphere or chevelure, about 6′ diameter. The nebulous matter is rather a little brighter towards the edge of the planetary disk, but very slightly so. I can see several extremely minute points or stars in the chevelure, but I do not consider them as indications of its being resolvable, although I have no doubt it is composed of stars	5
629	17	8	25	61	55	A very small faint round nebula, about 8″ or 10″ diameter, bright in the centre. There is a very small star south of the nebula, distant about 10″ from it, but is not involved or connected with the nebula	1

The Nebula Minor, to the naked eye, has very much the appearance of a small cirrus-cloud; and through the telescope, it has very much the appearance of one of the brighter portions of the milky way, although it is not so rich in stars of all the variety of small magnitudes, with which the brighter parts of the milky way in general abound, and therefore it is probably a beautiful specimen of the nebulosity of which the remote portion of that magnificent zone is composed.

Plate IV. is a very correct drawing of the nebula, which if faithfully represented by the engraver, will convey a better idea of it than I could possibly hope to do by words.

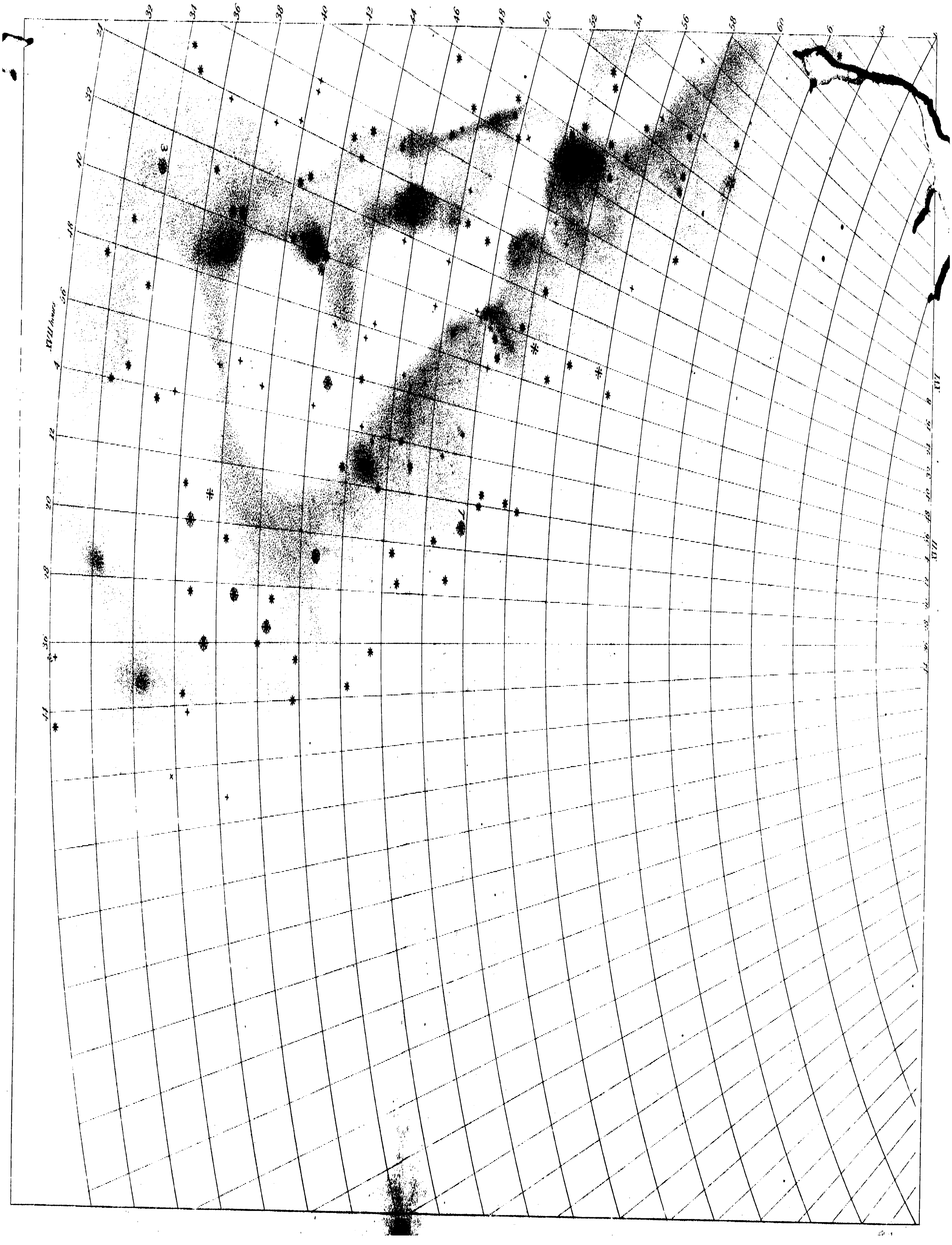
Its situation in the heavens is between 0^h 27′ and 1^h 6′ or 7′ in right ascension, and between 74° 30′ and 72° 53′ in south declination. Its position is oblique to the equator, south preceding and north following; and its form is nearly that of a parallelogram about two degrees long and fully one degree broad, and may be arranged according to its natural general appearance, into bright, faint, and very faint nebulosity. The bright nebula forms the south extremity and the preceding side, and is equal to the breadth of the nebula at the south end, and gradually diminishing in breadth and brightness till it terminates in an accumulation of the nebulous matter in the north extremity. The bright portion of the nebulous matter is not uniformly bright, but has something the appearance of small cumular clouds, although not very decidedly marked, and which I cannot well delineate. The faint nebula which is on the following side, is broad at the north extremity and gradually diminishing in breadth to where, with the other faint shade, it joins the following side of the brighter portion of the nebula, near the south extremity. The very faint shade is also on the following side, and extends from the northern to the southern extremity of the nebula, and is rather more strongly marked at what I would call its terminating border, than where it joins or blends with the faint shade; and I suspect it is faintly connected with a patch of faint nebula which follows at a little distance, and is represented in the figure.

There are two pretty bright small nebulæ situated in the following margin of the bright shade, and a considerable number of faint nebulæ and accumulations of the nebulous matter variously situated throughout, and also in the patch which follows; but they are described in the general catalogue.

The figure of the Nebula Major is so irregular, and divided into so many parcels, that without the assistance of letters of reference it will be impossible for me to attempt a description. However, the appearance and construction of the different nebulæ which compose it, are more minutely described in the general catalogue. I will here only attempt to describe the apparent connection of one portion or branch of the nebulous matter with another. I find the existence of extensively diffused faint nebulosity throughout a great portion of this quarter of the heavens, from the Robur Caroli to the Nebula Major, and I can even trace its existence in the vicinity of Nebula Minor.

The Nebula Major is situated between $4^h\ 46'$ and $6^h\ 3'$ in right ascension, and between $66^\circ\ 30'$ and $71^\circ\ 30'$ of south declination; but the body or principal portion of the nebula is situated between $5^h\ 7'$ and $5^h\ 40'$ in right ascension, and between 69° and 71° of south declination, and is composed of very strong bright nebula, very rich in small nebulæ and clustering stars of all the variety of small magnitudes: I compared this portion of the nebula with Sobieski's Shield, which in this latitude is near the zenith. The observation says, "The Nebula Major very much resembles the brightness in Sobieski's Shield; it is scarcely so large, but I think it is equally bright." Another observation says, "The ridge or brighter portion of Nebula Major is more condensed than the Shield." Plate V. is a correct representation of Nebula Major.

The bright ridge or body of the nebula is extended obliquely to the equator, north preceding and south following, and the following extremity breaks off rather suddenly, faint, decreasing in brightness in a south following direction to the distance of fully a degree and a half towards the star β, which is slightly involved in the narrow extremity: preceding the star marked γ, a considerable increase of the brightness of the nebulous matter takes place; another accumulation takes place at δ about $15'$ diameter. There is a small star north with a small nebula preceding, but neither of them are involved in the accumulation of the nebulous matter. δ and ϵ are connected by streams of unequal brightness, ϵ is pretty large and is rich in small stars and nebulæ: opposite δ and ϵ, towards the principal body of the nebula, the nebulous matter is very faint and of unequal brightness; ϵ is south following a beautiful group of nebulæ of various forms and magnitudes, on a ground of strong nebulosity common to all, with the 30 Doradûs (Bode) in the centre.



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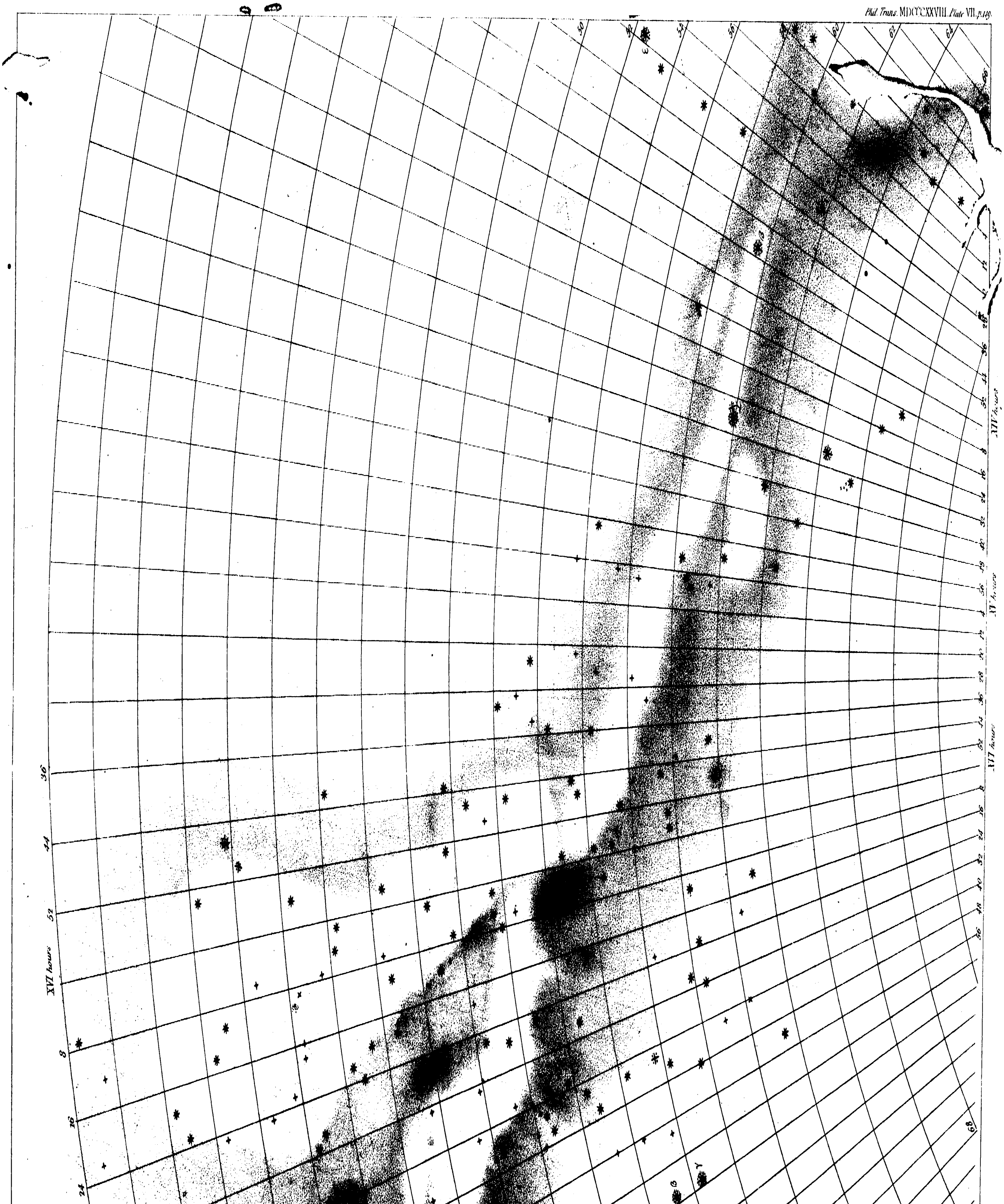
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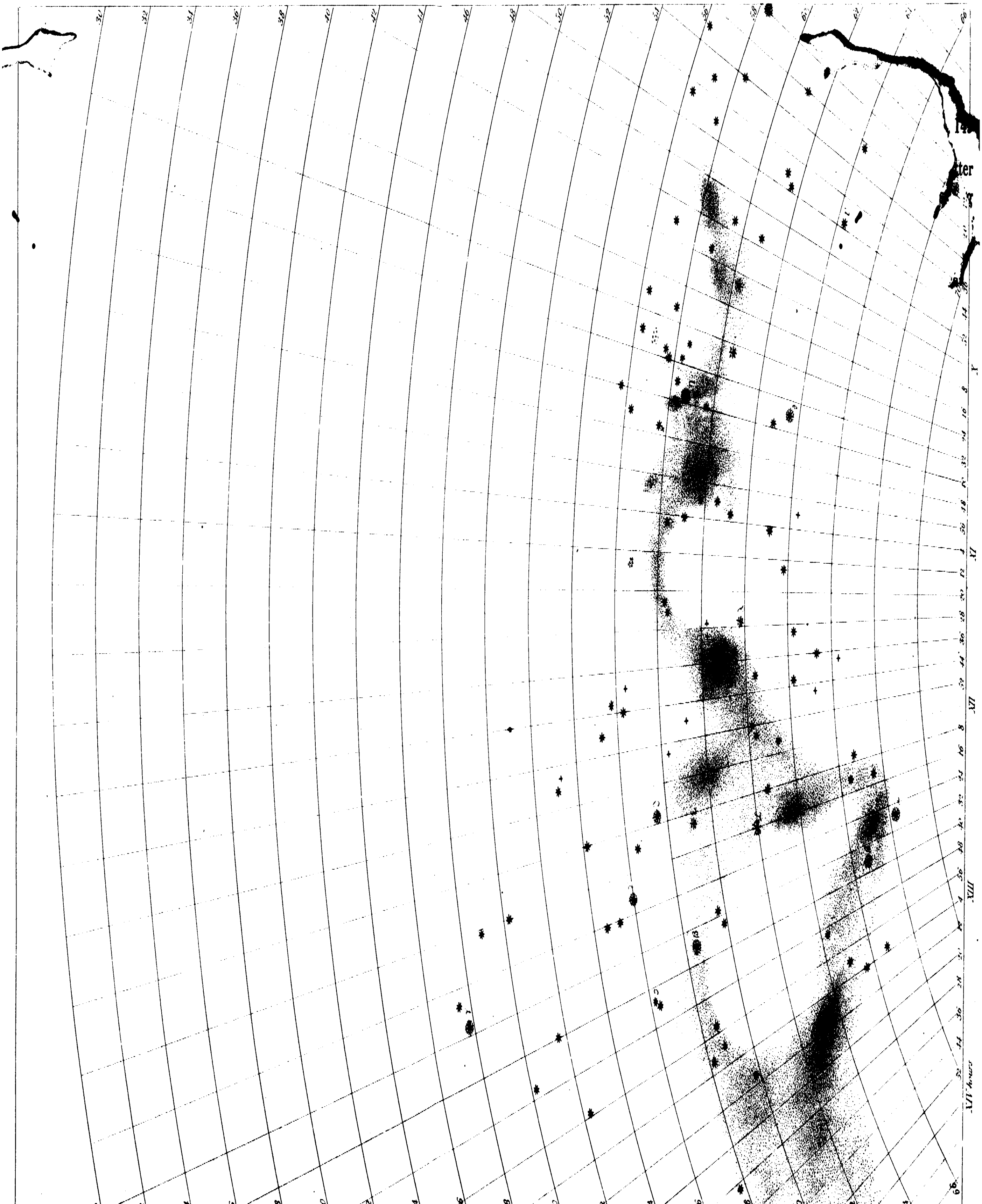
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Basire sc.

South of the 30 Doradûs a pretty bright accumulation of the nebulous matter takes place, extended, preceding and following, and is joined by pretty strong nebula to the arm κ, which proceeds in a northerly direction from the body of the nebula; the bright star near the north extremity of the arm is not involved in the bright nebula. Between the arms κ and λ the nebula is very faint, and the bright accumulations of the nebulous matter on the north side are all connected together by nebulosity of various brightness, and are connected to the main body by the arms κ and λ; and I strongly suspect the nebula at ϕ is connected by very faint nebula with the group surrounding the 30 Doradûs. The accumulation of the nebulous matter at ξ is connected with the preceding extremity of the body of the nebula, by nebula increasing in brightness towards the neck of the body, but I cannot say that the ψ is connected with the ξ. Two arms proceed from the neck towards the south, which are connected by faint nebula between them, which gradually increases in brightness towards the junction of the arms; between the arm η and the body the nebulosity is faint, of various shades of brightness, and from the arms η and ν, to the head ξ, the nebulosity is of various degrees of brightness.

I have made a very good general representation of the various appearances of the milky way, from the Robur Caroli to where it crosses the zenith in Scorpio. Plates VI. VII. and VIII. This was generally made by the naked eye, except in particular places where I suspected an opening or separation of the nebulous matter, when I applied the telescope. However, the dark space on the east side of the Cross, or the black cloud as it is called, is very accurately laid down by the telescope: the darkness in this space is occasioned by a vacancy or want of stars; it contains only two or three of the 7th magnitude, and very few of the 8th or 9th magnitude. I may here remark that the Nebula Minor is not so bright as the Nebula Major.

Neither of the two nebulæ, Major and Minor, are at present in the place assigned to them by Lacaille; and it has been suspected that nebulous appearances change their form and also their situation. Yet, although the situation of these nebulæ, as given by Lacaille and compared with their present situation, would be favourable to such a surmise, still we must consider the dimensions of the instruments with which he made his observations, and make a reasonable allowance.

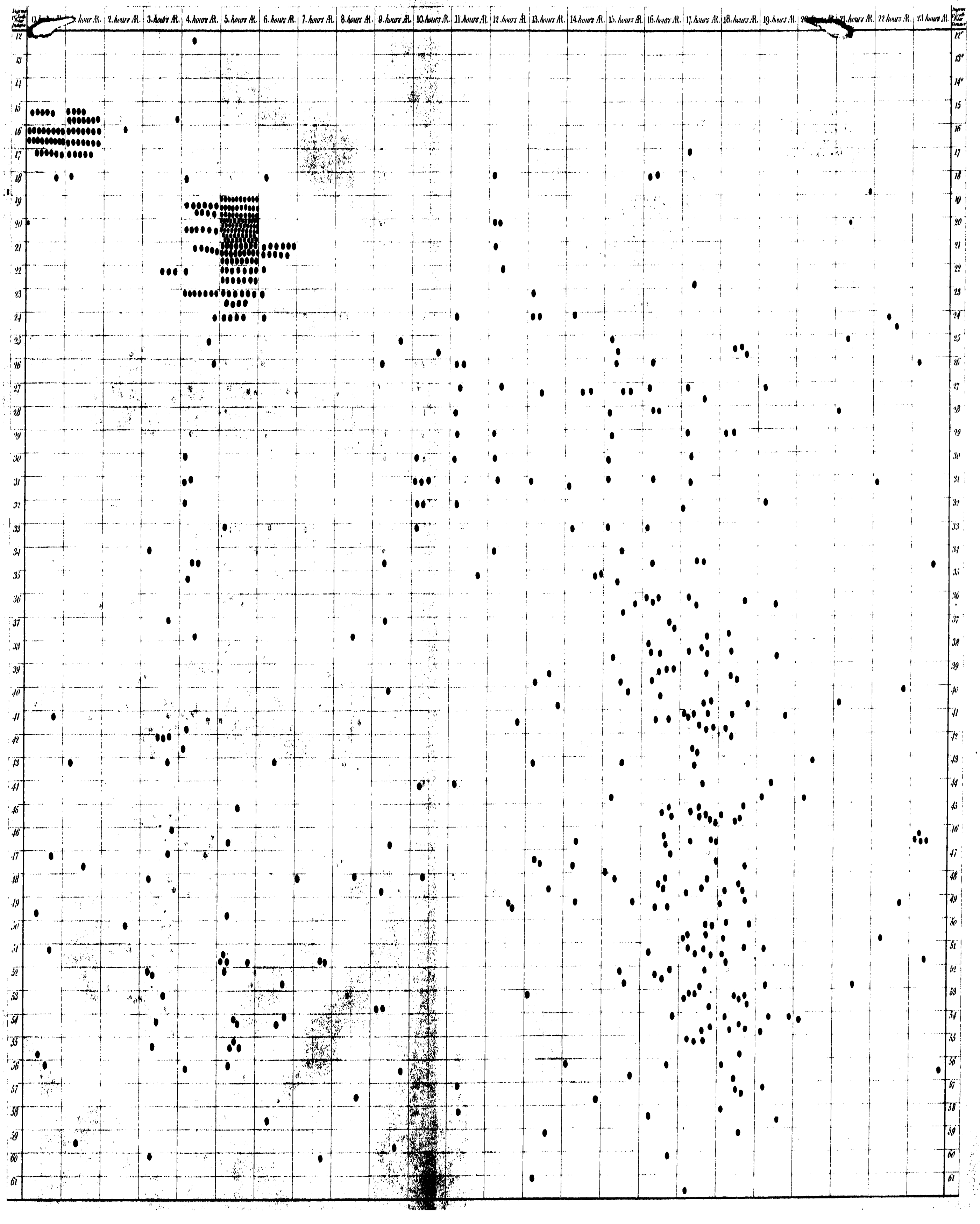
However, the 30 Doradûs is at present involved in pretty strong and pretty bright nebula, and is also situated very near the brightest part of the Nebula Major; and it would be singular if its relative situation was the same when LACAILLE observed it as it at present is; that he should have assigned to it a place in the Dorado and not in the Nebula Major, to which, from its nature, it was not only nearly allied, but in which it was actually involved. This circumstance, it must be confessed, is favourable to the conjecture; and the 47 Toucani is similarly situated, with respect to distance, from the Nebula Minor, although it is not involved in nebulosity or connected with the nebula.

When reflecting on these circumstances, I was led to examine the present state of these nebulæ, and find that scarcely any nebulæ exist in a high state of condensation, and very few in a state of moderate condensation towards the centre. A considerable number appear a little brighter towards the centre, and several have minute bright points immediately at the centre. Others have small or very minute stars variously situated in them, but many of those bright points in, or near, the centre may be stars, for the Nebula Major in particular is very rich in small stars. But the greater number of the nebulæ appear only like condensations of the general nebulous matter, into faint nebulæ of various forms and magnitudes, generally not well defined; and many of the larger nebulous appearances are resolvable into stars of mixed small magnitudes; and a great portion of the large cloud is resolvable into innumerable stars of all the variety of small magnitudes with strong nebula remaining, very similar to the brighter parts of the milky way. And whether the remaining nebulous appearance may not be occasioned by millions of stars disguised by their distance, is what I cannot say.

But a critical examination of these nebulæ would not only be a valuable treasure for the present generation to possess, but an invaluable inheritance for them to transmit to posterity. For it must be by the comparison of observations, made at distant periods of time, that we can draw any satisfactory conclusions concerning the breaking up or the greater condensation of the nebulous matter. It seems beyond a doubt that stars must assume a nebulous appearance when situated at immense distances; but whether all nebulous appearances are occasioned by stars, is a problem apparently beyond the reach of man to resolve, without the assistance of analogy, which ought not to be

Distribution of Nebulae in [redacted] Hemisphere, from the Pole to the Zenith of [redacted] in hours of R. and Degrees of Polar Distance.

Phil. Trans. MDCCCXXVIII. Plate IX. p.84.



trusted too freely, especially with objects almost equally beyond the reach of our hands and telescopes. Several of the very faint and delicate nebulæ can be resolved into stars, and also many of the brighter nebulæ are composed of stars: but there are a greater number which have not yet been resolved or shown to consist of stars; and it is not improbable, that "shining matter may exist in a state different from that of the starry."

JAMES DUNLOP.

P.S. Plate IX. has been added, at the suggestion of Mr. HERSCHEL, to illustrate the distribution of the Southern Nebulæ. The nebulæ are laid down without any regard to their form, magnitude, brightness, or nature; and but little to their strict places, only so far as to cause every rectangular space on the map, which occupies one degree in Polar distance and one hour in Right ascension, to contain the same number of nebulæ as actually occur in the heavens, according to the observations detailed in this paper; the object of the plate being solely to give an idea of their arrangement generally in the heavens.

IX. *An account of trigonometrical operations in the years* 1821, 1822 *and* 1823, *for determining the difference of longitude between the Royal Observatories of Paris and Greenwich. By Captain* HENRY KATER, *V.P.R.S.*

Read January 31, and February 7, 1828.

SECTION 1.

IN the year 1790, a series of trigonometrical operations was carried on by General ROY, in co-operation with Messrs. DE CASSINI, MECHAIN, and LEGENDRE, for the purpose of connecting the meridians of Paris and Greenwich. In England, the work commenced with a base measured on Hounslow Heath, whence triangles were carried through Hanger Hill Tower and Severndroog Castle on Shooter's Hill, to Fairlight Down, Folkstone Turnpike, and Dover Castle on the English coast; which last stations were connected with the church of Nôtre Dame at Calais, and with Blancnez and Montlambert upon the coast of France. An account of these operations will be found in the Philosophical Transactions for 1790.

In the year 1821, the Royal Academy of Sciences and the Board of Longitude at Paris communicated to the Royal Society of London their desire, that the operations for connecting the meridians of Paris and Greenwich should be repeated jointly by both countries, and that commissioners should be nominated by the Royal Academy of Sciences and by the Royal Society of London for that purpose. This proposal having been readily acceded to, Messrs. ARAGO and MATTHIEU were chosen on the part of the Royal Academy of Sciences, and Lieut.-Colonel (then Captain) COLBY and myself were appointed by the Royal Society to co-operate with them.

The instrument employed on this occasion was RAMSDEN's great theodolite, the property of the Royal Society, the same which had been used by General ROY. A party of the Royal Artillery and a sufficient number of tents were supplied by his Grace the DUKE OF WELLINGTON, then Master General of the

Ordnance, and every means were afforded which could tend to facilitate the work.

It was at first proposed to adopt some one of the distances given by the Trigonometrical Survey of Great Britain, as a base, and to connect this with General Roy's stations upon Fairlight Down and near Folkstone Turnpike. But the attempt to discover General Roy's stations upon Fairlight and at Folkstone proved, in the first instance, fruitless; and unfortunately, the gun which had marked the important station of the trigonometrical survey on Beachey Head, was not to be found. It is to be feared that, in consequence of some misapprehension, it had been removed along with some old guns which were formerly near that place, and thus one of the most valuable points of the survey of Great Britain was irrecoverably lost.

Colonel Colby was so good as to allow Mr. Gardner (then one of the assistants on the trigonometrical survey, and now agent for the sale of the Ordnance maps,) to accompany us; and to the talents, zeal, and exertion of that gentleman, on various occasions of difficulty, we were much indebted.

The signals used for connecting the stations upon the coasts of England and France were lamps with compound lenses, constructed under the direction of M. Fresnel, and of which he has published an account. It will be sufficient here to mention, that the lens, composed of numerous pieces, was three feet in diameter, and that the light far exceeded that of any of our light-houses, appearing at the distance of forty-eight miles like a star of the first magnitude. Staffs were also erected near the lamps, but these were only occasionally visible.

Having selected convenient stations upon Fairlight Down and near Folkstone Turnpike, and placed the lamps there with steady men to attend them, the party crossed the Channel on the 24th of September 1821, and proceeded to Cape Blancnez, a station to the south-west of Calais. Here we found an old guard-house, the roof of which was partially destroyed, but of which we nevertheless took possession, as it promised a less comfortless abode than our tents at that season would have afforded. At Blancnez we experienced very tempestuous weather; and on the night of the 4th of October it blew so violently that the men's tents were carried away, and we were obliged to take down the theodolite to preserve it from injury.

The observations at Blancnez having been concluded on the 7th of October, we proceeded to Montlambert (or as it is commonly called Boulambert), a small fort situated on a height near Boulogne; and by the 9th of October the instrument was ready for observing. In the course of our work at this station some delay was experienced in consequence of the lamp at Fairlight not being lighted, and M. MATTHIEU and Mr. GARDNER were dispatched to know the cause of this omission. On their arrival at Calais, finding no packet ready to depart, their anxiety led them to cross in an open boat, at night, in weather so tempestuous that they were nearly lost. They found that the glass chimneys of the lamp at Fairlight were all broken; but their ingenuity remedied this by joining the remaining pieces together; and on the evening of the 13th the light was seen, and satisfactory angles obtained between it and the other stations.

On the 14th of October, the observations at Montlambert being completed, we left that station for Calais. On the 17th we re-crossed the Channel, and on the 19th proceeded to Fairlight. Here I endeavoured to find General ROY's station, and discovered the cause of the failure of the former attempt. In the account of General ROY's operations, his station is stated to be 347 feet southward from the Mill; and the angle at his station between the Mill and Fairlight Church is given. Now it happens that the mill which stood in General ROY's time has been destroyed, and another built upon the Down in a different situation. A circular trace however of the old mill was at length discovered; and the distance from its centre to the station having been carefully measured nearly in the proper direction, a small theodolite placed at the end of this radius was shifted until the centre of ROY's Mill and Fairlight Church subtended the given angle. On digging under the theodolite, the wooden pipe by which General ROY had marked his station was found at the depth of four feet. In order to preserve this point, a millstone having the words "ROY's STATION" cut upon it, was placed level with the surface of the ground, its centre being precisely over the centre of the pipe.

The observations at Fairlight were completed by the 22nd of October, and the party proceeded on the 24th to a station chosen near Folkstone Turnpike.

In order to carry on the series towards London, stations had been selected on Stede Hill and Wrotham Hill; but as these were not visible from Folkstone, it became necessary to employ an intermediate point on Tolsford Hill.

A staff had been erected on General ROY's station upon Dover Castle, in order to connect this with the Church of Nôtre Dame at Calais. But as it would have been peculiarly inconvenient, and would have been attended with some risk to have got the great theodolite upon the Castle, the angle there was not taken; but the distance between Dover station and Nôtre Dame has been determined by means of two sides and the included angle, in a manner which will probably appear to be sufficiently satisfactory, as no other station is dependent upon this distance.

The observations at Folkstone were completed on the 27th of October; and with great regret we now bade adieu to our much-esteemed companion M. Arago, who left us for Paris; and as the season was too far advanced to admit of any further proceedings, the party returned to London.

It was now our intention to connect our triangles with the base measured by General Roy upon Hounslow Heath; but though upon examination it was found that the guns marking the termination of this base still existed, it was not thought advisable to attempt to avail ourselves of it, from the many buildings which intervened, and which prevented one end of the base being seen from the other. We were therefore under the necessity of employing the distance from Severndroog Castle to Hanger Hill Tower, as these were the nearest stations to General Roy's base that could be identified with sufficient precision.

During the operations of 1821, I was strongly impressed with the inconvenience of changing the zero point of the theodolite, in order to obtain the angle upon different arcs, so as to do away errors of division; and on my return to London I caused four additional microscopes to be adapted to the instrument, by Mr. Carey. On this important alteration I shall have further to remark in the Appendix.

The summer of 1822 was employed in the choice of stations, one of which was the temporary meridian mark erected near Chingford for the Royal Observatory. This station was chosen, in order that a side of one of our triangles might coincide with the meridian of Greenwich, and that the azimuths of the different stations, with respect to that meridian, might thence be deduced with greater accuracy than might have resulted from observations of the pole star.

Stations were also selected upon Leith Hill, Wrotham Hill, Stede Hill, and Crowborough. We anxiously sought a station to the south of Chingford, for the purpose of joining it with Severndroog Castle, in order to connect these points with the Royal Observatory; but our endeavours were without success, and we were obliged to content ourselves with accomplishing this object by intersecting the north-west pinnacle of Westminster Abbey, and also the Cross of St. Paul's.* The different methods, however, by which the distance from Chingford to Severndroog has been obtained, and the small difference in the results, leave little reason to fear any error of importance.

On the 12th of August 1822, the party proceeded to Hanger Hill Tower. This station is very unfavourable for observations, in consequence of the unsteadiness of the building. Here we felt the great advantage of the additional microscopes with which the theodolite had been furnished, as by their aid we were enabled to accomplish that in a week which it would otherwise have required a much longer period to have completed satisfactorily.

On the 17th of October, our observations being concluded at Hanger Hill, the party left that station for Fairlight Down. Lamps were employed at the stations on Wrotham Hill and Tolsford, and the observations at Fairlight were completed by the 28th.

From Fairlight we proceeded to Folkstone Turnpike. Here, as most of the required angles had been obtained the preceding autumn, little remained to be done, and we were enabled to quit this station on the 5th of September.

Before the party left Folkstone, an attempt was made to discover General Roy's station; and at length the pipe which marked it was found in a state of complete decay, at the distance of three feet to the North-west. The angle between Roy's station and Fairlight being 80° 13′.

The party now proceeded to Tolsford Hill, a commanding eminence, from which the stations on the French coast are visible. Here we saw Fiennes, and succeeded in obtaining the angle between it and Montlambert.

From Tolsford we proceeded on the 9th of September to Stede Hill, a station in the grounds of William Baldwin, Esq. To this gentleman we were indebted for the most kind and friendly attentions, and it would be difficult to do justice to the warm hospitality which we experienced from him. Not only was every thing that could facilitate our objects instantly supplied; but the personal comfort of the whole party, including that of the private soldiers, provided for with the kindest solicitude.

Our observations at Stede Hill being completed on the 14th of September, we left that station on the 16th for Crowborough, and on the 25th proceeded to Leith Hill, a remarkably fine commanding station.

We left Leith Hill on the 5th of October for Wrotham Hill, where, having completed our observations, the party proceeded to Severndroog Castle upon Shooter's Hill. We had here to erect a shed upon the summit of the tower to cover the instrument: this was speedily accomplished by the kind assistance afforded by Lieut. Colonel JONES of the Royal Engineers, who supplied us with carpenters and all that was necessary from Woolwich.

On the 24th of October the theodolite was safely hoisted by proper tackle to the summit of the tower, and the flagstaff having been removed, the instrument was placed with its centre precisely over the spot which the flagstaff had occupied. A platform of boards was attached to the brickwork, so as to be clear of the leads upon which the instrument rested: so unsteady, however, was this building, that we thought it advisable ultimately to reject the angles which had been taken by reading off the five microscopes, in consequence of the disturbance which was found to be occasioned by any person moving upon the platform. We therefore resolved to content ourselves with reading the two opposite microscopes, which might be done without any change of position in the observers. The angles, however, which were deduced from the observations with the five microscopes are given in the Appendix, but are separated by a line from the results furnished by the two microscopes, from which they differ but little, and which have been employed in preference.

At this station we experienced considerable difficulty in obtaining the requisite angles with Hanger Hill, as the signal erected upon that tower was seen only once, in consequence of the intervening smoke of London. At length Colonel COLBY thought of a method by which this difficulty was overcome. Tin plates were nailed to the staff upon Hanger Hill Tower, the plates being disposed above each other in certain angles, so as to reflect the sun's rays to Severndroog. This contrivance, which answers the purpose in a certain degree of the heliostat of Professor GAUSS, was perfectly successful; each plate gave in succession a neat image of the sun resembling a fixed star, which was seen through a smoke so thick that even the hill was invisible.

From Severndroog the party proceeded to the station at Chingford, and by the 10th of November the instrument was ready for observation. The season, however, was so far advanced that it was found impossible to obtain the requisite angles with the Royal Observatory or with Westminster Abbey. The health of the men too began to suffer from their being encamped upon a wet clayey soil; we therefore thought it prudent to strike our tents on the 18th, and return to London.

Colonel Colby intending to use Chingford as one of the stations of the Trigonometrical Survey of Great Britain, the theodolite belonging to the Ordnance was placed at Chingford in July 1823, and with it the angles were obtained which we were not able to observe the preceding autumn. This instrument is in every respect similar to that belonging to the Royal Society, excepting that Colonel Colby had recently caused three equidistant microscopes to be adapted to it, which may be used instead of the two microscopes formerly employed.

The transit-room not being visible from Severndroog Castle, the staff erected upon the Royal Observatory was placed upon the centre of the octagonal room of that building; and the angle at Chingford between the staff and the centre of the transit instrument, as well as their distance from each other, is calculated from data furnished by the Astronomer Royal.

As the preservation of the stations was felt to be an object of considerable importance, a stone was procured for each about one foot square and four or five feet long. This was sunk endways until it was level with the ground, and had the word "Station" and the date of the year cut upon it. We did not however rely wholly upon the stone, though its great weight would render its removal a task of some difficulty; each station, wherever practicable, is also fixed by angles formed by steeples or other permanent objects in the vicinity, and by means of which, should the stone be removed, the station may be readily recovered within a very few inches.

Section 2.—*Of the method of computation employed.*

A triangle upon the surface of the earth, the sides of which are small in proportion to the radius, may be considered as a spherical triangle, and the sides may be computed by means of spherical trigonometry. Or, the angles formed by the chords may be calculated, and the spherical triangle be thus reduced to a plane triangle, of which one of the sides and the angles being known, the other sides or chords may be readily determined. This is the method which has hitherto been employed in the English and Indian geodesical operations.

A third method, which is due to Legendre, is as follows: If from each of the observed angles of a small spherical triangle, one third of the spherical excess be deducted, the sines of the angles thus diminished will be proportional to the lengths of the opposite sides, so that the triangle may be resolved as if perfectly rectilineal. This method, which is beautifully simple and accurate, is usually employed on the continent, and is that of which I shall avail myself on the present occasion.

The excess of the sum of the three angles of a spherical triangle above two right angles, termed the spherical excess, is useful to indicate the degree of reliance which may be placed upon the observed angles. I have therefore given it in a separate column, from which the sum of the errors of the observed angles of any one of the triangles may readily be inferred. It is also necessary, when only two angles of a triangle have been observed, that the spherical excess should be known, in order that one third of it may be deducted from each of these angles to prepare them for calculation. The spherical excess of a triangle may be found in seconds, by adding together the logarithm of any two sides, the logarithmic sine of the contained angle, and the constant logarithm 0.3733260.

Section 3.—*Triangles and distances.*

The distance given by General Roy from his station upon Severndroog Castle to that upon Hanger Hill Tower, is 84376.68 feet; but the distance from the station of 1822 upon Severndroog Castle to General Roy's station was $10\frac{7}{8}$ inches; and the angle between General Roy's station and Hanger Hill being about 47° 23′, we have 0.62 of a foot to be added in order to obtain 84377.3 feet, the distance from the station of 1822 to Hanger Hill.

By the comparison of various British standards of linear measure, published in the Phil. Trans. for 1821, it appears that the standard employed by General Roy for the measurement of the base upon Hounslow Heath differed from the Imperial standard yard; and in consequence it becomes necessary to multiply

General Roy's distance by .0000691 to obtain 5.82, the correction to be added to such distance, in order to convert the feet of his survey into Imperial feet *. Applying this correction, we have 84383.12 for the distance in Imperial feet from Severndroog Castle to Hanger Hill Tower.

Hanger Hill from Severndroog Castle, 84383.12 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Leith Hill Station	35° 23′ 13.87″	......	35° 23′ 13.32″	
Hanger Hill	83 26 23.60	......	83 26 23.05	127658.21
Severndroog Castle	61 10 24.18	......	61 10 23.63	144760.96
	180 0 1.65	2.53		

Severndroog Castle from Leith Hill Station, 144760.96 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Wrotham Station	65° 26′ 47.68″	......	65° 26′ 46.85″	
Severndroog Castle	86 25 58.40	......	86 25 57.57	75014.27
Leith Hill Station	28 7 16.42	......	28 7 15.58	158844.37
	180 0 2.50	2.56		

Wrotham Station from Severndroog Castle, 75014.27 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Chingford Station	16° 35′ 1.77″	......	16° 35′ 2.00″	
Severndroog Castle	149 26 13.36	......	149 26 13.58	63488.87
Wrotham Station	13 58 44.20	......	13 58 44.42	133640.58
	179 59 59.33	0.97		

Hanger Hill from Leith Hill Station, 127658.21 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Westminster Abbey	° ′ ″ ———	......	77° 17′ 27.37″	
Hanger Hill	84 59 56.81	......	84 59 56.41	39809.02
Leith Hill Station	17 42 36.62	......	17 42 36.22	130366.27
		1.20		

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* The sides of the triangles of the Trigonometrical Survey of Great Britain are, I believe, derived from bases measured by General Roy's standard, and they will therefore require the same correction as that employed above, should it be necessary to convert them into Imperial feet.

Westminster Abbey from Leith Hill Station, 130366.27 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Severndroog Castle	62° 33′ 57″.67	......	62° 33′ 57″.22	
Westminster Abbey	———	......	99 45 26.38	44601.10
Leith Hill Station	17 40 36.85	......	17 40 36.40	144759.97
		1.35		

Westminster Abbey from Severndroog Castle, 44601.10 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Chingford Station	42° 52′ 10″.16	......	42° 52′ 9″.96	
Severndroog Castle........	61 33 50.95	......	61 33 50.75	63488.87
Westminster Abbey	———	......	75 33 59.29	57648.50
		0.59		

Leith Hill Station from Severndroog Castle, 144760.96 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Westminster Abbey	° ′ ″ ———	......	99° 45′ 26″.38	
Leith Hill Station	17 40 36.85	......	17 40 36.40	130367.18
Severndroog Castle........	62 33 57.67	......	62 33 57.22	44601.41
		1.35		

Westminster Abbey from Severndroog Castle, 44601.41 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Chingford Station	42° 52′ 10″.16	......	42° 52′ 9″.96	
Westminster Abbey	———	......	75 33 59.29	57648.90
Severndroog Castle	61 33 50.95	......	61 33 50.75	63489.30
		0.59		

Hanger Hill from Leith Hill Station, 127658.21 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
St. Paul's................	° ′ ″ ———	......	67° 24′ 58″.34	
Hanger Hill.............	93 13 3.10	......	93 13 2.63	45848.20
Leith Hill Station	19 21 59.50	......	19 21 59.03	138042.29
		1.41		

St. Paul's from Leith Hill Station, 138042.29 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Severndroog Castle........	72° 24′ 29″.57	......	72° 24′ 29″.14	
St. Paul's................	————	......	91 34 15.54	39967.20
Leith Hill Station..........	16 1 15.75	......	16 1 15.32	144760.30
		1.30		

Severndroog Castle from St. Paul's, 39967.20 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Chingford Station..........	39° 0′ 36″.11	......	39° 0′ 35″.95	
Severndroog Castle........	51 43 19.05	......	51 43 18.89	63489.66
St. Paul's................	————	......	89 16 5.16	49844.30
		0.47		

Leith Hill Station from Severndroog Castle, 144760.96 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
St. Paul's................	° ′ ″ ————	......	91° 34′ 15″.54	
Leith Hill Station	16 1 15.75	......	16 1 15.32	138042.86
Severndroog Castle........	72 24 29.57	......	72 24 29.14	39967.36
		1.30		

Severndroog Castle from St. Paul's, 39967.36 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Chingford Station	39° 0′ 36″.11	......	39° 0′ 35″.95	
Severndroog Castle........	51 43 19.05	......	51 43 18.89	63489.91
St. Paul's................	————	......	89 16 5.16	49844.50
		0.47		

By the preceding triangles we have the following distances from Chingford to Severndroog Castle.

63488.87
63488.87
63489.30
63489.66
63489.91

Mean 63489.32

Mean distance of Severndroog Castle from Chingford Station, 63489.32 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Royal Observatory	—	......	106 13 13.67	
Severndroog Castle	60 55 21.23	......	60 55 21.17	14713.21
Chingford Station	12 51 25.22	......	12 51 25.16	57787.63
		0.19		

To connect the centre of the transit instrument at the Royal Observatory with the preceding triangle, the Astronomer Royal favoured me with the data given in Plate X. fig. 1. It may there be seen that the distance from the centre of the octagon room to the centre of the transit is 105.89 feet, the angle at the transit between the octagon room and the meridian of Greenwich 55° 25′ 33″.6, and that the length of a perpendicular let fall from the centre of the octagon room upon the meridian of Greenwich is 87.19 feet. By means of these data and the distance from the centre of the octagon room to Chingford Station, the angle at Chingford Station between the centre of the octagon room and the centre of the transit, is found to be 5′ 11″.21.

If any proof were necessary of the accuracy of the preceding data, I might observe that in the account of General Roy's survey, a plan is given of the Royal Observatory at Greenwich, in which I find the distance from the octagon room to the centre of the transit, and the angle it forms with the meridian, to agree as nearly as possible with the measurements given to me by the Astronomer Royal.

Chingford Station from the Royal Observatory, 57787.63 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
			° ′ ″	
Centre of Transit..........	—	......	55 25 33.6	
Chingford Station	—	......	0 5 11.21	57847.66
Royal Observatory	—	......	124 29 15.19	105.89

Fig. 1.

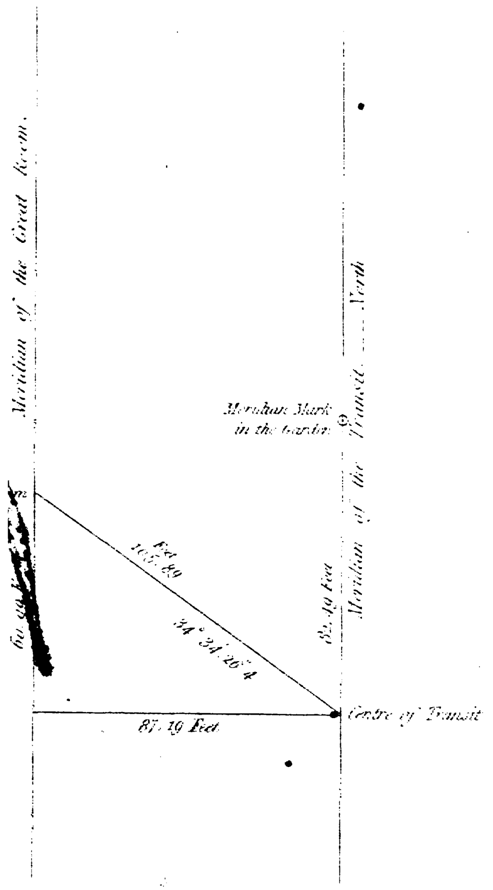


Fig. 2

Folkstone Station.

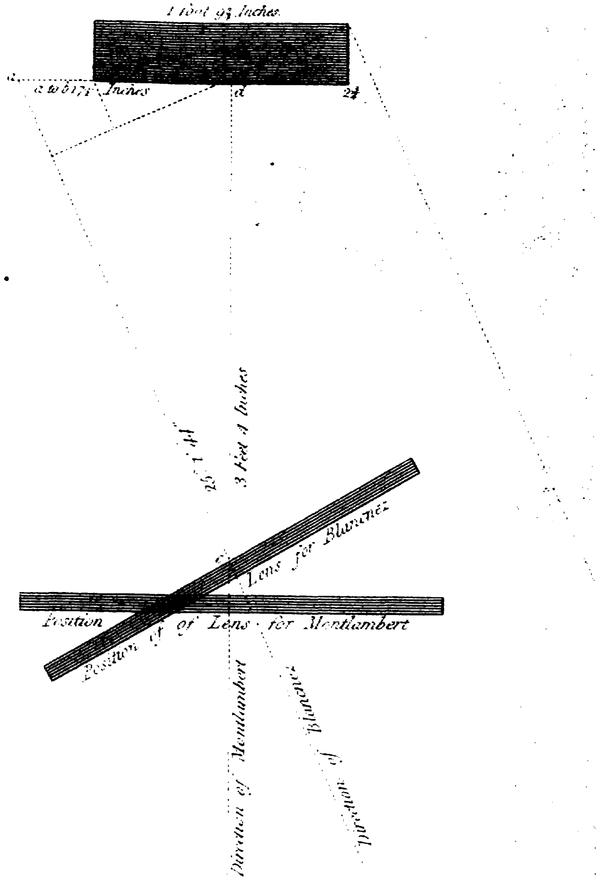
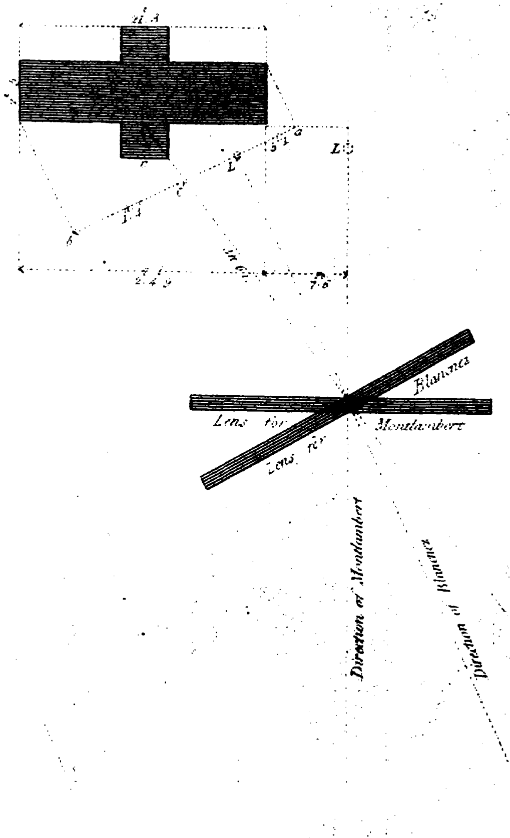


Fig. 3.

Fairlight Station.



Scale ½ of an Inch to one Foot

Angle between the Lamp and Staff at Blancnez. } 2

Angle at Blancnez between the Lamp and Staff } 0.49

Angle at Montlambert........ 1.26

The apparent centre of Signal is at { Montlambert as in c
Blancnez is on c middle of a b

The distance between the lamp and apparent centre of Signal is at { Montlambert L C = 18.2
Blancnez L C = 5.4

With the distance 63489.32 feet, of Chingford Station from Severndroog Castle, the distance 57847.66 feet, from Chingford Station to the centre of the transit, and the contained angle 12° 46′ 13″.95, we obtain the angles and distance given in the following triangle.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
			° ′ ″	
Severndroog Castle	————	......	61 3 9.56	
Centre of Transit..........	————	......	106 10 36.48	14612.73
Chingford Station	————	......	12 46 13.95	————

The distance given by General Roy from the centre of the transit to his station on Severndroog, is	14610.58 feet.
Add for difference of stations	0.62
Add to convert into Imperial feet	1.01
General Roy's distance in Imperial feet	14612.21
Distance above given	14612.73
Difference	0.52

Leith Hill Station from Wrotham Station, 158844.37 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Crowborough Station	87 5 15.01	......	87 5 14.32	
Leith Hill Station	38 56 55.95	......	38 56 55.25	128615.26
Wrotham Station...........	53 57 51.13	......	53 57 50.43	99982.55
	180 0 2.09	3.03		

Wrotham Station from Crowborough Station, 99982.55 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Stede Hill Station	44 44 52.83	......	44 44 51.73	
Crowborough Station	41 58 20.94	......	41 58 19.84	141790.75
Wrotham Station..........	93 16 49.54	......	93 16 48.43	94980.95
	180 0 3.31	2.24		

Stede Hill Station from Crowborough Station, 141790.75 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Fairlight Station..........	65° 2′ 35.83″	......	65° 2′ 34.54″	
Stede Hill Station	53 13 24.33	......	53 13 23.05	137745.52
Crowborough Station......	61 44 3.69	......	61 44 2.41	125267.46
	180 0 3.85	3.70		

Stede Hill Station from Fairlight Station, 137745.52 feet.

Tolsford Station..........	69° 7′ 58.69″	......	69° 7′ 57.10″	
Fairlight Station..........	45 27 54.39	......	45 27 52.81	134038.00
Stede Hill Station	65 24 11.67	......	65 24 10.09	105080.02
	180 0 4.75	3.11		

Wrotham Station from Crowborough Station, 99982.55 feet.

Fairlight Station..........	33° 6′ 31.28″	......	33° 6′ 29.69″	
Wrotham Station	43 11 8.83	......	43 11 7.27	177831.03
Crowborough Station......	103 42 24.66	......	103 42 23.04	125267.87
	180 0 4.77	2.87		

Crowborough Station from Fairlight Station, 125267.87 feet.

Stede Hill Station	53° 13′ 24.33″	......	53° 13′ 23.05″	
Crowborough Station......	61 44 3.69	......	61 44 2.41	141791.20
Fairlight Station..........	65 2 35.83	......	65 2 34.54	137745.95
	180 0 3.85	3.70		

Stede Hill Station from Fairlight Station, 137745.95 feet.

Tolsford Station..........	69° 7′ 58.69″	......	69° 7′ 57.10″	
Stede Hill Station	65 24 11.67	......	65 24 10.09	105080.36
Fairlight Station..........	45 27 54.39	......	45 27 52.81	134038.43
	180 0 4.75	3.11		

Wrotham Station from Stede Hill Station, 94980.95 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Fairlight Station..........	31° 56′ 2.49″	......	31° 56′ 2.41″	
Wrotham Station	50 5 40.62	......	50 5 40.54	177832.66
Stede Hill Station	97 58 17.13	......	97 58 17.05	137747.27
		3.06		

Stede Hill Station from Fairlight Station, 137747.27 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Tolsford Station...........	69° 7′ 58.69″	......	69° 7′ 57.10″	
Stede Hill Station	65 24 11.67	......	65 24 10.09	105081.36
Fairlight Station...........	45 27 54.39	......	45 27 52.81	134039.68
	180 0 4.75	3.11		

The preceding triangles give three distances from Tolsford to Fairlight, derived from the three sides of the triangle; Stede Hill, Wrotham, Crowborough,—viz.

	134038.00 feet.
	134038.43
	134039.68
Mean	134038.70

Mean distance Tolsford Station from Fairlight Station, 134038.70 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Crowborough Station.......	36° 5′ 24.01″	......	36° 5′ 23.75″	
Tolsford Station...........	33 24 6.89	......	33 24 6.63	213125.73
Fairlight Station...........	110 30 29.88	......	110 30 29.62	125267.72
	180 0 0.78	3.72		

Mean distance Stede Hill Station from Tolsford Station, 105080.58 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Crowborough Station.......	25° 38′ 39.85″	......	25° 38′ 37.62″	
Stede Hill Station	118 37 36.34	......	118 37 34.12	141791.16
Tolsford Station...........	35 43 50.48	......	35 43 48.26	213127.05
		3.09		

Mean distance Tolsford Station from Fairlight Station, 134038.70 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Folkstone Station	36° 17′ 57.06″	......	36° 17′ 56.85″	
Tolsford Station..........	136 51 46.61	......	136 51 46.41	26957.63
Fairlight Station....	6 50 16.94	......	6 50 16.74	154811.39
	180 0 0.61	0.58		

Folkstone Station from Fairlight Station, 154811.39 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Dungeness Light-House ..	° ′ ″	......	136° 55′ 5.46″	
Folkstone Station	21 14 49.48	......	21 14 49.11	84298.42
Fairlight Station..........	21 50 5.80	......	21 50 5.43	82135.35
		1.12		

The following triangles connect our work with the stations on the French coast.

Tolsford Station from Fairlight Station, 134038.70 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Montlambert Station......	32° 53′ 2.05″	......	32° 53′ 0.13″	
Tolsford Station..........	95 48 2.05	......	95 48 0.12	192717.35
Fairlight Station..........	51 19 1.68	......	51 18 59.75	245616.17
	180 0 5.78	6.07		

Fairlight Station from Montlambert Station, 245616.17 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Blancnez Station..........	75° 56′ 24.49″	......	75° 56′ 23.57″	
Fairlight Station	17 39 26.36	......	17 39 25.44	252702.93
Montlambert Station	86 24 11.91	......	86 24 10.99	76800.92
	180 0 2.76	4.45		

Tolsford Station from Montlambert Station, 192717.35 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Blancnez Station..........	103° 42′ 5.81″	......	103° 42′ 4.96″	
Tolsford Station	22 46 47.48	......	22 46 46.64	159493.81
Montlambert Station	53 31 9.25	......	53 31 8.40	76803.37
	180 0 2.54	2.81		

Tolsford Station from Fairlight Station, 134038.70 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Blancnez Station	27° 45′ 39.99″	......	27° 45′ 38.34″	
Tolsford Station..........	118 34 48.97	......	118 34 47.32	159500.18
Fairlight Station..........	33 39 35.99	......	33 39 34.34	252708.40
	180 0 4.95	4.44		

Tolsford Station from Blancnez Station, 159500.18 feet.

Montlambert Station......	53° 31′ 9.25″	......	53° 31′ 8.40″	
Tolsford Station..........	22 46 47.48	......	22 46 46.64	192725.04
Blancnez Station	103 42 5.81	......	103 42 4.96	76806.43
	180 0 2.54	2.81		

Fairlight from Blancnez Station, 252708.40 feet.

Montlambert Station......	86° 24′ 11.91″	......	86° 24′ 10.99″	
Fairlight Station..........	17 39 26.36	......	17 39 25.44	245621.50
Blancnez Station	75 56 24.49	......	75 56 23.57	76802.60
	180 0 2.76	4.45		

Folkstone Station from Fairlight Station, 154811.39 feet.

Montlambert Station......	38° 44′ 53.42″	......	38° 44′ 51.92″	
Folkstone Station	96 46 26.32	......	96 46 24.83	173300.64
Fairlight Station..........	44 28 44.74	......	44 28 43.25	245618.40
	180 0 4.48	6.29		

Fairlight Station from Montlambert Station, 245618.40 feet.

Blancnez Station	75° 56′ 24.49″	......	75° 56′ 23.57″	
Fairlight Station..........	17 39 26.36	......	17 39 25.44	252705.23
Montlambert Station......	86 24 11.91	......	86 24 10.99	76801.62
	180 0 2.76	4.45		

Folkstone Station from Montlambert Station, 173300.64 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
Blancnez Station	107° 18′ 55″.90	......	107° 18′ 55″.54	
Folkstone Station	25 1 46.69	......	25 1 46.33	134167.37
Montlambert Station	47 39 18.49	......	47 39 18.13	76801.57
	180 0 1.08	2.32		

Folkstone Station from Fairlight Station, 154811.39 feet.

Blancnez Station	31° 22′ 31″.13	......	31° 22′ 30″.02	
Folkstone Station	121 48 13.55	......	121 48 12.43	134168.12
Fairlight Station..........	26 49 18.67	......	26 49 17.55	252705.93
	180 0 3.35	4.17		

Folkstone Station from Blancnez Station, 134168.12 feet.

Montlambert Station......	47° 39′ 18″.49	......	47° 39′ 18″.13	
Folkstone Station	25 1 46.69	......	25 1 46.33	173301.60
Blancnez Station	107 18 55.90	......	107 18 55.54	76802.00
	180 0 1.08	2.32		

Fairlight Station from Blancnez Station, 252705.93 feet.

Montlambert Station......	86° 24′ 11″.91	......	86° 24′ 10″.99	
Fairlight Station..........	17 39 26.36	......	17 39 25.44	245619.11
Blancnez Station	75 56 24.49	......	75 56 23.57	76801.82
	180 0 2.76	4.45		

To show the degree of reliance that may be placed upon the triangles connecting the coasts of England and France, I shall here give the distances resulting from different triangles, derived respectively from the distance Tolsford from Fairlight, and the distance Folkstone from Fairlight.

	By Tolsford from Fairlight. Feet.	By Folkstone from Fairlight. Feet.
Fairlight from Montlambert	245616.17	245618.40
	245621.50	245619.11
Mean	245618.88	245618.75
Fairlight from Blancnez	252702.93	252705.23
	252708.40	252705.93
Mean	252705.66	252705.58
Tolsford from Montlambert	192717.35	
	192725.04	
Mean	192721.19	
Tolsford from Blancnez	159493.81	
	159500.18	
Mean	159496.99	
Folkstone from Montlambert		173300.64
		173301.60
Mean		173301.12
Folkstone from Blancnez		134167.37
		134168.12
Mean		134167.74
Blancnez from Montlambert	76800.92	76801.62
	76803.37	76801.57
	76806.43	76802.00
	76802.60	76801.82
Mean	76803.33	76801.75

Mean distance Folkstone Station from Blancnez Station, 134167.74 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Dover Station............	————	......	117 18 16.41	
Folkstone Station	50 37 50.23	......	50 37 49.97	31560.06
Blancnez Station	12 3 53.88	......	12 3 53.62	116726.89
		0.77		

Mean distance Folkstone Station from Blancnez Station, 134167.74 feet.

	° ′ ″		° ′ ″	
Nôtre Dame, Calais	————	......	38 42 1.54	
Folkstone Station	9 21 18.50	......	9 21 18.23	159605.30
Blancnez Station..........	131 56 40.50	......	131 56 40.23	34880.94
		0.82		

With the sides "Folkstone to Nôtre Dame, Calais," "Folkstone to Dover," and the included angle 41° 16′ 30″.7, the remaining angles and the distance of Dover Station from Nôtre Dame, Calais, were computed. Also by means of the sides "Blancnez to Dover," "Blancnez to Calais," and the included angle 119° 52′ 50″.32, we obtain another distance from Dover to Nôtre Dame, Calais. These results are contained in the two following triangles:

Folkstone Station from Nôtre Dame, Calais, 159605.30 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Nôtre Dame, Calais	————	......	8 42 38.35	
Folkstone Station	41 16 30.70	......	41 16 30.44	
Dover Station............	————	......	130 0 51.21	137471.95
		0.78		

Dover Station from Blancnez Station, 116726.89 feet.

	° ′ ″		° ′ ″	
Nôtre Dame, Calais	————	......	47 24 37.27	
Blancnez Station..........	119 52 50.32	......	119 52 50.04	
Dover Station............	————	......	12 42 32.69	137472.03
		0.83		

—As two of the angles were observed in the triangle "Fiennes, Montlambert, and Blancnez," and as an opportunity occurred at Tolsford of obtaining the angle between Fiennes and Montlambert, I have added the following triangles connecting these stations :

Mean distance Montlambert from Blancnez, 76802.54 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Fiennes		......	94 10 48.60	
Montlambert	34 27 39.83	......	34 27 39.62	60148.31
Blancnez	51 21 31.99	......	51 21 31.78	43574.27
		0.62		

Mean distance Montlambert from Tolsford 192721.19 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Fiennes		......	74 30 57.26	
Montlambert	87 58 48.81	......	87 58 47.90	60148.74
Tolsford	17 30 15.75	......	17 30 14.84	199855.18
		2.72		

With the sides "Blancnez from Nôtre Dame, Calais," "Blancnez from Fiennes," and the contained angle, we obtain the distance from Fiennes to Nôtre Dame, Calais.

Fiennes from Blancnez, 43574.27 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Nôtre Dame, Calais		......	64 24 14.39	
Fiennes		......	46 12 52.27	45221.01
Blancnez	69 22 53.45	......	69 22 53.34	
		0.34		

As we thought it desirable to compare General Roy's operations with our own, staffs were erected upon his stations on Tenterden, Frant, Goudhurst and

Lydd steeples; but of these we were able to connect only Frant and Tenterden with our work. The results are as follow:

Tolsford from Fairlight, 134038.70 feet.

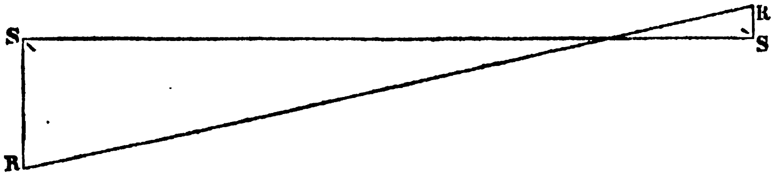
	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Tenterden Church........		......	110 42 17.46	
Tolsford................	29 58 10.86	......	29 58 10.38	90809.26
Fairlight...............	39 19 32.64	......	39 19 32.16	71580.75
		1.44		

Fairlight from Crowborough, 125267.72 feet.

	Observed Angles.	Sp. Excess.	Angles for Calculation.	Distances. Feet.
	° ′ ″		° ′ ″	
Frant Church............		......	104 44 17.92	
Fairlight...............	13 44 20.24	......	13 44 19.97	113857.34
Crowborough.............	61 31 22.38	......	61 31 22.11	30762.92
		0.80		

In a former part of this paper I have mentioned that General Roy's station at Folkstone was discovered at the distance of three feet to the North-west of the new station; the angle between his station at Folkstone and our station at Fairlight being 80° 13′.

