THE PRACTICAL ASTRONOMY OF THE MOON:

OR, NEW

TABLES OF THE MOON'S MOTIONS,

Exactly conſtructed from Sir *Iſaac Newton*'s Theory, as publiſhed by Dr. *Gregory* in his Aſtronomy.

With PRECEPTS for computing the Place of the Moon, and Eclipſes of the Luminaries.

By RICHARD DUNTHORNE.

CAMBRIDGE:

Printed for the AUTHOR, and ſold by JOHN SENEX at the *Globe* over againſt St. *Dunſtan*'s Church, *Fleet-ſtreet*, *London*; and by JAMES FLETCHER in *Oxford*. MDCCXXXIX.

National Oceanic and Atmospheric Administration

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TO

THE REVEREND

Dr. LONG,

MASTER OF PEMBROKE-HALL

IN THE

UNIVERSITY OF CAMBRIDGE,

F. R. S.

Theſe TABLES of the LUNAR MOTIONS, are
moſt humbly inſcribed

by his obliged

and moſt obedient Servant

RI. DUNTHORNE.

TO THE

READER.

THe following Tables of the Lunar Motions were at first calculated purely for my own private Use; but being informed by several Friends who are more conversant in Books than my self, that there has not been a compleat Set of such Tables framed from the Theory of Gravity, as yet published; I was willing to present you with these: They are constructed from Sir Isaac Newton's *Theory, as published by Dr.* Gregory *in his Astronomy; and though I find, by comparing them with Observations, that the Newtonian Numbers are a little deficient, they will (at least) have this Use, that such Persons as desire farther to rectify the Lunar Astronomy, may by being assisted with Tables already framed from nearly true Numbers, be better enabled to compare those Numbers with Observations, and by that means obtain Numbers still more exact.*

In shewing the Use of the Tables, I have inserted a new Method of computing Eclipses of the Sun, as they are seen from a given Place upon the Earth's Surface; wherein I have endeavoured to clear that Part of Astronomy from the Imputation of Want of Geometry, *to which, notwithstanding the great Improvements of* Kepler, Flamsteed *and others, it has hitherto been liable.*

Instead of Tables as his Author it seems intended, remain behind at Westchester in the year 1722

THE

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A Table

Sig.	♈ ♎	♉ ♏	♊ ♐	
°	° ′ ″	° ′ ″	° ′ ″	°
0	0. 0. 0	11. 29. 33	20. 11. 16	30
1	0. 23. 54	11. 50. 35	20. 23. 49	29
2	0. 47. 49	12. 11. 26	20. 35. 59	28
3	1. 11. 42	12. 32. 5	20. 47. 48	27
4	1. 35. 34	12. 52. 31	20. 59. 13	26
5	1. 59. 25	13. 12. 44	21. 10. 15	25
6	2. 23. 14	13. 32. 45	21. 20. 53	24
7	2. 47. 1	13. 52. 32	21. 31. 7	23
8	3. 10. 45	14. 12. 5	21. 40. 58	22
9	3. 34. 26	14. 31. 24	21. 50. 24	21
10	3. 58. 4	14. 50. 29	21. 59. 25	20
11	4. 21. 38	15. 9. 18	22. 8. 2	19
12	4. 45. 8	15. 27. 51	22. 16. 14	18
13	5. 8. 34	15. 46. 9	22. 24. 0	17
14	5. 31. 55	16. 4. 11	22. 31. 21	16
15	5. 55. 11	16. 21. 57	22. 38. 16	15
16	6. 18. 21	16. 39. 26	22. 44. 45	14
17	6. 41. 26	16. 56. 37	22. 50. 49	13
18	7. 4. 24	17. 13. 31	22. 56. 26	12
19	7. 27. 15	17. 30. 7	23. 1. 36	11
20	7. 49. 59	17. 46. 25	23. 6. 20	10
21	8. 12. 36	18. 2. 24	23. 10. 38	9
22	8. 35. 5	18. 18. 3	23. 14. 29	8
23	8. 57. 26	18. 33. 24	23. 17. 53	7
24	9. 19. 39	18. 48. 25	23. 20. 49	6
25	9. 41. 42	19. 3. 5	23. 23. 19	5
26	10. 3. 37	19. 17. 26	23. 25. 22	4
27	10. 25. 21	19. 31. 25	23. 26. 57	3
28	10. 46. 56	19. 45. 3	23. 28. 5	2
29	11. 8. 20	19. 58. 20	23. 28. 46	1
30	11. 29. 33	20. 11. 16	23. 29. 0	0
	♓ ♍	♒ ♌	♑ ♋	Sig.

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

Sig.	♋	♌	♍
	° ′ ″	° ′ ″	° ′ ″
0	90. 0. 0	122. 11. 24	152. 5. 51
1	91. 5. 25	123. 13. 47	153. 3. 5
2	92. 10. 50	124. 15. 59	154. 0. 10
3	93. 16. 13	125. 18. 2	154. 57. 8
4	94. 21. 36	126. 19. 53	155. 53. 57
5	95. 26. 56	127. 21. 34	156. 50. 39
6	96. 32. 14	128. 23. 4	157. 47. 14
7	97. 37. 30	129. 24. 24	158. 43. 41
8	98. 42. 42	130. 25. 32	159. 40. 2
9	99. 47. 51	131. 26. 30	160. 36. 16
10	100. 52. 56	132. 27. 16	161. 32. 23
11	101. 57. 57	133. 27. 52	162. 28. 24
12	103. 2. 53	134. 28. 17	163. 24. 20
13	104. 7. 44	135. 28. 30	164. 20. 10
14	105. 12. 29	136. 28. 33	165. 15. 54
15	106. 17. 8	137. 28. 25	166. 11. 34
16	107. 21. 41	138. 28. 7	167. 7. 9
17	108. 26. 7	139. 27. 37	168. 2. 40
18	109. 30. 26	140. 26. 57	168. 58. 6
19	110. 34. 38	141. 26. 6	169. 53. 29
20	111. 38. 42	142. 25. 5	170. 48. 49
21	112. 42. 38	143. 23. 53	171. 44. 5
22	113. 46. 26	144. 22. 32	172. 39. 18
23	114. 50. 6	145. 21. 0	173. 34. 29
24	115. 53. 37	146. 19. 18	174. 29. 37
25	116. 56. 58	147. 17. 27	175. 24. 44
26	118. 0. 11	148. 15. 26	176. 19. 49
27	119. 3. 14	149. 13. 16	177. 14. 53
28	120. 6. 7	150. 10. 56	178. 9. 56
29	121. 8. 50	151. 8. 28	179. 4. 58
30	122. 11. 24	152. 5. 51	180. 0. 0

Sig.	♎	♏	♐
	° ′ ″	° ′ ″	° ′ ″
0	180. 0. 0	207. 54. 9	237. 48. 36
1	180. 55. 2	208. 51. 32	238. 51. 10
2	181. 50. 4	209. 49. 4	239. 53. 53
3	182. 45. 7	210. 46. 44	240. 56. 46
4	183. 40. 11	211. 44. 34	241. 59. 49
5	184. 35. 16	212. 42. 33	243. 3. 2
6	185. 30. 23	213. 40. 42	244. 6. 23
7	186. 25. 31	214. 39. 0	245. 9. 54
8	187. 20. 42	215. 37. 28	246. 13. 34
9	188. 15. 55	216. 36. 7	247. 17. 22
10	189. 11. 11	217. 34. 55	248. 21. 18
11	190. 6. 31	218. 33. 54	249. 25. 22
12	191. 1. 54	219. 33. 3	250. 29. 34
13	191. 57. 20	220. 32. 23	251. 33. 53
14	192. 52. 51	221. 31. 53	252. 38. 19
15	193. 48. 26	222. 31. 35	253. 42. 52
16	194. 44. 6	223. 31. 27	254. 47. 31
17	195. 39. 50	224. 31. 30	255. 52. 16
18	196. 35. 40	225. 31. 43	256. 57. 7
19	197. 31. 36	226. 32. 8	258. 2. 3
20	198. 27. 37	227. 32. 44	259. 7. 4
21	199. 23. 44	228. 33. 30	260. 12. 9
22	200. 19. 58	229. 34. 28	261. 17. 18
23	201. 16. 19	230. 35. 36	262. 22. 30
24	202. 12. 46	231. 36. 56	263. 27. 46
25	203. 9. 21	232. 38. 26	264. 33. 4
26	204. 6. 3	233. 40. 7	265. 38. 24
27	205. 2. 52	234. 41. 58	266. 43. 47
28	205. 59. 50	235. 44. 1	267. 49. 10
29	206. 56. 55	236. 46. 13	268. 54. 35
30	207. 54. 9	237. 48. 36	270. 0. 0

Sig.	♑	♒	♓
0'	° ' "	° ' "	° ' "
0	270. 0. 0	302. 11. 24	332. 5. 51
1	271. 5. 25	303. 13. 47	333. 3. 5
2	272. 10. 50	304. 15. 59	334. 0. 10
3	273. 16. 13	305. 18. 2	334. 57. 8
4	274. 21. 36	306. 19. 53	335. 53. 57
5	275. 26. 56	307. 21. 34	336. 50. 39
6	276. 32. 14	308. 23. 4	337. 47. 14
7	277. 37. 30	309. 24. 24	338. 43. 41
8	278. 42. 42	310. 25. 32	339. 40. 2
9	279. 47. 51	311. 26. 30	340. 36. 16
10	280. 52. 56	312. 27. 16	341. 32. 23
11	281. 57. 57	313. 27. 52	342. 28. 24
12	283. 2. 53	314. 28. 17	343. 24. 20
13	284. 7. 44	315. 28. 30	344. 20. 10
14	285. 12. 29	316. 28. 33	345. 15. 54
15	286. 17. 8	317. 28. 25	346. 11. 34
16	287. 21. 41	318. 28. 7	347. 7. 9
17	288. 26. 7	319. 27. 37	348. 2. 40
18	289. 30. 26	320. 26. 57	348. 58. 6
19	290. 34. 38	321. 26. 6	349. 53. 29
20	291. 38. 42	322. 25. 5	350. 48. 49
21	292. 42. 38	323. 23. 53	351. 44. 5
22	293. 46. 26	324. 22. 32	352. 39. 18
23	294. 50. 6	325. 21. 0	353. 34. 29
24	295. 53. 37	326. 19. 18	354. 29. 37
25	296. 56. 58	327. 17. 27	355. 24. 44
26	298. 0. 11	328. 15. 26	356. 19. 49
27	299. 3. 14	329. 13. 16	357. 14. 53
28	300. 6. 7	330. 10. 56	358. 9. 56
29	301. 8. 50	331. 8. 28	359. 4. 58
30	302. 11. 24	332. 5. 51	360. 0. 0

Substract from the apparent.

The true Place of the Sun.

Sig.	♈ ♎	♉ ♏	♊ ♐	
°	′ ″	′ ″	′ ″	°
0	0. 0	8. 23	8. 46	30
1	0. 20	8. 34	8. 35	29
2	0. 40	8. 44	8. 24	28
3	1. 0	8. 53	8. 13	27
4	1. 19	9. 2	8. 1	26
5	1. 39	9. 10	7. 48	25
6	1. 58	9. 17	7. 34	24
7	2. 18	9. 24	7. 20	23
8	2. 37	9. 30	7. 6	22
9	2. 56	9. 36	6. 51	21
10	3. 15	9. 40	6. 35	20
11	3. 34	9. 44	6. 19	19
12	3. 52	9. 48	6. 2	18
13	4. 11	9. 50	5. 44	17
14	4. 29	9. 52	5. 27	16
15	4. 46	9. 54	5. 9	15
16	5. 4	9. 54	4. 50	14
17	5. 21	9. 54	4. 31	13
18	5. 37	9. 53	4. 12	12
19	5. 54	9. 51	3. 52	11
20	6. 10	9. 49	3. 32	10
21	6. 25	9. 46	3. 11	9
22	6. 40	9. 42	2. 51	8
23	6. 55	9. 38	2. 30	7
24	7. 9	9. 32	2. 9	6
25	7. 23	9. 26	1. 48	5
26	7. 36	9. 20	1. 26	4
27	7. 49	9. 12	1. 5	3
28	8. 1	9. 4	0. 43	2
29	8. 12	8. 55	0. 22	1
30	8. 23	8. 46	0. 0	0
	♓ ♍	♒ ♌	♑ ♋	Sig.

Add to the apparent.

Substract from the apparent.

The mean Anomaly of the Sun.

Sig.	0	1	2	3	4	5	
0	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	0
0	0. 0	3. 48	6. 39	7. 45	6. 47	3. 57	30
1	0. 8	3. 55	6. 43	7. 45	6. 43	3. 50	29
2	0. 16	4. 2	6. 47	7. 45	6. 39	3. 43	28
3	0. 24	4. 9	6. 51	7. 45	6. 35	3. 35	27
4	0. 32	4. 16	6. 54	7. 45	6. 30	3. 28	26
5	0. 40	4. 22	6. 58	7. 44	6. 26	3. 20	25
6	0. 48	4. 29	7. 1	7. 44	6. 21	3. 13	24
7	0. 56	4. 35	7. 5	7. 43	6. 16	3. 5	23
8	1. 3	4. 42	7. 8	7. 42	6. 11	2. 58	22
9	1. 11	4. 48	7. 11	7. 41	6. 6	2. 50	21
10	1. 19	4. 54	7. 14	7. 40	6. 1	2. 42	20
11	1. 27	5. 0	7. 17	7. 38	5. 56	2. 35	19
12	1. 35	5. 6	7. 20	7. 37	5. 51	2. 27	18
13	1. 43	5. 12	7. 22	7. 35	5. 45	2. 19	17
14	1. 50	5. 18	7. 25	7. 34	5. 40	2. 11	16
15	1. 58	5. 24	7. 27	7. 32	5. 34	2. 3	15
16	2. 6	5. 30	7. 29	7. 30	5. 28	1. 55	14
17	2. 13	5. 35	7. 31	7. 28	5. 22	1. 47	13
18	2. 21	5. 41	7. 33	7. 25	5. 16	1. 39	12
19	2. 28	5. 46	7. 35	7. 23	5. 10	1. 31	11
20	2. 36	5. 52	7. 36	7. 20	5. 4	1. 22	10
21	2. 43	5. 57	7. 38	7. 18	4. 58	1. 14	9
22	2. 51	6. 2	7. 39	7. 15	4. 51	1. 6	8
23	2. 58	6. 7	7. 41	7. 12	4. 45	0. 58	7
24	3. 6	6. 12	7. 42	7. 9	4. 38	0. 50	6
25	3. 13	6. 16	7. 43	7. 5	4. 31	0. 41	5
26	3. 20	6. 21	7. 43	7. 2	4. 25	0. 33	4
27	3. 27	6. 26	7. 44	6. 58	4. 18	0. 25	3
28	3. 34	6. 30	7. 45	6. 55	4. 11	0. 17	2
29	3. 41	6. 34	7. 45	6. 51	4. 4	0. 8	1
30	3. 48	6. 39	7. 45	6. 47	3. 57	0. 0	0
	11	10	9	8	7	6	Sig.

Add to the apparent.

Years of Christ current	mean Lon. ☉ s ° ′ ″	Apogee ☉ s ° ′ ″
1	9. 7.53.10	2. 7.59.30
1501	9.19.13.10	3. 4.14.30
1601	9.19.58.30	3. 5.59.30
1681	9.20.34.46	3. 7.23.30
1701	9.20.43.50	3. 7.44.30
1721	9.20.52.54	3. 8. 5.30
1741	9.21. 1.58	3. 8.26.30
1761	9.21.11. 2	3. 8.47.30
1781	9.21.20. 6	3. 9. 8.30
1801	9.21.29.10	3. 9.29.30
1821	9.21.38.14	3. 9.50.30
1841	9.21.47.18	3.10.11.30
1861	9.21.56.22	3.10.32.30
1881	9.22. 5.26	3.10.53.30
1901	9.22.14.30	3.11.14.30
2001	9.22.59.50	3.12.59.30

Years	mean Mot ☉ s ° ′ ″	Mot. Apog. s ° ′ ″
20	0. 0. 9. 4	0. 0.21. 0
40	0. 0.18. 8	0. 0.42. 0
60	0. 0.27.12	0. 1. 3. 0
80	0. 0.36.16	0. 1.24. 0
100	0. 0.45.20	0. 1.45. 0
200	0. 1.30.40	0. 3.30. 0
300	0. 2.16. 0	0. 5.15. 0
400	0. 3. 1.20	0. 7. 0. 0
500	0. 3.46.40	0. 8.45. 0
600	0. 4.32. 0	0.10.30. 0
700	0. 5.17.20	0.12.15. 0
800	0. 6. 2.40	0.14. 0. 0
900	0. 6.48. 0	0.15.45. 0
1000	0. 7.33.20	0.17.30. 0
2000	0.15. 6.40	1. 5. 0. 0
3000	0.22.40. 0	1.22.30. 0
4000	1. 0.13.20	2.10. 0. 0
5000	1. 7.46.40	2.27.30. 0
6000	1.15.20. 0	3.15. 0. 0

Years	mean Mot. ☉ s ° ′ ″	Mot Ap ′ ″
1	11.29.45.40	1. 3
2	11.29.31.20	2. 6
3	11.29.17. 0	3. 9
4	0. 0. 1.49	4. 12
5	11.29.47.29	5. 15
6	11.29.33. 9	6. 18
7	11.29.18.49	7. 21
8	0. 0. 3.38	8. 24
9	11.29.49.18	9. 27
10	11.29.34.58	10. 30
11	11.29.20.38	11. 33
12	0. 0. 5.26	12. 36
13	11.29.51. 7	13. 39
14	11.29.36.47	14. 42
15	11.29.22.27	15. 45
16	0. 0. 7.15	16. 48
17	11.29.52.55	17. 51
18	11.29.38.35	18. 54
19	11.29.24.16	19. 57
20	0. 0. 9. 4	21. 0

Months common	mean Mot. ☉ s ° ′ ″	ap. ″
Janua.	0. 0. 0. 0	0
Februa.	1. 0.33.18	5
March	1.28. 9.11	10
April	2.28.42.30	16
May	3.28.16.40	21
June	4.28.49.58	26
July	5.28.24. 8	31
August	6.28.57.26	37
Septem.	7.29.30.44	42
October	8.29. 4.54	47
Novem	9.29.38.12	52
Decem.	10.29.12.32	58

In Leap-Year after February, add one Day, and one Day's Motion.

This Table is formed from what this Author says in the Philos. Transact. N°. 482 that he had determined the mean motion of ☉ Sun at Greenwich the last Day of December at Noon An. 1700. O. S. ♋ 20°. 43'. 40". & its Apogee ♋. 7°. 30'. 00".

Years of Christ current	mean Lon. ☉ S. ° ' "	Apogee ☉ S. ° ' "
1	9.07.53.00	2.07.45.00
1501	9.19.13.00	3.04.00.00
1601	9.19.58.20	3.05.45.00
1681	9.20.34.36	3.07.09.00
1701	9.20.43.40	3.07.30.00
1721	9.20.52.44	3.07.51.00
1741	9.21.01.48	3.08.12.00
1761	9.21.10.52	3.08.33.00
1781	9.21.19.56	3.08.54.00
1801	9.21.29.00	3.09.15.00
1821	9.21.38.04	3.09.36.00
1841	9.21.47.08	3.09.57.00
1861	9.21.56.12	3.10.18.00
1881	9.22.05.16	3.10.39.00
1901	9.22.14.20	3.11.00.00
2001	9.22.59.40	3.12.45.00

The Abbé de la Caille makes the mean Longitude of the Sun at the Beginning of ☉ Year 1760 to be 9s. 10°. 34'. 53". The Place of the Apogee 3s. 8°. 40'. 59". And the mean motion of the Sun for 100 Years, the last being a Bissextile, 45'. 55",6. Likewise the mean motion of the Apogee for the same Time, 1°. 49'. 10". And the greatest Equation of the Sun's Center 1°. 55'. 31",6

These Tables of Mr Dunthorne's are composed for ☉ Julian or Old Stile as those of Abbe de la Caille are for the New. In order to

compare them together therefore from ye Time given in De la Caille's Tables substract 11 days & then calculate for that Time by these Tables.

Thus by ye beginning of 1760 above is to be understood ye Noon of January ye 1st. 1760 From thence substract 11 & we have Decemb^r ye 21st. 1759.

1759	9·20·40·33	3·08·45·24
Decemb^r	10·29·12·22	58
21	20·41·55	3·08·46·22
☉'s mean Long.	9·10·34·50	mean anom.
De la Caille	9·10·34·53	
	+3	

By Dr Halley's Tables we have

☉'s mean Longitude —— 9°.10°.34.40
9·10·34·53
+13

Days.	mean Mot. ☉ s	°	′	″	Hours.	mean M ☉ °	′	″	H.	mean M ☉ °	′	″
					′	′	″	‴	′	′	″	‴
					″	″	‴	iv	″	″	‴	iv
1	0.	0.	59.	8								
2	0.	1.	58.	17								
3	0.	2.	57.	25	1	0.	2.	28	31	1.	16.	23
4	0.	3.	56.	33	2	0.	4.	56	32	1.	18.	51
5	0.	4.	55.	42	3	0.	7.	24	33	1.	21.	19
6	0.	5.	54.	50	4	0.	9.	51	34	1.	23.	47
7	0.	6.	53.	58	5	0.	12.	19	35	1.	26.	15
8	0.	7.	53.	7	6	0.	14.	47	36	1.	28.	42
9	0.	8.	52.	15	7	0.	17.	15	37	1.	31.	10
10	0.	9.	51.	23	8	0.	19.	43	38	1.	33.	38
11	0.	10.	50.	32	9	0.	22.	11	39	1.	36.	6
12	0.	11.	49.	40	10	0.	24.	38	40	1.	38.	34
13	0.	12.	48.	48	11	0.	27.	6	41	1.	41.	2
14	0.	13.	47.	57	12	0.	29.	34	42	1.	43.	30
15	0.	14.	47.	[illegible]	13	0.	32.	2	43	1.	45.	57
16	0.	15.	46.	13	14	0.	34.	30	44	1.	48.	25
17	0.	16.	45.	22	15	0.	36.	58	45	1.	50.	53
18	0.	17.	44.	30	16	0.	39.	26	46	1.	53.	21
19	0.	18.	43.	38	17	0.	41.	53	47	1.	55.	49
20	0.	19.	42.	47	18	0.	44.	21	48	1.	58.	17
21	0.	20.	41.	55	19	0.	46.	49	49	2.	0.	44
22	0.	21.	41.	3	20	0.	49.	17	50	2.	3.	12
23	0.	22.	40.	12	21	0.	51.	45	51	2.	5.	40
24	0.	23.	39.	20	22	0.	54.	13	52	2.	8.	8
25	0.	24.	38.	28	23	0.	56.	40	53	2.	10.	36
26	0.	25.	37.	37	24	0.	59.	8	54	2.	13.	4
27	0.	26.	36.	45	25	1.	1.	36	55	2.	15.	32
28	0.	27.	35.	53	26	1.	4.	4	56	2.	17.	59
29	0.	28.	35.	2	27	1.	6.	32	57	2.	20.	27
30	0.	29.	34.	10	28	1.	9.	0	58	2.	22.	55
31	1.	0.	33.	18	29	1.	11.	28	59	2.	25.	23
32	1.	1.	32.	27	30	1.	13.	55	60	2.	27.	51

Mean Anom.	Sig. 0 Sub.	Sig. 1 Sub.	Sig. 2 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	0. 0. 0	0. 57. 5	1. 39. 40	30
1	0. 1. 59	0. 58. 50	1. 40. 41	29
2	0. 3. 58	1. 0. 33	1. 41. 40	28
3	0. 5. 57	1. 2. 15	1. 42. 38	27
4	0. 7. 57	1. 3. 55	1. 43. 34	26
5	0. 9. 56	1. 5. 34	1. 44. 28	25
6	0. 11. 54	1. 7. 12	1. 45. 20	24
7	0. 13. 53	1. 8. 49	1. 46. 10	23
8	0. 15. 51	1. 10. 25	1. 46. 59	22
9	0. 17. 49	1. 12. 0	1. 47. 46	21
10	0. 19. 47	1. 13. 34	1. 48. 30	20
11	0. 21. 44	1. 15. 6	1. 49. 13	19
12	0. 23. 41	1. 16. 37	1. 49. 53	18
13	0. 25. 38	1. 18. 6	1. 50. 32	17
14	0. 27. 34	1. 19. 34	1. 51. 9	16
15	0. 29. 29	1. 21. 1	1. 51. 43	15
16	0. 31. 24	1. 22. 26	1. 52. 16	14
17	0. 33. 19	1. 23. 50	1. 52. 47	13
18	0. 35. 13	1. 25. 13	1. 53. 16	12
19	0. 37. 7	1. 26. 34	1. 53. 42	11
20	0. 39. 0	1. 27. 53	1. 54. 7	10
21	0. 40. 52	1. 29. 11	1. 54. 30	9
22	0. 42. 44	1. 30. 28	1. 54. 50	8
23	0. 44. 35	1. 31. 43	1. 55. 8	7
24	0. 46. 25	1. 32. 56	1. 55. 25	6
25	0. 48. 14	1. 34. 7	1. 55. 39	5
26	0. 50. 2	1. 35. 17	1. 55. 51	4
27	0. 51. 49	1. 36. 26	1. 56. 1	3
28	0. 53. 36	1. 37. 32	1. 56. 9	2
29	0. 55. 21	1. 38. 37	1. 56. 14	1
30	0. 57. 5	1. 39. 40	1. 56. 17	0
	Sig. 11 Add	Sig. 10 Add	Sig. 9 Add	Mean Anom.

mean Anom.	Sig. 3 Sub.	Sig. 4 Sub.	Sig. 5 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	1. 56. 17	1. 41. 47	0. 59. 14	30
1	1. 56. 19 +	1. 40. 47	0. 57. 27	29
2	1. 56. 19	1. 39. 44	0. 55. 39	28
3	1. 56. 16	1. 38. 40	0. 53. 49	27
4	1. 56. 11	1. 37. 34	0. 51. 58	26
5	1. 56. 4	1. 36. 26	0. 50. 6	25
6	1. 55. 55	1. 35. 16	0. 48. 14	24
7	1. 55. 44	1. 34. 5	0. 46. 21	23
8	1. 55. 31	1. 32. 51	0. 44. 26	22
9	1. 55. 15	1. 31. 36	0. 42. 31	21
10	1. 54. 57	1. 30. 19	0. 40. 35	20
11	1. 54. 37	1. 29. 0	0. 38. 39	19
12	1. 54. 15	1. 27. 40	0. 36. 41	18
13	1. 53. 52	1. 26. 18	0. 34. 42	17
14	1. 53. 26	1. 24. 54	0. 32. 43	16
15	1. 52. 57	1. 23. 29	0. 30. 43	15
16	1. 52. 27	1. 22. 2	0. 28. 43	14
17	1. 51. 55	1. 20. 34	0. 26. 42	13
18	1. 51. 20	1. 19. 4	0. 24. 41	12
19	1. 50. 43	1. 17. 32	0. 22. 39	11
20	1. 50. 5	1. 15. 59	0. 20. 37	10
21	1. 49. 24	1. 14. 25	0. 18. 34	9
22	1. 48. 41	1. 12. 49	0. 16. 31	8
23	1. 47. 57	1. 11. 11	0. 14. 28	7
24	1. 47. 10	1. 9. 32	0. 12. 25	6
25	1. 46. 21	1. 7. 52	0. 10. 21	5
26	1. 45. 30	1. 6. 11	0. 8. 17	4
27	1. 44. 37	1. 4. 29	0. 6. 13	3
28	1. 43. 43	1. 2. 45	0. 4. 9	2
29	1. 42. 46	1. 1. 0	0. 2. 4	1
30	1. 41. 47	0. 59. 14	0. 0. 0	0
	Sig. 8 Add	Sig. 7 Add	Sig. 6 Add	mean Anom.

+ This Author in ye Philos. Trans. No. 482. says ye Suns greatest Equation is only 1°. 55′. 40″.