At Fairlight, General Roy's station was 87.69 feet to the South-east; the angle between his station and Folkstone being 89° 14′ 31″. The relative positions of the several stations will be better understood from the following diagram,

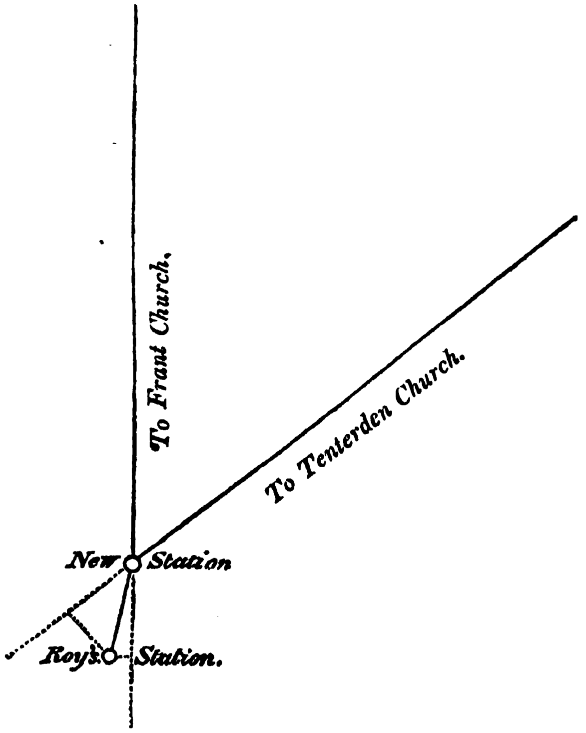


in which R and R designate General Roy's stations, and S and S those of the present operations. From these data the computed distance between General Roy's stations at Fairlight and Folkstone is 154807.00 feet.

We have now several distances which we may compare with those given by General Roy.

The distance from Frant Church to Fairlight is stated by General Roy to be 113928.20 feet. Now if we suppose the distance from Frant to Fairlight to be prolonged, we have the angle between this prolongation and General Roy's station 12° 50′ 56″; and multiplying 87.69 feet, the distance from the new station to that of General Roy, by the cosine of this angle, we obtain 85.48 feet to be subtracted from General Roy's distance, to reduce it to the new station. The distance thus obtained is 113842.72 feet.

In like manner, multiplying 87.69 feet by the cosine of 44° 35′ 41″.75, (the angle between General Roy's station and the prolongation of the distance from Tenterden Church,) we obtain 62.44 feet; which being subtracted from 71634.73 feet, the distance from General Roy's station to Tenterden, will give 71572.29 feet, according to General Roy, for the distance from Tenterden to the new station, without sensible error. The following diagram may serve to render this more intelligible.



General Roy did not obtain directly the distance between his stations at Folkstone and Fairlight; but by using the distances Paddlesworth to Folkstone, Paddlesworth to Fairlight, and the included angle 117° 45′ 42″.65, we are enabled to supply this omission; and we thus obtain 154792.00 feet for General Roy's distance from Fairlight to Folkstone.—We have also the distance from Dover Castle station to Nôtre Dame, Calais, according to General Roy, 137449.90 feet.

Lastly, The distance from Nôtre Dame, Calais, to Fiennes is given by General Roy, using his own observations, and the angles observed by the French: this distance is stated to be 45219.60 feet.

Converting General Roy's distances into Imperial feet in the manner formerly stated, we have the following results:

From	By General Roy.	By the present Operations.	Difference.
	Feet.	Feet.	Feet.
Fairlight to Frant	113850.59	113857.34	6.75
Fairlight to Tenterden	71577.24	71580.75	3.51
Fairlight to Folkstone........	154802.70	154807.00	4.30
Dover to Nôtre Dame, Calais..	137459.40	137471.99	12.59
Nôtre Dame, Calais, to Fiennes	45222.72	45221.01	1.71

SECTION 4.—*Of the distances from the meridian, and from the perpendicular to the meridian, of Greenwich.*

It has been mentioned that the station at Chingford was the spot where the temporary meridian mark was erected. This being removed, a staff was put up in its place, having a triangular board fastened to it, the base of which was parallel to the horizon, and the vertex coinciding with the staff.

As it was highly important to ascertain with the greatest precision the situation of this staff with respect to the meridian of Greenwich, Mr. GARDNER went to the Royal Observatory, in order to observe it with the transit instrument. He found that the middle wire of the transit appeared to touch one of the angles at the base of the triangular board, and that the vertex was to the West of the meridian. The angular distance from the meridian to the staff was then measured by means of the micrometer of the transit instrument, and found to be thirty-seven divisions of the micrometer, or 6''.16, &c.

By means of the roughly computed distance from the Royal Observatory to Chingford, and its angle with the meridian, the distance of the station from the meridian of Greenwich was found to be 20 inches; and the base of the triangular board proved on measurement to be exactly double that quantity.

When the theodolite was put up at Chingford, the distance of twenty inches was measured to the eastward from the line joining the Station and the Royal Observatory, and an Argand's lamp was placed upon this spot, the position of which I requested the Astronomer Royal to observe. In the Greenwich observations for 1822 I find accordingly, under November 15th, the following remark:—" Observed Captain KATER's light apparently about the thickness of the wire to the west of the meridian." This affords, it is presumed, a sufficient proof that the direction of the station at Chingford, with respect to the meridian of Greenwich, has been accurately determined.

If we suppose a parallel to the meridian of Greenwich and to its perpendicular to be drawn through each station contained in the left-hand column of the following Table, we have the bearings and the distances of the other stations from such parallels, calculated by means of a right-angled plane triangle, the hypothenuse and one of the angles of which are given to find the two other sides: or, let K be the distance between the given stations; M, the distance from the parallel to the perpendicular; P, the distance from the parallel to the meridian; and θ, the bearing or angle with the parallel to the meridian. Then, $M = K . \cos \theta$, and $P = K . \sin \theta$.

TABLE I.

Stations.	Objects.	Bearings.	Distance from a parallel to the meridian of Greenwich. P. Feet.	Distance from a parallel to the perpendicular to the meridian of Greenwich. M. Feet.
Transit Royal Obs.	Chingford	0° 0′ 6.17″ N.W.	1.73 W.	57847.66 N.
	Severndroog	73 49 29.69 S.E.	14034.28 E.	4070.72 S.
Chingford	Transit Royal Obs...	0 0 6.17 S.E.	1.73 E.	57847.66 S.
	St. Paul's	26 14 15.83 S.W.	22036.04 W.	44708.80 S.
	Westminster Abbey	30 5 49.84 S.W.	28908.97 W.	49876.27 S.
	Severndroog	12 46 20.12 S.W.	14035.98 E.	61918.36 S.
	Wrotham..........	29 21 22.12 S.E.	65515.51 E.	116479.69 S.
Severndroog	Chingford	12 46 20.12 N.W.	14035.98 W.	61918.36 N.
	Wrotham..........	43 20 6.54 S.E.	51479.66 E.	54561.77 S.
	Leith Hill	43 5 51.03 S.W.	98906.80 W.	105703.32 S.
	Hanger Hill	75 43 45.34 N.W.	81779.19 W.	20800.79 N.
	Westminster Abbey	74 20 11.75 N.W.	42944.95 W.	12041.68 N.
	St. Paul's	64 29 39.83 N.W.	36072.20 W.	17209.88 N.
Leith Hill	Severndroog	43 5 51.03 N.E.	98906.80 E.	105703.32 N.
	Wrotham..........	71 13 6.61 N.E.	150386.41 E.	51141.52 N.
	Crowborough	69 49 58.14 S.E.	120729.94 E.	44341.48 S.
	Hanger Hill	7 42 37.81 N.E.	17127.63 E.	126504.06 N.
	Westminster Abbey	25 25 14.03 N.E.	55961.13 E.	117744.81 N.
	St. Paul's	27 4 36.84 N.E.	62835.06 E.	122912.60 N.

TABLE I. (Continued.)

Stations.	Objects.	Bearings.				Distance from a parallel to the meridian of Greenwich. P. Feet.		Distance from a parallel to the perpendicular to the meridian of Greenwich. M. Feet.	
Wrotham........	Leith Hill	71°	13′	6.61″	S.W.	150386.41	W.	51141.52	S.
	Severndroog	43	20	6.54	N.W.	51479.66	W.	54561.77	N.
	Chingford	29	21	22.12	N.W.	65515.51	W.	116479.69	N.
	Stede Hill	76	1	32.25	S.E.	92169.87	E.	22936.75	S.
	Crowborough	17	15	16.18	S.W.	29656.47	W.	95483.00	S.
Crowborough	Wrotham..........	17	15	16.18	N.E.	29656.47	E.	95483.00	N.
	Stede Hill	59	13	36.02	N.E.	121826.34	E.	72546.24	N.
	Frant	59	26	16.32	N.E.	26489.28	E.	15642.10	N.
	Tolsford	84	52	13.64	N.E.	212272.83	E.	19055.17	N.
	Fairlight	59	2	21.57	S.E.	107419.64	E.	64443.95	S.
	Leith Hill	69	49	58.14	N.W.	120729.94	W.	44341.48	N.
Stede Hill	Crowborough	59	13	36.02	S.W.	121826.34	W.	72546.24	S.
	Wrotham..........	76	1	32.25	N.W.	92169.87	W.	22936.75	N.
	Tolsford	59	23	57.12	S.E.	90446.52	E.	53491.64	S.
	Fairlight	6	0	12.97	S.W.	14407.05	W.	136991.06	S.
Fairlight	Stede Hill	6	0	12.97	N.E.	14407.05	E.	136991.06	N.
	Tenterden	12	8	33.62	N.E.	15056.77	E.	69979.29	N.
	Tolsford	51	28	5.78	N.E.	104853.53	E.	83499.12	N.
	Folkstone	58	18	22.52	N.E.	131724.15	E.	81334.62	N.
	Dungeness Lt. House	80	8	28.69	N.E.	80922.34	E.	14063.10	N.
	Blancnez..........	85	7	40.07	N.E.	251792.52	E.	21463.18	N.
	Montlambert	77	12	54.49	S.E.	239529.39	E.	54353.08	S.
	Crowborough	59	2	21.57	N.W.	107419.64	W.	64443.95	N.
	Frant	45	18	1.60	N.W.	80930.37	W.	80086.04	N.
Tolsford	Fairlight	51	28	5.78	S.W.	104853.53	W.	83499.12	S.
	Tenterden	81	26	16.16	S.W.	89797.20	W.	13519.92	S.
	Crowborough	84	52	12.41	S.W.	212272.68	W.	19056.45	S.
	Stede Hill	59	23	57.12	N.W.	90446.52	W.	53491.64	N.
	Folkstone	85	23	40.63	S.E.	26870.59	E.	2164.49	S.
	Blancnez..........	67	6	41.54	S.E.	146938.81	E.	62034.50	S.
	Fiennes	61	50	9.18	S.E.	176192.20	E.	94331.42	S.
	Montlambert	44	19	54.34	S.E.	134672.78	E.	137854.54	S.
Folkstone	Tolsford	85	23	40.63	N.W.	26870.59	W.	2164.49	N.
	Dover	65	52	20.12	N.E.	28802.86	E.	12900.88	N.
	Nôtre Dame, Calais	72	51	8.14	S.E.	152510.49	E.	47057.49	S.
	Blancnez..........	63	29	49.91	S.E.	120068.38	E.	59871.23	S.
	Montlambert	38	28	2.31	S.E.	107805.05	E.	135688.40	S.
	Dungeness Lt. House	37	3	33.04	S.W.	50801.68	W.	67271.43	S.
	Fairlight	58	18	22.52	S.W.	131724.15	W.	81334.62	S.
Montlambert	Fairlight	77	12	54.49	N.W.	239529.39	W.	54353.08	N.
	Tolsford	44	19	54.34	N.W.	134672.78	W.	137854.54	N.
	Folkstone	38	28	2.57	N.W.	107805.22	W.	135688.28	N.
	Blancnez..........	9	11	15.56	N.E.	12262.95	E.	75817.22	N.
	Fiennes	43	38	55.18	N.E.	41516.43	E.	43522.48	N.
Blancnez........	Montlambert	9	11	16.50	S.W.	12263.29	W.	75817.15	S.
	Fairlight	85	7	40.07	S.W.	251792.52	W.	21463.18	S.
	Tolsford	67	6	41.59	N.W.	146938.81	W.	62034.50	N.
	Folkstone	63	29	49.91	N.W.	120068.38	W.	59871.23	N.
	Dover	51	25	56.29	N.W.	91265.50	W.	72772.10	N.
	Nôtre Dame, Calais	68	26	50.32	N.E.	32442.07	E.	12813.75	N.
	Fiennes	42	10	16.34	S.E.	29253.50	E.	32294.72	S.

From the preceding Table the following is derived, containing the distances from the meridian of Greenwich and from its perpendicular.

TABLE II.

Stations.	Distance from the meridian of Greenwich. Feet.		Distance from the perpendicular to the meridian of Greenwich. Feet.	
Chingford	1.73	W.	57847.66	N.
Severndroog Castle	14034.28	E.	4070.72	S.
Severndroog Castle	14034.25	E.	4070.70	S.
St. Paul's	22037.77	W.	13138.86	N.
Westminster Abbey	28910.70	W.	7971.39	N.
Wrotham	65513.78	E.	58632.03	S.
Wrotham	65513.92	E.	58632.48	S.
Hanger Hill Tower	67744.93	W.	16730.08	N.
Westminster Abbey	28910.69	W.	7970.97	N.
St. Paul's	22037.94	W.	13139.17	N.
Leith Hill	84872.54	W.	109774.03	S.
Severndroog Tower	14034.26	E.	4070.71	S.
Crowborough	35857.40	E.	154115.51	S.
Hanger Hill Tower	67744.91	W.	16730.03	N.
Westminster Abbey	28911.41	W.	7970.78	N.
St. Paul's	22037.48	W.	13138.57	N.
Leith Hill	84872.56	W.	109773.77	S.
Stede Hill	157683.72	E.	81569.00	S.
Crowborough	35857.38	E.	154115.25	S.
Wrotham	65513.86	E.	58632.38	S.
Stede Hill	157683.73	E.	81569.14	S.
Frant Church	62346.67	E.	138473.28	S.
Tolsford	248130.22	E.	135060.21	S.
Fairlight	143277.03	E.	218559.33	S.
Leith Hill	84872.55	W.	109773.90	S.
Crowborough	35857.39	E.	154115.31	S.
Wrotham	65513.86	E.	58632.32	S.
Tolsford	248130.25	E.	135060.71	S.
Fairlight	143276.68	E.	218560.13	S.
Stede Hill	157684.40	E.	81568.67	S.
Tenterden Church	158334.12	E.	148580.44	S.
Tolsford	248130.88	E.	135060.61	S.
Folkstone	275001.50	E.	137225.11	S.
Dungeness Light House	224199.23	E.	204496.55	S.
Blancnez	395069.87	E.	197096.55	S.
Montlambert	382806.74	E.	272912.81	S.
Crowborough	35857.71	E.	154115.78	S.
Frant Church	62346.98	E.	138473.69	S.
Fairlight	143276.92	E.	218559.63	S.
Tenterden Church	158333.25	E.	148580.43	S.
Crowborough	35857.77	E.	154116.96	S.
Stede Hill	157683.93	E.	81568.87	S.
Folkstone	275001.04	E.	137225.00	S.
Blancnez	395069.26	E.	197095.01	S.
Fiennes	424322.65	E.	229391.93	S.

TABLE II. (Continued.)

Stations.	Distance from the meridian of Greenwich. Feet.		Distance from the perpendicular to the meridian of Greenwich. Feet.	
Montlambert	382803.23	E.	272915.05	S.
Tolsford	248130.68	E.	135060.56	S.
Dover Castle	303804.13	E.	124324.17	S.
Nôtre Dame, Calais	427511.76	E.	184282.54	S.
Blancnez	395069.65	E.	197096.28	S.
Montlambert	382806.32	E.	272913.45	S.
Dungeness Light House	224199.06	E.	204496.69	S.
Fairlight	143277.12	E.	218559.67	S.
Fairlight	143276.04	E.	218560.69	S.
Tolsford	248132.65	E.	135059.23	S.
Folkstone	275000.21	E.	137225.49	S.
Blancnez	395068.38	E.	197096.55	S.
Fiennes	424321.86	E.	229391.29	S.
Montlambert	382805.75	E.	272913.25	S.
Fairlight	143276.52	E.	218559.28	S.
Tolsford	248130.48	E.	135061.60	S.
Folkstone	275000.91	E.	137224.87	S.
Dover Castle	303803.54	E.	124324.00	S.
Nôtre Dame, Calais	427511.11	E.	184282.35	S.
Fiennes	424322.54	E.	229390.82	S.

The following Table contains the distance of each Station from the meridian and from the perpendicular to the meridian of Greenwich, obtained by taking the mean of the distances given in the preceding Table.

TABLE III.

Stations.	Distance from the meridian of Greenwich. Feet.		Distance from the perpendicular to the meridian of Greenwich. Feet.	
Westminster Abbey	28910.93	W.	7971.05	N.
St. Paul's	22037.73	W.	13138.87	N.
Hanger Hill Tower	67744.92	W.	16730.05	N.
Chingford	1.73	W.	57847.66	N.
Centre of Transit, Royal Obs.	———		———	
Severndroog Castle	14034.26	E.	4070.71	S.
Wrotham	65513.85	E.	58632.80	S.
Stede Hill	157683.94	E.	81568.92	S.
Leith Hill	84872.55	W.	109773.90	S.
Dover Castle	303803.83	E.	124324.08	S.
Tolsford	248130.86	E.	135060.49	S.
Folkstone	275000.91	E.	137225.12	S.
Frant Church	62346.83	E.	138473.48	S.
Tenterden Church	158333.68	E.	148580.43	S.
Crowborough	35857.53	E.	154115.76	S.
Nôtre Dame, Calais	427511.43	E.	184282.44	S.
Blancnez	395069.29	E.	197096.10	S.
Dungeness Light House	224199.14	E.	204496.62	S.
Fairlight	143276.72	E.	218559.79	S.
Fiennes	424322.35	E.	229391.35	S.
Montlambert	32805.518	E.	272913.64	S.

SECTION 5.—*Of the latitudes and longitudes of the Stations.*

If the earth were a sphere of known diameter, the latitude and longitude of any point upon its surface might readily be calculated by spherical trigonometry. But the earth being an ellipsoid, other methods of computation involving the eccentricity become necessary. This subject has engaged the attention of the most eminent mathematicians, and various formulæ have been given for the purpose of facilitating such computations. These, though equal in accuracy, differ much in practical convenience; and by far the most manageable that I have met with, and of which I shall avail myself on the present occasion, are to be found in a memoir by ORIANI, but little known I believe in England, which he published at Milan in 1826, under the title of "Opusculi Astronomici *."

Let a, be the semi-major axis of the earth, = 3962.439 miles.

b, the semi-minor axis.

e, the eccentricity of the earth $= \sqrt{\frac{a^2-b^2}{a^2}}$.

M, the distance in feet from the perpendicular to the meridian at Greenwich.

P, the distance in feet from the meridian of Greenwich.

$m, = \frac{\mathrm{M}}{b \sin 1''}$.

$p, = \frac{\mathrm{P}}{b \sin 1''}$.

L, the latitude of Greenwich.

λ, the latitude of the foot of the perpendicular let fall from the given station on the meridian of Greenwich.

φ, the required latitude of the given station.

u, the required longitude of the given station.

Then I) $\lambda = \mathrm{L} \pm m \left[1 - e^2 + \frac{3}{2} e^2 \cos^2 \left(\mathrm{L} \pm \frac{m}{2}\right)\right]$

II) $\psi = p\,(1 - e^2 \sin^2 \lambda)$

III) $\sin \varphi = \sin \lambda \cos \psi$

IV) $\tan u = \frac{\tan \psi}{\cos \lambda} \left(1 - \frac{e^2}{2} \cos^2 \lambda\right)$

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* I am indebted for my knowledge of this work to the valuable journal of Baron ZACH.

In computing the eccentricity I have supposed the compression to be $\frac{1}{300}$, and I have assumed this (which perhaps for our portion of the meridian may not be very far from the truth), because it is nearly the mean between $\frac{1}{310}$ and $\frac{1}{289}$, the limits between which I believe the ellipticity is generally supposed to be comprised.

Table of Latitudes and Longitudes.

Stations.	Latitude.	Longitude.	Longitude in Time.
	° ′ ″	° ′ ″	m s
Chingford Station	51 38 9.59	0 0 0 W.	———
Hunger Hill Tower........	51 31 22.65	0 17 51.28 W.	1 11.42
St. Paul's (Cross)..........	51 30 48.42	0 5 48.42 W.	0 23.24
Westminster Abbey (north-west Pinnacle)	51 29 57.34	0 7 36.95 W.	0 30.46
Centre of Transit, Royal Observatory	51 28 38.96	———	———
Severndroog Castle........	51 27 58.74	0 3 41.64 E.	0 14.77
Wrotham Station..........	51 18 59.35	0 17 11.33 E.	1 8.75
Stede Hill Station	51 15 7.00	0 41 18.86 E.	2 45.26
Leith Hill Station	51 10 34.00	0 22 12.01 W.	1 28.80
Dover Castle Station	51 7 45.59	1 19 23.45 E.	5 17.55
Tolsford Station	51 6 8.65	1 4 48.19 E.	4 23.21
Frant Church	51 5 51.82	0 16 16.84 E.	1 5.12
Folkstone Station..........	51 5 43.18	1 11 48.61 E.	4 47.24
Tenterden Church	51 4 5.95	0 41 19.20 E.	2 45.27
Crowborough Station	51 3 18.30	0 9 21.45 E.	0 37.43
Church of Nôtre Dame, Calais	50 57 27.95	1 51 18.73 E.	7 25.24
Blancnez Station	50 55 29.36	1 42 47.45 E.	6 51.16
Dungeness Light House....	50 54 47.00	0 58 18.89 E.	3 53.26
Fairlight Station	50 52 36.88	0 37 14.23 E.	2 28.94
Fiennes Station	50 50 4.00	1 50 11.41 E.	7 20.76
Montlambert Station	50 43 4.41	1 39 9.62 E.	6 36.64

SECTION 6.—*Observations of the pole star for determining the direction of the meridian.*

The following is the manner in which observations of the pole star have been usually conducted. The greatest elongation of the star and the time of its greatest elongation being computed, the theodolite was carefully levelled, so that the bubble of the level remained stationary during a whole revolution of the instrument. Then, at the time of the greatest elongation, General ROY states "the angle which the star made with the" (referring) "lamp being noted, the telescope removed, and the plane of the instrument being turned 180° or half round, the telescope replaced and directed again to the star, the difference on the circle was found to be only $1\frac{1}{4}''$. The same method was universally adhered to, in all places where observations of the star were obtained."

General MUDGE, in his account of the Trigonometrical Survey of Great Britain, says: "At the time of the greatest elongation, when the observer was satisfied of the star being properly bisected, another person at the microscope bisected the dot." "The transit was then taken off, and the instrument being turned half round and the telescope replaced, the star was observed again. This precaution was taken to obviate the errors which might arise from the arms of the instrument being out of the parallel with the plane of the circle, owing to any imperfections in the positions of the Y's on which the transit rested. It was however seldom found that a greater difference subsisted between the readings of the opposite microscopes than what might be supposed to be the consequence of a shake in the centre, or errors in division."

A little consideration will show that the method above described, of obviating an error which might arise from the arms of the telescope not being parallel to the plane of the circle, would not be successful except in the case of the vertical axis being strictly perpendicular to the horizon; but then, the error of the arms of the telescope or axis of the transit, (instantly detected by reversing the level,) could not well escape notice. There is however another source of inaccuracy to which azimuths by the pole star are liable, and which seems to have been wholly disregarded; I allude to an error of the line of collimation. The effect of this upon the azimuth in our latitude would be equal to about six tenths of the error of the line of collimation. This error may however be destroyed by inverting the telescope, or placing that end of the axis which was to the east, to the west; and taking a mean of the observations of the star in both positions.

It must be evident that in taking the greatest elongation of the pole star, the observer is most inconveniently pressed for time; for the azimuth then varies about $1''$ in four minutes; and besides this, should a passing cloud obscure the star, the observation for that day is lost; consequently by this method of proceeding, a long period is necessary before the direction of the meridian can be obtained.

At Blancnez the weather was so tempestuous that the attempt to deduce the direction of the meridian in the usual way appeared hopeless, and it occurred to me that it would be a far preferable method to note the time at the moment of observing the star, and thence to calculate the azimuth. I was thus enabled to obtain as many observations as I thought convenient, choosing the time when the star was near its greatest elongation, and when consequently its motion in azimuth was the slowest.

The method pursued was the following:—The instrument being very carefully levelled, some terrestrial object was observed. The telescope was then directed to the pole star, and the star being bisected and the time noted, the microscopes were read off. Several observations of the star having been thus made, the telescope was taken out of the Y's and inverted, the end of the axis which was to the east being now turned towards the west, and sometimes, but not always, the circle was turned 180° or half round. Similar observations of the star were then made with the telescope in this position, and lastly the terrestrial object was again observed.

To lessen the labour of computation, the mean of each two successive observations was taken, and from the calculated azimuth of the star the reading at the meridian was deduced. The mean of such readings for each position of the telescope, compared with the reading of the observed terrestrial object, gave the apparent angle of this object with the meridian; and lastly, the mean of the bearing thus obtained in each position of the telescope gave the true bearing.

On the morning of the 2nd October, 1821, the first observations of the pole star were made at Blancnez; but it blew so violently, that from this, or from some other cause which I cannot discover, these observations, though agreeing well among themselves, differ so widely from those made on the evening of the 3rd, under more favourable circumstances, that I have declined employing them.

The object proposed, in observing the direction of the meridian at Crowborough, Fairlight, Tolsford, and Blancnez, was to obtain the longitude of Blancnez independently of any assumed ellipticity of the earth. Crowborough and Tolsford, and Fairlight and Blancnez are also respectively well situated for obtaining the length of a degree perpendicular to the meridian. It is well known, however, that a very small error in the observed direction of the meridian will produce an error of considerable magnitude in the length of the perpendicular degree;—and we shall ultimately perceive that deductions of this kind from observations of the pole star, appear to be little, if at all, worthy of confidence.

It has been demonstrated that the sum of the three angles upon a sphere and spheroid is so nearly equal, that the difference when the stations are nearly east and west is absolutely insensible. Having, then, the co-latitudes of two stations, with the observed angle at each, between the meridian and the other station, and consequently the sum of these angles, the difference of longitude or the angle at the pole is obtained by the following method:

As the tangent of half the sum of the co-latitudes is to the tangent of half their difference; so is the tangent of half the sum of the observed angles, to the tangent of half their difference.

The triangle is thus reduced to a spherical triangle, in which two angles and two sides are given to find the third angle.

The deductions from the observations detailed in the Appendix are as follow:

Crowborough and Fairlight: distance 125267.72 feet.

At Crowborough, the observed angle between the meridian and Fairlight	121° 4′ 58″.36
At Fairlight, the observed angle between the meridian and Crowborough	58 33 26 .14
The deduced spherical angle at Crowborough	121 13 52 .60
The deduced spherical angle at Fairlight	58 24 31 .90
The resulting difference of longitude	0 27 46 .67

Crowborough and Tolsford: distance 213116.39 feet.

At Crowborough, the observed angle between the meridian and Tolsford	84° 59′ 34″.35
At Tolsford, the observed angle between the meridian and Crowborough	94 17 21 .56
The deduced spherical angle at Crowborough	84 58 27 .84
The deduced spherical angle at Tolsford	94 18 28 .06
The resulting difference of longitude	0 55 21 .39

Fairlight and Blancnez: distance 252705.62 feet.

At Fairlight, the observed angle between the meridian and Blancnez	85° 36′ 39″.73
At Blancnez, (3rd October,) the observed angle between the meridian and Fairlight	93 32 31 .11
The deduced spherical angle at Fairlight	85 35 43 .07
The deduced spherical angle at Blancnez	93 33 27 .77
The resulting difference of longitude	1 5 29

Adding together the longitude of Crowborough and the differences of longitude obtained by means of the azimuths, we have between

Greenwich and Crowborough	0° 9′ 21″.45
Crowborough and Fairlight	0 27 46 .67
Fairlight and Blancnez	1 5 29
Longitude of Blancnez	1 42 37 .12

Differing 10″.33 in defect, from the longitude found by employing $\frac{1}{300}$ as the compression.

Section 7.—*Of the length of the degree upon a circle perpendicular to the meridian.*

I have already remarked that Crowborough and Tolsford, and Fairlight and Blancnez, were respectively very favourably situated for the determination of the length of degrees perpendicular to the meridian at each of these stations: I shall now proceed to state shortly the manner in which the computation was made.

Having obtained by means of the azimuths the difference of longitude, we have a right-angled spherical triangle, the base of which (the co-latitude of the given station,) and the angle at the pole, (the difference of longitude,) are given, to find the perpendicular. Having obtained this arc, we have next to compute the corresponding terrestrial perpendicular. This is effected by means of a small triangle considered as spherical, in which we have the terrestrial distance between the two stations given, and by means of the azimuths two of the angles are deduced. The spherical excess being then computed, and one third subtracted from each of the two angles, the remaining angle is obtained, and the length of the perpendicular arc in feet is calculated by plane trigonometry.

Lastly, having the perpendicular in arc and also in feet, the number of feet (or fathoms) due to the degree is found by simple proportion.

I shall give the angles of the small triangles used for obtaining the terrestrial perpendicular, in order to facilitate any examination of the work.

At Crowborough.				At Tolsford.			
	° ′ ″		° ′ ″		° ′ ″		° ′ ″
Crowborough	4 0 25.65		4 0 25.40	Tolsford	4 17 21.56		4 17 21.3
Tolsford	85 42 38.44		85 42 38.20	Crowborough	84 59 34.35		84 59 34.1
Remaining∠	————	0″.74	90 16 56.40	Remaining∠	————	0″.80	90 43 4.6

At Fairlight.				At Blancnez.			
	° ′ ″		° ′ ″		° ′ ″		° ′ ″
Fairlight	4 23 20.27		4 23 19.89	Blancnez	3 32 31.11		3 32 30.80
Blancnez	86 27 28.89		86 27 28.51	Fairlight	85 36 39.73		85 36 39.42
Remaining∠	————	1″.15	89 9 11.60	Remaining∠	————	0″.93	90 50 49.78

In the manner before explained, we obtain

The perpendicular arc at Crowborough 34′ 47″.84 equal to 212532.00 feet.
The perpendicular arc at Tolsford . . . 34 45 .71 equal to 212329.66 feet.
The perpendicular arc at Fairlight . . . 41 19 .32 equal to 252250.29 feet.
The perpendicular arc at Blancnez . . 41 16 .77 equal to 251991.98 feet.

The length of the degree perpendicular to the meridian at Crowborough . . . . 61077 fathoms.
. . . . . . at Tolsford . . . . 61081.3 fathoms.
. . . . . . at Fairlight . . . . 61045 fathoms.
. . . . . . at Blancnez . . . . 61045.3 fathoms.

And taking the means of the latitudes of Crowborough and Tolsford, and of Fairlight and Blancnez, and the means of the respective perpendicular degrees, we have

The perpendicular degree in lat. 51° 4′ 43″.47 = 61079.17 fathoms.
and in lat. 50 54 3 .12 = 61045.15 fathoms.

A moment's examination is sufficient to show that these results are totally unworthy of credit; and that the length of the perpendicular degree above given, must be erroneous about one hundred fathoms.

As very great care was bestowed in making the observations, it is important to determine the degree of error in the azimuth, which would produce an error so considerable, as that which is here indicated.

If 2″ be added to the azimuth at Crowborough and to that at Tolsford, the resulting difference of longitude would be diminished 5″.14, and the length of the perpendicular degree would be increased 95 fathoms.

Now an error of two seconds in azimuth may proceed from such a variety of sources, that it is scarcely possible to detect it. I think no one acquainted with the great theodolite would venture to assert that the level and its adjustment comprising that of the Y's, can be depended upon to within two seconds of the truth, and an error of 2″ in the level would affect the azimuth to the amount of about 2″.3. This error arising from the level, I have before explained is not to be destroyed by turning the instrument half round; and were there no other source of inaccuracy, I should consider this alone, as an insurmountable objection to the determination of azimuths by means of observations of the pole star.

But in addition to this, the level may be affected by irregular local density. At Arbury Hill (one of the stations of the Trigonometrical Survey of Great Britain), it is known that the plumb-line of the zenith sector was deflected, so as to occasion an anomaly of 5½ seconds in latitude. The same cause of disturbance would equally affect the level, and this admits of no remedy.

To the sources of inaccuracy, before enumerated, may be added a small uncertainty, (the fraction of a second for example,) in the polar distance of the pole star, which would influence the azimuth nearly double that quantity. The possibility, and I might perhaps venture to say the probability, of horizontal refraction, affecting the situation of the terrestrial object to which the star is referred, may also be considered; but this last is common to every method of obtaining the direction of the meridian.

From what has been advanced, it should seem that observations of the pole star, for the purpose of determining the length of the perpendicular degree in our latitude, are wholly unworthy of credit, and that some other method less liable to error should be employed.

Of these, the best which has occurred to me, is the well known method of observing a star when near the east or west point of the horizon, and from the time and the calculated azimuth to deduce the place of the meridian. Here the alteration of the azimuth from a variation in the refraction, must be carefully taken into account, and the altitude of the star must therefore be obtained.

It will not, however, be necessary to observe the star when *very* near the horizon, as the error in the azimuth arising from the level decreases as the tangent of the altitude, and at an elevation of 12° is scarcely more than two tenths of the error in the horizontality of the axis of the telescope.

SECTION 8.—*Of the heights of the stations above the level of the sea, and of the terrestrial refraction.*

Let the arc between the two stations be A. The depressions reciprocally observed at the two stations reduced to the height of the axis of the theodolite be D and d; and let R be the mean terrestrial refraction.

Then $R = \frac{A-(D+d)}{2}$. and should one of the stations appear elevated from the other station, calling the elevation E, we have $R = \frac{(A+E)-D}{2}$.

The axis of the instrument was about $5\frac{1}{2}$ feet above the ground, and the angle subtended by this, at the distance between the stations being computed and subtracted from the observed depression, the apparent depression of a point at the height of the axis was obtained. The distance between the stations was converted into arc, by allowing 101.7 feet for each second, and with the arc and the apparent depression, the refraction was computed. The refraction being added to the depression, the difference between this and half the contained arc, gave the angle subtended by the difference in the height of the two stations above the level of the sea; the height of that station being in excess, at which the true depression exceeded one half of the contained arc. Lastly, the angle thus obtained, and the distance between the stations, gave the difference of their heights in feet

At Folkstone Pier, there is a flag-staff, the height of which was carefully measured, and found to be 37 feet above the Pier. From the pier to the mark on the tide gauge indicating XXI feet, was 5 feet. The harbour master informed me that the highest spring tides rose 20 feet. We have therefore 43 feet from the top of the flag-staff to high water mark, and 63 feet to low water mark.

By means of the side Tolsford from Folkstone in the following triangle, the distances from Folkstone to the flag staff, and from Tolsford to the flag staff were obtained.

	° ' "	
Folkstone Pier Flag-staff		
Folkstone station	84 37 49	6152.0 feet.
Tolsford station	13 4 14	27083.6 feet.

With the depression of the summit of the flag-staff, observed at Folkstone and the above data, we obtain the height of the axis of the instrument at Folkstone station above low water mark 559.1 feet.

Similar observations were made at Tolsford, and the resulting height of that station above low water mark differed only 3 feet in defect from that obtained by means of Folkstone. The refraction employed in these computations was $\frac{1}{13.2}$ of the contained arc.

In the following TABLE, are given in one view the data and the computed results.

	Observed Depression or Elevation.	Contained Arc A.	Angle subtended by 5¼ feet.	Mean Refraction R	$\frac{1}{\frac{A}{R}}$	Angle of Difference of Height.	Difference of Height. Feet.	Above low Water. Feet.
	° ' "	' "	' "	' "		° ' "		
Folkstone	0 23 37	25 33.1		1 56.1				576.9
Horizon of sea								
Folkstone	0 10 44.6	25 21.85	0 7.3	1 49.42	$\frac{1}{14}$	+0 0 14.2	10.5	559.1
Fairlight	0 11 13							569.6
Folkstone	0 13 50	5 10	0 35.6	0 23·5		+0 11 2.9	101.4	559.1
Dover Castle								457.7
Folkstone	0 12 30	21 59	0 8.4	1 39.9		+0 3 2.0	118.4	559.1
Blancnez								440.7
Folkstone	4 40 5	1 0.38	3 4.4	0 4.6		+4 36 35	496.1	559.1
Pier Flag Staff								63.0

	Observed Depression or Elevation.	Contained Arc A.	Angle subtended by 5½ feet.	Mean Refraction R.	$\frac{1}{\frac{A}{R}}$	Angle of Difference of Height.	Difference of Height. Feet.	Above low Water. Feet.
	° ′ ″	′ ″	′ ″	′ ″		° ′ ″		
Folkstone.......... E Tolsford .... D	0 0 43.75 0 5 45	4 25	0 42.0	0 23.9	$\frac{1}{11}$	+0 3 14.4	25.4	559.1 584.5
Tolsford .... Horizon of sea........	0 23 39.7	25 36.7		1 57.0				581.8
Tolsford .... Stede Hill	0 6 10 0 8 12	17 13	0 10.8	1 36.3	$\frac{1}{11}$	+0 1 01.0	31.1	584.5 615.6
Tolsford .... Folkstone Pier Fl. Staff	1 8 22	4 26.25	0 42.0	0 20.2		+1 5 48	518.5	581.5 63.0
Tolsford .... Fairlight	0 9 5 0 9 7.5	21 58	0 8.5	2 1.25	$\frac{1}{11}$	+0 0 1.25	0.65	584.5 585.2
Fairlight .... Horizon of sea........	0 23 48.5	25 45.6		1 57.1				586.7
Fairlight .... Crowborough	0 2 22 0 15 29	20 30	0 9.0	1 28.5	$\frac{1}{14}$	+0 6 33.5	239.0	577.4 816.4
Fairlight .... Stede Hill	0 8 43.5 0 10 34	22 34	0 8.2	1 46.45	$\frac{1}{12}$	+0 0 55.25	36.9	577.4 614.3
Fairlight .... Wrotham............	0 8 56.5 0 16 35	29 8	0 6.3	1 54.55	$\frac{1}{13}$	+0 3 49.25	197.7	577.4 775.1
Stede Hill .... Horizon of sea........	0 23 56	25 53.6		1 57.6				591.6
Stede Hill .... Wrotham............	0 1 0 0 12 57	15 34	0 11.9	1 0.4	$\frac{1}{13}$	+0 5 58.5	165.1	615.0 780.1
Stede Hill .... Crowborough	0 5 24 0 14 49	23 14	0 8.0	1 38.5	$\frac{1}{14}$	+0 4 42.5	194.2	615.0 809.2
Crowborough .... Horizon of sea........	0 27 58	30 15.4		2 17.4				813.0
Crowborough .... Leith Hill	0 4 47.5 0 13 21	21 4	0 8.8	1 37	$\frac{1}{13}$	+0 4 16.8	159.6	812.8 972.4
Crowborough .... Wrotham............	0 8 9 0 6 19.5	16 23	0 11.4	1 8.6	$\frac{1}{14}$	+0 0 54.7	26.7	812.8 786.1
Wrotham............ Leith Hill	0 7 15.5 0 15 17.25	26 1	0 7.1	1 51.2	$\frac{1}{14}$	+0 4 0.8	185.6	780.4 966.0
Leith Hill .... Horizon of sea........	0 30 42	33 12.9		2 30.9				978.3
Leith Hill .... Severndroog	0 21 47	23.43	0 7.8	1 48		+0 11 35.7	488.4	966.0 477.6
Blancnez .... Horizon of sea........	0 20 33.3	22 14.4		1 41.1				438.2

At every station from which the sea was visible, the depression of the horizon was carefully observed, and the resulting heights will be found in the preceding table. These serve to verify to a certain degree the conclusions otherwise obtained.

The mean of the proportion of the refraction to the contained arc, is $\frac{1}{13.2}$, and this has been employed on every occasion where the refraction was not deduced from reciprocal observations.

I shall now give the elevation of the ground at each station, above the level of the sea at low water, the point chosen by other observers.

	Above low water. Feet.	By depression of horizon.	Difference. Feet.
Folkstone Station ..	553.6	571.4	+17.8
Tolsford Station ..	579.0	576.3	− 2.7
Blancnez	435.2	432.7	− 2.5
Fairlight	572.0	581.2	+ 9.2
Dover Castle Battlements..........	452.2	465.8	
Stede Hill Station ..	609.5	586.1	−23.4
Crowborough Station	807.3	807.5	+ 0.2
Leith Hill Station ..	960.5	972.8	+12 3
Wrotham Station ..	775.0		
Severndroog Castle Battlements	472.1	Mean..	+ 1.5

The mean of the differences is so small that we are authorized to co lude that no error of consequence exists in the heights above given; but as he depressions of the horizon were taken probably in various states of the de, the mean result should perhaps have differed in defect about 10 feet. his, however, may be fairly attributed to uncertainty in the refraction emp ed.

In the course of the operations which have been detailed, eat pains were taken to identify the stations, by the bearings of such obje as were conveniently situated for the purpose;—these are given in the A endix.

It is to be regretted that our excellent associate M ARAGO has not yet published the results of his operations in France; a I must therefore, in the absence of higher authority, take the longitud f Calais, as given in the Connaissance des Tems, to be 0° 28′ 59″ wes Paris. Adding this to 1° 51′ 18″.73 the east longitude of Calais from Gr wich, given by the present work, we obtain 2° 30′ 17″.73 for the differer of longitude between Paris and Greenwich. This converted into time is 9^m 21^s.18, differing only 0^s.28 in defect from the admirable results obtained by the operations with fire signals, reported in the Philosophical Transactions for 1826, by Mr. HERSCHEL.

The truth of the preceding work wholly depends upon the degree of reliance that may be placed upon the base on Hounslow Heath; and as the accuracy of this is in some measure questionable[*], it is certainly desirable that a new base should be measured, to connect in the most unexceptionable manner the stations at Leith Hill and Wrotham. The measurement of a base has hitherto not kept pace with the progress of other parts of geodetical operations; but the elegant arrangement which Lieut.-Colonel COLBY has recently imagined for compensating expansion, and which has already been tried in Ireland with perfect success, leaves no doubt of the future accuracy of this most important part of trigonometrical operations.

APPENDIX.

I HAVE reserved for an Appendix such remarks as could not have been introduced in the body of the work, without interrupting the regular connection of its parts.

The original observations are deposited with the Royal Society, and may be consulted whenever occasion may require. It has not been thought necessary to print them, as all the angles employed in this work have been carefully deduced from them, and are given at the end of the present communication. The letter prefixed to each angle indicates the name of the observer; and where the degrees and minutes are repeated, it is to be understood that the instrument has been shifted, and the readings for the angle taken upon different parts of the circle.

The great theodolite had originally only two opposite microscopes, and until the addition I am about to describe was made, the observations were conducted in the following manner.

The instrument being carefully levelled, the objects were intersected, and the microscopes were read off; but it is evident the truth of the angle thus obtained would depend upon the accuracy of the divisions of the circle from

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[*] See Phil. Trans. for 1821, "On the Comparison of various British Standards," &c.

which it was deduced. In order to do away any error of this kind, the whole instrument was shifted by turning it horizontally a few degrees; and being again levelled, the observations were repeated, and the angle was obtained on different parts of the circle. This operation was repeated seldom fewer than eight times, which it was supposed would be sufficient to do away errors of division. Now as at each observation the angle is deduced from readings taken on four different parts of the circle, eight repetitions of this kind would give a mean angle deduced from thirty-two different points of the instrument. The time, however, required for this was so considerable as to constitute a very serious objection; in addition to which, when the instrument had been recently shifted, it was feared the spring of the parts might introduce error. These inconveniences led me to have four additional microscopes fixed to the theodolite, at such distances as with one of the original microscopes to divide the circle into five equal parts. This arrangement of any number of microscopes or verniers which form a prime number, and the manner of using them, is due to Mr. Pond the Astronomer Royal, but was never published by him. By means of five microscopes, raising the telescope from the Y's, turning the circle 180° in azimuth, and repeating the observations, the angle is obtained upon twenty different parts of the circle, without shifting the instrument, and consequently any error of division may be supposed to be reduced to a very small quantity. Employing in like manner three equidistant microscopes, the angle is obtained by readings upon twelve different parts of the circle.

The second original microscope was not removed, and this afforded an opportunity of comparing the angles obtained by two opposite microscopes, with those deduced by means of five.

In the course of this work I remarked a curious fact, new to me, and for which I was at a loss to account. In hazy weather when the staff was so faint as to be only just visible, it disappeared upon bringing it to the intersection of the cross wires, so that the angle could not be observed.

A remedy for this inconvenience was suggested and put in practice by Mr. Gardner. The horizontal spider's web of the micrometer being moved above the centre, Mr. Gardner succeeded in lodging upon it a very minute particle of dust. When the image of the staff was brought to this, it appeared as if planted upon a mole-hill, and we were thus enabled to observe with great accuracy. I consider this as a very important improvement in the theodolite, and we availed ourselves of it upon all occasions excepting in the observations of the pole star.

As I was desirous of knowing the degree of precision with which an object could be observed with the telescope of the great theodolite magnifying about fifty times, and also the accuracy with which the microscopes could be read off, as well as the comparative merits of cross wires and Mr. GARDNER's dot, we resolved to make some experiments on the subject. A staff upon a steeple was taken which was faintly seen; Colonel COLBY marked the time occupied by the observations, and Mr. GARDNER read off a certain microscope. The position of the telescope and of the micrometer of the microscope were of course altered between each observation. The following were the results:—

With the Cross Wires.

Time at the commencement . . . 0^h 43^m.

Observations.	Readings.	Observations.	Readings.
1. . . .	35″$\frac{3}{4}$	6. . . .	36″$\frac{1}{2}$
2. . . .	35 $\frac{1}{2}$	7. . . .	35 $\frac{3}{4}$
3. . . .	35 $\frac{3}{4}$	8. . . .	36 $\frac{2}{3}$
[illegible] . . .	35 $\frac{2}{3}$	9. . . .	36 $\frac{3}{4}$
5. . . .	35 $\frac{4}{5}$	10. . . .	36 $\frac{3}{4}$

Mean . . . 36″.03

Time at the end . . . 0^h 45^m 15^s.

With Mr. GARDNER's *Dot.*

Time at the commencement . . . 0^h 47^m.

Observations.	Readings.	Observations.	Readings.
1. . . .	1″$\frac{1}{2}$	6. . . .	1″$\frac{7}{8}$
2. . . .	1 $\frac{3}{4}$	7. . . .	2
3. . . .	1 $\frac{3}{4}$	8. . . .	1 $\frac{7}{8}$
4. . . .	2	9. . . .	2
5. . . .	2	10. . . .	2 $\frac{1}{4}$

Mean . . . 1″.9

Time at the end . . . 0^h 48^m 27^s.

The time occupied in making ten observations with the cross wires was 2^m 15^s, and the greatest difference from the mean 0″.72.

The time required for ten observations with Mr. GARDNER's dot was 1^m 27^s, and the greatest difference from the mean only 0″.4.

These experiments appear to be important; they seem to show that in any single observation the combined errors of the telescope and microscopes cannot exceed, when the cross wires are employed, three quarters of a second, and when Mr. GARDNER's dot is used, they amount only to four-tenths of a second. The time, too, required for the latter observations is little more than half of that which is requisite for the former.

Much error has been supposed to arise both in astronomical and geodetical observations, from unequal expansion of the limb of the instrument. In order to bring this to the test of experiment, the index of one of the microscopes was placed at zero, and a certain division on the circle brought to its wire. The other microscopes were then read off, the divisions under them having been carefully bisected, and the mean was registered. A piece of lead was placed in boiling water until it acquired the same temperature; and it was then laid upon the limb of the instrument, between two of the microscopes. Having allowed some time to elapse, the first division was again brought to the zero microscope, and the other divisions bisected by their respective micrometers; when the readings were found to be very different, but the mean varied little from the mean first taken. These experiments were repeated with the same results, and satisfactorily proved that no error of consequence is to be feared from unequal expansion of the circle when several microscopes are employed.

Very different, however, was the consequence of applying the hand to any one of the radii to which the microscopes were attached. Then, the expansion which took place immediately and to a very considerable degree, affected the mean of the readings, by altering the position of the microscope to the support of which the hand had been applied.

From these experiments we may infer the very great importance of securing the permanent respective positions of the microscopes. Perhaps this might be best effected by imitating the principle of the mural circle. In this instrument the microscopes are firmly attached to a wall, and any sensible change in their relative positions can scarcely be imagined to take place. In like manner the microscopes of portable instruments might be fixed to a solid plate of metal; and this being a good conductor of heat, should any partial change of temperature take place it is probably to be expected that it would be so rapidly diffused throughout the whole mass as to occasion no perceptible change in the relative distances of the microscopes from each other *.

During our stay at Fairlight, a source of error was remarked which it may

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* In instruments constructed in the usual manner, where the microscopes are attached to arms or radii, these may be covered to some thickness by strips of flannel or leather, and thus the ill consequences to be apprehended from currents of air of different temperatures may, perhaps, be avoided. The great theodolite was treated in this manner; but as this was done at Chingford, the last station we visited, no opportunity was afforded of remarking the effect.

be important to mention. An object having been carefully bisected by moving the tangent screw slowly in one direction, and the microscopes read off, the result was found to differ three seconds from that obtained when the tangent screw was moved slowly in the opposite direction. This could arise only from friction upon the axis, and the yielding of the radii of the circle, when drawn by the tangent screw clamped to its circumference. Numerous experiments were made with similar results; so that the force thus applied to the circumference of the circle, occasioned an error of one second and a half, plus or minus, according to the direction in which the tangent screw was made to act.

On shaking the screw, if I may so express myself, backwards and forwards with little jerks, before the object was finally bisected, the error just described was obviated. It would perhaps, however, be preferable, instead of giving motion to the instrument by means of a tangent screw acting on the circumference of the circle, to have a bar, connected at one end with a tangent screw, and a collar at the other end passing round the axis, to which it might be clamped at pleasure. The axis would then be the first part moved, and the probable error arising from dragging the instrument round by the limb would be avoided. This arrangement seems to be particularly called for in circles of large dimensions.

The errors which may arise from lateral refraction have often been suspected but never clearly ascertained. In the course of our work, however, we had such evidence of the fact as to leave no doubt of its existence. The angle between the same objects would differ under the most favourable circumstances about five seconds on different days, and perhaps a second and a half or two seconds may be considered as the error which may affect an angle from lateral refraction in an ordinary state of the atmosphere. During the observations at S[illegible]ede Hill one fine day, the telescope being directed to the staff at Wrotham, a shower rapidly approached from the left, and the staff gradually receded from the cross wires until it was obscured by the intervening haze. At Leith Hill, after unfavourable weather, it cleared up in the evening, and though there was no wind, very extraordinary differences were perceived in the angles, for which it would have been difficult to assign any other cause than lateral refraction, varying considerably at short intervals.

At Chingford.

Wrotham and Severndroog.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K.	16° 34′ 60″.25	″	62″.00	″
G.	58.90		60.88	
G.	16 34 60.90	60.70	62.12	61.99
	60·50		61.87	
	16 34 61.20	62.42	59.50	60.75
	63.55		62.00	
	16 34 61.80	61.20	63.87	64.81
	60.60		65.75	
	16 34 60.10	60.97	60.38	60.81
	61.85		61.25	
	16 34 62.70	62.55	64.87	63.62
	62.40		62.37	
	Mean	61.57	....	62.40

Severndroog and St. Paul's.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K.	39° 0′ 37″.05	″ 36.62	35″.13	″ 35.13
	36.20		35.13	
C. & G.	36.33	35.54	34.94	34.47
	34.75		34.00	
K.	38.00	37.80	23.13	30.06
	37.60		37.00	
G.	39 0 34.70	34.90	34.00	34.31
	35.10		34.62	
G.	34.50	35.70	33.25	34.75
	36.90		36.25	
	Mean	36.11	....	33.74

With the Ordnance Theodolite, July 1823.

Wrotham and Severndroog.

Observers.	Three Microscopes.	Mean. Three.		
K.	16° 34′ 62″.75	″ 62.54		
	62.33			
C.	65.00	63.08		
	61.16			
K.	62.00	61.87		
	61.75			
K.	62.50	62.63		
	62.75			
K.	62.91	62.79		
	62.67			
K.	62.58	62.13		
	61.67			
K.	16 34 55.83	58.33		
	60.83			
	Mean	61.91		

Severndroog, and Greenwich Observatory.

Observers.	Three Microscopes.	Mean. Three.		
K.	12° 51′ 23″.92	″ 25.63		
	27.34			
	24.50	24.58		
	24.66			
	26.00	24.91		
	23.83			
	26.17	25.37		
	24.58			
	12 51 27.59	25.63		
	23.67			
	Mean	25.[illegible]2		

Chingford (Continued).

With the Ordnance Theodolite, July 1823.

Severndroog and St. Paul's.

Observers.	Three Microscopes.	Mean. Three.		
K.	39° 0′ 36″.92 35.50	″ 36.21		

Westminster Abbey and Severndroog.

Observers.	Three Microscopes.			
	42° 52′ 09″.42 09.50 09.42 42 52 12.12 42 52 10.35			
	Mean 10.16			

Wrotham, and Centre of Observatory.

Observers.	Three Microscopes.	Mean. Three.		
K.	29° 26′ 25″.96 29.09	″ 27.52		
	27.33 27.41	27.37		
	28.91 26.50	27.70		
	28.67 27.75	28.21		
	28.75 24.92	26.82		
	29 26 23.42 24.50	23.96		
	Mean	26.93		

Observations for identifying the Station.

	Readings.		Readings.
St. Paul's	32° 49′ 39″.37	Hadleigh Church Beacon	108° 33′ 59″.37
Holloway Chapel	43 36 31.87	Barnet Church Vane	104 25 22.50
Chingford Church Tower	41 44 15.75		

At Wrotham.

Crowborough, and Leith Hill.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K. (P.M.)	53° 57′ 50″.00 49.95	″ 49.97	″ 50.00 51.25	″ 50.62
K. (A.M.)	49.70 49.95	49.82	50.25 50.37	50.31
G. (P.M.)	53 57 52.45 53.40	52.92	51.75 51.37	51.56
C. (P.M.)	53.70 51.25	52.47	51.75 50.75	51.25
C. (P.M.)	51.25 49.25	50.25	50.75 47.37	49.06
G. (P.M.)	51.05 51.80	51.42	49.75 50.50	50.12
G.	51.45	51.05	50.88	51.50
K.	53 57 51.30		51.87	
	50.80		51.13	
G.	52.70		52.75	
	Mean	51.13	......	50.63

Fairlight and Severndroog.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K.	162° 35′ 46″.45 50.35	″ 48.40	″ 45.87 50.75	″ 48.31
K.	47.40 45.65	46.52	46.75 46.38	46.56
K.	48.75 45.40	47.07	48.75 46.88	47.81
G.	47.40 44.05	45.72	46.63 43.75	45.19
G.	48.50 46.65	47.57	49.25 47.12	48.18
G.	47.90 48.15	48.02	48.75 48.50	48.62
G.	162 35 49.75 46.75	48.25	48.00 44.87	46.43
	Mean	47.36	......	47.30

Wrotham (Continued).

Severndroog and Chingford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	13° 58′ 44″.55	″45.87	42″.38	″44.87
	47.20		47.37	
G.	13 58 41.00	43.15	38.62	39.25
	45.30		39.88	
C.	42.12	43.68	38.75	40.56
	45.25		42.38	
G.	45.60	45.60	43.38	42.37
	45.60		41.37	
G.	42.50	42.67	38.87	39.31
	42.85		39.75	
C.	42.65	42.57	39.63	39.63
	42.50		39.63	
G.	13 58 46.40	45.85	45.75	45.06
	45.30		44.37	
C.	44.85	44.62	44.50	44.25
	44.40		44.00	
G.	44.50	43.77	44.25	45.06
	43.05		45.88	
	Mean	44.20		42.26

Leith Hill and Severndroog.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K. (P.M.)	65° 26′ 47″.65	″48.22	46″.62	″47.12
	48.80		47.63	
K. (P.M.)	47.80	47.15	46.00	45.31
	46.50		44.63	
C. (P.M.)	48.65	47.62	48.12	46.75
	46.60		45.38	
K. (A.M.)	49.25	47.82	47.87	46.87
	46.40		45.88	
G. (P.M.)	65 26 48.55	46.60	47.25	46.37
	44.65		45.50	
C. (P.M.)	44.80	46.95	47.13	47.81
	49.10		48.50	
G. (P.M.)	47.10	48.30	47.75	47.93
	49.50		48.12	
G. (P.M.	52.00	48.79	51.00	48.93
	45.58		46.87	
K.	65 26 45.40		47.13	
	Mean	47.68	......	47.14

Crowborough and Chingford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	133° 23′ 26″.65	″25.20	27″.00	″24.87
	23.75		22.75	
	Mean	25.20	......	24.87

Stede Hill and Crowborough.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K. (P.M.)	93° 16′ 51″.65	″51.47	50″.88	″51.19
	51.30		51.50	
	51.95		51.82	
K. (P.M.)	49.45	49.57	50.87	49.81
	49.70		48.75	
K. (A.M.)	47.65	47.60	47.06	47.47
	47.55		47.88	
K. (A.M.)	47.55	47.82	47.88	47.81
	48.10		47.75	
C. (A.M.)	50.30	49.17	49.37	48.75
	48.05		48.13	
G. (P.M.)	93 16 48.30	49.40	49.50	50.69
	50.50		51.88	
C. (P.M.)	50.90	50.05	51.25	51.12
	49.20		51.00	
G. (P.M.)	52.85	50.72	53.75	52.50
	48.60		51.25	
G. (P.M.)	93 16 51.65	51.82	51.88	52.75
	52.00		53.63	
C. (P.M.)	50.55		51.63	motion
	motion [illegible].05		56.00	
G. (P.M.)	51.90	50.70	52.00	51.81
	49.50		51.63	
G. (P.M.)	51.25	52.77	52.63	53.31
	54.30		54.00	
K.	93 16 53.00	51.09	49.75	49.53
	49.18		49.31	
K.	44.30	45.05	44.63	44.12
	45.80		43.62	
	46.35	46.27	44.50	45.00
	46.20		45.50	
	Mean	49.54	......	49.70

Wrotham (Continued).

Stede Hill and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K. (P.M.)	50° 5′ 42″.35 38.55	″40.45	″42.13 38.00	″40.06
K. (P.M.)	39.85 40.50	40.17	40.12 38.25	39.18
K. (A.M.)	37.67 37.75	37.71	36.44 37.25	36.84
K. (A.M.)	37.75 39.05	38.40	37.25 37.12	37.18
C. (A.M.)	39.95 38.95	39.45	38.62 38.00	38.31
G. (P.M.)	50 5 41.90 44.50	43.20	41.87 45.00	43.43
C. (P.M.)	40.90 42.90	41.90	40.88 43.13	42.00
G. (P.M.)	43.10 41.75	42.42	42.50 41.37	41.93
C. (P.M.)	50 5 40.15 40.25	40.20	41.75 42.88	42.31
G. (P.M.)	41.10 44.40	42.75	42.75 46.63	44.69
C. (P.M.)	supposed 38.70 motion. 40.65	39.67	41.00 43.13	42.06
G. (P.M.)	40.55 41.70	41.12	43.12 44.38	43.75
	Mean	40.62	......	40.98

Fairlight and Crowborough.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K. (P.M.)	43° 11′ 9″.60 9.20	″9.40	″10.75 10.50	″10.62
K. (A.M.)	9.98 9.80	9.89	10.62 10.63	10.62
K. (A.M.)	9.80 9 05	9.42	10.63 10.63	10 63
C. (A.M.)	10.35 9.10	9.72	10.75 10.13	10.44
G. (P.M.)	43 11 6.40 6.00	6.20	7.63 6 88	7.25
C. (P.M.)	10.00 6.30	8.15	10.37 7.87	9.12
G. (P.M.)	9.75 6.85	8.30	11.25 9.88	10.56
G. (P.M.)	43 11 10.55 7.60	9.07	9.13 7.00	8.06
C. (P.M.)	supposed 11.85 motion. 14.40	13.12	10.63 12.87	11.25
G. (P.M.)	11.35 7.80	9.57	8.88 7.25	8.06
	Mean	9.28	......	9.66
	Reject^g 13.12	8.86	......	9.48

Observations for identifying the Station.

	Readings.		Readings.
A Spire	23° 47′ 47″.00	A Tower about 2 miles distant ..	94° 54′ 46″.62
A Tower near	23 51 18.25	Wadhurst Spire	88 12 1.00

The Station is in the north-west corner of a field upon Wrotham Hill, called "The Plains."

At Leith Hill.

Hanger Hill and St. Paul's.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	19° 21′ 59″.65 61.70	″60.67	″61.25 63.00	″62.12
K.	60.85 59.30	60.07	61.25 61.00	61.12
G.	19 21 58.90 56.25	57.57	58.18 54.25	56.21
K.	60.70 58.70	59.70	59.56 58.75	59.15
	Mean	59.50	....	59.65

St. Paul's and Severndroog.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	16° 1′ 17″.00 14.70	″15.85	″17.62 14.13	″15.87
K.	15.80 15.05	15.42	15.50 14.12	14.81
G.	16 1 14.60 17.65	16.12	15.13 19.38	17.25
K.	13.32 17.90	15.61	14.50 19.00	16.75
	Mean	15.75	....	16.17

Leith Hill (Continued).

Hanger Hill and Severndroog.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	35° 23′ 14″.80	13″.57	16″.50	15″.68
	12.35		14.87	
C.	12.75	13.80	15.00	15.19
	14.85		15.38	
K.	11.75		13.75	
G.	35 23 12.60	12.25	12.88	12.94
	11.90		13.00	
K.	13.88	13.41	14.69	13.72
	12.95		12.75	
G.	10.97	10.78	10.75	11.31
	10.60		11.87	
K.	14.40		16.62	
G.	35 23 16.65	16.52	18.87	18.00
	16.40		17.13	
K.	16.65	15.50	16.75	15.93
	14.35		15.12	
G.	35 23 13.50	13.70	13.31	13.47
	13.90		13.63	
K.	14.02	15.31	14.06	15.90
	16.60		17.75	
	Mean	13.87	....	14.68

Severndroog and Wrotham.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	28° 7′ 17″.57	18″.31	18″.56	18″.21
	19.05		17.87	
K.	28 7 17.60	17.61	18.75	18.19
	17.63		17.63	
C.	17.35	16.87	17.50	17.25
	16.40		17.00	
G.	16.35	15.70	17.38	16.78
	15.05		16.19	
K.	28 7 17.75	15.57	16.25	13.94
	13.40		11.63	
K.	18.60	17.62	16.63	16.00
	16.65		15.37	
G.	28 7 15.50	15.47	14.00	14.18
	15.45		14.37	
K.	13.75	14.02	14.13	13.75
	14.30		13.38	
G.	28 7 18.15	16.57	17.25	16.06
	15.00		14.87	
	Mean	16.42	....	16.04

Wrotham and Crowborough.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	38° 56′ 57″.45	56″.88	59″.87	58″.24
	56.32		56.62	
G.	56.00	54.65	55.38	56.38
	53.30		57.38	
G.	54.50	56.90	57.00	58.15
	59.30		59.31	
G.	57.60		57.00	
G.	56.61	55.65	56.36	56.30
	54.70		56.25	
K.	55.65	55.60	59.00	57.31
	55.55		55.62	
G.	55.85	54.87	55.00	55.87
	53.90		56.75	
K.	38 56 56.75	56.90	56.75	57.06
	57.05		57.37	
C.	56.85	56.85	56.13	57.19
	56.85		58.25	
G.	56.90	56.22	56.87	55.81
	55.55		54.75	
G.	38 56 55.00	55.00	55.25	54.56
	55.00		53.88	
	Mean	55.95	....	56.69

Hanger Hill and Westminster.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	17° 42′ 36″.70	37″.20	38″.87	38″.81
	37.70		38.75	
G.	17 42 39.39	34.66	39.88	35.59
	29.93		31.31	
G.	17 42 33.10	34.22	35.25	35.43
	35.35		35.62	
K.	35.67	34.78	35.99	35.80
	33.90		35.62	
G.	37.85	39.30	39.75	40.19
	40.75		40.63	
K.	36.45	37.10	37.50	38.31
	37.75		39.12	
G.	17 42 37.65	36.82	35.18	35.15
	36.00		35.13	
K.	37.97	38.86	37.31	37.78
	39.75		38.25	
	Mean	36.62	....	37.13

Leith Hill (Continued).

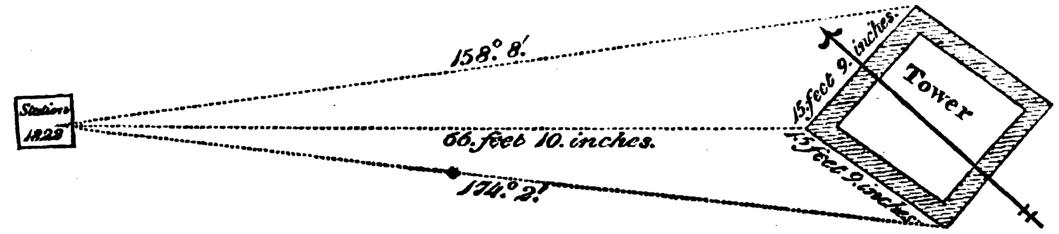
Westminster Abbey and Severndroog.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	17° 40′ 38″.10 34.65	″ 36.37	″ 37.63 36.12	″ 36.87
G.	31.58 40.67	36.12	30.87 40.56	35.71
G.	17 40 39.20 35.65	37.42	39.12 36.50	37.81
K.	39.20 36.60	37.90	39.25 36.00	37.62
G.	17 40 35.85 37.90	36.87	38.13 38.50	38.31
K.	36.05 36.85	36.45	36.75 39.50	38.12
	Mean	36.85	....	37.41

Observations for identifying the Station.

	Readings. °	′	″
Vane of a Church about 2 miles beyond Box Hill on high ground	59	6	50.12
Cupola Vane of Ewherst Church	90	17	1.12
Abinger Church Spire	168	20	57.50
Severndroog Castle Flag-staff..	71	15	51.25
Left Edge of Leith Tower	158	8	0.00
Right Edge of Leith Tower....	174	1	48.50
Apex of a White Tower Church about 2 miles, (possibly Okeley)	175	13	59.00

The North-west Angle of Leith Tower is distant from the Station 66 feet 10 inches.



At Stede Hill.

Fairlight and Crowborough.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	53° 13′ 24″.15 24.25	″ 24.20	″ 25.15 26.38	″ 25.76
G.	53 13 23.35 25.30	24.33	23.62 25.25	24.44
G.	53 13	....	22.38	
	without clamping			
K.	53 13 25.65			
	slight clamping			
G.	...... 25.00 23.95	24.47		
	Mean	24.33	......	25.10

Tolsford and Crowborough.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	118° 37′ 37″.00 36.92	″ 36.96	″ 37.02 39.44	″ 38.23
G.	118 37 35.55 37.39	36.47	37.12 41.00	39.06
G.	118 37	....	36.50	
	without clamping			
K.	...... 35.80			
	slight clamping			
G.	...... 34.85 36.35	35.60		
	Mean	36.34	38.22	38.64

Stede Hill (Continued).

Fairlight and Wrotham.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	97° 58′ 15″.72 17.02	″ 16.37	″ 15.56 17.56	″ 16.56
G.	97 58 15.60 17.80	16.70	13.62 15.50	14.56
G.	97 58 14.38			
with	out clamping. H	eavy sh	ower appro	aching
	Wrotham from	Crowb	orough.	
K.	21.20			
	slight clamping			
G.	16.80 20.10	18.45		
	without clamping			
K.	18.20 15.85	17.02		
	Mean	17.13		15.56

Tolsford and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	65° 24′ 12″.85 12.67	″ 12.76	″ 11.87 13.06	″ 12.46
G.	65 24 12.20 12.09	12.14	13.50 16.12	14.81
G.	65 24	....	14.12	
K.	65 24 10.15			
	slight clamping			
G.	9.85 12.40	11.12		
	without clamping			
K.	11.15 12.10	11.62		
	slight clamping			
G.	65 24 11.15 10.30	10.72		
C.	....	....	11.32	
	Mean	11.67	13.33	13.63

Tolsford and Wrotham.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	163° 22′ 28″.57 29.67	″ 29.12	″ 27.43 30.62	″ 29.02
G.	163 22 27.80 29.89	28.84	27.12 31.25	29.18
G.	163 22	....	28.50	
G.	29.85			
	slight clamping			
G.	...... 26.65 32.50	29.57		
	without clamping			
K.	...... 29.35 27.95	28.65		
	Mean	29.52	......	29.10

Crowborough and Wrotham.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	44° 44′ 51″.57 52.75	″ 52.16	″ 50.41 51.18	″ 50.79
G.	44 44 52.25 52.50	52.36	50.00 50.25	50·12
G.	44 44	....	52.00	
	slight clamping			
G.	51.80 56.15	53.97		
	Mean	52.83	......	50.45

Observations for identifying the Station.

	Readings.
Bottom of the Spindle of the Vane of Charing Church.	92° 10′ 5″.00
Bottom of the Spindle of the Vane of Lenham Church.	65 2 32.12
Bottom of the Spindle of the Vane of Harrietsham Church.	128 24 39.37
Bottom of the Spindle of the Vane of Hollingbourn Church.	51 15 6.12

At Crowborough.

Tolsford and Fairlight.

Observers.	Five Microscopes.	Mean. Five.		
G.	36° 5′ 24″.53	25″.26		
	26.00			
K.	28.48	27.04		
	25.60			
G.	36 5 20.75	22.07		
	23.40			
G.	36 5 22.83	21.66		
	20.50			
	Mean	24.01		

Wrotham and Tolsford.

Observers.	Five Microscopes.	Mean. Five.		
G.	67° 36′ 60″.42	59″.38		
	58.35			
K.	57.77	58.76		
	59.75			
G.	60.67	60.43		
	60.20			
G.	67 36 62.02	63.26		
	64.50			
	Mean	60.46		

Frant Church and Tolsford.

Observers.	Five Microscopes.	Mean. Five.		
G.	25° 25′ 57″.75	″		
G.	59.57	57.91		
	56.25			
K.	55.52	56.83		
	58.15			
G.	25 25 59.47	58.57		
	57.67			
G.	25 25 63.02			
	Mean.. 58.42	57.77		

Leith Hill and Wrotham.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K.	87° 5′ 14″.55	15″.10	″	″
	15.65			
K.	15 97	14.98	18.19	17.34
	14.00		16.50	
G.	14.83	15.44		
	16.05			
K.	15.40	14.85		
	14.30			
C.	87 5 14.48	15.24		
	16.00			
G.	87 5 15.05	14.35		
	13.65			
G.	87 5 13.90	13.10		
	12.30			
G.	87 5	....	14.38	
	87 5	....	12.87	
G.	16.90	15.75	17.25	17.25
	14.60		17.25	
G.	87 5 17.90	16.46	17.63	16.63
	15.20		15.63	
	87 5 16.15	14.87	13.25	12.62
	13.60		12.00	
	Mean	15.01	......	15.96

Frant Church and Fairlight.

Observers.	Five Microscopes.	Mean. Five.		
K.	61° 31′ 22″.75	″		
K.	19.85	20.75		
	21.65			
G.	24.10	23.17		
	22.25			
K.	24.00	23.87		
	23.75			
C.	61 31 22.15	23.45		
	24.75			
G.	61 31 20.22	20.64		
	21.07			
G.	61 31 25.85			
	Mean	22.38		

Crowborough (Continued).

Leith Hill and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	129 4 34.40			
K.	36.85	35.92	38.62	38.43
	35.00		38.25	
G.	35.91	36.13		
	36.35			
K.	35.75	35.65		
	35.55			
C.	129 4 36.78	37.94		
	39.10			
G.	129 4 33.30	34.44		
	35.58			
G.	129 4 32.70	34.06		
	35.42			
G.	129 4 37.25	35.30	33.38	32.69
	33.35		32.00	
	Mean	35.63	......	35.56

Wrotham and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	103 42 25.60			
K.	23.63	23.99	23.06	23.25
	24.35		23.44	
G.	24.95	24.65		
	24.35			
K.	26.25	25.80		
	25.35			
C.	103 42 24.90	26.52		
	28.15			
G.	103 42 21.42	22.51		
	23.60			
G.	103 42 24.85	24.92		
	25.00			
G.	103 42 23.80	24.05	23.00	23.31
	24.30		23.62	
	Mean	24.63	......	23.28

Wrotham, and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	41 58 19.85			
K.	20.88	20.94	20.43	21.09
	21.00		21.75	
G.	21.08	20.69		
	20.30			
K.	20.35	20.80		
	21.25			
C.	41 58 22.30	22.70		
	23.10			
G.	41 58 18.25	20.09		
	21.93			
G.	41 58 18.80	20.96		
	23.12			
	41 58 21.10	20.42	20.13	20.06
	19.75		20.00	
	Mean	20.94	......	20.57

Stede Hill and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	61 44 5.75			
K.	2.75	3.05	2.63	2.16
	3.35		1.69	
G.	3.87	3.96		
	4.05			
K.	5.90	5.00		
	4.10			
C.	61 44 2.60	3.82		
	5.05			
G.	61 44 3.17	2.42		
	1.67			
G.	61 44 6.05	3.96		
	1.88			
G.	61 44 2.70	3.62	2.87	3.24
	4.55		3.62	
	Mean	3.69	......	2.70

Crowborough (Continued).

Frant Church and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	0 12 43.00			
K.	42.90	42.30	41.75	41.37
	41.70		41.00	
G.	41.25			
G.	39.77	40.28		
	41.80			
K.	41.90	41.12		
	40.35			
C.	0 12 40.45	40.37		
	40.30			
	Mean.. 41.34	41.02		

Stede Hill and Tolsford.

Observers.	Five Microscopes.	Mean. Five.
	° ′ ″	″
G.	25 38 39.00	
G.	39.57	38.81
	38.05	
K.	37.42	37.96
	38.50	
G.	25 38 42.42	40.34
	38.27	
G.	25 38 43.22	42.30
	41.38	
	Mean	39.85

Observations for identifying the Station.

	Readings.		Readings.
	° ′ ″		° ′ ″
Hartfield Spire	70 39 3.00	Crowborough Chapel Spire	11 31 19.00
Wadhurst Spire	7 4 48.75	Rotherfield Spire	23 52 44.25

Observations repeated.

	Readings.		Readings.
	° ′ ″		° ′ ″
Hartfield Spire	4 38 5.00	Crowborough Chapel Spire	125 20 25.50
Wadhurst Spire	120 53 48.00	Rotherfield Spire	137 41 46.50

At Tolsford.

Blancnez and Fairlight.

Observers.	Five Microscopes.	Mean. Five.
	° ′ ″	″
G.	118 34 46.95	47.80
	48.65	
G.	118 34 48.55	
G.	118 34 51.72	
	Mean.. 48.97	

Fiennes, and Montlambert Station.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.C.&G.	17 30 15.40	15.05	17.46	16.93
	14.70		16.41	
K.	15.80	16.46	16.38	17.10
K.C.&G.	17.13		17.83	
	Mean	15.75	......	17.01

Tolsford (Continued).

Folkstone and Fairlight.

Observers.	Five Microscopes.	Mean. Five.
G.	136° 51′ 43″.40	″ 44.72
	46.05	
K.	45.20	46.01
	46.83	
G.	136 51 46.85	46.40
	45.95	
K.	46.45	45.99
	45.53	
G.	136 51 48.85	48.00
	47.15	
K.	50.45	48.55
	46.65	
	Mean	46.61

Fairlight, and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.
G.	69° 7′ 60″.65	″ 60.40
	60.15	
K.	61.75	60.25
	58.75	
G.	69 7 57.50	59.05
	60.60	
K.	59.33	59.51
	59.70	
G.	69 7 54.50	54.72
	54.95	
K.	56.10	58.22
	60.35	
	Mean	58.69

Folkstone Church and Folkstone Station.

Observers.	Five Microscopes.	Mean. Five.
G.	14° 49′ 43″.70	″ 43.32
	42.95	
	Mean	43.32

Fiennes and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
K.	113° 18′ 17″.08	″ 16.90	″ 19.82	″ 19.34
	16.72		18.87	
K. C. & G.	17.50	18.01	20.34	21.25
	18.53		22.17	
	Mean	17.45	......	20.29

Fairlight and Crowborough.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	33° 24′ 10″.56	″ 8.48	″	″
	6.40			
G.	6.40	3.00		
	59.60			
K. C. & G.	5.12		2.28	
G.	33 24 10.00	9.19	9.62	8.96
	8.38		8.31	
	Mean .. 6.64	6.89	6.74	

Crowborough, and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.
G.	35° 43′ 48″.00	″
G.	35 43 48.10	51.72
	55.35	
	Mean.. 50.48	

Folkstone and Nôtre Dame.

Observers.	Five Microscopes.
G.	10° 44′ 15″.90
G.	10 44 16.20
K.	17.20
	Mean.. 16.43

Tolsford (Continued).

Folkstone and Blancnez.

Observers.	Five Microscopes.	Mean. Five.		
	° ′ ″	″		
G.	18 16 56.45	56.92		
	57.40			
G.	18 16 57.13			
	Mean . . 56.99			

Nôtre Dame and Fiennes.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	12 49 12.15	12.68	12.50	13.84
	13.22		15.18	
K.C.&G.	15.18	15.26	17.25	16.75
	15.35		16.25	
	Mean	13.97	. . . . . .	15.29

Nôtre Dame, and Montlambert Staff.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.C.&G.	30 19 29.88	30.51	33.63	33.85
	31.15		34.08	
	Mean	30.51		33.85

Fairlight, and Montlambert Staff.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
C.K.&G.	95 48 1.32	2.06	2.41	3.18
	2.80		3.96	
	2.80	2.76	3.96	4.15
	2.73		4.34	
	Mean	2.41	. . . . . .	3.66

Nôtre Dame and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	126 7 27.50			
G.	126 7 29.75			
K.	30.30		35.00	
K.C.&G.	32.68	33.28	37.59	38.00
	33.88		38.42	
	Mean 30.82	. . . .	37.00	

Stede Hill and Folkstone.

Observers.	Five Microscopes.	Mean. Five.		
	° ′ ″	″		
G.	154 0 15.95	14.87		
	13.80			
K.	13.92	14.54		
	15.16			
K.	13.05	13.73		
	14.42			
G.	154 0 15.65	14.55		
	13.45			
K.	13.70			
K.	14.22	14.49		
	14.77			
G.	154 0 16.65	17.27		
	17.90			
K.	13.45	13.22		
	13.00			
	Mean	14.67		

Folkstone, and Tenterden Church.

Observers.	Five Microscopes.			
	° ′ ″			
K.	166 49 58.53			
K.	55.58			
K.	166 49 60.40			
	Mean 58.17			

Tolsford (Continued).

Folkstone Pier Flag-staff, and Folkstone Station.

Observers.	Five Microscopes.	Mean. Five.		
G.	13° 4′ 14″.75 13.40	″ 14.07		
	Mean	14.07		

Folkstone and Crowborough.

	Five Microscopes.	Mean. Five.		
	170° 15′ 55″.25 46.75	″ 51.00		
	Mean	51.00		

Fairlight and Tenterden Church.

Observers.	Five Microscopes.			
K.	29° 58′ 8″.75			

Nôtre Dame and Blancnez.

Observers.	Five Microscopes.			
G.	7° 32′ 40″.55			

Angles derived at Tolsford.

	°	′	″
Fiennes and Fairlight	113	18	17.45
Fiennes and Montlambert	17	30	15.75
Montlambert and Fairlight.	95	48	1.70
Montlambert and Fairlight (observed)	95	48	2.41
Mean...Montlambert and Fairlight	95	48	2.05
Folkstone and Fairlight	136	51	46.61
Montlambert and Fairlight	95	48	2.05
Folkstone and Montlambert.	41	3	44.36
Folkstone and Nôtre Dame, Calais	10	44	16.43
Nôtre Dame, Calais, and Fiennes.	12	49	13.97
Fiennes and Montlambert	17	30	15.75
Folkstone and Montlambert.	41	3	46.15
	41	3	44.56
Mean...Folkstone and Montlambert	41	3	45.35

	°	′	″
Folkstone and Fairlight	136	51	46.61
Blancnez and Fairlight (observed)	118	34	48.97
Folkstone and Blancnez	18	16	57.64
Folkstone and Blancnez (observed)	18	16	56.99
Mean...Folkstone and Blancnez	18	16	57.31
Folkstone and Montlambert	41	3	45.35
Folkstone and Blancnez	18	16	57.31
Blancnez and Montlambert.	22	46	48.04
Blancnez and Fairlight (observed)	118	34	48.97
Montlambert and Fairlight	95	48	2.05
Blancnez and Montlambert.	22	46	46.92
	22	46	48.04
Mean...Blancnez and Montlambert	22	46	47.48

	°	′	″
Tenterden Church and Folkstone	166	49	58.17
Folkstone and Fairlight........	136	51	46.61
Tenterden Church and Fairlight.................	29	58	11.56
Tenterden Church and Fairlight (observed)........	29	58	8.75

And taking the value of these angles according to the number of the different parts of the circle from which they were obtained, that is as 30 to 10, we have,—

	°	′	″
Mean....Tenterden Church and Fairlight................	29	58	10.86

Observations for identifying the Station.

	Readings. °	′	″
Beachborough Summer-house ..	55	50	3.00
Stanford Church	28	10	11.62
Ashford Church..............	48	41	6.37
Left-hand Edge of the Summit of Lyme Castle	166	49	5.00
Right-hand Edge of the Summit of Lyme Castle.............	166	56	25.37
Left-hand Edge of the summit of Saltwood Castle	107	14	4.50

At Folkstone Station.

Montlambert, and Dungeness Light-House.

Observers.	Two Microscopes.		Two Microscopes.	
A.	° ′ 75 31		″ 42.75	
K.	75 31		41.00	
C.	75 31		39.75	
G.	75 31		41.13	
A.	75 31		40.01	
K.	75 31		43.50	
A.	75 31		41.75	
A.	75 31		38.87	
	Mean....	....	41.10	

Folkstone Church Vane, and Tolsford.

Observers.	Two Microscopes.		Two Microscopes.	
K.	° ′ 69 13		″ 51.62	
	Mean....	....	51.62	

Dover Flag-staff and Blancnez.

Observers.	Two Microscopes.		Two Microscopes.	
1821.				
A.	° ′ 50 26		″ 43.27	
K.	50 26		47.94	
K.	50 26		46.94	
K.	50 26		47.00	
A.	50 26		47.35	
K.	50 26		51.06	
	Mean....	....	47.28	

Nôtre Dame and Blancnez.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	° ′ ″ 9 21 19.85 17.15	″ 18.50	″ 18.75 16.25	″ 17.50
C.	9 21		21.12	
	Mean....	18.50	18.71	

Folkstone Station (Continued).

Fairlight and Tolsford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
1821.	° ′ ″	″	″	″
C.	36 17		58.13	
1822.				
G.	36 17		59.25	
G.	61.30	58.62	60.87	58.75
	55.95		56.63	
C.	36 17		54.75	
G.	36 17		54.56	
G.	36 17 56.35	55.50	55.13	54.69
	54.65		54.25	
	Mean	57.06	56.70	56.72

Dover Station and Nôtre Dame, Calais.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	41 16		25.81	
G.	29.10	30.70	29.88	31.00
	32.30		32.13	
C.	41 16		32.00	
	Mean	30.70	29.95	

Dover Station and Blancnez.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
1821.	° ′ ″	″	″	″
A.	50 37		48.12	
K.	50 37		47.19	
K.	50 37		53.00	
A.	50 37		50.37	
C.	50 37		51.69	
A.	50 37		48.69	
K.	50 37		48.75	
K.	50 37		54.62	
1822.				
G.	50 37 48.95	49.20	48.63	48.50
	49.45		48.38	
C.	50 37		53.12	
	Mean of all..	49.20	50.23	

Blancnez and Montlambert Lamps.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
A.	25 1		44.75	
K.	25 1		48.31	
C.	25 1		47.81	
A.	25 1 much	motion	41.88	
K.	25 1		48.37	
C.	25 1		48.94	
G.	25 1		50.00	
A.	25 1		46.81	
C.	25 1		46.25	
K.	25 1		45.94	
C.	25 1		45.13	
A.	25 1		47.18	
K.	25 1		46.31	
A.	25 1		47.93	
K.	25 1		46.00	
A.	25 1		45.41	
	Mean	....	46.69	

Dover Station and Dover Flag-staff.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
A.	0 11		4.75	
K.	0 11		0.25	
K.	0 11		6.00	
A.	0 11		3.12	
K.	0 11		3.56	
	Mean	....	3.54	

Blancnez, and Dungeness Light-House.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
A.	100 33		27.50	
K.	100 33		29.31	
C.	100 33		27.56	
A.	100 33		28.56	
K.	100 33		23.12	
	Mean	....	27.21	

Folkstone Station (Continued).

Blancnez and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
1821.	° ′ ″	″	″	″
A.	121 48		17.07	
C.	121 48		08.37	
A.	121 48		15.06	
K.	121 48		11.50	
1822.				
G.	121 48 12.55	14.65	12.50	14.93
	16.75		17.37	
C.	121 48		14.50	
		14.65	13.77	
	Mean used ..	14.13		

Montlambert and Fairlight.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
A.	96 46		32.32	
C.	96 46		23.24	
A.	96 46		27.88	
K.	96 46		25.50	
C.	96 46		28.82	
A.	96 46		25.12	
K.	96 46		25.19	
C.	96 46		26.63	
A.	96 46		25.12	
Mean....................			26.65	
Rejecting the first and second			26.32	

Folkstone Pier Flag-staff and Tolsford.

Observers.	Two Microscopes.		Two Microscopes.	
K.	° ″ 84 37		″ 49.0	
	Mean....	....	49.0	

Dungeness Light-House and Fairlight.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
A.	21 14		49.57	
C.	21 14		52.62	
A.	21 14		46.25	
	Mean....	....	49.48	

Nôtre Dame and Fairlight.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	131 9		35.76	
G.	32.40	33.15	31.25	32.43
	33.90		33.62	
C.	131 9		35.62	
	Mean....	33.15	34.06	

Angles derived at Folkstone.

	° ′ ″
Montlambert and Fairlight	96 46 26.32
Montlambert and Blancnez	25 1 46.69
Blancnez and Fairlight	121 48 13.01
Blancnez and Fairlight (observed)..........................	121 48 14.13
Mean....Blancnez and Fairlight..........................	121 48 13.57

Observations for identifying the Station.

	Readings.		
	°	′	″
Dover Castle Flag-staff	175	51	39.50
Summit of the Left Side of Martello Tower nearest the Beach	98	28	28.75
Right-hand Summit of ditto	99	3	38.50
Left-hand Summit of nearest Martello Tower	98	47	59.75
Right-hand Summit of nearest Martello Tower	99	38	36.25
Top of the Flag-staff Folkstone Harbour	119	46	45.25
Folkstone Church Vane Spindle	135	10	42.75
Tolsford Station	24	24	34.37

At Fairlight.

Stede Hill and Tolsford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
1821.				
G.	45 27		53.56	
	45 27		55.56	
1822.				
G.	45 27 54.95	55.97		
	57.00			
G.	55.92			
G.	45 27 56.17	54 89		
	53.62			
C.	51.45	51 66		
	51.87			
G.	45 27 54.65	56.07		
	57.50			
G.	45 27 50.20	51.97	51.12	53.46
	53.75		55.81	
	55.85	55.77	57.25	57.06
	55.70		56.87	
	Mean....	54.39	55.03	55.26

Dungeness and Blancnez.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
K.	4 59		11.00	
G.	4 59		12.12	
A.	4 59		15.13	
G.	4 59		12.68	
C.	4 59		13.41	
	Mean....	....	12.87	

Wrotham and Tolsford Staffs.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	77 23 57.62			
G.	56.07	56.98		
	57.90			
G.	77 23 57.55	57.60		
	57.65			
C.	58.40			
G.	77 23 57.75	57.92	53.63	55.87
	58.10		58.12	
	Mean....	57.50		

Wrotham and Tolsford Lamps.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	77 23 58.50	57.92		
	57.35			
G.	61.65	60.26		
	58.88			
K.	77 23 60.25	58.21		
	56.18			
G.	77 23 58.35	59.35	59.24	59.74
	60.35		60.25	
K.	58.10	59.55	58.63	55.56
	61.00		62.50	
C.	57.98	59.94	59.81	60.78
	61.90		61.75	
K.	77 23 59.95	61.15	58.75	59.37
	62.35		60.00	
	Mean....	59.48	......	58.86

Fairlight (Continued).

Crowborough and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	65 2 35.86	34.36		
	32.87			
G.	34.65			
G.	65 2 33.43	33.38		
	33.33			
C.	37.98	37.27		
	36.57			
G.	65 2 40.90	38.39	40.25	38.27
	35.88		36.29	
G.	33.50	35.75	34.00	35.81
	38.00		37.63	
	Mean....	35.83	......	37.04

Folkstone and Dungeness Light-House.

Observers.	Five Microscopes.		Two Microscopes.	
	° ′		″	
G. K.	21 50		6.51	
C.	21 50		7.13	
G.	21 50		5.25	
G.	21 50		12.75	
A. C.	21 50		4.50	
C.	21 50		2.25	
A.	21 50		4.25	
K.	21 50		8.06	
G.	21 50		4.88	
Mean			6.17	
Rejecting greatest and least			5.80	

Crowborough Staff, and Wrotham Lamp.

Observers.	Five Microscopes.	Mean. Five.		
	° ′ ″	″		
K.	33 6 32.18	31.91		
	31.65			
G.	29.60			
K.	33 6 31.95	29.34		
	26.73			
	Mean . . 30.42	30.62		

Crowborough and Folkstone.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	117 20 51.25	49.16		
	47.07			
G.	48.62	48.09		
	47.57			
G.	117 20 46.85	45.55		
	44.25			
C.	45.63	44.58		
	43.54			
G.	117 20		46.37	
	117 20		47.38	
	117 20		47.87	
	117 20		45.37	
	117 20		43.88	
	117 20		47.75	
G.	117 20 45.67	44.62	45.49	44.73
	43.58		43.97	
G.	44.80	45.85	45.37	46.06
	46.90		46.75	
	Mean	46.31	46.02	

Blancnez, and Fairlight Church.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
G.	6 16		28.00	
A.	6 16		27.81	
K.	6 16		29.63	
C.	6 16		26.63	
	Mean	....	28.01	

Dungeness Light-House and Montlambert.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
K.	22 38		42.13	
G.	22 38		35.25	
A.	22 38		40.50	
G.	22 38		38.87	
K.	22 38		36.50	
	Mean	....	38.65	

Fairlight (Continued).

Tolsford and Folkstone.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
1821.				
G.	6° 50′ ″	″	14.69″	
G. & C.	6 50		11.38	
K. & G.	6 50		14.94	
G.	6 50		16.75	
1822.				
G.	6 50 20.44	18.82		
	17.20			
K.	18.58	17.97		
	17.37			
G.	18.05	18.48		
	18.92			
G.	6 50 17.25	17.27		
	17.30			
C.	16.20	15.65		
	15.10			
G.	6 50 17.65	18.72		
	19.80			
G.	6 50 14.57	14.26	14.12	12.99
	13.95		11.87	
G.	15.45	14.32	14.12	13.18
	13.20		12.25	
	Mean	16.94	13.77	13.08

Spire for the Pole Star and Folkstone.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	62° 50′ 55.15″	″	″	″
G.	62 50 54.10	53.92	54.74	54.18
	53.75		53.62	
	Mean.. 54.33			

Fairlight Church and Montlambert.

Observers.	Two Microscropes.		Two Microscopes.	
A.	11° 22′		58.19″	
K.	11 22		61.50	
	Mean	....	59.84	

Crowborough and Wrotham Staffs.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	33° 6′ 32.25″	″	″	″
G.	34.50	32.62		
	30.75			
G.	33 6 32.05	30.67		
	29.30			
C.	31.03			
G.	33 6 31.60	33.60	37.62	37.00
	35.60		36.38	
	Mean.. 32.14	32.29		

Crowborough and Tolsford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	110° 30′ 30.81″	30.34″	″	″
	29.87			
G.	30.57	29.61		
	28.65			
G.	110 30 29.60	28.27		
	26.95			
C.	29.43	28.93		
	28.44			
G.	110 30 31.10	30.61	31.37	29.63
	30.13		27.90	
G.	29.35	31.52	31.25	32.87
	33.70		34.50	
	Mean	29.88	....	31.25

Wrotham and Stede Hill.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
G.	31° 56′ 0.62″	″	″	″
G.	0.15			
G.	31 56 1.38	2.71		
	4.03			
C.	6.95			
G.	31 56 1.90	2.15	6.38	3.81
	2.40		1.25	
	Mean.. 2.49	2.43		

Fairlight (Continued).

Wrotham and Tolsford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
K.	77 23 58.50	57.92		
	57.35			
G.	61.65	60.26		
	58.88			
G.	77 23 57.62			
K.	60.25	58.21		
	56.18			
G.	56.07	56.98		
	57.90			
G.	77 23 57.55	57.60		
	57.65			
C.	58.40			
G.	77 23 58.35	59.35	59.24	59.74
	60.35		60.25	
K.	58.10	59.55	58.63	60.56
	61.00		62.50	
C.	57.98	59.94	59.81	60.78
	61.90		61.75	
K.	77 23 59.95	61.45	58.75	59.38
	62.95		60.00	
G.	57.75	57.92	53.63	55.88
	58.10		58.12	
	Mean	58.92		59.27

Blancnez and Montlambert.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
A.	17 39		26.00	
K.	17 39		31.13	
G.	17 39		23.13	
A.	17 39		25.37	
G.	17 39		26.19	
	Mean	....	26.36	

Tenterden Church and Tolsford.

Observer.	Two Microscopes.		Two Microscopes.	
	° ′		″	
G.	39 19		36.44	

Tenterden Church and Folkstone.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
G.	46 9		50.87	
C. & A.	46 9		46.50	
K. & G.	46 9		51.38	
	Mean		49.58	

Spire for the Pole Star and Tolsford.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	56 0 37.90			
G.	56 0 39.53	39.66	40.62	41.18
	39.80		41.75	
	Mean.. 39.08			

Frant and Stede Hill.

Observer.	Five Microscopes.		Two Microscopes.	
	° ′ ″		″	
	51 18		19.18	
	51 18		16.13	
G.	51 18 13.53			
	Mean 13.53	....	17.65	

Folkstone, and Fairlight Church.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
C. & A.	33 5		45.56	
C.	33 5		41.63	
A.	33 5		46.12	
K.	33 5		47.81	
	Mean	....	45.28	

Fairlight (Continued).

Frant Church and Tenterden Church.

Observers.	Two Microscopes.		Two Microscopes.	
	° ′		″	
K. & G.	57 26		31.87	
C.	57 26		41.12	
A.	57 26		38.13	
	Mean	....	37.04	

Frant and Crowborough.

Observer.	Five Microscopes.			
	° ′ ″			
G.	13 44 19.90			

Wrotham and Folkstone.

Observers.	Five Microscopes.	Mean. Five.	Two Microscopes.	Mean. Two.
	° ′ ″	″	″	″
G.	84 14 14.82			
G.	14.12	15.47		
	16.82			
G.	84 14 14.80	14.87		
	14.95			
C.	14.60			
G.	84 14 13.20	12.25	7.75	9.06
	11.30		10.37	
	Mean.. 14.33	14.19		

Angles derived at Fairlight.

	°	′	″
Folkstone and Montlambert	44	28	44.74
Folkstone and Tolsford	6	50	16.94
Tolsford and Montlambert ..	51	19	1.68
Folkstone and Dungeness	21	50	5.80
Dungeness and Blancnez	4	59	12.87
Folkstone and Blancnez.....	26	49	18.67
Folkstone and Blancnez, using the mean of all the angles between Folkstone and Dungeness	26	49	19.04
Tolsford and Folkstone	6	50	16.94
Tolsford and Blancnez......	33	39	35.99

	°	′	″
Folkstone and Blancnez	26	49	18.67
Blancnez and Montlambert	17	39	26.36
Folkstone and Montlambert .	44	28	45.03
Folkstone and Dungeness	21	50	5.80
Dungeness and Montlambert.....	22	38	38.65
	44	28	44.45
	44	28	45.03
Mean...Folkstone and Montlambert..................	44	28	44.74
Tenterden Church and Folkstone .	46	9	49.58
Tolsford and Folkstone.........	6	50	16.94
Tenterden Church and Tolsford	39	19	32.64
Stede Hill and Frant Church	51	18	15.59
Crowborough and Stede Hill	65	2	35.83
Frant Church and Crowborough	13	44	20.24

Observations for identifying the Station.

	Readings.				Readings.		
	°	′	″		°	′	″
Ashford Tower	176	0	7.62	East Edge of Fairlight Mill	130	54	24.62
Mr. Fuller's Observatory Dome	84	37	51.12	Hastings Church	4	9	9.12
Roy's Station	113	33	57	Dungeness Light-House	46	9	36.50
Church about three miles	131	32	13.25	Fairlight Church	57	25	13.49
West Edge of Fairlight Mill	149	55	59.25				

From the Station to the nearest angle of the Windmill, 69 feet 2 inches.

Roy's Station from the nearest angle of the Windmill, 26 feet 4 inches.

Roy's Station from the new Station, 87 feet 8¼ inches.

At Blancnez.

Montlambert Lamp and Fairlight Lamp.

Two Microscopes.

	°	′	″
	75	56	24.64
	75	56	23.98
	75	56	23.03
	75	56	25.25
	75	56	25.53
Mean	75	56	24.49

Fairlight Lamp and Folkstone Lamp.

	°	′	″
	31	22	30.72
	31	22	33.99
	31	22	27.82
	31	22	30.56
	31	22	33.30
	31	22	28.03
	31	22	30.60
	31	22	29.91
	31	22	31.27
	31	22	32.61
	31	22	31.53
	31	22	31.53
	31	22	32.68
	31	22	31.25
Mean	31	22	31.13

Montlambert Lamp and Folkstone Lamp.

Two Microscopes.

	°	′	″
	107	18	56.17
	107	18	55.71
	107	18	53.64
	107	18	57.18
	107	18	56.78
Mean	107	18	55.90

Dungeness, and Folkstone Lamp.

	°	′	″
	28	58	55.91
	28	59	2.06
	28	58	55.84
Mean	28	58	57.94

Dungeness, and Fairlight Lamp.

	°	′	″
	2	23	35.36
	2	23	29.47
	2	23	35.69
Mean	2	23	33.51

Montlambert Staff and Fiennes.

Two Microscopes.

	°	′	″
	51	21	34.19
	51	21	35.18
	51	21	33.88
	51	21	33.12
	51	21	29.97
	51	21	37.53
Mean	51	21	33.98

Dungeness, and Montlambert Lamp.

	°	′	″
	78	20	0.33
	78	20	0.33

Nôtre Dame Calais, and Folkstone Lamp.

	°	′	″
	131	56	37.34
	131	56	39.23
	131	56	40.39
	131	56	39.53
Mean	131	56	39.12

Folkstone Lamp and Tolsford.

Two Microscopes.

	°	′	″
	3	36	52.37
	3	36	50.05
	3	36	52.78
Mean	3	36	51.73

Folkstone Staff and Dover Station.

	°	′	″
	12	3	50.81
	12	3	53.44
	12	3	51.41
Mean	12	3	51.88
Add....			2.00
	12	3	53.88

Dover Station and Nôtre Dame Calais.

	°	′	″
	119	52	47.12
	119	52	53.53
Mean	119	52	50.32

Blancnez (Continued).

Folkstone Staff and Tolsford.
Two Microscopes.
3° 36′ 50.00″
3 36 51.63
3 36 48.88
3 36 53.37
3 36 49.63
3 36 51.25
3 36 54.88
Mean 3 36 51.38
Subtract.... 2.00
3 36 49.38

Nôtre Dame Calais, and Folkstone Staff.
131° 56′ 44.94″
131 56 39.22
131 56 37.93
131 56 37.43
Mean 131 56 39.88
Add.... 2.00
131 56 41.88

Fairlight, and South Foreland High Light.
49° 16′ 42.54″
49 16 42.54

Folkstone Staff, and South Foreland Low Light.
17° 24′ 16.37″
Add.... 2.00
17 24 18.37

Dover Castle Flag-staff and Folkstone Staff.
Two Microscopes.
12° 1′ 15.43″
12 1 15.75
12 1 17.75
Mean 12 1 16.31
Add...... 2.00
12 1 18.31

Dover Station, and Dover Castle Flag-staff.
0° 2′ 33.66″
0 2 35.38
0 2 37.69
Mean 0 2 35.58

Tolsford, and Fairlight Staff.
27° 45′ 41.86″
27 45 42.62
27 45 37.13
27 45 36.25
Mean 27 45 39.46
Subtract.. 0.49
27 45 38.97

Tolsford, and Fairlight Lamp.
27° 45′ 38.23″
27 45 39.86
27 45 38.75
Mean 27 45 38.95

Nôtre Dame Calais, and Fiennes.
Two Microscopes.
69° 22′ 50.78″
69 22 53.50
69 22 54.23
69 22 56.31
69 22 52.92
69 22 52.79
69 22 53.63
Mean 69 22 53.45

Folkstone Staff, and South Foreland High Light.
17° 54′ 17.50″
Add.... 2.00
17 54 19.50

Folkstone Lamp, and South Foreland High Light.
17° 54′ 11.27″
17 54 11.27

Folkstone Lamp, and South Foreland Low Light.
17° 24′ 16.55″
17 24 16.55

Fairlight, and South Foreland Low Light.
48° 46′ 47.82″
48 46 47.82

North Foreland Light-House, and Folkstone Staff.
Two Microscopes.
41° 51′ 11.50″
Add.... 2.00
41 51 13.50

Montlambert Lamp and Fiennes.
51° 21′ 30.67″
51 21 27.04
51 21 29.85
51 21 32.16
51 21 30.29
Mean 51 21 30.00

Centre of Dunkirk Tower, and Nôtre Dame Calais.
5° 13′ 50.87″
5 13 49.98
5 13 50.91
5 13 50.28
Mean 5 13 50.51

Dover Castle Flag-staff and Nôtre Dame Calais.
119° 55′ 22.50″
119 55 27.19
Mean 119 55 24.84

Angles derived at Blancnez.

	°	′	″
Montlambert and Folkstone	107	18	55.90
Folkstone and Tolsford $\frac{(3° 36' 49''.38 \times 7) + (3° 36' 51''.73 \times 3)}{10} =$	3	36	50.09
Montlambert and Tolsford	103	42	5.81
Fairlight and Folkstone	31	22	31.13
Tolsford and Folkstone	3	36	50.09
Fairlight and Tolsford	27	45	41.04
Fairlight and Tolsford (observed)	27	45	38.95
Mean....Fairlight and Tolsford	27	45	39.99

The Station at Blancnez is in a right line drawn from the Ball of Nôtre Dame, Calais, to a point upon the wall of the Guard-house, distant from the north edge of the house 4 feet 3.25 inches, and from the north-east edge 14 feet 10.3 inches. Mr. Gardner cut a cross upon the wall, marking this point. The distance on the ground from a vertical line passing through the cross to the Station is 107 feet 5 inches.

At Montlambert.

Observers.	Folkstone Lamp and Blancnez. Two Microscopes.
K.	47° 39′ 18″.25
A.	47 39 19.44
G.	47 39 21.00
M.	47 39 19.75
C.	47 39 20.75
A.	47 39 18.87
K.	47 39 16.93
A.	47 39 17.19
A.	47 39 17.25
A. & C.	47 39 15.50
Mean..	....47 39 18.49

Observers.	Dungeness, and Folkstone Lamp. Two Microscopes.
A.	27° 56′ 55″.62
	27 56 55.62

Observers.	Dungeness and Blancnez. Two Microscopes.
C.	75° 51′ 13″.63
A. C.	75 51 14.87
Mean..	....75 51 14.25

	Dungeness, and Fairlight Lamp.
A.	10° 47′ 54″.25
	10 47 54.25

	S. Foreland Light and Folkstone.
C.	14° 35′ 16″.12
	14 35 16.12

	Fairlight Lamp and Tolsford.
A.	32° 53′ 1″.62
	32 53 1.62

	Fairlight Mill and Folkstone.
A.C.&K.	38° 46′ 0″.48
	38 46 0.48

	S. Foreland Light* and Folkstone.
A. & C.	14° 58′ 42″.5
	14 58 42.5

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* There are two Lights at the South Foreland, the High and the Low Light.

Montlambert (Continued).

Fairlight Lamp and Folkstone Lamp.

Observers.	Two Microscopes.
	° ′ ″
A.	38 44 55.94
K.	38 44 57.44
C.	38 44 50.38
A.	38 44 52.44
K.	38 44 54.50
C.	38 44 52.82
A. & C.	38 44 56.75
..	....
C.	38 44 52.63
A.	38 44 52.57
K.	38 44 55.75
C.	38 44 49.92
A.	38 44 49.87
Mean..	....38 44 53.42

Tolsford, and Folkstone Staff.

	° ′ ″
C.	5 51 52.32
A. & C.	5 51 49.56
Mean..	.... 5 51 50.94

Tolsford and Blancnez.

Observers.	Two Microscopes.
	° ′ ″
C.	53 31 8.79
C.	53 31 12.00
A. & C.	53 31 6.44
Mean......	53 31 9.08

Fiennes and Tolsford.

	° ′ ″
C.	87 58 48.58
C.	87 58 50.50
A. & C.	87 58 47.36
Mean..	....87 58 48.81

Fiennes and Blancnez.

Observers.	Two Microscopes.
	° ′ ″
K.	34 27 39.68
G.	34 27 40.06
M.	34 27 37.62
C.	34 27 39.79
K.	34 27 41.37
K.	34 27 39.75
A.	34 27 41.07
C.	34 27 39.18
K.	34 27 40.31
C.	34 27 38.68
C.	34 27 38.50
A.	34 27 40.88
A. & C.	34 27 40.92
Mean..	....34 27 39.83

Angles derived at Montlambert.

	°	′	″
Fairlight and Folkstone	38	44	53.43
Tolsford and Folkstone	5	51	50.94
Fairlight and Tolsford	32	53	2.49
Fairlight and Tolsford (observed)	32	53	1.62
Mean....Fairlight and Tolsford	32	53	2.05
Fairlight and Folkstone	38	44	53.43
Folkstone and Blancnez	47	39	18.49
Fairlight and Blancnez	86	24	11.91

	°	′	″
Folkstone and Blancnez	47	39	18.49
Tolsford and Folkstone	5	51	50.94
Tolsford and Blancnez	53	31	9.43
Tolsford and Blancnez (observed)	53	31	9.08
Mean....Tolsford and Blancnez	53	31	9.25

The Station at Montlambert is on the North Bastion, about 7½ feet from the angle, measuring from the foot of the parapet, and equally distant from the faces.

OBSERVATIONS *of the Pole Star.*

1821, October 3rd, at Blancnez. In the evening. Chronometer slow 1m 46s.4 on Mean Time.

	Readings.
Nôtre Dame, Calais	51° 49′ 43″.06
South Foreland High Light	117 47 13 .55
South Foreland Low Light	117 17 18 .63

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
5 59 23.5	91 8 4	164 38 46.50	164 38 54.81	2 35 59	162 2 55.81
6 6 53.0		164 39 3.12			
6 13 10.0	88 10 34	164 39 10.25	164 39 11.12	2 36 14	162 2 57.12
6 16 43.0		164 39 12.00			
6 18 35.0	87 3 46	164 39 11.37	164 39 11.49	2 36 13	162 2 58.49
6 20 5.0		164 39 11.62			
6 21 21.0	86 19 46	164 39 9.87	164 39 9.31	2 36 10	162 2 59.31
6 23 16.0		164 39 8.75			
Telescope inverted.					
6 43 49.0	80 37 20	164 38 12.25	164 38 5.81	2 34 56	162 3 9.81
6 46 19.0		164 37 59.37			

	Readings.
South Foreland High Light	117° 47′ 16″.21
South Foreland Low Light	117 17 22 .53

1822, August 25th, at Fairlight. In the morning. Chronometer slow 3m 7s.64 on Mean Time.

	Reading.
Summit of the Spire of a Church	134° 18′ 59″.30

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
8 58 43.50	94 19 42	135 47 31.0	135 47 37.5	2 34 54	138 22 31.50
9 1 11.50		135 47 44.0			
Telescope inverted.					
9 11 28.00	97 27 58	135 48 33.75	135 48 40.2	2 33 45	138 22 25.20
9 13 28.30		135 48 46.65			

	Reading.
Summit of the Spire	134° 19′ 0″.27

Much motion in the Spire.

1822, August 25th, at Fairlight. In the evening. Chronometer slow 3m 7s.64 on Mean Time.

Reading.
Wrotham Lamp .... 112° 55′ 34″.4

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
8 39 9	89 59 43.6	140 58 6.25	140 58 8.62	2 35 46	138 22 22.62
8 42 59		140 58 11.00			
8 45 59	88 22 14	140 58 14.65	140 58 14.72	2 35 52	138 22 22.72
8 48 27		140 58 14.80			
		Telescope inverted.			
8 52 20	86 49 28.4	140 58 18.60	140 58 17.62	2 35 49	138 22 28.62
8 54 25.7		140 58 16.65			
8 58 15	85 36 16	140 58 8.55	140 58 8.55	2 35 44	138 22 24.55

Reading.
Wrotham Lamp .... 112° 55′ 33″.00

August 26th, at Fairlight. In the evening. Chronometer slow 3m 9s.9 on Mean Time.

Reading.
Wrotham Lamp .... 99° 36′ 33″.97

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
8 39 42	89 2 12.50	127 39 18.20	127 39 19.80	2 35 50	125 3 29.8
8 41 51		127 39 21.35			
8 44 4	87 55 24	127 39 24.05	127 39 23.22	2 35 51	125 3 32.22
8 46 22		127 39 22.40			
		Telescope inverted.			
8 49 50	86 30 25.50	127 39 18.05	127 39 16.25	2 35 49	125 3 27.25
8 51 54		127 39 14.45			
8 53 55	85 33 38.50	127 39 11.65	127 39 10.22	2 35 44	125 3 26.22
8 55 22		127 39 8.80			

Reading.
Wrotham Lamp .... 99° 36′ 35″.58

Much motion in the Lamp.

August 27th, at Fairlight. In the evening. Chronometer slow 3m 12s.1 on Mean Time.

	Reading.
Tolsford Lamp	4° 48′ 41″.50

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
8 36 59	88 39 23.50	135 27 38.00	135 27 33.40	2 35 51	132 51 42.40
8 39 20		135 27 28.80			
8 40 49	87 51 1.00	135 27 36.95	135 27 36.77	2 35 52	132 51 44.77
8 41 56		135 27 36.60			
8 43 3	87 25 49.00	135 27 35.85	135 27 35.85	2 35 51	132 51 44.85
Telescope inverted.					
8 45 19	86 21 09.00	135 27 14.80	135 27 21.62	2 35 48	132 51 33.62
8 49 23		135 27 28.45			
8 50 44	85 30 15.00	135 27 22.55	135 27 22.55	2 35 42	132 51 40.55

	Reading.
Tolsford Lamp..	4° 48′ 35″.08

September 7th, at Tolsford. In the morning. Chronometer slow 5m 40s on Mean Time.

	Reading.
Folkstone Staff	34° 32′ 27″.43

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
7 25 27	84 26 42.50	116 29 33.45	116 29 30.42	2 36 14	119 5 44.42
7 28 32		116 29 27.40			
7 30 42	85 53 4.50	116 29 22.10	116 29 18.77	2 36 25	119 5 43.77
7 36 46		116 29 15.45			
7 41 14	88 20 13.00	116 29 12.45	116 29 12.95	2 36 32	119 5 44.95
7 43 48		116 29 13.45			
Telescope inverted.					
7 48 7	89 55 6	116 29 1.60	116 29 2.72	2 36 26	119 5 28.72
7 49 32		116 29 3.85			
7 51 24	90 49 0	116 29 7.55	116 29 59.7	2 36 20	119 5 29.75
7 53 25		116 29 11.95			
8 2 32	93 37 5	116 29 40.95	116 29 43.72	2 35 46	119 5 29.72
8 4 38.5		116 29 46.50			

	Reading.
Folkstone Staff	34° 32′ 16″.25

September 19th, at Crowborough. In the morning. Chronometer slow 2ᵐ 15ˢ on Mean Time.

Reading.
Frant Church Staff .... 12° 4′ 8″.55

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
6 59 30	88 44 47.00	129 54 14.55	129 54 16.07	2 36 14	132 30 30.07
7 1 24		129 54 17.60			
7 2 37	89 17 23.00	129 54 19.05	129 54 19.05	2 36 12	132 30 31.05
Telescope inverted.					
7 4 22	89 59 59.60	129 54 17.35	129 54 18.27	2 36 9	132 30 27.27
7 6 32		129 54 19.20			
7 7 37	90 38 43.00	129 54 19.95	129 54 21.25	2 36 5	132 30 26.25
7 8 48		129 54 22.55			

Reading.
Frant Church Staff........................ 12° 4′ 6″.17

September 20th, at Crowborough. In the morning. Chronometer slow 2ᵐ 17ˢ.6 on Mean Time.

Reading.
Frant Church Staff (motion) .... 12° 4′ 22″.7

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
6 39 54	84 45 38	129 54 46.40	129 54 45.47	2 36 0	132 30 45.47
6 41 20		129 54 44.55			
6 42 29	85 23 14	129 54 41.60	129 54 40.00	2 36 5	132 30 45.00
6 43 45		129 54 38.40			
6 45 37	86 8 43.50	129 54 35.50	129 54 34.82	2 36 10	132 30 44.82
6 46 40		129 54 34.15			
6 47 55	86 44 42.40	129 54 32.60	129 54 31.75	2 36 13	132 30 44.75
6 49 9		129 54 30.90			
Telescope inverted.					
6 53 13	88 2 55.50	129 54 46.45	129 54 46.50	2 36 15	132 31 1.50
6 54 15		129 54 46.55			
6 55 15	88 40 16.00	129 54 47.05	129 54 47.40	2 36 14	132 31 1.40
6 57 11		129 54 47.75			
6 58 51	88 56 16.00	129 54 49.10	129 54 49.77	2 36 13	132 31 2.77
6 59 42		129 54 50.45			
7 1 46	90 3 45.00	129 54 54.55	129 54 54.55	2 36 9	132 31 3.55

Reading.
Frant Church Staff (steady) .... 12° 4′ 34″.01

September 21st, at Crowborough. In the morning. Chronometer slow 2m 19s.6 on Mean Time.

Frant Church Staff .... Reading. 160° 14′ 11″.73

Chronometer.	Mean Horary Angle.	Reading at the Star.	Mean Reading at the Star.	Azimuth.	Reading at the Meridian.
h m s	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
6 41 32 6 44 11	86 36 33.60	98 4 25.55 98 4 22.30	98 4 23.92	2 36 12	100 40 35.92
6 47 11	87 41 37.00	98 4 20.90	98 4 20.90	2 36 15	100 40 35.90
		Telescope inverted.			
6 50 8 6 52 2	88 40 16.40	98 4 31.45 98 4 32.20	98 4 31.82	2 36 14	100 40 45.82
6 53 42 6 54 47	89 27 46.40	98 4 33.80 98 4 34.15	98 4 33.97	2 36 11	100 40 44.97

Frant Church Staff .... Reading. 160° 14′ 18″.66

Deductions from the preceding Tables.

Blancnez.

	°	′	″
1821, October 3rd: Mean Reading at the Meridian	162	2	57.68
At Nôtre Dame, Calais	51	49	43.06
Between Nôtre Dame Calais, and the Meridian	69	46	45.38
Between Nôtre Dame Calais, and Fairlight	163	19	11.63
Between Fairlight and the Meridian	93	32	26.25
Between Fairlight and the Meridian, using the South Foreland High Light	93	32	26.67
Between Fairlight and the Meridian, using the South Foreland Low Light	93	32	26.87
Mean . .	93	32	26.60

	°	′	″
Reading at the Meridian (the Telescope inverted)	162	3	9.81
At the South Foreland High Light	117	47	16.21
Between the South Foreland High Light and the Meridian	44	15	53.60
Between the South Foreland High Light and Fairlight	49	16	42.54
Between Fairlight and the Meridian (Telescope inverted)	93	32	36.14
Between Fairlight and the Meridian, using South Foreland Low Light (Telescope inverted)	93	32	35.10
Mean	93	32	35.62
Mean (above)	93	32	26.60
Between Fairlight and the Meridian	93	32	31.11

Fairlight.

	°	′	″
1822, 25th August A.M. Reading at the Meridian	138	22	31.50
Spire of a Church	134	18	59.30
Between the Spire and the Meridian	4	3	32.20
Between Folkstone and the Spire	62	50	54.33
Between Folkstone and the Meridian	58	47	22.13
Between Folkstone and Blancnez	26	49	18.67
Between Blancnez and the Meridian	85	36	40.80

	°	′	″
Reading at the Meridian (Telescope inverted)	138	22	25.20
Spire of a Church	134	19	0.27
Between the Spire and the Meridian	4	3	24.93
Between Folkstone and the Spire	62	50	54.33
Between Folkstone and the Meridian (Telescope inverted)	58	47	29.40
Between Folkstone and Blancnez	26	49	18.67
Between Blancnez and the Meridian (Telescope inverted)	85	36	48.07
Between Blancnez and the Meridian (above)	85	36	40.80
Between Blancnez and the Meridian (Mean)	85	36	44.43

	°	′	″
25th August P.M. Mean Reading at the Meridian	138	22	22.62
Wrotham Lamp	112	55	34.40
Between Wrotham and the Meridian	25	26	48.22
Between Wrotham and Blancnez	111	3	32.87
Between Blancnez and the Meridian	85	36	44.65

	°	′	″
Mean Reading at the Meridian (Telescope inverted)	138	22	26.58
Wrotham Lamp	112	55	33.00
Between Wrotham and the Meridian	25	26	53.58
Between Wrotham and Blancnez	111	3	32.87
Between Blancnez and the Meridian (Telescope inverted)	85	36	39.29
Between Blancnez and the Meridian (above)	85	36	44.65
Between Blancnez and the Meridian . . . Mean	85	36	41.97

	°	′	″
26th August P.M. Mean reading at the Meridian	125	3	31.01
Wrotham Lamp	99	36	33.97
Between Wrotham and the Meridian	25	26	57.04
Between Wrotham and Blancnez	111	3	32.87
Between Blancnez and the Meridian	85	36	35.83

	°	′	″
Mean Reading at the Meridian (Telescope inverted)	125	3	26.73
Wrotham Lamp	99	36	35.58
Between Wrotham and the Meridian	25	26	51.15
Between Wrotham and Blancnez	111	3	32.87
Between Blancnez and the Meridian (Telescope inverted)	85	36	41.72
Between Blancnez and the Meridian (above)	85	36	35.83
Between Blancnez and the Meridian . . . Mean	85	36	38.77

	°	′	″
27th August P.M. Mean Reading at the Meridian	132	51	44.00
Tolsford Lamp	4	48	41.50
Between Tolsford and the Meridian	51	56	57.50
Between Tolsford and Blancnez	33	89	35.99
Between Blancnez and the Meridian	85	36	33.49

	°	′	″
Mean Reading at the Meridian (Telescope inverted)	132	51	37.08
Tolsford Lamp	4	48	35.08
Between Tolsford and the Meridian	51	56	58.00
Between Tolsford and Blancnez	33	39	35.99
Between Blancnez and the Meridian (Telescope inverted)	85	36	33.99
Between Blancnez and the Meridian (above)	85	36	33.49
Between Blancnez and the Meridian . . Mean	85	36	33 74

Summary.

At Fairlight, the Angle between the Meridian and Blancnez:

	°	′	″
August 25, A.M.	85	36	44.43
P.M.	85	36	41.97
August 26, P.M.	85	36	38.77
August 27, P.M.	85	36	33.74
Between the Meridian and Blancnez	85	36	39.73
Between Tolsford and Blancnez	33	39	35.99
Between the Meridian and Tolsford	51	57	3.74
Between Crowborough and Tolsford	110	30	29.88
Between the Meridian and Crowborough	58	33	26.14

Tolsford.

	°	′	″
1822. September 7th, A.M. Reading at the Meridian	119	5	44.38
Folkstone	34	32	27.40
Between Folkstone and the Meridian	95	26	43.02
Between Folkstone and Crowborough	189	44	6.50
Between Crowborough and the Meridian	94	17	23.48

	°	′	″
Mean reading at the Meridian (Telescope inverted)	119	5	29.39
Folkstone	34	32	16.25
Between Folkstone and the Meridian	95	26	46.86
Between Folkstone and Crowborough	189	44	6.50
Between Crowborough and the Meridian (Telescope inverted)	94	17	19.64
Between Crowborough and the Meridian (above)	94	17	23.48
Between Crowborough and the Meridian. . . Mean	94	17	21.56

Crowborough.

	°	′	″
September 19th, A.M. Mean reading at the Meridian	132	30	30.56
Frant Church	12	4	8.55
Between Frant and the Meridian	59	33	37.99
Between Tolsford and Frant	25	25	58.37
Between Tolsford and the Meridian	84	59	36.36

	°	′	″
Mean reading at the Meridian (Telescope inverted)	132	30	26.76
Frant Church	12	4	6.17
Between Frant and the Meridian	59	33	39.41
Between Tolsford and Frant	25	25	58.37
Between Tolsford and the Meridian (Telescope inverted)	84	59	37.78
Between Tolsford and the Meridian (above)	84	59	36.36
Between Tolsford and the Meridian. . . Mean	84	59	37.07

	°	′	″
September 20th, A.M. Mean reading at the Meridian . . .	132	20	45.01
Frant Church . . .	12	4	22.70
Between Frant and the Meridian	59	33	37.69
Between Tolsford and Frant	25	25	58.37
Between Tolsford and the Meridian	84	59	36.06

	°	′	″
Mean reading at the Meridian (Telescope inverted)	132	31	2.30
Frant Church	12	4	34.01
Between Frant and the Meridian	59	33	31.71
Between Tolsford and Frant	25	25	58.37
Between Tolsford and the Meridian (Telescope inverted) .	84	59	30.08
Between Tolsford and the Meridian (above)	84	59	36.06
Between Tolsford and the Meridian. . . Mean . . .	84	59	33.07

	°	′	″
September 21st., A.M. Mean reading at the Meridian . . .	100	40	35.91
Frant Church . . .	160	14	11.73
Between Frant and the Meridian	59	33	35.82
Between Tolsford and Frant.	25	25	58.37
Between Tolsford and the Meridian	84	59	34.19

	°	′	″
Mean reading at the Meridian (Telescope inverted)	100	40	45.39
Frant Church	160	14	18.66
Between Frant and the Meridian	59	33	33.27
Between Tolsford and Frant	25	25	58.37
Between Tolsford and the Meridian (Telescope inverted) .	84	59	31.64
Between Tolsford and the Meridian (above)	84	59	34.19
Between Tolsford and the Meridian. . . Mean . . .	84	59	32.91

Summary.

	°	′	″
At Crowborough the Angle between the Meridian and Tolsford—19th September, A.M.	84	59	37.07
20th September, A.M.	84	59	33.07
21st September, A.M.	84	59	32.91
Between the Meridian and Tolsford	84	59	34.35
Between Crowborough and Fairlight	36	5	24.01
Between the Meridian and Fairlight	121	4	58.36

X. *On the phænomena of volcanoes.* *By Sir* HUMPHRY DAVY, *Bart. F.R.S.*

Read March 20, 1828.

WHEN in the years 1807 and 1808 I discovered that the alkalies and the earths were composed of inflammable matter united to oxygen, a number of inquiries suggested themselves with respect to various parts of chemical science, some of which were capable of being immediately assisted by experiment, and others required for their solution a long series of observations, and circumstances obtained only with difficulty. Of the last kind were the inferences concerning the geological appearances connected with these discoveries.

The metals of the alkalies, and those of such of the earths as I had decomposed, were found to be highly combustible, and altered by air and water even at the usual temperatures of the atmosphere; it was not possible, consequently, that they should be found at the surface of the globe, but probable that they might exist in the interior: and allowing this hypothesis, it became easy to account for volcanic fires, by exposure of the metals of earths and alkalies to air and water; and to explain, not only the formation of lavas, but likewise that of basalts and many other crystalline rocks, from the slow cooling of the products of combustion or oxidation of the newly discovered substances.

I developed this opinion in a paper on the decomposition of the earths, published in 1808; and since 1812 I have endeavoured to gain evidence respecting it by examining volcanic phænomena of ancient and recent occurrence in various parts of Europe.

In this communication I shall have the honour of laying before the Royal Society some results of my inquiries. If they do not solve the problem respecting the cause of volcanic fires, they will, I trust, be found to offer some elucidations of the subject, and may serve as the foundation of future labours.

The active volcano on which I have made my observations is Vesuvius; and there probably does not exist another so admirably fitted for the purpose:

its vicinity to a great city; the facility with which it may be ascended in every season of the year; and the nature of its activity,—all offer peculiar advantages to the philosophic inquirer.

I had made several observations on Vesuvius in the springs of 1814 and 1815, which I shall refer to on a future occasion in these pages; but it was in December 1819, and January and February 1820, that the volcano offered the most favourable opportunity for investigation. On my arrival at Naples, Dec. 4, I found that there had been a small eruption a few days before, and that a stream of lava was flowing with considerable activity from an aperture in the mountain a little below the crater. On the 5th I ascended the mountain, and examined the crater and the stream of lava. The crater emitted so large a quantity of smoke, with muriatic and sulphurous acid fumes, that it was impossible to approach it except in the direction of the wind; and it threw up every two or three minutes showers of red hot stones. The lava was flowing from an aperture about one hundred yards below it, being apparently forced out by elastic fluids with a noise like that made by the steam disengaged from a pressure engine: it rose, perfectly fluid, forming a stream of from five to six feet in diameter, and immediately fell, as a cataract, into a chasm about forty feet below, where it was lost under a kind of bridge formed of cooled lava; but it re-appeared sixty or seventy yards further down. Where it issued from the mountain, it was nearly white hot, and exhibited an appearance similar to that which is shown when a pole of wood is introduced into the melted copper of a foundry, its surface appearing in violent agitation, large bubbles rising, which in bursting produced a white smoke; but the lava became of a red colour, though still visible in the sunshine, where it issued from under the bridge. The force with which it flowed was so great, that the strength of the guide, a very stout young man, was insufficient to keep a long iron rod in the current. The whole of its course, with two or three interruptions where it flowed under a cooled surface, was nearly three quarters of a mile, and it threw off clouds of a white smoke. It smoked less as it cooled and became pasty; but even where it terminated in moving masses of scoria, smoke was still visible, which became more distinct whenever the scoria was moved, or the red hot lava in the interior exposed.

Having ascertained that it was possible to approach within four or five feet of the lava, and to examine the vapour immediately close to the aperture, I returned the next day, having provided the means of making a number of experiments on the nature of the lava, and of the elastic fluids with which it was accompanied. I found the aperture nearly in the same state as the day before, but the lava spread over a larger surface, forming an eddy in the hollow of the rock, over which it fell, from which it could be raised in an iron ladle more easily than from the current, and where there was much more facility of placing and withdrawing substances intended to be exposed to its agency.

One of the most important points to be ascertained was, whether any combustion was going on at the moment the lava issued from the mountain. There was certainly no appearance of more vivid ignition when it was exposed to air, nor did it glow with more intensity when it was raised into the air by an iron ladle. I put the circumstance, however, beyond the possibility of doubt: I threw some of the fused lava into a glass bottle furnished with a ground stopper, containing siliceous sand in the bottom: I closed it at the moment, and examined the air on my return. A measure of it mixed with a measure of nitrous gas gave exactly the same degree of diminution as a measure of common air which had been collected in another bottle on the mountain.