	Years of Christ current	mean Long. ☽ s ° ′ ″	Apogee ☽ s ° ′ ″	Asc. Node ☽ s ° ′ ″
4.02.02.45	1	4. 1. 52. 45	9. 12. 7. 5	8. 28. 35. 35
1.29.39.00	1501	1. 29. 29. 0	3. 29. 55. 50	1. 25. 46. 50
0.07.25.25	1601	0. 7. 19. 25	7. 19. 7. 5	9. 11. 35. 35
6. 1.45.45	1681	6. 1. 35. 45	8. 4. 28. 5	5. 24. 14. 35
10.15.15.50	1701	10. 15. 9. 50	11. 8. 18. 20	4. 27. 24. 20
2.28.53.55	1721	2. 28. 43. 55	2. 12. 8. 35	4. 0. 34. 5
7.12.28.00	1741	7. 12. 18. 0	5. 15. 58. 50	3. 3. 43. 50
11.26.02.05	1761	11. 25. 52. 5	8. 19. 49. 5	2. 6. 53. 35
4.09.30.10	1781	4. 9. 26. 10	11. 23. 39. 20	1. 10. 3. 20
8.23.00.15	1801	8. 23. 00. 15	2. 27. 29. 35	0. 13. 13. 5
1.06.44.20	1821	1. 6. 34. 20	6. 1. 19. 50	11. 16. 22. 50
5.20.18.25	1841	5. 20. 08. 25	9. 5. 10. 5	10. 19. 32. 35
10.03.52.30	1861	10. 3. 42. 30	0. 9. 0. 20	9. 22. 42. 20
2.17.26.35	1881	2. 17. 16. 35	3. 12. 50. 35	8. 25. 52. 5
7.01.00.40	1901	7. 00. 50. 40	6. 16. 40. 50	7. 29. 1. 50
5.08.31.05	2001	5. 8. 41. 5	10. 5. 52. 5	3. 14. 50. 35

Years	mean Mot. ☽ s ° ′ ″	Mot. Apog. ☽ s ° ′ ″	Mot. ☊ ret. s ° ′ ″
20	4. 13. 34. 5	3. 3. 50. 15	0. 26. 50. 15
40	8. 27. 8. 10	6. 7. 40. 30	1. 23. 40. 30
60	1. 10. 42. 15	9. 11. 30. 45	2. 20. 30. 45
80	5. 24. 16. 20	0. 15. 21. 0	3. 17. 21. 0
100	10. 7. 50. 25	3. 19. 11. 15	4. 14. 11. 15
200	8. 15. 40. 50	7. 8. 22. 30	8. 28. 22. 30
300	6. 23. 31. 15	10. 27. 33. 45	1. 12. 33. 45
400	5. 1. 21. 40	2. 16. 45. 0	5. 26. 45. 0
500	3. 9. 12. 5	6. 5. 56. 15	10. 10. 56. 15
600	1. 17. 2. 30	9. 25. 7. 30	2. 25. 7. 30
700	11. 24. 52. 55	1. 14. 18. 45	7. 9. 18. 45
800	10. 2. 43. 20	5. 3. 30. 0	11. 23. 30. 0
900	8. 10. 33. 45	8. 22. 41. 15	4. 7. 41. 15
1000	6. 18. 24. 10	0. 11. 52. 30	8. 21. 52. 30
2000	1. 6. 48. 20	0. 23. 45. 0	5. 13. 45. 0
3000	7. 25. 12. 30	1. 5. 37. 30	2. 5. 37. 30
4000	2. 13. 36. 40	1. 17. 30. 0	10. 27. 30. 0
5000	9. 2. 0. 50	1. 29. 22. 30	7. 19. 22. 30
6000	3. 20. 25. 0	2. 11. 15. 0	4. 11. 15. 0

Years	mean Mot. ☽				Mot. Apog. ☽				Mot. ☊ ret.			
	s	o	′	″	s	o	′	″	s	o	′	″
1	4.	9.	23.	3	1.	10.	39.	50	0.	19.	19.	43
2	8.	18.	46.	7	2.	21.	19.	41	1.	8.	39.	26
3	0.	28.	9.	10	4.	1.	59.	31	1.	27.	59.	9
4	5.	20.	42.	49	5.	12.	46.	3	2.	17.	22.	3
5	10.	0.	5.	52	6.	23.	25.	53	3.	6.	41.	46
6	2.	9.	28.	56	8.	4.	5.	44	3.	26.	1.	29
7	6.	18.	51.	59	9.	14.	45.	34	4.	15.	21.	12
8	11.	11.	25.	38	10.	25.	32.	6	5.	4.	44.	6
9	3.	20.	48.	41	0.	6.	11.	56	5.	24.	3.	49
10	8.	0.	11.	45	1.	16.	51.	47	6.	13.	23.	32
11	0.	9.	34.	48	2.	27.	31.	37	7.	2.	43.	15
12	5.	2.	8.	27	4.	8.	18.	9	7.	22.	6.	9
13	9.	11.	31.	30	5.	18.	57.	59	8.	11.	25.	52
14	1.	20.	54.	34	6.	29.	37.	50	9.	0.	45.	35
15	6.	0.	17.	37	8.	10.	17.	40	9.	20.	5.	18
16	10.	22.	51.	16	9.	21.	4.	12	10.	9.	28.	12
17	3.	2.	14.	19	11.	1.	44.	2	10.	28.	47.	55
18	7.	11.	37.	23	0.	12.	23.	53	11.	18.	7.	38
19	11.	21.	0.	26	1.	23.	3.	43	0.	7.	27.	21
20	4.	13.	34.	5	3.	3.	50.	15	0.	26.	50.	15

Months common	mean Mot. ☽				Mot. Apog. ☽				Mot. ☊ ret.		
	s	o	′	″	s	o	′	″	o	′	″
Janua.	0.	0.	0.	0	0.	0.	0.	0	0.	0.	0
Februa.	1.	18.	28.	6	0.	3.	27.	13	1.	38.	30
March	1.	27.	24.	26	0.	6.	34.	23	3.	7.	28
April	3.	15.	52.	32	0.	10.	1.	36	4.	45.	58
May	4.	21.	10.	3	0.	13.	22.	8	6.	21.	17
June	6.	9.	38.	8	0.	16.	49.	22	7.	59.	46
July	7.	14.	55.	39	0.	20.	9.	54	9.	35.	6
August	9.	3.	23.	45	0.	23.	37.	7	11.	13.	35
Septem.	10.	21.	51.	51	0.	27.	4.	20	12.	52.	5
October	11.	27.	9.	21	1.	0.	24.	52	14.	27.	24
Novem	1.	15.	37.	27	1.	3.	52.	5	16.	5.	54
Decem.	2.	20.	54.	58	1.	7.	12.	37	17.	41.	13

In Leap-Year, after February, add one Day, and one Day's Motion.

Days	mean Mot. ☽ s ° ′ ″	Mot Ap. ☽ ° ′ ″	Mot. ☊ rec. ° ′ ″
1	0. 13. 10. 35	0. 6. 41	0. 3. 11
2	0. 26. 21. 10	0. 13. 22	0. 6. 21
3	1. 9. 31. 45	0. 20. 3	0. 9. 32
4	1. 22. 42. 20	0. 26. 44	0. 12. 43
5	2. 5. 52. 55	0. 33. 25	0. 15. 53
6	2. 19. 3. 30	0. 40. 6	0. 19. 4
7	3. 2. 14. 5	0. 46. 47	0. 22. 14
8	3. 15. 24. 40	0. 53. 29	0. 25. 25
9	3. 28. 35. 15	1. 0. 10	0. 28. 36
10	4. 11. 45. 50	1. 6. 51	0. 31. 46
11	4. 24. 56. 25	1. 13. 32	0. 34. 57
12	5. 8. 7. 0	1. 20. 13	0. 38. 8
13	5. 21. 17. 35	1. 26. 54	0. 41. 18
14	6. 4. 28. 10	1. 33. 35	0. 44. 29
15	6. 17. 38. 45	1. 40. 16	0. 47. 40
16	7. 0. 49. 20	1. 46. 57	0. 50. 50
17	7. 13. 59. 55	1. 53. 38	0. 54. 1
18	7. 27. 10. 30	2. 0. 19	0. 57. 11
19	8. 10. 21. 5	2. 7. 0	1. 0. 22
20	8. 23. 31. 40	2. 13. 41	1. 3. 33
21	9. 6. 42. 15	2. 20. 22	1. 6. 43
22	9. 19. 52. 51	2. 27. 4	1. 9. 54
23	10. 3. 3. 26	2. 33. 45	1. 13. 5
24	10. 16. 14. 1	2. 40. 26	1. 16. 15
25	10. 29. 24. 36	2. 47. 7	1. 19. 26
26	11. 12. 35. 11	2. 53. 48	1. 22. 37
27	11. 25. 45. 46	3. 0. 29	1. 25. 47
28	0. 8. 56. 21	3. 7. 10	1. 28. 58
29	0. 22. 6. 56	3. 13. 51	1. 32. 9
30	1. 5. 17. 31	3. 20. 32	1. 35. 19
31	1. 18. 28. 6	3. 27. 13	1. 38. 30
32	2. 1. 38. 41	3. 33. 54	1. 41. 40

Hour	mean Mot. ☽	apo. ☽	☊ ret.
	° ′ ″	′ ″	′ ″
′	′ ″ ‴	″ ‴	″ ‴
″	″ ‴ ⁗	‴ ⁗	‴ ⁗
1	0. 32. 56	0. 17	0. 8
2	1. 5. 53	0. 33	0. 16
3	1. 38. 49	0. 50	0. 24
4	2. 11. 46	1. 7	0. 32
5	2. 44. 42	1. 24	0. 40
6	3. 17. 39	1. 40	0. 48
7	3. 50. 35	1. 57	0. 56
8	4. 23. 32	2. 14	1. 4
9	4. 56. 28	2. 30	1. 11
10	5. 29. 25	2. 47	1. 19
11	6. 2. 21	3. 4	1. 27
12	6. 35. 18	3. 21	1. 35
13	7. 8. 14	3. 37	1. 43
14	7. 41. 10	3. 54	1. 51
15	8. 14. 7	4. 11	1. 59
16	8. 47. 3	4. 27	2. 7
17	9. 20. 0	4. 44	2. 15
18	9. 52. 56	5. 1	2. 23
19	10. 25. 53	5. 18	2. 31
20	10. 58. 49	5. 34	2. 39
21	11. 31. 46	5. 51	2. 47
22	12. 4. 42	6. 8	2. 55
23	12. 37. 39	6. 24	3. 3
24	13. 10. 35	6. 41	3. 11
25	13. 43. 31	6. 58	3. 19
26	14. 16. 28	7. 14	3. 27
27	14. 49. 24	7. 31	3. 34
28	15. 22. 21	7. 48	3. 42
29	15. 55. 17	8. 5	3. 50
30	16. 28. 14	8. 21	3. 58

Hour.	mean Mot. ☽ ° ′ ″	apog. ☽ ′ ″	☊ ret. ′ ″
′	′ ″ ‴	″ ‴	″ ‴
″	″ ‴ iv	‴ iv	‴ iv
31	17. 1. 10	8. 38	4. 6
32	17. 34. 7	8. 55	4. 14
33	18. 7. 3	9. 11	4. 22
34	18. 40. 0	9. 28	4. 30
35	19. 12. 56	9. 45	4. 38
36	19. 45. 53	10. 2	4. 46
37	20. 18. 49	10. 18	4. 54
38	20. 51. 45	10. 35	5. 2
39	21. 24. 42	10. 52	5. 10
40	21. 57. 38	11. 8	5. 18
41	22. 30. 35	11. 25	5. 26
42	23. 3. 31	11. 42	5. 34
43	23. 36. 28	11. 59	5. 42
44	24. 9. 24	12. 15	5. 50
45	24. 42. 21	12. 32	5. 57
46	25. 15. 17	12. 49	6. 5
47	25. 48. 14	13. 5	6. 13
48	26. 21. 10	13. 22	6. 21
49	26. 54. 7	13. 39	6. 29
50	27. 27. 3	13. 56	6. 37
51	27. 59. 59	14. 12	6. 45
52	28. 32. 56	14. 29	6. 53
53	29. 5. 52	14. 46	7. 1
54	29. 38. 49	15. 2	7. 9
55	30. 11. 45	15. 19	7. 17
56	30. 44. 42	15. 36	7. 25
57	31. 17. 38	15. 53	7. 33
58	31. 50. 35	16. 9	7. 41
59	32. 23. 31	16. 26	7. 49
60	32. 6. 28	16. 43	7. 57

an☉	Si.0 add	Sig.1 add	Sig.2 add	Sig.3 add	Sig.4 add	Si.5 add	
°	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	°
0	0. 0	5. 48	10. 8	11. 49	10. 21	6. 1	30
1	0. 12	5. 59	10. 14	11. 50	10. 15	5. 50	29
2	0. 24	6. 9	10. 20	11. 50	10. 8	5. 39	28
3	0. 36	6. 20	10. 26	11. 49	10. 2	5. 28	27
4	0. 49	6. 30	10. 32	11. 49	9. 55	5. 17	26
5	1. 1	6. 40	10. 37	11. 48	9. 48	5. 6	25
6	1. 13	6. 50	10. 43	11. 47	9. 41	4. 54	24
7	1. 25	7. 0	10. 48	11. 46	9. 34	4. 43	23
8	1. 37	7. 10	10. 53	11. 45	9. 26	4. 31	22
9	1. 49	7. 19	10. 57	11. 43	9. 19	4. 19	21
10	2. 1	7. 29	11. 2	11. 41	9. 11	4. 8	20
11	2. 13	7. 38	11. 6	11. 39	9. 3	3. 56	19
12	2. 24	7. 47	11. 10	11. 37	8. 55	3. 44	18
13	2. 36	7. 56	11. 14	11. 35	8. 46	3. 32	17
14	2. 48	8. 5	11. 18	11. 32	8. 38	3. 20	16
15	3. 0	8. 14	11. 21	11. 29	8. 29	3. 7	15
16	3. 12	8. 23	11. 25	11. 26	8. 20	2. 55	14
17	3. 23	8. 31	11. 28	11. 23	8. 11	2. 43	13
18	3. 35	8. 40	11. 31	11. 19	8. 2	2. 31	12
19	3. 46	8. 48	11. 34	11. 15	7. 53	2. 18	11
20	3. 58	8. 56	11. 36	11. 11	7. 43	2. 6	10
21	4. 9	9. 4	11. 38	11. 7	7. 34	1. 53	9
22	4. 21	9. 12	11. 40	11. 3	7. 24	1. 41	8
23	4. 32	9. 19	11. 42	10. 58	7. 14	1. 28	7
24	4. 43	9. 27	11. 44	10. 54	7. 4	1. 16	6
25	4. 54	9. 34	11. 45	10. 49	6. 54	1. 3	5
26	5. 5	9. 41	11. 47	10. 44	6. 44	0. 51	4
27	5. 16	9. 48	11. 48	10. 38	6. 33	0. 38	3
28	5. 27	9. 55	11. 49	10. 33	6. 23	0. 25	2
29	5. 38	10. 2	11. 49	10. 27	6. 12	0. 13	1
30	5. 48	10. 8	11. 49	10. 21	6. 1	0. 0	0
	Si.11 sub.	Si.10 sub.	Sig 9 sub.	Sig.8 sub.	Sig.7 sub.	Si.6 sub.	an☉

A Table of the Annual or first Equation of the Moon's Apogee.

an ☉	Si. 0 sub.	Sig. 1 sub	Sig. 2 sub.	Sig. 3 sub.	Sig. 4 sub.	Sig. 5 sub	
°	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	°
0	0. 0	9. 50	17. 10	20. 1	17. 32	10. 12	30
1	0. 20	10. 8	17. 20	20. 2	17. 21	9. 54	29
2	0. 41	10. 26	17. 31	20. 2	17. 11	9. 35	28
3	1. 1	10. 43	17. 41	20. 1	17. 0	9. 16	27
4	1. 22	11. 1	17. 50	20. 0	16. 48	8. 57	26
5	1. 42	11. 18	17. 59	19. 59	16. 36	8. 38	25
6	2. 3	11. 34	18. 8	19. 58	16. 24	8. 18	24
7	2. 23	11. 51	18. 17	19. 56	16. 12	7. 58	23
8	2. 44	12. 8	18. 25	19. 54	15. 59	7. 39	22
9	3. 4	12. 24	18. 34	19. 51	15. 46	7. 19	21
10	3. 24	12. 40	18. 42	19. 48	15. 33	6. 59	20
11	3. 45	12. 56	18. 49	19. 44	15. 20	6. 39	19
12	4. 5	13. 12	18. 56	19. 41	15. 6	6. 19	18
13	4. 25	13. 27	19. 2	19. 37	14. 52	5. 59	17
14	4. 45	13. 42	19. 8	19. 32	14. 37	5. 38	16
15	5. 5	13. 57	19. 14	19. 27	14. 23	5. 18	15
16	5. 24	14. 12	19. 20	19. 22	14. 8	4. 57	14
17	5. 44	14. 26	19. 25	19. 16	13. 52	4. 36	13
18	6. 4	14. 41	19. 30	19. 10	13. 37	4. 15	12
19	6. 24	14. 55	19. 35	19. 4	13. 21	3. 54	11
20	6. 43	15. 8	19. 39	18. 57	13. 5	3. 33	10
21	7. 2	15. 22	19. 43	18. 50	12. 49	3. 12	9
22	7. 22	15. 35	19. 47	18. 43	12. 33	2. 51	8
23	7. 41	15. 48	19. 50	18. 35	12. 16	2. 29	7
24	8. 0	16. 0	19. 53	18. 27	11. 59	2. 8	6
25	8. 19	16. 13	19. 55	18. 19	11. 41	1. 47	5
26	8. 37	16. 25	19. 57	18. 10	11. 24	1. 25	4
27	8. 56	16. 36	19. 59	18. 1	11. 6	1. 4	3
28	9. 14	16. 48	20. 0	17. 51	10. 48	0. 43	2
29	9. 32	16. 59	20. 0	17. 42	10. 30	0. 21	1
30	9. 50	17. 10	20. 1	17. 32	10. 12	0. 0	0
	S. 11 add	Si. 10 add	Sig. 9 add	Sig 8 add	Sig. 7 add	Sig. 6 add	an ☉

A Table of the Annual or first Equation of the Moon's Nodes.

an ☉	Si. 0 add	Si. 1 add	Si 2 add	Si. 3 add	Si. 4 add	Si. 5 add	
°	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	°
0	0. 0	4. 41	8. 10	9. 32	8. 20	4. 51	30
1	0. 10	4. 49	8. 15	9. 32	8. 15	4. 42	29
2	0. 19	4. 58	8. 20	9. 32	8. 10	4. 34	28
3	0. 29	5. 6	8. 25	9. 32	8. 5	4. 25	27
4	0. 39	5. 14	8. 29	9. 31	8. 0	4. 16	26
5	0. 49	5. 22	8. 34	9. 31	7. 54	4. 6	25
6	0. 59	5. 30	8. 38	9. 30	7. 49	3. 57	24
7	1. 8	5. 38	8. 42	9. 29	7. 43	3. 47	23
8	1. 18	5. 46	8. 46	9. 28	7. 37	3. 38	22
9	1. 28	5. 54	8. 50	9. 27	7. 30	3. 29	21
10	1. 37	6. 2	8. 53	9. 25	7. 24	3. 19	20
11	1. 47	6. 9	8. 57	9. 24	7. 17	3. 10	19
12	1. 56	6. 17	9. 0	9. 22	7. 11	3. 0	18
13	2. 6	6. 24	9. 3	9. 20	7. 4	2. 51	17
14	2. 16	6. 31	9. 6	9. 18	6. 57	2. 41	16
15	2. 25	6. 38	9. 9	9. 15	6. 50	2. 31	15
16	2. 35	6. 45	9. 12	9. 13	6. 43	2. 21	14
17	2. 44	6. 52	9. 15	9. 10	6. 36	2. 11	13
18	2. 53	6. 59	9. 17	9. 7	6. 29	2. 1	12
19	3. 2	7. 6	9. 19	9. 4	6. 21	1. 51	11
20	3. 12	7. 12	9. 21	9. 1	6. 14	1. 41	10
21	3. 21	7. 19	9. 23	8. 58	6. 6	1. 31	9
22	3. 30	7. 25	9. 25	8. 54	5. 58	1. 21	8
23	3. 39	7. 31	9. 26	8. 51	5. 50	1. 11	7
24	3. 48	7. 37	9. 28	8. 47	5. 42	1. 1	6
25	3. 57	7. 43	9. 29	8. 43	5. 34	0. 51	5
26	4. 6	7. 48	9. 30	8. 39	5. 25	0. 41	4
27	4. 15	7. 54	9. 30	8. 34	5. 17	0. 31	3
28	4. 24	8. 0	9. 31	8. 30	5. 8	0. 20	2
29	4. 32	8. 5	9. 31	8. 25	5. 0	0. 10	1
30	4. 41	8. 10	9. 32	8. 20	4. 51	0. 0	0
	S. 11 sub.	S. 10 sub.	Si. 9 sub.	Si. 8 sub	Si. 7 sub.	Si. 6 sub	an ☉

A Table of the first Semi-annual or second Equation of the Moon.

Gr. Equation in Octants.				Equation ☽, ☉ in Apogee.				
mean Anom. ☉		mean Anom. ☉	An Arg Apog.	Sig. 0 ♋ sub.	Sig. 1 ♎ sub.	Sig. 2 ♑ sub.		
s °	′ ″	s °	°	′ ″	′ ″	′ ″	°
0. 0	3. 34	12. 0	0	0. 0	3. 5	3. 5	30
0. 6	3. 34	11. 24	1	0. 7	3. 9	3. 1	29
0. 12	3. 34	11. 18	2	0. 15	3. 12	2. 57	28
0. 18	3. 34	11. 12	3	0. 22	3. 15	2. 53	27
0. 24	3. 35	11. 6	4	0. 30	3. 18	2. 49	26
1. 0	3. 35	11. 0	5	0. 37	3. 21	2. 44	25
1. 6	3. 36	10. 24	6	0. 44	3. 24	2. 39	24
1. 12	3. 37	10. 18	7	0. 52	3. 26	2. 34	23
1. 18	3. 37	10. 12	8	0. 59	3. 28	2. 29	22
1. 24	3. 38	10. 6	9	1. 6	3. 29	2. 23	21
2. 0	3. 39	10. 0	10	1. 13	3. 31	2. 18	20
2. 6	3. 40	9. 24	11	1. 20	3. 32	2. 12	19
2. 12	3. 41	9. 18	12	1. 27	3. 33	2. 6	18
2. 18	3. 42	9. 12	13	1. 34	3. 33	2. 0	17
2. 24	3. 44	9. 6	14	1. 40	3. 34	1. 53	16
3. 0	3. 45	9. 0	15	1. 47	3. 34	1. 47	15
3. 6	3. 46	8. 24	16	1. 53	3. 34	1. 40	14
3. 12	3. 47	8. 18	17	2. 0	3. 33	1. 34	13
3. 18	3. 48	8. 12	18	2. 6	3. 33	1. 27	12
3. 24	3. 50	8. 6	19	2. 12	3. 32	1. 20	11
4. 0	3. 51	8. 0	20	2. 18	3. 31	1. 13	10
4. 6	3. 52	7. 24	21	2. 23	3. 29	1. 6	9
4. 12	3. 53	7. 18	22	2. 29	3. 28	0. 59	8
4. 18	3. 54	7. 12	23	2. 34	3. 26	0. 52	7
4. 24	3. 54	7. 6	24	2. 39	3. 24	0. 44	6
5. 0	3. 55	7. 0	25	2. 44	3. 21	0. 37	5
5. 6	3. 56	6. 24	26	2. 49	3. 18	0. 30	4
5. 12	3. 56	6. 18	27	2. 53	3. 15	0. 22	3
5. 18	3. 57	6. 12	28	2. 57	3. 12	0. 15	2
5. 24	3. 57	6. 6	29	3. 1	3. 9	0. 7	1
6. 0	3. 57	6. 0	30	3. 5	3. 5	0. 0	0
				Si. 11 ♑ add	Si. 10 ♒ add	Sig. 9 ♓ add	An Arg Apog.

A Table of the second Semi-annual or third Equation of the Moon.

Axis. Arg. Node	Sig. 0. 6 *sub.*	Sig. 1. 7 *sub.*	Sig. 2. 8 *sub.*	
0	′ ″	′ ″	′ ″	0
0	0. 0	0. 41	0. 41	30
1	0. 2	0. 41	0. 40	29
2	0. 3	0. 42	0. 39	28
3	0. 5	0. 43	0. 38	27
4	0. 7	0. 44	0. 37	26
5	0. 8	0. 44	0. 36	25
6	0. 10	0. 45	0. 35	24
7	0. 11	0. 45	0. 34	23
8	0. 13	0. 46	0. 33	22
9	0. 15	0. 46	0. 31	21
10	0. 16	0. 46	0. 30	20
11	0. 18	0. 47	0. 29	19
12	0. 19	0. 47	0. 28	18
13	0. 21	0. 47	0. 26	17
14	0. 22	0. 47	0. 25	16
15	0. 24	0. 47	0. 24	15
16	0. 25	0. 47	0. 22	14
17	0. 26	0. 47	0. 21	13
18	0. 28	0. 47	0. 19	12
19	0. 29	0. 47	0. 18	11
20	0. 30	0. 46	0. 16	10
21	0. 31	0. 46	0. 15	9
22	0. 33	0. 46	0. 13	8
23	0. 34	0. 45	0. 11	7
24	0. 35	0. 45	0. 10	6
25	0. 36	0. 44	0. 8	5
26	0. 37	0. 44	0. 7	4
27	0. 38	0. 43	0. 5	3
28	0. 39	0. 42	0. 3	2
29	0. 40	0. 41	0. 2	1
30	0. 41	0. 41	0. 0	0
	Sig. 11. 5 *add*	*Sig.* 10. 4 *add*	*Sig.* 9. 3 *add*	*Arg.* ☊

A Table of the Semi-annual or second Equation of the Moon's Apogee.

Ann. Arg. Apogee	Sig. 0.6 add	Sig. 1.7 add	Sig. 2.8 add	
0	0 ′ ″	0 ′ ″	0 ′ ″	0
0	0. 0. 0	9. 28. 8	11. 40. 16	30
1	0. 21. 5	9. 42. 23	11. 30. 55	29
2	0. 42. 9	9. 56. 9	11. 20. 29	28
3	1. 3. 11	10. 9. 25	11. 8. 59	27
4	1. 24. 11	10. 22. 9	10. 56. 23	26
5	1. 45. 7	10. 34. 21	10. 42. 41	25
6	2. 5. 59	10. 45. 59	10. 27. 54	24
7	2. 26. 46	10. 57. 2	10. 12. 0	23
8	2. 47. 28	11. 7. 28	9. 55. 2	22
9	3. 8. 3	11. 17. 17	9. 36. 58	21
10	3. 28. 30	11. 26. 27	9. 17. 50	20
11	3. 48. 49	11. 34. 57	8. 57. 38	19
12	4. 8. 59	11. 42. 45	8. 36. 24	18
13	4. 28. 59	11. 49. 51	8. 14. 8	17
14	4. 48. 47	11. 56. 12	7. 50. 53	16
15	5. 8. 24	12. 1. 48	7. 26. 40	15
16	5. 27. 48	12. 6. 37	7. 1. 31	14
17	5. 46. 58	12. 10. 38	6. 35. 29	13
18	6. 5. 54	12. 13. 50	6. 8. 35	12
19	6. 24. 34	12. 16. 11	5. 40. 53	11
20	6. 42. 58	12. 17. 40	5. 12. 26	10
21	7. 1. 4	12. 18. 15	4. 43. 17	9
22	7. 18. 52	12. 17. 56	4. 13. 30	8
23	7. 36. 20	12. 16. 41	3. 43. 7	7
24	7. 53. 28	12. 14. 29	3. 12. 14	6
25	8. 10. 14	12. 11. 18	2. 40. 53	5
26	8. 26. 38	12. 7. 8	2. 9. 10	4
27	8. 42. 39	12. 1. 58	1. 37. 9	3
28	8. 58. 15	11. 55. 47	1. 4. 54	2
29	9. 13. 25	11. 48. 33	0. 32. 29	1
30	9. 28. 8	11. 40. 16	0. 0. 0	0
	Sig. 11.5 sub.	Sig 10.4 sub.	Sig. 0.3 sub.	Arg.