I threw upon the surface of the lava nitre, both in mass and in powder. After this salt had fused, there was a little increase of vividness in the ignition of the lava, but much too slight to be referred to pure combustible matter in any quantity; and on making the experiment on a portion of lava taken up in the ladle, it appeared that the disengagement of heat was partly owing to the peroxidation of the protoxide of iron, and to the combination of the alkali of the nitre with the earthy basis of the lava; for where the nitre had melted, the colour had changed from olive to brown. This conclusion was still further proved by the circumstance that chlorate of potash thrown upon the lava did not increase its degree of ignition so much as nitre. When a stick of wood was introduced into a portion of the lava so as to leave a little carbonaceous matter on its surface, nitre or chlorate of potassa then thrown upon it caused it to glow with great brilliancy. Some fused lava was thrown into water, and a glass bottle filled with water held over it to collect the gas disengaged; it was in very minute quantity only, and when analysed on my return proved to be common air a little less pure than that disengaged from the water by boiling. A wire of copper of $\frac{1}{20}$th of an inch in diameter, and a wire of silver of $\frac{1}{30}$th, introduced into the lava near its source, were instantly fused: an iron rod of $\frac{1}{5}$th of an inch, with a piece of iron wire of about $\frac{1}{30}$th, were kept for five minutes in the eddy in the stream of lava: they were not fused; they did not produce any smell [illegible] sulphuretted hydrogen when acted on by muriatic acid. A tin-plate funnel filled with cold water was held in the fumes disengaged with so much violence from the aperture through which the lava issued: fluid was immediately condensed upon it, which was of an acid and subastringent taste. It did not precipitate muriate of baryta; but copiously precipitated nitrate of silver, and rendered the triple prussiate of potassa of a bright blue. When the same funnel was held in the white fumes above the lava where it entered the bridge, no fluid was precipitated upon it, but it became coated with a white powder which had the taste and chemical qualities of common salt, and proved to be this substance absolutely pure. A bottle of water holding about $\frac{3}{4}$ of a pint, with a long narrow neck, was emptied immediately in the aperture from which the vapours pressing out the lava issued, and the neck was immediately closed. This air examined on my return was found to give no absorption with solution of potassa; so that it contained no notable proportion of carbonic acid, and it consisted of 9 parts of oxygen and 91 of azote. There was not the least smell of sulphurous acid in the vapour from the aperture, nor were the fumes of muriatic acid so strong as to be unpleasant; but during the last quarter of an hour that I was engaged in these experiments, the wind changed, and blew the smoke from the crater upon the spot where I was standing: the sulphurous acid gas in the fumes was highly irritating to the organs of respiration, and I suffered so much from the exposure to them that I was obliged to descend; and the effect was not transient, for a violent catarrhal affection ensued, which prevented me for a month from again ascending the mountain.

On the 6th of January I made another visit to Vesuvius. I found the appearance of the lava considerably changed; the bocca from which it issued on the 5th of December was closed, and the current now flowed quietly and without noise from a chasm in the cooled lava about three hundred feet lower down. The heat was evidently less intense. I repeated my experiments with nitre with the same results, and exposed pure silver and platinum to the fused lava: they were not at all changed in colour. I collected the sublimations from various parts of the cooled lava above. The rocks near the ancient bocca were entirely covered with white, yellow, and reddish saline substances. I found one specimen of large saline crystals in a cavity, which had a slight tint of purple: this examined, proved to be common salt with a minute portion of muriate of cobalt. The other sublimations consisted of common salt in great excess, much chloride of iron, some sulphate of soda; and by the test of muriate of platinum, there appeared to exist in them a small quantity of sulphate or muriate of potassa; and a solution of ammonia detected the presence of a minute quantity of the oxide of copper.

During the months of January and February I made several visits to the top of Vesuvius: I shall not particularize them all; but shall mention only such as afforded me some new observations. On the 26th of January, the lava was seen nearly white hot through a chasm near the place where it flowed from the mountain. I threw nitre upon it in large quantities through this chasm, in the presence of H. R. H. the Prince of Denmark, whom I had the honour of accompanying in this excursion to the mountain, and my friend the Cavaliere Monticelli: there was no more increase of ignition than when the experiment was made on lava exposed to the free air. The appearance of the sublimations was now considerably changed: those near the aperture were coloured green and blue by salts of copper; but there was still a great quantity of muriate of iron. I have mentioned, that on the 5th the sublimate of the lava was pure chloride of sodium: in the sublimate of January 6th, there were both sulphate of soda and indications of sulphate of potassa. In the sublimates that I collected on the 26th, the sulphate of soda was in much larger quantities, and there was much more of a salt of potassa. From the 5th of December to the 20th of February, the lava flowed in larger or smaller quantities, so that at night a stream of ignited matter was always visible, more or less interrupted by cooled lava. It changed its direction according to the obstacles it met with; and never, according to appearances, extended so much as a mile from its source. During the whole of this time the craters, of which there were two, were in activity. The large crater threw up showers of ignited ashes and stones to a height apparently of from 200 to 500 feet; and from a smaller crater, to the right of the large one on the side of Naples, steam arose with great violence. Whenever the crater could be approached it was found incrusted with saline incrustations; and the walk to the edge of the small crater on the 6th of January was through a mass of loose saline matter, principally common salt coloured by muriate of iron, in which the foot sunk to some depth. It was easy, even at a great distance, to distinguish between the steam disengaged by one of the craters, and the earthy matter thrown up by the other. The steam appeared white in the day, and formed perfectly white clouds, which reflected the morning and evening light of the purest tints of red and orange. The earthy matter always appeared as a black smoke, forming black clouds; and in the night it was highly luminous at the moment of the explosion.

On the 20th of February, the small crater which had been disengaging steam and elastic matter, began to throw out showers of stones; and both craters from the 20th to the 23rd were more than usually active. On the night of the 23rd, at half past 11 o'clock, being in my bed-room at Chiatimone, Naples, I heard the windows shake; and going to the window, I saw ascending from Vesuvius a column of ignited matter to a height at least equal to that of the mountain from its base; and the whole horizon was illuminated, notwithstanding the brightness of the moon, with direct volcanic light, and that reflected from the clouds above the column of ignited matter. Several eruptions of the same kind, but upon a smaller scale, followed at intervals of a minute and a half or two minutes; but there were no more symptoms of earthquake, nor did I hear any noise. On observing the lava, it appeared at its origin much broader and more vivid; and it was evident that a fresh stream had broken out to the right of the former one. On the morning of the 24th I visited the mountain; it was not possible to ascend to the top, which was covered with clouds, nor to examine the orifice from which the lava issued. The stream of lava near the place where it terminated was from 50 to 100 feet broad. It had precisely the same appearances as the lava which had been so long running. I collected the saline matter condensed upon some of the masses of scoria which were carried along by the current and deposited on the edge of the stream; they proved to be the same in the nature of their constituent parts as those of the lava of the 26th of January, but with a larger proportion of sulphate of soda, and a smaller proportion of muriate of iron; and I have no doubt that the dense white smoke which was emitted in immense columns by the lava during the whole of its course, was produced by the same substances.

I shall now mention the state of the volcano at some other periods.

When I was at Naples in May 1814, the crater had the appearance of an immense funnel, closed at the bottom, with many small apertures emitting steam; and on the side towards Torre del Greco, there was a large aperture from which flame issued to a height of at least 60 yards, producing a most violent hissing noise. This phænomenon was constant during the three weeks I remained at Naples. It was impossible to approach sufficiently near the flame to ascertain the results of the combustion; but a considerable quantity of steam ascended from it. When the wind blew the vapours upon us, there was a distinct smell both of sulphurous and muriatic acids. There was no indication of carbonaceous matter from the colour of the smoke; nor was any deposited upon the yellow and white saline matter which surrounded the crater, and which I found to be principally sulphate and muriate of soda, and muriate of iron: in some specimens there was a considerable quantity of muriate of ammonia.

In March 1815, the appearances presented by the crater were entirely different. There was no aperture in the crater; it was often quiet for minutes together, and then burst out into explosions with considerable violence, sending fluid lava and ignited stones and ashes to a considerable height, many hundred feet, in the air.

These eruptions were preceded by subterraneous thunder, which appeared to come from a great distance, and which sometimes lasted for a minute. During the four times that I was upon the crater in the month of March, I had at last learnt to estimate the violence of the eruption from the nature of the sound: loud and long continued subterraneous thunder indicated a considerable explosion. Before the eruption the crater appeared perfectly tranquil; and the bottom, apparently without an aperture, was covered with ashes. Soon, indistinct rumbling sounds were heard as if at a great distance; gradually the sound approached nearer, and was like the noise of artillery fired under our feet. The ashes then began to rise and to be thrown out with smoke from the bottom of the crater; and lastly, the lava and ignited matter was ejected with a most violent explosion. I need not say that when I was standing on the edge of the crater witnessing this phænomenon, the wind was blowing strongly from me: without this circumstance it would have been dangerous to have stood on the edge of the crater; and whenever from the loudness of the thunder the eruption promised to be violent, I always ran as far as possible from the seat of danger.

As soon as the eruption had taken place, the ashes and stones which rolled down the crater seemed to fill up the aperture, so that it appeared as if the ignited and elastic matter were discharged laterally; and the interior of the crater assumed the same appearance as before.

I shall now offer some observations on the theory of these phænomena. It appears almost demonstrable that none of the chemical causes anciently assigned for volcanic fires can be true. Amongst these, the combustion of mineral coal is one of the most current; but it seems wholly inadequate to account for the phænomena. However large a stratum of pit-coal, its combustion under the surface could never produce violent and extensive heat; for the production of carbonic acid gas, when there was no free circulation of air, must tend constantly to impede the process: and it is scarcely possible that carbonaceous matter, if such a cause existed, should not be found in the lava, and be disengaged with the saline or aqueous products from the bocca or craters. There are many instances in England of strata of mineral coal which have been long burning; but the results have been merely baked clay and schists, and it has produced no result similar to lava.

If the idea of Lemery were correct, that the action of sulphur on iron may be a cause of volcanic fires, sulphate of iron ought to be the great product of the volcano; which is known not to be the case; and the heat produced by the action of sulphur on the common metals, is quite inadequate to account for the appearances. When it is considered that volcanic fires occur and intermit with all the phænomena that indicate intense chemical action, it seems not unreasonable to refer them to chemical causes. But for phænomena upon such a scale, an immense mass of matter must be in activity, and the products of the volcano ought to give an idea of the nature of the substances primarily active. Now what are these products?. Mixtures of the earths in an oxidated and fused state, and intensely ignited; water and saline substances, such as might be furnished by the sea and air, altered in such a manner as might be expected from the formation of fixed oxidated matter. But it may be said, if the oxidation of the metals of the earths be the causes of the phænomena, some of these substances ought occasionally to be found in the lava, or the combustion ought to be increased at the moment the materials passed into the atmosphere. But the reply to this objection is, that it is evident that the changes which occasion volcanic fires, take place in immense subterranean cavities; and that the access of air to the acting substances occurs long before they reach the exterior surface.

There is no question but that the ground under the solfaterra is hollow, and there is scarcely any reason to doubt of a subterraneous communication between this crater and that of Vesuvius: whenever Vesuvius is in an active state, the solfaterra is comparatively tranquil. I examined the bocca of the solfaterra on the 21st of February 1820, two days before the activity of Vesuvius was at its height: the columns of steam which usually arise in large quantities when Vesuvius is tranquil, were now scarcely visible, and a piece of paper thrown into the aperture did not rise again; so that there was every reason to suppose the existence of a descending current of air*. The subterraneous thunder heard at such great distances under Vesuvius, is almost a demonstration of the existence of great cavities below filled with aëriform matter: and the same excavations which in the active state of the volcano throw out during so great a length of time immense volumes of steam, must, there is every reason to believe, in its quiet state become filled with atmospheric air†.

To what extent subterraneous cavities may exist even in common rocks, is shown in the limestone caverns of Carniola, some of which contain many hundred thousand cubical feet of air; and in proportion as the depth of an excavation is greater, so is the air more fit for combustion.

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* In 1814, in 1815, and in January 1819, when Vesuvius was comparatively tranquil, I observed the solfaterra in a very active state, throwing up large quantities of steam and some sulphuretted hydrogen.

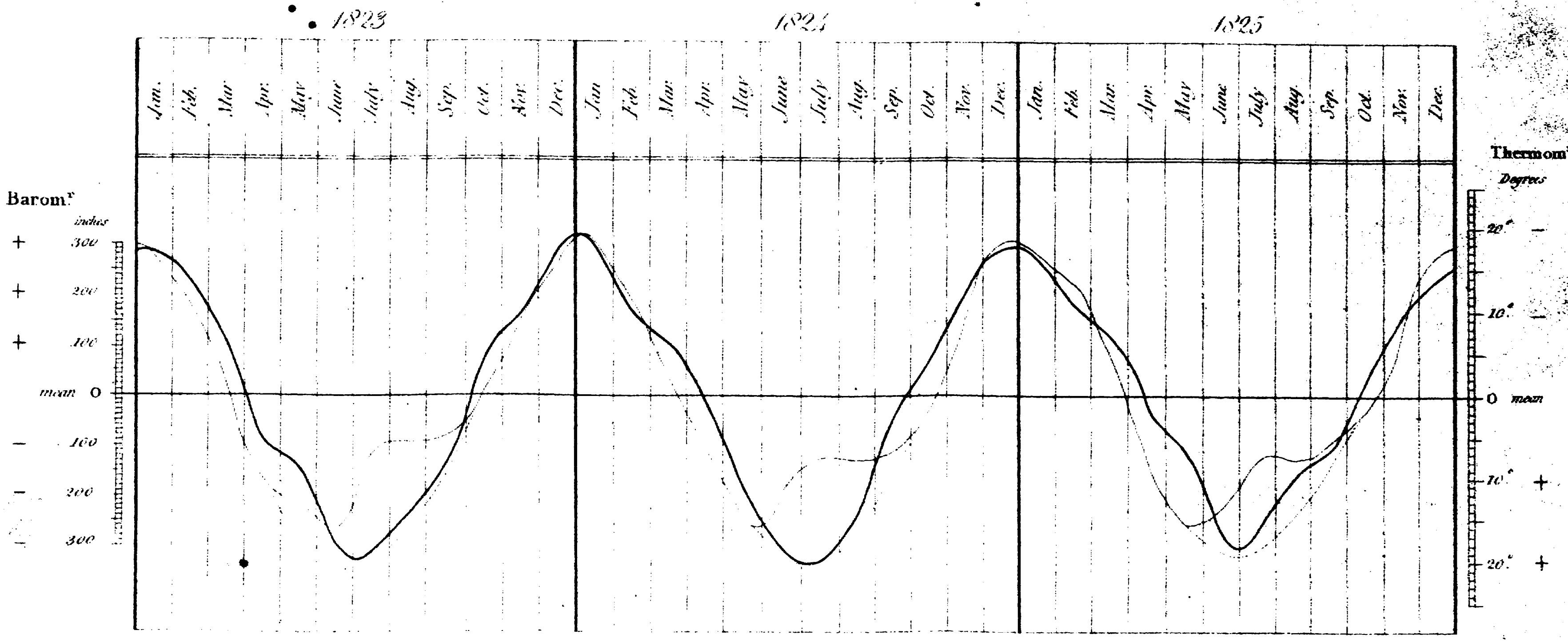
† Vesuvius is a mountain admirably fitted, from its form and situation, for experiments on the effect of its attraction on the pendulum: and it would be easy in this way to determine the problem of its cavities. On Etna, the problem might be solved on a larger scale.

The same circumstance which would give alloys of the metals of the earths the power of producing volcanic phænomena, namely, their extreme facility of oxidation, must likewise prevent them from ever being found in a pure combustible state in the products of volcanic eruptions; for before they reach the external surface, they must not only be exposed to the air in the subterranean cavities, but be propelled by steam; which must possess, under the circumstances, at least the same facility of oxidating them as air. Assuming the hypothesis of the existence of such alloys of the metals of the earths as may burn into lava in the interior, the whole phænomena may be easily explained from the action of the water of the sea and air on those metals; nor is there any fact or any of the circumstances which I have mentioned in the preceding part of this paper, which cannot be easily explained according to that hypothesis. For almost all the volcanoes in the old world of considerable magnitude are near, or at no considerable distance from the sea: and if it be assumed that the first eruptions are produced by the action of sea water upon the metals of the earths, and that considerable cavities are left by the oxidated metals thrown out as lava, the results of their action are such as might be anticipated; for after the first eruptions, the oxidations which produce the subsequent ones may take place in the caverns below the surface; and when the sea is distant, as in the volcanoes of South America, they may be supplied with water from great subterranean lakes; as HUMBOLDT states that some of them throw up quantities of fish.

On the hypothesis of a chemical cause for volcanic fires, and reasoning from known facts, there appears to me no other adequate source than the oxidation of the metals which form the bases of the earths and alkalies; but it must not be denied that considerations derived from thermometrical experiments on the temperature of mines and of sources of hot water, render it probable that the interior of the globe possesses a very high temperature: and the hypothesis of the nucleus of the globe being composed of fluid matter, offers a still more simple solution of the phænomena of volcanic fires than that which has been just developed.

Whatever opinion may be ultimately formed or adopted on this subject, I hope that these inquiries on the actual products of a volcano in eruption will not be without interest for the Royal Society.

Diagram



The Black line shews the March of the Barometer.

The Fine line that of the Thermometer.

The dotted portion shews the deviation caused by the Rains.

XI. *Abstract of a meteorological journal kept at Benares during the years* 1824, 1825, *and* 1826. *By* James Prinsep, *Esq. Assay Master of the mint at Benares. Communicated by* Peter Mark Roget, M.D. *Secretary of the Royal Society.*

Read January 25, 1828.

THE three principal Tables, each of which comprises the abstract for one year of the meteorological journal at Benares, are followed by two others, numbered I. and II., presenting the mean daily oscillations of the barometer, and the monthly deviations from its average height, for each month during four successive years, accompanied by the corresponding variations of the thermometer from its mean. These tables exhibit the remarkable coincidence preserved by these phænomena throughout the year. The indications of the barometer are all reduced to the freezing point by Dulong and Petit's formula for the dilatation of mercury. I have inserted in the first column of Table I. the mean of three years' observations made at Berhampoor by Dr. A. Russel; but the instrument employed being of the mountain construction, the mercury did not move freely in the tube, which will account for the oscillations being uniformly less than those measured by myself. Mr. Daniell has noticed the liability of barometers to deteriorate from the accumulation of air bubbles above the mercury: to obviate this cause of error, I made frequent comparisons with one of Wollaston's boiling thermometers. From October 1823 to August 1825, the error from this cause amounted to .046 inch, and I deemed it necessary to reboil the barometer; it then stood, as nearly as possible, correct once more. All of my tables have been cleared of the minute error thus found.

As a graphic representation more readily enables the eye to estimate the agreement of two lines in motion, I have delineated in a diagram the courses indicated by Table II., only reversing the direction of one curve, that the two lines may be collateral with respect to the centre line which stands for the annual mean. The scales at the sides will explain the formation of the curves. The year 1826 is omitted in the diagram, because the last two months are wanting in the series of observations.

Abstract of a Meteorological Journal: Benares, 1824.

Date.		Barometer.		Thermometer.						Wet Bulb Therm*.		Hair Hygro-meter.	Evapo-ration.	Rain.	Wind.	Weather.
		Obs.	Mean.	Interior.		Exterior.		Extremes.		Mean.	Diff. +0.8					
Jan. . .	9 A.M. 5½ P.M.	29.892 29.807	29.849	59.82 62.35	61.08	57.32 63.27	60.29	49.68 69.35	59.52	56.60	4.49	94.1	1.924	One shower.	W. and Calm.	Foggy: clear: change.
Feb. . .	10½ A.M. 5½ P.M.	29.786 29.688	29.737	66.40 70.12	68.26	68.16 67.32	67.74	55.40 76.52	65.96	61.34	7.20	83.7	3.220		W. and Calm.	Cirrocum. Hard winds.
March	10½ A.M. 6¼ P.M.	29.752 29.650	29.701	75.70 80.22	77.96	79.42 83.40	81.41	66.30 86.11	76.20	67.32	14.89	83.0	6.682	0.240	W.	Several gales.
April	10 A.M. 6½ P.M.	29.659 29.544	29.601	82.85 86.89	84.87	85.42 92.38	88.90	73.75 95.10	84.42	70.84	18.86	80.1	10.697	0.140	W.	Steady weather.
May . .	10 A.M. 6¾ P.M.	29.500 29.385	29.442	88.59 92.05	90.32	95.12 99.66	97.39	80.97 103.70	92.33	74.38	23.81	83.2	13.044	0.400	N.W. E. Var.	Clear: then misty: then gale and violent storm. (Sultanpoor barracks blown down.)
June. .	10¼ A.M. 6 P.M.	29.387 29.274	29.330	89.11 92.46	90.78	89.76 89.42	89.59	77.11 101.65	89.38	84.42	5.97	90.9	8.157	3.015	W. Var. E.	Little rain, but cloudy.
July . .	11 A.M. 5 P.M.	29.322 29.253	29.287	85.65 87.22	86.43	85.79 85.95	85.87	80.18 90.40	85.29	82.65	4.02	96.2	2.785	17.480	E. W. S.W. E.	Settled rain.
August	10 A.M. 5¼ P.M.	29.402 29.344	29.373	81.76 90.33	86.04	85.96 85.15	85.55	80.60 90.01	85.30	83.28	3.07	94.8	2.318	9.152	Calm. E. Var.	Fine towards the 15th.
Sept.	10½ A.M. 5½ P.M.	29.572 29.484	29.528	85.65 88.06	86.85	84.90 86.94	85.92	77.43 91.33	84.38	80.11	6.61	87.6	3.781	2.850	W. Var. E.	Showers: clear: cloudy.
Oct. . .	10½ A.M. 5½ P.M.	29.712 29.627	29.669	81.60 82.93	82.26	80.94 81.15	81.04	72.28 85.96	79.12	78.81	3.03	87.1	2.911	3.125	E. Calm. Var.	A gale from W: then clear: then squally.
Nov. . .	10½ A.M. 5 P.M.	29.819 29.729	29.774	74.36 76.37	75.36	72.11 73.78	72.94	59.68 78.50	69.09	66.89	6.85	81.0	2.925	0.500	Var. Calm.	Cleared up.
Dec. . .	10½ A.M. 5 P.M.	29.873 29.797	29.835	65.56 67.16	66.36	62.15 64.49	63.32	50.58 68.51	59.04	58.19	5.93	82.8	2.005	1.420	W. Var. S.E.	Clear and fine: gale on the 30th.
Annual Mean		. . . . . .	29.593		79.71		79.99		77.50	72.07		87.04				

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* This thermometer stands 0.8 deg. higher than the others; this quantity is therefore added to the column of differences.

Abstract of a Meteorological Journal: Benares, 1825.

Date.		Barometer.		Thermometer.						Wet Bulb Therm.			Hair Hygr.		Evaporation.	Rain.	Wind.	Weather.
		Obs.	Mean.	Interior.		Exterior.		Extremes.		Obsns.	Mean.	Diff. +0.8.	Obsns.	Mean.				
															Inches.	Inches.		
Jan. . .	10¾ A.M. 5 P.M.	29.883 29.797	29.840	64.54 66.15	65.35	62.97 64.09	63.53	54.12 68.14	61.13	61.05 62.06	61.55	2.78	92. 89.	90.5	1.826	4.095	Var. E. W. E.	Unseasonable strati: fogs: rain; storms: cumuli.
Feb. . .	11 A.M. 4½ P.M.	29.803 29.732	29.767	67.88 70.02	68.95	67.11 72.11	69.61	56.98 73.07	65.02	63.08 63.70	63.39	7.02	85. 81.	83.0	2.406	5.325	Var. W.	Clear: cirri. Several heavy storms: then clear.
March	10½ A.M. 5½ P.M.	29.785 29.673	29.729	74.53 78.42	76.47	74.22 75.96	75.09	63.68 84.00	73.84	66.00 65.02	65.51	11.38	83. 76.	79.5	4.029	0.335	E. Var. SE. W.	Dull haze: violent storm: clear.
April. .	10 A.M. 5¾ P.M.	29.661 29.550	29.605	85.29 86.39	85.84	88.05 91.90	89.92	75.11 100.20	87.65	73.93 71.30	72.61	18.11	79.2 74.	76.6	12.669	0.025	Calm. W. SE. W.	Clear: cirrostrati: hard gale E. Changeable.
May . .	10 A.M. 6 P.M.	29.595 29.485	29.540	89.10 90.54	89.82	93.39 96.14	94.76	81.79 105.43	93.61	79.31 78.05	78.68	16.88	Broken and replaced by an accurate Hair Hygrometer.		16.864	. . . . . .	E. Var. E.	Clear: gale from N.
June . .	10 A.M. 6¼ P.M.	29.420 29.311	29.365	89.68 90.32	90.00	91.30 93.65	92.47	85.19 97.93	91.56	79.99 80.38	80.18	13.09			7.720	5.725	NE. W. NE. Calm.	Cloudy: hard gale E: showers.
July . .	10¾ A.M. 6¼ P.M.	29.404 29.317	29.361	87.03 88.64	87.83	85.82 86.91	86.36	81.82 89.58	85.70	82.29 82.65	82.47	4.69			4.447	11.050	E.	Heavy rain: cloudy.
August	10½ A.M. 6 P.M.	29.518 29.425	29.471	87.68 89.92	88.80	86.61 88.50	87.55	81.76 90.34	86.05	81.30 82.30	81.80	6.55			4.426	4.650	E. SW. E.	Hot and cloudy.
Sept. . .	10¼ A.M. 6 P.M.	29.581 29.468	29.524	85.13 86.79	85.96	83.85 85.13	84.49	79.95 87.43	83.69	80.57 80.29	80.43	4.86	94.1 82.3	88.4	2.657	9.020	Var.	Gale three days: cumuli: cum.-cirri.: fair.
Oct. . .	10¼ A.M. 5½ P.M.	29.702 29.615	29.653	81.13 83.35	82.24	80.05 81.69	80.87	74.68 84.41	79.54	74.74 76.03	75.38	6.29	84.8 81.6	83.2	3.003	6.130	S. Calm. W.	Rain and gale: dry weather: clear.
Nov. . .	10¾ A.M. 5½ P.M.	29.829 29.718	29.773	72.59 75.48	74.04	69.84 72.78	71.31	62.29 75.63	68.96	64.73 65.09	64.91	7.20	80.5 73.2	76.8	3.168	0.550	W. Gentle. W.	Cloudless sky to the 18th: then showers.
Dec. . .	10½ A.M. 5½ P.M.	29.868 29.766	29.812	65.15 68.10	66.62	61.34 65.80	63.57	53.02 68.47	60.75	55.45 58.03	56.74	7.63	76.2 73.2	74.7	3.852	. . . . . .	W. Regular.	Dry and colder than usual.
Average		. . . . . .	29.620		80.16		79.96		78.12		71.97							

Abstract of a Meteorological Journal; Benares, 1826.

Date.		Barometer.		Thermometer.						Wet Bulb Therm.			Hair Hygr.		Evaporation.	Rain.	Wind.	Weather.
		Obs.	Mean.	Interior.		Exterior.		Extremes.		Obs.	Mean.	Diff. +0.8.	Obs.	Mean.				
															Inches.	Inches.		
Jan. . .	10½ A.M. 5½ P.M.	29.835 29.740	29.787	64.85 68.91	66.88	61.34 66.45	63.87	53.57 69.72	61.64	53.60 57.86	55.73	8.9	73.4 69.8	71.6	3.138	0.150	W. E. Calm. W.	Clear and cold: one storm.
Feb. . .	10½ A.M. 5½ P.M.	29.737 29.641	29.689	71.38 73.38	72.38	67.62 72.64	70.13	57.81 76.64	67.22	57.89 57.85	57.87	13.0	59.6 52.4	56.0	3.928	. . . .	W. Calm.	Steady: clear.
March	10¼ A.M. 5½ P.M.	29.751 29.645	29.698	77.14 82.65	79.89	77.98 83.59	80.78	67.91 86.55	77.23	63.75 64.72	64.23	17.3	62.4 54.2	58.1	9.853	0.410	Var. E.& W.	Very dry on 31st.
April. .	10 A.M. 6 P.M.	29.625 29.492	29.558	83.85 85.54	84.69	87.31 92.52	89.92	78.41 98.31	88.36	67.23 68.43	67.83	22.9	61.1 60.5	60.8	16.789	. . . .	W.	Steady hot wind.
May . .	9½ A.M. 6 P.M.	29.575 29.438	29.506	88.18 89.87	89.02	87.98 93.83	90.91	81.84 99.82	90.83	73.45 72.98	73.21	18.9	73.4 66.6	70.0	13.589	0.180	Calm. W. E. Var.	Several storms: ☽ eclipsed 21st.
June. .	9½ A.M. 6¼ P.M.	29.406 29.304	29.355	88.64 91.18	89.91	87.72 89.85	88.78	85.66 93.56	89.61	80.40 80.17	80.29	9.2	84.9 79.6	72.2	7.559	1.885	E. Var.	Changeable: one gale.
July . .	9½ A.M. 6 P.M.	29.325 29.263	29.294	86.74 87.43	87.08	84.42 85.36	84.89	80.70 87.64	84.17	81.69 81.55	81.62	4.1	91.6 89.2	90.4	3.980	25.730	Var. E. W.	Heavy rain.
Aug. . .	10 A.M. 6 P.M.	29.470 29.391	29.431	85.28 86.24	85.76	83.99 84.15	84.07	80.04 86.35	83.19	81.91 81.64	81.77	3.0	93.0 91.9	92.4	3.314	11.720	Very Var.	Cloudy and showery.
Sept. . .	10½ A.M. 6 P.M.	29.549 29.456	29.502	86.56 87.86	87.21	85.22 86.29	85.75	79.86 89.01	84.43	80.28 79.59	79.93	6.4	84.8 81.8	83.3	7.010	4.270	E. W.	Set in fine on the 16th.
Oct. . .	10 A.M. 6 P.M.	29.757 29.660	29.708	83.93 86.27	85.10	81.19 83.94	82.56	73.96 87.18	80.57	72.87 73.03	72.95	10.4	78.3 70.2	74.2	8.000	0.100	W. E. W.	Clear and fine: one squall 14th.

TABLE I. Daily Oscillations.

Month.	Barometer.					Thermometer.				
	3 Years by Dr. RUSSEL.	1824.	1825.	1826.	Mean of 3 last.	1823.	1824.	1825.	1826.	Mean.
	Inch.	Inch.	Inch.	Inch.						
January	.073	.092	.091	.109	.097	21°.5	19°.7	14°.0	16°.1	17°.8
February	.098	.109	.096	.103	.103	21.0	21.1	16.1	18.8	19.2
March	.098	.117	.124	.122	.121	24.0	19.8	20.3	18.6	20.7
April	.103	.127	.113	.135	.125	26.5	21.3	25.1	19.9	23.2
May	.103	.120	.113	.140	.124	23.4	22.7	23.6	18.0	21.9
June	.084	.119	.111	.109	.113	20.3	24.5	11.7*	7.9	16.1
July	.062	.071	.091	.070	.077	9.3	10.2	7.7	6.9	9.0
August	.068	.084	.099	.082	.088	8.9	9.4	8.6	6.3	8.3
September	.070	.094	.117	.098	.103	9.5	13.9	8.5	9.2	10.3
October	.070	.103	.094	.102	.100	16.0	13.7	9.7	13.2	18.1
November	.070	.095	.120	——	.107	18.4	18.8	13.3	——	16.8
December	.075	.085	.111	——	.098	15.7	17.9	15.4	——	16.3

* From this month the Register Thermometer stood in a new house much less exposed than before;—the ranges are consequently much smaller.

TABLE II. Monthly Deviations.

Month.	Barometer at 32°.					Thermometer (mean of extremes.)				
	1823.	1824.	1825.	1826.	Mean.	1823.	1824.	1825.	1826.	Mean.
January	+.285	+.299	+.277	+.232	+.273	−16°.7	−18°.0	−17°.0	−16°.5	−17°.0
February	+.233	+.165	+.184	+.119	+.175	−10.7	−11.5	−13.1	−10.9	−11.5
March	+.095	+.106	+.124	+.104	+.107	+ 0.5	− 1.3	− 4.3	− 0.9	− 1.5
April	−.083	−.016	−.027	−.048	−.043	+11.2	+ 6.9	+ 9.5	+10.3	+ 9.5
May	−.137	−.192	−.104	−.113	−.136	+12.7	+14.8	+15.5	+12.7	+13.9
June	−.307	−.304	−.278	−.267	−.289	+15.7	+11.9	+13.4	+11.5	+13.1
July	−.311	−.327	−.277	−.318	−.308	+ 6.1	+ 7.8	+ 7.6	+ 6.1	+ 6.9
August	−.227	−.242	−.168	−.175	−.203	+ 5.0	+ 7.8	+ 7.9	+ 5.1	+ 6.4
September	−.130	−.041	−.108	−.111	−.098	+ 4.5	+ 6.9	+ 5.6	+ 6.3	+ 5.8
October	+.084	+.066	+.036	+.099	+.074	− 0.1	+ 1.6	+ 1.4	+ 2.5	+ 1.3
November	+.169	+.201	+.175	——	+.181	−11.3	− 8.5	− 9.2	——	− 9.7
December	+.309	+.290	+.240	——	+.279	−17.0	−18.5	−17.4	——	−17.6

Mean Barometric Alt. 29°.468. Mean Thermometric Alt. 77°.81.

LONDON:
PRINTED BY RICHARD TAYLOR,
RED LION COURT, FLEET STREET.

PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXXVIII.

PART II.

LONDON:

PRINTED BY RICHARD TAYLOR, RED LION COURT, FLEET STREET;
AND SOLD BY G. AND W. NICOL, PALL MALL, BOOKSELLERS TO THE ROYAL SOCIETY.

MDCCCXXVIII.

CONTENTS.

APPENDIX.

PHILOSOPHICAL TRANSACTIONS.

XII. *A description of a vertical floating collimator; and an account of its application to astronomical observations with a circle and with a zenith telescope. By Captain* HENRY KATER, *V.P.R.S.*

Read April 24, and May 1, 1828.

IN the Philosophical Transactions for 1825, I gave an account of a floating collimator, and added a suggestion for the construction of a vertical floating collimator which had not then been carried into effect. I have since had an instrument of that description made, with such improvements as occasion required, and the results which it has afforded have been so satisfactory that I am induced to lay them before the Society.

The collimator which formed the subject of the paper I have mentioned was a *horizontal* floating collimator. This, in the manner in which I then used it, was the worst form in which the instrument could have been employed; as it was necessary to take the float out of the mercury and replace it in order to complete each observation. The result was therefore liable to be vitiated by any particle of dust or minute bubble of air which might have found a place between the float and the mercury. It cannot therefore but be considered as surprising, that out of one hundred and fifty-one results, only twenty-eight were found in error to an amount exceeding one second, the greatest error being $2''.58$ and the next $2''$.

The horizontal floating collimator was tried by the Rev. Dr. BRINKLEY, the present Bishop of Cloyne at the Dublin Observatory, and by the Rev. Dr. ROBINSON at the Observatory at Armagh. An account of Dr. BRINKLEY's observations is given in the Philosophical Transactions for 1826, where it may be seen that the mean difference between the results of Dr. Brinkley's catalogue of 1823, and those obtained by means of the horizontal floating collimator by observations upon twenty stars, is only $0''.03$.

Dr. Robinson, by ten observations of five stars made with the horizontal floating collimator and his equatorial, obtained a latitude differing only $0''.02$ from the latitude resulting from his observations of the preceding two years, when the level was employed; and by thirteen observations with the collimator at the winter solstice of 1825, the deduced obliquity of the ecliptic for the beginning of the year, differed only $0''.33$ from that given [illegible] Nautical Almanac.

These results should seem to leave little to be desired in point of accuracy; but the method of using the horizontal floating collimator is so inconvenient, as to constitute no small objection to the general employment of the instrument in this form. To which may be added, the possibility of error arising, as before stated, from the necessity of taking the float out of the mercury and replacing it. From both these objections the vertical floating collimator is wholly free.

The vertical floating collimator has also this further advantage, that it may not only be used with a circle, but may be applied to a telescope, either of the refracting or reflecting kind; such a telescope furnished with a wire micrometer and directed to the zenith, becomes a zenith telescope, free from all the objections to which the zenith sector and the zenith telescope with a plumb-line are liable.

In Plate XIII. I have given plans and sections of the different parts of which the vertical floating collimator is composed. Fig. 1. represents a board of well seasoned mahogany fourteen inches square, and an inch and a half thick. Into this board four legs are screwed, at the distance of an inch and a half from the edge of the board to the centre of each leg. In the middle of the board a circular hole is made, four inches in diameter, into which a tube of sheet iron is firmly driven, of such a length as to project about an inch or an inch and a half above the upper surface of the board. At the distance of five inches and a half from the centre, three brass rollers are let into the board. These are equidistant from each other, and are intended to support the iron pan hereafter to be described, and to facilitate its being moved round about the sheet iron tube as a centre, with but little friction.

Fig. 1.

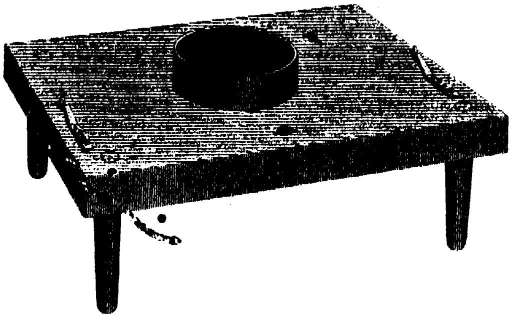


Fig. 2.

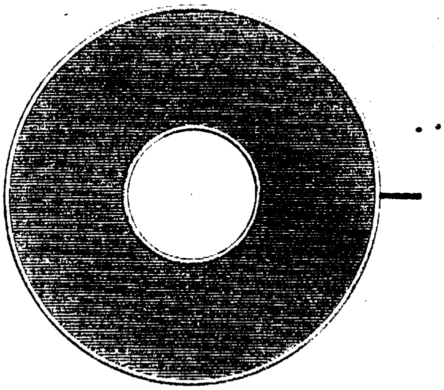


Fig. 4.

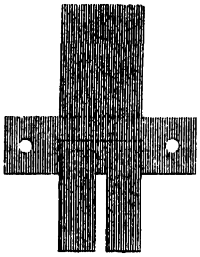


Fig. 5.

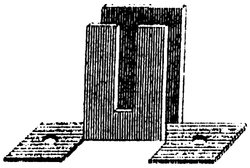
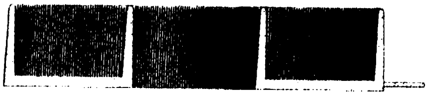


Fig. 3.



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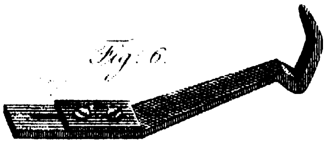

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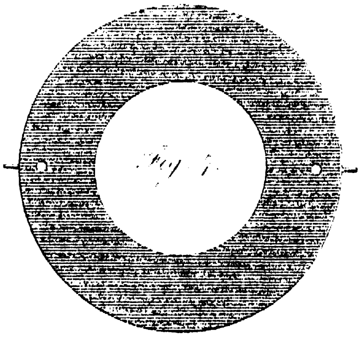


Fig. 10.

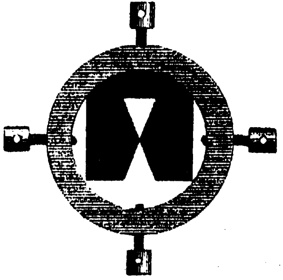


Fig. 11.

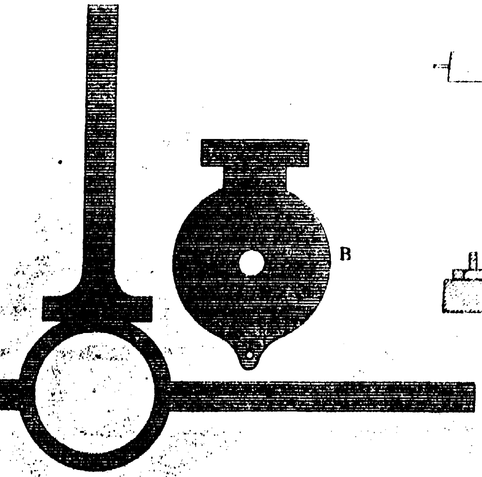
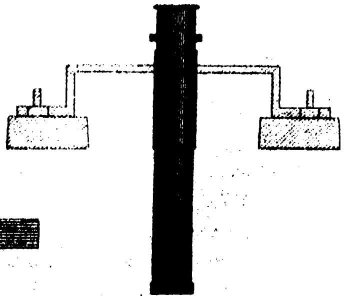


Fig. 8.

Fig. 9.



Figs. 2. and 3. are the plan and section of a cast iron circular pan; this is one foot in diameter, and has a circular opening of four inches, which passes easily upon the tube of sheet iron just described, and about which the pan is intended to be turned. The sides of the pan (fig. 3.) are 2.4 inches high on the outside, the inside depth being two inches, which leaves four-tenths of an inch for the thickness of the bottom of the pan. The sides of the model for the pan must be sloped as in the section, for the convenience of casting. Into the side of the pan at the bottom a stout iron wire is screwed, intended, as will be seen, to serve as a stop to prevent the pan from being turned round more than 180 degrees.

Figs. 4. and 5. represent (in half its real dimensions) one of two guides made of sheet iron, destined to receive pins, which are intended to prevent the float, presently to be described, from moving horizontally. A piece of plate iron is cut into the form represented at fig. 4. This is afterwards turned up as at fig. 5. leaving the distance of a quarter of an inch between the front and back. Two of these guides are screwed to the bottom of the pan in the inside, (their backs touching its sides,) in that diameter which is at right angles to the iron pin projecting from the outside of the pan.

Fig. 6. represents a spring of about two inches and a half long. The flat part has a longitudinal slit in it, through which screws pass which attach it to the mahogany board, fig. 1. A piece of plate brass is interposed between the screws and the spring. The longitudinal slit is for the purpose of adjusting the spring to its required position. At its extremity the spring is formed into a Y, terminating in a hook, as represented in the figure. Two of these springs are fixed to the mahogany board; the Y of each being distant a little more than six inches from the centre of the board, in opposite directions, and the direction of the spring is at right angles to this diameter. The springs both point the same way.

If now we suppose the pan to be placed upon the sheet iron tube, fig. 1. and it be turned round, the iron pin will come in contact with one of the springs, which will yield to the weight of the pan until the pin is lodged in the Y, beyond which it will be prevented from going by the projecting hook. On turning the pan the contrary way, the inclined plane of the Y will yield to the pressure of the pin and permit it to escape; and when the pin has gone through nearly a semicircle, the same process will take place at the other spring; these springs, therefore, afford the means of limiting the horizontal motion of the pan to 180 degrees.

Figs. 7. and 8. are the plan and section of a float of cast iron, 10.6 inches diameter, one inch thick, and having an opening in the middle of 5.7 inches diameter, consequently the breadth of the annulus is about two inches and a half. Into the sides of this float, at opposite points and equidistant from the two surfaces, two steel pins are screwed, of such a thickness as to pass freely into the grooves of the guides before mentioned with a very little shake. The ends of the pins are to be hemispherically rounded, and very smooth. When the float is placed in the pan, with the pins in the guides, the distance between the terminations of the pins should be such as to leave them just clear of the backs of the guides.

A section of the float with the bridge and telescope attached to it is given at fig. 9. The bridge is made of wrought iron. The length at the top is seven inches, and the perpendicular part of the bridge is of a sufficient height to enable the bridge to clear the middle part of the pan when the float is placed in it. In my vertical floating collimator the bridge is an inch and three-quarters above the float. The middle of the bridge consists of a piece of brass tube three or four inches long, destined to receive the telescope, which fits tightly into it. The width of the iron part of the bridge is half an inch, and the thickness about a quarter of an inch; but this may be varied according to circumstances which will hereafter appear. The parts where the bridge is screwed to the float have cross pieces four inches long, intended to give a firmer bearing. The heads of the screws are long, to serve as pins, upon which weights with holes in them may be placed, for the purpose of adjusting the float.

The bridge is screwed to the float in such a position that its length is at right angles to the pins inserted in the edge of the float, as before described. The intention being, that when the collimator is employed, the bridge should be in the direction of the meridian, and the guides at right angles to it. Two additional pins are fixed perpendicularly in the float near the guide pins. These are represented in the plan, fig. 7, and are intended to receive some of the weights by which the float is to be adjusted.

The telescope is achromatic, the object-glass in my collimator being about eight inches focal length, and one inch and a quarter aperture. The object-glass is fixed in a separate piece of tube, which slides within another tube, to which, after adjustment, it may be firmly attached by two opposite screws moving in longitudinal slits.

In the focus of the object-glass of my collimator, a diaphragm is placed, carrying fine cross wires flattened. These wires, however, do not form angles so neat as could be wished, in consequence of their thickness, and of a want of perfect straightness of their edges; and I am indebted to Dr. WOLLASTON for the suggestion of a method of constructing a substitute for the cross wires, which has been applied to a vertical floating collimator made for Captain FOSTER, R.N. and which I found to answer perfectly well.

The surfaces of a plate of brass (bell metal would perhaps be preferable), about the twentieth of an inch thick, were ground parallel. The plate was then cut in half, and the surfaces cemented together. One of the sides of this double plate was then formed by grinding, into a salient angle of about 135°, the faces of this angle being slightly bevilled and carefully finished. The plates were then separated, and their opposite surfaces cemented together, the angular points and edges being made accurately to coincide. One of the sides (not that opposite to the angle) of this compound plate was then ground at right angles to the surface, and the plates again separated and carefully cleaned.

A circular piece of glass having been fitted into the diaphragm, a bit of brass with a straight edge was cemented to the glass on one side by shell lac. This was at such a distance from the middle of the diaphragm, as to allow the angular points of the brass plates to be in its centre, when their ground sides were in contact with the straight edge.

One of the brass plates was now attached by shell lac to the glass, having its ground edge in contact with the brass straight edge, the obtuse angle of the bevilled edge being next the glass, and the angular point in the middle of the diaphragm. It is now evident that if the ground edge of the other brass plate be placed in contact with the straight piece of brass, the obtuse angle of the bevil being next the glass, the two angular points will, upon sliding the brass plate along the straight edge, be brought accurately into contact, and in this position the brass plate was fixed to the glass by shell lac.

This arrangement afforded an object having well defined acute angles of about 45°, which could be bisected with great precision. As this is a very important part of the instrument, I have been induced to describe thus minutely the manner in which it may be made. The diaphragm is placed in the telescope, with the brass plates next to the object-glass, in order that when the edges of the plates are seen with perfect distinctness, no particles of dust may be visible which may have lodged upon the surface of the glass. The angular point is brought into the centre of the tube in the usual manner, by means of opposite screws passing into the diaphragm. A piece of plane glass closes the end of the telescope, to keep out dust and to protect the diaphragm from accident. The diaphragm is represented at fig. 10*.

When observations are made with the floating collimator, it is necessary that all light should be excluded, except that which passes through its telescope. For this purpose a piece of sheet iron is formed, as represented at fig. 11. The aperture is the same as that of the iron basin of the collimator, and one side externally is straight, in order to form a hinge upon which the plate B moves. This plate may be raised to a perpendicular position, and when permitted to fall, rests steadily upon the ring. In the centre of the plate B, is a circular opening, rather less in diameter than the telescope. The three projecting parts of fig. 11. are intended, when bent close to the ring, to form legs, to be attached to the mahogany support, fig. 1, the length of these legs being [illegible] to allow the plate B, when resting on the ring, to be quite clear of the telescope of the collimator.

For the purpose of illuminating the diaphragm of the collimator, a small plane mirror is used, similar to that of a microscope. This is attached to the plate B over the opening, by a short firm pedestal, the manner of doing which is so obvious, as to need no figure. The instrument is represented in Plate XIV.

The collimator being thus completed, it will be found convenient to adjust the object-glass of its telescope very nearly to the distance of its focal length from the diaphragm. For this purpose, any telescope may be employed which has been carefully adjusted to distinct vision upon a fixed star. The telescope of the collimator is to be supported in a convenient position for looking into it through its object-glass with the other telescope, and a lamp so placed as to illuminate the diaphragm. All false light being excluded from the telescope

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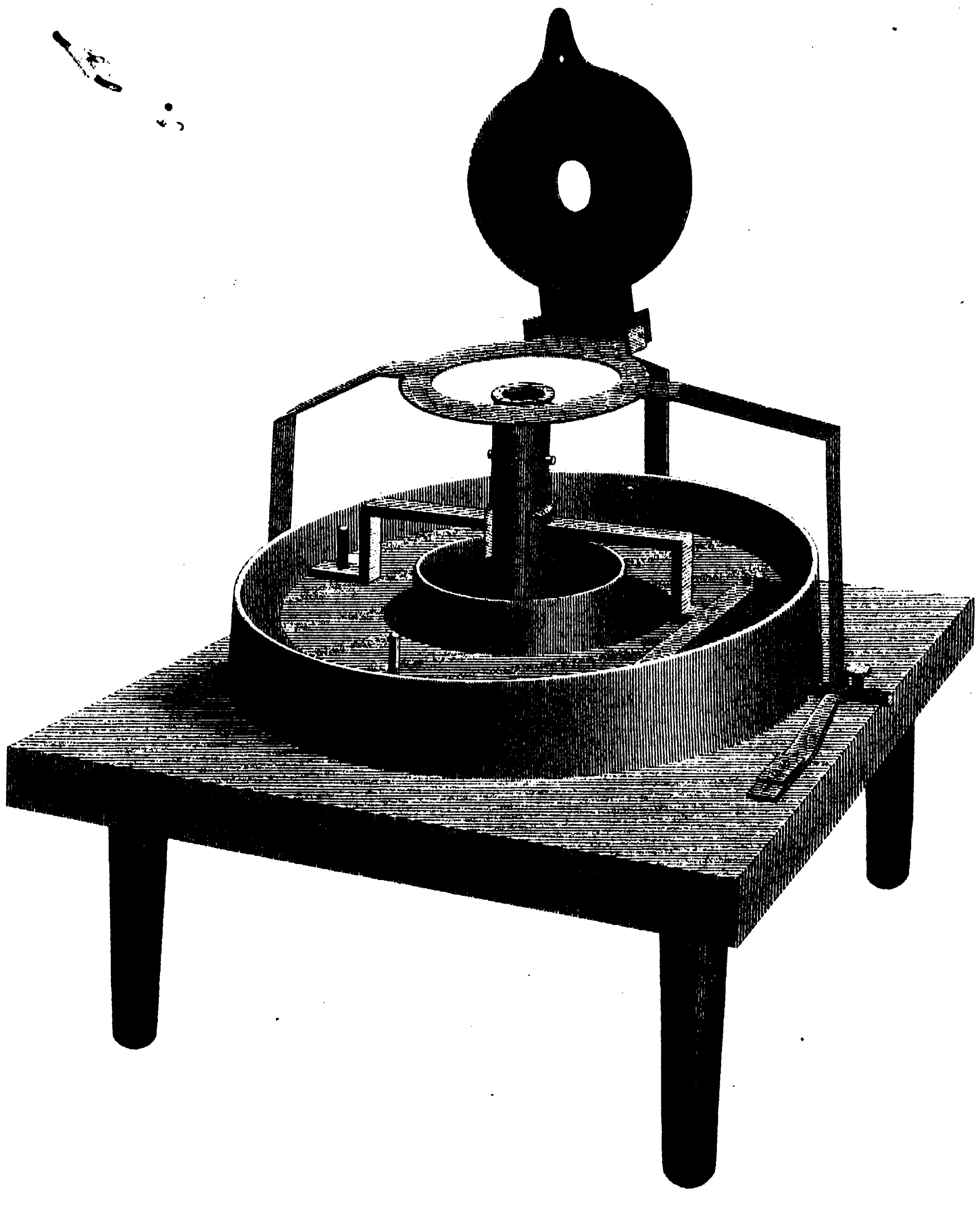
* Since the above was written, I have found that a cross of strong spiders threads answers very well.



L. Bario sc.

employed, by a black paper screen surrounding that of the collimator, the diaphragm is to be viewed, and the distance of the object-glass from it to be varied until its angles appear sharp and well-defined. This I consider merely as preparatory to the final adjustment; but if the telescope used has a magnifying power of about one hundred, this adjustment will probably be found to be sufficiently accurate.

Two beams of wood are to be fixed horizontally to the walls of the observatory in the direction of the meridian, beneath the opening in the roof, and at such a distance from each other as that the legs of the support of the collimator may pass between them, and the board rest upon the beams. It may then be moved along upon the beams, the legs confining the motion in the direction of the meridian. In order to render this motion more free, and to prevent the beams from wearing, their upper surfaces are covered with sheet iron, and four rollers are let into the board near the legs, one of the rollers being attached to a spring in order that all four may be always in contact with the beams.

The instrument employed for the final adjustment of the collimator and in the zenith observations which will hereafter be detailed, was a reflecting telescope of the Newtonian construction, having an aperture of six inches and a quarter, a focal length of forty inches, and a magnifying power of ninety-nine times. This was furnished with a spider's thread micrometer, each of the divisions of which is equal to half a second.

A slight frame of wood was made to receive the tube of the telescope when placed in the direction of the zenith. This frame consisted of a triangle embracing the tube a little below the micrometer. From the corners of this triangle, three rods of wood pass into the extremities of a T made of wood, the cross piece being about two feet in length. Near the extremities of the T, are also inserted coarse iron screws, for the purpose of placing the telescope in the direction of the zenith. The tube of the telescope is kept steady in the triangle by two small wedges of wood, the end containing the mirror resting on the middle of the perpendicular bar of the T. The telescope previously to its being placed in the observatory, was very nicely adjusted to distinct vision upon a fixed star*.

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* I have stated rather what ought to have been done, than what was actually effected at the time, as will be seen hereafter.

The room in which the observations were made, has a pit in it about two feet and a half wide, six feet long, and seven feet deep, filled with sand, upon which are laid two flat stones clear of the sides of the pit. These form a support for any instrument I employ, which is thus secured from any perceptible tremor which might be occasioned by passing carriages.

The Newtonian telescope, in its wooden frame, is placed under the collimator in such a position, that a plumb-line let fall from the centre of the collimator, passes on one side of the plane mirror of the telescope. The micrometer in my telescope is on the east side of the meridian, the micrometer head being to the right-hand of the observer; consequently the moveable line is perpendicular to the horizon, and from the nature of the telescope parallel to the equator. This line should be nicely adjusted so as to represent a parallel of declination, by turning the micrometer round in the eye-tube until a fixed star (γ Draconis in my observatory) runs along the wire.

A sufficient quantity of mercury is put into the basin of the collimator to support the float without risk of its touching the bottom. The diaphragm is illuminated by a lanthorn furnished with a lens, and placed upon a support attached to the board of the collimator. The illumination of the diaphragm was attended with much trouble in my first trials, but I afterwards discovered a method by which the difficulty was obviated. The end of the Newtonian telescope being closed by its cover, a sheet of white paper was placed upon it; the light of the lanthorn was thrown upon the plane mirror, and the position of the mirror varied until the shadow of the diaphragm appeared upon the paper.

If the diaphragm should not now be visible in the telescope, the telescope must be inclined to one side or the other by means of the foot-screws, till the diaphragm is seen in the centre of the field of view.

The next step is to place the line of collimation of the telescope of the collimator nearly in the direction of the zenith. For this purpose, the telescope is to be adjusted by its foot-screws, so that the horizontal thread of the micrometer shall pass through the angular point of the diaphragm, when the basin of the collimator must be turned half round. It is now possible that the diaphragm may be no longer in the field of view; in which case, whilst an assistant looks through the telescope, the float of the collimator must be depressed by the finger on one side or the other, until the diaphragm is again seen just within the field. Weights must then be put upon the pins to which the pressure was applied, and the process repeated till the centre of the diaphragm remains in the middle of the field of view, upon the collimator being turned half round. The telescope must of course be made to follow these adjustments by means of its foot-screws. The telescope of the collimator must now be turned round in its tube, (the pin on the outside of the basin being in one of the Y's,) until the diaphragm is brought into that position in which both its angles can be bisected by the moveable line of the micrometer. When the adjustment is sufficiently accurate, the angular point of the diaphragm will remain upon the horizontal line, or very near it, and not depart much from the moveable line of the micrometer when the collimator is turned half round.

The collimator is now to be moved along the cross beams until the angles become faintly illuminated, when they are to be carefully bisected with the moveable line. The collimator is then to be slid the contrary way till the angles again become faint, when, if the bisection is not as perfect as before, the distance of the object-glass of the collimator from the diaphragm is not adjusted to the last degree of precision. If the diaphragm appears to have moved from the line in the opposite direction to that in which the collimator was moved, the rays diverge, and the object-glass is too near the diaphragm. If the diaphragm has moved in the same direction as the collimator, the rays converge, and the object-glass must be brought nearer to the diaphragm. When the angles continue perfectly bisected in both positions of the collimator, the object-glass is to be secured in its place by means of the screws for that purpose.

We have seen that when the iron pin was in one of the Y's, the telescope of the collimator was turned round in the tube which carries it, till the angles of the diaphragm could be bisected by the moveable line of the micrometer. But it is possible that upon lodging the iron pin in the other Y, the angles may no longer be capable of bisection. This would happen if the basin of the collimator had not described a semicircle; and in that case, the spring or Y must be shifted till the angles can be perfectly bisected, when it must be firmly fixed in its place*.

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* It is evident that the adjustments which have been, I trust with sufficient minuteness, described, may be effected by employing the telescope attached to an astronomical circle, instead of using a detached telescope for the purpose.

I shall now show the manner in which the vertical floating collimator is to be used for determining the zenith point of an instrument, and the degree of dependence that may be placed upon the results.

The collimator is to be turned half round, and the iron pin lodged in one of the Y's. This is done merely to agitate the float slightly, in order to release the parts from any possible constraint. When the float is quite steady, which it will be in about half a minute, the angles of the diaphragm are to be carefully bisected by the moveable thread of the micrometer, and the division read off and registered. I have generally bisected the opposite angles separately, as will be seen in the tables which follow. The collimator is now to be turned half round, the angles again bisected, and the division of the micrometer read off. The mean of these readings will be the zenith point of the instrument employed, and half their difference will be the angle formed by the line of collimation of the telescope of the collimator with the zenith.

It must be evident that the accuracy of the results afforded by the floating collimator (excepting the unavoidable errors of observation) is wholly dependent upon the permanency of its line of collimation to the zenith, during the very short interval between the two observations, or bisections of the angles of the diaphragm which have been described. But this inclination may vary considerably from expansion, or otherwise, between any two determinations of the zenith point, without at all influencing the accuracy of either.

The agreement of the several determinations of the zenith point with each other, will depend upon the degree of stability with which the astronomical circle, or the zenith telescope is supported, and upon the supposition that its parts suffer no relative change of position from unequal temperature or otherwise. The time required for completing the determination of the zenith point by means of the vertical floating collimator, does not exceed two minutes; and if to this be added the time necessary for another determination of the zenith point, the whole time required will not be more than five minutes, during which, it may be allowable to suppose that no very sensible change can take place, either in the collimator or in the instrument, from variation of temperature. We will therefore consider the mean of these two separate determinations as the true zenith point, and conclude the difference between this mean, and the first determination of the zenith point to be the probable error with which such first determination can be charged. The second determination of the zenith point will have the same error as the first, but with a contrary sign. This second determination, however, will also have another error deduced by taking the difference between it, and the mean of the second and third readings of the zenith point. The mean of these two errors is considered to be the probable error of the second zenith point, and so of the rest. It would not be safe to take the mean of all the determinations of the zenith point which constitute a series for the standard of comparison, as the instrument may, and probably will, have suffered some slight change of position during so long a period. If the errors (supposed to belong to the floating collimator) be applied to the observed zenith points, the results will show the whole change of position which the zenith telescope may have suffered during the observations constituting the series; and as it may be interesting to see the degree of stability of an instrument supported in the slight manner I have described, I have added a column of the corrected zenith points.

I shall now proceed to detail the experiments that have been made; and in order that the inferences may not rest solely upon my own authority, I shall give the observations of such gentlemen as have been from time to time kind enough to assist me.

The Collimator turned half round rapidly and without care.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 20.	79.5 77.3 71.7 74.8	78.40 73.25	2.57	1″.28	75.82	37″.91	+0″.10	37″.81
	79.0 75.7 72.8 74.2	77.35 73.50	1.92	0.96	75.42	37.71	+0.00	37.71
	78.8 76.0 73.0 72.2	77.40 72.60	2.40	1.20	75.00	37.50	−0.11	37.61
						Mean....	0.00	

The Collimator turned half round rapidly and without care.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 21.	63.0 63.0 83.0 87.7	63.00 85.35	11.17	5″.58	74.17	37″.08	−0″.11	37″.19
	64.2 64.2 82.0 88.0	64.20 85.00	10.40	5.20	74.60	37.30	+0.05	37.25
	65.0 65.0 82.0 86.7	65.00 84.35	9.67	4.83	74.67	37.33	−0.02	37.35
	66.0 66.0 81.7 86.0	66.00 83.85	8.92	4.46	74.92	37.46	+0.01	37.45
	64.5 64.5 81.0 88.3	64.50 84.65	10.07	5.03	74.57	37.28	−0.10	37.38
	66.0 66.0 81.0 87.0	66.00 84.00	9.00	4.50	75.0	37.50	+0.08	37.42
	65.0 65.0 80.0 85.8	65.00 82.90	8.95	4.47	73.95	36.97	0.00	36.97
	64.0 64.0 78.0 85.5	64.00 81.75	8.87	4.43	72.87	36.43	−0.18	36.61
	63.5 63.5 80.0 86.0	63.50 83.00	9.75	4.87	73.25	36.62	+0.08	36.54
	64.0 64.0 78.2 85.5	64.00 81.85	8.92	4.46	72.92	36.46	+0.07	36.39
	62.0 62.0 78.0 86.0	62.00 82.00	10.00	5.00	72.00	36.00	−0.13	36.13
	63.0 63.0 78.2 84.3	63.00 81.25	9.12	4.56	72.12	36.06	+0.02	36.04
	61.8 61.8 79.2 85.5	61.80 82.35	10.27	5.13	72.07	36.03	−0.02	36.05
						Mean....	−0.01	

The Collimator turned half round slowly and carefully.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 22.	7.0 7.0 42.0 47.0	7.00 44.50	18.75	9″.37	25.75	12″.87	−0″.36	13″.23
	8.0 8.0 43.8 49.0	8.00 46.40	19.20	9.60	27.20	13.60	+0.23	13.37
	8.0 8.0 43.0 48.2	8.00 45.60	18.80	9.40	26.80	13.40	−0.14	13.54
	8.0 8.0 43.8 50.3	8.00 47.05	19.52	9.76	27.52	13.76	+0.29	13.47
	7.0 7.0 42.3 47.3	7.00 44.80	18.90	9.45	25.90	12.95	−0.26	13.21
	7.2 7.2 42.7 48.3	7.20 45.50	19.15	9.57	26.35	13.17	+0.04	13.13
	7.0 7.0 44.2 47.7	7.00 45.95	19.47	9.73	26.47	13.23	+0.06	13.17
	6.2 6.2 43.8 48.2	6.20 46.00	19.90	9.95	26.10	13.05	0.00	13.05
	6.7 6.7 43.0 46.8	6.70 44.90	19.10	9.50	25.80	12.90	−0.08	12.98
						Mean....	−0.02	

Oct. 27.	88.2 91.1 78.0 73.8	89.65 75.90	6.87	3″.43	82.77	41″.38	−0″.07	41″.45
	86.2 91.7 78.0 76.3	88.95 77.15	5.90	2.95	83.05	41.52	−0.11	41.63

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Oct. 27. (Continued.)	88.0 93.1 79.0 76.8	90.55 77.90	6.32	3″.16	84.22	42″.11	+0″.23	41″.88
	85.4 92.5 78.6 77.5	88.95 78.05	5.45	2.72	83.50	41.75	+0.31	41.44
	84.1 89.0 78.0 76.0	86.55 77.00	4.77	2.38	81.77	40.88	+0.03	40.85
	82.5 86.3 77.0 73.3	84.40 75.15	4.62	2.31	79.77	39.88	−0.28	40.16
	82.0 87.0 76.8 74.4	84.50 75.60	4.45	2.22	80.05	40.02	+0.05	39.97
	82.0 87.0 77.0 73.7	84.50 75.35	4.57	2.28	79.92	39.96	−0.08	40.04
	82.7 87.5 77.0 74.8	85.10 75.90	4.60	2.30	80.50	40.25	+0.14	40.11
						Mean . .	+0.02	
Oct. 28.	63.5 70.2 23.0 24.7	66.85 23.85	21.50	10″.75	45.35	22″.67	+0″.21	22″.46
	60.6 70.0 23.0 24.5	65.30 23.75	20.77	10.38	44.52	22.26	−0.21	22.47
	62.0 68.7 24.5 26.3	65.35 25.40	19.97	9.98	45.37	22.68	+0.05	22.63
	60.8 68.7 25.7 27.9	64.75 26.80	18.97	9.48	45.77	22.88	+0.11	22.77
	60.7 66.0 26.2 28.5	63.35 27.35	18.00	9.00	45.35	22.67	−0.11	22.78
						Mean . .	+0.01	

Experiments by Mr. HERSCHEL.

Date. 1827.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Nov. 26.	87.2	86.10	33.95	16″.97	52.15	26″.07	+0″.37	25″.70
	85.0							
	21.8	18.20						
	14.6							
	85.9	84.45	33.77	16.88	50.67	25.33	−0.21	25.54
	83.0							
	20.3	16.90						
	13.5							
	86.4	84.80	33.90	16.95	50.90	25.45	+0.25	25.20
	83.2							
	21.4	17.00						
	12.6							
	87.1	84.15	34.97	17.48	49.17	24.58	−0.09	24.67
	81.2							
	17.8	14.20						
	10.6							
	84.2	83.20	35.02	17.51	48.17	24.08	−0.11	24.19
	82.2							
	16.2	13.15						
	10.1							
	83.8	82.40	34.30	17.15	48.10	24.05	−0.02	24.07
	81.0							
	16.2	13.80						
	11.4							
						Mean....	+0.03	

Experiments by Mr. BAILY.

1828. Jan. 20.	17.0	13.15	9.27	4″.68	22.42	11″.21	+0″.39	10″.82
	9.3							
	32.2	31.70						
	31.2							
	16.2	13.05	8.82	4.41	21.87	10.43	−0.39	10.82
	9.9							
	31.9	30.70						
	29.5							

Experiments by Colonel COLBY.

Jan. 20.	36.0	34.60	9.90	4″.95	24.7	12″.35	+0″.51	11″.84
	33.2							
	18.7	14.80						
	10.9							
	35.2	33.90	11.22	5.61	22.67	11.33	−0.42	11.75
	32.6							
	14.0	11.45						
	8.9							
	34.9	33.50	9.45	4.72	24.05	12.02	+0.34	11.68
	32.1							
	17.0	14.60						
	12.2							
						Mean....	+0.14	

Experiments by Mr. South.

Date. 1828.	Reading of the Micrometer. Divisions.	Mean.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.	Corrected Zenith Point.
Jan. 22.	25.3 22.7 64.1 60.3	24.00 62.20	19.10	9″.55	43.10	21″.55	+0″.29	21″.26
	24.6 22.3 60.5 60.5	23.45 60.50	18.52	9.26	41.97	20.98	+0.09	20.89
	22.8 20.3 58.5 58.8	21.55 58.65	18.50	9.25	40.10	20.05	−0.51	20.56
	25.3 18.7 63.8 61.7	22.00 62.75	20.37	10.18	42.37	21.18	+0.48	20.70
	23.3 19.6 59.3 60.8	21.45 60.05	19.30	9.65	40.75	20.37	−0.41	20.78
						Mean....	−0.01	

Experiments by Captain Sabine.

Jan. 25.	69.0 64.8 30.0 25.0	66.90 27.50	19.70	9″.85	47.2	23″.60	+0″.13	23″.47
	67.8 64.6 29.0 25.4	66.20 27.20	19.50	9.75	46.7	23.35	−0.19	23.54
	67.6 63.8 31.5 27.9	65.70 29.70	18.00	9.00	47.7	23.85	+0.32	23.53
	66.3 64.8 28.0 25.3	65.55 26.65	19.45	9.77	46.10	23.05	+0.03	23.02
	65.5 61.2 27.7 24.6	63.35 26.15	18.60	9.30	44.75	22.37	−0.34	22.71
						Mean....	−0.01	

For greater convenience, I shall now give in one view the errors with which each of the preceding determinations of the zenith point can be charged, classing together such as do not exceed one-tenth of a second; those between one and two tenths; those between two and three tenths; those between three and four tenths; those between four and five tenths; and such as exceed half a second.

TABLE of the Errors of the preceding determinations of the Zenith Point.

Not exceeding One Tenth of a Second.	Between One and Two Tenths.	Between Two and Three Tenths.	Between Three and Four Tenths.	Between Four and Five Tenths.	Above Five Tenths.
+.10	−.11	+.23	−.36	−.42	+.51
.00	−.11	+.29	+.31	+.48	−.51
+.05	−.18	−.26	+.37	−.41	
−.02	−.13	+.23	+.39		
+.01	−.14	−.28	−.39		
−.10	−.11	+.21	+.34		
+.08	+.14	−.21	+.32		
.00	+.11	−.21	−.34		
+.08	−.11	+.25			
+.07	−.11	+.29			
+.02	+.13				
−.02	−.19				
+.04					
+.06					
.00					
−.08					
−.07					
+.03					
+.05					
−.08					
+.05					
−.09					
−.02					
+.09					
+.03					

We may here perceive, that of sixty independent determinations of the zenith point, there are twenty-five, the error of each of which does not exceed one tenth of a second, thirty-seven under two tenths, forty-seven under three tenths, fifty-five under four tenths, three between four and five tenths, and two a little above half a second.

But it is probable that the greater part of these errors, minute as they are, must be attributed to want of power in the micrometer; for I found that when the collimator was stationary, the repeated bisections of the same angle would generally differ one or two divisions from each other; and it must be remembered that one division is equal to half a second. The focal length of the telescope employed is only forty inches, and the power or scale of the micrometer, and consequently the precision of which it is capable, is directly as the focal length of the object-glass or mirror of the telescope to which it is attached.

The zenith telescope, and the telescope of the collimator, may be considered as forming together a compound microscope, having, as it were, a separable object-glass, the two parts of which may be placed at any distance from each other without altering the effect. The magnifying power of this microscope may be found in the usual manner, by dividing the focal length of the zenith telescope by that of the telescope of the collimator, and multiplying the result by the power of the eye-glass, or by the quotient of ten inches divided by its focal length. Thus the focal length of the zenith telescope being forty inches, and the magnifying power ninety-nine times, the focal length of the eye-glass will be about four tenths of an inch. Then dividing forty inches by eight inches, the focal length of the telescope of the collimator, and this again by the power of the eye-glass, we have $\frac{40}{5} + \frac{10}{0.4} = 125$ for the magnifying power exerted upon the diaphragm of the collimator.

The collimator I have described has a float 10.6 inches diameter; but I have had one constructed on a much smaller scale for Captain FOSTER, R.N. the float of which is only five inches in diameter, and its telescope about five inches long.

Some experiments have been made with this little instrument, the results of which have so far exceeded my expectations, that I think they may not prove uninteresting*.

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* On taking down my collimator after it had been exposed for six months, in order to replace it by that made for Captain FOSTER, I found it very rusty, and the mercury very dirty. On taking out the float, it appeared that the mercury had adhered to it, so as to form a kind of coating like amalgam. These circumstances may have slightly affected the accuracy of the instrument. I have since discovered that by rubbing the float with chalk, and afterwards wiping it, the adhesion of the mercury is prevented.

Experiments with Captain Foster's Collimator.

Date. 1828.	Reading of the Microm. Divisions.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.
			″		″	″
Feb. 22.	90.7 84.0	3.35	1.67	87.35	43.67	—0.12
	89.0 86.7	1.15	0.57	87.85	43.92	+0.23
	87.0 86.0	0.50	0.25	86.50	43.25	—0.45
	87.3 90.2	1.45	0.72	88.75	44.37	+0.27
	86.0 91.6	2.80	1.40	88.80	44.40	+0.17
	87.0 88.0	0.50	0.25	87.50	43.75	—0.14
	85.0 89.7	2.35	1.17	87.35	43.67	—0.04
	84.0 91.0	3.50	1.75	87.50	43.75	+0.21
	81.0 91.0	5.00	2.50	86.00	43.00	—0.71
	85.4 95.0	4.80	2.40	90.20	45.10	+0.53
	84.3 96.0	5.85	2.92	90.15	45.07	+0.15
	83.0 94.0	5.50	2.75	88.85	44.42	—0.33
					Mean. .	—0.02

Experiments by Captain Foster.

			″		″	″
Feb. 23.	63.2 118.0	27.40	13.70	90.60	45.30	+0.09
	65.0 115.5	25.25	12.62	90.25	45.12	—0.01
	63.5 116.5	26.50	13.25	90.00	45.00	+0.14
	64.0 113.3	24.65	12.32	88.65	44.32	+0.02
	66.2 108.0	25.90	12.95	87.10	43.55	—0.28
	67.8 107.8	20.00	10.00	87.80	43.90	+0.08
					Mean. .	+0.01

Experiments by Mr. Harvey.

Date. 1828.	Reading of the Microm. Divisions.	Inclination of the Collimator. Divisions.	Inclination in Seconds.	Reading at the Zenith. Divisions.	Zenith Point in Seconds.	Possible Error in Seconds.
			"		"	"
Feb. 26.	69.4 57.5	5.95	2.97	63.45	31.72	+0.35
	69.7 60.0	4.85	2.42	64.85	32.42	−0.17
	69.5 60.2	4.65	2.32	64.85	32.42	+0.02
	68.3 61.0	3.65	1.82	64.65	32.32	+0.13
	69.6 57.2	6.20	3.10	63.40	31.70	−0.43
	67.7 62.7	2.50	1.25	65.20	32.60	+0.34
	69.5 59.8	4.85	2.42	64.65	32.32	+0.14
	68.8 59.4	4.70	2.35	64.10	32.05	+0.29
	65.0 57.5	3.75	1.87	61.25	30.62	−0.67
	69.5 58.0	5.75	2.87	63.75	31.87	+0.62
					Mean..	+0.06

The following Table contains the Error of each of the preceding determinations of the Zenith Point, by Captain Foster's Collimator.

Not exceeding One Tenth of a Second.	Between One and Two Tenths.	Between Two and Three Tenths.	Between Three and Four Tenths.	Between Four and Five Tenths.	Above Five Tenths.
−.04	−.12	+.23	−.33	−.45	−.71
+.09	+.17	+.27	+.35	−.43	+.53
−.01	−.14	+.21	+.34		−.67
+.02	+.15	−.28			+.62
+.08	+.14	+.29			
+.02	−.17				
	+.13				
	+.14				

I leave the results of the little floating collimator to speak for themselves, and shall now return to my larger collimator before described.

On the manner of using the Vertical Floating Collimator in Astronomical Observations.

The instrument employed in the observations which I shall first detail, was the portable azimuth and altitude circle described by the Rev. F. Wollaston in his "Fasciculus Astronomicus," and was the property of the late D. Moore, Esq. F.R.S. This circle is only one foot in diameter; the divisions are dots upon brass, and it is also divided by lines. Of the dots, though they are the divisions used, I cannot learn the history. Many of them are much injured, and some nearly obliterated.

The instrument is furnished with two microscopes, the micrometer heads of which are divided to two seconds; but I have attempted by the eye to estimate the readings to tenths of a second. The focal length of the telescope is twenty inches, and it magnifies about thirty times.

I shall now describe the manner in which the different adjustments of an altitude and azimuth circle may be readily effected by means of the vertical floating collimator.

To adjust the Line of Collimation.

The circle being placed in the meridian, and the vertical floating collimator over it, the meridian wire is to be brought to the angular point of the diaphragm of the collimator, by means of one of the foot-screws of the circle. The axis is now to be taken out of the Y's and reversed; when if the meridian wire is no longer on the angular point of the diaphragm, the space over which it has moved is equal to double the error of the line of collimation. Bisect this space by moving the meridian wire by means of the screws in its diaphragm, and the line of collimation will then be at right angles to the axis. This is proved by the meridian wire suffering no change of place when the axis is reversed*.

To place the Horizontal axis of the Circle at right angles to the Vertical axis.

Bring the meridian wire to the angular point of the diaphragm of the collimator by means of the foot-screw. Turn the circle half round in azimuth, and then note the distance of the meridian wire from the angular point. Half this distance is the error of the horizontal axis, or its deviation from perpendicularity to the vertical axis. Cause the meridian wire to bisect this distance by

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* The operation just described, is nothing more than the process of adjusting the line of collimation of a transit instrument, the angular point of the diaphragm of the collimator serving instead of a distant terrestrial object. It may be done with great convenience by means of the horizontal floating collimator.

means of the screw which acts upon that Y which is opposite to the microscopes, and the horizontal axis will be perpendicular to the vertical axis. This adjustment is known to be perfect when the meridian wire remains upon the angular point after the circle has been turned half round in azimuth.

To place the axis of the circle parallel to the Horizon.

Lodge the iron pin of the basin of the collimator in one of the Y's, and by means of one of the foot-screws bring the meridian wire to the angular point of the diaphragm. Turn the collimator half round, and note the distance (if any) of the meridian wire from the angular point. Half this distance is the error of the axis or its deviation from horizontality. Cause the meridian wire to bisect this distance by means of the foot-screw, and the axis of the circle will then be parallel to the horizon. Examine this adjustment by turning the collimator half round; when if it is correct, the angular point will be equally distant on either side from the meridian wire, of which the eye will judge with considerable accuracy*.

These are all the adjustments that are necessary; and whoever has enjoyed the superior convenience and facility of effecting them by means of the floating collimator, will scarcely prevail on himself to return to the instability and uncertainty of a level.

Should it be necessary, the telescope of the collimator must be turned in its tube (the iron pin being lodged in one of the Y's) until the angles of the diaphragm can be bisected by the horizontal wire of the circle, when the instrument is ready to be employed in celestial observations. I have of course taken it for granted that the float has been adjusted by the application of weights to it, so that the angular point of the diaphragm remains either upon or very near the meridian wire, and does not depart far from the horizontal wire when the collimator is turned half round.

Before quitting the subject of adjustments, I may remark, that the vertical floating collimator affords the most perfect method of adjusting the line of collimation of a mural circle, or of placing it at right angles to the axis. But for this purpose it will be necessary to employ two of these instruments, one placed above, and the other below the circle. Bring then the meridian wire

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* I scarcely need point out the value of this mode of adjustment as applied to a transit instrument. It insures the line of collimation describing a vertical circle, and is independent of any inequality in the size of the pivots.

of the mural circle to the angular point of the diaphragm of the upper floating collimator. Turn the collimator half round and bring back the meridian wire by adjusting the axis of the circle through half the distance it has appeared to move from the angular point. Look now into the lower collimator, and note the distance at which the angular point appears to be from the meridian wire. Turn this collimator half round, and remark whether the angular point is at the same distance as before on the other side of the meridian wire; and if the distance is not the same, halve the estimated difference by moving the meridian wire by means of the adjusting screws of its diaphragm. Repeat these operations until in both collimators the angular point appears to move to an equal distance on each side of the meridian wire on the collimator being turned half round, when the line of collimation will be at right angles to the axis, and the axis will by the same process have been placed parallel to the horizon.

It will be found convenient before the observation of the star is made, to ascertain that the illumination of the collimator is perfect, as it must be evident that it is important to determine the zenith point of the instrument as soon after the observation of the star as possible.

Should the star be at such an altitude as for the view of it to be intercepted by the collimator, the collimator must be moved as far as may be requisite along the beams. After the star has been carefully bisected, and before the microscopes are read off, the shutter of the observatory is to be closed, and the collimator is to be brought back to its place and turned half round. The microscopes are then to be read off and registered, and by the time this is completed, the collimator will be steady. The angles of the diaphragm are now to be bisected by the horizontal wire, and the collimator immediately turned half round. The divisions of the circle are then to be examined, and the microscopes read off and registered. Long before this, the collimator will again be steady, when the angles are again to be bisected, and the readings of the microscopes registered. This forms a complete observation; but it is desirable to repeat the operation for the determination of the zenith point, in order to preclude or detect error. The mean of the readings at the collimator will be the place of the zenith point upon the circle, and the difference between this and 90 degrees or zero, will furnish a correction to be applied with its proper sign to the reading at the star, for the purpose of obtaining its apparent altitude or its zenith distance.

The refractions used in the following Table, are those given by Dr. YOUNG in the Nautical Almanac.

Observations with the Astronomical Circle.—(*Face West.*)

Date. 1827.	Star.	Readings.	Mean.	Mic^{s}	Collimator.	Collimator reversed.	Incl. of Collim.	Zenith Point.	Correction.	Apparent Altitude.	Barom.	Extern. Therm.	Refraction.	True Altitude.	Latitude.
		° ′ ″	° ′ ″		° ′ ″	° ′ ″	″	° ′ ″	′ ″	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
June 20	α Herculis	50 4 7.0	53 4 20.75	A	89 59 13.5	89 59 11.0	3.17	89 59 12.07	+0 47.93	53 5 8.68	29.90	54	0 43.21	53 4 25.47	51 31 20.23
		4 34.5		B	59 17.0	59 6.8									
	α Ophiuchi	51 10 0.3	51 10 14.15	A	89 59 6.5	89 59 12	2.37	89 59 12.12	+0 47.88	51 11 2.03	29.90	54	0 45.97	51 10 16.06	51 31 25.94
		10 28.0		B	59 13.0	59 17									
22	α Serpentis	45 26 34	45 26 59.5	A	89 58 45.0	89 58 52.5	3.67	89 59 54.07	+1 5.93	45 28 5.43	30.16	55	0 56.34	45 27 9.09	51 31 26.71
		27 25		B	58 55.8	59 3.0									
23	Arcturus	58 33 18	58 33 25	A	89 59 0.8	89 58 46.5	7.20	89 58 53.2	+1 6.8	58 34 31.8	30.18	58	0 34.49	58 33 57.31	51 31 14.47
		33 32		B	59 0.0	58 45.5									
	α Coronæ	65 45 59.7	65 46 8.75	A	89 58 59.8	89 58 47.0	5.97	89 58 52.82	+1 7.18	65 47 15.93	30.18	58	0 25.80	65 46 50.13	51 31 22.33
		46 17.8		B	58 57.8	58 46.7									
	Antares	12 29 18.0	12 29 22.6	A	89 58 50.0	89 58 56.0	2.75	89 58 52.50	+1 7.5	12 30 30.1	30.18	56	4 13.88	12 26 16.22	51 31 20.68
		29 27.2		B	58 49.5	58 54.5									
	α Herculis	53 3 57.5	53 4 5.15	A	89 58 55.0	89 58 50.0	2.12	89 58 51.62	+1 8.38	53 5 13.53	30.18	55	0 43.12	53 4 30.41	51 31 16.29
		4 12.8		B	58 52.5	58 49.0									
	α Ophiuchi	51 9 50.0	51 9 59	A	89 58 52.5	89 58 55.2	1.37	89 58 50.72	+1 9.28	51 11 8.28	30.18	53.5	0 46.32	51 10 21.96	51 31 20.60
		10 8.0		B	58 46.2	58 49.0									
24	α Coronæ	65 45 52.3	65 46 2.15	A	89 58 44.5	89 58 45.8	0.57	89 58 46.57	+1 13.43	65 47 15.58	30.18	61	0 25.64	65 46 49.94	51 31 22.71
		46 12.0		B	58 47.5	58 48.5									
	Antares	12 29 6.0	12 29 17.4	A	89 58 47.5	89 58 42.5	2.37	89 58 47.37	+1 12.63	12 30 30.03	30.17	59.5	4 11.94	12 26 18.09	51 31 19.86
		29 28.8		B	58 52.0	58 47.5									
26	Antares	12 29 12.2	12 29 23.85	A	89 58 52.5	89 58 54.7	1.20	89 58 55.65	+1 4.35	12 30 28.20	30.09	62	4 9.92	12 26 18.28	51 31 19.61
		29 35.5		B	58 56.4	58 59.0									
	α Herculis	53 3 54.0	53 4 3.15	A	89 58 57.0	89 58 48.0	3.72	89 58 53.87	+1 6.13	53 5 9.28	30.09	60.5	0 42.61	53 4 26.67	51 31 20.63
		4 12.3		B	58 58.2	58 52.3									
	α Ophiuchi	51 9 47.0	51 10 1.50	A	89 58 51.0	89 58 55.5	2.92	89 58 54.02	+1 5.98	51 11 7.48	30.09	60	0 45.72	51 10 21.76	51 31 21.37
		10 16.0		B	58 51.2	58 58.4									
														Face West, Mean...	51 31 20.88
(Face East.)															
		° ′ ″	° ′ ″		° ′ ″	° ′ ″	″	° ′ ″	′ ″	° ′ ″		°	′ ″	° ′ ″	° ′ ″
July 6	α Coronæ	65 46 9	65 46 9.35	B	89 58 41.3	89 59 1	11.85	89 58 46.9	+1 13.10	65 47 22.45	30.45	67	0 25.60	65 46 56.85	51 31 17.87
		46 9.7		A	58 38.8	58 56.5									
	Antares	12 29 7.2	12 29 13.2	B	89 59 3.2	89 58 28	16.45	89 58 46.05	+1 13.95	12 30 27.15	30.45	67	4 10.35	12 26 16.80	51 31 20.86
		29 19.2		A	59 2.0	58 31									
7	α Coronæ	65 46 8.5	65 46 11	B	89 58 51.2	89 58 48	4.55	89 58 51.55	+1 8.45	65 47 19.45	30.44	71	0 25.40	65 46 54.05	51 31 21.63
		46 13.5		A	59 1	58 46									
	Antares	12 29 8	12 29 11.5	B	89 58 50	89 58 52.8	1.70	89 58 53.2	+1 6.80	12 30 18.3	30.44	71	4 8.12	12 26 10.18	51 31 27.46
		29 15		A	58 53	58 57									
8	α Coronæ	65 45 45	65 45 49.5	B	89 58 29	89 58 31.2	0.62	89 58 29.97	+1 30.03	65 47 19.53	30.41	74	0 25.31	65 46 54.22	51 31 20.82
		45 54		A	58 29.7	58 30									
	α Serpentis	45 26 34.3	45 26 40.65	B	89 58 26	89 58 27	0.07	89 58 29.07	+1 30.93	45 28 11.58	30.41	74	0 54.78	45 27 16.80	51 31 20.88
		26 47		A	58 32.3	58 31									
	Antares	12 28 45.3	12 28 50.3	B	89 58 27	89 58 28.7	0.87	89 58 28.47	+1 31.53	12 30 21.83	30.41	71	4 7.87	12 26 13.96	51 31 23.66
		28 55.3		A	58 28.2	58 30									
	α Herculis	53 3 44	53 3 43.5	B	89 58 34.7	89 58 29	3.12	89 58 30.72	+1 29.28	53 5 12.78	30.41	70	0 42.25	53 4 30.43	51 31 19.09
		3 43		A	58 33	58 26.2									
	α Ophiuchi	51 9 38	51 9 45.25	B	89 58 29	89 58 31.3	1.62	89 58 28.12	+1 31.88	51 11 17.13	30.41	69	0 45.38	51 10 31.75	51 31 13.57
		9 52.5		A	58 24	58 28.2									
														Face East, Mean...	51 31 20.65
														Face West, Mean...	51 31 20.88
														Mean...	51 31 20.76

The resulting latitude of York Gate is 51° 31′ 20″.76.

The mean of 40 observations of different stars in 1825, using the horizontal floating collimator and the same circle, gave 51° 31′ 20″.94.

If we analyse the observations detailed in the preceding table, we may form an estimate: 1st, of the stability of the instrument, and the efficiency of its telescope and microscopes: 2dly, of the degree of accuracy with which a star has been bisected; and 3dly, of the equality or otherwise of the divisions of the circle.

On examining the column of the zenith point, we perceive that on the same evening the differences are but small: for example, on the 23rd of June the greatest difference from the mean was only 2″.25. From which we may infer, that the support of the instrument suffered little change of position during that evening, and that the telescope and microscopes were of a power sufficient to determine this quantity.

On referring to the corresponding inclination of the collimator, we find it in the course of the evening to have varied considerably, without affecting the accurate determination of the zenith point. The cause of this variation I conceive to be the bridge having in the first instance been made very slight, and being consequently readily affected by change of temperature when the shutter of the observatory was opened.

If the bisection of a star could be accurately made, and there existed no uncertainty with respect to refraction, the same latitude would be given on different evenings by the same star; as its altitude is determined by reference to the same division of the instrument. But, we may see that in the preceding table these results differ. With α Herculis the greatest difference is 4″.34, with α Ophiuchi 5″.34, and with Antares the difference amounts to 6″.6. From this we may conclude that, taking an unfavourable state of the atmosphere into consideration, the uncertainty in bisecting a star with this telescope may probably be about three seconds.

As the altitude of each star is referred to a different division of the circle, if the mean of the latitudes given by each star be taken, and these means be compared together, they ought, if the circle is well divided, to agree, and their difference will give some idea of the error in this respect. The observations of each star have not been sufficiently numerous to determine this with accuracy; but I am inclined to think it probable that the error of such points of the circle as have been used does not exceed three seconds.

It is possible that the dots to which the zenith point is referred may be in error; in which case, all the altitudes will be affected to an amount equal to that error. This however is destroyed by reversing the circle, observing with the face the contrary way, and taking the mean of the results in both positions.

If the circle should be upon stone pillars, or so circumstanced that there should be room for the floating collimator below it, it may be employed in that position, its legs serving as a support. The only alteration then necessary will be to invert its telescope, placing the object-glass uppermost, and illuminating the diaphragm from below by means of a mirror attached to a small mass of lead, which may be placed on the ground. The telescope of the circle will then look into that of the collimator downwards; and this, if the circle should not be too high, may sometimes be the more convenient method.

Of the Application of the Vertical Floating Collimator to a Zenith Telescope.

So much has already been said which is appropriate to this subject in describing the adjustment of the collimator, and the determination of the zenith point, that little remains to be added. The Newtonian telescope was the instrument employed; and in the two first observations of γ Draconis, its wooden frame not being finished, the telescope was brought nearly in the direction of the zenith by three small wedges of wood placed under the mirror end, and forming, it must be confessed, a very frail support. The focus of the telescope, too, had not been accurately adjusted, and the moveable wire was placed parallel to the equator merely by estimation. Between the two observations, the telescope was removed; they are recorded, however, as matter of curiosity, but I have not included them in the mean of the observations detailed, though they would not have vitiated the result.

Should the star pass the meridian at night, it will of course be requisite to illuminate the wires of the micrometer in the usual manner. The collimator having been moved along the beams which support it, out of the way of the telescope, the star is to be carefully bisected by the moveable wire, the collimator to be brought back and turned half round, and then the reading of the micrometer at the star to be registered. The angles of the diaphragm are now to be bisected, and the collimator having been turned half round, the divisions of the micrometer are to be recorded. Lastly, the angles of the diaphragm are again to be bisected, and the reading of the micrometer registered. This completes the observation, which altogether requires about five minutes. The mean of the readings at the collimator will give the zenith point; and the difference between the zenith point and the reading at the star, will be the star's zenith distance in divisions of the micrometer to be converted into seconds.

It will be advisable to repeat the determination of the zenith point as directed in observations with the circle, to guard against error.

If the aperture of the zenith telescope should be sufficiently large to render the loss of light from the interposition of the telescope of the collimator of no consequence, it may not be necessary to remove the collimator; but the iron cover B, (see Plate XIII.) may be raised, and the star observed through the opening in the support of the collimator. The cover is then to be replaced, and the zenith point determined in the usual manner.

The diameter of the opening of my collimator being four inches, and the extreme diameter of the telescope an inch and a half, the loss of light would be about one seventh part of the whole; I have not yet tried this method of observing, and perhaps it may be found that the bridge of the collimator (which for this purpose should be thin and deep) may occasion some distortion in the image of the star.

TABLE of Observations with the Zenith Telescope.

Date. 1827.	Reading at the Star. Divisions.	Reading at the Collimator. Divisions.	Zenith Point. Divisions.	Star's Zenith Distance. Divisions.	Star's Zenith Distance. Seconds.	Sum of Corrections.	Zenith Distance reduced to Jan^y 1827.	Remarks.
July 9.	367.5	278.0 385.5	331.75	35.75	17″.87	+13″.17	31″.04	Bad image, and nothing well adjusted.
Aug. 31.	247	294.2 141.0	217.6	29.4	14.7	+25.51	40.21	Bad image, and nothing well adjusted.
Sept. 1.	237	237.5 235.2 196.5 202.0	217.8	19.2	9″.6	+25″.61	35″.21	Excellent.
5	169	158.0 162.0 142.7 137.5	150.05	18.95	9.47	+25.99	35.46	Star past the meridian.
6	89	74.0 77.0 64.5 66.6	70.52	18.48	9.24	+26.07	35.31	Tremor.
Oct. 24.	63.7	21.2 31.8 42.0 48.4	35.85	27.85	13.92	+24.14	38.06	Focus bad, and adjusted a moment before the observation.

Observations with the Zenith Telescope. (Continued.)

Date. 1827.	Reading at the Star. Divisions.	Reading at the Collimator. Divisions.	Zenith Point. Divisions.	Star's Zenith Distance. Divisions.	Star's Zenith Distance. Seconds.	Sum of Corrections.	Zenith Distance reduced to Jan^{y} 1827.	Remarks.
Oct. 24. Continued.		21.0 31.7 44.8 49.0	36.64					
		21.9 32.6 45.0 49.5	37.25					
31	81.5 79.0	18.7 10.7 91.8 88.8	52.5	27.75	13″.87	+22″.83	36″.70	
		18.8 11.8 86.7 85.5	50.7					
		21.0 12.3 86.5 88.0	51.95					
Nov. 2.	145.6	143.0 160.7 82.5 97.3	120.87	24.73	12.36	+22.42	34.78	Doubtful.
5	62	47.5 0.0 72.0 24.0	35.87	26.13	13.06	+21.80	34.86	Line not well adjusted.
12	42.7	26.5 19.7 7.0 7.0	15.05	27.65	13.82	+20.17	33.99	Cloudy. Star scarcely visible.
22	137	118.0 112.0 83.0 78.7	97.92	39.08	19.54	+17.45	36.99	Flying clouds.
		119.8 110.7 81.0 78.7	97.55					
24	135.8	78.0 76.0 120.8 114.3	97.27	38.53	19.26	+16.86	36.12	
		80.0 78.0 119.8 114.0	97.95					
29	110.5	60.0 46.0 93.0 75.0	68.5	42.0	21.0	+15.40	36.40	

Observations with the Zenith Telescope. (Continued.)

Date. 1827.	Reading at the Star. Divisions.	Reading at the Collimator. Divisions.	Zenith Point. Divisions.	Star's Zenith Distance. Divisions.	Star's Zenith Distance. Seconds.	Sum of Corrections.	Zenith Distance reduced to Jan^{y} 1827.	Remarks.
Dec. 6.	164	150.8 135.0 107.0 95.0	121.95	42.05	21″.02	+13″.18	34″.20	Very favourable.
		149.2 133.0 110.0 95.4	121.90					
20	167.3	90.0 87.0 140.0 131.5	112.1	55.2	27.6	+ 8.82	36.42	Very favourable.
		93.0 89.3 141.0 130.0	113.32					
21	126.2	46.0 43.5 98.7 93.0	70.3	55.9	27.95	+ 8.13	36.08	Very favourable.
		47.3 43.4 99.3 90.0	70.0					
23	122.5	92.5 82.5 44.3 42.3	65.4	57.1	28.55	+ 7.45	36.00	
		91.0 82.0 42.0 41.2	64.05					
1828. Jan. 3.	134.1	108.0 84.0 52.0 35.0	69.75	64.35	32.17	+ 4.37	36.54	Flying clouds.
		107.3 82.2 53.2 35.6	69.57					
19	183.6	144.0 119.5 83.7 65.7	103.22	80.38	40.19	− 0.94	39.25	Very hazy.
		142.0 119.5 86.0 64.0	102.87					
			Mean rejecting the last..............				35.82	
			Mean rejecting the last and Oct. 24th..				35.67	

In the preceding Table I have given, as is my practice, every observation which has been made:—the first two, as I before said, are inserted merely as matter of curiosity, though their mean happens to be the same as that ultimately adopted. The last observation I consider inadmissible, as the weather was so hazy that the star was scarcely visible, and that only at intervals. The observation of the 24th of October I feel no hesitation in rejecting, from the disturbance the instrument might have suffered from adjusting the focus of the telescope to the star the moment before the star was bisected, and the consequent hurry in which the observation was made. I therefore consider 35″.67 as the mean, which is nearest the truth. The corrections for aberration, &c. &c. have been taken from the Tables just published by the Astronomer Royal.

It is far from my wish that the astronomical part of the observations here given should be considered as proofs of the utmost accuracy which a telescope so employed is capable of attaining; for it may readily be conceived that had the telescope been firmly fixed by stone- or brick-work, and time taken to place the moveable line of the micrometer accurately parallel to the equator, the bisection of the star might probably have been effected with a much greater degree of precision.

The focal length of the telescope employed was only forty inches, and the scale of the micrometer, or the number of divisions which are equal to a second, it has been remarked, is in proportion to the focal length of the telescope. The shortness of my telescope therefore, may be justly conceived to have taken somewhat from the accuracy of the results; and I ought also to mention, that by far the greater number of these observations, namely, those from the 24th of October, were made in the day time.

Notwithstanding these considerations, the power of the floating collimator is such, that I shall venture to compare the preceding observations with those made under the most favourable circumstances, and with an instrument which is justly esteemed the most perfect of its kind ever constructed, the Zenith Sector belonging to the Board of Ordnance*.

In a series of observations, one or two may perhaps be found which may accidentally differ considerably from the mean of the whole. But the difference

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* This instrument is furnished with an achromatic telescope of eight feet focal length.

between such insulated observations and the mean, cannot be considered as a measure either of the power of the instrument, or of the skill of the observer. These will be more justly estimated by taking the difference between the general mean, and the mean of such observations as exceed and fall short of it*.

In this manner I have examined the observations made with the zenith sector at the Stations of the Trigonometrical Survey, and the following are the results:

Number of Observations.	Difference from the Mean.		
7	+0″.49	−0″.74	β Draconis.
7	+0.88	−0.65	
9	+0.81	−1.02	η Ursæ.
8	+0.39	−0.71	β Draconis.
8	+0.52	−0.30	γ Draconis.
7	+0.42	−0.44	
7	+0.28	−1.70	β Draconis.
7	+0.67	−0.89	
8	+0.85	−0.84	γ Draconis.
9	+0.17	−0.57	51 Draconis.
9	+0.68	−0.55	ϰ Cygni.
8	+0.33	−0.63	ι Cygni.
Mean. . 8	+0.54	−0.75	

The above may be considered as a fair representation of the power of the zenith sector; and I may add, that I have selected those sets which consist of the greater number of observations, and have confined myself to such stars as passed within two degrees of the zenith, to avoid any possible error which might have arisen from uncertain refraction.

I shall now divide the fifteen zenith distances obtained by means of the floating collimator into two sets, consisting of seven and of eight observations each, in order that they may be similarly circumstanced with the observations made with the zenith sector. Proceeding in the same manner as before, we obtain the following results:

Number of Observations.	Difference from the Mean.	
7	+0″.48	−0″.65
8	+0.40	−0.66
Mean. . 8	+0.44	−0.66

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* I am indebted for this suggestion to Dr. WOLLASTON.

The comparison then between the zenith sector and the zenith telescope used with the vertical floating collimator, will stand thus:

Mean of errors by the zenith sector	+0″.54 and	−0″.75
Mean of errors by the zenith telescope used with the floating collimator*	+0″.44 and	−0″.66

I shall now proceed to deduce the latitude of York Gate from the observations made with the zenith telescope.

The polar distance of γ Draconis for January 1827, with which I have been favoured by the Astronomer Royal from the mean of 296 observations, was 38° 29′ 14″.64; which gives for the zenith distance of γ Draconis at Greenwich	0°	2′	6″.36
Add zenith distance at York Gate	0	0	35 .67
Difference of latitude between Greenwich and York Gate	0	2	42 .03
Latitude of Greenwich	51	28	38 .96
Latitude of York Gate	51	31	20 .99

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* It may be remarked, that if the first eight observations and the last seven had been taken to form the two sets, the result would have been less favourable to the zenith telescope. But in the last seven observations there would then have been only a single observation less than the mean; and this, as I have before said, is an inadmissible case for comparison. Were this observation excluded, and the two sets made to consist of eight and of six observations, the resulting differences from the mean would have been far more favourable. The following is a view of the results.

Number of Observations.	Difference from the Mean.	
8	+0″.97	−0″.58
7	+0.29	−1.77*
Mean.. 8	+0.63	−1.17
8	+0″.97	−0″.58
6	+0.19	−0.19
Mean.. 7	+0.58	−0.38

* One observation only, less than the mean, and result therefore inadmissible.

As any difference in the tables of refraction employed will equally affect the latitude and the zenith distance deduced from it, no correction is necessary on this account.

We have then for the latitude of York Gate,

By the azimuth and altitude circle and the horizontal floating collimator	51°	31′	20″.94
By the same instrument and the vertical floating collimator	51	31	20 .76
By the zenith telescope and the vertical floating collimator	51	31	20 .99
Mean . . .	51	31	20 .90

In my description of the horizontal floating collimator, I have recommended it to be employed in an observatory *as a fixed point;* its zenith distance being determined by means of the vertical floating collimator. For this purpose the box should be of cast iron, the openings in the ends of the box closed by pieces of plane glass, and the cover rendered air-tight. We have seen that the error in the vertical floating collimator is scarcely appreciable, though the mercury and float are agitated by turning the instrument half round; and it is not too much to anticipate, that where there is no such cause of disturbance, the horizontal floating collimator will suffer no change of inclination. This, however, may readily be ascertained by experiment.

If I have succeeded in the object of this paper, I shall have demonstrated that the vertical floating collimator is an instrument capable of determining the zenith point with a precision hitherto unknown; that by its aid a meridional observation of an altitude or of a zenith distance may be completed, not only the same evening, but within the space of a very few minutes, and that too, without the necessity of turning the circle in azimuth. These are advantages which no other method of observing affords, and which astronomers well know how to appreciate. If to these be added the facility with which the floating collimator may be constructed, the ease with which it is used, and its general applicability to all astronomical circles, whether small or of large dimensions, it may not perhaps be too much to infer that ere long the use of the level and of the plumb-line in celestial observations will be wholly abandoned.

XIII. *On the height of the Aurora borealis above the surface of the earth; particularly one seen on the 29th of March*, 1826. *By* JOHN DALTON, *F.R.S.*

Read April 17th, 1828.

APPREHENDING that the Royal Society will favourably receive accounts that have a direct tendency to determine the height of that interesting phænomenon, the Aurora borealis, I have been induced to transmit some observations that were made upon a very remarkable one, which appeared in the evening of the 29th of March, 1826. From some recent observations, an opinion seems to be entertained by some writers, that the aurora is not so high as has generally been estimated; but it is only from facts and observations such as the following, I conceive, that any near approximation to the true height can be obtained.

The aurora borealis above mentioned, was of a kind very rarely occurring. It assumed the appearance of a rainbow-like arch, stretching across the mid-heaven, at right angles to the magnetic meridian. It was subject to very little change of position for an hour or more, and therefore afforded time to observe the angle of its elevation above the horizon. In the period of five years' observations at Kendal formerly, above one hundred appearances of the aurora occurred to me, and only one of the kind just described. I had not an opportunity of seeing the one which is the subject of this paper, but it was seen here (at Manchester) by a friend of mine about 9 o'clock on his returning home from a visit to me. He did not indeed observe the luminous arch, either from its having vanished, or from the obscurity of our atmosphere; but he remarked some beams or corruscations in the north-western hemisphere, of a low altitude; and not having seen an aurora for a long time, he induced the family at home to go out and catch a glimpse of the phænomenon, now much more rarely seen than formerly.

A few days afterwards I accidentally noticed a paragraph in the Lancaster Gazette describing the luminous arch of the aurora, as well as the accompanying appearances; and as such a striking and unusual phænomenon could not fail to attract general attention, I examined the provincial newspapers and other periodicals of the time, and took occasion soon after to make inquiries personally, or by writing, of such individuals of judgement as had seen the phænomenon in various places near the line of the magnetic meridian. The result was, a collection of a more complete and extensive series of observations than was ever before made, in all probability, towards determining the height of the luminous arch of the aurora.—I shall now proceed to detail some of the particular observations.

The accounts represent the arch to have been seen in places 170 miles distant in a north and south direction, and forty-five miles distant in an east and west direction, comprising an area of seven or eight thousand square miles; but it must have been much more extensively visible, as in most cases the writers of the different accounts describe their situation as central with regard to the phænomenon. It was seen at Edinburgh and Leith, Kelso, Jedbergh, and Hawick in Scotland; at Carlisle, Penrith, Keswick, Cockermouth, and Whitehaven in Cumberland; at Kendal and at Kirkby-Stephen in Westmorland; at Lancaster, Preston, Warrington, and Manchester in Lancashire; and at Doncaster in Yorkshire. Descriptions of the phænomena as seen at most of these places were immediately given in the newspapers of Lancaster, Kendal, Carlisle, Whitehaven, Kelso, &c., and some of these accounts were copied into the London papers soon after.

All the accounts that I have seen from places between Lancaster and Edinburgh, as well as at these two places, agree that a luminous arch was first seen about 8 o'clock in the evening; that it continued without much motion for an hour nearly, and then gradually vanished, leaving the northern sky illuminated as usual after an aurora borealis of the common kind: so that it seems impossible to doubt that the same arch was seen at all the places of observation, and at the same time.

A good description of the phænomenon was published by Messrs. Coldstream and Foggo in the Edinburgh Journal of Science for June 1826: it is as follows:—

" March 29th. Immediately after the fading of the evening twilight, at 8^h 15^m P.M., a bright luminous ray was seen to rise from the eastern horizon, gradually to extend itself towards the zenith, and thence towards the western horizon, presenting, when completed, the appearance of an arch of silvery light, similar to that seen here on the 19th March, 1825.

" When first formed it was a few degrees to the north of the zenith of this place; the light in the centre was rather diffuse; its edges were irregular; and the western limb had, as it were, a plumose appearance. It soon evinced a decided motion towards the south, and in a few minutes reached our zenith. Its edges were now sharply defined, and throughout its whole course it was nearly uniform in appearance and breadth; the intensity of its light in the zenith had increased, while in the same quarter the breadth had considerably diminished.

" The direction it now had was very nearly at right angles with the magnetic meridian.

" At ½ past 8, faint beams of the aurora began to rise from the northern horizon, and at one time promised to form a splendid display; but the corruscations never became very vivid; they were not rapid in their motions, and did not flit along the horizon.

" The arch still continued its motion towards the south, and in 15 minutes passed through a space of about 20°. Its southern edge reached a point about 24° or 25° south of the zenith, beyond which it did not go. The light now became gradually fainter, and at length disappeared.

" Meanwhile the aurora in the north continued to play, but with no increase of vividness. For some minutes, soon after 9 o'clock, we observed broad bands of light, having their longer axes (which generally subtend angles of about 18° or 20°) parallel with the horizon, darting with great velocity across the illuminated space from east to west and from west to east. These formed, ran their course, and vanished in a moment; they had no vertical motion, but they appeared at various degrees of elevation, never higher however than 30°. Soon after this interesting (and perhaps unusual) display, the beams disappeared, and nothing was left but a diffuse luminousness along the horizon."

At Jedburgh, Hawick and Kelso, places about forty miles south of Edinburgh, the phænomena were much the same as above, as appears from the

Kelso Chronicle. (See also the London Courier, April 7th, and other of the daily papers.) At Jedburgh the arch is said to have commenced at 8ʰ 15ᵐ on the W. by S. point of the horizon, to have passed south of the star Aldebaran, between Castor and Pollux, and over Arcturus; its altitude 60° from the S.; waves of light seemed to run along the arch. At 8ʰ 30ᵐ the whole advanced 20° to the S. At Hawick it was at first 20° S. of the zenith, and at 8ʰ 40ᵐ it was stationary at 37° S. of the zenith; the arch passed 6° N. of Arcturus, 7° S. of Cor Caroli, 6° N. of Coma Berenices, through the hind foot of Ursa Major, 4° N. of Asellus Borealis, 6° S. of Pollux, through the head of Monoceros, through the three stars in Orion's girdle, and 1° S. of Rigel. From this it would seem that the arch, instead of appearing low in the north from the last-mentioned places, as it must have done if situated only five or even ten miles above the earth's surface, appeared as far to the south of the zenith as at Edinburgh, or rather further. This latter it could not do; and in such circumstances it is reasonable to allow a difference of a few degrees in the estimates of altitudes of arches neither well defined nor absolutely fixed, and possessing several degrees of breadth; but it clearly shows the arch was not low. The author of the Hawick account signs, GIDEON SCOTT.

At Carlisle, seventy-five miles S. of Edinburgh, the phænomena were much the same as in the preceding accounts. See the two weekly newspapers of that city.

About Cockermouth, twenty-five miles S. of Carlisle, I conversed with many persons who had seen the phænomena. One young gentleman, Mr. HARRIS, had committed to paper at the time some notes upon it, with which he favoured me. According to these, he first saw the arch at 7ʰ 45ᵐ P.M., it extended nearly from the western to the eastern horizon, through the W. part of the head of Orion, over Castor and Pollux, S. of Ursa Major, and ended in Corona Borealis; it continued with little variation in its situation till near 10 o'clock. At first the west end of the arch was most luminous, and finally before it vanished the east end was the most brilliant. The eastern end waxed and waned frequently. The sky was very clear, a few streamers appeared low in the horizon.

At Keswick, about twelve miles east of Cockermouth, the appearance was described as follows, in a letter to me from Mr. OTLEY. This gentleman is known to the public by an elegant little description of the Lakes and Mountains of the North of England, and is familiar with observations relating to meteorology, and to the angles of elevation of objects. "About 8 P.M., a luminous arch appeared very brilliant; the outside of the curve seemed a little south of the zenith. The eastern end tapered to a point above the horizon; the western end was broader, and lost in a cloud which rested on the mountain. It disappeared about 10 o'clock."

At Whitehaven, one hundred miles from Edinburgh, and a few miles more to the westward, a minute description of the phænomenon was given in one of the newspapers of that place, by Mr. HOLDEN, lecturer on astronomy, who happened to be there at that time. At 8^h 45^m the east leg of the arch covered α Coronæ Borealis, the northern edge of the bow touched Castor near its greatest altitude, and the west leg went over the three small stars marked λ in the head of Orion. The breadth at greatest altitude was 4° 40′, but tapered down to the horizon, where it was not more than one-fourth of that breadth. The east leg was 15° north of the east point, and about the same number of degrees south of the zenith; and the west leg was 15° south of the west point. At 9^h 8^m the arch had moved southward, Pollux touched the north of the bow, the west leg extended over α Orionis, and the east leg was still upon α Coronæ Borealis, but this star had been moving in its apparent track by the earth's motion for the space of twenty-three minutes. He saw several small clouds move before and cover portions of it for a few seconds of time.

From Kirkby-Stephen, about forty-five miles east of Whitehaven, a good description of the phænomenon is given in the Westmorland Gazette. The mean breadth of the luminous arch exceeded that of the rainbow, the vertex broader, the extremities narrower, and the light more dense. The arch gradually faded about 10 P.M., having existed nearly two hours. The light was white and transparent. Position at 9 P.M., the arch of a great circle from E. 25° N. through the zenith to W. 25° S. At first the eastern extremity of the arch was near β Herculis, thence it passed the north side of Corona Borealis, through the midst of the seven stars in the Great Bear, over the zenith to the north of Castor, exactly over Bellatrix, after which it contracted to a point in Eridanus just above west. This writer makes no mention of any appearance of the common aurora borealis at the same time.

Accounts from Penrith were much the same as the preceding ones; but I had no opportunity of seeing any of them.

At Kendal, which is 110 or 115 miles S. of Edinburgh, and very nearly on the same magnetic meridian, (consequently the same part of the arch must have crossed the meridian at both places,) the following is a description of the phænomena as they appeared there, and might have been adopted with very little error, it should seem, for that at Edinburgh or any one of the intervening places, except as to the altitude of the summit of the arch. "A most magnificent meteor was observed here between 8 and 9 o'clock. The appearance was that of a luminous arch, stretching quite across the heavens. Its direction was that of the magnetic east and west, intersecting the magnetic meridian at right angles. At the same time a splendid light was observable in the northern horizon. This meteor was similar in some particulars to one which appeared a few years ago." [Query in 1819?] "The arch itself appeared like two frustums of cones, with the less extremity in the horizon, and their bases meeting in the zenith. The densest parts of the bow were those near the horizon, and the west end the denser of the two."

The phænomenon was seen at Lancaster, twenty miles S. of Kendal, and 130 miles S. of Edinburgh; it was described in the next Lancaster Gazette, but without being specific as to the altitude of the centre of the arch. Inquiry having been made of an intelligent medical gentleman who had seen it, he described the luminous arch as extending from east to west across the zenith, the light increasing in intensity from the arch of the zenith to the line of the horizon; there were those faint corruscations which usually attend an aurora borealis. This was about 8 o'clock; at $10^h\ 30^m$ P.M. there was a luminous appearance along the northern horizon.

The aurora was seen at Preston, twenty miles S. of Lancaster; but I have not been able to learn the particular appearances at that place. It was also seen at Doncaster in Yorkshire, but I have not noticed any description of its appearance at that place.

At Warrington the luminous arch was seen by a friend of mine, Mr. Joseph Crosfield, who was so obliging as to give me interesting information on the subject, both verbally and by writing. He saw the arch about 9 o'clock, or between that and 10, in company with two other persons, to whom he pointed it out at the time. At the first glance he took it for the milky way, but soon discovered his mistake. The direction of the arch was from W.S.W. to E.N.E., passing to the north of the zenith. The western branch was longer and more brilliant. He saw no northern lights at the time, neither did he apprehend the phænomenon was connected with them. On elevating the pole of a celestial globe till the axis passed through a series of angles with the horizon, I desired him to fix upon an elevation which he judged most nearly to coincide with the elevation of the centre of the luminous arch. On examination, the angle was found to be 61°. I then fixed the axis at 70°; this he was almost certain was too high. When it was fixed at 50°, he was still more certain it was too low.

The aurora was seen at Manchester, as has been stated; but it does not appear to have attracted much attention at this place. I have not been able to trace any account of the phænomena having been seen further south.

These are all the material observations I have collected; from which it must appear that the descriptions every where given evidently apply to the same luminous arch. In proceeding from north to south we find the arch gradually advancing in altitude, always crossing the meridian to the *south* of the zenith, till we arrive about Kendal, at which place it crossed nearly in the zenith, and when at Warrington its culminating was to the *north* of the zenith. It is further remarkable, that in all the places the arch seemed to terminate nearly in the magnetic east and west, or at two opposite points of the horizon; these facts indicated the great height and extension of the arch.

In order to apply the data to calculate the height of the arch, it is evident that observations at the extremities of the magnetic meridians are to be preferred, and those on or near the same meridian, all other circumstances being the same. Unfortunately, the Edinburgh and Hawick observations do not harmonize together: however, those at Jedburgh, a place nearly of the same latitude as Hawick, seem to show that both the others are wrong, or rather perhaps, that they had not been cotemporary with each other and the rest of the observations. The Hawick altitude is probably too low, and that at Edinburgh considerably too high.

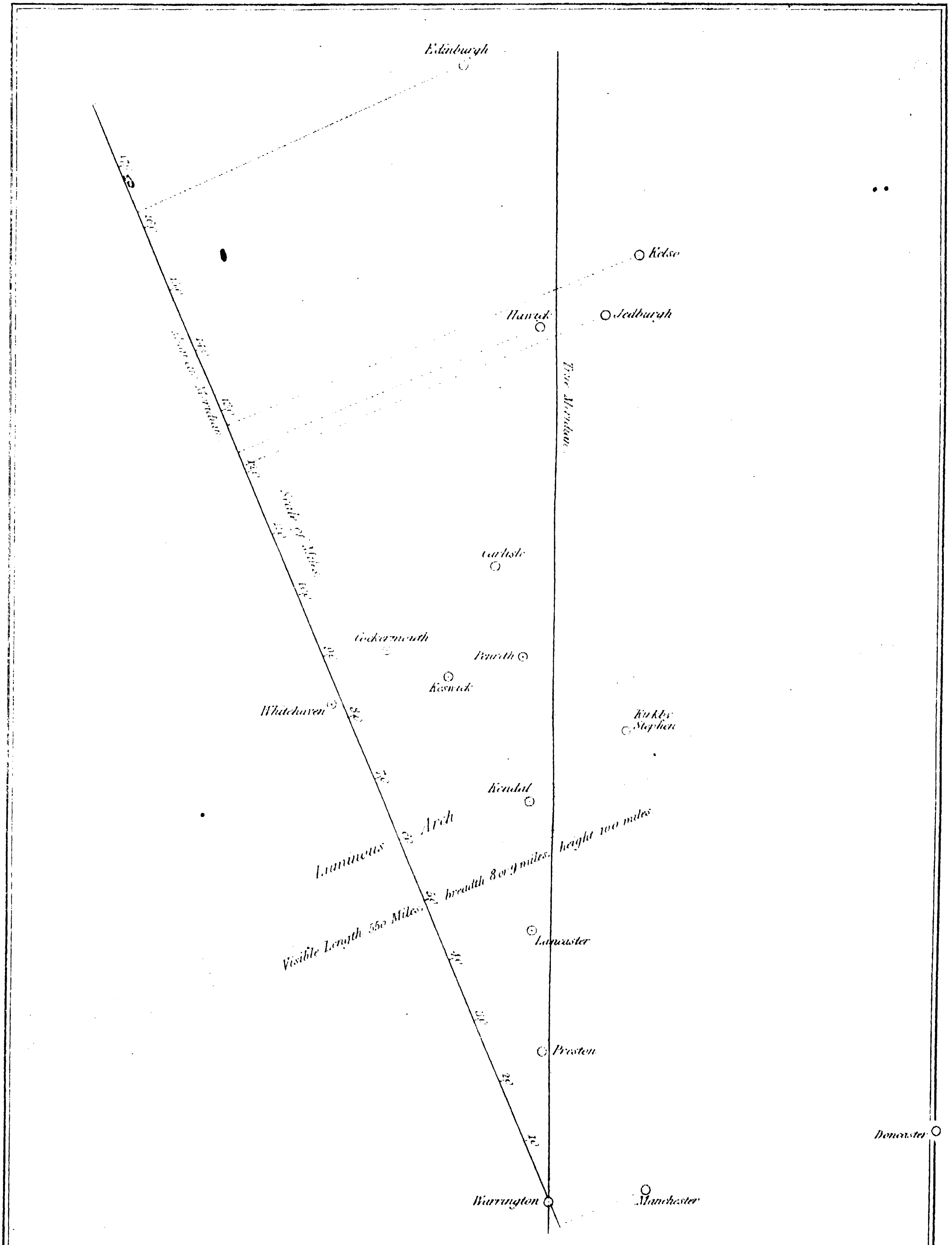
In this uncertainty we may be allowed to take the observations at Whitehaven and Warrington as guides. Those places are very nearly on the same magnetic meridian; they are distant eighty-three miles, giving an extensive base: the observations were nearly cotemporary, and made on the same part of the arch, the altitude at Whitehaven being 75° from the south, and that at Warrington 61° from the north. From these data, I find the height of the arch very nearly one hundred miles above the earth's surface, and its position vertical about Kendal and Kirkby-Stephen, which accords well with the observations at those places. This conclusion is corroborated by the observations at Jedburgh and Warrington, where, if we take the angles of elevation at 60° and 61° respectively, and the distance on the magnetic meridian 120 miles, the height will be found between 100 and 110 miles. But, lastly, if we assume the angle at Edinburgh to be correct at 65°, and that at Warrington at 61°, the height comes out 150 or 160 miles, and its position vertical about Carlisle, which is in opposition to the general tenor of the rest of the observations.

As for the heights of the streamers or vertical beams seen low in the north, we have no sufficient data for determining it. But it is evident that the beams which were seen low at Edinburgh were the same as those seen still lower at Cockermouth, Kendal, Lancaster, and Manchester, at which last place the angle was about 10° as my informant says. Now an object elevated about 25° from the north at Edinburgh would apparently be 10° or 12° at Manchester, if its real height were about one hundred miles above the earth's surface.

On the whole, I think it is fairly to be inferred that the height of the arch could not differ much from one hundred miles; and that its breadth would be eight or nine miles, and its visible length in an east and west direction, from any one place, would be about 550 miles. (See the accompanying figure.)

Observations on other Auroræ.

The height of a luminous arch calculated by the late Mr. CAVENDISH, F.R.S. in the Phil. Trans. for 1790, is entitled to notice. It was found to be betwixt fifty-two and seventy-one miles. The observations, however, were made at too small a distance from each other to admit of precision. A base of at least forty or fifty miles seems necessary, where the object to be measured is generally neither steady nor well defined.



Luminous Arch, or Aurora Borealis, seen March 29th 1826.

The luminous arch seen at Keswick and Kendal by Mr. Crosthwaite and myself, on February 15th, 1793, was calculated to be 150 miles high; but this was from a base of only twenty-two miles. (See my Meteorological Observations and Essays, page 69.)

Dr. Thomson has given a brief history of the Aurora borealis in the Annals of Philosophy for 1814, Vol. IV. He has copied a table from Bergman, being estimates of the heights of about thirty auroræ observed during the last century, calculated from observations made by different persons in various places. According to these results, the auroræ would seem to be of variable heights, from 130 to 1000 or more miles. The places of observation are often unsuitably situated; and the data from which the calculations were made not being given, I apprehend the great differences in the heights arise more from defects in the observations than from real differences.

In the same volume Mr. Longmire gives a description of a luminous arch seen at Troutbeck near Kendal, on the 11th of September, 1814. It was similar to that above described, and was most extensively seen: namely, at Glasgow, Dumfries, and Annan in Scotland; at Dublin and Newry in Ireland; and at Whitehaven, Carlisle, Kendal, Lancaster, Warrington, and Liverpool in England. It was accompanied with the usual appearances of the aurora borealis, or streamers distant in the north. The observations are insufficient for calculating the height. I find in my journal the aurora was noticed at Manchester that evening, but no particulars are given. Mr. Longmire mentions a similar arch seen at Kendal and Dublin on the 17th of April the same year. An aurora was seen in London at the same time. (Annals of Philosophy, Vol. III. p. 400.)

1819, October 17th.—A remarkable aurora borealis was seen this evening in very distant parts of England and Scotland. Mr. Otley of Keswick first drew my attention to this, by communicating the notes he made at the time upon it, on the occasion when he favoured me with his remarks upon that of the 29th of March, 1826. After which I collected such other accounts as I could meet with from the journals of the time. The series of observations is as follows:—

Annals of Philosophy, Vol. XIV. p. 472. Account from Newton-Stewart, (Scotland,) October 18th.—" A singular and beautiful phænomenon appeared in our atmosphere here last night (17th), about 8 o'clock: it was a bow or arch of silvery light stretching from east to west, and intersecting the hemisphere [meridian] at a few degrees to the southward of the zenith. After it had remained very bright for twenty minutes or so, dark blanks were first observed to take place here and there, and then, after expanding a little in breadth and shifting for a short way further to the southward, it disappeared. Some time before its appearance the atmosphere had been very cloudy; but when it was formed the sky was free from clouds, except towards the horizon to the westward and northward, where they hung very dark and heavy.—It was strikingly different from any of the usual forms of the boreal lights, which too were seen very vivid in the course of the evening."

Keswick. Mr. Otley's account:—"About 7 P.M. (the 17th), a dense cloud appeared in the horizon to the N.N.W. bounded by a bright line, the rest of the heavens being starry. Presently beams of an aurora began to shoot towards the Great Bear. About 8 o'clock a luminous arch extended from west to east; the crown of the arch at first appeared to me a little to the north of the zenith, and after some time to the south of it, and again more northerly before it disappeared, which it did suddenly, a few minutes after 9 o'clock."

Manchester.—I have an account in my journal of an aurora seen here the same evening, but no particulars are given.

London.—The aurora was seen in and about London the same evening. (See pages 478 and 480, Vol. XIV. Annals of Philosophy.)

Gosport.—In the same volume of Annals, page 395, there is an account of the same aurora as seen at Gosport Observatory, Hampshire, on that evening by Dr. Burney. The following is an extract: "On the 17th instant, at 7 P.M. a light about 30° on either side of the magnetic north point appeared in the shape of a luminous arch whose apex was 18° above the horizon." He then describes several beams of the common aurora which successively appeared and traversed about for a time chiefly within the arch, and then vanished and were succeeded by others. After which, he adds: "Soon after this (9 o'clock) the luminous arch in the northern hemisphere entirely disappeared, and some haze collected near the horizon."

Gosport and Keswick are very nearly under the same magnetic meridian, and 265 miles distant. Newton-Stewart is N.W. by W. of Keswick, distant about sixty-five miles, but only thirty-five miles in a meridional direction. Now I imagine it will be allowed that an extraordinary luminous arch seen at Newton-Stewart to cross the meridian a few degrees south of the zenith, and to continue from 8 to near 9 o'clock, nearly in that position, must have been the arch seen at Keswick at the same time to cross the meridian in like manner from east to west, and to pass nearly through the zenith. It may well be supposed, then, that this arch crossing through the zenith at Keswick would have a very diminished altitude if seen at Gosport, 265 miles south. From the account I have extracted, it appears that a luminous arch was seen there at the same time it was seen at the other places, and crossing the meridian at right angles, only its altitude 18° from the north, instead of being in the zenith, as at Keswick, or a few degrees south of it, as seen in Scotland. And further, the arch vanished at all the places at the same time. It scarcely admits of doubt, then, that these arches were all one and the same. By calculation from the data at Gosport and Keswick, I find the height of the arch above Keswick to be 100 or 102 miles; from which the angle of elevation from Newton-Stewart must have been 71° from the south, or the zenith distance of the arch 19°.

A luminous arch was seen at Kendal on the 27th of December, 1827, of which my friend Samuel Marshall was so good as to write me a circumstantial account. It was first seen at ten minutes past 6 in the evening, being an arch between the magnetic east and west, and passing through the zenith. It was broadest in the zenith, and it was more condensed in the eastern extremity than in the western. Another parallel arch appeared about 20° north of the former, of rather less intense light; and the northern horizon was luminous as usual on such occasions. After ten minutes or more, the arches advanced each of them to the south 20° with their centres. The appearance lasted about half an hour. A few streamers were seen in the east, which moved slowly northward. Mr. Marshall thinks the appearance would have been splendid if the moon had not shone at the time: a halo round the moon vanished when the bow approached it. I observed a halo round the moon at Manchester that evening.

Mr. Buchan, a gentleman accustomed to meteorological observations, had mentioned his having seen a similar arch at Manchester on that evening; but apprehending it might only have been a local phænomenon, I did not inquire particulars till I received the above account from Kendal. Mr. BUCHAN informs me he saw a luminous arch that evening, about 9 o'clock; the arch was highest to the west of the meridian, and its altitude was very nearly the same as the north pole, just under which it passed; he estimates it at 53°, and thinks it could not be above 1° more or less. As this observation was not cotemporary with that at Kendal, nothing certain can be deduced from them, but it may not be amiss to observe that an object in the zenith at Kendal, and elevated 53° from the north at Manchester, must be nearly one hundred miles high.

The results of this series of additional observations agreeing so nearly with that of the 29th of March, 1826, I am induced to believe that these luminous arches of the aurora which occasionally appear, stretching from east to west, are all of the same height, and that height about one hundred miles. What length the upright beams,—or to speak more properly, those parallel to the dipping needle,—may be, which are the ordinary forms of the aurora, we have not observations to determine. Whether those beams arise above the arches as from a base, or whether they descend below, as if appended to the arches, we cannot absolutely determine. It is remarkable that the arches and beams should rarely, if ever, be seen cognate or in juxta position, but always in parts of the heavens at a considerable distance from each other.

Manchester,
March 18, 1828.

POSTSCRIPT.

Query, Are the parallel bands usually about 20 degrees asunder? If so, their distance from each other will be about thirty-six miles.

XIV. *A comparison of the changes of magnetic intensity throughout the day in the dipping and horizontal needles, at Treurenburgh Bay in Spitsbergen. By* CAPTAIN HENRY FOSTER, *R.N. F.R.S.*

Read May 8, 1828.

THE few observations I had an opportunity of making at Port Bowen in 1825, on the diurnal changes of intensity shown by the dipping and horizontal needles, first suggested the idea of a daily rotatory motion of the general polarizing axis of the earth, as the cause, not only of the diurnal changes of intensity, but also of the diurnal oscillations of the horizontal needle throughout the world. And the circumstance, of the times of the maximum and minimum effect of these phænomena, occurring generally when the sun bore north, south, east, and west by compass, indicated his agency in producing this motion of the pole.

The entire confirmation of an hypothesis so important in the theory of terrestrial magnetism, requires the evidence of varied and extensive observation; and as my professional pursuits have recently led me to revisit those regions best calculated for the experiments, I have thought a continuation of them under favourable circumstances, might prove an useful auxiliary to those already honoured with a place in the Philosophical Transactions for 1826.

The observations which I have now the honour to present to the Royal Society, were performed in a manner somewhat different from those alluded to at Port Bowen, which were made with one needle only, first as a dipping needle, and then suspended horizontally. Whereas in this case, two needles were employed, each in its respective capacity; an arrangement far more convenient in practice, and equally satisfactory as to the object I had in view; which was simply to ascertain, whether or not a corresponding change of intensity exhibited itself in both needles, whether each was differently affected thereby, or whether such change belonged to the horizontal needle alone.