Ann. Arg. Apogee	Sig. 0.6	Sig. 1.7	Sig. 2.8	
0	Excen.	Excen.	Excen.	0
0	66782	61758	50223	30
1	66776	61438	49837	29
2	66758	61110	49456	28
3	66729	60775	49081	27
4	66688	60432	48713	26
5	66635	60083	48352	25
6	66570	59727	47999	24
7	66494	59365	47654	23
8	66406	58997	47319	22
9	66307	58624	46992	21
10	66196	58245	46677	20
11	66074	57861	46372	19
12	65941	57473	46078	18
13	65796	57081	45797	17
14	65640	56686	45528	16
15	65473	56287	45272	15
16	65296	55885	45030	14
17	65108	55481	44802	13
18	64909	55074	44589	12
19	64700	54666	44391	11
20	64480	54258	44209	10
21	64250	53848	44043	9
22	64010	53439	43893	8
23	63761	53030	43760	7
24	63502	52622	43644	6
25	63233	52215	43545	5
26	62956	51810	43464	4
27	62669	51408	43401	3
28	62373	51009	43356	2
29	62070	50614	43328	1
30	61758	50223	43319	0
	Sig. 11.5	Sig. 10.4	Sig. 9.3	Arg. Ap.

mean Anom.	Sig. 0 Sub.	Sig. 1 Sub.	Sig. 2 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	0. 0. 0	2. 27. 27	4. 20. 21	30
1	0. 5. 7	2. 31. 58	4. 23. 9	29
2	0. 10. 13	2. 36. 25	4. 25. 52	28
3	0. 15. 20	2. 40. 51	4. 28. 31	27
4	0. 20. 26	2. 45. 13	4. 31. 6	26
5	0. 25. 32	2. 49. 34	4. 33. 36	25
6	0. 30. 37	2. 53. 51	4. 36. 1	24
7	0. 35. 42	2. 58. 6	4. 38. 21	23
8	0. 40. 47	3. 2. 18	4. 40. 37	22
9	0. 45. 51	3. 6. 27	4. 42. 48	21
10	0. 50. 54	3. 10. 33	4. 44. 55	20
11	0. 55. 56	3. 14. 36	4. 46. 56	19
12	1. 0. 58	3. 18. 36	4. 48. 52	18
13	1. 5. 58	3. 22. 32	4. 50. 44	17
14	1. 10. 58	3. 26. 26	4. 52. 30	16
15	1. 15. 56	3. 30. 16	4. 54. 12	15
16	1. 20. 53	3. 34. 2	4. 55. 48	14
17	1. 25. 49	3. 37. 45	4. 57. 19	13
18	1. 30. 44	3. 41. 25	4. 58. 45	12
19	1. 35. 37	3. 45. 1	5. 0. 6	11
20	1. 40. 29	3. 48. 34	5. 1. 21	10
21	1. 45. 19	3. 52. 2	5. 2. 31	9
22	1. 50. 8	3. 55. 27	5. 3. 36	8
23	1. 54. 55	3. 58. 48	5. 4. 36	7
24	1. 59. 39	4. 2. 5	5. 5. 30	6
25	2. 4. 23	4. 5. 18	5. 6. 18	5
26	2. 9. 4	4. 8. 27	5. 7. 1	4
27	2. 13. 43	4. 11. 32	5. 7. 39	3
28	2. 18. 20	4. 14. 32	5. 8. 11	2
29	2. 22. 55	4. 17. 29	5. 8. 37	1
30	2. 27. 27	4. 20. 21	5. 8. 58	0
	Sig. 11 Add	Sig. 10 Add	Sig. 9 Add	mean Anom.

mean Anom.	Sig. 3 Sub.	Sig. 4 Sub.	Sig. 5 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	5. 8. 58	4. 35. 24	2. 42. 32	30
1	5. 9. 14	4. 32. 49	2. 37. 41	29
2	5. 9. 24	4. 30. 9	2. 32. 47	28
3	5. 9. 28	4. 27. 24	2. 27. 49	27
4	5. 9. 26	4. 24. 34	2. 22. 48	26
5	5. 9. 19	4. 21. 38	2. 17. 44	25
6	5. 9. 6	4. 18. 37	2. 12. 37	24
7	5. 8. 47	4. 15. 30	2. 7. 27	23
8	5. 8. 23	4. 12. 19	2. 2. 14	22
9	5. 7. 53	4. 9. 3	1. 56. 59	21
10	5. 7. 17	4. 5. 41	1. 51. 41	20
11	5. 6. 36	4. 2. 14	1. 46. 21	19
12	5. 5. 48	3. 58. 42	1. 40. 59	18
13	5. 4. 55	3. 55. 6	1. 35. 35	17
14	5. 3. 57	3. 51. 25	1. 30. 8	16
15	5. 2. 52	3. 47. 40	1. 24. 39	15
16	5. 1. 42	3. 43. 49	1. 19. 9	14
17	5. 0. 26	3. 39. 54	1. 13. 37	13
18	4. 59. 4	3. 35. 54	1. 8. 3	12
19	4. 57. 37	3. 31. 50	1. 2. 28	11
20	4. 56. 4	3. 27. 42	0. 56. 52	10
21	4. 54. 25	3. 23. 29	0. 51. 14	9
22	4. 52. 41	3. 19. 12	0. 45. 35	8
23	4. 50. 51	3. 14. 50	0. 39. 55	7
24	4. 48. 55	3. 10. 25	0. 34. 15	6
25	4. 46. 54	3. 5. 56	0. 28. 34	5
26	4. 44. 47	3. 1. 22	0. 22. 52	4
27	4. 42. 34	2. 56. 45	0. 17. 9	3
28	4. 40. 16	2. 52. 5	0. 11. 26	2
29	4. 37. 53	2. 47. 20	0. 5. 43	1
30	4. 35. 24	2. 42. 32	0. 0. 0	0
	Sig. 8 Add	Sig. 7 Add	Sig. 6 Add	mean Anom.

Mean Anom	Sig. 0 Sub.	Sig. 1 Sub.	Sig. 2 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	0. 0. 0	2. 42. 59	4. 48. 21	30
1	0. 5. 39	2. 47. 58	4. 51. 28	29
2	0. 11. 17	2. 52. 55	4. 54. 31	28
3	0. 16. 56	2. 57. 49	4. 57. 28	27
4	0. 22. 34	3. 2. 40	5. 0. 21	26
5	0. 28. 12	3. 7. 28	5. 3. 9	25
6	0. 33. 50	3. 12. 13	5. 5. 51	24
7	0. 39. 26	3. 16. 55	5. 8. 29	23
8	0. 45. 3	3. 21. 35	5. 11. 1	22
9	0. 50. 39	3. 26. 11	5. 13. 28	21
10	0. 56. 13	3. 30. 44	5. 15. 50	20
11	1. 1. 47	3. 35. 13	5. 18. 6	19
12	1. 7. 21	3. 39. 39	5. 20. 17	18
13	1. 12. 53	3. 44. 2	5. 22. 22	17
14	1. 18. 24	3. 48. 21	5. 24. 22	16
15	1. 23. 54	3. 52. 36	5. 26. 17	15
16	1. 29. 22	3. 56. 48	5. 28. 6	14
17	1. 34. 49	4. 0. 56	5. 29. 49	13
18	1. 40. 15	4. 4. 59	5. 31. 26	12
19	1. 45. 39	4. 8. 59	5. 32. 57	11
20	1. 51. 1	4. 12. 56	5. 34. 23	10
21	1. 56. 22	4. 16. 48	5. 35. 43	9
22	2. 1. 41	4. 20. 35	5. 36. 57	8
23	2. 6. 58	4. 24. 19	5. 38. 6	7
24	2. 12. 13	4. 27. 58	5. 39. 8	6
25	2. 17. 27	4. 31. 33	5. 40. 4	5
26	2. 22. 38	4. 35. 4	5. 40. 53	4
27	2. 27. 46	4. 38. 30	5. 41. 37	3
28	2. 32. 53	4. 41. 52	5. 42. 15	2
29	2. 37. 57	4. 45. 8	5. 42. 47	1
30	2. 42. 59	4. 48. 21	5. 43. 12	0
	Sig. 11 Add	Sig. 10 Add	Sig. 9 Add	Mean Anom.

mean Anom.	Sig. 3 Sub.	Sig. 4 Sub.	Sig. 5 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	5. 43. 12	5. 6. 55	3. 1. 37	30
1	5. 43. 32	5. 4. 5	2. 56. 12	29
2	5. 43. 45	5. 1. 8	2. 50. 44	28
3	5. 43. 52	4. 58. 6	2. 45. 11	27
4	5. 43. 52	4. 54. 58	2. 39. 36	26
5	5. 43. 46	4. 51. 43	2. 33. 56	25
6	5. 43. 34	4. 48. 23	2. 28. 14	24
7	5. 43. 16	4. 44. 57	2. 22. 28	23
8	5. 42. 51	4. 41. 25	2. 16. 39	22
9	5. 42. 20	4. 37. 47	2. 10. 47	21
10	5. 41. 43	4. 34. 4	2. 4. 52	20
11	5. 40. 59	4. 30. 15	1. 58. 55	19
12	5. 40. 8	4. 26. 21	1. 52. 55	18
13	5. 39. 12	4. 22. 21	1. 46. 52	17
14	5. 38. 9	4. 18. 16	1. 40. 47	16
15	5. 36. 59	4. 14. 5	1. 34. 40	15
16	5. 35. 43	4. 9. 49	1. 28. 31	14
17	5. 34. 21	4. 5. 28	1. 22. 20	13
18	5. 32. 52	4. 1. 1	1. 16. 7	12
19	5. 31. 17	3. 56. 30	1. 9. 52	11
20	5. 29. 36	3. 51. 54	1. 3. 36	10
21	5. 27. 48	3. 47. 12	0. 57. 18	9
22	5. 25. 54	3. 42. 26	0. 50. 59	8
23	5. 23. 53	3. 37. 36	0. 44. 39	7
24	5. 21. 47	3. 32. 40	0. 38. 18	6
25	5. 19. 34	3. 27. 41	0. 31. 57	5
26	5. 17. 14	3. 22. 36	0. 25. 34	4
27	5. 14. 49	3. 17. 28	0. 19. 11	3
28	5. 12. 17	3. 12. 15	0. 12. 48	2
29	5. 9. 39	3. 6. 58	0. 6. 24	1
30	5. 6. 55	3. 1. 37	0. 0. 0	0
	Sig. 8 Add	Sig. 7 Add	Sig. 6 Add	mean Anom.

mean Anom.	Sig. 0 Sub.	Sig. 1 Sub.	Sig. 2 Sub.	
0	0 ′ ″	0 ′ ″	0 ′ ″	0
0	0. 0. 0	2. 58. 21	5. 16. 8	30
1	0. 6. 10	3. 3. 49	5. 19. 36	29
2	0. 12. 21	3. 9. 14	5. 22. 57	28
3	0. 18. 31	3. 14. 36	5. 26. 13	27
4	0. 24. 41	3. 19. 55	5. 29. 25	26
5	0. 30. 50	3. 25. 11	5. 32. 30	25
6	0. 37. 0	3. 30. 24	5. 35. 30	24
7	0. 43. 8	3. 35. 34	5. 38. 25	23
8	0. 49. 16	3. 40. 40	5. 41. 14	22
9	0. 55. 23	3. 45. 43	5. 43. 57	21
10	1. 1. 29	3. 50. 43	5. 46. 35	20
11	1. 7. 35	3. 55. 38	5. 49. 6	19
12	1. 13. 39	4. 0. 31	5. 51. 32	18
13	1. 19. 42	4. 5. 19	5. 53. 52	17
14	1. 25. 44	4. 10. 4	5. 56. 5	16
15	1. 31. 45	4. 14. 44	5. 58. 13	15
16	1. 37. 45	4. 19. 21	6. 0. 15	14
17	1. 43. 43	4. 23. 53	6. 2. 10	13
18	1. 49. 39	4. 28. 22	6. 3. 59	12
19	1. 55. 34	4. 32. 46	6. 5. 42	11
20	2. 1. 27	4. 37. 6	6. 7. 18	10
21	2. 7. 18	4. 41. 21	6. 8. 48	9
22	2. 13. 7	4. 45. 32	6. 10. 12	8
23	2. 18. 54	4. 49. 38	6. 11. 29	7
24	2. 24. 39	4. 53. 40	6. 12. 40	6
25	2. 30. 22	4. 57. 37	6. 13. 44	5
26	2. 36. 3	5. 1. 29	6. 14. 41	4
27	2. 41. 41	5. 5. 16	6. 15. 32	3
28	2. 47. 17	5. 8. 59	6. 16. 16	2
29	2. 52. 50	5. 12. 36	6. 16. 53	1
30	2. 58. 21	5. 16. 8	6. 17. 23	0
	Sig. 11 Add	Sig. 10 Add	Sig. 9 Add	mean Anom.

mean Anom.	Sig. 3 Sub.	Sig. 4 Sub.	Sig. 5 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	6. 17. 23	5. 38. 35	3. 20. 54	30
1	6. 17. 47	5. 35. 30	3. 14. 56	29
2	6. 18. 4	5. 32. 17	3. 8. 53	28
3	6. 18. 14	5. 28. 58	3. 2. 46	27
4	6. 18. 17	5. 25. 32	2. 56. 34	26
5	6. 18. 13	5. 22. 0	2. 50. 19	25
6	6. 18. 2	5. 18. 21	2. 44. 1	24
7	6. 17. 44	5. 14. 35	2. 37. 39	23
8	6. 17. 20	5. 10. 43	2. 31. 14	22
9	6. 16. 48	5. 6. 45	2. 24. 45	21
10	6. 16. 9	5. 2. 40	2. 18. 12	20
11	6. 15. 24	4. 58. 29	2. 11. 37	19
12	6. 14. 31	4. 54. 12	2. 4. 59	18
13	6. 13. 31	4. 49. 48	1. 58. 18	17
14	6. 12. 24	4. 45. 19	1. 51. 34	16
15	6. 11. 10	4. 40. 43	1. 44. 48	15
16	6. 9. 49	4. 36. 2	1. 37. 59	14
17	6. 8. 20	4. 31. 15	1. 31. 9	13
18	6. 6. 45	4. 26. 22	1. 24. 16	12
19	6. 5. 3	4. 21. 24	1. 17. 21	11
20	6. 3. 14	4. 16. 19	1. 10. 25	10
21	6. 1. 17	4. 11. 10	1. 3. 27	9
22	5. 59. 14	4. 5. 55	0. 56. 27	8
23	5. 57. 3	4. 0. 35	0. 49. 27	7
24	5. 54. 46	3. 55. 10	0. 42. 25	6
25	5. 52. 21	3. 49. 39	0. 35. 22	5
26	5. 49. 50	3. 44. 3	0. 28. 19	4
27	5. 47. 12	3. 38. 23	0. 21. 15	3
28	5. 44. 27	3. 32. 38	0. 14. 10	2
29	5. 41. 34	3. 26. 48	0. 7. 5	1
30	5. 38. 35	3. 20. 54	0. 0. 0	0
	Sig. 8 Add	Sig. 7 Add	Sig. 6 Add	mean Anom.

mean Anom.	Sig. 0 Sub.	Sig. 1 Sub.	Sig. 2 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	0. 0. 0	3. 13. 33	5. 43. 44	30
1	0. 6. 42	3. 19. 30	5. 47. 31	29
2	0. 13. 23	3. 25. 23	5. 51. 12	28
3	0. 20. 5	3. 31. 13	5. 54. 48	27
4	0. 26. 46	3. 37. 0	5. 58. 18	26
5	0. 33. 27	3. 42. 44	6. 1. 42	25
6	0. 40. 7	3. 48. 24	6. 5. 0	24
7	0. 46. 47	3. 54. 1	6. 8. 12	23
8	0. 53. 26	3. 59. 35	6. 11. 17	22
9	1. 0. 4	4. 5. 4	6. 14. 17	21
10	1. 6. 42	4. 10. 30	6. 17. 10	20
11	1. 13. 18	4. 15. 52	6. 19. 58	19
12	1. 19. 53	4. 21. 11	6. 22. 38	18
13	1. 26. 27	4. 26. 25	6. 25. 13	17
14	1. 33. 0	4. 31. 35	6. 27. 41	16
15	1. 39. 32	4. 36. 40	6. 30. 2	15
16	1. 46. 2	4. 41. 42	6. 32. 16	14
17	1. 52. 30	4. 46. 40	6. 34. 24	13
18	1. 58. 57	4. 51. 32	6. 36. 25	12
19	2. 5. 22	4. 56. 20	6. 38. 20	11
20	2. 11. 45	5. 1. 4	6. 40. 7	10
21	2. 18. 6	5. 5. 42	6. 41. 48	9
22	2. 24. 25	5. 10. 16	6. 43. 21	8
23	2. 30. 42	5. 14. 45	6. 44. 48	7
24	2. 36. 57	5. 19. 9	6. 46. 7	6
25	2. 43. 9	5. 23. 28	6. 47. 20	5
26	2. 49. 19	5. 27. 42	6. 48. 25	4
27	2. 55. 27	5. 31. 51	6. 49. 23	3
28	3. 1. 32	5. 35. 54	6. 50. 14	2
29	3. 7. 34	5. 39. 52	6. 50. 56	1
30	3. 13. 33	5. 43. 44	6. 51. 33	0
	Sig. 11 Add	Sig. 10 Add	Sig. 9 Add	mean Anom.

mean Anom.	Sig. 3 Sub.	Sig. 4 Sub.	Sig. 5 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	6. 51. 33	6. 10. 27	3. 40. 24	30
1	6. 52. 1	6. 7. 6	3. 33. 52	29
2	6. 52. 22	6. 3. 38	3. 27. 14	28
3	6. 52. 35	6. 0. 2	3. 20. 33	27
4	6. 52. 42	5. 56. 19	3. 13. 46	26
5	6. 52. 40	5. 52. 29	3. 6. 56	25
6	6. 52. 31	5. 48. 31	3. 0. 1	24
7	6. 52. 14	5. 44. 26	2. 53. 2	23
8	6. 51. 50	5. 40. 14	2. 45. 59	22
9	6. 51. 18	5. 35. 55	2. 38. 52	21
10	6. 50. 39	5. 31. 29	2. 31. 42	20
11	6. 49. 52	5. 26. 56	2. 24. 29	19
12	6. 48. 56	5. 22. 16	2. 17. 12	18
13	6. 47. 53	5. 17. 29	2. 9. 52	17
14	6. 46. 43	5. 12. 36	2. 2. 29	16
15	6. 45. 25	5. 7. 36	1. 55. 4	15
16	6. 43. 59	5. 2. 29	1. 47. 35	14
17	6. 42. 26	4. 57. 16	1. 40. 4	13
18	6. 40. 44	4. 51. 57	1. 32. 31	12
19	6. 38. 55	4. 46. 31	1. 24. 56	11
20	6. 36. 58	4. 40. 59	1. 17. 19	10
21	6. 34. 54	4. 35. 21	1. 9. 40	9
22	6. 32. 42	4. 29. 37	1. 2. 0	8
23	6. 30. 21	4. 23. 47	0. 54. 18	7
24	6. 27. 54	4. 17. 52	0. 46. 36	6
25	6. 25. 18	4. 11. 51	0. 38. 51	5
26	6. 22. 35	4. 5. 44	0. 31. 6	4
27	6. 19. 44	3. 59. 32	0. 23. 20	3
28	6. 16. 46	3. 53. 14	0. 15. 34	2
29	6. 13. 40	3. 46. 52	0. 7. 47	1
30	6. 10. 27	3. 40. 24	0. 0. 0	0
	Sig. 8 Add	Sig. 7 Add	Sig. 6 Add	mean Anom.

mean Anom.	Sig. 0 Sub.	Sig. 1 Sub.	Sig. 2 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	0. 0. 0	3. 28. 36	6. 11. 10	30
1	0. 7. 13	3. 35. 1	6. 15. 16	29
2	0. 14. 25	3. 41. 22	6. 19. 17	28
3	0. 21. 38	3. 47. 40	6. 23. 12	27
4	0. 28. 50	3. 53. 55	6. 27. 0	26
5	0. 36. 2	4. 0. 6	6. 30. 43	25
6	0. 43. 13	4. 6. 14	6. 34. 19	24
7	0. 50. 23	4. 12. 18	6. 37. 48	23
8	0. 57. 33	4. 18. 18	6. 41. 11	22
9	1. 4. 42	4. 24. 15	6. 44. 27	21
10	1. 11. 50	4. 30. 7	6. 47. 37	20
11	1. 18. 57	4. 35. 55	6. 50. 40	19
12	1. 26. 3	4. 41. 39	6. 53. 36	18
13	1. 33. 7	4. 47. 19	6. 56. 25	17
14	1. 40. 11	4. 52. 54	6. 59. 7	16
15	1. 47. 13	4. 58. 25	7. 1. 42	15
16	1. 54. 13	5. 3. 52	7. 4. 10	14
17	2. 1. 12	5. 9. 13	7. 6. 31	13
18	2. 8. 8	5. 14. 30	7. 8. 45	12
19	2. 15. 3	5. 19. 43	7. 10. 51	11
20	2. 21. 56	5. 24. 50	7. 12. 50	10
21	2. 28. 47	5. 29. 52	7. 14. 41	9
22	2. 35. 36	5. 34. 49	7. 16. 26	8
23	2. 42. 23	5. 39. 41	7. 18. 2	7
24	2. 49. 7	5. 44. 27	7. 19. 30	6
25	2. 55. 48	5. 49. 8	7. 20. 51	5
26	3. 2. 27	5. 53. 44	7. 22. 4	4
27	3. 9. 4	5. 58. 14	7. 23. 10	3
28	3. 15. 37	6. 2. 38	7. 24. 8	2
29	3. 22. 8	6. 6. 57	7. 24. 57	1
30	3. 28. 36	6. 11. 10	7. 25. 39	0
	Sig. 11 Add	Sig. 10 Add	Sig. 9 Add	mean Anom.

mean Anom.	Sig. 3 Sub.	Sig. 4 Sub.	Sig. 5 Sub.	
°	° ′ ″	° ′ ″	° ′ ″	°
0	7. 25. 39	6. 42. 29	4. 0. 7	30
1	7. 26. 13	6. 38. 54	3. 53. 1	29
2	7. 26. 38	6. 35. 10	3. 45. 49	28
3	7. 26. 56	6. 31. 18	3. 38. 32	27
4	7. 27. 6	6. 27. 18	3. 31. 10	26
5	7. 27. 7	6. 23. 10	3. 23. 43	25
6	7. 27. 0	6. 18. 54	3. 16. 12	24
7	7. 26. 45	6. 14. 30	3. 8. 36	23
8	7. 26. 22	6. 9. 58	3. 0. 55	22
9	7. 25. 50	6. 5. 19	2. 53. 11	21
10	7. 25. 11	6. 0. 32	2. 45. 23	20
11	7. 24. 22	5. 55. 37	2. 37. 31	19
12	7. 23. 25	5. 50. 34	2. 29. 35	18
13	7. 22. 20	5. 45. 24	2. 21. 35	17
14	7. 21. 7	5. 40. 7	2. 13. 33	16
15	7. 19. 45	5. 34. 42	2. 5. 27	15
16	7. 18. 15	5. 29. 11	1. 57. 19	14
17	7. 16. 36	5. 23. 32	1. 49. 8	13
18	7. 14. 49	5. 17. 46	1. 40. 54	12
19	7. 12. 54	5. 11. 53	1. 32. 38	11
20	7. 10. 50	5. 5. 53	1. 24. 19	10
21	7. 8. 37	4. 59. 47	1. 15. 59	9
22	7. 6. 17	4. 53. 34	1. 7. 37	8
23	7. 3. 47	4. 47. 14	0. 59. 13	7
24	7. 1. 10	4. 40. 48	0. 50. 48	6
25	6. 58. 24	4. 34. 16	0. 42. 22	5
26	6. 55. 30	4. 27. 38	0. 33. 55	4
27	6. 52. 27	4. 20. 54	0. 25. 27	3
28	6. 49. 16	4. 14. 4	0. 16. 58	2
29	6. 45. 57	4. 7. 8	0. 8. 29	1
30	6. 42. 29	4. 0. 7	0. 0. 0	0
	Sig. 8 Add	Sig. 7 Add	Sig. 6 Add	mean Anom.

A Table of the Variation, Reflection, or fifth Equation of the Moon.

Gr. Variation in Octants.			Variation ☽, ☉ in Apogee.				
mean Anom. ☉		mean Anom. ☉	Moon from S. doubl.	Sig. 0 add / Sig. 6 sub.	Sig. 1 add / Sig. 7 sub.	Sig. 2 add / Sig. 8 sub.	
s °	′ ″	s °	°	′ ″	′ ″	′ ″	°
0. 0	33. 4	12. 0	0	0. 0	16. 32	28. 38	30
0. 6	33. 5	11. 24	1	0. 35	17. 2	28. 55	29
0. 12	33. 7	11. 18	2	1. 9	17. 31	29. 12	28
0. 18	33. 10	11. 12	3	1. 44	18. 1	29. 28	27
0. 24	33. 14	11. 6	4	2. 18	18. 29	29. 43	26
1. 0	33. 19	11. 0	5	2. 53	18. 58	29. 58	25
1. 6	33. 27	10. 24	6	3. 27	19. 26	30. 12	24
1. 12	33. 35	10. 18	7	4. 2	19. 54	30. 26	23
1. 18	33. 44	10. 12	8	4. 36	20. 21	30. 40	22
1. 24	33. 54	10. 6	9	5. 10	20. 49	30. 52	21
2. 0	34. 4	10. 0	10	5. 45	21. 15	31. 4	20
2. 6	34. 16	9. 24	11	6. 19	21. 42	31. 16	19
2. 12	34. 28	9. 18	12	6. 52	22. 8	31. 27	18
2. 18	34. 41	9. 12	13	7. 26	22. 33	31. 37	17
2. 24	34. 54	9. 6	14	8. 0	22. 58	31. 47	16
3. 0	35. 8	9. 0	15	8. 33	23. 23	31. 56	15
3. 6	35. 22	8. 24	16	9. 7	23. 47	32. 5	14
3. 12	35. 35	8. 18	17	9. 40	24. 11	32. 13	13
3. 18	35. 49	8. 12	18	10. 13	24. 34	32. 21	12
3. 24	36. 2	8. 6	19	10. 46	24. 57	32. 28	11
4. 0	36. 15	8. 0	20	11. 19	25. 20	32. 34	10
4. 6	36. 27	7. 24	21	11. 51	25. 42	32. 40	9
4. 12	36. 38	7. 18	22	12. 23	26. 3	32. 45	8
4. 18	36. 48	7. 12	23	12. 55	26. 24	32. 49	7
4. 24	36. 58	7. 6	24	13. 27	26. 45	32. 53	6
5. 0	37. 6	7. 0	25	13. 58	27. 5	32. 56	5
5. 6	37. 13	6. 24	26	14. 30	27. 25	32. 59	4
5. 12	37. 18	6. 18	27	15. 1	27. 44	33. 1	3
5. 18	37. 22	6. 12	28	15. 31	28. 3	33. 3	2
5. 24	37. 24	6. 6	29	16. 2	28. 21	33. 4	1
6. 0	37. 25	6. 0	30	16. 32	28. 38	33. 4	0
				Sig. 11 sub. / Sig. 5 add	Sig. 10 sub. / Sig. 4 add	Sig. 9 sub. / Sig. 3 add	Moon from S doubl.

Arg. 6th *Equation*	*Sub.*	*Arg.* 6th *Equation*
s °	′ ″	s °
0 . 0	0 . 0	12 . 0
0 . 6	0 . 15	11 . 24
0 . 12	0 . 30	11 . 18
0 . 18	0 . 45	11 . 12
0 . 24	0 . 59	11 . 6
1 . 0	1 . 12	11 . 0
1 . 6	1 . 25	10 . 24
1 . 12	1 . 37	10 . 18
1 . 18	1 . 48	10 . 12
1 . 24	1 . 57	10 . 6
2 . 0	2 . 5	10 . 0
2 . 6	2 . 12	9 . 24
2 . 12	2 . 18	9 . 18
2 . 18	2 . 22	9 . 12
2 . 24	2 . 24	9 . 6
3 . 0	2 . 25	9 . 0
3 . 6	2 . 24	8 . 24
3 . 12	2 . 22	8 . 18
3 . 18	2 . 18	8 . 12
3 . 24	2 . 12	8 . 6
4 . 0	2 . 5	8 . 0
4 . 6	1 . 57	7 . 24
4 . 12	1 . 48	7 . 18
4 . 18	1 . 37	7 . 12
4 . 24	1 . 25	7 . 6
5 . 0	1 . 12	7 . 0
5 . 6	0 . 59	6 . 24
5 . 12	0 . 45	6 . 18
5 . 18	0 . 30	6 . 12
5 . 24	0 . 15	6 . 6
6 . 0	0 . 0	6 . 0
	Add	

Dist. ☽ from ☉	Sub.	Dist. ☽ from ☉
s °	′ ″	s °
0 . 0	0 . 0	12 . 0
0 . 6	0 . 15	11 . 24
0 . 12	0 . 29	11 . 18
0 . 18	0 . 43	11 . 12
0 . 24	0 . 57	11 . 6
1 . 0	1 . 10	11 . 0
1 . 6	1 . 22	10 . 24
1 . 12	1 . 34	10 . 18
1 . 18	1 . 44	10 . 12
1 . 24	1 . 53	10 . 6
2 . 0	2 . 1	10 . 0
2 . 6	2 . 8	9 . 24
2 . 12	2 . 13	9 . 18
2 . 18	2 . 17	9 . 12
2 . 24	2 . 19	9 . 6
3 . 0	2 . 20	9 . 0
3 . 6	2 . 19	8 . 24
3 . 12	2 . 17	8 . 18
3 . 18	2 . 13	8 . 12
3 . 24	2 . 8	8 . 6
4 . 0	2 . 1	8 . 0
4 . 6	1 . 53	7 . 24
4 . 12	1 . 44	7 . 18
4 . 18	1 . 34	7 . 12
4 . 24	1 . 22	7 . 6
5 . 0	1 . 10	7 . 0
5 . 6	0 . 57	6 . 24
5 . 12	0 . 43	6 . 18
5 . 18	0 . 29	6 . 12
5 . 24	0 . 15	6 . 6
6 . 0	0 . 0	6 . 0
	Add	

A Table of the Semi-annual or second Equation of the Moon's Nodes.

Ann. Arg. Node	Sig. 0.6 add	Sig. 1.7 add	Sig. 2.8 add	
0	0 ′ ″	0 ′ ″	0 ′ ″	0
0	0. 0. 0	1. 16. 39	1. 18. 41	30
1	0. 3. 3	1. 18. 13	1. 17. 6	29
2	0. 6. 6	1. 19. 41	1. 15. 26	28
3	0. 9. 8	1. 21. 3	1. 13. 40	27
4	0. 12. 10	1. 22. 20	1. 11. 49	26
5	0. 15. 11	1. 23. 31	1. 9. 52	25
6	0. 18. 11	1. 24. 36	1. 7. 49	24
7	0. 21. 10	1. 25. 34	1. 5. 42	23
8	0. 24. 7	1. 26. 27	1. 3. 29	22
9	0. 27. 2	1. 27. 14	1. 1. 11	21
10	0. 29. 56	1. 27. 54	0. 58. 49	20
11	0. 32. 48	1. 28. 28	0. 56. 22	19
12	0. 35. 38	1. 28. 56	0. 53. 51	18
13	0. 38. 25	1. 29. 17	0. 51. 15	17
14	0. 41. 9	1. 29. 31	0. 48. 36	16
15	0. 43. 51	1. 29. 40	0. 45. 52	15
16	0. 46. 30	1. 29. 41	0. 43. 6	14
17	0. 49. 5	1. 29. 36	0. 40. 15	13
18	0. 51. 37	1. 29. 25	0. 37. 22	12
19	0. 54. 6	1. 29. 7	0. 34. 26	11
20	0. 56. 31	1. 28. 42	0. 31. 26	10
21	0. 58. 52	1. 28. 11	0. 28. 25	9
22	1. 1. 9	1. 27. 33	0. 25. 21	8
23	1. 3. 21	1. 26. 49	0. 22. 16	7
24	1. 5. 30	1. 25. 58	0. 19. 8	6
25	1. 7. 33	1. 25. 1	0. 15. 59	5
26	1. 9. 32	1. 23. 57	0. 12. 49	4
27	1. 11. 27	1. 22. 47	0. 9. 37	3
28	1. 13. 16	1. 21. 31	0. 6. 26	2
29	1. 15. 0	1. 20. 9	0. 3. 13	1
30	1. 16. 39	1. 18. 41	0. 0. 0	0
	Sig. 11.5 *sub.*	Sig. 10.4 *sub.*	Sig. 9.3 *sub.*	Arg. ☊

Ann. Arg. Node	Sig. 0.6	Sig. 1.7	Sig. 2.8	
0	° ′ ″	° ′ ″	° ′ ″	0
0	5. 17. 20	5. 12. 48	5. 3. 56	30
1	5. 17. 20	5. 12. 31	5. 3. 39	29
2	5. 17. 19	5. 12. 15	5. 3. 24	28
3	5. 17. 17	5. 11. 58	5. 3. 9	27
4	5. 17. 15	5. 11. 40	5. 2. 55	26
5	5. 17. 12	5. 11. 23	5. 2. 41	25
6	5. 17. 8	5. 11. 5	5. 2. 27	24
7	5. 17. 4	5. 10. 47	5. 2. 14	23
8	5. 16. 59	5. 10. 29	5. 2. 1	22
9	5. 16. 53	5. 10. 11	5. 1. 48	21
10	5. 16. 47	5. 9. 52	5. 1. 36	20
11	5. 16. 40	5. 9. 34	5. 1. 25	19
12	5. 16. 33	5. 9. 16	5. 1. 14	18
13	5. 16. 25	5. 8. 57	5. 1. 4	17
14	5. 16. 16	5. 8. 38	5. 0. 54	16
15	5. 16. 7	5. 8. 20	5. 0. 45	15
16	5. 15. 57	5. 8. 1	5. 0. 36	14
17	5. 15. 47	5. 7. 43	5. 0. 28	13
18	5. 15. 36	5. 7. 24	5. 0. 20	12
19	5. 15. 24	5. 7. 6	5. 0. 13	11
20	5. 15. 12	5. 6. 48	5. 0. 6	10
21	5. 15. 0	5. 6. 29	5. 0. 0	9
22	5. 14. 47	5. 6. 11	4. 59. 55	8
23	5. 14. 34	5. 5. 54	4. 59. 50	7
24	5. 14. 20	5. 5. 36	4. 59. 46	6
25	5. 14. 5	5. 5. 19	4. 59. 43	5
26	5. 13. 51	5. 5. 2	4. 59. 40	4
27	5. 13. 36	5. 4. 45	4. 59. 38	3
28	5. 13. 20	5. 4. 28	4. 59. 36	2
29	5. 13. 4	5. 4. 12	4. 59. 35	1
30	5. 12. 48	5. 3. 56	4. 59. 35	0
	Sig. 11.5	Sig. 10.4	Sig. 9.3	Arg. ☊

Arg Lat	Sig. 0 Nor. / Sig. 6 Sou. Latit. to least Incl.	Part. add in great. Incl.	Sig. 1 Nor. / Sig. 7 Sou. Latit. to least Incl.	Partic. add in greatest Inclin.	Sig. 2 Nor. / Sig. 8 Sou. Latit. to least Incl.	Partic. add in greatest Inclin.	
	° ′ ″	′ ″	° ′ ″	′ ″	° ′ ″	′ ″	°
0	0. 0. 0	0. 0	2.29.39	8.51	4.19.22	15.21	30
1	0. 5.13	0.19	2.34. 9	9. 7	4.21.57	15.30	29
2	0.10.27	0.37	2.38.37	9.22	4.24.27	15.39	28
3	0.15.39	0.56	2.43. 1	9.39	4.26.52	15.48	27
4	0.20.52	1.14	2.47.23	9.54	4.29.12	15.56	26
5	0.26. 5	1.32	2.51.41	10. 9	4.31.27	16. 5	25
6	0.31.17	1.50	2.55.57	10.24	4.33.38	16.12	24
7	0.36.28	2. 9	3. 0. 9	10.39	4.35.43	16.20	23
8	0.41.38	2.28	3. 4.18	10.54	4.37.43	16.27	22
9	0.46.48	2.46	3. 8.24	11. 8	4.39.39	16.33	21
10	0.51.57	3. 5	3.12.26	11.22	4.41.29	16.40	20
11	0.57. 5	3.23	3.16.24	11.37	4.43.14	16.46	19
12	1. 2.13	3.40	3.20.19	11.51	4.44.53	16.53	18
13	1. 7.19	3.58	3.24.11	12. 4	4.46.28	16.58	17
14	1.12.24	4.16	3.27.58	12.19	4.47.57	17. 3	16
15	1.17.27	4.34	3.31.42	12.32	4.49.21	17. 8	15
16	1.22.29	4.52	3.35.22	12.45	4.50.40	17.13	14
17	1.27.29	5.11	3.38.58	12.58	4.51.53	17.18	13
18	1.32.28	5.28	3.42.31	13. 9	4.53. 1	17.22	12
19	1.37.25	5.46	3.45.59	13.22	4.54. 4	17.25	11
20	1.42.21	6. 3	3.49.23	13.34	4.55. 1	17.29	10
21	1.47.15	6.20	3.52.42	13.47	4.55.53	17.32	9
22	1.52. 6	6.38	3.55.58	13.58	4.56.40	17.34	8
23	1.56.56	6.55	3.59. 9	14. 9	4.57.21	17.37	7
24	2. 1.44	7.11	4. 2.16	14.20	4.57.56	17.39	6
25	2. 6.29	7.28	4. 5.18	14.31	4.58.26	17.41	5
26	2.11.12	7.45	4. 8.16	14.42	4.58.51	17.42	4
27	2.15.52	8. 2	4.11. 9	14.53	4.59.10	17.44	3
28	2.20.30	8.19	4.13.58	15. 2	4.59.24	17.44	2
29	2.25. 6	8.35	4.16.42	15.12	4.59.32	17.45	1
30	2.29.39	8.51	4.19.22	15.21	4.59.35	17.45	0
	Sig. 11 Sou. / Sig. 5 Nor.		Sig. 10 Sou. / Sig. 4 Nor.		Sig. 9 Sou. / Sig. 3 Nor.		Arg Lat

A Table of the Moon's Reduction from her proper Orbit to the Ecliptic.

Arg. Lat.	Sig. 0/6 sub. Red. l. Inc.	Part. add in gr Inc.	Sig. 1/7 sub. Red. l. Inc.	Part. add in gr Inc.	Sig. 2/8 sub. Red. l. Inc.	Part. add in gr Inc.	
°	′ ″	″	′ ″	″	′ ″	″	°
0	0. 0	0	5. 39	42	5. 40	42	30
1	0. 14	1	5. 46	42	5. 33	41	29
2	0. 27	3	5. 52	43	5. 25	40	28
3	0. 41	5	5. 58	44	5. 18	39	27
4	0. 54	7	6. 3	45	5. 9	38	26
5	1. 8	8	6. 8	45	5. 1	37	25
6	1. 21	10	6. 13	46	4. 52	36	24
7	1. 35	11	6. 17	46	4. 42	35	23
8	1. 48	13	6. 20	47	4. 33	33	22
9	2. 1	15	6. 23	47	4. 23	32	21
10	2. 14	16	6. 26	47	4. 12	31	20
11	2. 27	18	6. 28	48	4. 2	29	19
12	2. 39	20	6. 30	48	3. 51	28	18
13	2. 52	21	6. 31	48	3. 40	27	17
14	3. 4	22	6. 32	48	3. 28	26	16
15	3. 16	24	6. 32	48	3. 16	24	15
16	3. 27	26	6. 32	48	3. 4	23	14
17	3. 39	27	6. 31	48	2. 52	21	13
18	3. 50	28	6. 30	48	2. 40	19	12
19	4. 1	29	6. 28	48	2. 27	18	11
20	4. 12	30	6. 26	48	2. 14	17	10
21	4. 22	32	6. 24	47	2. 1	15	9
22	4. 32	33	6. 20	47	1. 48	14	8
23	4. 42	34	6. 17	46	1. 35	12	7
24	4. 51	36	6. 13	46	1. 22	10	6
25	5. 0	37	6. 9	45	1. 8	8	5
26	5. 8	38	6. 4	44	0. 55	6	4
27	5. 17	39	5. 58	44	0. 41	5	3
28	5. 25	40	5. 53	43	0. 27	3	2
29	5. 32	41	5. 47	42	0. 14	1	1
30	5. 39	42	5. 40	42	0. 0	0	0
	Sig. 11/5 add		Sig. 10/4 add		Sig 9/3 add		Arg. Lat.

Dr. Bradley makes ☉'s Diameter at his Apogee only 31′. 28″ & consequently his Semidiam. [illegible] is only 15′. 44″ which [illegible] it is made here.

A Table of the hourly Motions, and Semidiameters of the Sun.

mean Anom. ☉	hourly Mot. ☉	Semid. ☉	mean Anom. ☉
s °	′ ″	′ ″	s °
0. 0	2. 23	15. 51	12. 0
0. 6	2. 23	15. 51	11. 24
0. 12	2. 23	15. 52	11. 18
0. 18	2. 23	15. 52	11. 12
0. 24	2. 23	15. 53	11. 6
1. 0	2. 24	15. 53	11. 0
1. 6	2. 24	15. 54	10. 24
1. 12	2. 24	15. 55	10. 18
1. 18	2. 24	15. 57	10. 12
1. 24	2. 25	15. 58	10. 6
2. 0	2. 25	15. 59	10. 0
2. 6	2. 26	16. 1	9. 24
2. 12	2. 26	16. 2	9. 18
2. 18	2. 27	16. 4	9. 12
2. 24	2. 27	16. 6	9. 6
3. 0	2. 28	16. 7	9. 0
3. 6	2. 28	16. 9	8. 24
3. 12	2. 29	16. 11	8. 18
3. 18	2. 29	16. 13	8. 12
3. 24	2. 30	16. 14	8. 6
4. 0	2. 30	16. 16	8. 0
4. 6	2. 31	16. 17	7. 24
4. 12	2. 31	16. 18	7. 18
4. 18	2. 32	16. 20	7. 12
4. 24	2. 32	16. 21	7. 6
5. 0	2. 32	16. 22	7. 0
5. 6	2. 32	16. 23	6. 24
5. 12	2. 33	16. 23	6. 18
5. 18	2. 33	16. 24	6. 12
5. 24	2. 33	16. 24	6. 6
6. 0	2. 33	16. 24	6. 0

The Sun's horizontal Parallax is 10″.

 A Table of the Semidiameters, and horizontal Parallaxes of the Moon, in the Syzygies.

mean Anom. ☽	Excentricity 45000. Semid. ☽	Excentricity 45000. hor. Par. ☽	Excentricity 65000. Semid. ☽	Excentricity 65000. hor. Par. ☽	mean Anom. ☽
s °	′ ″	′ ″	′ ″	′ ″	s °
0. 0	15. 4	55. 1	14. 47	53. 59	12. 0
0. 6	15. 5	55. 2	14. 48	54. 0	11. 24
0. 12	15. 5	55. 4	14. 48	54. 3	11. 18
0. 18	15. 6	55. 8	14. 50	54. 8	11. 12
0. 24	15. 7	55. 13	14. 51	54. 15	11. 6
1. 0	15. 9	55. 19	14. 54	54. 23	11. 0
1. 6	15. 11	55. 27	14. 57	54. 33	10. 24
1. 12	15. 14	55. 36	15. 0	54. 46	10. 18
1. 18	15. 16	55. 46	15. 4	54. 59	10. 12
1. 24	15. 20	55. 57	15. 8	55. 15	10. 6
2. 0	15. 23	56. 9	15. 13	55. 32	10. 0
2. 6	15. 27	56. 23	15. 18	55. 50	9. 24
2. 12	15. 30	56. 37	15. 23	56. 10	9. 18
2. 18	15. 34	56. 52	15. 29	56. 31	9. 12
2. 24	15. 39	57. 7	15. 35	56. 53	9. 6
3. 0	15. 43	57. 23	15. 41	57. 16	9. 0
3. 6	15. 48	57. 39	15. 47	57. 39	8. 24
3. 12	15. 52	57. 56	15. 54	58. 3	8. 18
3. 18	15. 57	58. 12	16. 1	58. 27	8. 12
3. 24	16. 1	58. 28	16. 7	58. 50	8. 6
4. 0	16. 5	58. 44	16. 13	59. 14	8. 0
4. 6	16. 9	58. 59	16. 20	59. 36	7. 24
4. 12	16. 13	59. 13	16. 26	59. 58	7. 18
4. 18	16. 17	59. 26	16. 31	60. 17	7. 12
4. 24	16. 20	59. 38	16. 36	60. 35	7. 6
5. 0	16. 23	59. 48	16. 40	60. 51	7. 0
5. 6	16. 25	59. 57	16. 44	61. 5	6. 24
5. 12	16. 27	60. 3	16. 47	61. 16	6. 18
5. 18	16. 28	60. 8	16. 49	61. 23	6. 12
5. 24	16. 29	60. 12	16. 50	61. 28	6. 6
6. 0	16. 30	60. 13	16. 51	61. 30	6. 0

A Table of Particles to be substracted from the Semidiameters, and horiz. Parallaxes of ☽, out of the Syzygies.

Dist. ☽ from ☉	sub fr. Semid.	sub fr. Par.	Dist. ☽ from ☉
s o	″	″	s o
0. 0	0	0	12. 0
0. 6	0	1	11. 24
0. 12	1	2	11. 18
0. 18	1	5	11. 12
0. 24	2	8	11. 6
1. 0	3	13	11. 0
1. 6	5	17	10. 24
1. 12	6	22	10. 18
1. 18	7	27	10. 12
1. 24	9	33	10. 6
2. 0	10	37	10. 0
2. 6	11	41	9. 24
2. 12	12	45	9. 18
2. 18	13	48	9. 12
2. 24	13	49	9. 6
3. 0	13	50	9. 0
3. 6	13	49	8. 24
3. 12	13	48	8. 18
3. 18	12	45	8. 12
3. 24	11	41	8. 6
4. 0	10	37	8. 0
4. 6	9	33	7. 24
4. 12	7	27	7. 18
4. 18	6	22	7. 12
4. 24	5	17	7. 6
5. 0	3	13	7. 0
5. 6	2	8	6. 24
5. 12	1	5	6. 18
5. 18	1	2	6. 12
5. 24	0	1	6. 6
6. 0	0	0	6. 0

A Table of Particles to be added to the Moon's horizontal Semidiameter, on her Altitude.

Alt. ☽	Part. add
0	″
0	0
3	1
6	2
9	2
12	3
15	4
18	5
21	6
24	6
27	7
30	8
33	9
36	9
39	10
42	11
45	11
48	12
51	12
54	13
57	13
60	14
63	14
66	15
69	15
72	15
75	16
78	16
81	16
84	16
87	16
90	16

A Table of the Angles which the Way of ☽ from ☉, makes with a Circle of Latitude, in Eclipses of the Luminaries.

ArgLat	The hourly Motion of the Moon from the Sun.										ArgLat
Sig. 0. 6	27′	28′	29′	30′	31′	32′	33′	34′	35′	36′	Si 5. 11
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
0	84. 14	84. 15	84. 16	84. 17	84. 18	84. 18	84. 19	84. 20	84. 20	84. 21	30
1	84. 14	84. 15	84. 16	84. 17	84. 18	84. 18	84. 19	84. 20	84. 20	84. 21	29
2	84. 14	84. 15	84. 16	84. 17	84. 18	84. 19	84. 19	84. 20	84. 21	84. 21	28
3	84. 14	84. 15	84. 16	84. 17	84. 18	84. 19	84. 20	84. 20	84. 21	84. 22	27
4	84. 15	84. 16	84. 17	84. 18	84. 18	84. 19	84. 20	84. 21	84. 21	84. 22	26
5	84. 15	84. 16	84. 17	84. 18	84. 19	84. 20	84. 21	84. 21	84. 22	84. 22	25
6	84. 16	84. 17	84. 18	84. 19	84. 20	84. 20	84. 21	84. 22	84. 23	84. 23	24
7	84. 17	84. 18	84. 19	84. 20	84. 20	84. 21	84. 22	84. 23	84. 23	84. 24	23
8	84. 18	84. 19	84. 20	84. 20	84. 21	84. 22	84. 23	84. 23	84. 24	84. 25	22
9	84. 19	84. 20	84. 21	84. 21	84. 22	84. 23	84. 24	84. 24	84. 25	84. 26	21
10	84. 20	84. 21	84. 22	84. 23	84. 23	84. 24	84. 25	84. 26	84. 26	84. 27	20
11	84. 21	84. 22	84. 23	84. 24	84. 25	84. 25	84. 26	84. 27	84. 27	84. 28	19
12	84. 22	84. 23	84. 24	84. 25	84. 26	84. 27	84. 27	84. 28	84. 29	84. 29	18
13	84. 24	84. 25	84. 26	84. 26	84. 27	84. 28	84. 29	84. 29	84. 30	84. 31	17
14	84. 25	84. 26	84. 27	84. 28	84. 29	84. 30	84. 30	84. 31	84. 32	84. 32	16
15	84. 27	84. 28	84. 29	84. 30	84. 30	84. 31	84. 32	84. 33	84. 33	84. 34	15
16	84. 29	84. 30	84. 31	84. 31	84. 32	84. 33	84. 34	84. 34	84. 35	84. 36	14
17	84. 31	84. 31	84. 32	84. 33	84. 34	84. 35	84. 35	84. 36	84. 37	84. 37	13

A Table of the Times between the true Syzygy, and the mean Eclipse, or greatest Obscuration.

Arg Lat	The hourly Motion of the Moon from the Sun.										Arg Lat
Sig. 0. 6	27′	28′	29′	30′	31′	32′	33′	34′	35′	36′	Si. 5. 11
°	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	°
0	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0	30
1	1. 14	1. 11	1. 8	1. 6	1. 4	1. 2	1. 0	0. 58	0. 56	0. 54	29
2	2. 28	2. 22	2. 17	2. 12	2. 7	2. 3	1. 59	1. 55	1. 52	1. 48	28
3	3. 41	3. 33	3. 25	3. 17	3. 10	3. 4	2. 58	2. 52	2. 47	2. 42	27
4	4. 54	4. 43	4. 32	4. 23	4. 13	4. 5	3. 57	3. 49	3. 42	3. 36	26
5	6. 7	5. 53	5. 40	5. 28	5. 16	5. 5	4. 55	4. 46	4. 38	4. 29	25
6	7. 19	7. 2	6. 46	6. 32	6. 18	6. 5	5. 54	5. 43	5. 32	5. 22	24
7	8. 30	8. 10	7. 52	7. 36	7. 20	7. 5	6. 52	6. 39	6. 26	6. 15	23
8	9. 41	9. 18	8. 58	8. 39	8. 21	8. 4	7. 49	7. 34	7. 20	7. 7	22
9	10. 51	10. 26	10. 3	9. 41	9. 22	9. 3	8. 45	8. 28	8. 13	7. 58	21
10	12. 0	11. 32	11. 7	10. 43	10. 21	10. 1	9. 41	9. 23	9. 5	8. 49	20
11	13. 8	12. 38	12. 10	11. 44	11. 20	10. 57	10. 36	10. 16	9. 57	9. 39	19
12	14. 16	13. 43	13. 13	12. 44	12. 18	11. 53	11. 30	11. 8	10. 48	10. 28	18
13	15. 22	14. 46	14. 14	13. 43	13. 15	12. 48	12. 23	11. 59	11. 38	11. 16	17
14	16. 26	15. 48	15. 13	14. 40	14. 10	13. 42	13. 15	12. 50	12. 27	12. 4	16
15	17. 29	16. 49	16. 11	15. 37	15. 4	14. 34	14. 6	13. 39	13. 14	12. 50	15
16	18. 30	17. 48	17. 9	16. 32	15. 58	15. 26	14. 56	14. 27	14. 1	13. 35	14
17	19. 30	18. 46	18. 5	17. 26	16. 50	16. 16	15. 44	15. 15	14. 47	14. 20	13

Years of Christ current	mean Mot. ☽ fr. ☉ s	o	′	″
1	6.	24.	9.	35
1501	4.	10.	25.	50
1601	2.	17.	30.	55
1681	8.	11.	10.	59
1701	0.	24.	36.	0
1721	5.	8.	1.	1
1741	9.	21.	26.	2
1761	2.	4.	51.	3
1781	6.	18.	16.	4
1801	11.	1.	41.	5
1821	3.	15.	6.	6
1841	7.	28.	31.	7
1861	0.	11.	56.	8
1881	4.	25.	21.	9
1901	9.	8.	46.	10
2001	7.	15.	51.	15

Years	Mot. ☽ from ☉ s	o	′	″
20	4.	13.	25.	1
40	8.	26.	50.	2
60	1.	10.	15.	3
80	5.	23.	40.	4
100	10.	7.	5.	5
200	8.	14.	10.	10
300	6.	21.	15.	15
400	4.	28.	20.	20
500	3.	5.	25.	25
600	1.	12.	30.	30
700	11.	19.	35.	35
800	9.	26.	40.	40
900	8.	3.	45.	45
1000	6.	10.	50.	50
2000	0.	21.	41.	40
3000	7.	2.	32.	30
4000	1.	13.	23.	20
5000	7.	24.	14.	10
6000	2.	5.	5.	0

Years	Mot. ☽ from ☉ s	o	′	″
1	4.	9.	37.	23
2	8.	19.	14.	47
3	0.	28.	52.	10
4	5.	20.	41.	0
5	10.	0.	18.	24
6	2.	9.	55.	47
7	6.	19.	33.	10
8	11.	11.	22.	0
9	3.	20.	59.	24
10	8.	0.	36.	47
11	0.	10.	14.	11
12	5.	2.	3.	1
13	9.	11.	40.	24
14	1.	21.	17.	47
15	6.	0.	55.	11
16	10.	22.	44.	1
17	3.	2.	21.	24
18	7.	11.	58.	48
19	11.	21.	36.	11
20	4.	13.	25.	1

Months common	Mot. ☽ from ☉ s	o	′	″
Janua.	0.	0.	0.	0
Februa.	0.	17.	54.	48
March	11.	29.	15.	15
April	0.	17.	10.	2
May	0.	22.	53.	23
June	1.	10.	48.	11
July	1.	16.	31.	32
August	2.	4.	26.	19
Septem.	2.	22.	21.	7
October	2.	28.	4.	28
Novem	3.	15.	59.	15
Decem.	3.	21.	42.	36

In Leap-Year, after February, add one Day, and one Day's Motion.

Days	Mot. ☽ from ☉ s ° ′ ″	Hour	Mot ☽ fr. ☉ ° ′ ″	H.	Mot ☽ fr. ☉ ° ′ ″
1	0. 12. 11. 27	′	′ ″ ‴	′	′ ″ ‴
2	0. 24. 22. 53	″	″ ‴ ⁗	″	″ ‴ ⁗
3	1. 6. 34. 20	1	0. 30. 29	31	15. 44. 47
4	1. 18. 45. 47	2	1. 0. 57	32	16. 15. 16
5	2. 0. 57. 13	3	1. 31. 26	33	16. 45. 44
6	2. 13. 8. 40	4	2. 1. 54	34	17. 16. 13
7	2. 25. 20. 7	5	2. 32. 23	35	17. 46. 41
8	3. 7. 31. 34	6	3. 2. 52	36	18. 17. 10
9	3. 19. 43. 0	7	3. 33. 20	37	18. 47. 39
10	4. 1. 54. 27	8	4. 3. 49	38	19. 18. 7
11	4. 14. 5. 54	9	4. 34. 18	39	19. 48. 36
12	4. 26. 17. 20	10	5. 4. 46	40	20. 19. 4
13	5. 8. 28. 47	11	5. 35. 15	41	20. 49. 33
14	5. 20. 40. 14	12	6. 5. 43	42	21. 20. 2
15	6. 2. 51. 40	13	6. 36. 12	43	21. 50. 30
16	6. 15. 3. 7	14	7. 6. 41	44	22. 20. 59
17	6. 27. 14. 34	15	7. 37. 9	45	22. 51. 28
18	7. 9. 26. 0	16	8. 7. 38	46	23. 21. 56
19	7. 21. 37. 27	17	8. 38. 6	47	23. 52. 25
20	8. 3. 48. 54	18	9. 8. 35	48	24. 22. 53
21	8. 16. 0. 21	19	9. 39. 4	49	24. 53. 22
22	8. 28. 11. 47	20	10. 9. 32	50	25. 23. 51
23	9. 10. 23. 14	21	10. 40. 1	51	25. 54. 19
24	9. 22. 34. 41	22	11. 10. 29	52	26. 24. 48
25	10. 4. 46. 7	23	11. 40. 58	53	26. 55. 16
26	10. 16. 57. 34	24	12. 11. 27	54	27. 25. 45
27	10. 29. 9. 1	25	12. 41. 55	55	27. 56. 14
28	11. 11. 20. 27	26	13. 12. 24	56	28. 26. 42
29	11. 23. 31. 54	27	13. 42. 53	57	28. 57. 11
30	0. 5. 43. 21	28	14. 13. 21	58	29. 27. 40
31	0. 17. 54. 48	29	14. 43. 50	59	29. 58. 8
32	1. 0. 6. 14	30	15. 14. 18	60	30. 28. 37

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THE USE OF THE PRECEEDING TABLES.

THe Radix of each middle Motion is accommodated to the laſt Day of the Julian Year in the Meridian of the Royal Obſervatory of *Greenwich.*

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1 *To reduce the apparent Time to the equal, and the converſe.*

UNder the Title (*Tables of the Equation of Time*) enter the firſt Table with the Sign and Degree of the Sun's true Longitude, and the ſecond with his mean Anomaly, ſo you have the Equation in two Parts; of which, if both add or both ſubſtract, the ſum, but if one add and the other ſubſtract, the difference (according to the greater Part) is the abſolute Equation, which as the Titles direct, added to or ſubſtracted from the apparent Time, gives the equal, and *vice verſa.*

---

2 *To calculate the true Place of the Sun.*

FIrſt in the Table entituled *A Table of the Sun's mean Motions,* find the neareſt leſſer Year to that in which the Sun's Place is ſought, and

you have the Sun's mean Longitude anſwerable thereto, as alſo the Place of the Sun's Apogee; to which add the mean Motion of the Sun and of his Apogee for the reſidue of the Years, with the Month, Day, Hour and Minute (taken from the ſaid Table) and you have the Sun's mean Longitude and Place of the Apogee for the given Time, as in the Example following.

In the Year 1737 *January* $2^{d}.3^{h}.40'$ Time equated, the Sun's true Place is required.

Eq. Time	*Longitude* ☉	*Apogee* ☉
1721	$9^{s}\ 20^{\circ}\ 52'\ 54''$	$3^{s}\ 8^{\circ}\ 5'\ 30''$
16	0 0 7 15	0 0 16 48
January	0 0 0 0	0
d.2	0 1 58 17	
h.3	0 7 24	
′40	1 39	
mean Mot. ☉	9 23 7 29	3 8 22 18 *Apo.*

Then from the Sun's mean Longitude ſubſtract the Place of the Apogee, and the remainder (6^{s} $14^{\circ}\ 45'\ 11''$) will be Sun's mean Anomaly, with which in *the Table of the Equation of the Sun's Centre* next following (by making proportion as need requires) find the Equation $0^{\circ}\ 29'\ 53''$ which (according to the Title) added to the mean, gives the Sun's true Longitude $9^{s}\ 23^{\circ}\ 37'\ 22''$.

To

3 *To calculate the true place of the Moon.*

TO the given Time find the true Place of the Sun from the Equinox, as before.

Then in *the Table of the Moon's mean Motions*, collect the mean Longitude and Apogee into two distinct Sums, in like manner as the mean Longitude and Apogee of the Sun in the foregoing Example. Only the mean Motion of the Nodes being retrograde, subtract the mean Motion for the residue of Years with the Month, Day, Hour and Minute, from the radical Place for the Year first found, as in the following Example.