The expression for the intensity of the dipping needle, is $I = 2A\sqrt{\frac{1}{4 - 3\sin^2\delta}}$, and for the horizontal needle, $I = 2A\sqrt{\frac{1}{3 + \sec.^2\delta}}$, δ denoting the dip, A a general co-efficient. Consequently, if the change took place in the co-efficient A only, that is in the general magnetic intensity, both needles would be proportionally affected, and in the same manner; but if the change were in the dip only, then the two needles would be differently affected; the dipping needle, as $\sqrt{\frac{1}{4 - 3\sin^2\delta}}$, and the horizontal needle, as $\sqrt{\frac{1}{3 + \sec^2\delta}}$, so that one would increase in intensity and attain its maximum, while the other would decrease and attain its minimum, and *vice versa.*

If both δ and A be variable, the relation between the simultaneous intensities of the two needles would remain the same as if δ only changed, because it is common to both needles; but the comparison of the same needles, at different times of the day, would be considerably modified by such a change in the value of A, and which would appear to be the case both from the present observations and those at Port Bowen. For example, if A was a maximum when the dip was the greatest, and consequently when the horizontal intensity, from considerations of dip only, was the least, the one effect would in some measure counteract the other on the horizontal needle; whereas the dipping needle would have its intensity increased from both these causes operating at the same time, and contrariwise if at the moment of least dip A should be at its minimum. It is, however, by no means my intention at present to enter upon this intricate inquiry; my object being to examine whether the simultaneous changes in the intensities of the two needles are of a character to indicate a change of dip as one at least of the causes, or whether the dip remains constant, and the change is due to that of intensity alone. As far as this question is concerned, the results are certainly satisfactory; for on comparing the intensities of the two needles given in Table II. it will be found that the intensity of one needle was generally the greatest when the other was the least, and the contrary. That a change actually takes place in the general intensity of the earth's magnetism, is as an hypothesis very reasonable; still, however, it is but an hypothesis, and as such I shall not insist upon it in this place, notwithstanding the circumstantial evidence furnished by these observations, but leave it for more extended experiments to decide, and proceed at once to a detail of those observations from which the former deduction is made.

With respect to the instruments, they differed so little from those employed at Port Bowen, which have already been described, that it is unnecessary to say more than that the dipping needle was one belonging to the Board of Longitude, and made by Dollond; the needle used was in form a parallelopipedon, 6 inches long, 0.4 broad, and 0.05 thick, and that its magnetism was not interfered with while it was in my possession. The same may be observed of the horizontal needle, which was one of the same form and weight as the above.

The experiments were commenced upon the 30th of July, and continued to the 9th of August by myself only; and they were so arranged, that in the course of two days an observation was made every hour of the twenty-four, but part of them in one day, and part of them in the other, as shown in the Table.

Previous to the commencement of the observations, the silk thread (eleven inches long) which was employed for suspending the horizontal needle, was divested as far as could be of torsion, by suspending a brass needle of like form and of equal weight with the one above described; it was then replaced by the magnetized needle itself, the centre of which was brought directly over the centre of a graduated circle, by means of foot-screws attached to a board on which the apparatus stood. The needle being thus freely suspended, it was drawn out of the magnetic meridian somewhat more than 40 degrees, by a contrivance for that purpose; but its oscillations were not noticed until the arc had decreased to 40 degrees, when the observations were commenced on the times of performing ten vibrations successively, until two hundred were completed; the terminal arc and temperature of the instrument were then registered, and in this manner all the results given in the following Table were obtained.

The vibrations on the dipping needle were taken as follows: viz. one hundred with the face of the instrument East, previous to those on the horizontal needle as above described; and another hundred after the latter, with the face West; so that the mean time of observation for both needles was nearly the same, as will be seen by referring to Table I., relative to which, however, it should be observed, that although two hundred vibrations were taken by each needle, the time of performing one hundred only is recorded in the Table, as also the mean arcs of vibration.

TABLE I.

Containing the Observations on the Diurnal Changes of Intensity in the Dipping and Horizontal Needles at Treurenburgh Bay in Spitsbergen, in the Months of July and August 1827.

Dates.	Dipping Needle.				Horizontal Needle.			
	Hour.	Time of performing 100 Vibns.	Mean Arc.	Temp. Fahr.	Hour.	Time of performing 100 Vibns.	Mean Arc.	Temp. Fahr.
	h m	s	°	°	h m	s	°	°
July 30, A.M.	2 4	291.6	23.7	35	1 56	619.0	26.2	34½
	3 4	291.3	24	34½	2 56	620.0	24	34½
	3 58	291.2	23.8	34	3 50	620.9	23.7	35
	4 57	291.4	23.8	34	4 48	619.0	24.5	34
	6 1	292.1	23.5	35½	5 52	618.7	25	35
	7 0	291.9	23.2	35½	6 56	619.4	26	36
	7 47	292.2	22.8	36	7 46	619.4	26	35
	5 35	291.2	21.3	36½	5 36	613.6	25.5	36½
P.M.	6 3	291.2	21.2	35¾	6 22	616.6	25	36½
	8 14	291.9	22.2	35¼	8 19	615.6	25	36½
	8 56	291.7	22.2	35½	9 00	615.8	26	36½
	9 38	291.6	21.7	36	9 39	615.0	26	36
	10 26	291.6	21.7	36	10 37	615.1	25	36
	11 16	291.4	21.3	35½	11 25	621.1	26	36
	12 02	291.8	21.3	35	12 00	620.4	25	37
July 31, A.M.	9 17	292.2	21.7	40.2	9 23	618.6	25½	41½
	10 18	291.8	21.2	41.2	10 23	616.1	25¾	43
	11 20	292.4	22	41	11 25	612.5	25¾	41
P.M.	0 18	292.6	22.2	40½	0 22	610.0	26	42
	0 57	292.6	22	40	0 54	611.0	25½	42
	1 56	292.8	22.3	40	1 54	613.2	26	42
	2 56	293.0	22.5	39¼	2 54	619.1	26	40½
	3 52	292.5	22.2	39½	3 51	622.0	26	40
Aug. 1, A.M.	0 55	291.7	22.2	38	0 50	619.8	26	39
	1 55	292.0	22.1	38	1 55	618.6	25½	39
	2 54	291.6	21.9	38½	2 50	617.7	26	39
	3 52	291.6	22.2	39	3 51	618.3	25½	40
	4 53	292.3	22.3	39½	4 50	619.5	25½	40½
	5 50	292.4	22.1	40	5 47	618.9	25½	41
	6 57	292.3	22.2	41½	6 54	619.5	26	42
	7 41	292.4	21.8	41¾	7 42	619.9	25½	43
P.M.	5 36	292.9	22	48½	5 37	617.0	25½	50½
	6 57	292.8	22½	47¾	6 56	616.8	25½	46½
	7 57	292.6	22½	47½	7 58	617.4	25½	50
	9 1	292.6	22.3	47¼	8 56	617.9	26	52
	9 55	292.3	22.2	44	9 50	617.1	25½	45
	10 46	292.3	22.3	42½	10 47	617.7	25½	44
	11 52	292.7	20.7	41½	11 48	617.5	25½	43

TABLE I. (Continued).

Dates.	Dipping Needle.				Horizontal Needle.			
	Hour.	Time of performing 100 Vibns.	Mean Arc.	Temp. Fahr.	Hour.	Time of performing 100 Vibns.	Mean Arc.	Temp. Fahr.
	h m	s	°	°	h m	s	°	°
Aug. 2, A.M.	9 41	293.7	22.3	62.2	9 42	620.2	25½	64
	10 41	293.4	22.1	59.2	10 41	621.2	25½	59½
	11 39	293.5	22.1	58.2	11 41	619.0	25½	59
P.M.	0 50	293.8	22.2	57½	0 48	616.6	26	58
	1 53	293.3	21.9	56¾	1 48	618.8	25½	56
	2 49	293.7	21.7	53.7	2 46	617.8	25½	55½
	3 37	293.6	21.1	53	3 40	619.0	25½	53
Aug. 3, A.M.	0 44	291.7	21.6	47	0 45	619.8	25	52
	1 46	292.2	21.5	47	1 47	618.8	25	51½
	2 45	292.0	21.3	48¼	2 46	619.9	25	52
	3 41	291.7	21.5	50	3 43	619.7	25	55
	4 42	292.2	21.8	51	4 45	616.9	25	57
	5 45	293.0	22.1	52¾	5 45	617.7	25	57
	6 43	293.4	22.1	54½	6 44	625.4	25	59
	7 46	293.4	21.9	56¼	7 49	620.0	25	61
P.M.	6 41	293.7	22.7	57¼	6 42	620.2	25	58
	8 2	293.6	22.7	53	8	619.7	25	54
	8 44	293.1	22.5	51½	8 46	619.8	25	52
	9 46	293.4	22.5	49¼	9 47	621.1	25½	51
	10 46	293.1	22.2	49¼	10 48	618.2	25	51
	11 41	292.2	22.1	49	11 43	617.3	25	53
Aug. 4, A.M.	9 12	293.7	22.3	56½	9 16	620.2	26	61
	9 57	293.9	22.7	59½	9 55	618.5	25½	63
	10 44	293.3	22.5	60	10 45	619.2	26	63
	11 37	292.6	22.1	59½	11 39	619.5	26	62
P.M.	0 40	292.8	22	60	0 41	619.2	26	63
	1 59	292.8	21.7	62½	1 55	619.0	25½	63
	2 42	293.6	22	61¾	2 44	619.0	25½	64
	3 36	293.8	22.1	63½	3 38	618.4	25½	65
Aug. 5, A.M.	1 00	291.9	22	51	0 57	620.0	23	52
	1 43	291.5	22	51	1 44	620.8	25	52½
	2 45	291.9	22.1	51	2 47	619.5	24½	52
	3 41	291.5	21.7	50	3 42	618.5	24	51
	4 44	292.1	22.5	50	4 45	620.2	24	51
	5 41	291.4	21.8	47½	5 43	618.4	23½	49½
	6 43	291.8	22.1	49	6 45	616.4	24	51
	7 35	292.5	22.3	53	7 36	621.1	24	52½
P.M.	5 44	293.6	22.2	49¾	5 46	619.2	26	49½
	6 35	293.1	22.7	49½	6 36	617.7	25	50
	8 1	291.6	22.4	47	7 57	620.7	25.5	47½
	8 46	292.1	22.2	47¼	8 45	619.6	25.5	48
	9 45	291.8	22	47	9 46	619.6	26.5	46½
	10 46	292.5	22.3	47	10 47	618.3	25.5	47½
	11 43	292.0	22.2	46½	11 47	618.1	25	47

TABLE I. (Continued.)

Dates.	Dipping Needle.				Horizontal Needle.			
	Hour.	Time of performing 100 Vibns.	Mean Arc.	Temp. FAHR.	Hour.	Time of performing 100 Vibns.	Mean Arc.	Temp. FAHR.
	h m	s	°	°	h m	s	°	°
Aug. 6, A.M.	9 20	293.0	23.3	53¼	9 26	616.6	26	54
	10 00	292.7	23.3	54½	9 57	615.3	25½	54½
	10 42	292.4	23	55¼	10 44	614.0	26	55
	11 41	293.2	22.6	54¼	11 43	613.2	25.5	50
P.M.	0 51	292.6	22.4	56¼	0 49	614.7	25.5	57
	1 40	293.0	22.9	55	1 41	615.3	26	56
	2 51	292.9	23	55¾	2 49	616.8	26	58
	3 37	293.2	23.5	58¾	3 38	615.3	25.5	57
Aug. 7, A.M.	0 46	292.7	22.6	47	0 47	618.9	24.5	49
	1 42	291.8	22	48½	1 43	620.3	25	51
	2 44	292.5	22.5	45¼	2 47	619.6	25	46½
	3 38	292.1	22.9	45	3 38	620.9	25	46
	4 41	292.2	23	44½	4 42	620.0	25	45
	5 36	292.2	23	46	5 38	620.1	25.5	45
	6 41	292.1	23	43½	6 42	620.3	25.5	45
	7 38	292.7	23.2	42½	7 39	620.2	25.5	44
P.M.	5 37	292.1	23.6	41½	5 38	619.1	25.5	43
	6 42	292.1	23.5	40½	6 44	616.7	25.5	42½
	8 13	291.8	23.7	41	8 18	618.0	25.5	41½
	9 00	292.7	23.5	41¼	8 57	618.0	25.5	41½
	9 42	292.1	23.6	40½	9 43	618.1	25.5	41
	10 41	292.0	23.5	40	10 43	617.7	26	41
	11 44	291.2	23.5	40½	11 45	623.1	25.5	40½
Aug. 8, A.M.	9 18	291.6	23.5	47½	9 23	618.2	25.5	49
	10 6	292.6	23.4	51	10 14	619.9	26	53
	10 56	292.7	23.2	55¼	10 56	618.5	26	56
	11 39	293.1	23.1	56	11 40	618.0	26	57
P.M.	0 38	293.5	23.1	57¾	0 39	617.8	26	58½
	1 41	293.7	23.6	59	1 43	617.6	25.5	59
	2 39	293.8	23.3	58	2 41	622.1	25.5	60
	3 36	293.3	23.5	58¾	3 38	619.9	26	60
Aug. 9, A.M.	0 58	291.6	23.1	50	0 55	624.0	25	53½
	1 44	291.7	23.2	49½	1 45	622.5	25	52½
	2 37	291.6	23.5	50	2 39	623.2	25	53
	3 38	292.0	22.5	50½	3 38	625.3	25	54
	4 40	292.2	22.7	50	4 41	623.1	24.5	55
	5 55	292.1	22.3	52¾	5 53	622.1	21	54
	6 40	291.6	21.8	54	6 39	621.7	22.5	60
	7 35	293.3	22.3	57	7 36	623.0	25.5	61
P.M.	5 40	293.0	23.1	58	5 41	621.6	25.5	58
	6 40	293.3	23	58¾	6 42	622.6	26	58
	8 17	293.0	23.2	56	8 12	621.9	25.5	56½
	8 52	292.7	23.2	54½	8 50	621.5	25.5	55½
	9 42	292.3	22.9	53½	9 43	621.8	25	55
	10 41	291.9	22.7	54	10 42	619.8	25.5	54
	11 41	292.2	22.8	50¾	11 43	619.5	25	53

In order to bring more clearly into view the results of the foregoing observations, the following Table has been formed, by adding together all the *times* each needle took to perform one hundred oscillations at the respective hours of observation on the several days, and converting these times into proportional intensities. In the third and sixth columns are inserted the numbers expressive of intensities, which have been obtained, by squaring the reciprocal of the times, and multiplying those squares by 100,000, to render them all integral.

TABLE II.

Dipping Needle.			Horizontal Needle.		
Hour.	Time in seconds of performing 100 oscillations.	Proportional Intensity.	Hour.	Time in seconds of performing 100 oscillations.	Proportional Intensity.
h m			h m		
A.M. 0 52	291.9	1173	A.M. 0 51	620.5	2597
1 49	291.8	1174	1 46	620.0	2601
2 48	291.8	1174	2 48	620.0	2601
3 44	291.7	1175	3 44	620.6	2596
4 46	292.1	1172	4 45	619.8	2603
5 48	292.2	1171	5 46	619.3	2607
6 47	292.2	1171	6 46	620.4	2598
7 40	292.7	1167	7 41	620.6	2596
9 16	292.6	1168	9 22	618.3	2616
10 00	292.9	1166	10 2	618.0	2618
10 52	292.8	1167	10 54	617.1	2626
11 47	293.0	1165	11 49	615.9	2636
P.M. 0 47	293.1	1164	P.M. 0 46	615.9	2636
1 50	293.1	1164	1 48	616.8	2629
2 47	293.4	1161	2 47	618.9	2611
3 40	293.3	1162	3 41	618.9	2611
5 43	292.3	1171	5 47	617.8	2620
6 43	293.0	1165	6 44	618.8	2612
8 7	292.4	1170	8 7	618.9	2611
8 53	292.5	1169	8 52	618.8	2612
9 51	292.1	1172	9 52	618.2	2617
10 49	292.2	1171	10 52	618.8	2612
11 47	292.0	1173	11 48	619.3	2607

On looking over this Table it will be seen, that when an increased intensity obtained in the dipping needle, a corresponding diminution generally exhibited itself in the horizontal needle, and vice versa. But to compare this Table with the results deduced from my former experiments, and with the hypothesis of a rotation of the general polarizing axis of the earth about its mean position as a centre, it will be best to express the intensities in terms of the magnetic latitude; viz.

$$^{*}\ I = A \sqrt{3 \text{ sine}^2 \lambda + 1} = \text{Intensity dipping needle,}$$

$$I = A \cos \lambda \qquad = \text{Intensity horizontal needle:}$$

where λ is the magnetic latitude. If we assume 81° as the mean dip at Treurenburgh Bay, and since

$$\text{Tang.}\,\delta = 2 \text{ tang.}\,\lambda,$$

or tang. $\lambda = \frac{1}{2}$ tang. 81°, we have $\lambda = 72° 30'$ the mean magnetic latitude. Let x be the radius of the circle of rotation assumed in the hypothesis; then the extreme latitudes will be $72\frac{1}{2}° + x$ and $72\frac{1}{2}° - x$, and the intensities varying in their greatest extreme, as 2596 [illegible] 2636; we have to find x such, that

$$\text{Cos}\,(72\tfrac{1}{2}° + x) : \cos\,(72\tfrac{1}{2}° - x) : 2596 : 2636.$$

This gives $x = 8$ minutes very nearly; whereas in my former paper I suppose this radius not to exceed 2½ minutes. In that case, however, the deduction was made from the mean results of several months' observations, commencing with January, when the effect is the least; whereas this is drawn from the extreme results of eleven days only, and at that season when the effects are the greatest.

Assuming the above radius of rotation, viz. 8 minutes, it is easily ascertained that the corresponding maximum change in the daily variation ought to be 54 minutes; whereas it appears by the Table published in the Appendix to Captain Parry's Narrative of his Attempt to reach the North Pole of the Earth, to have amounted to 1° 32′ from the mean of eleven days' observations.

The 2½ minutes assumed as the radius of rotation of the magnetic pole, from the mean of the Port Bowen experiments, is certainly too small to answer even to the mean results: but if we take the mean results as there obtained for the month of May, which was the greatest observed, it will be found that the radius of rotation would require to be taken at 8 minutes, the very quantity above determined. It will, however, be seen by referring to the paper in which the former experiments and observations are recorded, that the 2½ minutes assumed for the radius was stated as a quantity altogether conjectural, no attempt being made to establish it by calculation. At all events it will be

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* Barlow's Essay on Magnetic Attractions, page 197, 2nd edition.

necessary to consider this radius as changing very considerably as the sun advances to the north.

The change of intensity in the dipping needle as depending on the change of dip or of the magnetic latitude, would be only as 3726 to 3732, whereas it is found to amount to $\frac{1}{83}$rd part of the whole. This therefore seems to indicate a change in the general co-efficient A, and that this is greatest when the dip is greatest, and least when the dip is least.

We might be able to separate these two counteracting effects on the horizontal needle; but it would probably be considered too speculative in the present stage of this inquiry. All therefore that I shall consider as demonstrated by these experiments is, that the cause of the daily change in the horizontal intensity is principally due to a change of dip, as I found to be the case at Port Bowen, and that the times of the day when these changes are the greatest and least, point clearly to the sun as the primary agent in the production of them; and that this agency is such as to produce a constant inflection of the pole towards the sun during the twenty-four hours: this is, I think, clearly established as far as comparison has yet been made, and I hope soon to be able to submit this inquiry to the test of experiments under circumstances so different in every respect from these and the former, that they cannot fail of either confirming or contradicting the hypothesis in question.

London,
March 4th, 1828.

HENRY FOSTER.

XV. *Experiments relative to the effect of temperature on the refractive index and dispersive power of expansible fluids, and on the influence of these changes in a telescope with a fluid lens. By* PETER BARLOW, *Esq. F.R.S. &c.*

Read May 15, 1828.

IN a paper I had the honour to present to the Royal Society in January last, relative to the construction of achromatic telescopes with fluid lenses, I have stated that between the temperatures of 31° and 84° I had not been able to detect any very sensible change in the index denoting the focal length of the telescope: these observations however being made at intervals of some months, I was doubtful whether there might not be some minute variation which had escaped my notice; and I have since, by means of temperature artificially produced, ascertained that there is a certain small change, and the amount of that change, which is $\frac{134}{1000}$ths of an inch in the length of the telescope employed, between each of these extremes and the mean temperature of 57°. That is, the eye-piece of the telescope and the fluid lens being fixed, as was the case in this instrument, the plate lens required an adjustment of 0.134 of an inch, between the temperature of 57° and each of the above extremes, to produce the brightest and most perfect image.

Before I proceed, however, to detail the results of my inquiry on these subjects, it will be proper to define a few terms which appear in one or two instances to have been misunderstood.

1. The length or focal length of the telescope, is the distance from the front lens to the focus.

2. The fluid focus or fluid focal length, is the distance from the fluid lens to the focus.

3. The focal power of the telescope, or the equivalent focal length, is the focal length of a telescope of the usual construction, which gives the same convergency to the rays or the same sized image as the telescope in question.

In what follows:

l will denote the length of the telescope.
f the focal length of the plate lens.
f' the focal length of the fluid lens.
f'' the fluid focal length.
f''' the equivalent focal length.
d the distance of the lenses.

Under the particular form of construction to which we are now referring, f and f'' remain fixed or constant, but the rest are variable under different temperatures, in consequence of the effect which temperature produces in the value of f'.

If we knew the change in the value of f', or in the refractive index of the fluid under different temperatures, we might proceed immediately to compute its effects on the focal power of the telescope; but as this may be considered doubtful, I have endeavoured to determine the effect on the power of the telescope by direct observations, and have thence computed the corresponding change in the refractive index of the fluid.

In order to determine the change in the position of the front lens due to a certain range of the thermometer, I placed the telescope in a small room about twelve feet square in my garden, and having adjusted it very carefully to a dial-plate of a watch, at the distance of 150 feet, when the thermometer was at 40°, I had a fire lighted, the room shut up, and the temperature gradually raised to 75°, re-adjusting and registering the focus for every change of 5°.

As, however, the intermediate changes were very small, it will be sufficient to state, that between the two extremes, viz. 40° and 75°, the whole change was 0.177 of an inch; and hence, supposing the change uniform for equal variations of temperature, we find for the difference between the mean temperature of 57° and each extreme before mentioned, viz. 31° and 84°, an alteration in the length of the telescope of .134 of an inch, as stated in the beginning of this paper.

In the instrument on which these observations were made, the following are the values of the different quantities at the mean temperature 57°; viz. $f = 32.5$, $f' = 32.65$, $f'' = 40.5$, $l = 54.92$, $d = 14.42$, $f''' = \frac{ff''}{f-d} = 72.8$.

And since by the observations above referred to, the value of d varied 0.134 of an inch between the mean temperature and each of the extremes, we have in one case $d = 14.554$, and in the other $d = 14.286$. Whence the focal power of the telescope was

$$\text{at } 31^\circ,\ f''' = \frac{ff''}{f-d} = 73.34$$

$$\text{at } 84^\circ,\ f''' = \frac{ff''}{f-d} = 72.28$$

So that the instrument being adjusted at the mean temperature 57°, and fitted with a micrometer, it will require a correction of about $\frac{1}{3600}$th part of the angular measure for every change of 1° in the thermometer; that is, a 60th part of a second for every minute in the angle, a quantity too small to require any notice, except in cases of extreme delicacy.

In order to find the actual change in the focus of the fluid lens which rendered the foregoing adjustments of the plate lens necessary, we have

$$\frac{1}{f-d} - \frac{1}{f'} = \frac{1}{f''} \quad \text{or} \quad \frac{1}{f-d} - \frac{1}{f''} = \frac{1}{f'}.$$

In this expression, $f'' = 40.5, f - d$ at $31^\circ = 17.946$

$f - d$ at $57^\circ = 18.080$

$f - d$ at $84^\circ = 18.214$

And substituting these values successively for $f-d$ in the above expression, we find

f' at $31^\circ = 32.222$

f' at $57^\circ = 32.650$

f' at $84^\circ = 33.090$

And since it has been shown, Phil. Trans. 1827, Art. XV. that $\frac{\overline{f-d}|^2}{ff'}$ = dispersive ratio, we have at 31° dispersion = .3067

57° dispersion = .3075

84° dispersion = .3084

a difference sufficiently small to baffle the most acute and experienced eye. The change therefore in the power and colour of the telescope is so small, and the correction due to it (in any case where such correction is thought necessary) so easily made, that an instrument on this construction may I trust be considered just as applicable to all the nice purposes of modern astronomy, as one of the usual refractors of the same power.

The very inconsiderable change in the focal power of the telescope led me to conclude, in the early part of my experiments, that no optical change took place in the fluid between the above limits, or at least that the change was extremely small. It appears however from the preceding experiments and investigation, that the permanency of the telescopic effect is attributable to the peculiar construction of the instrument, and that the change in the refractive index of the fluid is much more considerable than I had imagined; for we have seen that the focal length of the fluid lens was at 31° = 32.22
at 57° = 32.65
at 84° = 33.03

And since the focal length is cæteris paribus inversely as the index, and the index at 57° being 0.634, we find 32.22 : 32.65 : : 0.634 : 0.642
33.09 : 32.65 : : 0.634 : 0.626

Hence the mean index of the sulphuret of carbon is at 31° = 0.642
at 57° = 0.634
at 84° = 0.625

That is, with a variation of temperature of 53°; the change of index amounts to $\frac{.017}{.634} = \frac{1}{37}$th part nearly of the whole index at 57°.

Which, supposing the change to be uniformly proportional in greater thermometrical ranges, gives a change in the refractive index of nearly $\frac{1}{10}$th between 32° and 212°. Now it has been stated on the result of experiment (Dr. Ure's Chemical Dictionary), that the expansion of sulphuret of carbon amounts to $\frac{1}{9}$th between the above limits. We have therefore strong reasons to conclude that in this, and all other expansible fluids, the index of refraction varies directly as the density; the trifling difference in the two results being attributable, in all probability, to slight errors of observation in one or other of the two processes, so different from each other, from which these results are deduced.

With respect to the dispersive ratio, it is probably the same at all temperatures; for, supposing $1 : 1 + a$ $1 : 1 + a'$, $1 : 1 + a''$ to be the ratio of the sines of incidence and refraction of the extreme and mean rays of the spectrum at any given temperature, the dispersive power is expressed by $\frac{a - a''}{a'}$. And as we have seen that the mean index a' varies as the density of the fluid, we have strong reason to suppose that a and a'' vary also in the same proportion; and if so, the dispersive power will of course remain constant; and this deduction is verified, as far as the eye can judge of colour in the telescope, by the preceding experiments, which certainly indicated no perceptible change in the colour of the image. This, however, is a subject I intend to examine more particularly when my large telescope is completed.

It may be proper to observe, that the form of the instrument here employed differs a little from that described in my former paper: in the latter, the plate lens is a fixture, and the adjustment is made by a slight motion of the fluid lens. In this I can move either lens at pleasure; and I have chosen to fix the fluid, and to adjust the plate lens, merely for the sake of simplifying the investigation.

XVI. *On some circumstances relating to the economy of bees. By* THOMAS ANDREW KNIGHT, *Esq. F.R.S. President of the Horticultural Society.*

Read May 22, 1828.

IN a paper which I had the honour to address to the Royal Society about twenty years ago (in the year 1807) upon the Economy of Bees, I stated, that having adapted cavities in hollow trees for the reception of swarms of those insects, I had observed that several days previous to the arrival of a swarm, a considerable number of bees were constantly employed in examining the state of the tree, and particularly of every dead knot above the cavity which appeared likely to admit water into it. At that period it appeared to me rather extraordinary, that animals so industrious as bees, and so much disposed to make the best use of their time, should, at that important season of the year, waste so much of it in apparently useless repetitions of the same act: for I, at that time, supposed that on different days, and at different periods of the same day, I saw only the same individuals. But in a case which at a subsequent period came under my observation, where the cavity into which the bees apparently proposed to enter, was not more than a quarter of a mile distant from the hive whence a swarm were prepared to emigrate, I witnessed a very rapid change of the individuals who visited their future contemplated habitation; and the number which in the course of three days entered it, appeared to me to be fully equal to constitute a very large swarm: and upon the evidence of these and other facts, which I shall proceed to state, I am much disposed to infer, that not a single labouring bee ever emigrates in a swarm without having seen the future proposed habitation of that swarm. That the queen bee has also always seen her future habitation, I am also much inclined to believe, as she is well known to absent herself from the hive some time previously to the emigration of a swarm: though her object may be to meet a male of another hive; for I much doubt whether she ever receives the embraces of a brother. The results of some of HUBER's experiments are very favourable to this conclusion, as is the otherwise excessive number of male bees, and in both the animal and vegetable world nature has taken very ample means of facilitating what the breeders of improved varieties of domesticated animals call cross breeding.

I have also been led by the following facts to believe, that not only the future permanent habitation of each swarm, but the place where they temporarily settle, apparently to collect their numbers, soon after they quit their hive, is known also to each individual. Different families of domesticated animals of every species present some peculiarities of disposition and habit; and the swarms of the family of bees, which were the subject of my experiments, showed, I think, more than an ordinary disposition to unite, by two apparently joining the same queen. My attention was consequently attracted to the circumstances which preceded such unions.

The simultaneous movements and agitation of two hives, had during several days led me to expect that a junction of their swarms was contemplated; and the two ultimately issued out almost at the same moment, and instantly united, as I had concluded they would. The weather was excessively hot; and I put them into a hive which was scarcely large enough to hold them, affording them no further shelter from the sun than I thought just sufficient to prevent the melting of their combs. This occurred upon the first day of June, and in the morning of the twenty-third a very large swarm emigrated. There was in this, I believe, nothing very extraordinary or peculiar, except the excessive expedition apparently employed in raising a second queen.

In the following year two other hives presented similar indications that their swarms would unite; and being anxious to ascertain whether such unions were accidental, or the consequence of previous arrangements, I paid very close attention to their proceedings, and the following singular circumstances came under my observation. After both hives had given frequent indications that a swarm was ready to issue from each of them, one swarm only rose, and that, after hovering in the air during a much longer time than ordinary, settled upon, and around, a bush about twenty-five yards distant from the hive, whence they had issued: but instead of collecting together into a compact mass, as they usually do, they remained thinly dispersed, scarcely two being any where in contact with each other. In this state they continued nearly half an hour motionless and apparently discontented and sulky; and they then gradually began to rise and return home, not apparently in obedience to any command or signal; for they did not rise more abundantly at any one point of time than at another, but each individual seemed to go when tired of waiting.

The next morning a swarm issued from the other hive, and proceeded to the bush upon and around which the other swarm had settled on the preceding day, collecting themselves into a mass as they usually do when their queen is present. This was precisely what I had anticipated, but I was much disappointed that no movement or agitation took place in the other hive. Within a very few minutes, however, and very soon after the swarm above mentioned had fully settled, a very large number of bees suddenly rushed from the hive to which the swarm had returned on the preceding day, and proceeded so directly to the swarm which had just settled, that their course was marked through its whole extent by a perfectly visible dark and narrow line, and they united themselves, without hovering a single instant, to the other swarm. These circumstances conjointly with others which I have stated in my former communication upon this subject, satisfied me that these unions are generally, if not always, the result of previous and perfectly well understood arrangements, though it is not easy to conjecture how such arrangements can be made.

I shall proceed to state a few circumstances which appear to throw light upon some of the phænomena observable in the mode of breeding of bees. It has long been known that these animals possess the power of raising a queen bee from any recently deposited egg, which under ordinary circumstances would have produced a labouring bee; but whether this power extends to those eggs, which, when deposited in larger cells, afford male or drone bees, has not, I believe, been accurately ascertained. The following circumstances lead me to believe that sex is not given to the eggs of birds, or to the spawn of fishes or insects, at any very early period of their growth.

I selected early in winter four female birds of the common duck, which I kept apart from any male bird of that or any kindred species, till the period of their laying eggs approached. One was then killed, and the largest of its eggs was found to be three lines in diameter. A musk drake (Anas moschata) was then put into company with the three remaining ducks; and from these I obtained a numerous offspring, six out of seven of which proved to be males, as the result of similar previous experiments (but in which the male of another species had been introduced at a period when the growth of the eggs was less advanced,) had led me to expect. I repeated the experiment often, and always with nearly the same result, a large majority of male birds being uniformly produced; and hence I conclude that the eggs of birds in early periods of their growth are without sex.

I have never possessed means of obtaining mule fishes; but one kind of fish, which I think is obviously a mule, is found in many rivers where the common river-trout abounds, and where a solitary salmon is sometimes seen. These formerly existed, in some seasons, in considerable numbers, in the river which passes near my residence; but since salmon have become scarce, they have wholly disappeared. I had formerly opportunities of examining a large number of them, without having ever found a single female. I have subsequently found them in large numbers in small mountain rivulets in Wales, below, but never above, the lowest Cataract. They are readily distinguished from the young salmon, by their form being intermediate between that of a trout and of a salmon; by their being all, or nearly all, males; and by their remaining through the summer and autumn in the rivers, long after the young salmon have descended to the sea: they leave the fresh water with the first winter floods, and I believe are not known ever to return. In the North of England they are distinguished by the name of wrackriders, and by that of samlets in some other parts. If these be mules, as I do not entertain any doubt that they are, the spawn of fishes must be without sex when it is deposited by the female; and I am much disposed to entertain the same opinion respecting the spawn (for it is more properly spawn than eggs) of bees.

I have frequently witnessed some somewhat analogous circumstances in the vegetable world, respecting the sexes of the blossoms of plants; and I can at any time succeed in causing several kinds of monoecious plants to produce solely male or solely female blossoms. If heat be, comparatively with the quantity of light which the plant receives, excessive, male flowers only appear; but if light be in excess, female flowers alone will be produced:—the experiments necessary must of course be made with skill and accuracy.

In a former communication to the Royal Society "Upon the comparative influence of the male and female parent upon the character of the offspring," I have inferred, from facts there stated, that the sex of the offspring of some species of animals is given by the female parent. Subsequent experience and observation have strengthened my belief in the truth of this inference: but I believe the power of the female parent to be rather strongly influential than positive, and that external causes operate, which (I have some reason to suspect) are not in all cases wholly beyond the reach of human controul.

THOMAS ANDREW KNIGHT.

London,
May 20*th,* 1828.

XVII. *On the laws of the deviation of magnetized needles towards iron. By*

SAMUEL HUNTER CHRISTIE, *Esq.* M.A. *F.R.S.* *&c.*

Read June 5, 1828.

THE deviations of a magnetized needle from its natural direction in the plane in which it is constrained to move, due to the action of masses of iron, may be referred to a very simple law, excepting in those cases where the length of the needle bears a very sensible ratio to the distance of the iron. The law is this: if we suppose that the centre of a magnetic particle in the direction of the terrestrial magnetic force, or the centre of a small magnetic needle freely suspended by its centre of gravity, coincides with the centre of the needle whose motion is restricted; that the iron attracts both poles of this particle, or freely suspended needle; and that the whole, or very nearly the whole action takes place on these poles;—then the position of the other needle, in the plane in which it is constrained to move, will be found by referring the freely suspended needle to that plane, by a plane perpendicular to the first. The truth of this being established by experiment, it is very clear that whatever may be the position of a mass of iron, the direction of the deviations of a horizontal or dipping needle due to its action, will be immediately indicated, and a sufficiently simple calculation will give the amount. Several years have elapsed since I first pointed out this law, showing at the same time, by a series of experiments, that the observed deviations are in conformity with it. I have since omitted no opportunity of submitting it to the test of experiment; and taking it as the basis of calculation, have always found, except indeed in cases, as I have before stated, of too great proximity of the disturbing body, that the results which I obtained approximated so closely to the observations, as to leave no doubt in my own mind of its correctness.

However, the truth of this law has latterly been called in question; and, in a paper published in the Transactions of last year, some experiments on horizontal needles, having their magnetism unequally distributed in the two branches, are described, which are considered by the author as quite decisive of its fallacy *. It is not my intention to enter into an examination of what are there, erroneously I apprehend, considered as the effects that would result from this law, when the equal distribution of magnetism in the two branches of a needle has been disturbed. Immediately after having heard that paper read, I proceeded to ascertain some circumstances which appear to have been overlooked in these experiments, and then noted what, according to the law in question, ought to be the deviations of a needle having either of its branches "deteriorated" when in different positions with respect to an iron shell. Not being then in possession of the experimental results in that paper, I could not compare my conclusions with them; but on doing so when the Part of the Transactions was published, I found them perfectly to accord.

Whatever hypothesis we may adopt for the explanation of the phænomena observed with a needle having its magnetism thus disturbed, or to whatever laws we may apply these phænomena as tests, it is essential that we should know, not only to which end of the needle the disturbing cause has been applied, and its effect on the directive force, but likewise the effect produced on the distribution of the magnetism throughout the needle. It is particularly necessary that the positions of the points where the intensity of the magnetism is the greatest, and of that where the magnetism of contrary names, and on opposite sides balance each other, and which may be termed the magnetic centre of the needle, should be determined. As this had not been done in the experiments to which I have alluded, it became necessary to repeat those experiments, and to determine the positions of these points in the needles employed in that repetition. With this view, I cut three needles of precisely the same form and weight, from the same piece of steel, and applying them over each other, hardened the ends of the three at the same time. These were successively placed in the middle of a groove which two twelve-inch bar magnets exactly fitted, and were each magnetized in precisely the same manner, by passing the ends of the bar magnets, inclined always at the same angle, from centre to ends, the same number of times. One of these was left thus magnetized. The other two were successively placed on a thin board, and the marked

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* Phil. Trans. 1827. p. 281.

end of one of the twelve-inch bar magnets was passed twice, on the opposite side of the board, from the centre to the marked end of one needle; and the unmarked end of the magnet, similarly, from the centre to the unmarked end of the other*.

Having determined in these needles the points of greatest intensity, which we may consider as the poles, and likewise the centres of their magnetism, I made observations with them precisely similar to those detailed in the paper already cited†. In the first instance, I proposed to determine the several values of a particular constant, by applying the hypothesis of a central action of the iron to the observations with the needle whose magnetism had been undisturbed, and to employ the mean value in calculating the effects which would arise, according to this hypothesis, from the disturbance of the magnetism in the other needles: but as these values, though not differing greatly from each other, had a pretty regular increase and decrease according to the azimuth of the shell, I considered that the length of the needle might, in this case, bear too great a proportion to the distance of the shell for the proposed law to be strictly applicable, although it might give results approximating to the experiments. The fact however, which is stated to have been ascertained by experiment, that the length of a needle has no sensible influence on the extent of its deviations‡, was opposed to this view; and I therefore compared with each other the values of the constant which would result from these observations, by applying to them a law considered to have been established by experiment: viz. " the tangent of the deviation is proportional to the rectangle of the cosine of the longitude, and the sine of the double latitude" of the needle's centre with reference to that of the shell§.

The values of the constant, thus deduced, differed so widely from each other, that I could have no expectation of obtaining from the mean value, results that should at all approximate to the experiments; and indeed, could entertain no

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* These terms, marked end and unmarked end, I employ instead of north end and south end, or south pole and north pole, merely to avoid the ambiguity that might arise in some of the experiments if the name of the end of the magnet or needle had any reference to position.

† Phil. Trans. 1827. p. 284.

‡ Mr. Barlow's Magnetic Attractions, second edition, p. 59.

§ Ibid. p. 39.

doubt of the fallacy of this law, even as approximative. These circumstances led me to suspect the accuracy of the conclusion, that the length of a needle has no sensible influence upon its deviation; and I considered that it would be desirable to ascertain whether such were or were not the fact. This in a theoretical point of view is of some importance; since such a fact would be in direct opposition to the conclusions derived from the theory advocated in the paper in question, and so ably and elaborately developed in M. POISSON's Memoirs on Magnetism. M. POISSON says: "A la vérité, M. BARLOW annonce qu'ayant placé successivement dans le même point le milieu de l'aiguille de six pouces, et celui d'une petite aiguille d'un demi-pouce (d'un pouce et demi?) en longueur, il n'a pas observé de différence entre leur déviations; ce qui ferait penser que les deux corrections dont nous parlons, dont l'une a pour effet d'augmenter la déviation, et l'autre, de la diminuer, se seraient à peu près compensées. Mais nous avons lieu de croire que cette compensation a été très-imparfaite; car en calculant les déviations de l'aiguille, sans avoir égard à la double corrections due à sa longueur et à sa force magnétique, les differences que l'on trouve entre le calcul et l'experience, sont trop grandes pour être attribuées en entier aux erreurs des observations*."

These considerations induced me to extend my experiments much beyond the limits which I had originally proposed to myself; and as these experiments were made with great care, and I may fairly state, without any consideration of what might or might not be in conformity with theoretical views, they will afford good tests which may be applied to any theory of magnetism, as well as to the laws with which I have compared them. Previously to detailing any of these experiments, or to entering upon any investigations founded upon the law which they so decidedly establish, I shall briefly notice the facts which I ascertained, and the general explanation they afford, in conformity with that law, of the experiments which are considered by their author to be decisive of its fallacy.

In the first instance, I ascertained that if any bar of steel, uniformly magnetized by the method of double touch, have this state of its magnetism disturbed, by drawing the end of a magnet from its centre to the end of the same

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* Mémoire sur la Théorie du Magnetisme, p. 87.

name as that applied to it; that is, drawing the marked end of the magnet towards the marked end of the needle, or the unmarked end towards its unmarked end; then the pole at the end to which the magnet has been applied, or that which has been termed the "deteriorated branch" will approach the centre of the needle. In the other, or "undeteriorated branch," the pole will recede from the centre.

And the magnetic centre will invariably recede from the centre of figure towards the "undeteriorated end," or that to which the disturbing magnet has not been applied. The changes in the positions of these points, in consequence of the disturbance of the magnetism, is best illustrated by the following figures, in which I. II. represent two bar magnets, 8.92 inches in length, 0.16 inch in breadth, 0.09 inch in thickness.

Fig. 1.

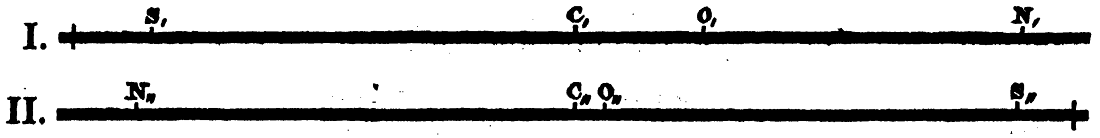


Fig. 2.

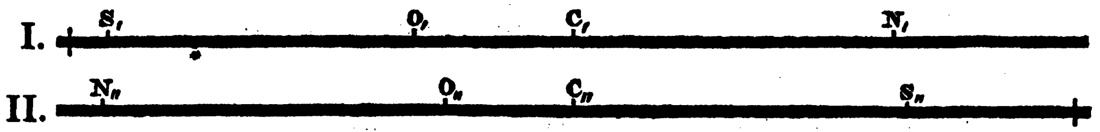
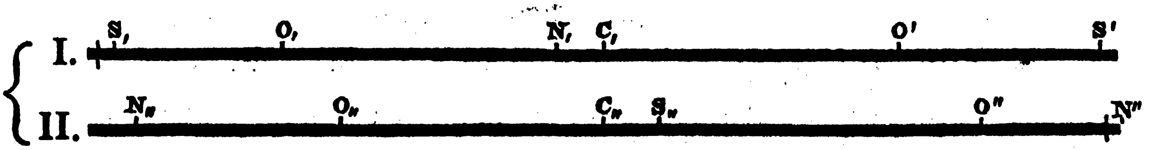


Fig. 3.



End towards which the end of the same name of the disturbing magnet is drawn.

Fig. 1. represents the positions of the poles and magnetic centres after the bars had been magnetized by double touch: $N_{,}$, $N_{,,}$ the north poles; $S_{,}$, $S_{,,}$ the south poles; $C_{,}$, $C_{,,}$ the centres of the bars; $O_{,}$, $O_{,,}$ their magnetic centres.

$C_{,}\,S_{,} = 3.74$ inches; $C_{,}O_{,} = 1.14$ inch; $C_{,}N_{,} = 3{\cdot}97$ inches;
$C_{,,}N_{,,} = 3.84$ inches; $C_{,,}O_{,,} = 0.24$ inch; $C_{,,}S_{,,} = 3{\cdot}86$ inches.

Fig. 2. represents the positions of these points when the magnetism had been disturbed, by drawing the end of a twelve-inch bar magnet, as before described, once very quickly from the centre to the ends of I. and II.

$C_{,}\,S_{,} = 4.09$ inches; $C_{,}O_{,} = 1.41$ inch; $C_{,}N_{,} = 2.79$ inches;
$C_{,,}N_{,,} = 3.99$ inches; $C_{,,}O_{,,} = 1.14$ inch; $C_{,,}S_{,,} = 2.91$ inches.

Fig. 3. represents the positions of the same points, and of new poles S', N'', and magnetic centres O', O'', in consequence of a further disturbance of the magnetism, by drawing the end of the twelve-inch magnet twice from the centre to the ends of I. and II.

$$C_{\prime}S_{\prime} = 4.26 \text{ in.}; \; C_{\prime}O_{\prime} = 2.83 \text{ in.}; \; C_{\prime}N_{\prime} = 0.41 \text{ in.}; \; C_{\prime}O' = 2.57 \text{ in.}; \; C_{\prime}S' = 4.32 \text{ in.};$$
$$C_{\prime\prime}N_{\prime\prime} = 4.24 \text{ in.}; \; C_{\prime\prime}O_{\prime\prime} = 2.34 \text{ in.}; \; C_{\prime\prime}S_{\prime\prime} = 0.48 \text{ in.}; \; C_{\prime\prime}O'' = 3.31 \text{ in.}; \; C_{\prime\prime}N'' = 4.51 \text{ in.}.$$

It is easily shown that such changes in the positions of these points will account for what are termed "the secondary deflections," arising from disturbance in the magnetism of the needle, according to the law that the horizontal needle will always assume the position of the projection on the horizontal plane of a needle freely suspended by its centre of gravity, that centre coinciding with the magnetic centre of the horizontal needle, and the iron attracting both poles of the inclined needle.

In the paper to which I have referred it is stated, that when the needle is "placed any where in the magnetic equator of the ball, whichever end of the needle has its magnetism deteriorated, that end will approach the ball."

According to my view of the subject, the centre of the spherical shell will, in this case, coincide with the equator of a freely suspended needle whose centre coincides with the centre of figure, and if the magnetism be equally distributed, of magnetism likewise of the horizontal needle; in which latter case the shell would produce no deviation in the freely suspended needle, and consequently none in the horizontal needle. But when either "branch is deteriorated," I have shown that the magnetic centre of the needle will recede from the centre of figure along the "undeteriorated branch," and the centre of the imaginary suspended needle coinciding with this centre, the centre of the shell will now be in the hemisphere on that side of the equator of the suspended needle in which is the "deteriorated branch." This branch then of the suspended needle, and consequently also, according to the law in question of the horizontal needle, will approach the shell.

The explanation is equally simple in other positions of the needle. The effects are stated to be these: "Generally, in other positions, one branch of the needle will be nearer to the centre of the ball than the other; then, if the near end have its magnetism deteriorated, the needle will approach its natural meridian; but if the more distant end be deteriorated, the needle will be more deflected, or recede from the meridian."

It is evident that "if the near end have its magnetism deteriorated," the needle's magnetic centre will recede from the shell, and its deviation will nearly correspond to that of another horizontal needle having its magnetism symmetrically distributed in the two branches, and its centre coinciding with the magnetic centre of the former; the deviation will therefore in this case be diminished, or in other words, "the needle will approach its natural meridian." And "if the more distant end be deteriorated," it is clear that the magnetic centre will approach the shell, and consequently "the needle will be more deflected, or recede from the meridian."

This is, I consider, quite sufficient to show the general accordance of these experiments with the law to prove the fallacy of which they were brought forward; and I shall in the subsequent part of this paper, show that this law not only indicates clearly the nature of the deviations which in such cases take place, but that calculations founded upon it, give close approximations to their numerical values.

At the same time that I found the effects which have been described were invariably produced, on the positions of the poles and magnetic centre of the magnetized bars and needles by the disturbance of their magnetism, I likewise found that the intensities of both poles were greatly changed. With the three needles to which I have before referred, and which previous to the disturbance of their magnetism made ten vibrations in about thirty-four seconds, and after it, ten vibrations in about fifty-three seconds; the intensity of the pole in the branch on which the disturbing magnet had been applied, had decreased in about the ratio of five to two, and in the other of seven to four. But these effects I shall more particularly describe when I detail the observations by which I ascertained them.

With regard to the difference in the extent of the deviations of a needle six inches in length, and of one about a third of that length, when successively placed in the same position with respect to the shell, I found that at the distance 16.8 inches from the shell, this difference amounted in some instances to more than 2° 30′; the deviation being in the one case 13° 38′, and in the other 11° 04′: also that there was a sensible, though small difference in the deviations of the shorter of these needles, and of one only an inch in length; the latter deviation being in the above situation only 10° 51′. I likewise found that even at the distance of twenty-four inches from the shell, the deviations of the longer needle were still sensibly different from those of either of the others. In general, when the needles were near to north or south from the shell's centre, the deviations of the longer needle exceeded those of the shorter; and the reverse took place when the needles were near to east or west from that centre. This is of course a very general description of the effects on the different needles, the precise nature of those effects will be best understood by consulting the tables containing the details of the observations. From this general description, however, we may draw a practical inference of some consequence; viz., that if the deviations that would take place in a needle from the influence of large and distant masses of iron, be counteracted by that of a small mass placed near to the needle, so that it retains its direction in the magnetic meridian in a certain position of the lines joining these masses and the centre of the needle with respect to that meridian; then the needle and these masses preserving their relative positions, if the whole revolve, the deviations caused by the large and distant mass will in some positions preponderate over those due to the smaller, and in some the contrary effect will be produced. It is therefore of importance that the counteracting mass of iron should be at such a distance from the needle that the difference of its effects upon a long needle and upon a very short one would be scarcely appreciable.

Having given a general view of some of the results which I obtained, I shall now deduce, according to the law which I have proposed, equations for the deviations of a horizontal needle due to the action of an iron sphere or shell, applicable to the different circumstances of the experiments which I shall afterwards detail.

Take the centre of the horizontal needle as the origin of three rectangular co-ordinates x, y, z to the centre of the sphere; z being in the direction of the terrestrial force, or the axis of a freely suspended needle concentric with the horizontal needle; y, in that of the magnetic meridian on the plane of the equator of this dipping needle; and x, in that of the intersection of this equator with the horizon: x being measured towards east, y towards north, and z downwards in the direction of the south pole of the dipping needle. Let the distance of each pole of this dipping needle from its centre be e, or its length $2e$; m the terrestrial magnetic force acting upon each pole in the direction of the dip, and f the force of the sphere upon either pole at the unity of distance, supposing the whole mass collected in the centre. The square of the distance of the sphere's centre from the south pole of the dipping needle will be $x^2 + y^2 + (z - e)^2$; and from its north pole $x^2 + y^2 + (z + e)^2$. So that the forces urging these poles towards the centre of the sphere will be

$$\frac{f}{x^2 + y^2 + (z - e)^2} \text{ and } \frac{f}{x^2 + y^2 + (z + e)^2}.$$

The deviation of the needle will take place in the plane passing through the centre of the sphere and the axis z; and it is evident that it will be the same, if instead of the forces acting upon the north pole, we suppose forces equal to these, but in contrary directions, to act upon the south pole. If then we resolve these forces into others in the direction of the axis z, and perpendicular to it in the plane passing through z and the centre of the sphere, the south pole will be acted upon by a force in the direction z equal to

$$2m + \frac{f.(z - e)}{\{x^2 + y^2 + (z - e)^2\}^{\frac{3}{2}}} - \frac{f.(z + e)}{\{x^2 + y^2 + (z + e)^2\}^{\frac{3}{2}}};$$

and by a force in the direction perpendicular to it equal to

$$f.(x^2 + y^2)^{\frac{1}{2}} \left\{ \frac{1}{\{x^2 + y^2 + (z - e)^2\}^{\frac{3}{2}}} - \frac{1}{\{x^2 + y^2 + (z + e)^2\}^{\frac{3}{2}}} \right\}.$$

Let R be the distance of the sphere's centre from that of the needle, and γ the angle which this distance makes with the axis z. If we substitute R^2 for $x^2 + y^2 + z^2$, $R \cos \gamma$ for z, and $R \sin \gamma$ for $(x^2 + y^2)^{\frac{1}{2}}$, in these expressions, and expand those which result, neglecting the terms containing powers of e higher than the third,

$$2m + \frac{fe}{R^3} \cdot \left[2.(\cos^2\gamma - 1) + \frac{e^2}{R^2} \cdot \{3 - 5 \cos^2\gamma (6 - 7 \cos^2\gamma)\} \right]$$

will represent the force in the direction z; and

$$\frac{fe}{R^3} \cdot \sin\gamma \cos\gamma \left\{ 2.3 - \frac{e^2}{R^2} (3.5 - 5.7 \cos^2\gamma) \right\},$$

the force perpendicular to z, in the plane passing through the axis z and the centre of the sphere.

If then ψ is the angle of deviation of the needle from the axis z, ψ will also be the angle which the resultant of these forces makes with that axis: we shall therefore have

$$\text{Tan}\,\psi = \frac{\sin\gamma\cos\gamma\left\{2.3 - \frac{e^2}{\text{R}^2}(3.5 - 5.7\cos^2\gamma)\right\}}{\frac{2\,m\,\text{R}^3}{fe} + 2(3\cos^2\gamma - 1) + \frac{e^2}{\text{R}^2}\{3 - 5\cos^2\gamma(6 - 7\cos^2\gamma)\}} \qquad (1)$$

If e is extremely small, we may neglect the terms containing $\frac{e^2}{\text{R}^2}$, and the equation then becomes

$$\text{Tan}\,\psi = \frac{3\sin\gamma\cos\gamma}{\frac{m\,\text{R}^3}{fe} + 3\cos^2\gamma - 1} \qquad (2)$$

or

$$\text{Tan}\,\psi = \frac{3\sin 2\gamma}{\frac{2\,m\,\text{R}^3}{fe} + 3\cos 2\gamma + 1} \qquad (3)$$

These equations give the position which an extremely short freely suspended needle would assume by the combined action of the iron sphere, and of terrestrial magnetism; and according to the law which I consider obtains, the projection of this inclined needle upon the horizontal plane will give the position which the horizontal needle will assume in consequence of the same action*.

The rectangular co-ordinates x, y, z determine the position of the iron sphere; but if ω be the angle which the projection of the radius vector R upon the plane $x\,y$ makes with the axis y, its position will be determined by the polar co-ordinates R, γ, ω. Let the angle which the axis z makes with the vertical, or the complement of the dip, be represented by η, and the angle which the projection of the freely suspended needle upon the horizontal plane makes

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* This principle, that the deviations of the horizontal needle may be referred to those of the inclined needle, I had pointed out a considerable time previous to my showing, in a paper in the Camb. Phil. Trans. for 1820, that it is consistent with experimental results. It was adopted in the first edition of Mr. Barlow's "Essay on Magnetic Attractions," and likewise in the theoretical investigations in the second edition of that work. M. Poisson, in his "Mémoire sur la Théorie du Magnetisme," published in 1824, employs the same principle.

with the projection of the axis z upon the same plane or the magnetic meridian, and which, according to the principle adopted, is the deviation of the horizontal needle, be represented by ϕ: then the intersection of the axis z, of the vertical, and of the line of the inclined needle with the surface of a sphere described about the centre of the needle, will be the angular points of a spherical triangle, of which two sides are η, ψ, their included angle $\pi-\omega$, and ϕ the angle opposite to ψ. We shall therefore have

$$\sin\omega \,.\, \cot\phi = \sin\eta \cot\psi + \cos\omega\cos\eta\,;$$

from which and the equation (3), we obtain

$$\mathrm{Cot}\,\phi = \frac{\sin\eta\left\{\frac{2mR^3}{fe} + 3\cos 2\gamma + 1\right\}}{3\sin 2\gamma\sin\omega} + \cos\eta\cot\omega. \qquad (4)$$

If we determine the position of the iron sphere by polar co-ordinates relative to the vertical and the plane of the horizon, calling the angle which the radius R makes with the vertical v, and the angle which its projection on the plane of the horizon makes with the magnetic meridian, or the azimuth of the iron sphere, θ; then v, γ, η will be the sides of a spherical triangle of which the angles opposite to v and γ are $\pi-\omega$ and θ. We have therefore

$$\cos\gamma = \cos\theta \,.\, \sin\eta \,.\, \sin v + \cos\eta \,.\, \cos v,$$

$$\sin\omega \,.\, \sin\gamma = \sin\theta \,.\, \sin v,$$

$$\cot\theta\sin\omega = \cot\gamma\sin\eta + \cos\omega\cos\eta.$$

From these, putting the equation (4) in the form

$$\mathrm{Cot}\,\phi = \frac{\sin\eta \,.\, \left(\frac{mR^3}{fe} - 1\right)}{3\sin\gamma\cos\gamma\sin\omega} + \frac{\cot\gamma\sin\eta + \cos\omega\cos\eta}{\sin\omega},$$

we obtain

$$\mathrm{Cot}\,\phi = \frac{\frac{mR^3}{fe} - 1}{3\sin\theta\sin v(\cos\theta\sin v + \cot\eta\cos v)} + \cot\theta. \qquad (5)$$

If, as is most convenient for experiment, the position of the iron sphere be determined by its vertical distance below the horizontal plane on which the needle is, and its horizontal distance from the centre of the needle, let r be the projection of R on the horizontal plane, and h the distance of the sphere's centre below that plane: then since, $\sin v = \frac{r}{R}$, and $\cos v = \frac{h}{R}$,

$$\text{Cot}\,\varphi = \frac{\left(\frac{m\,\text{R}^3}{fe} - 1\right).\,\text{R}^3}{3\,r \sin\theta\,(r\cos\theta + h\cot\eta)} + \cot\theta \qquad (6)$$

This when $h = 0$, or the centre of the sphere is in the same horizontal plane as that of the needle, becomes

$$\text{Cot}\,\varphi = \frac{2\left(\frac{m\,\text{R}^3}{fe} - 1\right)}{3\sin 2\theta} + \cot\theta \qquad (7)$$

from which the values of $\frac{m}{fe}$ will be determined in different magnetic latitudes from the observed values of φ, independent of the dip.

We may, in a similar manner, deduce an equation for the deviations of a needle in which the magnetism has been disturbed by applying to one of its poles the corresponding pole of a magnet; and thence determine the deviations of a needle having its magnetism symmetrically distributed in its two branches from the observed deviations of a needle in which such distribution has been disturbed. I have already stated that under these circumstances the intensities of both poles were changed, and it will be seen by the experiments detailed in a subsequent part of this paper, that their distances from the new magnetic centre were not the same, the more energetic pole being the nearer; and I will assume that the same is the case with the needle freely suspended from a point which, as before, is its centre of gravity and of magnetism. Let the quantities which before were indicated by m, f, e be indicated by m', f', e' for the north or upper pole of the suspended needle, and by $m_{\prime}, f_{\prime}, e_{\prime}$ for its south or lower pole. We will also suppose that the south pole, or that which is usually marked, is that to which the corresponding pole of a magnet has been applied, or that "the deteriorated branch" is the northern; and that $\text{R}_{\prime}$ is the distance of the sphere's centre from the magnetic centre of this needle, $\gamma_{\prime}$ the angle which $\text{R}_{\prime}$ makes with the axis z passing through this centre, and $\psi_{\prime}$ the angle which the freely suspended needle makes with the same axis, or its deviation due to the action of the iron sphere. The equation corresponding to (2) will now become

$$\text{Tan}\,\psi_{\prime} = \frac{\sin\gamma_{\prime}\{\text{R}_{\prime}(f'e' - f_{\prime}e_{\prime}) + 3\cos\gamma_{\prime}(f'e'^2 + f_{\prime}e_{\prime}^2)\}}{(m'e' + m_{\prime}e_{\prime}).\,\text{R}_{\prime}^3 + \cos\gamma_{\prime}\{\text{R}_{\prime}(f'e' - f_{\prime}e_{\prime}) + 3\cos\gamma_{\prime}(f'e'^2 + f_{\prime}e_{\prime}^2)\} - (f'e'^2 + f_{\prime}e_{\prime}^2)}$$

Now $\frac{m'}{f'} = \frac{m_{\prime}}{f_{\prime}} = \frac{m}{f}$; and it will be seen by the experiments that the values of the products of the intensity of each pole by its distance from the magnetic centre are so nearly the same, that, as an approximation, we may assume them equal; and supposing the same distribution in the inclined neeedle, we have $\frac{e'}{e_{\prime}} = \frac{f_{\prime}}{f'} = \frac{m_{\prime}}{m'}$. Consequently,

$$\text{Tan}\,\psi_{\prime} = \frac{3\sin\gamma_{\prime}\cos\gamma_{\prime}}{\frac{2e}{e_{\prime}+e'}\cdot\frac{m\,\text{R}_{\prime}^{3}}{fe} + 3\cos^{2}\gamma_{\prime} - 1} \qquad (8)$$

If then $\theta_{\prime}$ is the azimuth of the iron sphere's centre from the magnetic centre of the deteriorated horizontal needle; $\varphi_{\prime}$ the deviation of this needle from the magnetic meridian; and $r_{\prime}$ the projection of $\text{R}_{\prime}$ upon the horizontal plane; we have, putting p for $\frac{2e}{e_{\prime}+e'}$,

$$\text{Cot}\,\varphi_{\prime} = \frac{\left(\frac{p\,m\,\text{R}_{\prime}^{3}}{fe} - 1\right)\cdot\text{R}_{\prime}^{2}}{3\,r_{\prime}\sin\theta_{\prime}\,(r_{\prime}\cos\theta_{\prime} + h\cot\eta)} + \cot\theta_{\prime} \qquad (9)$$

Let k be the distance of the magnetic centre of the deteriorated needle from its centre of figure, which distance, as will be seen from the experiments, is to be measured towards the south when the northern branch of the needle is that "deteriorated;" then

$$r_{\prime}^{2} = r^{2} + k^{2} + 2\,r\,k\cos(\theta - \varphi_{\prime})\,; \quad \text{R}_{\prime}^{2} = \text{R}^{2} + k^{2} + 2\,r\,k\cos(\theta - \varphi_{\prime})\,;$$

$$r_{\prime}\sin\theta_{\prime} = r\sin\theta + k\sin\varphi_{\prime}\,; \quad r_{\prime}\cos\theta_{\prime} = r\cos\theta + k\cos\varphi_{\prime}.$$

Substituting these values in the equation (9), and limiting the approximation to the first power of $\frac{k}{r}$, we have,

$$\text{Cot}\,\varphi_{\prime} = \frac{p\,m\,\text{R}^{3}}{fe}\cdot\frac{\text{R}^{2}}{3\,r\,\text{Q}}\cdot\left\{1+\left(\frac{5\,r^{2}}{\text{R}^{3}}\cdot\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right)\cdot\frac{k}{r}\right\} - \frac{\text{R}^{2}}{3\,r\,\text{Q}}\left\{1+\left(\frac{2\,r^{2}}{\text{R}^{2}}\cdot\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right)\cdot\frac{k}{r}\right\} + \cot\theta + \frac{\sin(\theta-\varphi_{\prime})}{\sin^{2}\theta}\cdot\frac{k}{r}$$

where $\text{Q} \doteq \sin\theta\,.\,(r\cos\theta + h\cot\eta)$, and $\text{S} = r\sin(\theta+\varphi_{\prime}) + h\cot\eta\sin\varphi_{\prime}$.

Putting for $\frac{p\,m\,\text{R}^{3}}{fe}\cdot\frac{\text{R}^{2}}{3\,r\,\text{Q}}$ its value from the equation (6), $\cot\varphi - \cot\theta + \frac{\text{R}^{2}}{3\,r\,\text{Q}}$, we obtain

$$\text{Cot}\,\varphi = \frac{\cot\varphi_{\prime}+(p-1)\cdot\left\{\cot\theta-\frac{\text{R}^{2}}{3\,r\,\text{Q}}\right\}+\left[p\cdot\left\{\cot\theta-\frac{\text{R}^{2}}{3\,r\,\text{Q}}\right\}\cdot\left\{\frac{5\,r^{2}}{\text{R}^{2}}\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right\}+\frac{\text{R}^{2}}{3\,r\,\text{Q}}\cdot\left\{\frac{2\,r^{2}}{\text{R}^{2}}\cdot\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right\}-\frac{\sin(\theta-\varphi_{\prime})}{\sin^{2}\theta}\right]\cdot\frac{k}{r}}{p\cdot\left[1+\left\{\frac{5\,r^{2}}{\text{R}^{2}}\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right\}\cdot\frac{k}{r}\right]},$$

or

$$\text{Cot}\,\varphi = \frac{\cot\varphi_{\prime}-\left(\cot\theta-\frac{\text{R}^{2}}{3\,r\,\text{Q}}\right)+\left[\frac{\text{R}^{2}}{3\,r\,\text{Q}}\cdot\left\{\frac{2\,r^{2}}{\text{R}^{2}}\cdot\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right\}-\frac{\sin(\theta-\varphi_{\prime})}{\sin^{2}\theta}\right]\cdot\frac{k}{r}}{p\cdot\left[1+\left\{\frac{5\,r^{2}}{\text{R}^{2}}\cdot\cos(\theta-\varphi_{\prime})-\frac{\text{S}}{\text{Q}}\right\}\cdot\frac{k}{r}\right]} + \cot\theta - \frac{\text{R}^{2}}{3\,r\,\text{Q}} \qquad (10),$$

the latter being rather more convenient for computation.