In the Year 1737 *January* $2^{d}.3^{h}.40'$ Time equated, the Moon's true Place is required.

Eq.T.	*Longitude* ☽	*Apogee* ☽	*Asc. Node* ☽
1721	$2^{s}\ 28^{\circ}\ 53'\ 55''$	$2^{s}\ 12^{\circ}\ 8'\ 35''$	$4^{s}\ 0^{\circ}\ 34'\ 5''$
16	10 22 51 16	9 21 4 12	10 9 28 12
Jan.	0 0 0 0	0 0 0 0	0 0 0
d.2	0 26 21 10	0 13 22	0 6 21
h.3	1 38 49	0 50	0 24
'40	21 58	11	5
			10 9 35 2
m.M.	2 20 7 8	0 3 27 10	5 20 59 3

Then enter the Table entituled *A Table of the Annual or first Equation of the Moon*, with the mean Anomaly of the Sun before found, and you

 have

have the firſt Equation of the Moon's mean Longitude, which (as the Title directs) added to or ſubſtracted from the mean Place of the Moon, gives her Place a firſt Time equated.

In like manner, enter the Table entituled *A Table of the Annual or firſt Equation of the Moon's Apogee*, as alſo that entituled *A Table of the Annual or firſt Equation of the Moon's Nodes*, each with the Sun's mean Anomaly, and you have the firſt Equation of the Moon's Apogee, and of her Node, which (as their Titles direct) added to or ſubſtracted from their mean Places, give their Places a firſt Time equated.

From the Sun's true Place ſubſtract the Place of the Moon's Apogee a firſt Time equated, and the remainder is the Annual Argument of the ſaid Apogee.

Then with the Sun's mean Anomaly, enter the firſt part of *the Table of the firſt Semi-annual or ſecond Equation of the Moon*, under the Title *Gr. Equation in Octants*, and take thence the greateſt Equation; alſo from the ſecond part of the ſaid Table under the Title *Equation* ☽, ☉ *in Apogee*, (with the Annual Argument of the Moon's Apogee) take out the Equation anſwerable to that Argument, the Sun being in Apogee, and ſay,

As the greateſt Equation in the Octants, Sun being in Apogee,

To the preſent Equation, Sun being in Apogee;

So

So is the greateſt Equation in the Octants, agreeable to the Sun's mean Anomaly,

To the true Equation anſwerable thereto; which (according to the Title) added to or ſubſtracted from the Moon's Place once equated, gives her Place equated a ſecond Time.

Likewiſe from the Sun's true Place ſubſtract the Place of the Moon's aſcending Node equated as before, and the remainder is the Annual Argument of the Node, with which enter the Table entituled *A Table of the ſecond Semi-annual or third Equation of the Moon*, and take out the Equation, which (as the Title directs) added to or ſubſtracted from the Moon's Place twice equated, gives her mean Longitude a third Time equated.

Then with the Annual Argument of the Moon's Apogee (before found) enter the Table entituled *A Table of the Semi-annual or ſecond Equation of the Moon's Apogee*, and you have the ſecond and principal Equation of the ſaid Apogee, which (as the Title directs) added to or ſubſtracted from its Place a firſt Time equated, gives the ſecond equated or true Place of the Moon's Apogee; which ſubſtracted from the Moon's Place a third Time equated, the remainder will be the Moon's mean Anomaly.

Alſo with the Annual Argument of the Moon's Apogee, enter *the Table of the Excentricity of the Moon's*

Moon's Orbit, and take out the Excentricity agreeable to the present State of the Moon's Orbit.

Then with the Moon's mean Anomaly enter *the Table of the Equation of the Moon's Centre* for the next lesser Excentricity to that before found, and take out the Equation answerable to that mean Anomaly; also with the said mean Anomaly, enter *the Table of the Equation of the Moon's Centre* for the next greater Excentricity, and take out thence the Equation agreeing thereto; and say,

As the difference of the two next Excentricities, to which the Equations are found,

To the difference of the said Equations;

So is the difference of any one of the said Excentricities, from the present Excentricity,

To a fourth Number; which, added to or substracted from the Equation belonging to the last used Excentricity, according as that is lesser or greater than the present Excentricity, gives the true Equation of the Moon's Centre, or Prosthaphæresis, which (as the Title directs) added to or substracted from the Moon's Place hitherto three Times equated, gives her Place a fourth Time equated.

From the fourth equated Place of the Moon substract the true Place of the Sun, and double the difference, then with the Sun's mean Anomaly, enter the first part of the Table entituled *A Table of the Variation, Reflection, or fifth Equation of*

of the Moon, under the Title *Gr. Variation in Octants*, and take thence the greateſt Variation, alſo from the ſecond part of the ſaid Table, under the Title *Variation* ☽, ☉ *in Apogee* (with the doubled diſtance of the Moon from the Sun) take out the Variation anſwerable to that diſtance, the Sun being in Apogee; and ſay,

As the greateſt Variation in the Octants, Sun being in Apogee,

To the preſent Variation, Sun being in Apogee;

So is the greateſt Variation in the Octants, agreeable to the Sun's mean Anomaly,

To the true Variation of the Moon; which (according to the Title) added to or ſubſtracted from the Moon's Place four Times equated, will give her Place equated a fifth Time.

Again, to the diſtance of the Moon from the Sun add the diſtance of the Moon's Apogee from the Sun's Apogee, that ſum will be the Argument of the ſixth Equation of the Moon, with which, enter *the Table of the ſixth Equation*, and take thence the Equation, which (as the Title directs) added to or ſubſtracted from the Moon's Place already five Times equated, will give her Place a ſixth Time equated.

twice equated
or ſubstracting
of leſs from
of greater

Alſo with the diſtance of the Moon from the Sun, enter the Table entituled *A Table of the ſeventh Equation of the Moon*, and take out the ſeventh Equation, which (according to the Title) added to or ſubſtracted from the Moon's Place

now

now ſix Times equated, gives her ſeventhly equated, or true Place in her proper Orbit.

This Equation, Sir *Iſaac Newton* ſays, is to be increaſed and diminiſhed according to the ſituation of the Lunar Apogee: For if the Lunar Apogee be in Conjunction with the Sun's Apogee, and alſo in the Sun's Syzygies, the ſaid Equation becomes greater by 54″, that is 3′ 14″; and if the Lunar Apogee be in Oppoſition to the Sun's Apogee, and in the Sun's Syzygies, it becomes leſs by 54″, that is 1′ 26″. Alſo if the Moon's Apogee be in Conjunction with the Sun's Apogee, and in the Sun's Quadratures, the ſaid Equation is to be diminiſhed by about 50″ or one whole Minute; but if the Moon's Apogee and the Sun's are in Oppoſition, and in the Sun's Quadratures, Sir *Iſaac* ſays, he cannot determine (for want of Obſervations) whether it is to be increaſed or diminiſhed: neither can he affirm any thing certain concerning the aforementioned increaſe and decreaſe of this Equation, for want of Obſervations exact enough.

N. B. The ſixth and ſeventh Equations are to be increaſed and diminiſhed in a reciprocal Ratio of the diſtance of the Moon from the Earth; that is, in a direct Ratio of the Moon's horizontal Parallax.

With the Annual Argument of the Moon's Node (before found) enter the Table entituled *A Table of the Semi-annual or ſecond Equation of the Moon's Nodes*, and you have the ſecond and chief

chief Equation of the Nodes, which (as the Title directs) added to or ſubſtracted from the Place of the Moon's aſcending Node a firſt Time equated, gives its ſecond equated or true Place; which, ſubſtracted from the true Place of the Moon in her Orbit, the reſidue will be the Argument of the Moon's Latitude.

Alſo with the aforeſaid Annual Argument of the Moon's Node, enter *the Table of the Inclination of the Moon's Orbit to the Ecliptic*, and take out thence the preſent Inclination.

Then with the Argument of Latitude enter *the Table of the Moon's Latitude*, and take out the Moon's Latitude for the leaſt Inclination of her Orbit, and alſo the Particle to be added in the greateſt Inclination, anſwerable to that Argument; and ſay,

As the exceſs of the greateſt Inclination of the Moon's Orbit to the Ecliptic above its leaſt Inclination,

To the Particle taken from the Table of Latitude;

So is the exceſs of the preſent Inclination of the Moon's Orbit to the Ecliptic above its leaſt Inclination,

To the Particle to be added in the preſent Inclination; which, added to the Moon's Latitude for the leaſt Inclination of her Orbit taken from the Table, gives her true Latitude.

Alſo with the aforeſaid Argument of Latitude enter the Table entituled *A Table of the Moon's Reduction from her proper Orbit to the Ecliptic*, and take thence the Reduction for the leaſt Inclination of her Orbit, and the Particle to be added in the greateſt Inclination; and ſay (in like manner as before)

As the exceſs of the greateſt Inclination of the Moon's Orbit to the Ecliptic, above its leaſt Inclination,

To the Particle taken from the Table of Reduction;

So is the exceſs of the preſent Inclination of the Moon's Orbit to the Ecliptic above its leaſt Inclination,

To the Particle to be added in the preſent Inclination; which, added to the Reduction for the leaſt Inclination of the Moon's Orbit taken from the Table, gives her true Reduction; which (as the Title directs) added to or ſubſtracted from the Place of the Moon in her proper Orbit, gives her true Place in the Ecliptic.

Example

Example continued.

Equ. Time	*Longitude* ☽				*Apogee* ☽				*Asc. Node* ☽				
	s	o	′	″	s	o	′	″	s	o	′	″	
1721	2	28	53	55	2	12	8	35	4	0	34	5	
16	10	22	51	16	9	21	4	12	10	9	28	12	
January	0	0	0	0	0	0	0	0		0	0	0	
d.2	0	26	21	10		0	13	22		0	6	21	
h.3		1	38	49			0	50			0	24	
′40			21	58				11				5	
mean Mot	2	20	7	8	0	3	27	10	10	9	35	2	
									5	20	59	3	☊
1 *Equation*		—	3	2		+	5	9		—	2	27	
☽ 1 *Equa.*	2	20	4	6	0	3	32	19	5	20	56	36	☊ 1 *Eq.*
2 *Equation*		+	2	33	9	23	37	22	9	23	37	22	*Suns Pl.*
☽ 2 *Equa.*	2	20	6	39	9	20	5	3	4	2	40	46	*An. Arg.*
3 *Equation*			+	43	—	9	19	27	—	1	22	232	*Eq.* ☊
☽ 3 *Equa.*	2	20	7	22	11	24	12	52	5	19	34	13	☊ 2 *Eq.*
4 *Equation*	—	5	18	29	2	25	54	30	*mean Anom.*				
☽ 4 *Equa.*	2	14	48	53	*Excentricity*				8	24	35	17	*Arg. Lat*
5 *Equation*		—	36	28	46703					5	4	40	*Inc. Lim.*
☽ 5 *Equa.*	2	14	12	25	4	21	11	31	☽ *a* ☉				
6 *Equation*		—	1	27	9	12	23	2	*doubled*				
☽ 6 *Equa.*	2	14	10	58	3	8	22	18	*Apogee* ☉				
7 *Equation*		—	1	28	8	15	50	34	*Ap.* ☽ *à Ap.* ☉				
☽ *in Orbit*	2	14	9	30	1	7	2	5	*Arg.* 6 *Equation*				
Reduction		—	1	17									
☽ *in Eclip*	2	14	8	13									
Lat. South		5	3	18									

4 *To find the apparent Place of the Moon.*

FIrſt, find her Right Aſcenſion and Declination, which is done by reſolving the ſpherical Triangle A B C (fig. 1) wherein A repreſents the Pole of the Ecliptic, B the Pole of the Equator, and C the Moon's Centre, in which there are given the Sides A B the diſtance of the Poles of the Ecliptic and Equator 23° 29′, A C the diſtance of the Moon from the Pole of the Ecliptic, known by her Latitude, and the Angle B A C the Moon's Longitude from ♋ or ♑: therefore the Side B C the diſtance of the Moon from the Pole of the Equator, and the Angle A B C her difference in Right Aſcenſion from 90° or 270° will be found.

Then to the Sun's Right Aſcenſion (taken from *the Table of Right Aſcenſions*) add the apparent Time from Noon converted into Degrees and Minutes, the ſum is the Right Aſcenſion of the Mid-heaven, whoſe difference from the Moon's Right Aſcenſion, is the Angle at the Pole of the Equator comprehended between the Meridian and the Circle of Declination paſſing through the Moon's Centre; therefore in the Triangle Z P M (fig. 2) in which Z repreſents the Zenith, P the Pole, and M the Place of the Moon, there are given the Sides Z P (the Complement of the Poles Elevation) and P M, together with the Angle Z P M juſt now found; whence the Side Z M the Complement of the Moon's Altitude, and the Angle

Angle M Z P her Azimuth will be known alſo; and thence the diſtance in the Horizon between the true Eaſt, and a vertical Circle drawn through the Moon's Centre.

Alſo to the Right Aſcenſion of the Mid-heaven add 90°, and you have the Oblique Aſcenſion of the Aſcendant, whence in the Triangle D E F (fig. 2) comprehended between the Ecliptic E F, Equator E D, and Horizon F D, is given the Side E D the Oblique Aſenſion of the Aſcendant, or its difference from a Semicircle, or Circle, the Angles D E F the *Inclination of the Ecliptic to* the Equator 23° 29′, and E D F the height of the Equator, or its Complement to a Semicircle; from whence the Angle of the Eaſt D F E which the Ecliptic makes with the Horizon, and the Side F D the diſtance of the ariſing Point of the Ecliptic from the true Eaſt will be found: So you have the diſtance in the Horizon between the ariſing Point of the Ecliptic and a vertical Circle drawn though the Moon's Centre; wherefore in the right angled Triangle F G H comprehended between the Vertical H G, Ecliptic H F and Horizon G F, you have given (beſides the right Angle at G) the Angle H F G, and the Side G F; whence the Angle G H F, which the Vertical makes with the Ecliptic is found.

Then with the Moon's mean Anomaly, and Excentricity of her Orbit, enter *the Table of the Semidiameters, and horizontal Parallaxes of the Moon*

Moon, in the Syzygies, and take thence the horizontal Parallax answerable thereto, also with the distance of the Moon from the Sun, in *the Table of Particles to be substracted from the Semidiameters and horizontal Parallaxes of the Moon, out of the Syzygies*, take the Particle to be substracted from her horizontal Parallax, which accordingly substracted gives the Moon's true horizontal Parallax.

Then say,
As Radius,
To the Sine of the horizontal Parallax;
So is the Co-sine of the Moon's Altitude,
To the Sine of her Parallax in Altitude.
And,
As Radius,
To the Tangent of the Parallax in Altitude;
So is the Co-sine of the Angle which the vertical Circle drawn through the Moon's Centre makes with the Ecliptic,
To the Tangent of the Parallax in Longitude; which, added in the Oriental and substracted in the Occidental Quadrant of the Ecliptic, to and from the true, gives the apparent Longitude of the Moon.
Again,
As Radius,
To the Sine of the Moon's Parallax in Altitude;
So is the Sine of the Angle which the vertical Circle drawn through the Moon's Centre makes with the Ecliptic,

To

To the Sine of her Parallax in Latitude; whence from the true, you have the Moon's viſible Latitude.

Or (which is more exact) from the Moon's Latitude, and the Angle which the vertical Circle drawn through the Moon's Centre makes with the Ecliptic, you may proceed to find the Angle at the Moon's Centre which the Vertical makes with a Circle of Latitude; and thence the Moon's Parallax both in Longitude and Latitude.

In computing the Moon's Parallax at the Time of Eclipſes of the Sun, the Moon's Place may be taken the ſame with the Sun's (without ſenſible error in the Parallax) which very much ſhortens the work, for from only the Angle of the Eaſt which the Ecliptic makes with the Horizon, and Altitude of the Sun, the Angle which the Vertical drawn through the Sun's Centre makes with the Ecliptic is found. Alſo if inſtead of the abſolute horizontal Parallax of the Moon, you take the exceſs of the Moon's horizontal Parallax above the Sun's horizontal Parallax, you will have the Parallax of the Moon from the Sun in Altitude, Longitude, and Latitude.

5 *To find the Time of a mean Conjunction or Opposition of the Sun and Moon.*

FRom the Table entituled *A Table of the mean Motion of the Moon from the Sun*, for the given Year and Month, collect the mean distance of the Moon from the Sun, and take its Complement to a Circle, if you want a mean Conjunction; or add 6 Signs to that Complement, if you want a mean Opposition: then in the said *Table of the mean Motion of the Moon from the Sun*, seek the nearest lesser mean Motion to that Complement or its Opposite, which substract from it, and mark the Time answerable thereto; also seek the nearest lesser mean Motion to that remainder, which substract from it, and mark its correspondent Time; and so on, till nothing remains; which Times collected will be the Day, Hour, &c. of the mean Syzygy required.

Example 1.

In the Year 1737, *in February*, the Time of the mean Conjunction of the Sun and Moon is required.

1721	5^s	8°	1′	1″
16	10	22	44	1
February	0	17	54	48
Mot. ☽ *from* ☉	4	18	39	50
Complement	7	11	20	10
d. 18	7	9	26	0
		1	54	10
h. 3		1	31	26
′ 45			22	44

Whence the mean ♂ is *February* 18 d. 3 h. 45′.

Example 2.

In the ſame *Year*, *in Auguſt*, the Time of the mean Oppoſition of the Sun and Moon is required.

1721	5^s	8°	1′	1″
16	10	22	44	1
Auguſt	2	4	26	19
Mot. ☽ *from* ☉	6	5	11	21
Complement	5	24	48	39
♂	11	24	48	39
d. 29	11	23	31	54
		1	16	35
h. 2		1	0	57
′ 31			15	38

Whence the mean ♂ is *Auguſt* 29 d. 2 h. 31′.

 To

6 *To find the Time of a true Conjunction or Opposition of the Luminaries* *.

TO the Time of the mean Conjunction or Opposition (found as before) find the true Place of the Sun, and of the Moon in the Ecliptic; if they be exactly the same, or opposite, the Time of the mean and true Syzygies do also coincide; but if those Places differ, note their difference; and compute again the Places of the Sun and Moon for an Hour before or after that Point of Time for which you have them already; by which means you will have the hourly Motion of the Moon from the Sun in the Ecliptic;

Then say,

As the hourly Motion of the Moon from the Sun,

To 1 Hour, or 60′;

So is the distance of the Moon from the Sun's Syzygy (before noted)

To the interval of the mean and true Conjunction or Opposition; which, added to or substracted from the Time of the mean Conjunction or Opposition, according as the Moon has not yet come to, or is already past the Sun's Syzygy, gives the Time of the true Conjunction, or Opposition required.

Example

* A true Conjunction of the Sun and Moon is when the Sun's true Place is the same with the Moon's true Place reduced to the Ecliptic; and a true Opposition when the Sun's true Place is directly opposite to the Moon's true Place reduced to the Ecliptic.

Example.

In the Year 1737, *in August*, the Time of the true Opposition of the Sun and Moon is required.

The Time of the mean ☌ is	29^d	2^h	$31'$	
To which Time,				
The true Place of the Sun is	5^s	$16°$	$50'$	$8''$
of the Moon in the Ecliptic	11	21	53	24
The difference from the ☌ past	0	5	3	16
To 1 Hour before the mean ☌, *viz.*	1^h	$31'$		
The true Place of the Sun is	5	16	47	41
of the Moon in the Ecliptic	11	21	23	2
The hourly Motion of the Sun			2	27
of the Moon in the Ecliptic			30	22
of ☽ from ☉ in the Ecliptic			27	55
The interval of the mean and true ☌ sub.		10^h	51	48
The equal Time of the true ☌	28^d	15	39	12

N. B. If the greatest Exactness be required, as is done in ecliptical Syzygies; to the lately found Time of the true Conjunction or Opposition, compute again the Sun and Moon's true Places, and if they be exactly the same, or precisely opposite, the thing is done; but if not, from the almost true Time of the true Syzygy already found, find the exactly true Time, in like manner as you found the almost true Time, from the Time of the mean Syzygy before found.

The exactly true Time of the true ☌ (in this Example) is $28^d\ 15^h\ 40'\ 49''$

7 *To calculate an Eclipse of the Moon* *.

AT the Time of the true Opposition of the Sun and Moon, with the Argument of Latitude, and hourly Motion of the Moon from the Sun in the Ecliptic, in *the Table of the Angles which the Way of the Moon from the Sun makes with a Circle of Latitude*, find the Angle; and (having found the Moon's Latitude, as is before directed) say,

As Radius,
To the Sine of the Moon's Latitude;
So is the Sine of that Angle,
To the Sine of the nearest Approach of the Centres of the Moon and Shadow.

With the Sun's mean Anomaly, enter *the Table of the hourly Motions, and Semidiameters of the Sun*, and take thence his Semidiameter: As also with the Moon's mean Anomaly, and Excentricity

* All opake Bodies, when exposed to the Sun, cast a Shadow behind them; that is, they intercept the Sun's Rays, and hinder them from enlightening the opposite Space: thus, the Earth being an opake Body, casts a Shadow on the Space opposite to the Sun, into which Space if the Moon shall come, she must necessarily be deprived of the Sun's Light, and so disabled from enlightening the Earth by Reflection, which occasions the Phenomenon that we call an Eclipse of the Moon.

Besides the Shadow which is wholly deprived of the Sun's Light, there is a certain ambient Space which is but partially deprived thereof; that is, whereon all the Sun's Body does not shine, only Rays coming from some part thereof enter it, and enlighten it, and that more or less as the Place is nearer to or farther from the total Shadow: this partial Shadow is called a Penumbra.

city of her Orbit, in *the Table of the Semidiameters, and horizontal Parallaxes of the Moon, in the Syzygies*, find her Semidiameter, and horizontal Parallax. Then from the ſum of the horizontal Parallaxes of the Sun and Moon, ſubſtract the Semidiameter of the Sun, the remainder will be the apparent Semidiameter of the Earth's Shadow, which is to be increaſed by about 50″ on account of the Earth's Atmoſphere.

To the Semidiameter of the Shadow thus increaſed add the Semidiameter of the Moon; if the ſum be greater than the neareſt Approach of their Centres (before found) the Moon will be eclipſed at that Time, otherwiſe not.

If the Moon be found eclipſed, from the ſum of the Semidiameters of the Moon and Shadow ſubſtract the neareſt Approach of their Centres, the remainder will be the Part deficient; then ſay,

As the Semidiameter of the Moon,
To 6 Digits or 360′;
So is the Part deficient,
To the Digits eclipſed.

Then with the Argument of Latitude, and hourly Motion of the Moon from the Sun, enter the Table entituled *A Table of the Times between the true Syzygy, and the mean Eclipſe, or greateſt Obſcuration*, and take thence the Time correſpondent thereto; which, added to or ſubſtracted from the Time of the true Oppoſition, according as

as the Moon has not yet come to, or is already paſt the next Node, gives the Time of the greateſt Obſcuration.

From the ſquare of the ſum of the Semidiameters of the Moon and Shadow in Seconds, ſubſtract the ſquare of the neareſt Approach of their Centres in Seconds, the ſquare Root of the remainder will be the Motion of Semiduration in Seconds.

If the Eclipſe be found of more than 12 Digits (*i. e.* Total) from the ſquare of the difference of the Semidiameters of the Moon and Shadow in Seconds, ſubſtract the ſquare of the neareſt Approach of their Centres in Seconds, the ſquare Root of the remainder will be the Motion of Semiduration in total Darkneſs in Seconds.

Then ſay,

As the hourly Motion of the Moon from the Sun in her Orbit (to be reſerved in the Operation of finding the true Oppoſition)

To 1 Hour, or 60′;

So is the Motion of Semiduration,

To the Time of Semiduration:

And, ſo is the Motion of Semiduration in total Darkneſs,

To the Time of Semiduration in total Darkneſs: which, reſpectively ſubſtracted from and added to the Time of the greateſt Obſcuration, gives

gives the Time of the Beginning and End of the Eclipse, and of total Darkness.

Example.

In the Year 1737, *in August*, the equal Time of the true ☌ of ☉ and ☽ is 28d 15h 40′ 49″

To which Time,

The true Place of the Sun is	♍	16°	23′	45″
of the Moon in her Orbit	♓	16	25	40
Place of the ascending Node	5	8	53	56
Argument of Latitude	6	7	31	44
Reduction, sub.			1	54
The Place of ☽ in the Ecliptic	♓	16	23	46
The Moon's Latitude, South			41	28
The Angle of the way of ☽ from ☉ with a Circle of Latitude		84	19	
The nearest Approach of the Centres of the Moon and Shadow			41	16
The horizontal Parallax of the Sun is				10
of the Moon			54	53
The sum of the horizontal Parallaxes			55	3
Semidiameter of the Sun, sub.			16	2
Semidiameter of the Earth's Shadow			39	1
increased			39	51
Semidiameter of the Moon			15	2
The sum of the Semidiameters			54	53
Nearest Approach of their Centres, sub.			41	16
The Part deficient			13	37
Digits eclipsed		5d	26	
The Time between the true Syzygy, and the mean Eclipse, sub.			8	45

Equal

Equal Time of the greatest Obscur.	15^h	$32'$	$4''$
Equation of Time, sub.		2	51
Apparent Time of the gr. Obscur.	15	29	13
The Motion of Semiduration		36	11
The Time of Semiduration	1	17	4
The Beginning of the Eclipse	14	12	9
The End	16	46	17

8 *To calculate an Eclipse of the Sun* *.

AT the Time of the true Conjunction of the Sun and Moon, from the horizontal Parallax of the Moon substract the horizontal Parallax of the Sun, the remainder is the Semidiameter of the Earth's Disk; also, to the Semidiameter

* The Phenomenon which is commonly called an Eclipse of the Sun, may more properly be termed an Eclipse of the Earth; for it is only the Earth and its Inhabitants that are deprived of the Sun's Rays, whilst the Sun himself suffers not the least decrease of Light. If we imagine a Spectator placed in the Moon, at the Time of an Eclipse of the Sun, he will see the Moon's Shadow and her Penumbra pass over the Earth, like as an Inhabitant of the Earth sees the Earth's Shadow and its Penumbra pass over the Moon, in a Lunar Eclipse: here it is to be noted, that the Sun is eclipsed when only the Moon's Penumbra falls upon the Earth, whereas the Moon is not said to be eclipsed except she comes into the total Shadow of the Earth. Moreover while the Earth by its diurnal Gyration revolves about its Axis; a Spectator placed in the Moon, will see Countries, Cities, and Towns move upon the Earth's Disk from West to East; and as such Spectator, at the Time of an Eclipse of the Sun, sees only the Earth's enlightened Hemisphere, he will see Places emerge from behind the western Edge of the Disk, and move Eastward, when the Inhabitants of such Places on the Earth, see the Sun rise and go towards the West; and when such Spectator sees the Edge of the Penumbra touch any Place upon the Disk, the Inhabitants of that Place will see the Sun begin to be eclipsed; &c.

meter of the Sun add the Semidiameter of the Moon, the ſum is the Semidiameter of the Moon's Penumbra.

Then, to the Semidiameter of the Earth's Diſk add the Semidiameter of the Moon's Penumbra; if the ſum exceeds the neareſt Approach of their Centres (to be found in like manner as the neareſt Approach of the Centres of the Moon and Shadow, in the foregoing Operation of the Moon's Eclipſe) the Sun will be eclipſed in ſome Part of the Earth, otherwiſe not.

If the Sun be found eclipſed in ſome Part of the Earth, the Beginning, Middle, and End, both of the general and central Eclipſe (with reſpect to the whole Earth) may be found in like Manner as is before directed concerning the Beginning, Middle, and End, of the Moon's Eclipſe.

But to find the Places upon the Earth, where the principal Appearances of Solar Eclipſes happen,

Let the Circle A B C (fig. 3) repreſent the Earth's enlightened Diſk, A E C a Portion of the Ecliptic projected * thereon, E B its Axis, B its Pole, P the Projection of the Pole of the Earth, and F G H the Path of the Shadow or Way of the Moon from the Sun projected on the Diſk;

 Then

* The Projection here ſuppoſed, is the Orthographic; being ſuch as would be ſeen by a Spectator placed at a very great diſtance in the right Line which joyns the Centres of the Sun and Earth.

Then in the right angled ſpherical Triangle B I P, there are given (beſides the right Angle at I) the Side B P the diſtance of the Poles of the Ecliptic and Equator, and the Angle P B I equal to the Sun's diſtance from the next Equinoctial Point; whence the Side B I the Meaſure of the Angle B E I (the Inclination of the Earth's Axis to the Axis of the Ecliptic) may be found. Here it is to be obſerved, that when the Sun is in the Signs ♑ ♒ ♓ ♈ ♉ ♊, the Point P (the Projection of the Pole of the Equator) falls on the Right Hand of the Axis of the Ecliptic; but when the Sun is in the other ſix Signs, the Point P falls on the Left Hand of the Axis of the Ecliptic, contrary to what happens when the Projection is ſuppoſed to be made on a Plane parallel to the Diſk at the Orbit of the Moon.

The Angle B E G that a Perpendicular to the Path of the Shadow makes with the Axis of the Ecliptic, is known by being the Complement of the Angle which the Way of the Moon from the Sun makes with a Circle of Latitude: only obſerve, that this Perpendicular falls on the Left Hand of the Axis of the Ecliptic when the Moon is neareſt her aſcending Node, but on the Right Hand of that Axis, when ſhe is neareſt her deſcending Node.

The Angles B E I and B E G being thus known, and conſequently the Angle G E I (their ſum or difference) the Place ☾ upon the Earth's Surface, which

which is firſt touched by the Penumbra, and where the riſing Sun begins to be eclipſed in his upper Limb, may be found as follows.

Firſt, draw the Meridian P Q. Then in the right angled plane Triangle F G E, you have given the Sides F E the ſum of the Semidiameters of the Diſk and Penumbra, and G E the neareſt Approach of their Centres; whence the Angle F E G may be found: from which, by adding or ſubſtracting the known Angle G E I, you will have the Angle F E I.

Therefore in the ſpherical Triangle P I Q on the Earth's Surface, right angled at I, you have the Sides P I equal to the Sun's Declination, and Q I the meaſure of the Angle F E I; from whence you may find the Side P Q the Complement of the Latitude of the Place Q, and the Angle I P Q; which Angle, or its Complement to a Semicircle (according as the elevated Pole in the Place Q is obſcured or enlightened) is the Angle contained between the Meridian of the Place Q, and the Meridian of the Place where the Sun is then vertical; but the Longitude of the Place where the Sun is vertical is known by the Time, and conſequently the Longitude of the Place Q, and having both Longitude and Latitude, the Place itſelf will be known.

By the ſame Method you may find the Place of the Earth, where the Centre of the Penumbra enters the Earth's Diſk, and the Sun riſes cen-

trally eclipſed; as alſo the Places where both central Eclipſe and Penumbra leave the Earth.

Alſo by a like Proceſs the Place N upon the Surface of the Earth, which is under the Centre of the Penumbra at the Time of the true Conjunction, where the Sun is centrally eclipſed in the nonageſimal (or higheſt) Degree of the Ecliptic, may be found. For if E B (the Semidiameter of the Diſk) be made Radius, N E (the Moon's Latitude) will be the Sine of the Sun's diſtance from the Vertex of the Place N; ſo that in the ſpherical Triangle N E P on the Earth's Surface, you will have the Sides P E the Sun's diſtance from the Pole, and N E his diſtance from the Vertex, together with the Angle N E P; whence the Side N P the Complement of the Latitude of the Place N, and the Angle N P E, which ſhews the difference of the Meridians of the Place N and of the Place where the Sun is then Vertical, may be found: from which the Place N it ſelf will be known, as before.

In the ſame Manner the Place of the Earth may be found, which is under the Centre of the Penumbra at any given Point of Time.

But the Place M upon the Earth's Surface, where the Sun is centrally eclipſed in the Meridian, is found by only reſolving the right angled plane Triangle E G M in which there are given all the Angles, and the Side G E; to find the other two Sides: one of which, *viz.* G M divided by

by the hourly Motion of the Moon from the Sun gives the difference of the Time when the Centre of the Shade is upon the universal Meridian* from the Middle of the Eclipse; by which the Longitude of the Place M will be known, being the same with the Longitude of the Place where the Sun is vertical when the Centre of the Shade is upon the universal Meridian: and the other Side M E is the Sine of the Sun's distance from the Vertex of the Place M (the Semidiameter of the Disk being made Radius) by which its Latitude will be known also.

Example.

In the Year 1737, *in February*, the apparent Time of the true ☌ of ☉ and ☽ is 18d 2h 13′ 3″

To which Time,

The true Place of the Luminaries	♓ 11°	6′	43″
The Moon's Latitude, North		38	5
The horizontal Parallax of the Moon		54	20
of the Sun, sub.			10
Semidiameter of the Earth's Disk		54	10
Semidiameter of the Sun		16	16
Semidiameter of the Moon, add		14	53
Semidiameter of the Moon's Penumbra		31	9
The Angle of the Way of ☽ from ☉ with a Circle of Latitude	84	17	
The nearest Approach of the Centres of the Disk and Penumbra		37	54

The

* The Line I P E wherein the Axis of the Earth is projected; so called, because when a Spectator placed in the Moon, observes any Place come to this Line (by the Earth's diurnal Rotation) the Inhabitants of that Place will have Mid-day.

The Time between the true Syzygy, and the mean Eclipſe, add		8′	16″
Apparent Time of the Middle of the general Eclipſe	2h	21	19
The Time of Semiduration of the general Eclipſe	2	46	46
The Beginning	23	34	33
The End	5	8	5
The Time of Semiduration of the central Eclipſe	1	24	26
The Beginning of the central Eclipſe	0	56	53
The End	3	45	45

The Inclination of the Earth's Axis to the Axis of the Ecliptic, to the R. Hand	22° 21′
The Angle of the Perpendicular of the Path of the Shadow with the Axis of the Ecliptic, to the Right Hand	5° 43′
The Sun's Declination, South	7 25

In the Latitude of 9° 39′ North, Longitude 82° 22′ Weſt from *Greenwich* the Eclipſe begins at Sun riſe. In Lat. 27° 31′ N. Long. 100° 20′ W. the Sun riſes centrally eclipſed. In Lat. 33° 34′ N. Long. 51° 58′ W. the Sun is centrally eclipſed in the 90th Degree of the Ecliptic. At 2h 46′ 2″ at *Greenwich* in Lat. 39° 29′ N. Long. 41° 30′ W. the Sun is centrally eclipſed at Noon. In Lat. 60° 11′ N. Long. 20° 26′ E. the Sun ſets centrally eclipſed. In Lat. 42° 33′ N. Long. 6° 7′ E. the Eclipſe ends at Sun ſet, and wholly leaves the Earth.

The

The Beginning, greateſt Obſcuration, and End, of a Solar Eclipſe in any particular Place of the Earth, may be found (by analytic Calculus) as follows.

Let A B C (fig. 4) repreſent half the Earth's enlightened Diſk, A E C a Portion of the Ecliptic, and F G H the Path of the Shadow, both projected thereon (as before) let E I be the univerſal Meridian, and the Ellipſe R S T V the Projection of the Parallel of any given Place.

Then, if E B the Semidiameter of the Diſk be made Radius, and be ſuppoſed = 1, R O the greater Semi-axe of the Ellipſe will be the Co-ſine of the Parallel's Latitude, S O its leſſer Semi-axe will be equal to the Rectangle of the Co-ſines of the Latitude and of the Sun's diſtance from the Pole, and E O will be equal to the Rectangle of their Sines.

Suppoſe the Motion of the Centre of the Shadow to be reſolved into two Motions in Lines parallel to R T and S V, and let the hourly Motion in each of theſe be found, and reduced in Proportion to the Semidiameter of the Diſk = 1; alſo let the Semidiameter of the Penumbra be reduced in the ſame Proportion: and having found the Time when the Centre of the Shade is upon the univerſal Meridian (at M) and the Line E M (as is before directed)

Put

Put $a = $ O M, $b = $ R O, $c = $ S O, $d = $ the Semi-diameter of the Penumbra, $e = $ the Sine of the Hour when the Centre of the Shade is at M, $f = $ its Cosine, $g = $ the Motion of the Shadow in Lines parallel to R T in 3.8197 Hours (being the Time correspondent to an Arch equal to Radius) $h = $ its Motion in Lines parallel to S V in the same Time, and $y = $ the Arch answering to the difference between the Time when the Centre of the Shade is at M and the Time sought (whether it be Beginning, greatest Obscuration, or End) *.

Then will $e + fy - \frac{ey^2}{2} - \frac{fy^3}{6} + \frac{ey^4}{24} + \frac{fy^5}{120} - \frac{ey^6}{720}$ &c. = the Sine of the Hour sought, and $f - ey - \frac{fy^2}{2} + \frac{ey^3}{6} + \frac{fy^4}{24} - \frac{ey^5}{120} - \frac{fy^6}{720}$ &c. = its Cosine. Also $be + bfy - \frac{bey^2}{2} - \frac{bfy^3}{6} + \frac{bey^4}{24} + \frac{bfy^5}{120} - \frac{bey^6}{720}$ &c. $= \alpha\beta$, $gy = \gamma\delta$, and $be + bfy - gy - \frac{bey^2}{2} - \frac{bfy^3}{6} + \frac{bey^4}{24} + \frac{bfy^5}{120} - \frac{bey^6}{720}$ &c. $= \alpha\beta - \gamma\delta$. Again $cf - cey - \frac{cfy^2}{2} + \frac{cey^3}{6} + \frac{cfy^4}{24} - \frac{cey^5}{120} - \frac{cfy^6}{720}$ &c. $= \alpha$ O, $hy = $ Mδ, and $a + cf - cey + hy - \frac{cfy^2}{2} + \frac{cey^3}{6} + \frac{cfy^4}{24} - \frac{cey^5}{120} - \frac{cfy^6}{720}$ &c. $= \alpha\delta$. Substitute $k = bf - g$, $l = a + cf$, and

m

* In applying the following Theorems to Practice, it is carefully to be observed, that a is Negative when the Point M falls to the South of the Point O, c is Negative when the Sun is in the southern Signs, e when the Time of the Centre of the Shade's being at M is before Noon, f when that Time is distant from Noon by more than 6 Hours, h when the Line G E falls to the Right Hand of the Line I E, but in other cases Affirmative; and that b and g are always Affirmative.

$m = ce - h$. Then by 47 Prop. 1 Book *Eucl.*

$$\left.\begin{array}{r}
bbee + 2beky - bbeey^2 - \frac{bbefy^3}{3} + \frac{bbeey^4}{3} + \frac{11bbefy^5}{60} - \frac{2bbeey^6}{45} \text{ \&c.} \\
+ kky^2 - beky^3 - \frac{bfky^4}{3} + \frac{beky^5}{12} + \frac{bfky^5}{60} \text{ \&c.} \\
+ \frac{bbffy^5}{36} \text{ \&c.} \\
+ ll - 2lmy - cfly^2 + \frac{cely^3}{3} + \frac{cfly^4}{12} - \frac{cely^5}{60} - \frac{cfly^6}{360} \text{ \&c.} \\
+ mmy^2 + cfmy^3 - \frac{cemy^4}{3} - \frac{cfmy^5}{12} + \frac{cemy^6}{60} \text{ \&c.} \\
+ \frac{ccffy^4}{4} - \frac{ccefy^5}{6} - \frac{ccffy^6}{24} \text{ \&c.} \\
+ \frac{cceey^6}{36} \text{ \&c.}
\end{array}\right\} = \overline{\beta\gamma}^2$$

which, by substituting $n = bbee + ll$, and p, q, r, s, t, v for the Coefficients of y and its several Powers, becomes $n + py + qy^2 + ry^3 + sy^4 + ty^5 + vy^6$ &c. $= \overline{\beta\gamma}^2$: but it is manifest that $\beta\gamma$ (and consequently its square) is a *Minimum* at the Time of the greatest Obscuration; therefore $p\dot{y} + 2qy\dot{y} + 3ry^2\dot{y} + 4sy^3\dot{y} + 5ty^4\dot{y} + 6vy^5\dot{y}$ &c. $= 0$ and by Transposition and Division $2qy + 3ry^2 + 4sy^3 + 5ty^4 + 6vy^5$ &c. $= -p$; from whence either by Sir *Isaac Newton*'s Method of inverting Series, or by the common Methods of resolving adfected Equations*, the Value of y may be found, which will shew the Time of the greatest Obscuration.

E Also

* If the Series be resolved as an adfected Equation, it must be so discontinued that the Exponent of the highest Power of y which is taken into that Equation, may be an odd Number; otherwise either all the Roots will be impossible, or it will have more than one possible Root.

Alſo, if for y and its ſeveral Powers in the Series $n+py+qy^2$ &c. you ſubſtitute its Value thus found, you will have the ſquare of $\beta\gamma$ at the Time of the greateſt Obſcuration; whoſe ſquare Root ($\beta\gamma$) reduced into Minutes and Seconds, and ſubſtracted from the Semidiameter of the Penumbra gives the Part deficient: then ſay,

As the Semidiameter of the Sun,
To 6 Digits, or 360′;
So is the Part deficient,
To the Digits eclipſed.

Again, both at the Time of the Beginning and End of the Eclipſe, $\beta\gamma$ is equal to the Semidiameter of the Penumbra; ſo that $n+py+qy^2+ry^3+sy^4+ty^5+vy^6$ &c. $=dd$: which, reſolved by the known Methods for reſolving adfected Equations, will have two poſſible Roots*, one whereof ſhews the Time of the Beginning, and the other the Time of the End of the Eclipſe.

Example.

Let it be required to find the Beginning, greateſt Obſcuration, and End of the beforementioned Eclipſe of the Sun, *February* the 18th 1737, at *London*†.

Here $a=-.0463$, $b=.6221$, $c=-.0803$, $d=.5751$, $e=.6627$, $f=.7489$, $g=1.8581$, and h

* The Series muſt be ſo diſcontinued that the Exponent of the higheſt Power of y which is taken into the Equation, may be an even Number; otherwiſe it will have either but one poſſible Root, or more than two poſſible ones.

† The difference of the Meridian of *London* from that of *Greenwich* (being ſmall) is neglected both in this and the following Example.

$h = .5551$; so that $k = -1.3922$, $l = -.1064$, $m = -.6083$, $n = .1813$, $p = -1.2773$, $q = 2.1320$, $r = .5484$, $s = .2635$, $t = -.0163$, $v = -.0119$, and by resolving the preceeding Equations, the several Values of y will be found: which give the Time of the gr. Obscuration $3^h 47' 25''$, Digits $10^d 15'$, Beginning $2^h 23' 0''$, and End. $5^h 3' 16''$.

But the Method of computing Solar Eclipses by Parallaxes, being that commonly used by Astronomers; is thus, *viz.*

To the apparent Time of the true Conjunction of the Luminaries, compute the Parallax of the Moon from the Sun, in Longitude;

Also to half an Hour, an Hour, or more (as that Parallax is small or great) before or after the true Conjunction, according as the Moon is in the Oriental or Occidental Quadrant of the Ecliptic, compute again the Parallax of the Moon from the Sun in Longitude; by which means (from the true) you will have the visible half hourly, hourly, &c. Motion of the Moon from the Sun:

Then say,

As the visible Motion of the Moon from the Sun,

To the Time taken;

So is the Parallax of the Moon from the Sun in Longitude at the Time of the true Conjunction,

To the interval of the true and visible Conjunction: which, added to or substracted from the Time of the true Conjunction, as the Moon is in the Occidental or Oriental Quadrant of the E-

cliptic, gives the Time of the viſible Conjunction of the Luminaries.

To which Time find again the true Places of the Sun and Moon, with the Parallax of the Moon from the Sun in Longitude and Latitude, and ſo her apparent Place in reſpect of the Sun.

Alſo to an Hour before the Time of the viſible Conjunction, compute the viſible Longitude of the Moon from the Sun in Antecedence, with her viſible Latitude; as alſo, to an Hour after the viſible Conjunction, compute the viſible Longitude of the Moon from the Sun in Conſequence, with her viſible Latitude: and ſay,

As the Sine of the viſible Motion of the Moon from the Sun in Longitude, in thoſe two Hours,

To Radius;

So is the Tangent of the difference of the viſible Latitudes,

To the Tangent of the Angle of the viſible Way of the Moon with the Ecliptic at the Time of the viſible Conjunction.

And, as Radius,

To the Sine of the viſible Latitude of the Moon at the Time of the viſible Conjunction;

So is the Sine of the Angle of the viſible Way of the Moon with the Ecliptic, at that Time,

To the Sine of the Motion ſeen from the viſible Conjunction to the greateſt Obſcuration:

And, ſo is the Co-ſine of that Angle,

To the Sine of the viſible diſtance of the Centres of the Sun and Moon at the Time of the greateſt

greateſt Obſcuration; *i. e.* their neareſt viſible diſtance.

If this diſtance be leſs than the Semidiameter of the Moon's Penumbra (found as is before directed) the Sun will be eclipſed in that Place, otherwiſe not.

If the Sun be found eclipſed in that Place, from the Semidiameter of the Penumbra ſubſtract the neareſt viſible diſtance of the Centres of the Sun and Moon, the remainder will be the Part deficient; from which the Digits eclipſed may be found, as is directed in p. 82.

Then ſay,

As the viſible Motion of the Moon from the Sun from an Hour before to an Hour after the Time of the viſible Conjunction,

To 2 Hours, or 120′;

So is the Motion ſeen from the viſible Conjunction to the greateſt Obſcuration,

To the interval in Time: which, added to or ſubſtracted from the Time of the viſible Conjunction (according as the Moon's viſible Latitude is decreaſing or increaſing) gives the Time of the greateſt Obſcuration.

From the ſquare of the Semidiameter of the Penumbra in Seconds, ſubſtract the ſquare of the neareſt viſible diſtance of the Centres of the Sun and Moon in Seconds, the ſquare Root of the remainder will be the viſible Motion of Semiduration in Seconds.

Then

Then ſay,

As the Sine of the viſible Motion of the Moon from the Sun in Longitude for an Hour before the viſible Conjunction,

To Radius;

So is the Tangent of the difference of the viſible Latitudes in that Time,

To the Tangent of the Angle of the viſible Way of the Moon with the Ecliptic from the Beginning of the Eclipſe to the viſible Conjunction.

And, as Radius,

To the Sine of the viſible Motion of Semiduration;

So is the Co-ſine of that Angle,

To the Sine of the viſible Motion in Longitude from the Beginning of the Eclipſe to the greateſt Obſcuration.

Alſo, as the viſible Motion of the Moon from the Sun in Longitude in the Hour before the viſible Conjunction,

To 1 Hour, or 60′;

So is the Motion in Longitude ſeen from the Beginning of the Eclipſe to the greateſt Obſcuration,

To the Time of Incidence: which, ſubſtracted from the Time of the greateſt Obſcuration, gives the Time of the Beginning of the Eclipſe.

By the like Proportions (from the viſible Longitude of the Moon from the Sun in Conſequence with her viſible Latitude for an Hour after the viſible Conjunction) you may find the Time of Emergence, and ſo the End of the Eclipſe.

Example

Example.

In the Year 1737, *in February*, the apparent Time of the true ☌ of ☉ and ☽ is 18d 2h 13′ 3″

To which Time,

The true Place of the Luminaries	♓	11°	6′	43″
Right Aſcenſion of the Sun		342	35	
Time from Noon in Degr. and Min.		33	16	
Right Aſcenſion of the Mid-heaven		15	51	
Angle Orient, in Lat. 51° 32′ North		49	26	
Declination of the Sun, South		7	25	
Altitude of the Sun		24	30	
Angle of the vertical Circle with the Ecliptic		45	37	
The horizontal Parallax of the Moon			54	20″
Parallax of ☽ from ☉ in Altitude			49	17
in Longitude			34	28

To an Hour and an half after the true ☌ *viz.* 3h 43′ 3″

Parallax of ☽ from ☉ in Longitude			42	41
The true Motion of ☽ from ☉ in 1½h			41	3
The viſible Motion of ☽ from ☉ in 1½h			32	50
Interval of the true and viſible ☌ add		1h	34	28
Apparent Time of the viſible ☌		3	47	31

To which Time,

The true Place of the Sun is	♓	11°	10	40
of ☽ in the Ecliptic	♓	11	53	44
The Moon's Latitude, North			33	45
Parallax of ☽ from ☉ in Longitude			42	59
in Latitude			30	21
Viſible Longitude of ☽	♓	11	10	45
Viſible Latitude, North			3	24

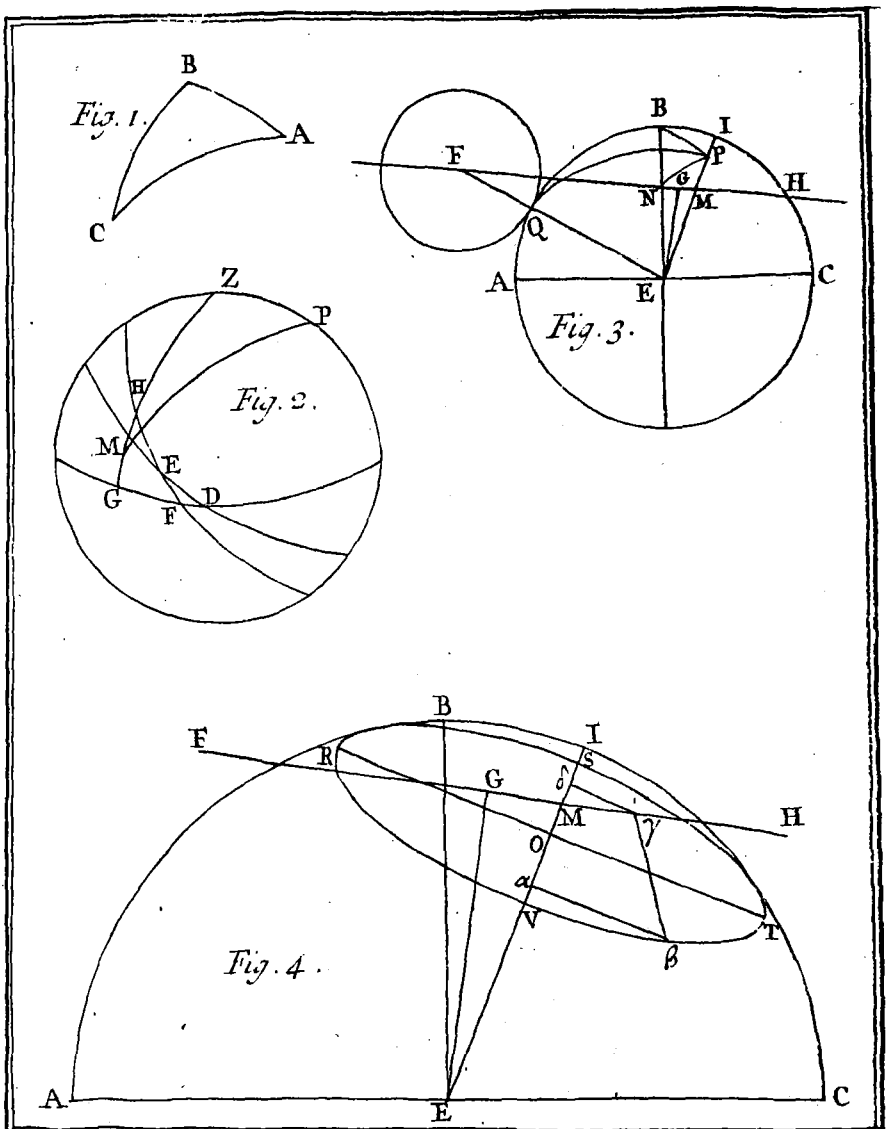
To

To an Hour before the visible ☌ *viz.*	2^h	$47'$	$31''$
Visible Long. of ☽ from ☉ in Antecedence		22	25
Visible Latitude of ☽, North		3	10
To an Hour after the visible ☌, *viz.*	4^h	47	31
Visible Long. of ☽ from ☉ in Consequence		24	14
Visible Latitude of ☽, North		3	3

So that in this Eclipse the visible Way of ☽ is almost parallel to the Ecliptic: wherefore the Times of the visible ☌ and greatest Obscuration do nearly coincide.

Semidiameter of the Sun		16	16
Semidiameter of the Moon, add		14	53
Semidiameter of the Penumbra		31	9
The nearest visible distance of the Centres of ☉ and ☽, sub.		3	24
The Part deficient		27	45
Digits eclipsed	10^d	14	
Visible Motion of Semiduration		30	58
Time of Incidence	1^h	22	53
The Beginning of the Eclipse	2	24	38
Time of Emergence	1	16	40
The End	5	4	11

FINIS.



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THE CALCULATION OF Solar Eclipſes WITHOUT PARALLAXES

THE CALCULATION OF *Solar Eclipses* WITHOUT PARALLAXES.

WITH

A SPECIMEN of the ſame in the Total Eclipſe of the Sun, *May* 11. 1724.

Now firſt made Publick.

To which is added,

A PROPOSAL how, with the Latitude given, the Geographical Longitude of all the Parts of the Earth may be ſettled by the bare Knowledge of the Duration of Solar Eclipſes, and eſpecially of Total Darkneſs.

WITH

An ACCOUNT of ſome late Obſervations made with Dipping Needles, in order to diſcover the LONGITUDE and LATITUDE at Sea.

By *WILL. WHISTON*, M. A.
Sometime Profeſſor of the Mathematicks in the Univerſity of *Cambridge*.

LONDON:
Printed for J. SENEX in *Fleetſtreet*; and W. TAYLOR in *Pater-Noſter-Row*. 1724.

LEMMATA:

OR,

Preparatory Propositions.

I.

THE most useful and most remarkable *Cycle* or *Period* for the Revolution of Eclipses, both Solar and Lunar, mentioned by *Pliny*, (*Nat. Hist.* II.) and by him only of all the Ancients, is the Interval of 223 Synodical Months = 6585 Days: or = 18 *Julian* Years: with 10 Days, when the Cycle or Period contains 5 Leap-Years: and with 11 Days, when with 7 Hours $43' \frac{1}{4}$. In which Time the direct mean Motion of the *Moon* and her *Apogee* in the Ecliptick, is nearly so much *more*; and the Retrograde mean Motion of the *Nodes* nearly so much *less* than entire Revolutions, as the mean Motion of the *Moon from the Sun*, upon which all mean

Conjunctions, Oppositions, and Eclipses properly depend, exceeds the like entire Revolutions. Which Coincidences do therefore nearly restore the mean State of the Moon it self, its Apogee, Nodes, and Lunations: And produce an eminent Revolution of correspondent New Moons, Full Moons, and Eclipses, after that Interval perpetually.

This appears by the following Calculation of all these mean Motions from the Astronomical Tables.

Mean Motion of the Sun or Earth.

		s	o	′	″
Years	18	11	29	28	32
Days	11	0	10	50	32
Hours	7	0	0	17	15
′	43	0	0	1	46
″	15	0	0	0	1
Sum		0	10	48	6

Mean Motion of the Moon in the Ecliptick.

		s	o	′	″
Years	18	7	11	37	22
Days	11	4	24	56	25
Hours	7	0	03	50	35
′	43	0	00	23	36
″	15	00	00	00	08
Sum		00	10	48	06

Mean

Mean Motion of the Apogee.

		s	°	′	″
Years	18	0	12	23	53
Days	11	0	1	13	32
Hours	7	0	0	1	57
′	43¼	0	0	0	12
Sum		0	13	39	34

Mean Motion of the Node backward.

		s	°	′	″
Years	18	11	18	7	39
Days	11	0	0	34	57
Hours	7	0	0	0	56
′	43¼	0	0	0	6
Sum		11	18	43	38

Mean Motion of the Moon from the Sun.

		s	°	′	″
Years	18	7	11	58	50
Days	11	4	14	5	53
Hours	7	0	3	33	20
′	43	0	0	21	50
″	15	0	0	0	7
Sum		0	0	0	0

 From

	°	′	″
From the mean Motion of the Apogee—	13	39	34
Substract that of the Moon in the Eclipt. -	10	48	6
Remains —— (2°L9) —— ——	2	51	28
To the mean Motion of the Moon--	0	10	48	6
Add that of the Node —— ———	11	18	43	38
Sum —— —— —— ——	11	29	31	44
Difference from 12 Signs (0°L47)—	0	0	28	16

Whence it appears that the Difference of the mean Motions of the Apogee and of the Nodes from that of the Moon her self in the Ecliptick, in such a Period, is but small: Not more in the former Case than 2° 51′ 28″ = 2°L9, nor in the latter than 28′ 16″ = 0°L47. Whence also it appears that the Lunar Apogee does in every such Cycle differ but $\frac{1}{62}$ of the entire Difference 2L9) 180(62. That the Lunar Node only differs in that Cycle $\frac{1}{383}$ of the entire Difference 0°L47) 180 (383. And that the Anomaly of the Sun it self differs only $\frac{1}{16L6}$ of the entire Anomaly: 10L8) 180(16L6. Which Quantities being generally small, cannot occasion any great Inequality in the Times and Circumstances of New and Full Moons, or of Eclipses; nor by consequence greatly disturb the regular Succession of the same in any single Period; nor indeed very greatly in several successive Periods. For since the mean Motion of the *Moon from the Sun* is within a very small Matter ever certain and invariable, that Revolution is always just; and always determines the mean Time of all Conjunctions, Oppositions, and Eclipses rightly; and since the other Anomalies are but small, and always come right again in Length of Time, they cannot ever produce any very

very great Anomalies in our Calculations from them. As will farther appear under the following *Scholia*.

N. B. This Period for Eclipses, has of late been called, both by Mr. *Flamsteed*, and Dr. *Halley*, the *Saros*, or the *Chaldean Saros*: As if it were known and us'd by the old *Chaldeans*, and thence called by that Name. For which I know no sufficient Foundation. There is indeed a gross Mistake of *Pliny*'s Number in *Suidas*, (who thus applies this term) 222 for 223 Months, as almost all the Editions of *Pliny* still have it; and He calls that Period by this *Chaldean* Name *Saros*. Yet the *Chaldeans* never, that we find, apply'd it to any other Period than that of 3600 *Years* or *Days*; by which Period alone all the Antediluvian Reigns are determined both in *Abydenus* and *Berosus* themselves, from the ancientest Records of that Kingdom. See my *New Theory*, the later Editions, *Hypoth.* X. *Lem.* to the third Argument; and *Appendix* to the *Essay* towards restoring the true Text of the Old Testament, *p.* 203, —— 213.