From this equation the values of φ, or the deviations of a needle having its magnetism similarly distributed in its two branches, may be computed from the observed values of $\varphi_{,}$, or the observed deviations of a needle having its magnetism dissimilarly distributed.

The equation (10) admits of considerable simplification when the centre of the shell is in the same horizontal plane as that of the needle. In this case $h = 0$; r becomes R; $Q = R \sin\theta \cos\theta$; $S = R \sin(\theta + \varphi_{,})$; and consequently,

$$\text{Cot}\,\varphi = \frac{\cot\varphi_{,} - \frac{3\cos^2\theta - 1}{3\sin\theta\cos\theta} + \left[\frac{1}{3\sin\theta\cos\theta}\left\{2\cos(\theta-\varphi_{,}) - \frac{\sin(\theta+\varphi_{,})}{\sin\theta.\cos\theta}\right\} - \frac{\sin(\theta-\varphi_{,})}{\sin^2\theta}\right].\frac{k}{R}}{p.\left[1 + \left\{5\cos(\theta-\varphi_{,}) - \frac{\sin(\theta+\varphi_{,})}{\sin\theta\cos\theta}\right\}.\frac{k}{R}\right]} + \frac{3\cos^2\theta - 1}{3\sin\theta\cos\theta},$$

or since $$2\cos(\theta - \varphi_{,}) - \frac{\sin(\theta + \varphi_{,})}{\sin\theta\cos\theta} = 2\cot 2\theta.\sin(\theta - \varphi_{,}),$$

$$\text{Cot}\,\varphi = \frac{\cot\varphi_{,} - \frac{3\cos 2\theta + 1}{3\sin 2\theta} - \frac{2(\cos 2\theta + 3)}{3\sin^2 2\theta}.\sin(\theta - \varphi_{,}).\frac{k}{R}}{p.\left[1 + \left\{3\cos(\theta-\varphi_{,}) + 2\cot 2\theta.\sin(\theta-\varphi_{,})\right\}.\frac{k}{R}\right]} + \frac{3\cos 2\theta + 1}{3\sin 2\theta} \qquad (11)$$

If φ and $\varphi_{,}$ have both been determined from observation, the value of p may be determined from this equation,

$$p = \frac{\cot\varphi_{,} - \frac{3\cos 2\theta + 1}{3\sin 2\theta} - \frac{2(\cos 2\theta + 3)}{3\sin^2 2\theta}.\sin(\theta - \varphi_{,}).\frac{k}{R}}{\left\{\cot\varphi - \frac{3\cos 2\theta + 1}{3\sin 2\theta}\right\}.\left[1 + \left\{3\cos(\theta-\varphi_{,}) + 2\cot 2\theta.\sin(\theta-\varphi_{,})\right\}.\frac{k}{R}\right]} \qquad (12)$$

The equations (10), (11), (12) have been obtained on the supposition that the disturbing magnet has been applied to the northern branch of the needle, or that the northern branch is "deteriorated," in which case the magnetic centre will be found between the centre of figure and the southern extremity; but if the disturbing magnet is applied to the southern branch, or it is this branch which is "deteriorated," the magnetic centre will be found between the centre of figure and the northern extremity; and therefore in applying these equations to the latter case, k must be considered negative.

Having deduced equations by which the deviations of a horizontal needle, due to the action of an iron sphere or shell, may be computed, both when the distribution of magnetism is similar, and when it is dissimilar in the two branches of the needle, I shall now proceed to the detail of experiments, and to their comparison with these theoretical results.

I have already stated that circumstances led me to suspect the accuracy of the observations from which the conclusion had been drawn, that a mass of soft iron will cause the same deviation in a magnetized needle of six inches, and in one of an inch and a half in length; or in other words, that, within these limits, the deviations are independent of the needle's length; and the first observations which I made, not only confirmed my suspicions, but placed the matter beyond doubt. The apparatus which I made use of is nearly the same as that which I employed for the experiments by which I first showed, that the deviations of a horizontal needle due to the action of a mass of iron are in conformity with the law in question. In those experiments I employed a shell 12.78 inches in diameter: the diameter of that used in the experiments I am about to describe is 17.7 inches. I was indebted for the use of this shell to Sir William Congreve, who allowed me to select it from a few of that diameter in the Repository at Woolwich. This shell can be lowered or raised by means of pulleys, and passes through a circular hole in a horizontal table. On this table I had described two circles concentric with the shell, when its centre was in the plane of the table, one 9.5 inches radius, the other 28 inches; and these circles I had divided very carefully to thirds of a degree: so that, a very fine wire being stretched from a division in the one to the corresponding division in the other, the compass can be adjusted with considerable accuracy to any azimuth from the shell's centre, by means of indexes outside the box, corresponding to 0 and 180 on the divided ring. This ring is divided to 20′; and as I had made the needles to fit it very accurately, and had terminated them by very sharp points, I consider that I could read the deviations pretty accurately to 2′ by means of a lens; and as in all cases, the readings at both ends of the needle were registered and a mean taken, the errors of centering were avoided, and the whole amount of error diminished. When the shell had been lowered so that its vertical distance above or below the plane of the table was that at which the observations were to be made, I very carefully adjusted it, by means of plummets suspended from very fine wires crossing over it, so that the vertical through its centre passed through the centre of the concentric graduated circles on the horizontal table.

To determine the influence which the length of a needle has on its deviations, I made use of three different needles, which I had marked A, D, P. A is 6.01 inches in length, bounded by circular arcs, its greatest breadth being 0.52 inch; D is 1.87 inch in length, its breadth 0.22 inch; P is 1.03 inch in-length, and 0.19 inch in breadth; the forms of D and P being nearly similar to that of A. The weight of A is 77.5 grains; of D 7.0 grains; and of P 7.75 grains. To the needles D and P were attached slips of mica, of the same length as A, having fine lines drawn on them, and with which the axes of the needles were made to coincide; so that I could observe the corresponding deviations of the three needles by placing them successively on the pivot of the same compass-box, which therefore remained in the same position for each, after it had been so adjusted that the centre of the shell had the required azimuth with respect to that of the needle. With these needles, observations were made in three different positions of the shell; viz. when its centre was ten inches above the horizontal plane passing through the needle's centre; when its centre coincided with; and when ten inches below that plane. When the shell was above or below that plane, the horizontal distance of the needle's centre from the vertical passing through that of the shell was 13.5 inches; so that placing the needle in different azimuths on the horizontal table, had the same effect as making the shell describe a parallel to the horizon in a sphere 16.8 inches radius described about the needle. When the centre of the shell was in the horizontal plane passing through the needle's centre, the distance between these centres was 16.8 inches. In all these cases the deviations of the three needles were observed at every 20° of azimuth round the circle. These distances were adopted as they are those selected in the experiments described in the paper, "On the secondary deflections produced in a magnetized needle by an iron shell, &c." in the Transactions of last year; and I had consequently computed the values of the angles γ, ω, in the equations (3), (4), according to such adjustments. Whatever errors might be made in the adjustment of the compass,—and I have no hesitation in saying that these were always of small amount,—the relative deviations of the three needles for each azimuth were independent of these errors, since the compass-box remained in the same position for the corresponding observations with each needle.

The following Tables contain the deviations of the north end of the needle, deduced from the readings at both ends, in three different sets of experiments; in each of which all the adjustments of the height of the shell, its centering, the azimuth and distance of the compass, were made afresh. The mean of the deviations corresponding to each azimuth of the shell to the west is taken, and likewise of those corresponding to each azimuth to the east;

and again the mean of these mean deviations in opposite directions for each azimuth. In these, + indicates that the deviation of the north end of the needle is of the same name as the azimuth of the shell, or that it is towards the shell; and —, that it is of a contrary name, or from the shell.

The centre of the Shell 10 inches below the horizontal plane passing through the Needle's centre, and its distance from that centre 16.8 inches.

Needle of which the deviation was observed.	Azimuth of the Shell's centre from North.	The Azimuth of the Shell's centre from that of the Needle being								Means of the deviations with the Shell West and with the Shell East.
		West.				East.				
		Deviations of the North end.			Means.	Deviations of the North end.			Means.	
A. Length = 6.01 inches.	20°	10° 40′W	10° 46′W	10° 48′W	10° 44′ 40″W	10° 40′E	10° 32′E	10° 33′E	10° 35′ 00″E	+10° 39′ 50″
	40	20 24	20 34	20 30	20 29 20	20 24	20 14	20 17	20 18 20	20 23 50
	60	28 02	28 06	28 10	28 06 00	28 05	27 55	27 55	27 58 20	28 02 10
	80	32 23	32 27	32 29	32 26 20	32 47	32 41	32 46	32 44 40	32 35 30
	100	32 00	32 08	32 08	32 05 20	32 40	32 35	32 27	32 34 00	32 19 40
	120	27 50	28 09	27 58	27 59 00	28 18	28 18	28 08	28 14 40	28 06 50
	140	22 02	22 11	21 56	22 03 00	22 19	22 21	22 11	22 17 00	22 10 00
	160	13 34	13 46	13 21	13 33 40	13 32	13 31	13 18	13 27 00	13 30 20
D. Length = 1.87 inch.	20	9 50	10 00	9 57	9 55 40	9 54	9 47	9 46	9 49 00	9 52 20
	40	19 01	19 10	19 02	19 04 20	19 05	18 56	18 52	18 57 40	19 01 00
	60	26 32	26 36	26 34	26 34 00	26 31	26 27	26 22	26 26 40	26 30 20
	80	31 31	31 36	31 35	31 34 00	31 49	31 46	31 45	31 46 40	31 40 20
	100	32 51	32 57	32 52	32 53 20	33 16	33 12	33 06	33 11 20	33 02 20
	120	29 29	29 44	29 31	29 34 40	29 42	29 44	29 35	29 40 20	29 37 30
	140	21 36	21 49	21 36	21 40 20	21 51	21 51	21 53	21 51 40	21 46 00
	160	10 58	11 10	10 59	11 02 20	11 07	10 58	10 56	11 00 20	11 01 20
P. Length = 1.03 inch.	20	9 51	9 56	9 54	9 53 40	9 50	9 42	9 48	9 46 40	9 50 10
	40	18 57	19 07	18 57	19 00 20	19 02	18 49	18 53	18 54 40	18 57 30
	60	26 28	26 34	26 28	26 30 00	26 30	26 20	26 24	26 24 40	26 27 20
	80	31 31	31 40	31 30	31 33 40	31 53	31 41	31 48	31 47 20	31 40 30
	100	32 57	33 03	32 56	32 58 40	33 23	33 21	33 14	33 19 20	33 09 00
	120	29 36	29 54	29 33	29 41 00	29 46	29 49	29 46	29 47 00	29 44 00
	140	21 46	21 49	21 32	21 42 20	21 46	21 49	21 56	21 50 20	21 46 20
	160	10 55	11 00	10 48	10 54 20	10 46	10 42	10 40	10 42 40	10 48 30

The centre of the Shell in the horizontal plane passing through the Needle's centre, and its distance from that centre 16.8 inches.

Needle of which the deviation was observed.	Azimuth of the Shell's centre from North.	The Azimuth of the Shell's centre from that of the Needle being								Means of the deviations with the Shell West and with the Shell East.
		West.				East.				
		Deviations of the North end.			Means.	Deviations of the North end.			Means.	
A. Length = 6.01 inches.	20°	7° 14′W	7° 16′W	7° 20′W	7° 16′ 40″W	7° 07′E	7° 16′E	7° 13′E	7° 12′ 00″E	+ 7° 14′ 20″
	40	11 45	11 46	11 52	11 47 40	11 41	11 34	11 35	11 36 40	11 42 10
	60	10 20	10 33	10 24	10 25 40	10 06	10 03	10 06	10 05 00	10 15 20
	80	3 46	3 55	3 53	3 51 20	3 30	3 30	3 22	3 27 20	3 39 20
	100	4 30E	4 21E	4 24E	4 25 00E	4 42W	4 34W	4 39W	4 38 20W	− 4 31 40
	120	11 05	11 04	10 58	11 02 20	11 22	11 16	11 28	11 22 00	11 12 10
	140	12 07	12 07	12 04	12 06 00	12 13	12 17	12 10	12 13 20	12 09 40
	160	7 20	7 19	7 20	7 19 40	7 38	7 45	7 38	7 40 20	7 30 00
D. Length = 1.87 inch.	20	6 13W	6 17W	6 22W	6 17 20W	6 07E	6 11E	6 08E	6 08 40E	+ 6 13 00
	40	10 26	10 34	10 39	10 33 00	10 29	10 18	10 18	10 21 40	10 27 20
	60	10 17	10 26	10 24	10 22 20	9 59	9 58	9 58	9 58 20	10 10 20
	80	4 24	4 40	4 38	4 34 00	4 01	4 09	4 02	4 04 00	4 19 00
	100	4 40E	4 27E	4 19E	4 28 40E	4 54W	4 44W	4 53W	4 50 20W	− 4 39 30
	120	10 27	10 22	10 19	10 22 40	10 41	10 40	10 43	10 41 20	10 32 00
	140	10 25	10 24	10 23	10 24 00	10 34	10 38	10 38	10 36 40	10 30 20
	160	6 06	6 04	6 05	6 05 00	6 31	6 39	6 36	6 35 20	6 20 10
P. Length = 1.03 inch.	20	6 12W	6 12W	6 16W	6 13 20W	6 01E	6 12E	6 13E	6 08 40E	+ 6 11 00
	40	10 24	10 28	10 34	10 28 40	10 20	10 18	10 22	10 20 00	10 24 20
	60	10 10	10 25	10 17	10 17 20	9 55	10 04	10 05	10 01 20	10 09 20
	80	4 29	4 37	4 36	4 34 00	4 04	4 14	4 05	4 07 40	4 20 50
	100	4 37E	4 28E	4 26E	4 30 20E	5 00W	4 47W	4 50W	4 52 20W	− 4 41 20
	120	10 21	10 21	10 18	10 20 00	10 41	10 33	10 37	10 37 00	10 28 30
	140	10 16	10 21	10 25	10 20 40	10 30	10 29	10 26	10 28 20	10 24 30
	160	5 59	6 03	6 06	6 02 40	6 21	6 29	6 25	6 25 00	6 13 50

The centre of the Shell 10 inches above the horizontal plane passing through the Needle's centre, and its distance from that centre 16.8 inches.

Needle of which the deviation was observed.	Azimuth of the Shell's centre from North.	The Azimuth of the Shell's centre from that of the Needle being								Means of the deviations with the Shell West and with the Shell East.
		West.				East.				
		Deviations of the North end.			Means.	Deviations of the North end.			Means.	
A. Length = 6.01 inches.	20°	13° 00′E	12° 51′E	13° 04′E	12° 58′ 20″E	12° 32′W	12° 13′W	12° 32′W	12° 25′ 40″W	−12° 42′ 00″
	40	21 41	21 26	21 34	21 33 40	21 07	20 40	21 10	20 59 00	21 16 20
	60	28 09	28 03	27 57	28 03 00	27 32	27 04	27 35	27 23 40	27 43 20
	80	32 38	32 34	32 15	32 29 00	31 51	31 27	31 50	31 42 40	32 05 50
	100	32 54	32 54	32 43	32 50 20	32 12	31 56	32 13	32 07 00	32 28 40
	120	28 04	28 16	28 06	28 08 40	27 54	27 50	27 56	27 53 20	28 01 00
	140	20 06	20 04	20 02	20 04 00	20 04	20 07	20 09	20 06 40	20 05 20
	160	10 16	10 08	10 13	10 12 20	10 43	10 44	10 43	10 43 20	10 27 50
D. Length = 1.87 inch.	20	11 00	10 52	10 59	10 57 00	10 39	10 20	10 25	10 28 00	10 42 30
	40	21 31	21 19	21 20	21 23 20	21 04	20 34	20 55	20 51 00	21 07 10
	60	29 49	29 46	29 21	29 38 40	29 13	28 44	29 19	29 05 20	29 22 00
	80	33 16	33 18	32 54	33 09 20	32 38	32 07	32 43	32 29 20	32 49 20
	100	31 50	31 50	31 40	31 46 40	31 27	31 04	31 25	31 18 40	31 32 40
	120	26 30	26 35	26 28	26 31 00	26 20	26 20	26 32	26 24 00	26 27 30
	140	18 39	18 38	18 35	18 37 20	18 38	18 47	18 50	18 45 00	18 41 10
	160	9 36	9 21	9 19	9 25 20	9 50	10 00	9 59	9 56 20	9 40 50
P. Length = 1.03 inch.	20	11 05	10 59	11 02	11 02 00	10 24	10 11	10 12	10 15 40	10 38 50
	40	21 31	21 26	21 20	21 25 40	21 01	20 35	20 53	20 49 40	21 07 40
	60	29 41	29 50	29 31	29 40 40	29 17	28 36	29 10	29 01 00	29 20 50
	80	33 21	33 15	33 03	33 13 00	32 31	32 08	32 33	32 24 00	32 48 30
	100	31 40	31 39	31 36	31 38 20	31 15	31 01	31 18	31 11 20	31 24 50
	120	26 23	26 26	26 23	26 24 00	26 09	26 13	26 14	26 12 00	26 18 00
	140	18 31	18 30	18 34	18 31 40	18 38	18 43	18 41	18 40 40	18 36 10
	160	9 24	9 19	9 22	9 21 40	9 56	9 55	9 54	9 55 00	9 38 20

I did not consider it necessary to make corresponding observations to these at an increased distance between the centres of the shell and needle at every 20° of azimuth; I however made the following observations in those positions where the differences in the deviations of the needles are the greatest, when that distance was increased to twenty-four inches. The results show that at this distance the differences, though small, are still appreciable.

Needle of which the deviation was observed.	Azimuth of the Shell's centre from North.	The centre of the Shell 24 inches from that of the Needle, and									
		14.29 inches below the horizontal plane passing through the centre of the Needle.			14.29 inches above the horizontal plane passing through the centre of the Needle.			In the horizontal plane passing through the centre of the Needle.			
		Azimuth West.	Azimuth East.		Azimuth West.	Azimuth East.		Azimuth of Shell's centre from North.	Azimuth West.	Azimuth East.	
		Deviation.	Deviation.	Mean Deviation.	Deviation.	Deviation.	Mean Deviation.		Deviation.	Deviation.	Mean Deviation.
A.	20°	10° 45′W	10° 50′E	+10° 47½′	2° 47′E	2° 39′W	− 2° 43′				
	60	8 10	8 13	8 11½	8 22	8 04	8 13	40°	3° 48′W	3° 55′E	+3° 51½′
	120	2 55	2 42	2 48½	11 07	11 02	11 04½	140	3 57E	4 00W	−3 58½
D.	20	10 29	10 52	10 40½	2 34	2 22	2 28				
	60	8 10	8 18	8 14	8 29	7 57	8 13	40	3 33W	3 57E	+3 45
	120	2 40	2 25	2 32½	10 59	10 46	10 52½	140	3 44E	3 40W	−3 42
P.	20	10 10	11 09	10 39½	2 38	2 15	2 26½				
	60	7 52	8 35	8 13½	8 49	7 41	8 15	40	3 09W	4 18E	+3 43½
	120	2 38	2 27	2 32½	11 18	10 27	10 52½	140	3 04E	3 21W	−3 42½

The differences in the deviations of the three needles in the foregoing tables may perhaps partly be attributed to the difference of their masses; and this probably produced some slight effect, especially at the nearer distance. This effect, arising from the shell becoming magnetic by the influence of the needle itself, would be in all cases to make the nearer end of the needle deviate towards the shell; and consequently in the position where the difference in the deviations of the long and short needles was observed to be greatest, it would be contrary to that observed, and must therefore have diminished the difference according to the extent to which the cause operated. These observations therefore show beyond doubt, that the length of a needle has a very sensible influence on the extent of its deviations. Although I did not consider that the difference in the masses of the needles had much effect in diminishing the difference of their deviations in some cases, or in increasing it in others, yet in order to decide what part of the difference was due to mass, and what to length, it was my intention, could I have found leisure, to have made observations corresponding to the foregoing with the needles A and P, and two others six inches in length, one extremely light and the other much heavier than A.

In order to compare the theoretical results which we have obtained, that is the equations (3) and (6), with the observed deviations of the three needles, I take a mean of the deviations with the shell below the horizontal plane of the needle, and with it above, when the azimuth of its centre from south in the second case was the same as its azimuth from north in the first, as the values of φ corresponding to the different azimuths with the shell's centre below the horizontal plane of the needle: and likewise with the shell's centre in the horizontal plane of the needle, I take a mean of the deviations in the corresponding azimuths from north and south as the values of φ in this case. From the values of h, r, η*, θ are derived those of γ and ω, and thence, from the values of φ, may be computed the corresponding values of ψ or the deviations of a freely suspended needle; and the value of the constant $\frac{2mR^3}{fe}$ will be determined from the equation,

$$\operatorname{Tan}\psi = \frac{3\sin 2\gamma}{\frac{2mR^3}{fe} + 3\cos 2\gamma + 1};$$

or we have

$$\frac{2mR^3}{fe} = \frac{6r}{R^3}(r\cos\theta + h\cot\eta) \cdot \frac{\sin(\theta - \varphi)}{\sin\varphi} + 2,$$

from the equation (6), without the previous computation of γ, ω, ψ. The values of γ and ω corresponding to the different adjustments of the shell, the values of ψ and of the constant $\frac{2mR^3}{fe}$, computed from the means of the observed values of φ, with the different needles, are contained in the following Table.

The vertical distance of the centre of the Shell from that of the needle or $h = 10$ inches, $r = 13.5$ inches, and $R = 16.8$ inches.

										Mean values of $\frac{2mR^3}{fe}$
	$\theta =$	20° 00′ 00″	40° 00′ 00″	60° 00′ 00″	80° 00′ 00″	100° 00′ 00″	120° 00′ 00″	140° 00′ 00″	160° 00′ 00″	
	$\gamma =$	35 09 21	39 39 30	45 50 00	52 37 23	59 13 45	65 02 40	69 35 11	72 28 41	
	$\omega =$	28 30 34	54 01 48	75 57 51	95 13 54	112 55 33	129 51 52	146 33 20	163 14 58	
Deviations with	A =	10 33 50	20 14 35	28 01 35	32 32 05	32 12 45	27 55 05	21 43 10	13 06 10	
	D =	9 46 35	18 51 05	26 28 55	31 36 30	32 55 50	29 29 45	21 26 35	10 51 55	
	P =	9 44 15	18 46 50	26 22 40	31 32 40	32 58 45	29 32 25	21 27 00	10 43 40	
Values of ψ with	A =	11 09 37	11 45 42	12 06 19	11 43 59	10 35 54	9 28 04	8 57 59	9 05 19	
	D =	9 58 36	10 39 07	11 15 00	11 21 01	10 49 44	9 54 08	8 53 14	8 06 22	
	P =	9 55 13	10 35 49	11 11 37	11 19 27	10 50 40	9 54 52	8 53 21	8 02 27	
Values of $\frac{2mR^3}{fe}$ with	A =	12.307	12.602	13.069	13.725	14.525	14.694	13.701	12.225	13.356
	D =	14.047	14.118	14.163	14.208	14.218	14.079	13.813	13.551	14.025
	P =	14,140	14.201	14.241	14.242	14.198	14.063	13.810	13.650	14.068

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* I take $\eta = 20°$, the most recent observation giving the dip at this place 70° 00′.

The centre of the Shell in the same horizontal plane as that of the Needle or $h = 0$, and $R = 16.68$ inches.

	$\theta =$	$20^\circ\ 00'\ 00''$	$40^\circ\ 00'\ 00''$	$60^\circ\ 00'\ 00''$	$80^\circ\ 00'\ 00''$	Mean values of $\frac{2mR^3}{fe}$
	$\gamma =$	71 15 10	74 48 40	80 09 12	86 35 42	
	$\omega =$	21 10 22	41 45 48	61 31 08	80 35 31	
Deviations with	A =	7 22 10	11 55 55	10 43 45	4 05 30	
	D =	6 16 35	10 28 50	10 21 10	4 29 15	
	P =	6 12 25	10 24 25	10 18 55	4 31 05	
Values of ψ with	A =	10 07 10	7 56 38	4 39 57	1 26 12	
	D =	8 05 06	6 43 38	4 28 55	1 34 40	
	P =	7 57 51	6 40 04	4 27 49	1 35 19	
Values of $\frac{2mR^3}{fe}$ with	A =	11.612	12.460	14.212	16.163	13.612
	D =	14.235	14.450	14.722	14.893	14.575
	P =	14.433	14.565	14.775	14.804	14.644

From these values of $\frac{2mR^3}{fe}$, with the different needles, it is evident that if the mean value with the needle A were substituted in the equation (6), the computed values of φ would not differ greatly from the observed values; but that with the needles D and P, the approximation would be so close, that the differences would clearly be within the limits of errors of observation. There can therefore be no doubt that the law which I proposed will give an extremely close approximation to experimental results, when the length of the needle does not bear too sensible a proportion to its distance from the centre of the attracting mass of iron; and that even if this ratio is not less than 1 to 3, the theoretical and experimental results will not differ greatly from each other.

I will now, for the purpose of comparison, deduce from these experiments the values of the constant depending upon the law, that "the tangent of the deviation is proportional to the rectangle of the cosine of the longitude, and the sine of the double latitude." If λ is the latitude of the needle's centre from a great circle of the shell perpendicular to the dip; and l its longitude measured from the intersection of this circle with the horizontal plane through the shell's centre; δ the dip of the needle; and M a constant,—then the law is

$$\operatorname{Tan} \varphi = \frac{\sin 2\lambda \cos l}{M \cos \delta}:$$

in which equation λ, l, δ are the complements of γ, ω, η in the foregoing equations.

The values of M determined by means of this equation from the mean of the observed values of φ in the different azimuths, with the three needles, are contained in the Tables below.

The vertical distance of the centre of the Shell from that of the Needle or $h = 10$ inches, $r = 13.5$ inches, and $R = 16.8$ inches.

	$\theta=$	20°	40°	60°	80°	100°	120°	140°	160°
Values of M with	A=	21.137	18.916	15.980	13.211	11.273	9.721	7.934	6.236
	D=	22.877	20.431	17.074	13.694	10.966	9.105	8.047	7.566
	P=	22.970	20.514	17.152	13.728	10.945	9.089	8.044	7.662

The centre of the Shell in the same horizontal plane as that of the Needle or $h = 0$, and $R = 16.8$ inches.

	$\theta=$	20°	40°	60°	80°
Values of M with	A=	14.910	13.981	13.712	14.344
	D=	17.533	15.971	14.222	13.074
	P=	17.731	16.086	14.275	12.986

Here it appears that the values of M derived from these experiments, instead of being constant or nearly so, as they ought to be, vary from 6 to 21 with the long needle, and with the short ones from 8 to 23. The results are most consistent when the centres of the shell and needle are in the same horizontal plane; and within certain limits of the values of l, l being likewise constant throughout a set of observations, results that should not differ so very widely as the foregoing might be obtained: it is somewhat singular that the truth of the law should have been considered to be established experimentally from observations made in precisely these relative positions of the shell and needle*. When the centre of the shell and needle are in the same horizontal plane, the values of M deduced from the observations with the long needle A, agree much more nearly with each other than those deduced from the observations with either of the shorter needles D or P; and when they are not in the same plane, the disagreement in the values of M is nearly the same with each of the needles: we may therefore infer, that the proximity of the needle to the shell is not the cause of this disagreement, and that the same would be found to be the case if the values of M were deduced from deviations of the needle observed at greater distances from the shell's centre.

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* Mr. BARLOW's Magnetic Attractions, 2nd ed. pp. 34, 37, 38.

We must therefore conclude, that although the law that "the tangent of the deviation is proportional to the rectangle of the cosine of the longitude and the sine of the double latitude" has been derived from experiment, and considered as giving close approximations to experimental results[*]; yet as it is quite clear that no law giving such inconsistent results as appear here[†] can be considered as even approximately true, it must be wholly rejected.

On the principle which I have assumed, I have already given the general explanation of the phænomena observed with needles having their magnetism unequally distributed; I shall now describe the experiments which I made with such needles, with the view of comparing them with the equations that I should derive from this principle, according to the distribution of magnetism which I found to take place under different circumstances of disturbance, which equations, (10) and (11), have been already given. In the beginning of this paper I have described the needles made use of in these experiments, and the manner of magnetizing them. These needles are distinguished by the letters A, B, C; A being that made use of in the experiments already described, and B and C of precisely the same form and weight as A.

In order to determine nearly the situations of the magnetic centre, and of the points towards which the forces are directed near the ends, in these needles, which points may be considered as their poles nearly, I successively placed them on a wooden rectangular scale, so that their axes coincided with a line drawn through the middle parallel to its sides. This scale, which is graduated

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[*] Mr. Barlow's Magnetic Attractions, 2nd ed. pp. 38, 39.

[†] If we take a mean of the deviations with the undeteriorated needle in the observations given in the Transactions of last year, p. 285, in the corresponding azimuths with the shell above and below the table, the values of M will be these:

$\theta =$	20°	40°	60°	80°	100°	120°	140°	160°
$M =$		17.65	14.51	12.38	10.81	10.22	8.51	6.61

The observation corresponding to $\theta = 20°$, which would have given by much the greatest value of M, does not appear to have been made. These values are not quite so discordant as those resulting from my observations, but are equally conclusive against the law from which they are derived. The means of the deviations when the shell was in the same horizontal plane as the needle, give the following values of M.

$\theta =$	20°	40°	60°	80°
$M =$	14.40	13.33	12.91	12.83,

which are rather more discordant than the corresponding values from my observations.

across to tenths of an inch, and can be made to revolve about a vertical axis, being placed horizontally so that the axis of the needle was at right angles to the meridian, a rectangular stand, carrying the small needle P level with the other, was passed along and in contact with the northern side of the scale, until the axis of P pointed accurately in the meridian. This occurred in two positions; in the one, the force of the needle under trial concurring with the terrestrial directive force; and in the other, being in direct opposition to it. The distances, from the centre of the needle, of the points to which the centre of P was in these cases opposite were noted; and the same was done when P was passed to the south of the rectangular scale: the mean of the respective distances gave the distances, from the centre, of the points towards which the forces are directed, or nearly those of the poles. The position of the magnetic centre was determined similarly, by placing the rectangular scale, carrying the needle under trial, so that the axis of this needle was in the magnetic meridian with the marked end towards north, and passing P along the eastern side until its axis was in the meridian with its marked end south, and then along the western side. In all cases the distance between the axis of the needle and the centre of P was 1.5 inch.

The positions of these points in each needle, so ascertained after it had been carefully magnetized by double touch, as I have before described, and the times of the needle's vibration, were as follow.

Needle.	Distances from the Needle's centre.			Time of making 10 vibrations.
	Of the south or marked pole.	Of the magnetic centre or zero.	Of the north or unmarked pole.	
	inches.	inches.	inches.	sec.
A.	2.43	0.00	2.42	34.1
B.	2.39	0.04 U.	2.42	32.75
C.	2.35	0.07 U.	2.47	32.7

After making these observations, the magnetism of the needle A was undisturbed; that of B was disturbed by drawing the unmarked end of a 12-inch bar magnet from the centre to the unmarked end of the needle twice, a thin board being interposed; that is, the needle B had its "southern branch deteriorated;" and the needle C had its "northern branch deteriorated," by similarly drawing the marked end of the magnet twice from the centre to the marked end. The situations of the poles and magnetic centre were ascertained, as before, immediately after making the first set of observations, shortly to be described, on the deviations of these needles, when the shell was above the table on which they were placed; likewise previously to commencing the second set, when the shell was below the table; and also after the observations with the shell's centre in the plane of the table were concluded. The time in which each needle made ten vibrations was likewise observed. The following are the results.

Needle.	Distances from the Needle's centre.			Time of making 10 vibrations.	Date.	Hour.
	Of the south or marked pole.	Of the magnetic centre or zero.	Of the north or unmarked pole.			
	inches.	inches.	inches.	sec.		
C.	1.41	1.06 U.	2.80	51.8	28 Nov.	6 P.M.
	1.43	1.06	2.80	50.1	3 Dec.	1 P.M.
	1.49	1.04	2.80	50.65	5 Dec.	3 P.M.
Means	1.44	1.05	2.80	50.85		
A.	2.40	0.05 U.	2.44	35.1	28 Nov.	6 P.M.
	2.41	0.03	2.43	34.35	3 Dec.	1 P.M.
	2.42	0.025	2.43	35.3	5 Dec.	8 P.M.
Means	2.41	0.035	2.433	34.92		
B.	2.74	0.71 M.	2.23	52.85	28 Nov.	6 P.M.
	2.73	0.70	2.26	51.4	3 Dec.	1 P.M.
	2.72	0.62	2.33	51.8	5 Dec.	11 A.M.
Means	2.73	0.677	2.273	52.02		

In these the letter M placed after the distance of zero from the needle's centre, indicates that the distance was measured towards the marked end of the needle; and the letter U, that it was measured towards the unmarked end. The distances of the poles and magnetic centres, as determined on different days, show that only a small change took place in the situations of these points in the needles during the time of making the observations on their deviations*.

To determine the intensity of the free magnetism on each side of the centres

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* With the view of ascertaining what degree of permanency this disturbed state of the magnetism in a needle may have, I made observations similar to these, at considerable intervals of time, with the two 9-inch bar magnets which I have already mentioned. The bars had been carefully and strongly magnetized by double touch on the 5th of November, when the positions of the poles and magnetic centres appeared to be as in the first observations to each magnet, on that day, in the following Table. The magnetism of the bars was then disturbed by passing the unmarked end of a 12-inch magnet from the centre of I, to its unmarked end, and the marked end of the same magnet from the centre to the

of force, and likewise the position of the points in these needles where the intensities of contrary names were equal, I adopted the method of Coulomb. For this purpose a small needle 0.72 inch in length, 0.15 inch in breadth, of a form somewhat similar to A, B, or C, and weighing 1.25 grain, which for distinction I name I, was suspended by a single fibre of the silk-worm within a glass cylinder attached to a high rectangular support of wood, in which is

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marked end of II: after this, the second observations on the 5th of November were made. In the interval between these observations and the subsequent ones, care was taken that these bars were quite out of the reach of accidental disturbance in their magnetism.

Magnet.	Distances from the Bar's centre.			Date of observation.
	Of the south or marked pole.	Of the magnetic centre or zero.	Of the north or unmarked pole.	
	inches.	inches.	inches.	
I. Magnetism undisturbed	3.75	0.48 U.	3.80	5 Nov. 1827
I. Magnetism disturbed at unmarked end......	4.06	1.49 M.	2.73	5 Nov.
	4.10	1.31	2.84	12 Dec.
	4.12	1.32	2.86	23 April, 1828
	4.12	1.32	2.86	14 May
II. Magnetism undisturbed	3.73	0.01	3.76	5 Nov. 1827
II. Magnetism disturbed at marked end......	2.64	1.52	4.05	5 Nov.
	2.67	1.47	4.07	12 Dec.
	2.75	1.45	4.05	23 April, 1828
	2.82	1.37	4.05	14 May

It appears that some, though an inconsiderable change took place in the distribution of the magnetism of the bar I, from the 5th of November to the 12th of December, but that it has remained almost precisely in the same state from the 12th of December to the 14th of May; and it will probably continue in this state so long as it meets with no extraneous disturbance. In the latter interval the observations indicate some change in the magnetism at the marked end of II; but even here it is not to a great extent. In neither of these bars are there any indications of other poles than those whose situations I observed. I am not aware of any experiments having been made to ascertain whether in magnetized steel bars the action of the magnetic particles upon each other has a tendency to restore a symmetrical arrangement of their magnetism when such arrangement has been disturbed; but the results I have obtained show that if such tendency exist for a short time after this disturbance, it soon, at least in some cases, either ceases to exist, or is so feeble as not to overcome, or to overcome very slowly, the coercive force of the steel. In the bars which I employed, this coercive force could not be great, if it depend upon hardness, since they are softer than requisite for working with a file. We ought, however, to be in possession of more extended observations before we draw any general conclusions from such facts as I have stated.

an opening from top to bottom parallel to its sides, of the same size as the stems of two clamping screws fixed to the rectangular scale, before mentioned, to which the needle under trial was attached. This rectangular support was rendered vertical by means of foot-screws, and a level attached to it; so that when the scale was applied to it, the axis of the needle to be examined was likewise vertical; and the instrument was adjusted so that the axis of this needle and the centre of the needle I, were in the magnetic meridian. In the same horizontal plane as the centre of I, was an index, which marked on the scale the point of the needle on it horizontally opposite to that centre. As the stems of the clamping screws fitted the opening in the support, the scale and the axis of the large needle could be moved vertically, so that any required point of this needle should be opposite to the centre of I: when the scale had been so adjusted, it was clamped to the support. The needle I was then vibrated 45° from 0, and the time of making 100 vibrations being carefully noted, the force accelerating I was known. The terrestrial force accelerating I having been determined previously to applying the larger needle, the intensity of the force by which this needle accelerated I, and consequently nearly the inten-

		From the Needle's centre of figure towards its marked end.										
Needle C, having had its magnetism disturbed in the marked or northern branch.	Distance of the point opposite to the needle I	2.99 in.	2.80 in.	2.60 in.	2.40 in.	2.20 in.	2.00 in.	1.80 in.	1.60 in.	1.40 in.	1.20 in.	1.00 in.
	Time in which the needle I made 100 vib^{ns}.	70.4^s	67.8^s	65.5^s	63.8^s	61.95^s	60.3^s	59.7^s	58.9^s	58.1^s	57.9^s	57.7^s
	Intensity of force accelerating I	+2.9933	+3.2273	+3.4579	+3.6447	+3.8656	+4.0800	+4.1624	+4.2763	+4.3948	+4.4253	+4.4560
	Intensity of magnetism in C.....................	+1.9933	+2.2273	+2.4579	+2.6447	+2.8656	+3.0800	+3.1624	+3.2763	+3.3948	+3.4253	+3.4560
Needle A, having its magnetism similarly distributed in the two branches.	Distance of the point opposite to the needle I	2.99 in.	2.80 in.	2.60 in.	2.42 in.	2.20 in.	2.00 in.	1.80 in.				
	Time in which the needle I made 100 vib^{ns}.	43.25^s	40.8^s	39.8^s	39.25^s	39.25^s	39.45^s	40.1^s				
	Intensity of force accelerating I	+7.8785	+8.8535	+9.3040	+9.5666	+9.5666	+9.4699	+9.1653				
	Intensity of magnetism in A.....................	+6.8785	+7.8535	+8.3040	+8.5666	+8.5666	+8.4699	+8.1653				
Needle B, having had its magnetism disturbed in the unmarked or southern branch.	Distance of the point opposite to the needle I	2.99 in.	2.80 in.	2.72 in.	2.60 in.	2.50 in.	2.40 in.				0.70 in.	0.625 in.
	Time in which the needle I made 100 vib^{ns}.	55.3^s	53.8^s	53.4^s	53.2^s	53.2^s	53.5^s				112.2^s	121.4^s
	Intensity of force accelerating I..............	+4.8590	+5.1338	+5.2110	+5.2503	+5.2503	+5.1916				+1.1804	+1.0083
	Intensity of magnetism in B.....................	+3.8590	+4.1338	+4.2110	+4.2503	+4.2503	+4.1916				+0.1804	+0.0083

sity of the magnetism in its different points, became known. The needle I was rendered extremely hard, and was strongly magnetized, in order that its magnetism should not be disturbed by that of the large needle. The distance between the centre of I and the axis of the large needle was in all cases 1.63 inch, so that in some positions the vibrations of I, with its own inertia alone to overcome, would have been too rapid for observation; and to obviate this, it had attached to it, in all the observations, a thin disc of mica. The needle I was vibrated to the north of the large needle, whose marked or south pole was always downwards. The time of vibration of I, corresponding to each point of the large needle was determined by two trials, and as these never differed by more than a fifth of a second, the time may be considered to have been determined at least within this limit. The following Table shows the times of vibration of I, when not affected by the needles A, B, C, and when points at different distances from the centres of these needles were horizontally opposite to the centre of I; also the intensity of the magnetism in these points, deduced from those times of vibration; + indicating south polarity, or that predominating in the marked end of the needle, and — indicating north polarity.

			From the Needle's centre of figure towards its unmarked end.										Vibrating by the terrestrial force alone.
0.80 in.	0.60 in.	0.00 in.	1.035 in.	1.10 in.	1.12 in.		2.00 in.	2.20 in.	2.40 in.	2.60 in.	2.80 in.	2.99 in.	
57.7^{s}	58.75^{s}		107.7^{s}	120.4^{s}	126.0^{s}		73.1^{s}	65.9^{s}	61.8^{s}	59.7^{s}	59.8^{s}	61.6^{s}	121.8^{s}
+4.4560	+4.2981		+1.2790	+1.0234	+0.9345		−2.7763	−3.4160	−3.8843	−4.1624	−4.1485	−3.9096	1.0000
+3.4560	+3.2981		+0.2790	+0.0234	−0.0655		−3.7763	−4.4160	−4.8843	−5.1624	−5.1485	−4.9096	
		0.00 in.	0.025 in.	0.05 in.	0.075 in.	1.80 in.	2.00 in.	2.20 in.	2.43 in.	2.60 in.	2.80 in.	2.99 in.	
		108.6^{s}	115.6^{s}	120.1^{s}	129.2^{s}	47.3^{s}	46.2^{s}	45.9^{s}	45.6^{s}	45.8^{s}	48.1^{s}	50.2^{s}	121.4^{s}
		+1.2496	+1.1029	+1.0218	+0.8829	−6.5874	−6.9048	−6.9954	−7.0877	−7.0260	−6.3701	−5.8483	1.0000
		+0.2496	+0.1029	+0.0218	−0.1171	−7.5874	−7.9048	−7.9954	−8.0877	−8.0260	−7.3701	−6.8483	
0.615 in.	0.60 in.				2.00 in.	2.10 in.	2.20 in.	2.33 in.	2.40 in.	2.60 in.	2.80 in.	2.99 in.	
122.8^{s}	126.8^{s}				84.2^{s}	83.55^{s}	83.25^{s}	83.50^{s}	83.85^{s}	85.5^{s}	89.0^{s}	94.1^{s}	121.9^{s}
+0.9854	+0.9242				−2.0960	−2.1287	−2.1441	−2.1313	−2.1135	−2.0327	−1.8760	−1.6781	1.0000
−0.0146	−0.0758				−3.0960	−3.1287	−3.1441	−3.1313	−3.1135	−3.0327	−2.8760	−2.6781	

From these results it appears, that the points previously determined as the centres of force are not, in the needles C and B, precisely those in which the intensities are the greatest, but that the situations of the magnetic centres determined by the two methods very nearly agree; the distance of this centre from that of figure being, for the needle C, 1.105 inch towards the unmarked end, and for the needle B, 0.6214 towards its marked end. As might have been anticipated, the intensities of the poles were changed, as well as their situations, by the disturbance of the magnetism in either branch; and this not only in the branch to which the disturbing magnet had been applied, but also in the other. In the branch to which the magnet had been applied, the intensity was reduced in about the ratio of 83 to 31 in the needle B, and of 83 to 35 in the needle C; and in the other branch, in the ratio of 83 to 43 in B, and of 83 to 52 in C. In both cases the least intense pole was much more diffused than the other; the intensity in the branch to which the magnet had been applied changing but little over a space of nearly two inches. It appears likewise, that at the points previously determined as the centres of force in the two branches of each needle, the intensity multiplied by the distance from the magnetic centre is nearly the same on each side of that centre; these products on the contrary sides being 8.9 and 9.2 with the needle B, and with C, 8.7 and 8.8.

The observations on the deviations of the three needles, A, B, C, with their magnetism thus distributed, produced by the 18-inch shell, are contained in the following Table: they were made in precisely the same manner as those already described, with the needles A, D, P; the deviation of one needle having been observed for any azimuth, it was removed from the pivot and replaced by another, and this again by the third without moving the pivot after it had been adjusted to the required position: the vertical and horizontal distances of the shell were likewise the same as in the former case.

Needle of which the deviation was observed.	Azimuth of the Shell's centre from North.	The centre of the Shell 16.8 inches from the Needle's centre, and								
		10 inches below the horizontal plane passing through that centre.			In the horizontal plane passing through that centre.			10 inches above the horizontal plane passing through that centre.		
		Azimuth of the Shell's centre.		Means of the deviations with the Shell West and with the Shell East.	Azimuth of the Shell's centre.		Means of the deviations with the Shell West and with the Shell East.	Azimuth of the Shell's centre.		Means of the deviations with the Shell West and with the Shell East.
		• West.	East.		West.	East.		West.	East.	
		Deviations.	Deviations.		Deviations.	Deviations.		Deviations.	Deviations.	
C, having had its magnetism disturbed in the marked or northern branch.	20°	9° 13′W	8° 57′E	+ 9° 05′ 00″	5° 38′W	5° 20′E	+ 5° 29′ 00″	7° 06′E	6° 42′W	− 6° 54′ 00″
	40	17 07	17 02	17 04 30	9 03	8 54	8 58 30	14 33	13 57	14 15 00
	60	23 57	23 37	23 47 00	9 14	8 33	8 53 30	24 26	24 05	24 15 30
	80	27 48	28 04	27 56 00	4 58	4 27	4 42 30	35 36	35 20	35 28 00
	100	29 34	29 50	29 42 00	2 41E	3 05W	− 2 53 00	38 28	38 33	38 30 30
	120	29 30	29 26	29 28 00	12 22	12 47	12 34 30	32 56	33 07	33 01 30
	140	27 27	27 08	27 17 30	14 45	15 15	15 00 00	23 17	23 51	23 34 00
	160	21 21	21 19	21 20 00	8 54	9 22	9 08 00	11 46	12 23	12 04 30
A, having its magnetism similarly distributed in the two branches.	20	10 50	10 36	10 43 00	7 18W	7 05E	+ 7 11 30	12 53	12 22	12 37 30
	40	20 30	20 18	20 24 00	11 38	11 36	11 37 00	21 18	20 46	21 02 00
	60	28 24	28 09	28 16 30	10 30	10 04	10 17 00	27 39	27 30	27 34 30
	80	32 22	32 47	32 34 30	3 43	3 28	3 35 30	32 12	31 57	32 04 30
	100	31 54	32 32	32 13 00	4 28E	4 44W	− 4 26 00	32 28	32 23	32 30 30
	120	27 54	28 10	28 02 00	11 20	11 35	11 27 30	28 09	28 02	28 05 30
	140	21 48	21 50	21 49 00	12 20	12 38	12 29 00	20 10	20 31	20 20 30
	160	13 18	13 10	13 14 00	7 30	7 48	7 39 00	10 18	10 41	10 29 30
B, having had its magnetism disturbed in the unmarked or southern branch.	20	11 40	11 32	11 36 00	7 53W	7 50E	+ 7 51 30	17 58	17 12	17 35 00
	40	22 06	22 03	22 04 30	12 30	12 35	12 32 30	24 53	24 24	24 38 30
	60	30 50	30 37	30 43 30	10 33	10 12	10 22 30	28 37	28 25	28 31 00
	80	34 52	35 32	35 12 00	2 42	2 31	2 36 30	30 30	30 12	30 21 00
	100	33 06	33 56	33 31 00	4 58E	5 04W	− 5 01 00	29 45	29 23	29 34 00
	120	26 24	26 52	26 38 00	10 20	10 23	10 21 30	25 24	25 15	25 19 30
	140	19 00	19 08	19 04 00	11 00	11 10	11 05 00	18 26	18 34	18 30 00
	160	10 40	10 36	10 38 00	6 46	6 54	6 50 00	9 22	9 41	9 31 30

The deviations of A in this Table, are the values of φ in the equations (10) and (11): the deviations of C and B are the corresponding values of $\varphi_{,}$, the value of k being plus in the first case, and minus in the second. To compare these equations with the observations, it is necessary that the value of p should be known as well as that of k. This may be determined from the equations by means of the observed values of $\varphi_{,}$ and φ in the above table; but the computations from the equation (10) would be so laborious, that I must acknowledge I have not, for this reason, entered upon them. I have however computed the values of p from the equation (12), when the centre of the shell was in the same horizontal plane as that of the needle, although these computations are sufficiently tedious: and from the mean of the values thus determined, I have likewise computed the values of φ, or the deviations of A, both from the observations with C and from those with B, by means of the equation (11), taking $k = 1.105$ in the one case, and $k = -0.6214$ in the other, as determined from the times of vibration of the Needle I.

The following Table contains the results thus obtained.

The centre of the Shell in the same horizontal plane as that of the Needle.										
Azimuth of the Shell's centre from north, or values of θ.	The deviations of A deduced from those of C.					The deviations of A deduced from those of B.				
	Observed values of $\varphi_{,}$	Observed values of φ.	Values of p, computed from the equation (12), making $k = 1.105$.	Values of φ, computed from the equation (11), making $p = 1.0782$.	Difference between the observed and computed values of φ.	Observed values of $\varphi_{,}$	Observed values of φ.	Values of p, computed from the equation (12), making $k = -0.6214$.	Values of φ, computed from the equation (11), making $p = 1.0551$.	Difference between the observed and computed values of φ.
20°	5° 29′	7° 11½′	1.1256	6° 57′	−14½′	7° 51½′	7° 11½′	1.0289	7° 20′	+08½′
40	8 58½	11 37	1.1180	11 15	−22	12 32½	11 37	1.0314	11 51	+14
60	8 53½	10 17	1.0654	10 25	+08	10 22½	10 17	1.0433	10 24	+07
80	4 42½	3 35½	1.0617	3 39	+03½	2 36½	3 35½	1.1617	3 14	−21½
100	2 53	4 36	1.2045	4 03	−33	5 01	4 36	1.0781	4 29	−07
120	12 34½	11 27½	1.0116	12 13	+45½	10 21½	11 27½	1.0489	11 30	+02½
140	15 00	12 29	1.0095	13 12	+43	11 05	12 29	1.0306	12 44	+15
160	9 08	7 39	1.0294	7 55	+16	6 50	7 39	1.0176	7 52	+13
	Mean value of p		1.0782			Mean value of p		1.0551		

The deviations of A computed from those of B, agree with the observed deviations of A quite as nearly as we can expect; but those computed from the deviations of C do not approximate so closely to the observations. The difference in the values of φ and $\varphi_{,}$ principally arises from the value of k, and any error in determining this will have a corresponding effect in the values of φ determined from those of $\varphi_{,}$. From the results here, the value of k for the needle B appears to have been determined with considerable accuracy; and I am not aware of any circumstances in the observations that should have rendered it less so for the needle C. It is however to be observed, that the magnetic centre will not be precisely the same for all distances at which the needle may act, and that the position of this point will vary the more, the greater is its distance from the centre of figure of the needle. If for the needle C we increase the value of k by one-tenth, that is making it 1.2155 instead of 1.105, all but one of the computed values of ϕ will agree more closely with the observed values, and this one will still be extremely near to the corresponding observed value. This will be seen by the following Table computed as the preceding, excepting that, in taking the mean of the values of p, I omit that corresponding to θ = 100°, and which I have done because a very small error of adjustment, whether arising from the compass not being placed exactly in the required position, or from the centre of the shell not occupying accurately the centre of the circle to which the compass was adjusted, would here have a most sensible effect upon the deviations; and such appears to have been the case, from the difference in the observed values of ϕ, when θ was 80°, and when θ was 100°.

The centre of the Shell in the same horizontal plane as that of the Needle.					
Azimuth of the Shell's centre from north, or values of θ.	The deviations of A deduced from those of C.				
	Observed values of ϕ.	Observed values of ϕ.	Values of p, computed from the equation (12), making $k = 1.2155$.	Values of ϕ, computed from the equation (11), making $p = 1.069$.	Difference between the observed and computed values of ϕ.
20°	5° 29′	7° 11½′	1.1037	7° 01′	−10½′
40	8 58½	11 37	1.0996	11 20	−17
60	8 53½	10 17	1.0570	10 24	+07
80	4 42½	3 35½	1.1031	3 28	−07½
100	2 53	4 36	(1.1807)	4 05	−32
120	12 34½	11 27½	1.0224	11 59	+32
140	15 00	12 29	1.0354	12 49	+20
160	9 08	7 39	1.0617	7 41	+02
		Mean value of p	1.0690		

Considering that the equation (6), from which (11) is derived, does not afford a close approximation at this distance of the shell when the length of the needle is six inches, as appears from the observations with the needles A, D, P; and that in deducing this equation, the approximation was limited to the first power of $\frac{k}{R}$, I scarcely anticipated so close an agreement between the observed deviations of the undeteriorated needle A, and the deviations of such a needle computed from the observed deviations of the deteriorated needles B and C: this agreement has therefore fully confirmed the views which I originally took of this subject, as stated in a note to my paper in the Transactions of last year. There can be no doubt that the equation (11) affords the proper correction by which to obtain the values of φ from those of $\varphi_{,}$, when the centre of the shell is in the same horizontal plane as that of the needle; and the equation (10) will give the same correction when its centre is not in that plane. I have given the observations requisite for comparison; but this comparison I must leave to others who may be interested in the inquiry, and have more leisure for these tedious computations than the duties of my situation have allowed me.

Instead then of these "secondary deflections," as they have been termed, due to the deterioration of the needles, being inconsistent with the hypothesis "which attributes the deflection of a magnetized needle to the general central attraction of the iron on an imaginary needle passing through the pivot (centre) in the line of the dip," as is assumed in the paper giving an account of experiments with deteriorated needles, I have shown I think clearly, not only that they are consistent with it, but that this hypothesis affords the proper corrections to observations with such imperfect instruments; and therefore additional weight is given to the arguments which might have been previously adduced in support of this hypothesis. Should there be any still disposed to think that the hypothesis of induced magnetism will give closer approximations to the observed deviations than I have derived from that of a central action of the iron, the determinations which I have given of the distribution of the magnetism in these needles, will enable them to compute the deviations on that hypothesis, and to exhibit the resulting approximations.

I have, however, no intention of controverting the hypothesis of induced magnetism. That hypothesis undoubtedly affords satisfactory explanations of many magnetical phænomena; but there is one experiment, and that a very decisive one, which appears quite inconsistent with it; and until that experiment can be clearly explained on the hypothesis, that iron acts by induced magnetism alone, I think some reservation is necessary in our assent to that hypothesis. According to it, the lower part of a bar of steel or iron is a south pole, and the upper a north pole; and when the ends of the bar are reversed, the poles are immediately so likewise. We might admit such change of the poles in the case of soft steel or iron, but by no means in that of hard steel. The following experiment of Mr. Barlow's requires the same admission in both cases: "I procured a steel bar three feet long, an inch broad, and half an inch thick, and had it rendered, according to the expression of the workmen, "as hard as fire and water could make it;" and I must say that I was not at all surprised to find that it produced precisely the same effect as the softest iron, changing its poles with its position (to adopt the language of our author, Biot,) with equal facility*;" that is, I conceive, the deviations of a needle corresponding to such change. As the rapid change in the poles, which is here necessary to suppose, on the hypothesis of induction from the earth, is quite at variance with the phænomena observed on the approach of a magnet to a bar of hard steel, and its subsequent removal, it is necessary that the cause of this difference should be clearly shown, before we admit that iron or steel has no action upon a needle, but that which arises from the separation of its magnetism by the influence of the earth or of the needle. When a mass of iron is so far removed from a magnetized needle that the magnetism induced in it from the needle produces but little effect, I have shown that the deviations computed on the hypothesis of a central attraction, agree with those observed, even in cases which were supposed directly opposed to such an hypothesis; and therefore it is not necessary to suppose that the iron is polarized by the action of the earth.

However, whether we admit the hypothesis of a central attraction independent of the action by induction when the iron is in the immediate neighbourhood of a magnet, or not, this hypothesis has the advantage of very readily connecting all the phænomena observed in the deviations of a mag-

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* Magnetic Attractions, p. 124, 1st edition: the experiment is omitted in the 2nd edition.

netized needle which are due to the action of iron; of indicating immediately the nature of the deviations, even under very complicated circumstances, as I have shown in the case of the deteriorated needles; and still further of affording ready and close approximations to numerical results in all positions within certain limits of distance from the attracting body.

S. H. Christie.

Royal Military Academy,
22*nd May,* 1828.

XVIII. *Description of a sounding board in Attercliffe Church, invented by the Rev.* JOHN BLACKBURN, *Minister of Attercliffe-cum-Darnall, Sheffield.*

Read June 5, 1828.

THE material is pine wood. The surface is concave, and is generated by half a revolution of one branch of a parabola on its axis.

The distance from the focus to the vertex = 2 feet.
The length of the abscissa is . . . . . = 4 feet.
The length of the ordinate to the axis . = $\sqrt{32}$ feet.
= nearly 5.7
= rad. of outer circle.

The axis is inclined forwards to the plane of the floor at an angle of about 10 or 15 degrees, and elevated so as that the speaker's mouth may be in the focus.

A small curvilinear section is taken away on each side from beneath, that the view of the preacher from the north and south galleries may not be intercepted; whence the outer semicircle is imperfect.

This, however, gives an appearance that is not inelegant; and the outer edge being ornamented with crockets and leaves and with a finial at the highest point, and the concave surface being painted in imitation of a groined oak canopy, the effect of the whole is pleasing to the eye.

A curtain is suspended from the lower edge of the canopy for about 18 inches on each side.

1. By means of this erection the volume of sound is increased in a very considerable ratio (perhaps as 5 : 1), and is thrown powerfully, as well as distinctly, to the most distant parts of the church; so that whereas formerly the difficulty of hearing an intelligible sound was very great, now that difficulty is effectually removed. e. g.

The preacher was scarcely audible even in the pews near the pulpit, and not at all in those more remote: he may now be heard in every part, and nowhere more distinctly than in the west gallery, or under it, on the ground-floor.

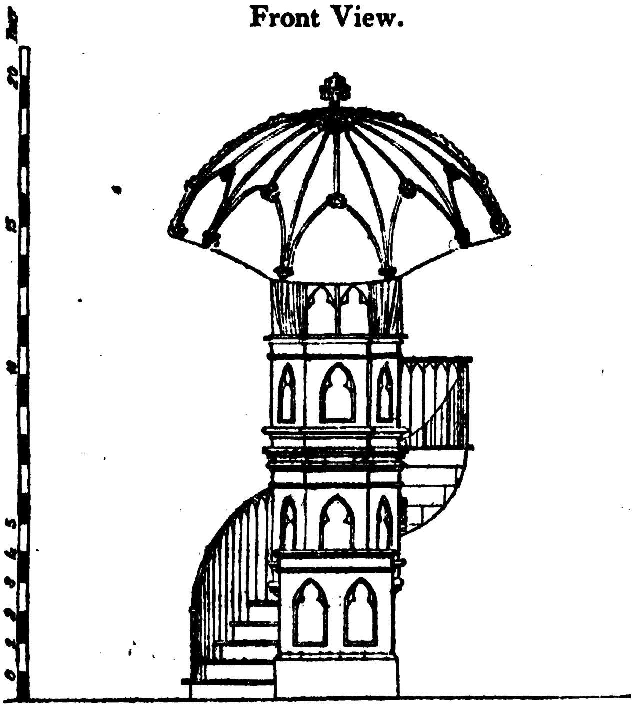
2. It should seem that the voice is reflected in a direction parallel to the axis; for let A stand in the pulpit, and B stand first in the west gallery opposite to the pulpit, and then in the side galleries; though B is much nearer to A in the latter case than in the former, he can yet hear with decided advantage when opposite to A (i. e. at the greater distance from him).

The side galleries appear to be benefited rather by the increased volume of sound, and by the secondary vibrations excited in a lateral direction.

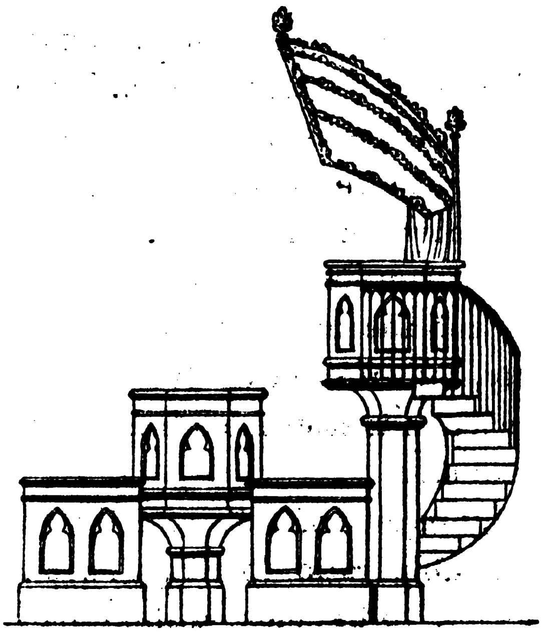
3. It appears also that vibrations proceeding from a distant point and moving in the direction of the axis, are reflected from the parabolic surface towards the focus. For let A stand in the pulpit as before, and B in a distant point opposite to A, A can then converse with B in a whisper; whilst C, standing at an intermediate point, cannot at all distinguish the words spoken by B; he can however hear what is said by A. Also if B, at a distance, opposite to the sounding board, speaks; whilst A places one ear in the focus of the parabola and one ear towards B, the effect produced is that of a voice close to the ear, and in a direction the reverse of that from which it really proceeds.

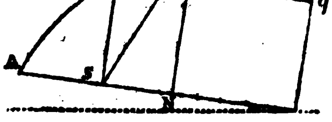
4. The converse of this also appears true from the following experiment.

Front View.



Side View.





Let B remain in the situation last supposed, and let A place his face towards the parabolic surface, and his back towards B; let A now speak, having his mouth in the situation of the focus, and he will be heard as distinctly as when his face was turned towards B.

5. If the mouth of the speaker is placed much within or without, above or below the focus, the effect is proportionably diminished.

6. The distinctness of articulation preserved may perhaps in some measure be accounted for thus. Assuming that the sound issuing from the focus is reflected in a direction parallel to the axis; assuming also that the velocity of sound is uniform; then the vibrations of the air proceeding from the focus and striking the parabolic surface, at whatever point, will arrive at the same moment of time at a plane perpendicular to the axis. For (according to the properties of the parabola) the sums of the distances (from the focus to the paraboloid, and from the paraboloid to the plane so situated) are always equal to each other: it must however be admitted, that the velocity of sound is too great to allow much dependence to be placed on this conclusion; but it is here proved beyond dispute, that a parabolic surface is capable of being successfully applied to the purpose of a sounding board; whether other concave surfaces similarly situated would be equally successful, or other materials better adapted to answer the end than pine, it might be worth while by experiment to ascertain.

7. Whilst the figure of the canopy remained perfect, the effect was most complete; perhaps it might be improved if constructed larger, or in other words, if continued further; or (should circumstances permit) if the parabola were to perform an entire revolution round its axis; but the distance from the focus to the vertex (which regulates the curve) must depend on the supposed situation of the speaker, which will vary according to the diameter of the pulpit.

John Blackburn.

Attercliffe Parsonage, near Sheffield,
May 23, 1828.

XIX. *On the mutual action of sulphuric acid and alcohol, and on the nature of the process by which ether is formed.* *By* HENRY HENNELL, *Esq. Communicated by* WILLIAM THOMAS BRANDE, *Esq. F.R.S.*

Read June 19, 1828.

1. I WAS some time since engaged in an investigation of the nature of oil of wine and of the salts called sulphovinates: the results I obtained were considered of sufficient importance to be honoured with a place in the Philosophical Transactions*. The oil of wine and sulphovinic acid are substances produced during the mutual action of sulphuric acid and alcohol in the well-known process adopted for the preparation of ether; and an important point with me, during the above investigations and since that time, has been to develop the particular changes which take place when ether is formed from sulphuric acid and alcohol. I perceive by the Annales de Chimie for November last, that MM. DUMAS and BOULLAY have been engaged on the same subject, and ~~have~~ experimented on and considered, not only the formation of ether, but also the nature of sulphovinates, and, as they supposed, though incorrectly, of oil of wine†. That our results with regard to sulphovinates and oil of wine differ, may be seen from the published accounts; and there is not less difference between their conclusions with regard to etherification, and the results I have obtained, which I have now to describe.

2. When alcohol and sulphuric acid in equal weights are put together without the application of any heat beyond that generated during the mixture, the most abundant and important product is sulphovinic acid, above one half of the sulphuric acid being converted into that peculiar acid by union with hydro-carbon‡. But when such a mixture containing so large a proportion

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* Phil. Trans. 1826. Part 3rd.

† The substance which these gentlemen operated upon appears, from their own account of its preparation, to have been the hydro-carbon separable from oil of wine by the action of alkalies, and not that peculiar substance which has hitherto been called oil of wine.

‡ The sulphuric acid loses half its saturating power by the union, and all the salts formed by the new acid are soluble.

of sulphovinic acid is distilled, the most important product is a new substance, namely ether, and the sulphovinic acid disappears. The questions which then arose were, whether the ether was formed altogether from the direct action of the remaining alcohol and sulphuric acid in the mixture, or whether the sulphovinic acid might not also assist, or whether it might not be an essential state of the elements intermediate between the mixture of the acid and alcohol and the development of the perfectly formed ether. MM. Dumas and Boullay, who have considered the same questions, or at least some of them,—decide, that the portions of materials which form ether, are altogether independent of those which produce sulphovinic acid: but the following facts prove in my opinion the contrary of this conclusion.

3. A portion of oil of vitriol was selected for some comparative experiments, and also some alcohol of specific gravity 0.820: five hundred grains of the oil of vitriol precipitated by acetate of lead, gave 1500 grains of sulphate of lead.

4. Five hundred grains of the oil of vitriol were mixed with five hundred grains of the alcohol, and after forty-eight hours, diluted and precipitated by acetate of lead; only 616 grains of sulphate of lead were produced; so that very nearly three-fifths of the sulphuric acid had become sulphovinic acid by the effect of mixture, and little more than two-fifths remained to act as sulphuric acid upon the remaining alcohol, full two-thirds of the quantity employed.

5. Another mixture of acid and alcohol in the same proportions, and made at the same time as the above, was then distilled until 117 grains had passed over, consisting of water, alcohol, and a portion of ether. The residue in the retort had not undergone any charring effect; and being diluted, was precipitated by the acetate of lead: the quantity of sulphate of lead obtained, amounted to 804 grains, indicating an increase in the quantity of sulphuric acid equivalent to 188 grains of sulphate of lead.

6. A similar mixture of alcohol and sulphuric acid, made at the time and in the same proportions as the two former, was then distilled until two hundred grains had been received, the greater part of which was ether; the uncharred residual matter in the retort being then diluted, was precipitated by acetate of lead as before; 986 grains of sulphate of lead were obtained. This contained

nearly two-thirds of the sulphuric acid first added, and the increase by distillation had been much more than one-half of that which existed before the application of heat: so that during the distillation, and simultaneously with the formation of ether, a quantity of sulphovinic acid had been re-converted into sulphuric acid, and the latter appeared to increase in quantity in proportion to the increase of ether in the distilled products.

7. A similar mixture of alcohol and acid, made at the same time and in the same proportions as the three former, was then distilled until two hundred grains had passed over. Two hundred grains of water were added to the contents of the retort; 160 grains were distilled off; a second addition of two hundred grains of water was made, and the distillation continued: a further addition of five hundred grains of water was made, and the operation continued until as much product had been separated as equalled the water added;—the object was to separate all the ether and alcohol possible, for the purpose of ascertaining to what extent the conversion of sulphovinic acid into sulphuric could be carried. No smell of sulphurous acid was produced during the operation, nor did any charring of the contents of the retort occur; when precipitated by acetate of lead, 1480 grains of sulphate of lead were obtained. This is very little short of the 1500 given by the acid when unacted upon by alcohol, and shows that nearly the whole of the sulphovinic acid had been changed back into the state of sulphuric acid; and is completely at variance with the opinion, that when sulphuric acid and alcohol act upon each other, hypo-sulphuric acid is formed.

8. From these experiments it appeared probable that the ether was the product of the decomposition of the sulphovinic acid: but a mixture of equal weights of alcohol and sulphuric acid contains, besides the sulphovinic acid, a considerable quantity of unaltered acid and alcohol; for in such a mixture three-fifths (4) of the sulphuric acid would be converted into sulphovinic acid by combination with the hydro-carbon of less than one-third of the alcohol employed. I next proceeded to ascertain, whether, when no alcohol was present, ether would be produced. A quantity of the sulphovinate of potash was therefore prepared. The composition of this salt has been given in the paper in the Philosophical Transactions before referred to, and one hundred parts contain 28.84 of potash. Five hundred grains were mixed with 150 grains of sulphuric

acid, being nearly the equivalent of the potash in the salt, and then heat applied. The experiment therefore may be considered as the distillation of sulphovinic acid mixed with sulphate of potash, which it may be presumed remained inert during the process, and also with the water of the acid and of the salt. The proportion of water, it is found, has an important influence; but in the present experiment about a drachm of fluid distilled over, and left a blackened and acid salt in the retort, having the smell of sulphurous acid. A few grains of carbonate of potash being added to the distilled product, abstracted a little water: the clear decanted liquor was then mixed with a little dry muriate of lime, and by agitation separated into two portions; the upper one being decanted, amounted to nearly half a drachm, and was found to be pure ether. This result proves that ether may be formed from a sulphovinate or sulphovinic acid when no alcohol is present.

9. An experiment similar to the last in the nature and proportions of the substances used, was made, except that the sulphovinate was dissolved in its own weight of water previous to the addition of the sulphuric acid. The experiment is one therefore of the distillation of dilute sulphovinous acid, in place of that which is concentrated. The distilled product had no smell of ether, nor could any be discovered in it. About nine fluid drachms were obtained; to these, carbonate of potash was added, which separated the water, and left three drachms of a supernatant liquid, appearing by taste, smell and flame, to be alcohol: this was decanted, and poured upon muriate of lime; no ether separated, but the whole formed one solution; being distilled from the muriate it was evidently alcohol; and being mixed with its weight of sulphuric acid, gave sulphuric ether or sulphovinic acid again.

In this experiment there was no charring of the contents of the retort; and by precipitation by acetate of lead, the whole of the sulphuric acid was obtained;—not only the portion added to decompose the salt, but the double portion evolved from the sulphovinic acid upon the separation and re-arrangement of the hydrocarbon.

10. In the former paper it was shown that oil of wine when heated in water is resolved into hydrocarbon and sulphovinic acid: an experiment was therefore made upon it. Two hundred grains of oil of wine were placed in a retort, a little water added, and heat applied: about a drachm was received, which being

redistilled from carbonate of potash the product appeared to be principally alcohol, but the presence of ether was very evident.—This experiment proves the formation of ether from sulphovinic acid when no sulphuric acid was present as such at the commencement of the distillation.

With regard to the questions at the commencement of this paper, it appears to me from the facts detailed, that in the usual process for obtaining ether, the ether is not formed altogether from the direct action of the alcohol and sulphuric acid considered independently of the sulphovinic acid present; for the quantity of free sulphuric acid is small compared to the quantity of alcohol present, two-fifths only of the acid remaining, while of the alcohol more than two-thirds remain; and further, sulphovinic acid alone is readily converted into ether and sulphuric acid, (see 8.) and during the distillation of ether in the ordinary way the sulphovinic acid is always re-converted more or less completely into sulphuric acid (4. 5. 6.) it probably therefore assists much in the process. With regard to the third question, the opinion may be supported that the formation of sulphovinic acid is a necessary and intermediate step to the production of ether from alcohol and sulphuric acid; and although I do not mean to assert this view, yet it deserves a few remarks.

In no manner which has yet been devised can ether be formed from alcohol and sulphuric acid without the presence of sulphovinic acid. Whenever ether has been formed, sulphovinic acid has been present; whenever the sulphuric acid is diluted so far as not to form sulphovinic acid with alcohol, it also refuses to form ether with alcohol. Sulphovinic acid will produce ether without the assistance of alcohol. And although the ether produced when a mixture of equal weights of alcohol and sulphuric acid are distilled, appears to be in greater quantity than can arise from the decomposition of the sulphovinic acid existing in the mixture previous to the action of heat, it is not I think inconsistent to suppose, that at the same time that one portion of sulphovinic acid is resolved into sulphuric acid and ether, another may be formed from alcohol and sulphuric acid; and that sulphovinic acid is formed in a mixture of sulphuric acid and alcohol by heat, is proved by the following experiment. Five hundred grains of oil of vitriol were diluted by five hundred grains of water; when cold, to the dilute acid was added two thousand grains of alcohol, specific gravity 0.820. The following day this mixture was examined for sulphovinic acid, but none had been formed: it was placed in a retort, and a quantity distilled off nearly equal to the weight of the alcohol employed: this had a specific gravity of 0.842. Carbonate of potash separated a considerable portion of water, the original alcohol would not even moisten that salt; the residue in the retort was examined, and now sulphovinic acid was found; the evidence of which was, carbonate of lead being dissolved in considerable quantity; here sulphovinic acid had been formed by heat, where it did not previously exist. This result appears also opposed to the opinion, that in the formation of ether the sulphuric acid acts simply by abstracting water from the alcohol; for the dilute acid here gave up a portion of its water during the distillation, and separated from the alcohol a portion of hydro-carbon.

It has already been shown (9.) that the production of ether is materially influenced by the quantity of water present, and that the same sulphovinic acid will yield either ether or alcohol, as it is in a concentrated or dilute state. The hydro-carbon which, as was shown in the former paper, has the extraordinary power in oil of wine of neutralizing the whole of the acid properties of sulphuric acid, and in sulphovinic acid of neutralizing the half of them, being in the latter body in so peculiar a condition that it will unite either with that proportion of water necessary to form ether, or with the larger proportion requisite to form alcohol, according to circumstances.

In the experiments (8. 9.), in the production by distillation of ether or alcohol from sulphovinic acid more or less diluted, it appeared that sulphovinic acid might easily have its proximate elements separated and restored to their original state of sulphuric acid and alcohol. The following experiment was made with a view to illustrate this point. Five hundred grains of acid and five hundred grains of alcohol were mixed as before, and left for several days: by previous experiment it is known that more than half the sulphuric acid in this way becomes sulphovinic acid (4). By distillation and dilution at proper periods this would have given ether and alcohol, and nearly the whole of the sulphuric acid (7.): but instead of doing this, it was mixed with one thousand grains of water, and then distilled until 1400 grains had passed over. No charring or decomposition of the sulphuric acid took place; no ether was formed; but nearly the whole of the original alcohol and sulphuric acid were recovered. It may be a question whether the production of alcohol and ether in those and similar experiments is altogether determined by the proportion of water present, or whether the difference of temperature consequent upon its variation may not have an effect.

When ether and sulphuric acid are heated together, oil of wine and sulphovinic acid are amongst the products obtained; and as this sulphovinic acid is readily converted when diluted into alcohol and sulphuric acid, so it affords a method of converting ether into alcohol: thus ether may be formed from alcohol, and alcohol from ether at pleasure, by throwing the hydro-carbon of these bodies into that peculiar state which it assumes when combined with sulphuric acid in sulphovinic acid. We may even proceed beyond this, and form either alcohol or ether, using olefiant gas as the hydro-carbon base: for I have shown in my last paper, that olefiant gas by combining with sulphuric acid, forms sulphovinic acid, and the acid so produced forms either ether or alcohol, according to circumstances which are under perfect command.

It can hardly be necessary to refer to the extraordinary remark at the end of MM. Dumas and Boullay's second paper, except to state that it is singularly at variance with the facts and opinions given throughout the former part of that and the preceding paper by the same authors. Those persons who read both papers, and also those of Mr. Faraday and myself, which were published long before the appearance of the former, will be able to decide without further comment from whom the particular views contained in those papers first emanated.

H. Hennell.

Apothecaries' Hall.

XX. *Experiments and observations on electric conduction. By* WILLIAM RITCHIE, *A.M. F.R.S. Rector of Tain Academy.*

Read June 19, 1828.

THAT some substances conduct or convey the electric fluid to a distance better than others, is a fact known to the earliest electricians; but on what power or property of the body this superiority depends, is a question on which different opinions still seem to prevail. We constantly hear the expressions "electricity is attracted by metals; the lightning is attracted by the metallic points of a conducting rod," and other expressions of similar import,—all signifying that a powerful attraction does exist between metals and the electric fluid. Now the contrary is really the fact, those bodies being the best conductors which have the least attraction for the electric fluid. From the profound mathematical investigations of M. POISSON, and the luminous writings of M. BIOT, it appears that these philosophers consider the metals merely as forming the passive interior of a vessel, of which the exterior surface is the ambient air; and that the electric fluid rushes along between the atmospheric boundary and the surface of the metal, where it finds an easy passage. We are therefore to consider the metals as quite passive in the conduction of the electric fluid, and that the prime mover is the repulsive energy existing between similar atoms of the compound electric fluid. When a metallic ball connected with the earth is placed near the prime conductor, the vitreous electricity surrounding the conductor repels the vitreous electricity of the ball, and forces it to glide along to a greater distance, whilst the ball will now be surrounded by a thin film of the resinous fluid. The vitreous electricity of the conductor thus finding an easier passage in the direction of the ball, and being in a high state of tension, will, like every other elastic fluid, glide along in the direction of the ball as if it had actually been attracted by that body. The reason why it does not strike off with equal facility to a vitreous body is, not because it is less attracted by that body, but simply because it is unable to decompose with the same facility the natural electricity belonging to the glass, on account of the powerful attraction existing between the atoms of the glass and those of the electric fluid. If the glass be thin and a metallic conductor placed in its interior, the vitreous electricity will act through the glass, decompose the fluid in the metallic conductor, and then actually strike through the glass in the direction of the metal where the resistance is least.

Exp. I. On the ends of two thermometer tubes I blew two balls of extreme tenuity. I then introduced two pieces of brass wire into the tubes till the ends reached within a small distance of the interior surface of the balls. Having brought the other ends of the tubes together, I joined them at the flame of the blowpipe, so that I had now a metallic conductor completely surrounded with glass. This being placed on a stand, and one of the balls brought near the prime conductor, I found I could take sparks, for any length of time, from the other end, in the same manner as if the glass had not been interposed. When the bulbs were about the thickness of those of a common thermometer, I observed that if sparks were taken for any length of time from the same place, they afterwards chose the same tract. I naturally concluded that the glass had been pierced, though I could not determine it by the naked eye. I found, however, that if the tubes were again separated and the air partially expelled from one of the balls by heat, and the open end of the tube placed in a vessel containing mercury, the mercury rose in the tube, but after a short time it again sunk to its proper level; clearly showing that the bulb had been pierced, though the aperture was extremely minute. I now began to suspect that in every case in which glass seemed to have been freely permeated by the electric fluid, that the fluid had been either silently conducted through it, or that, if carefully examined, it would have been found to have forced out some of the atoms of the glass. I therefore repeated the experiment with glass as thin as it could be blown without bursting, and found that the electric fluid would in that case freely permeate it; and that by no known method could I detect the smallest aperture in the glass.

Exp. II. Place an electric jar in a receiver, and partially exhaust the air; and the charge which can be given it will be very much diminished: exhaust the air still further, and it will be found impossible to communicate the slightest charge. In continuing to exhaust the air, the sparks between the ball connected with the prime conductor and knob of the jar will become less and less till the electric fluid begins to flow in a continuous stream. From this experiment it is obvious that the jar ceases to receive a charge when the pressure of the air becomes equal or less than the repulsive energy existing between the atoms of similar kinds of electricity.

Exp. III. Place the Leyden phial in a receiver, to which is adapted a condensing syringe; condense the air, and the phial will receive a higher charge than in air of the ordinary density. In charging the jar, the sparks will be larger, and strike off at greater intervals than in common air.

It is quite obvious that in both of these experiments, the pressure of the air prevents the radiation of the electric fluid in the same manner as it acts in partially preventing the radiation of caloric from a heated body, or evaporation from the surface of water.

Exp. IV. Raise the end of an iron rod to a white heat, place the other end in either conductor, and the vitreous or resinous electricity will flow off to a metallic ball in a continuous stream. When the iron assumes a red heat, the current will change into a rapid succession of small sparks, which will increase in size as the iron cools. If the heated iron be presented to either conductor, the same effects will take place.

In this experiment the air surrounding the heated iron is highly rarified, and consequently exerts a diminished pressure on the electric fluid, which of course flows off by its own repulsion, exactly as it does in a receiver partially exhausted of air. The attraction of the iron for the electric fluid, when saturated with heat, will be diminished; and consequently the fluid will begin to flow off in a continuous stream, when the pressure of the air is greater than that of the air in a similar experiment in the exhausted receiver. When the iron has assumed a red heat, the surrounding air, not being so much rarified as in the case of a white heat, forces the electricity to accumulate in a small degree on the surface of the metal, and hence the commencement of the passage of the silent current into small sparks, exactly as it does in air of a certain density.

Exp. V. Raise the ends of two iron rods to a white heat, place them in the same line, with their heated ends at a considerable distance from each other; connect the cold ends with the opposite sides of a charged jar, and the jar will be discharged by explosion, when the heated ends are at a much greater distance than it can be when the rods are cold. The air between the ends of the rods being partially rarified, will of course afford an easier passage to the electric current than air of the ordinary density, and hence the discharge will take place when the ends of the rods are more remote. This is exactly what takes place when cold rods are placed in a tall receiver partially exhausted.

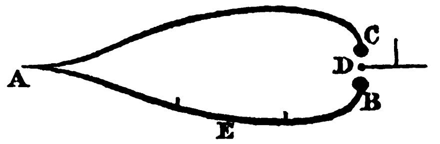
Exp. VI. Place two metallic wires in the ends of a long pencil of flame formed by the blowpipe, connect them with the opposite sides of a charged jar, and the jar will be discharged by explosion along the flame. The spark will make its appearance at the point of the flame. The flame of a blowpipe is a hollow cone containing highly rarified air. The electric fluid will therefore glide along such a cone, exactly as it does along the interior of a hollow cone of glass partially exhausted of air. We are therefore not to regard flame as a conductor of electricity in the ordinary sense of the term; when the only part it performs in the conduction is merely that of forming a partial vacuum.

This fact is sometimes illustrated in a magnificent manner during violent irruptions of volcanic mountains. The air in the crater is highly rarified: and during a thunder-storm, the lightning is observed to dart into the hollow cone as if it were attracted by the flame, or by the mass of melted lava at the bottom of the crater; whereas the true cause of the phænomenon is found in the ready passage which the partial vacuum affords to the electric fluid driven off by its own repulsion from the charged cloud.

It is a well-known fact that imperfect conductors become tolerably good conductors when heated. Glass, for example, which is a very imperfect conductor when cold, conducts the electric fluid very readily when heated red hot. This is indeed what we might naturally expect from what we have assigned as the cause of conduction. Glass when cold has a powerful attraction for the electric fluid; it is therefore natural to expect that when charged with caloric, which is at least one of the ingredients of electricity, its attraction for that fluid would become less, and consequently afford a freer passage for the current along its surface. If the body be naturally a pretty good conductor of electricity, the ratio of its conducting power will not be so much increased by heat as in the case of a less perfect conductor. This at least was found by Marianini to be the case with fluid conductors; and from some experiments which I have lately performed, I am led to believe that it will be found to be the case with every kind of conductor. Sir H. Davy in some of his experiments on the conducting powers of metals, was led to conclude that the conducting powers of metals are diminished by heat, at least for voltaic electricity. It is perhaps true, that if a slender wire be heated in the middle by a spirit-lamp, the same quantity of the electric fluid will not find its way to the other end of the wire, as happens when the whole is cold. But unless the quantity of the electric fluid which escapes by the rarified portion of air surrounding the heated part be ascertained, no conclusion can be drawn with regard to the increase or diminution of the conducting powers of the wire.

In my experiments on the conducting powers of hot and cold iron, I very soon relinquished the use of wires for that of rods about half an inch in diameter.

Exp. VII. Let an iron rod be converted into the annexed form, in which C, B are brass balls, and A drawn to a fine point. Let a glass tube be drawn out at a lamp to form a slender needle about six inches long, which is to be suspended by the middle by a fine thread of glass. Place two slender pieces of glass at each end of the horizontal needle, to prevent it having much motion. Twist the thread a little till the needle rest against the opposite supports. Place its pith ball D between B, C. Heat about a foot of A B in the middle, place the rod on an insulating support, with A near the prime conductor, and bring it rapidly to its former position. Turn the index till the attraction of B just overcomes that of C, continue to turn the machine, and the attraction of B will diminish so that the ball D will move off to C as the iron cools. From this experiment, it would seem that iron when heated is a better conductor of the electric fluid than when cold. The following experiment, which I have repeated at least ten times with uniformly the same results, will place this fact beyond the possibility of doubt.



Exp. VIII. Bring two brass balls connected with the earth near the balls B, C, (the part E being heated red hot,) till the electric fluid strike off almost equally to both; allow E to cool, and the electricity will cease striking off from B, and the whole will flow off in rapid sparks from C. The experiment may be rendered still more striking, by making the whole electricity at first flow from B: as the iron cools, sparks will begin to appear between C and its ball, and in a short time the current will cease entirely from B, and the whole will now strike off from C.

As the ball B was at a considerable distance from E, its temperature remained uniform: we are therefore led to the conclusion that the electric fluid finds an easier passage along hot than cold iron; or, to use the ordinary language of the science, iron when red hot is a better conductor of electricity than when cold.

Whether the cause of this be found in the diminished attraction which hot iron has for the electric fluid, in the diminished pressure of the ambient air, or in both causes combined, is a question which has not yet been solved; but whatever be the cause, the fact is certain, though at complete variance with our preconceived notions on the subject, and even with the results of former experiments.

Exp. IX. Suspend a magnetic needle by the glass thread as in Exp. VII. Place a rod of iron heated white hot opposite either end of the needle, apply either pole of a horseshoe magnet to the other end of the iron, and the deviation of the needle both by attraction and repulsion will be found to be greatest when the rod reaches a red heat, and will continue to diminish as the rod cools. From this experiment it is obvious that iron at a red heat conducts the magnetic influence better than when cold. Though this experiment bears some resemblance to those of Mr. Barlow, yet, as far as I know, the fact has not been previously observed; and it affords us another striking analogy between the electric and magnetic influences.

XXI. *On magnetic influence in the solar rays.* *By* Samuel Hunter Christie, *Esq.* M.A. *F.R.S.* *&c.*

Read June 19, 1828.

THE facts which I communicated in my former paper on this subject appeared so inexplicable on any known principle, that I am induced to present my subsequent observations to the Society, although I have not succeeded in ascertaining the causes of the singular effects which I have observed. From the experiments described in that paper, it appeared that a magnetized needle, when vibrated exposed to the sun's rays, will come to rest sooner than when screened from their influence: that a similar effect is produced on a needle of glass or of copper; but that the effect upon the magnetized needle greatly exceeds that upon either of the others. To the experiments from which this was inferred, it might be objected, that the magnetized needle and the other metallic needle were not of the same weight, and that the effect upon an unmagnetized steel needle had not been compared with that upon a similar needle magnetized. I therefore, on the first opportunity, made these experiments in the most unexceptionable manner, and the results most decidedly confirmed those I had previously obtained. I endeavoured likewise to ascertain the effects that would be produced by the separate rays; but, possibly owing to the inefficiency of my apparatus, I obtained no very decided results: the violet rays appeared to produce the same effect as partially screening the needle; and the red rays, the greatest effect in diminishing the arc of vibration. The observations themselves will however best point out the nature of these effects.

My first object was to compare the effects on an unmagnetized steel needle with those on a magnetized needle, under circumstances as nearly as possible the same. For this purpose I made another needle of the same form and weight, and from the same piece of clock-spring, as the magnetized needle which I had already employed. Each needle had pasteboard glued to the under side, to render it of precisely the same weight as two other needles of copper and of glass, which I had cut of the same form for the purpose of comparing the effects upon needles of different kinds. The length of each needle is 6 inches, and the greatest breadth 1.5 inch, the boundaries being circular arcs. The needles were vibrated by means of an apparatus, described in my former paper, from which metal was scrupulously excluded; the suspending wire being the only metal within several feet of the needle. This wire was of brass, and of such diameter, that the unmagnetized needles vibrated by the force of its torsion in very nearly the same time as the magnetized needle by the directive force of the earth. The observations are contained in the following table, where the terminal arc is, in all cases, the extent to which the needle vibrated beyond zero after completing the 100th vibration; and the terminal excess is the excess of the terminal arc when the needle vibrated in the shade above that when it vibrated exposed to the sun.

Needle vibrated.	Needle vibrated screened from the Sun.				Needle vibrated exposed to the Sun.					
	Extent of 1st Vibration.	Time of making 100 Vibrations.	100th or Terminal Arc.	Therm.	Extent of 1st Vibration.	Time of making 100 Vibrations.	100th or Terminal Arc.	Therm.	Terminal excess.	Difference of Temp.
		m s				m s				
Magnetized Steel Needle.	90°+88°	6 06.2	31°.5	57°.5	90°+88°	6 01.9	16°.5	106°		
Weight = 252¼ grains.	90+88.5	6 06.0	31.5	57.5	90+88	6 02.0	16.5	107		
	90+88	6 06.0	31.25	58.5	90+88	6 01.8	16.5	109		
Means...	90+88.2	6 06.1	31.4	57.8	90+88	6 01.9	16.5	107.3	14°.9	49°.5
	Apr. 19, from 9^h A.M. to 9^h 40^m A.M.				April 19, from 9^h 53^m A.M. to 10^h 17^m A.M.					
Unmagnetized Steel Needle.	90+92.5	5 59.6	25	65	90+91.5	5 59.4	19	121		
Weight = 252¼ grains.	90+91.5	5 59.6	26.5	65	90+90.5	5 59.4	18.5	114		
	90+91.5	5 59.8	26.75	65	90+91	5 59.4	19	115		
Means...	90+91.8	5 59.7	26.1	65	90+91	5 59.4	18.8	116.7	7.3	51.7
	Apr. 21, from 23^m P.M. to 52^m P.M.				April 21, from 1^h 07^m P.M. to 1^h 39^m P.M.					

The circumstances under which the observations with the two needles were made, were as nearly the same as I could expect to have them; and the results show that the effect produced by the sun's rays on a steel needle, when vibrated exposed to their influence, is most decidedly increased when that needle is magnetized. The small differences which are to be noticed in the extent of the first arc of vibration would have little influence on the terminal arc, the diminution in the large arcs being so much greater than in the small ones: for instance, the needle vibrating 90° beyond zero in the first vibration, in the second it would not vibrate to 88°; whereas the 100th vibration being 26°, the 101st would be $25\frac{1}{2}$° beyond zero. This remark applies to all the observations which I have made.

In making these observations, I first noticed that time appeared to be required, in order that the full effect arising from exposure to the sun should be produced. Thus the last observation in the shade with the magnetized needle being concluded at $9^h\ 40^m$, the screen was immediately removed, and I commenced an observation in the sun at $9^h\ 43^m$, which gave the terminal arc 23°; and the next observation in the sun, commencing at $9^h\ 53^m$, gave the terminal arc $16\frac{1}{2}$°. With the unmagnetized needle, the last in the shade being concluded at $0^h\ 52^m$, I commenced an observation in the sun at $0^h\ 53^m$, which gave the terminal arc 22°; the terminal arc in the next observation commencing at $1^h\ 07^m$ was 19°: and again the needle being screened at $1^h\ 39^m\ 45^s$, an observation in the shade, commencing at $1^h\ 39^m\ 30^s$, gave the terminal arc $24\frac{1}{2}$° instead of 26°, which I had obtained previously. I ought to mention, that during the observation with the magnetized needle in the sun to which I have referred, the power of the sun was diminished by a haze which produced a halo round it; and the extent of the terminal arc might partly be attributed to this circumstance. I have, however, observed the same effect on other occasions where no such cause operated.

In the following table, are contained similar observations, which I made with these steel needles and two others, the one of copper, and the other of glass. The four needles were of the same form and weight, and vibrated nearly in the same time; the unmagnetized steel needle, the copper needle and the glass needle being suspended by the same wire as I had used in the foregoing experiments with the unmagnetized steel needle.

Needle vibrated.		Time of commencing Observation.	Extent of first Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer.		Remarks.
						Exposed to Sun.	In Shade.	
Glass Needle. Weight 252¼ grains.	Screened from the Sun.	July 2nd. h m		m s				
		10 02	90°+88°	6 01.0	29°.5	124°.5	74°	Sun shining clear.
		10 12	90+88	6 01.0	29.0	132.0	75	Sun shining clear.
		10 21	90+88	6 01.0	29.0	118.0	73.5	Clouds over sun.
		Means...	90+88	6 01.0	29.17		74.2	
	Exposed to the Sun.	10 38	90+87.5	6 01.0	23.0	123.0	74.8	Sun clear.
		0 46	90+88	6 01.6	22.0	132.0	78.5	Sun clear: dew on the glass of the instrument.
		0 56	90+88.3	6 01.6	23.5	141.5	79.0	Sun clear: dew on the glass of the instrument.
		Means...	90+87.9	6 01.4	22.83	132.2		Terminal excess = 6°.34; { diff. of temp. in sun and in shade. } = 58°
Copper Needle. Weight 252¼ grains.	Exposed to the Sun.	3 35	90+90	5 57.4	29.0	136	80.0	Sun clear.
		3 45	90+89.5	5 57.2	27.5	140	80.6	Sun clear.
		3 53	90+89.3	5 57.2	28.0	141	80.4	Sun clear.
		Means...	90+89.6	5 57.27	28.17	139		
	Screened from the Sun.	4 03	90+90.5	5 57.2	32.75	142	80.0	Sun clear.
		4 12	90+91.0	5 57.2	34.0	143	80.0	Sun clear.
		4 20	90+89.0	5 57.0	33.0	142	80.0	Sun clear.
		Means...	90+90.2	5 57.13	33.25		80.0	Terminal excess = 5°.08; { diff. of temp. in sun and in shade. } = 59°
Unmagnetized Steel Needle. Weight 252¼ grains.	Screened from the Sun.	July 3rd. 9 15	90+87	6 00.2	28.5	135	74.7	Sun clear.
		9 25	90+88	6 00.4	29.25	136	75.3	Sun clear.
		9 31	90+89	6 00.4	29.5	138	76.0	Sun clear.
		Means...	90+88	6 00.33	29.08		75.3	
	Exposed to the Sun.	9 43	90+88	5 59.8	25.25	136	76.0	Sun clear. } These two observations are not included in the mean.
		9 52	90+89	5 59.6	23.5	141	78.0	Sun clear.
		10 02	90+87.5	5 59.2	22.0	147.8	79.0	Sun clear: dew on the glass of the instrument.
		10 11	90+89.5	5 59.0	22.0	148	79.4	Sun clear: dew on the glass of the instrument.
		10 20	90+87	5 59.0	21.0	149	80.0	Sun clear: dew on the glass of the instrument.
		Means...	90+88	5 59.07	21.67	148.3		Terminal excess = 7°.31; { diff. of temp. in sun and in shade. } = 73°
Magnetized Steel Needle. Weight 252¼ grains.	Screened from the Sun.	0 38	90+87	6 12.3	29.5	142	86	Sun clear.
		0 48	90+88	6 12.6	29.5	140	85.7	Sun clouded for 50'.
		1 04	90+87.5	6 12.2	29.5	122	85.4	Sun clouded.
		Means...	90+87.5	6 12.37	29.5		85.7	
	Exposed to the Sun.	1 16	90+88	6 12.4	21.5	141	86.2	Sun clear. Not included in the mean.
		1 26	90+88	6 12.4	17.5	149.8	87.6	Sun clear.
		1 35	00+88.3	6 13.9	16.0	155.0	88.8	Sun clear.
		Means...	90+88.1	6 13.15	16.75	152.4		Terminal excess = 12°.75; { diff. of temp. in sun and in shade. } = 66°.7

This table exhibits in the clearest manner the difference between the effect on a magnetized needle and that on any other, when vibrating exposed to the influence of the sun's rays. Had the time during which the magnetized needle vibrated been 6^m instead of 6^m 13^s, the terminal excess would have been 12°.3 nearly, supposing it to be nearly proportional to the time. However, to render the time in which this needle made one hundred vibrations more nearly equal to those of the others, I remagnetized it; and four hours afterwards made the following observations.

Needle vibrated.		Time of commencing Observation.	Extent of the first Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer. Exposed to Sun.	Thermometer. In the Shade.	Remarks.
Magnetized Steel Needle. Weight 252¼ grains.	Screened from the Sun.	July 4th. h m	° °	m s	°	°	°	
		0 10	90+88	6 01.1	29	149	84.5	Sun clear.
		0 28	90+87.75	6 01.3	29	150	84.6	Sun clear.
		0 37	90+88	6 01.4	29	149.6	83.0	Sun clear.
		Means	90+87.9	6 01.27	29		84.0	
	Exposed to the Sun.	0 46	90+88	6 02.4	18	149.0	83.5	Sun clear. At 6^m 02^s.4, terminal arc = 18°
		1 00	90+88	6 05.8	16.75	146	83.2	Sun clear. At 5 58.5 or 98th vib. arc = 17.25
		1 12	90+87.75	6 06.4	16.5	147	83.0	Sun clear. At 5 59.1 or 98th vib. arc = 17.0
		1 24	90+87.75	6 06.8	15.5	145	83.4	Sun clear. At 5 59.5 or 98th vib. arc = 16.0
		Means	90+87.9	6 05.35	16.7	146.75	83.3	Time = 5^m 59.98^s, arc = 17.06
	Screened from Sun.	1 33	90+87.75	6 07.6	24.5	145.0	83.8	Sun clear. At 6^m 0.0^s or 98th vib. arc = 24.75 Not included in the mean.
		1 46	90+87.75	6 08.8	27.5	144.0	83.8	Sun clear. At 6 01.4 or 98th vib. arc = 28.25
		1 55	90+87.75	6 09.0	27.75	140.8	82.8	Sun clear. At 6 01.6 or 98th vib. arc = 28.5
		Means	90+87.75	6 08.9	27.62		83.3	Time = 6^m 01^s.5, arc = 28.38

Taking the mean of the arcs in the shade, and in the sun, when the time of vibrating was the same, we have, Terminal Excess = 11°.5; Difference of temperature in sun and in shade = 63°.1.

Some of these observations again appear to indicate, that the full effect of diminishing the terminal arc was not produced immediately on exposing the needle to the sun's rays, nor was the full effect of increasing it immediately produced on screening the needle from their influence. The first observation with the unmagnetized needle exposed to the sun, commenced immediately that the screen was removed, and the terminal arc was 25¼°; in the next observation the terminal arc was 23½°; but in those which followed, it was reduced to 22° and 21°, which appeared to be the limit. The observations with the magnetized needle give similar results. The terminal arc was 21½° in the first observation with the needle exposed to the sun, which commenced immediately that the screen was removed; and this arc was only 17½° and 16° in the subsequent observations. The result was similar in the first observation in the sun on the 4th of July; although the difference between the terminal arc in this and the following observations was not so considerable: but in the first observation when the needle was screened, after having been exposed to the sun, and which commenced immediately that the needle was screened, the terminal arc was only 24¾° instead of 29°, which it had been in the shade previous to exposure to the sun. This circumstance would appear to indicate that the diminution of the terminal arc, on exposure to the sun, was caused by the heat which it imparted; but subsequent observations clearly showed that this was not the case, and that the effect was only so far dependent on the heat of the sun, that this appeared in some instances to measure the intensity of the action which produced the diminution. These observations in July, compared with those in April, appear to indicate that the effect of the sun's rays on the magnetized needle in April was greater than in July; although their intensity, measured by the heat imparted, was much less in the former case than in the latter. If, however, such is really the case, nothing but observations carefully made and repeated during a series of years, would satisfactorily establish such a fact. It may appear that I have unnecessarily multiplied observations all pointing to the same conclusions: my object in making them was, in the first instance, to satisfy myself that the effects which I observed invariably took place under certain circumstances; and I, in all cases, give these repeated observations, that others may be enabled to draw their own conclusions from them, should they doubt the correctness of mine.

In order to determine how far the vibrations of a needle are influenced by the separate rays, I placed a glass cylinder, ground plane on the under edge, upon the plate of glass covering the compass-box; and I proposed, by having fluids of different colours in this cylinder, to transmit only particular rays to the needle. Owing, however, to the irregularities on the sides of the cylinder, so much light was lost in transmission through the cylinder even when empty, that the effect was considerably diminished; and after a few trials I gave up this method of observing, as before I could have procured another cylinder better adapted to my purpose, I should no longer have been able to devote the requisite time to the inquiry. The only effect which I observed was, that transmitting the rays through half an inch of the sulphate of indigo very much diluted, appeared to be nearly equivalent to intercepting them altogether. Another method which I adopted for transmitting only particular rays, was by placing circles of glass painted with different transparent colours over the compass; but in this manner I obtained no very determinate results as respected the effects of rays of different colours. Although I failed in the particular object I had in view, the observations led to one important conclusion, which I have already noticed, that the diminution in the terminal arc was not produced by the heat imparted by the sun, either to the needle or the medium in which it vibrated.

The difference made in the apparatus was, that the compass-box was nine inches in diameter, to contain a graduated circle of paper eight inches in diameter; so that the needle having bristles in the direction of its axis projecting 1.5 inch beyond its extremities as indexes, I was enabled to read the direction of the needle, although it was hid by the coloured glass placed over the glass top of the instrument. In order that I might have a tolerably correct measure of the temperature within the compass-box during the different observations, I placed inside, a small spirit thermometer, graduated on ivory, and having the tube fixed to the scale by narrow bands of paper. I likewise employed a powerful lens eleven inches in diameter to concentrate the rays on the space in which the needle vibrated. I attempted also to bring the focus of the lens within the compass-box, but the heat was so great that it burned part of the apparatus; and I desisted, lest by injuring the essential parts I should put an end to my experiments. The coloured glass consisted of two semicircles, each having a small concentric semicircle cut out, so that they fitted each other round the tube carrying the suspending wire. Having clearly ascertained the fact that the effect produced on the magnetized needle was different from that on any other, the observations which I now made were on the vibrations of a magnetized needle alone; and I employed that which I had already used, removing however the additional weight of paper which had been fixed to it, so that its weight was now only 197 grains, and its time of vibration was likewise diminished. The following are the observations which I thus made.

Circumstances under which the Needle vibrated.	Time of commencing the Observation.	Extent of the first arc of Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer. Within the Compass-box.	Thermometer. Exposed to the Sun.	Thermometer. In Shade.	Remarks.
	July 29th. h m	° °	m s	°	°	°	°	
Screened from the Sun.	9 15	90+84.5	5 31.0	19.8	72.5	123.0	61.4	Sun clear.
	9 30	90+84.8	5 31.5	21.5	73.0	110.6	60.8	Sun clear.
	9 40	90+84.8	5 31.1	20.5	73.0	126.0	63.0	Sun clear.
Exposed to the Sun.	9 50	90+84.8	5 30.0	9.8	100.0	134.0	65.0	Sun clear. } The full effect appears to have been produced almost immediately.
	10 04	90+84.8	5 30.4	14.8	95.5	104.0	64.6	Sun obscured by dark clouds.
	10 15	90+84.8	5 29.8	9.3	102.9	120.0	64.8	Sun clear.
	10 23	90+84.8	5 31.1	14.3	102.5	108.4	64.6	Sun obscured by dark clouds, 165° + 35°.
	10 35	90+84.5	5 29.8	9.3	117.7	127.4	66.0	Sun clear.
Sun's rays concentrated by lens: Needle beyond the focus of lens: two semicircles of blue glass over.	11 20	90+84	5 33.4	18.5	114.5	143.0	68.8	Sun clear.
	11 29	90+86	5 34.0	17.3	107.5	140.0	69.5	Sun obscured, 120 sec.
	11 40	90+86.5	5 34.3	18.5	107.4	147.0	69.8	Sun obscured, 15 sec.
	11 58	90+85.5	5 34.0	20.8	104.5	142.5	70.0	Sun clear.
	0 10	89.5+83	5 32.6	19.5	109.0	143.0	72.0	Sun clear.
Blue glass removed	0 22	90+84.8	5 34.4	10.5	128.0	141.0	73.0	Light haze with coloured halo round the sun.
Lens edgewise to the Sun . .	0 44	90+84	5 33.8	15.5	113.9	115.3	73.0	Sun scarcely seen; obscured by dense haze.
Lens removed .	0 58	90+84.8	5 34.2	17.5	111.0	108.2	74.0	Sun cast a very faint shadow.
Screened from the Sun.	1 11	90+84.8	5 34.3	20.5	104.6	122.4	74.6	Sun not clear; faint haze over.
	1 21	90+85.3	5 33.6	21.5	97.0	132.7	73.6	Sun clear at intervals.
	1 35	90+85.3	5 33.7	20.5	91.7	113.6	71.8	Sun hid entirely by a hazy cloud.
			Time of making 98 vibrations.					The intensity of the needle had been so much reduced by having the rays concentrated on it in some attempts with the lens, that the time of vibration was increased.
Exposed to the Sun.	3 15	90+85.3	5 34.1	16.0	101.3	127.2	74.0	Sun obscured by a light hazy cloud.
	3 24	90+85	5 34.7	18.0	111.5	128.7	74.0	Sun slightly obscured by very light haze.
	3 45	90+85	5 33.8	15.0	117.0	132.2	74.0	Sun slightly obscured by very light haze.
Screened from the Sun.	3 56	90+85	5 34.4	20.3	104.0	130.0	74.6	Sun obscured by light haze.
	4 07	90+84.5	5 33.4	21.0	93.5	122.0	74.0	Sun obscured by hazy cloud.
	5 43	90+84.5	5 34.4	22.5	79.5	80.5	72.2	Sun obscured by cloud.
	5 54	90+84.5	5 34.6	22.0	79.0	80.3	72.2	Sun obscured by cloud.

From these observations it appears, that the diminution in the terminal arc in all cases corresponded to the intensity with which the sun shone on the needle; that this arc was in all cases increased by a screen being interposed, whether the screen entirely excluded the direct rays, as when the wooden screen was interposed, or only partially, as in the cases of the sun being obscured by haze or cloud, or the needle being covered with blue glass, which appeared to act simply as a screen; and that the diminution in the terminal arc did not correspond to the heat imparted to the needle or the medium in which it vibrated, excepting so far as this in some cases might correspond with the intensity of the sun's rays.

In the following observations I varied some of the circumstances: the day was most favourable for them, the sky continuing cloudless throughout, and the heat of the sun great, in the middle of the day intense.

Circumstances under which the Needle vibrated.		Time of commencing the Observation.	Extent of the first arc of Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer.			Remarks.
						Within the Compass-box.	Exposed to the Sun.	In Shade.	
		July 30th. h m	° °	m s	°	°	°	°	
Screened from the Sun.		10 27	90+86.5	5 41.0	19.5	77.5	132.8	64.8	The sky cloudless throughout the day, and the heat of the sun very great, in the middle of the day intense.
		10 36	90+86.5	5 41.0	20.5	77.5	139.5	68.2	
		10 45	90+86.3	5 42.2	20.5	78.4	143.5	69.0	
Exposed to the Sun.		10 56	90+86.5	5 40.4	12.8	97.7	146.0	70.0	The full effect does not appear to have been produced immediately.
		11 20	90+86.5	5 40.2	8.3	130.5	145.3	71.8	
		11 30	90+86.5	5 40.5	8.0	136.5	146.0	72.0	
Screened from the Sun.		11 44	90+86	5 41.6	17.5	124.5	147.0	72.3	The full effect does not appear to have been produced immediately.
		11 56	90+86	5 42.6	21.0	101.0	149.0	73.3	
		0 06	90+86	5 42.6	21.5	96.0	152.0	74.0	
Exposed to the Sun, but two semicircles of red glass over the Compass-box.		0 23	90+87	5 41.7	12.5	114.0	150.4	74.2	
		0 33	90+86	5 41.7	13.0	120.3	151.8	74.6	
		0 44	90+85.8	5 42.2	13.0	124.4	150.8	75.0	
The Sun's rays concentrated by the lens nearly over the space in which the Needle vibrates.	Two semicircles of red glass over the Needle.	1 11	90+85	5 42.4	13.0	129.0	150.7	75.4	
		1 26	90+85.5	5 42.7	12.8	132.9	149.0	76.0	
	The semicircles of red glass removed.	1 36	90+85.5	5 42.6	7.3	141.0	149.5	76.0	N. end of the needle vibrates, on the west side, in the violet rays from the lens.
		1 48	90+85	5 41.9	5.8	156.0	150.2	77.0	The violet rays further from the N. end of the needle.
		1 59	90+85.3	5 41.4	6.8	156.0	150.4	77.2	The violet rays again nearer to the N. end of the needle.
	Two semicircles of blue glass over the Needle.	2 13	90+85.3	5 41.8	13.5	137.8	151.0	78.0	
		2 26	90+85.5	5 43.0	17.5	124.0	149.9	78.0	
	A semicircle of blue glass over S. side of Compass-box.	2 37	90+86	5 42.8	14.5	†119.5	148.0	78.2	† The rays on the bulb of the thermometer transmitted through the blue glass.
		2 48	90+86	5 42.6	15.0	†116.5	145.5	78.2	
	A semicircle of blue glass over E. side of Compass-box.	3 04	90+85.5	5 41.4	11.0	‡126.5	140.0	78.4	‡ The rays again striking immediately on the bulb.
		3 15	90+84.5	5 41.4	13.3	‡125.5	137.0	78.4	
	Blue glass removed: Needle exposed to concentrated rays.	3 33	90+86	5 42.6	5.5	165.5	135.0	78.4	Rays of greatest intensity on S. side of compass-box.
		3 43	90+85	5 43.4	3.8	167.0	130.5	78.2	Rays of greatest intensity on centre of needle.
Lens removed: needle exposed to the Sun.		3 53	90+84.8	5 41.8	7.0	158.0	129.0	78.2	
		4 04	90+85.8	5 42.6	8.8	139.5	123.0	78.4	
Screened from the Sun.		4 14	90+85	5 42.8	17.5	123.5	120.0	78.0	The full effect does not appear to have been produced immediately.
		5 55	90+86	5 44.2	21.5	82.0	*79.5	74.0	* This thermometer had now become shaded by a wall.
		6 05	90+85.8	5 43.8	21.5	81.0	*78.3	73.2	
		6 14	90+86	5 43.8	21.8	80.0	*76.4	73.0	

Although it appears from these observations, as from the preceding ones, that the diminution of the terminal arc did not in all cases correspond to the temperature of the needle or of the medium, yet it depended essentially on the intensity of the rays in the space in which the needle vibrated; the terminal arc being 3°.8 when the rays were most concentrated, and 5°.5, 5°.8, 6°.8, 7°, 8°, and 8°.8 as their intensity was diminished. The results obtained with the coloured glasses appear to indicate that the red rays had a greater effect in diminishing the terminal arc than the blue; for although the blue on the glass was very transparent, and the red far from being so, yet when the needle was screened by the blue glass, the terminal arc was 17°.5, and when screened by the red 13°, the thermometer within the compass-box indicating nearly the same temperature in the two cases. The effect which I observed on throwing the violet rays, as separated by the lens, further from the end of the needle and then bringing them nearer, although not very decided, favours the same conclusion. No further effect than that of partially screening, appears to have been produced by making one end of the needle vibrate in the blue rays while the other vibrated in the direct light of the sun.

If we may conclude from these observations, that the red rays are those which cause the diminution in the terminal arc, we might infer that the heat imparted to the needle or to the air was the cause of this diminution; but the experiments themselves show that this was not the case. However, to remove all doubt on this part of the subject, I determined to observe the terminal arcs with the different needles when their temperature and that of the medium in which they vibrated varied, and all other circumstances remained precisely the same.

For the purpose of making these observations, I placed a graduated circle of paper in a shallow vessel of earthenware, 7.5 inches in diameter, and 1.2 inch deep, having a rim projecting 1.2 inch all round. This rim rested on the rim of another vessel of earthenware 9.4 inches in diameter, and 3.6 inches deep, and which contained hot or cold water, according to circumstances, so as to surround the upper vessel to its rim. The glass cover of the compass, having in its centre the glass tube carrying the wire of suspension, was placed over the upper vessel, which thus supplied the place of a compass-box. The needles were successively suspended within this vessel by the same wires and in the same stirrups as before; the magnetized needle by the very fine brass wire; the glass, the copper, and the unmagnetized steel needle by the much thicker wire, which caused them to vibrate in nearly the same time as the magnetized needle. So that, as before, the needles and suspending wires were the only substances of metal used in the apparatus. The upper vessel contained the small spirit thermometer which had before been placed in the compass-box. The ivory scale rested upon pieces of cork, which prevented the contact of the bulb or scale with the bottom or sides of the vessel; so that this thermometer indicated pretty accurately the temperature of the air within the vessel in which the needle vibrated; and likewise nearly that of the needle itself, by allowing some time to elapse, after making a considerable change in the temperature, previously to commencing the observations.

In making the observations, the under vessel was first filled with cold water, and the apparatus so adjusted that the needle pointed to zero on the graduated circle when the wire was devoid of torsion. The needle was then made to vibrate until the arc on the western side of zero was as near to 90° as I could obtain*; the time of its next passing zero was noted, and also the arc of vibration on the other side. At the hundredth vibration, the time and the arc beyond zero were noted, as before. The state of the thermometer in the upper vessel was taken at the commencement and likewise at the conclusion of the observation, the mean being considered as the temperature of the needle and of the air in which it vibrated. After thus making three observations, the upper vessel containing the needle was removed, the cold water contained in the lower one poured out, that vessel heated and filled with boiling water, and the upper vessel replaced and adjusted as before. Cloths steeped in boiling water were placed over the glass cover, for the double purpose of more rapidly heating the air in the vessel in which the needle vibrated, and of preventing the deposition of dew on the under surface by condensation. When the temperature of the air within the upper vessel had nearly attained its maximum, observations on the vibrations of the needle were made as before. The lower vessel was again filled with cold water, and the observations repeated. The following table contains two sets of observations with the magnetized steel needle: in the first set, the plane of the needle having been somewhat inclined laterally

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* The magnetized needle was made to vibrate by means of a weak magnet held on the outside of the box, and the other needles by turning the index to which the upper part of the suspending wire was attached, and again bringing that index to zero. As I could have no perforation either in the side of the vessel containing the needle, or in the glass cover, I was obliged to adopt this method.

to the horizon, it was rendered horizontal previous to making the second, which is the reason that the terminal arcs in the first are rather less than the corresponding arcs in the second.

	Extent of 1st Vibration.	Time of making 100 Vibrations.	100th or Terminal Arc.	Inclosed Thermometer.	Terminal Excess.	Difference of Temperature.
		m s				
Magnetized Needle. Weight = 197 grains.	90 +88	5 55.0	28°.5	62°.0		
	90 +88	5 55.4	28.75	62.5		
	90 +88	5 55.1	28.5	63.0		
Means......	90 +88	5 55.2	28.6	62.5		
	90 +89	6 01.8	34.5	137.5		
	89 +87.5	6 02.2	34.0	139.0		
	90 +89	6 00.8	33.75	137.5		
Means at High Temperature	89.7 +88.3	6 01.6	34.1	138.0	5°.05	75°.1
	90.5 +88	5 54.8	29.5	64.25		
	90.5 +88	5 54.7	29.5	62.5		
Means......	90.5 +88	5 54.75	29.5	63.37		
Means at Low Temperature	90.25+88	5 55.0	29.05	62.9		
Magnetized Needle. Weight = 197 grains.	90 +89	5 55.2	33.0	50.0		
	89.5 +89	5 55.2	32.0	50.0		
	91 +90	5 55.7	32.0	50.0		
Means......	90.2 +89.3	5 55.4	32.3	50.0		
	90 +90	6 01.8	36.5	124.5		
	90 +90.5	6 02.2	37.0	128.5		
	90 +89	6 01.5	36.5	126.0		
Means at High Temperature	90 +89.8	6 01.8	36.7	126.3	4.1	75.2
	91 +90.5	5 56.4	33.0	53.5		
	89.5 +89	5 55.8	32.75	52.0		
Means......	90.25+89.75	5 56.1	32.9	52.75		
Means at Low Temperature	90.2 +89.5	5 55.7	32.6	51.1		

Since, as might have been anticipated, it appears here that the effect upon the terminal arc, produced by an increase of temperature, is decidedly the reverse of that caused by the direct influence of the sun's rays, it follows that the latter effect does not arise from an increase in the temperature of the needle or of the medium in which it is vibrated. That there might be no doubt on the subject, I repeated the observations with the magnetized needle, and made corresponding observations with the other three, the two steel needles having been previously rendered, as before, of the same weight as the others. In these observations, contained in the following table, the extent of the arc at the hundredth vibration was observed on both sides of zero, except with the copper needle.

Needle vibrated.	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Thermometer.	Terminal Excess.	Difference of Temperature.
		m s				
Magnetized Steel Needle.	90° +88°.5	5 58.8	33° +33°.5	51°.5		
Weight = 252¼ grains.	90 +88	5 58.5	33.5+33.5	51.0		
	90 +88.5	5 58.2	33.5+33.5	51.5		
Means......	90 +88.3	5 58.5	33.3+33.5	51.3		
	90 +88	6 13.2	40 +40	140.5		
	90 +88	6 11.8	39 +38.5	135.5		
	90 +88	6 11.8	41 +39.8	134.0		
Means at High Temperature.	90 +88	6 12.3	40 +39.4	136.7	5°.8	85°.2
	90.5+88.5	6 06.5	34 +34	51.75		
	90.5+88.5	6 05.0	35 +34	51.75		
	90.5+88	6 05.2	35 +34	51.75		
Means......	90.5+88.3	6 05.6	34.7+34	51.75		
Means at Low Temperature.	90.3+88.3	6 02.05	34 +33.8	51.5		
Unmagnetized Steel Needle.	90 +87	5 52.8	21 +22	49.0		
Weight = 252¼ grains.	90 +88	5 52.6	21 +23	49.5		
	90 +87	5 52.6	21 +23	50.0		
Means......	90 +87.3	5 52.7	21 +22.7	49.5		
	89 +87	5 51.4	26 +26.5	143.5		
	90 +88	5 50.8	25.5+26.5	139.0		
	90 +87.5	5 50.5	26 +26.5	130.5		
Means at High Temperature.	89.7+87.8	5 50.9	25.8+26.5	137.7	4.4	88.6
	90.5+88	5 50.0	22 +22	48.0		
	90 +87.5	5 49.9	21.5+22	48.5		
	90 +87	5 49.8	21.5+21.5	49.5		
Means......	90.2+87.5	5 49.9	21.7+21.8	48.7		
Means at Low Temperature.	90.1+87.4	5 51.3	21.3+22.2	49.1		

Needle vibrated.	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Thermometer.	Terminal Excess.	Difference of Temperature.
	° °	m s	° °	°		
Copper Needle.	90 +89	5 51.1	28	57.0		
Weight = 252¼ grains.	89.5+88	5 51.2	28	57.0		
	90 +88.5	5 51.2	28	57.0		
Means......	89.8+88.5	5 51.2	28	57.0		
	91 +89	5 49.9	32	136.5		
	89.5+89	5 49.8	32.3	138.0		
	90 +88.5	5 49.6	32	135.0		
Means at High Temperature.	90.2+88.8	5 49.8	32.1	136.5	4.0	79.75
	90 +89.5	5 51.2	28	57.5		
	90 +88	5 51.0	28.5	56.0		
	90 +88	5 51.2	28.5	56.0		
Means......	90 +88.5	5 51.1	28.3	56.5		
Means at Low Temperature.	89.9+88.5	5 51.15	28.1	56.75		
Glass Needle.	90.5+90	5 56.0	27	51.0		
Weight = 252¼ grains.	90 +88	5 56.2	26.5	51.0		
	90 +88.5	5 56.2	26.5	52.0		
Means......	90.2+88.8	5 56.1	26.7	51.3		
	90 +88	5 56.6	32.5+31.5	142.0		
	90 +88.3	5 56.4	31 +32	139.0		
	90 +88	5 56.4	32 +31.5	135.5		
Means at High Temperature.	90 +88.1	5 56.5	31.8+31.7	138.8	5.4	86.6
	90 +88	5 56.4	26 +25.5	57.0		
	90.5+88.5	5 56.0	26 +26	51.5		
	91 +90	5 56.2	26.5+26	50.75		
Means......	90.5+88.8	5 56.2	26.2+25.8	53.1		
Means at Low Temperature.	90.3+88.8	5 56.2	26.3	52.2		

The effects here are not very different with the four needles. The glass needle and the two steel needles presenting broader surfaces on their sides to the air's resistance than the copper needle, it was to be expected that the terminal excess with these should be greater than with that needle; and I am not aware of any circumstance, except the shorter time during which the vibrations continued, that should have rendered it less with the unmagnetized steel needle than with the other two. The principal fact, however, which I looked to ascertaining by these experiments was, whether the terminal excess was of the same character here when the temperature was increased, as that arising from vibrating the needle successively in the shade and exposed to the sun, when an increase of temperature likewise took place; and on this point they were quite conclusive, showing clearly, that if the terminal excess is considered plus in the latter case, it will be minus in the former. It is evident then from all these results, that if the rays of the sun had simply, uniformly increased the temperature of the medium in which the needle vibrated, and of the needle itself, the effect would have been in all cases to increase the length of the terminal arc, instead of diminishing it, as was invariably the case when exposure to the rays of the sun caused an increase of temperature. There can therefore be no doubt that the influence of the sun was not confined to uniformly heating the medium and the needle, but that, in all cases, other effects than would arise from this were produced, and that the influence upon the magnetized needle was very different from that upon either of the others.

I next proposed to determine the effects that would be produced on the arcs of vibration by the heat of a fire. For this purpose I placed the apparatus before a strong fire, at the distance of about two feet from the front, and six inches below the bottom of the iron grate containing it, and vibrated the magnetized needle, and likewise the glass needle, when successively screened from, and exposed to its direct influence. The observations, which are contained in the subjoined Table, show that the effect produced by exposure to the fire, though small, was to bring the needle sooner to rest, or that it was of the same character as that produced by exposure to the sun. I am not disposed to lay any stress upon the circumstance that the terminal excess was almost precisely the same in the two cases, but to attribute it to the small errors in the observations having accidentally so compensated each other as to produce this very close agreement. Indeed, if I could have detected such minute differences, the terminal excess ought to have been rather greater with the magnetized than with the glass needle, since the intensity of the fire's heat appeared to be greater with the former than with the latter. We may, however, infer from these experiments, that if the intensity of the fire's heat had been precisely the same with the two needles, no sensible difference would have been observed in the effects produced on them. The observations were made in this order: The first three observations with the apparatus screened from the fire by a thick board; then immediately the four with the screen removed; after which it was replaced, and the other observations made.

Needle vibrated.	Needle vibrated screened from the Fire.				Needle vibrated exposed to the Fire.					
	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Therm.	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Therm.	Terminal excess.	Difference of Temp.
Magnetized Needle.	90°+89°	m s 5 48.2	35° +34°.5	51°.0						
Weight = 252⅓ grains.	90+88.5	5 48.4	34.5+34.3	51.5						
	90+89	5 48.4	34.5+34.3	52.0	90°+89°	m s 5 48.8	34°.3+34°	56°.5		
	90+89	5 49.2	34.5+34	84.0	90+89	5 49.8	33.5+34	76.0		
	90+88.5	5 48.8	34.5+34.2	76.5	90+88.5	5 50.4	33.5+34.2	83.0		
	90+89.5	5 48.7	35 +34.5	67.0	90+89	5 50.6	33.8+34	90.0		
Means…	90+88.9	5 48.6	34.7+34.3	63.7	90+88.9	5 49.9	33.8+34	76.4	0°.57	12°.8
Glass Needle.	90+84	5 56.8	25 +25.5	58.0						
Weight = 252¼ grains.	90+85	5 57.2	25.2+25.8	58.25	90+84.5	5 58.0	24 +25.5	62.5		
	90+84	5 57.3	25 +25.5	58.75	90+85	5 58.4	24 +25.3	70.0		
	90+84	5 57.8	25 +25.3	74.5	90+85	5 58.6	24.2+25.3	75.0		
	90+84	5 57.5	25 +25.3	71.5	90+85	5 58.6	24.2+25	77.0		
Do.	90+84.2	5 57.3	25 +25.5	64.25	90+84.9	5 58.4	24.1+25.3	71.1	0.56	6.9

From all the experiments which I have described, there can, I think, be no doubt that the rays of the sun have a peculiar influence on a magnetized needle, which causes, when such a needle is exposed to them, a greater diminution in its arcs of vibration than in those of any other needle under like circumstances; and that this effect is independent of the heat imparted to the needle or to the medium in which it vibrates. That part of the effect which is produced on all needles may perhaps be caused in this manner: as the air directly below the needle is in the shade, and therefore colder than that above it, a current of air will pass the edges of the needle, which may considerably increase the resistance and consequently diminish the terminal arc; and this may possibly account for the full effect not taking place immediately, since these currents would not be excited in full force immediately on exposing the needle to the sun, nor on screening it would they immediately subside*. Had this, however, been the

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* If this is the cause of the terminal excess with the non-magnetic needles, this excess would nearly vanish if a wire frame of the same form as the needles were successively vibrated in the shade and exposed to the influence of the sun, since in this case there would be little shadow below the needle. This experiment I proposed making, but have not yet had an opportunity.

only cause of the terminal excess with the magnetized needle as well as with the others, this excess would have been nearly the same for all, or it would only have differed according to the thickness of the needle. The terminal excess ought in this case to have been nearly the same for the glass, the unmagnetized steel and the magnetized steel needles, and less for the copper than for either of these. This accords, in some measure, with the experimental results which I obtained with the copper needle, the glass needle, and the unmagnetized steel needle; but as the effect on the last was only about four-sevenths of that on the magnetized steel needle, we must, for part of the effect upon this needle, look to causes distinct from that which produced the effect on the others.

It is extremely difficult to point out any principle to which this effect upon the magnetized needle can be referred. Are we to infer from these experiments that light and magnetism have relative density, although the density of either is evanescent with regard to that of the rarest gas; and that therefore light may offer a sensible resistance to magnetic particles in their passage through it, and consequently also to the bodies with which they are united? That light is of such extreme tenuity as to offer no resistance to the passage of the rarest gas,—of which, however, we have no proof,—cannot be adduced as an argument against such an inference. Or, is it possible that the effect may be produced in a manner similar to that on needles vibrating within metallic rings? If this be the case, we must suppose that the rays become magnetic by induction, in their passage by the needle, and that their maximum of magnetism not being developed until after they have passed it, the most magnetic rays will always be in the rear of the needle, and by their attraction impede its progress. If the effect is produced in this manner, we might expect, when a strong magnet is brought near to a ray of light transmitted through a small opening into a dark room, that the ray would be inflected. I have not had an opportunity of making this experiment in a conclusive manner, but in the trials which I have made I have observed no such effect.

In the conclusion of my former paper I stated, that as magnetic influence in the compound solar rays was indicated by the effects which I had described, this would tend to remove the doubts which had been entertained respecting the results obtained by **Morichini**, by means of the violet rays; and Mrs. **Somerville**'s paper, read almost immediately after mine, describing the effects which that lady had observed to be produced under different circumstances by the more refrangible rays, appeared completely to verify MORICHINI's results, and to corroborate my opinion. Although the experiments of Mrs. SOMERVILLE have, on repetition, in many instances failed, we cannot, seeing the precautions that were taken, suppose that the effects described were due to other causes than the influence of the rays, but must rather infer that we are not aware of all the circumstances which may interfere with the success of the experiment. It cannot, however, be denied that the subject is at present involved in much mystery; and it is therefore very desirable that the circumstances on which the success of Mrs. SOMERVILLE's experiment depends should be clearly ascertained, and that the effects which I have invariably found to be produced by the compound rays should be traced to some known principle of action. I had proposed to myself to make several series of observations with the view of obtaining comparative results with different azimuths of the sun, at different seasons of the year, and likewise with the horizontal needle and the dipping needle vibrated both in the meridian and at right angles to it; and also to determine, with some degree of precision, the effects produced by the several separated rays under different circumstances. But in the experiments which I have already made, I have met with so many and such vexatious interruptions, arising principally from the uncertainty of our climate, and partly from my not always being able to avail myself of a favourable state of the weather, that seeing no prospect of succeeding in experiments requiring continued clear weather and uninterrupted leisure, I must leave them to be made by those who may be placed under more favourable circumstances, and be content to prosecute the inquiry by making such experiments as intervals of leisure, which I may have during fine weather, will allow.

Royal Military Academy,
2nd June, 1828.

S. H. CHRISTIE.

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TO THE

PHILOSOPHICAL TRANSACTIONS

FOR THE YEAR 1828.

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PRINTED BY RICHARD TAYLOR,
RED LION COURT, FLEET STREET.
MDCCCXXVIII.

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