SCHOLIA.

(1.) We may here Observe, that since the Limit for Eclipses of the Moon is about 11° 40′ = 700′ on each Side of the Node; as is the Limit for Eclipses of the Sun, about 16° 40′ = 1000′. If we divide 700, the Limit of the Moon's Eclipses, by 28′ 16″ = 28′.3, which is the Difference between the Revolution of the Moon to the Sun and of the Node above given, we shall have nearly Twenty Five for the Number of Cycles,, after a Central Lunar Eclipse in one of

of the Nodes, before the Moon goes off the Shadow of the Earth entirely at the ſame Node, and 450 Years ($25 \times 18 = 450$,) or double that Number 900 Years for the Time that the Moon begins to enter the Ecliptick Limit on one Side, till it goes out of it on the other. During which long Interval there will ſtill be Eclipſes of the Moon each Period. And if we divide 1000′ the Limit of the Sun's Eclipſes, by the ſame Number 28′.3, we ſhall have nearly 35 for the Number of Periods after a Solar Central Eclipſe at the Middle of the Earth, in one of the Nodes, before the Penumbra goes off the *North* or *South* Parts of the Diſk of the Earth entirely at the ſame Time; *i. e.* 630 Years. ($35 \times 18 = 630$,) or double that Number 1260 Years, from the Time that the Moon in any ſuch Period begins to enter the Ecliptick Limit on one Side, till it goes out of on the other: During which longer Interval there will ſtill be ſomewhere Eclipſes of the Sun each Period. After which reſpective long Intervals of Time there will be no ſuch Eclipſes for much longer Intervals.

(2.) Since the utmoſt Latitude of the Moon that can permit any Lunar Eclipſe, is about 62′, and the ſame utmoſt Latitude that can permit a Solar Eclipſe is about 92′: If we divide the firſt Number by 25, or the laſt by 35, the Numbers of Revolutions for the Ecliptick Limits, we ſhall have about 2′.6 = 2′ : 36″ for the mean Alteration of the Moon's Latitude in each ſingle Period all along; and this both for Solar and Lunar Eclipſes. Which Latitude will be *South* during the one half of the long Period of the Ecliptick Limits before-mentioned; and *North* during the other half: Gradually increaſing, and

and as gradually decreasing perpetually: As in the following Table.

A Table of the mean Latitudes of the Moon each single Cycle, either *North* or *South*; beginning at an Eclipse in one of the Nodes, without any Latitude at all.

Latitudes for 25 *Cycles in Lunar, and* 35 *in Solar Eclipses.*

Cycles	′	″
1	2	26
2	4	52
3	7	19
4	9	46
5	12	14
6	14	43
7	17	12
8	19	42
9	22	12
10	24	43
11	27	14
12	29	46
13	32	19
14	34	52
15	37	26
16	40	1
17	42	36
18	45	12
19	47	48
20	50	25
21	53	3
22	55	41
23	59	20
24	60	59
25	63	39
26	66	0
27	68	41
28	71	23
29	74	6
30	76	49
31	79	33
32	82	17
33	85	2
34	87	48
35	90	34

(3.) Since

(3.) Since the principal Alteration in the Quantity and Duration of total Eclipses of the Sun, arises from the Difference there is at any Time between the real Distances, and apparent Diameters of the Sun and Moon, at the Time of such Eclipses, that Quantity and Duration must depend on the Difference of their mean Anomalies, which gives us that Difference of Distances and Diameters; and must therefore answer in each Cycle one with another, to the Differences of those mean Anomalies during that Interval; which in the Sun comes to $\frac{100.8}{180}$ or $\frac{1}{16.6}$ of its entire Anomaly. And in the Moon to $\frac{2}{170}$ or $\frac{1}{85}$ of its entire Anomaly. And since the whole mean Excentricity of the Moon is somewhat above three Times as great as that of the Sun, or as $\frac{55}{1000}$ to $\frac{17}{1000}$. The Differences of the Sun's Distances and Diameters will be but a little greater in each Period one with another, than those of the Moon.

(4.) When therefore the Anomalies of the Sun and Moon are of the same Species; I mean both ascending, or both descending; their Distances and Diameters will, one with another, increase or decrease nearly in the same Proportion; and the Quantity and Duration of total Darkness will alter but little in such a Period. But when those Anomalies are of the contrary Species; that is, the one ascending while the other descends; they will alter considerably. So that if the Sun be descending, and its apparent Diameter Increasing; while the Moon is ascending, and its apparent Diameter Decreasing, the Eclipse of the Sun will, each succeeding Cycle, afford a smaller total Shadow; till at last it afford no total Shadow

dow at all; but the Eclipses become *Annular*. And if the Sun be Ascending while the Moon is Descending, the contrary will happen; and the total Shadow grow greater perpetually. From which Circumstances of the Sun and Moon in each Revolution of the Cycle duly considered, we may nearly determine whether any succeeding correspondent Eclipse will afford us a greater or less total Shadow, or whether the Eclipses will be only *Annular*.

(5.) From the like Circumstances we may also nearly determine whether such Eclipses will come somewhat sooner or later, than that of the mean Revolution of the Period before us. For if the Earth be much nearer its Aphelion, than the Moon its Apogæon, at the end of any Cycle; and by consequence if the Earth then revolve comparatively slower, and the Moon swifter than ordinary; the meeting of the Luminaries will be accelerated. And if the Earth be much remoter from its Aphelion than the Moon from its Apogæon, the contrary will happen; and the Moon will be later than ordinary e'er it overtake the Sun. So that in the former Case the Eclipse will come a little *before*, and in the latter a little *after* the proper Conclusion of that Period.

(6.) Since the Motion of the Node backward in one of these Periods does not quite reach to the Conjunction or Opposition, that Node must every Cycle go forward, with respect to the Lunations and Eclipses; and at the ascending Node the Moon will pass more *Southward*, and at the descending Node more *Northward* successively. Thus at the Solar Eclipse *May* 1. 1706. the Moon, near its ascending Node, had greater *Northern* Latitude than it will have at the next corresponding Solar Eclipse, *May* 11. 1724. And thus at

the total Solar Eclipse, *April* 22. 1715. the Moon near its descending Node, had less *Northern* Latitude than it will have at its corresponding great Eclipse, *May* 2. 1733.

(7.) Since the Motion of the Moon's Apogee forward is greater in one of these Periods than that of the Lunations, that Apogee must also go forward every Cycle: And if at any one Solar Eclipse that Apogee be in quadrature with the Sun, after it had been in Conjunction, the Moon will the next Period descend by going backward in its Eclipses, towards the Perigee. And if at any one such Apogee it be in the quadrature, after it had been in Opposition, it will the next Cycle ascend: The Reverse of all which is true in Lunar Eclipses.

(8.) The Place and Motion of the Sun in its Ellipsis is so easily known, and that for many Ages, by bare Memory and Reflection, that a few Words will suffice. The Sun is now farthest from the Earth Eight Days after the longest Day; and nearest to it Eight Days after the shortest: And its Motion about 1 Degree in 72 Years. Whence it is evident, that it has, for all the past Ages of Astronomy, been about the Summer Solstice in our Apogee, and about the Winter Solstice in our Perigee; if I may use the Terms of the *Ptolemaick* System. Nor is it therefore any Wonder that the greatest total Eclipses of the Sun have happened still in the Summer, and the greatest Annular ones in the Winter half Year: Since the farther the Sun is off in the Winter, the less must be its apparent Diameter, and by consequence the greater the Excess of the Moon's Diameter above it. On which Excess alone the Greatness of such Eclipses depends. And the Reverse is equally evident in the Case of Annu-

lar

lar Eclipses in Winter: Nor indeed is it very strange, that Annular Eclipses are in these Parts of the World so rarely observed; since they most usually happen in Winter Days; which being short, must afford us a proportionably small Number of them. To the Inhabitants of the other Side of the Equator the Reverse must happen. But those Eclipses very rarely come to our Notice.

(9.) Since this Period reaches only from the middle of one general Eclipse to another, without regard to the Position of any particular Place on the Earth's Surface, arising from the diurnal Motion, we must remember that if an Eclipse of the Sun happens at any particular Place considerably before Noon, it will come sooner, and after Noon later than the proper Conclusion of this Period. Though it must be noted, that Eclipses of the Moon being absolute in their own Nature, are here wholly unconcerned; and no way subject to any Acceleration, Retardation, or Alteration on account of the diurnal Motion of the Earth.

(10.) The principal Alteration of the Time of the Day in all Eclipses depends on the Excess of this Period above an even Number of Days; which is 7 Hours and $43\frac{1}{4}$. So that the Cycle does naturally put every correspondent Eclipse later than the foregoing, almost 8 Hours, or one third part of a Day; which thing, by reason of the intervening diurnal Motion, greatly alters all Eclipses, especially Solar, not only as to the bare Time of the Day when, but also as to the Places on the Earth where such correspondent Eclipse will be visible.

(11.) If therefore we join three of these Cycles together, those odd Hours and Minutes will amount nearly to a whole Day; and will therefore nearly bring the middle Point of the correspondent Eclipses to the same Time, in the same Place, and, in part, with the same Circumstances as before: Which a single Cycle cannot possibly do. Only, with the Anticipation of 50′ in Time. Which three single Cycles therefore of 19,756 Days, or of 54 Years; with 32 or 33 Days; I call the *Grand Cycle*. And this will be, I think, of the greatest and readiest use in remote Eclipses of any other Period whatsoever.

Thus, for Example, there was a total Eclipse of the Sun on *Black Monday*; as it has thence been called ever since, *March* 29. 1652. about Ten a Clock in the Morning. *Total*, I say it was in the *North* of *Ireland*, and the *Northwest* of *Scotland*, tho' not so at *London*, ot the remoter Parts of *England* and *Scotland*. To this if we add one Cycle, the Time of the next correspondent Eclipse will thus be discovered:

	y	d	h	′	″
To *A. D.* 1652. *March*,	00	28	22	00	00
Add———————	18	10	7	43	15
Sum 1670 *April*	00	8	5	43	15

So that the correspondent total Eclipse ought to have been *A. D.* 1670. *April* the 8th 43′¼ past 5 a-Clock in the Evening. And because the Earth was then a small Matter nearer its Aphelion, than the Moon its Apogæon, the Time would be a little anticipated on that Account. But then, because this Eclipse was towards Evening, it would be much more retarded on that Account, than anticipated on the other; and the main Part of the

the Eclipse would happen after Sun-set, and be here invisible.

To this Time if we add another Cycle, the next correspondent Eclipse will in like Manner be discovered:

	y	d	h	′	″
To *A. D.* 1670. *April* —	00	08	5	43	15
Add———————	18	11	7	43	15
Sum 1688. *April*	00	19	13	26	30

So that the next correspondent total Eclipse ought to have been *April* 20th, 26′½ after one in the Morning; and was therefore, to be sure, utterly invisible to us here. To this Time if we add another Cycle, we have the next correspondent total Eclipse thus:

	y	d	h	′	″
To *A. D.* 1688 *April*	00	19	13	26	30
Add ———	18	10	07	43	15
Sum 1706 *May*	00	00	21	09	45

So that the next correspondent total Eclipse was to have been *A. D.* 1706. 9′¼ past Nine a-Clock in the Morning; which is not much before the Time when it was observ'd here; and was no other than that famous Eclipse which was total at *Cadiz*, *Barcelona*, *Marseilles*, *Geneva*, *Bern*, and *Zurich*; and became very remarkable for the raising of the Siege of *Barcelona* during that total Darkness: Though I have been inform'd by several there present, that it came to both Armies wholly unexpected, till the great Darkness of the Sky forced them to attend to it. Now this affords us also a remarkable Instance of the near Approximation of our *Grand Cycle*, both

both as to Time and Place. For if instead of tracing this correspondent Eclipse through the distinct Cycles we had at once taken our *Grand Cycle* of 54 Years, and 33 Days; we had come immediately to this Eclipse: And by allowing the Anticipation of 50′ had been within about 20′ of the Calculation at *London.*

To this Time if we add another single Cycle, we shall have the next correspondent Eclipse thus:

	y	d	h	′	″
To *A. D.* 1706. *May* —	00	00	21	09	45
Add ———	18	10	07	43	15
Sum 1724 *May* ———	00	11	04	53	00

So that we ought hence to expect the total Eclipse next *May* 11, 53′ past 4 in the Afternoon. And because both the Position of the Sun and Moon in their Ellipses, and the more considerable Alteration from the Time of the Day, which is here much farther in the Evening than the last was in the Morning; oblige us to suppose about $1^h \frac{1}{4}$ Retardation, we hence justly expect that this Eclipse will be the nearest Total at *London* about 40′ past Six in the Evening; as the exactest Calculations do determine.

(12.) If we would now trace a few Lunar Eclipses by this Cycle, we may do it according to the following Examples:

A. D. $168\frac{1}{2}$, *Feb.* 11. about 59′ past 10 a-Clock at Night, Mr. *Flamsteed* observ'd the Middle of a great and total Eclipse of the Moon at *Greenwich.* Proceed therefore as is already directed to find the next correspondent Eclipse of the Moon thus:

To

	y	d	h	′	″
To *A. D.* $168\frac{1}{2}$ *February*	00	11	10	59	00
Add ———————	18	11	07	43	15
Sum $1\frac{699}{700}$ *Febr.*	00	22	18	42	15

So that this first correspondent total Eclipse of the Moon ought to have been *Feb.* 23. $1\frac{699}{700}$, $42'\frac{1}{4}$ past Six a-Clock in the Morning; or in the day-time, and so must needs have been in great Part to us invisible.

	y	d	h	′	″
To *A. D.* $1\frac{699}{700}$, *Feb.*	00	22	18	42	15
Add ———————	18	10	07	43	15
Sum $17\frac{17}{18}$ *March* —	00	05	02	25	30

So that the next correspondent total Eclipse of the Moon ought to have been *March* 5, $17\frac{17}{18}$. $25'\frac{1}{2}$ after Two a-Clock in the Afternoon; which was in the day-time also; and so must equally with the former have been here invisible.

	y	d	h	′	″
To *A. D.* $17\frac{17}{18}$, *March* —	00	05	02	25	30
Add ———————	18	10	07	43	15
Sum 1736 *March* —	00	15	10	08	45

So that the next total correspondent Eclipse of the Moon is hence to be expected *A. D.* 1736. *March* 15. $8^{h}\frac{1}{4}$ past 10 a-Clock at Night: which is about an Hour and half sooner than the Calculation. Which difference we shall presently find to be near the greatest Difference that can happen.

This

This may alſo be equally obtain'd by one entire *Grand Cycle* of 54 Years, and 33 Days; with the fore-mentioned Anticipation of 50′ which from *Feb.* 11. 168½ 10ʰ 59′, brings us directly to *March* 15, 1736, 9′ paſt 10 a-Clock at Night; or to ſomewhat above an Hour and half before the Calculation.

N. B. As to the proper Quantity of the ſeveral Alterations ariſing in each Period, which ought to be allowed for, they are nearly theſe: The Moon and Sun being about 31′ ⅔ in Diameter, and the Digits of their Obſervation being 12. while the Difference of the Moon's Latitude, as we have ſeen, is about 2′ 36″ or the Twelfth Part of thoſe Diameters, it is plain that the mean natural Alteration of every Period in the ſame Circumſtances is about one Digit; though leſs in the leſſer, and greater in greater Latitudes: which in the Moon, whoſe Eclipſe is to all Spectators the ſame, holds conſtantly: And though the diurnal Motion of the Earth removes all particular Places, ſo much each Period as to render this Rule leſs obſervable in Solar Eclipſes, yet after each grand Period, which nearly reſtores their former Poſition, it will hold in a good Degree there alſo, I mean ſo as to alter about 3 Digits therein: But beſides that of the Digits eclipſed, we ought alſo to ſee what Alteration in Time may happen to each Period. Now as to the Inequality of the Sun's Motion, it is as we have ſeen 10°,8, and its greateſt Velocity is at the Earth's Perihelion, and its leaſt at its Aphelion: Its greateſt Alteration therefore muſt be in *Aphelio* and *Perihelio*, and is the Difference of the Equation belonging every where to the Addition of 10°,8, and is here 48″, which Space the Earth

goes

goes in about 20′ of Time. So that the Difference of Time on this Account, must each Period be some Quantity less than 20′. And as to the Inequality of the Moon's Motion, it is also greatest at the Perigee and Apogee, and its greatest Alteration at the extreme Eccentricities of its Orbit is the Difference of the Equations at 2° 51′½ in Perigee and Apogee, according to those extreme Eccentricities: = 9″ which the Moon usually goes in somewhat less than 20′. So that the Difference of Time, on this Account, must each Cycle be some Quantity less than 20 Minutes also.

And now we come to the principal Alteration in Time that can happen in Eclipses; though it belongs only to those of the Sun: And that is the Time of the Day when they happen in any particular Place. Now because the Center of the Moon usually goes over an entire Diameter of the Disk of the Earth, in about three Hours and an half, Part of which is almost always before, and Part after Noon: while the odd Hours of a small Cycle 7^h 43′¼, may reach equally from a Forenoon to an Afternoon's successive Eclipse; 'tis possible, such an Eclipse may appear an Hour and three Quarters later than the Period it self would determine it. Tho' usually this Alteration will not be near so great; especially when the Latitude of the Moon is very considerable. But then it is so easy to allow very nearly for this Inequality, upon a little Consideration, that it ought not to be objected against the Accuracy of this Period. If for Six Hours from Noon we allow about an Hour and half; and for two Hours, three Quarters of an Hour; we shall not err very much from the true Time.

Corollary. If we would know what is the greateſt Inequality in Digits and Time in a grand Period, made up of Three common ones, or of 54 Years, 32 or 33 Days, beſides the conſtant Anticipation of 50′, we muſt ſay it may poſſibly, though it will very rarely, be almoſt thrice the Quantities already ſtated for a ſingle Cycle: excepting the laſt and principal Difference, peculiar to Solar Eclipſes: which is never much greater than that already mentioned.

N. B. If any are not contented to know theſe Matters by ſuch Approximations, but deſire the utmoſt Accuracy; they muſt either make uſe of Dr. *Halley*'s Equations, fitted to this Cycle, when publiſhed; or rather make uſe of Mr. *Flamſteed*'s or Dr. *Halley*'s moſt accurate Aſtronomical Tables, when publiſhed; with that Trigonometrical Calculation afterward, which I publiſh and exemplify in this Paper. In the former Part of which Work, this Cycle, with its proper Equations, will, at leaſt, ſave us the one half of our Calculation, if it will not bring us it ſelf to that utmoſt Accuracy: which indeed is hardly to be expected from it.

So that, upon the whole, If we duly conſider the particular Circumſtances of the Sun and Moon, with thoſe of the Aphelion, Apogee and Node, and with the Times of the Day or Night when the Cycle ends, and rightly apply them to this ſingle Cycle and to this grand Cycle, we ſhall be able nearly to determine the correſpondent Eclipſes with very ſmall Trouble or Calculation.

The

II.

The Plane in which the Center of the Moon moves in Eclipſes, is not that of the Ecliptick, but of the Orbit of the Moon, conſider'd with the Annual Motion: Or it is a Plane inclined to the Plane of the Ecliptick in an Angle of about 5° 36′. Which in the Calculation of Eclipſes is uſually ſtiled, *The Angle of the Moon's viſible Way.* This principal Plane I call, *The Lunar Plane.*

III.

This *Lunar Plane* cuts the Sphere of the Earth, conſidered without its diurnal Motion, in a Circle whoſe Pole or Vertex is diſtant from the Pole of the Ecliptick in the ſame Angle. This Circle I call *The Lunar Circle.*

IV.

In Eclipſes which happen at the Solſtices, and in the Nodes of the Moon's Orbit, the Diſtance of theſe Poles is exactly *Eaſtward* or *Weſtward.* In thoſe which happen at the Equinoxes and Nodes, the Diſtance is exactly *North* and *South.* But in all other Caſes it is Oblique.

V.

The Angle of that Obliquity is always compos'd of the Diſtance of the Sun and Moon from the Solſtitial Colure; with the Diſtance of the ſame from the Nodes: And is ſometimes the *Sum,* and ſometimes the *Difference* of thoſe Quantities.

VI.

The Diſtance between this Vertex and the Pole of the Earth, when Eclipſes happen at the Solſtices, is the *Sum* or *Difference* of the two forementioned Angles of Inclination; the one, of the Pole of the Equator and of the Pole of the Ecliptick = 23° 29′; the other of the Pole of the Ecliptick, and of the Vertex of the Lunar Circle = 5° 36′ nearly. But in all other Caſes a Spherical Triangle muſt be ſolv'd, in order to find that Diſtance: Of which hereafter.

VII.

Since the Solſtitial Colure is a great Circle, that is alſo a Meridian, or paſſes through the Poles of the Earth and Ecliptick: And ſince beſides the Diſtance between the Vertex of the Lunar Circle and the Pole of the Earth, we ſhall want the Angle included between the Colure and that Line; this alſo muſt be obtained by the like Solution of a Spherical Triangle: Of which hereafter.

VIII.

Since the great Circle that paſſes thro' the Poles of the Earth, and of the Lunar Circle, and that alone cuts both thoſe Circles, and their Parallels at Right Angles, That Meridian, and that alone wherein that Diſtance lies, is perpendicular to the *Path of the Moon's Center* along the other; and will determine the Point in that Path wherein the Center of the Shadow cuts that Meridian at Right Angles, and approaches neareſt of all to the Pole of the Earth: And indeed lays the Foundation of our future Calculations. This Meridian I call *The Primary Meridian.*

IX. The

IX.

The angular Diſtance about the Pole of the Earth, of the Meridian that is directed to the Sun at the middle Point of the whole Eclipſe from the primary Meridian, is compoſed of the *Sum* or *Difference* of the Angle made by the Solſtitial Colure and the primary Meridian; and of the Complement of the Sun's Right Aſcenſion at the middle of the general Solar Eclipſe. Which Angle is of the greateſt Conſequence in our future Calculations. This Angle I call *the Primary Angle*.

X.

Since the Motion of the Center of the Shadow of the Moon, in Solar Eclipſes, is nearly even, and nearly recti-linear; ſince it is alſo in the Plane of the Lunar Circle; and is all one as if it were along a Line that touched that Circle at the Middle of the general Eclipſe, the Point of Contact; we muſt divide each Quadrant of 90 Degrees into 90 or 180 unequal Parts: but ſo that the *Difference* of the Sines of thoſe unequal Angles may be equal, and $\frac{1}{90}$ or $\frac{1}{180}$ of the entire Radius: That ſo the firſt Sine $\frac{1}{90}$ may be $\frac{1111}{1000000}$; the ſecond $\frac{2222}{1000000}$; the third $\frac{3333}{1000000}$, *&c.* and this from the Table of natural Sines, with their correſponding Arcs or Angles at the Vertex, as follows:

Arçs.

Arcs. Diff.	° ′	Diff. Sines Equal.
19L1	0 18	½
19L1	0 38	1
19L1	0 57	½
19L1	1 16	2
19L1	1 35	½
19L1	1 54	3
19L1	2 13	½
19L2	2 33	4
19L2	2 52	½
19L2	3 11	5
19L2	3 30	½
19L2	3 49	6
19L2	4 8	½
19L2	4 28	7
19L3	4 47	½
19L3	5 6	8
19L3	5 25	½
19L3	5 44	9
19L3	6 3	½
19L4	6 23	10
19L4	6 42	½

Arcs. Diff.	° ′	Diff. Sines Equal.
19L4	7 1	11
19L4	7 20	½
19L5	7 40	12
19L5	7 59	½
19L5	8 18	13
19L5	8 37	½
19L6	8 57	14
19L6	9 16	½
19L6	9 36	15
19L6	9 55	½
19L7	10 14	16
19L7	10 33	½
19L7	10 53	17
19L7	11 12	½
19L7	11 32	18
19L7	11 51	½
19L7	12 11	19
19L8	12 30	½
19L8	12 50	20
19L8	13 10	½
19L8	13 30	21

Arcs.

Arcs. Diff.	°	′	Diff. Sines Equal.
19L8			
	13	49	½
19L9			
	14	9	22
20			
	14	28	½
20			
	14	48	23
20			
	15	8	½
20			
	15	28	24
20			
	15	48	½
20L1			
	16	7	25
20L1			
	16	27	½
20L1			
	16	47	26
20L2			
	17	7	½
20L2			
	17	27	27
20L2			
	17	47	½
20L2			
	18	8	28
20L3			
	18	28	½
20L3			
	18	48	29
20L3			
	19	8	½
20L3			
	19	28	30
20L4			
	19	48	½
20L4			
	20	9	31
20L4			
	20	29	½

Arcs. Diff.	°	′	Diff. Sines Equal.
20L5			
	20	50	32
20L5			
	21	10	½
20L5			
	21	30	33
20L6			
	21	50	½
20L6			
	22	11	34
20L7			
	22	32	½
20L7			
	22	53	35
20L8			
	23	13	½
20L9			
	23	34	36
21			
	23	55	½
21			
	24	17	37
21L1			
	24	38	½
21L1			
	24	59	38
21L2			
	25	20	½
21L2			
	25	41	39
21L2			
	26	2	½
21L3			
	26	23	40
21L3			
	26	44	½
21L4			
	27	6	41
21L4			
	27	27	½
21L6			
	27	49	42

Arcs.

Arcs. Diff.	°	′	Diff. Sines Equal.
21L7			
	28	11	½
21L8			
	28	32	43
21L9			
	28	54	½
22L0			
	29	16	44
22L1			
	29	38	½
22L2			
	30	0	45
22L3			
	30	22	½
22L4			
	30	44	46
22L6			
	31	6	½
22L8			
	31	51	47
23L1			
	31	29	½
23L2			
	32	14	48
23L4			
	32	36	½
23L5			
	32	59	49
23L6			
	33	22	½
23L6			
	33	45	50
23L7			
	34	9	½
23L8			
	34	31	51
23L9			
	34	54	½
23L9			
	35	18	52
24L1			
	35	41	½

Arcs. Diff.	°	′	Diff. Sines Equal.
24L2			
	36	4	53
24L3			
	36	27	½
24L4			
	36	52	54
24L6			
	37	16	½
24L7			
	37	40	55
24L8			
	38	4	½
24L9			
	38	29	56
25L1			
	38	54	½
25L2			
	39	18	57
25L4			
	39	43	½
25L5			
	40	7	58
25L7			
	40	32	½
25L8			
	40	57	59
25L9			
	41	22	½
26L1			
	41	48	60
26L3			
	42	14	½
26L4			
	42	40	61
26L5			
	43	6	½
26L7			
	43	32	62
26L9			
	43	58	½
27L3			
	44	25	63

Arcs. Diff.	°	′	Diff. Sines Equal.
27L6			
	44	52	½
27L8			
	45	19	64
28L2			
	45	46	½
28L4			
	46	14	65
28L5			
	46	42	½
28L6			
	47	10	66
28L7			
	47	38	½
28L8			
	48	6	67
28L9			
	48	36	½
29			
	49	4	68
29			
	49	33	½
30			
	50	3	69
30L2			
	50	33	½
30L4			
	51	3	70
30L6			
	51	33	½
31			
	52	4	71
31L5			
	52	35	½
32			
	53	7	72
32L5			
	53	39	½
33			
	54	12	73
33L5			
	54	45	½

Arcs. Diff.	°	′	Diff. Sines Equal.
34			
	55	19	74
34L4			
	55	52	½
34L8			
	56	26	75
35L0			
	57	1	½
35L4			
	57	37	76
35L8			
	58	13	½
36L3			
	58	49	77
37			
	59	16	½
37L8			
	60	4	78
38L6			
	60	42	½
39L8			
	61	22	79
40L9			
	62	2	½
41L8			
	62	44	80
42L5			
	63	26	½
43			
	64	9	81
44L5			
	64	54	½
46			
	65	40	82
48			
	66	26	½
50			
	67	15	83
52			
	68	5	½
53			
	68	58	84

Diff.	Arcs. °	′	Diff. Sines Equal.	Diff.	Arcs. °	′	Diff. Sines Equal.
54				(86)			
	69	52	½		77	54	88
56				(97)			
	70	49	85		79	31	½
59				(116)			
	71	48	½		81	27	89
63				(69)			
	72	51	86		82	56	¼
61				(81)			
	73	58	½		83	57	½
72				(105)			
	75	10	87		85	42	¾
78				(258)			
	76	28	½		90	00	90

Where the Angle made by the Lunar Circle, and the Parallel of the Latitude is considerable, instead of the first Number 19′L1 you must take for $\frac{1}{180}$ the Numbers following; being in a reciprocal Proportion to the Secants of those Angles.

Angl.	
0	19L1
5	19L1
10	18L8
15	18L4
20	17L9
25	17L3
30	16L5

B. N.

N. B. Where the Parallel is different from that at the very Middle of the Eclipse; as it usually is; you must increase or decrease the same Numbers $19_{L}1$, &c. in the Proportion of the Cosines of the Latitude thus:

°	
00	000
10	174
20	342
30	500
40	643
50	766
60	867
70	940
80	$98_{L}5$
90	$100_{L}0$

E. G. If the Co-latitude at the Middle of the Eclipse be 60°, and come to be 40°; say, As 867 to 643, So is $19_{L}1$ to $14_{L}2$, which is there to be taken in its stead.

N. B. The Hint that I had several Years ago, that in the Determination of Solar Eclipses the *Equality* of the *Difference* of Sines was made use of by Dr. *Halley*, was the Occasion of the Discoveries in these Papers.

XI.

The perpendicular Diſtance of every Point of the Penumbra; and the like Diſtance of every Point of the total Shadow from the Path of the Moon's Center, may be diſcovered by Tables made from the natural Sines; where thoſe Sines themſelves, as before, differ equally, or in arithmetical Progreſſion; according to the Duration of the whole Eclipſe, or of total Darkneſs: and their Co-ſines correſpond to the Diſtances from that Path. Both which Tables here follow:

For entire Eclipses: Which are here suppos'd 108′ ¼ *long in the Middle, and the Semidiameter of the Penumbra* 2000 *Miles.*

Duration in Minut.	Distance in Miles.	Duration in Minut.	Distance in Miles.	Digits.
1	2000	37	1879	
2	1999	38	1872	
3	1999	39	1866	
4	1999	40	1859	
5	1998	41	1852	
6	1997	42	1844	
7	1996		1838	1
8	1995	43	1835	
9	1993	44	1828	
10	1991	55	1820	
11	1990	56	1812	
12	1988	47	1803	
13	1986	48	1795	
14	1984	49	1786	
15	1981	50	1776	
16	1979	½	1771	
17	1976	51	1766	
18	1973	½	1761	
19	1970	52	1756	
20	1966	½	1751	
21	1963	53	1746	
22	1959	½	1741	
23	1955	54	1736	
24	1951	½	1731	
25	1946	55	1725	
26	1942	½	1720	
27	1937	56	1714	
28	1932	½	1708	
29	1927	57	1703	
30	1922	½	1697	
31	1917	58	1691	
32	1911	½	1685	
33	1905	59	1679	
34	1899		1676	2
35	1893	½	1672	
36	1886	60	1667	

Dura-

Duration in Minut.	Distance in Miles.	Digits	Duration in Minut.	Distance in Miles.	Digits
½	1662		80	1354	
61	1655			1350	4
½	1648		½	1344	
62	1642		81	1333	
½	1635		½	1322	
63	1628		82	1312	
½	1621		½	1302	
64	1614		83	1291	
½	1609		½	1280	
65	1603		84	1269	
½	1596		½	1258	
66	1589		85	1246	
½	1582		½	1234	
67	1575		86	1222	
½	1568		½	1110	
68	1561		87	1098	
½	1554			1188	5
69	1546		½	1186	
½	1538		88	1173	
70	1534		½	1160	
½	1528		89	1147	
71	1521		½	1134	
½	1514		90	1121	
	1513	3	½	1107	
72	1506		91	1093	
½	1498		½	1079	
73	1490		92	1065	
½	1482		½	1050	
74	1474		93	1034	
½	1456			1025	6
75	1448		½	1017	
½	1439		94	1000	
76	1430		½	983	
½	1424		95	971	
77	1412		½	955	
½	1403		96	937	
78	1394		½	919	
½	1384		97	902	
79	1374		½	884	
½	1364		98	864	

Dura-

Duration in Minut.	Distance in Miles.	Digits.	Duration in Minut.	Distance in Miles.	Digits.
	863	7	$\frac{1}{2}$	550	
$\frac{1}{2}$	844			537	9
99	824		$\frac{3}{4}$	534	
$\frac{1}{2}$	804		105	517	
100	784		$\frac{1}{4}$	499	
$\frac{1}{4}$	773		$\frac{1}{2}$	482	
$\frac{1}{2}$	762		$\frac{3}{4}$	463	
$\frac{3}{4}$	751		106	443	
101	739		$\frac{1}{4}$	421	
$\frac{1}{4}$	728		$\frac{1}{2}$	399	
$\frac{1}{2}$	716		$\frac{3}{4}$	376	
$\frac{3}{4}$	704			375	10
	700	8	107	352	
102	691		$\frac{1}{4}$	320	
$\frac{1}{4}$	679		$\frac{1}{2}$	288	
$\frac{1}{2}$	666		$\frac{3}{4}$	258	
$\frac{3}{4}$	653		108	226	
103	639			212	11
$\frac{1}{4}$	625		$\frac{1}{4}$	180	
$\frac{1}{2}$	611		$\frac{1}{2}$	119	
$\frac{3}{4}$	597			50	12
104	582		$\frac{3}{4}$	000	
$\frac{1}{4}$	566				

For

For Total Darkness of 166″ ⅔.

Duration in Secds.	Distance in Miles.	Duration in Secds.	Distance in Miles.
″		″	
1	50.0	37	49.0
2	50.0	38	49.0
3	50.0	39	49.0
4	50.0	40	48.9
5	50.0	41	48.9
6	50.0	42	48.8
7	50.0	43	48.7
8	50.9	44	48.6
9	50.9	45	48.5
10	50.9	46	48.4
11	49.9	47	48.2
12	49.8	48	48.1
13	49.8	49	47.9
14	49.8	50	47.7
15	49.7	51	47.6
16	49.7	52	47.5
17	49.7	53	47.4
18	49.6	54	47.3
19	49.6	55	47.2
20	49.6	56	47.1
21	49.6	57	47.0
22	49.5	58	46.9
23	49.5	59	46.8
24	49.5	60	46.6
25	49.4	61	46.5
26	49.4	62	46.4
27	49.4	63	46.3
28	49.3	64	46.2
29	49.3	65	46.0
30	49.3	66	45.9
31	49.2	67	45.8
32	49.2	68	45.6
33	49.2	69	45.5
34	49.1	70	45.3
35	49.1	71	45.2
36	49.1	72	45.1

Dura-

Duration in Secds.	Distance in Miles.	Duration in Secds.	Distance in Miles.
"		"	
73	45.0	111	37.4
74	44.8	112	37.1
75	44.6	113	36.8
76	44.5	114	36.5
77	44.3	115	36.2
78	44.1	116	35.9
79	44.0	117	35.6
80	43.8	118	35.3
81	43.7	119	35.0
82	43.5	120	34.7
83	43.3	121	34.4
84	43.2	122	34.1
85	43.0	123	33.8
86	42.9	124	33.4
87	42.7	125	33.0
88	42.5	126	32.7
89	42.3	127	32.4
90	42.1	128	32.1
91	41.9	129	31.7
92	41.7	130	31.3
93	41.5	131	30.9
94	41.3	132	30.5
95	41.1	133	30.1
96	40.9	134	29.7
97	40.7	135	29.3
98	40.5	136	28.9
99	40.3	137	28.5
100	40.0	138	28.0
101	39.8	139	27.5
102	39.6	140	27.1
103	39.4	141	26.6
104	39.1	142	26.1
105	38.8	143	25.6
106	38.6	144	25.1
107	38.4	145	24.6
108	38.1	146	24.0
109	37.9	147	23.5
110	37.6	148	23.0

Duration in Secds.	Distance in Miles.	Duration in Secds.	Distance in Miles.
"		"	
149	22L4	159	14L9
150	21L8	160	14L0
151	21L1	161	12L9
152	20L5	162	11L7
153	19L8	163	10L4
154	19L1	164	8L9
155	18L3	165	7L0
156	17L6	166	4L4
157	16L7	166 $\frac{2}{3}$	0L0
158	15L9		

Semidiameter of the Umbra or Total Darkness = 50 Miles.

XII.

The Angles at the Vertex of the Lunar Circle, on each Side of the Point of Contact, by Reason of the perpendicular Situation of that Axis to its own Circle; are always right Angles: Only diminish'd in the Proportion of the Minutes describ'd by the Annual Motion during the Continuance of the Eclipse. Thus in our present Eclipse, which retains the Center of the Shadow near three Hours upon the Earth's Disk, in which Time the annual Motion amounts to about 8′; each of those right Angles in Strictness are to be esteem'd only 89° 56′, and both together 179° 52′. Only because the Refraction of the Rays of the Sun through our Atmosphere, requires a somewhat greater Increase of this Angle, than the annual Motion requires its Diminution, I shall wholly omit it, in all my Calculations hereafter.

XIII.

The Angles made at the Poles of the Earth, which ſhew the Difference of the two extreme Meridians, and limit the Extent of the entire central Eclipſe, by reaſon of the Obliquity of the Earth's Axis to that Lunar Circle, are uſually unequal to one another; and more or fewer than twice 90°, as the Eclipſe happens at different Latitudes of the Moon, and Times of the Year.

XIV.

The Meridian that paſſes through the Middle or Central Point of general Solar Eclipſes, is the ſame with that which paſſes through the Center of the Sun at the ſame Time, when the Moon has no Latitude, and the Eclipſes are Central in the Plane of the Ecliptick; as alſo when they happen in either Solſtices. Otherwiſe the Moon's Latitude being taken perpendicular to the Plane of the Ecliptick; and the neareſt Diſtance of the Moon's Motion being taken perpendicular to the Lunar Circle, while the Meridians always paſs through the Poles of the Earth; theſe Two Meridians will, generally ſpeaking, be different, and their included Angle no otherwiſe to be known than by Trigonometry, as will appear hereafter.

XV.

The Dimenſions of the Penumbra, or entire Eclipſe, and the Extent of the total Shadow on the Earth, are continually different, according to the different Elevations of the Sun and Moon above any particular Horizon. For as the Moon is about the ſame Diſtance from every Place, when it is in its Horizon, as it is from the Earth's Cen-

ter it ſelf; with regard to which Center alone our firſt Calculations are always made: So when it is in the Zenith of any Place, it is one Semidiameter of the Earth nearer it; which Semidiameter being uſually $\frac{1}{60}$, and at our next Eclipſe $\frac{1}{55}$ of its entire Diſtance, as will appear hereafter, will deſerve an Allowance. Nor will any leſſer Elevation of the Moon be wholly inconſiderable in Eclipſes, but in all accurate Determinations thereof muſt be particularly computed, in order to the diſtinct Knowledge of the Extent of ſuch Eclipſes; eſpecially of the Breadth of the Total Shadow therein. Accordingly we are to obſerve that this Breadth of the Total Shadow will certainly be at this Eclipſe conſiderably greater over *North America*; where the Luminaries are greater elevated above the Horizon; than over *Europe*, where they are much nearer it; as this Calculation requires: Of which hereafter.

XVI.

The *Figure* of the entire *Penumbra*, or general Eclipſe; and of the *Umbra*, or Total Darkneſs; as they appear upon every Country, is different, on account of the different Obliquity of every Horizon; and will make Ovals or Ellipſes of different Species perpetually. This in the vaſt *Penumbra* is beſt underſtood by ſuch an Inſtrument as my *Copernicus*; or by the Peruſal of a very ſcarce Book written by *P. Courſier*, (*Philoſ. Tranſact.* N°. 343. p. 259.) and cited by Dr. *Halley*: Which diſtinctly treats of the Interſection of a Conical and Spherical Surface. But in the ſmaller *Umbra*, or Total Darkneſs, which is confined to a much narrower Compaſs, it very nearly approaches to the Interſection of a conick Surface with a Plane, which is a true Ellipſis.

XVII.

XVII.

The *Species* of that Ellipsis depends on the Sun's Altitude above the Horizon at the Time of Total Darkness; as does the *Position* of its longer Axis on the Azimuth of the Sun at the same Time. Nor is it at all necessary that the Direction of this or any other Ellipsis should be along either of the Axes, but may as well be along any other Diameter whatsoever.

XVIII.

The *Direction* of the Center of the Shadow is according to the Direction of the Moon's Motion, along the Plane of the Lunar Circle, as compounded with the diurnal Motion, or with the Direction and Velocity of those Parts of the Earth over which it passes; and will be hereafter brought to Calculation. And indeed this Angle may be had, either by finding the several Points of the Path of the Moon's Way upon the Earth, in as many Meridians as we please, and drawing a curve Line through those Points; or by solving a Spherical Triangle, whose Sides are the Complements of the Latitudes of two neighbouring Places equally distant, *East* and *West*, from the Place you work for; and whose included Angle is the Angle at the Pole suited to the Difference of their Meridians; and taking half the the two Angles at the Base, the one internal and the other external, for the Angle desir'd: Of which hereafter.

XIX.

Every Ellipsis, made by the oblique Section of a Cone, has the Intersection of the (*Fig.* 1.) Axis of the Cone *C* at some Distance from the Center of the

the Ellipsis *D*. And the Proportion of those unequal Divisions *B C* and *C A* are the same with that of the Sides of the Cone *V B* and *V A* : As appears by the (*Elem.* III. 6.) Elements of *Euclid.* Whence it is evident, that the proper Center of the total Shadow in Eclipses of the Sun, or that made by the Axis of the Cone, is not the same with the Center of the Elliptick Shadow; and that the Proportion of its Distance from that Center may be easily determin'd by the Proposition here refer'd to: Of which more hereafter.

Scholium. This Ellipsis, when the Sun is of a considerable Altitude, is almost an exact one; but when the Sun is near the Horizon, it will be very long, and so less exact; because the Spherical Surface of the Earth is at that Distance more remote from a Plane.

XX.

The perpendicular *Breadth* of the Shadow is neither that of the longer, nor that of the shorter Axis: But that of the two longest Perpendiculars (*Fig.* 2.) *A B* and *CD* drawn from the Tangents parallel to the Diameter *D B*, along which the Direction of the Motion is: The length of which Perpendiculars will be hereafter determined.

XXI.

The *Velocity* of the Motion of the Center of the Shadow is unequal; not only on account of the Difference of the Moon's own Motion, at the beginning and ending of the entire Eclipse; which indeed is very inconsiderable; but chiefly by reason of the Difference of the Obliquity of the

the Horizon all the Way of its Paſſage. However, ſince the ſeveral Points may, in all Meridians be diſtinctly found by Trigonometry, as we ſhall ſhew preſently, this Inequality need create us no new Difficulty in the Determination of Eclipſes.

XXII.

The Number of *Digits* eclips'd, which are twelfth Parts of the Sun's Diameter, with ſexageſimal Parts of the ſame Digits, are always to be eſtimated as diſtinct from the total Shadow; and may be diſcovered by the help of the foregoing Table, p. 29,30,31. Where the Digits are already noted at every proper Diſtance from the Path of the Moons Center; and where the intermediate Fraction $\frac{1}{1021\angle 6}$ is more exact than $\frac{1}{85}$; but which, by dividing that Number $\frac{1}{1021\angle 6}$ by $2\angle 7$ will give thoſe Sexageſimals, without any farther Trouble. The Application of that Table will be taught hereafter.

XXIII.

The *Diſtance* of the Vertex of the conical Shadow of the Moon, which ſometimes juſt reaches the Surface of the Earth, as in total Eclipſes *ſine morâ*, Sometimes does not reach it; as in Annular Eclipſes; and ſometimes would overreach it, if it were not intercepted, as in total Eclipſes *cum morâ*; may be eaſily diſcovered at any time by the Analogy following: As *PC* the (*Fig.* 3.) Semidiameter of the Moon: = 941 geographical Miles is to *CV* the Diſtance of the Moon from that Vertex = 215000 :: So is *Rs* = 45 the ſmalleſt Semidiameter of the total Shadow, which is the ſame as of the circular Shadow itſelf, to *sV*, the Diſtance of that Vertex therefrom

from = 10316, which is thus: 941 : 215000 :: 45 : 10316.

XXIV.

The Determination of the Circumſtances of Solar Eclipſes, for any given Diſtance from the Path of the Moon's Center, either way, has no new Difficulty in it; but is to be made juſt as is that for the Center of the Penumbra. Only the Quantity of the Diſtance of the Vertex of the Lunar Plane from that Circle will be different; as the Path of the Moon's Center it ſelf might be at another Eclipſe, of otherwiſe the ſame Circumſtances.

XXV.

If Two Bodies *A* and *B* ſet out together, the one from *A*, the other from *B*: and move evenly forward in a known Proportion as to Velocity; the Point C will be determined where the ſwifter will overtake the ſlower, and they will be coincident. Thus if the Velocity of *A*, (*Fig*.4.) be to that of *B*, as 5 to 1, the Proportion of the Lines *AB* to *BC* will be as 4 to 1, and if we add 1 to 4 = 5 we have the place *C* where the ſwifter will overtake the ſlower. Thus if their Velocities be to each other as 5,48 to 1, the Lines of their Motion *AB* and *BC*, will be as 4,48 to 1. So that if we take in the former Caſe $\frac{1}{5}$ of *AB* and in the other $\frac{1}{5,48}$ of *AB*, and add it to *AB*, we gain *AC* the Diſtance of the Point C from *A*.

Corollary. If therefore *A* repreſent the Center of the Shadow of a Solar Eclipſe, as it is plac'd at the Middle of the general Eclipſe; and B *Greenwich* at the ſame Moment of abſolute Time; and at a known Diſtance from the middle Point;

Point; and if the Velocity of the Center of the Shadow along the Circle be to the Velocity of *Greenwich* in its diurnal Motion as 5,48 to 1, if we ad 4,48 of their Diſtance at their ſetting out to that known Diſtance, we obtain the Point or Place where the Center of the Eclipſe will overtake *Greenwich*, or the Time when the Eclipſe will be at the Meridian of *Greenwich*. And this whether the Center and *Greenwich* move along the ſame Line as *ABC*, or two different Lines, as *ABC* and *abc*.

XXVI.

The Duration of Solar Eclipſes is different, according as their Middle happens about Six in the Morning or Evening; or about Noon; or about any intermediate Time. If that happens about Six a-Clock, Morning or Evening, the diurnal Motion then neither much conſpires with, nor oppoſes the proper Motion of the Center of the Shadow; and the Duration is almoſt the ſame as it would be if the Earth had no diurnal Motion at all. If that happens about Noon, the diurnal Motion moſt of all conſpires with that proper Motion of the Center, and makes the Duration of the Eclipſe the longeſt poſſible. If it happens in the intermediate Times, the diurnal Motion, in a leſs Degree, conſpires with the other Motion, and makes the Duration of a mean Quantity, between that of the other Caſes. But if it happens conſiderably before Six a-Clock in the Morning, or after Six a-Clock in the Evening, the diurnal Motion is backward, and ſhortens that Duration proportionably. Of the Quantity of which Duration we ſhall enquire more hereafter.

PROBLEMS.

I.

To find the neareſt Diſtance of the Path of the Moon's Center, to the Center of the Diſk of the Earth, as ſeen at the Diſtance of the Mo n in the total Eclipſe of the Sun *A. D.* 1724. *May* 11°. *P. M.*

This is equal to the Moon's true Latitude at the Time of the Conjunction in her own Orbit; and is ſet down in the Calculation 32′ 19″.

II.

To find the Sun's *Declination* at the Middle of the Eclipſe.

As the Radius of the Circle: is to the Sine of the Sun's Longitude at that Time = 61′ 39″: : So is the Sine of the Sun's greateſt Declination, = 23° 29′: to the Sine of the Sun's Declination then.

Rad.		10. 000000			
S. 61°	39′	9. 944514			
S. 23°	29′	9. 600409		°	″
S.		8. 544923	=	20	32
			=	Declination ☉.	

III.

To find the Sun's *Right Aſcenſion* for the ſame Time.

As the Radius : to the Coſine of the Sun's greateſt Declination : : So is the Tangent of the Sun's Latitude: to the Tangent of the Sun's right Aſcenſion. Rad.

Rad.		10.			
Sin.	66 31	9. 962453			
Tang.	61 39	10. 267952		°	′
Tang. Right Ascen.		10. 230405	=	59	31
			Compl.	30	29

IV.

To find the *Distance* between the Vertex of the Lunar Circle and the Pole of the Earth.

Let (*Fig.* 5.) *E P* represent the Distance between the two Poles of the Earth, and of the Ecliptick : = 23° 29′. *E V* the Distance between the Pole of the Ecliptick, and the Vertex of the Lunar Circle : = 5° 36′. *P E V* the Angle made by the Solstitial Colure *P E* : (in which the two Poles of the Earth, and of the Ecliptick always are) and that Arc *E V*. And because the Sun is here 28° 21′ distant from that Colure, which is the Complement of its Longitude from *Aries* ; and the Ascending Node, or Argument of Latitude is then 5° 49′ distant from the Sun backward ; The Sum of these Numbers gives 34° 10′, whose Complement is the Angle *V E R* = 55° 50′. In order then to gain *V P* proceed thus :

R.		10.			
CS *VER*.	55 50.	9. 749429			
T. *VE*.	5 36	8. 991451		°	′
T. *RE*		8. 740880	=	3.	10.
			+	23.	29.
			=	26.	39.

Then say,

				°	′
CS. *RE*	3 9	9. 992343			
CS. *VE*	5 36	9. 997922			
CS. *PR*	26 39	9. 951222			
		19. 949144		°	′
CS. *PV*	=	9. 949801	=	27.	0

V. In

V.

In the ſame Triangle *VPE*, to find the Angle *VPE*, included between the Colure *EP*, and the Prime Meridian *PV*.

	°	′		
S. *PV*	27	0.	9. 657047	
S. *VER*	55	50.	9. 917719	
S. *VE*	5	36.	8. 989374	
			18. 507098	° ′
S *VPE*			= 9. 249961	= 10 15

Corollary. The *Primary Angle*, compoſed of the Complement of the Right Aſcenſion, and of this Angle *VPE*, is = 40° 44′.

Compl. Rad. 30° 29′
+ 10 15
= 40 44

VI.

To find the *Diſtance* of the Pole or Vertex of the Lunar Circle from the Circle it ſelf.

As the Semidiameter of the Earth's Diſk = 61′ 38″: To the Latitude of the Moon, or neareſt Diſtance to the Path of the Moon's Center from the Center of the Diſk; 32° 19′ :: So is the Radius: to the Sine of the Complement of that Diſtance. In Decimals thus: 61′,63 : 32′,32 :: 10000 : 5244 = S. 31° 38′, whoſe Complement is 58° 22′: equal to the Diſtance of the Lunar Circle from its Vertex.

VII.

To find the *Angle* included between the Meridian that paſſes through the Center of the general Eclipſe, and that paſſing through the Center of the Sun at the ſame Time.

In

In the Triangle (*Fig.* 6.) *MSP* where the Side *SP* is already given, = Complement of the Sun's Declination; find the Angle *MSP* thus:

R.		10.		
S. of the Sun's Diſtance from the Solſtitial Colure:	= 28° 21′	9. 676562		
S. of the Sun's greateſt Declination	= 23° 29′	9. 600409	°	′
S. of an Angle		9. 276971	= 10.	54.
To which add the Angle of the Moon's Way:			+ 5	36
The Sum is the Angle *MSP*			= 16.	30

Then, in the ſame Triangle *PMS*, we have two Sides: *MS* equal to the Latitude of the Moon, or the length of the Perpendicular to the Moon's way = 31° 38′. and *PS* = 69° 28′. and the included Angle *MSP* = 16° 30′. to find *MPS* thus:

R.		10.		
	° ′			
CS. *MSP*.	16. 30.	9. 981774		
T. *SM*.	31. 38.	9. 789585		
T. R *M*. =		9. 771359	= 30 34	*MR*
			+ 31 38	*MS*
Then ſay,			= 62 12	*RS*
S. *SP*.	69. 28.	9. 971493		
S. *SR*.	62. 12.	9. 946738		
T. *MSP*.	16. 30.	9. 471605		
		9. 418343	°	′
T. *MPS* =		9. 446850	= 15	38
			+ 40	44
			= 56	22 = Angle with the Primary Meridian.

VIII.

VIII.

To find the *Longitude* and *Latitude* of the Center of the Shadow at the Middle of the general Eclipse; or to solve the primary Triangle.

Under *Problem* IV. we have found the Distance of the Vertex of the Lunar Circle from the Pole of the Earth = 27°. 0′. Under *Problem* VI. we have found the Distance of that Vertex from its Circle = 58°. 22′; and under the last *Problem* we have found the Angle at the Pole of the Earth, between the Primary Meridian, and that Meridian which passes through the Center of the Eclipse, = 56° 22′. From which *data* the Primary Triangle (*Fig.* 7.) is thus to be solv'd:

R.			10.
	°	′	
CS. *CP* ☊	56.	22.	9. 743412
T. *VP*.	27.	0.	9. 707166
T. *PR*. =	15.	46.	9. 450578

Then say,

CS. *VP*	27.	0.	9. 949880		
CS. *PR*	15.	46.	9. 983345		
CS. *VC*.	58.	22.	9. 719730		
			19. 703075	°	′
CS. *PC*.			9. 753195 =	55.	30
			Deduct *PR* =	15.	46
			Rem^t. = *PC*. =	39.	44
			Ergo Lat. =	50.	16

To find the Angle at the Vertex *CVP*, proceed in this Manner:

S. *CV*.

	° ′			° ′
S. *CV.*	58. 22.	9. 930145		
S. *CPQ.*	56. 22.	9. 920436		
S. *PC.*	39. 44.	9. 805647		
		19. 726083		
S. *CVP.*	=	9. 795938	=	38 41

The following Analogy will give *VCP* the Complement of the Angle which the Direction of the Center of the Eclipse makes with the Meridian, that Direction being perpendicular to *VC*.

	° ′			° ′
S. *CV.*	58. 22.	9. 930145		
S. *CPQ.*	56. 22.	9. 920436		
S. *VP.*	27. 0.	9. 657047		
		19. 577483		
S. *VCP.*	=	9. 647338	=	26. 21
		Compl.	=	63. 39

Corollary. Hence we also learn the most *Northern Latitude*, where the Center of the Shadow will cross the Meridian at Noon, and at right Angles: And this without any particular distinct Calculation. For $VQ = 58° 22' - VP\ 27° 0' = PQ = 31° 22'$. whose Complement $= 58° 38'$. is that very *Northern Latitude*.

IX.

To find the *Longitude* and *Latitude* of the Center of the Shadow, when it crosses the Meridian that passes through the Center of the Sun at the Middle of the Eclipse; or to solve the second principal Triangle.

If

If in the foregoing Triangle we ſuppoſe the Angle at the Pole to be equal to the Primary Angle, or 40° 44′. we may thus ſolve this Triangle:

R.			10.			
	°	′				
CS. *CP*☊	40.	44.	9. 879529			
T. *VP*.	27.	0.	9. 707166		°	′
T. *PR*.			= 19. 586695	=	21	7

Then ſay,

CS. *VP*.	27.	0.	9. 949880			
CS. *PR*.	21.	7.	9. 969811			
CS. *VC*.	58.	22.	9. 719730			
			19. 689541		°	′
CS. *CR*.			= 9. 739661	=	56	42
			Deduct		21	7
			Rem^t. *CP*.		35	35
			Ergo, Lat.	=	54	25

To find the Angle at the Center of the Eclipſe *VCP*, proceed thus:

	°	′				
S. *VC*.	58.	22.	9. 930145			
S. *CP*☊	40.	44.	9. 814607			
S. *VP*.	27.	0.	9. 657047			
			19. 471654		°	′
S. *CVP*.			= 9. 541509	=	20	22

X.

To find the *Longitude* and *Latitude* of the Center of the Shadow at its Entrance on the Diſk of the Earth: Or to ſolve the third Principal Triangle.

Add the vertical Angle already found = 38° 41′ to a right Angle at the Vertex; = 90 + 38°. 41′ = 128°. 41′ this is equal to the Angle at the

tex CVP. Subſtract this Angle from two right Angles. $180^{\circ} - 128^{\circ}. 41' = 51^{\circ}. 19'$, in order to gain the Supplement, whoſe Sines, *&c.* are the ſame with the others. (*Fig.* 8.) Then ſay,

R.			10.	
	°	′		
CS. CVP.	51.	19.	9. 795891	
T. VP.	27.	0.	9. 707166	° ′
T. VR.			= 9. 503057	= 17 40 = VR
				+ 58 22 = VC
Then ſay,				= 76 02 = CR

	°	′		
CS. VR.	17.	40.	9. 979019	
CS. VP.	27.	00.	9. 949880	
CS. CR.	76.	02.	9. 382661	
			19. 332541	° ′
CS. CP.			= 9. 353522	= 76 : 57
				Ergo, Lat. 13. 03

In order to find the Angle at the Pole VPC, whoſe Supplement is the Longitude of that Point where the Center of the Shadow enters the Diſk of the Earth from the Primary Meridian, proceed thus :

	°	′		
S. CP.	76.	57.	9. 988636	
S. CVP.	51.	19.	9. 892435	
S. CV.	58.	22.	9. 930145	
			19. 822580	180 °
S. VPC.			= 9. 833944	= 43 01
				Suppl. 136 : 59

To find the Angle VCP, proceed thus :

	° ′	
S. *CP.*	76. 57.	9. 988636
S. *CVP.*	51. 19.	9. 892435
S. *VP.*	27. 00.	9. 657047
		19. 549482
S. *VCP.* =		9. 560846 = 21. 20

XI.

To find the Longitude and Latitude of the Center of the Shadow at its Exit from the Disk of the Earth; or to solve the fourth Principal Triangle.

Substract the Angle already found 38° 41′ from a right Angle 90° — 38° 41′ = 51° 19 = Angle at the Vertex *PVC* (*Fig.* 9.) Then say,

R.		10.
	° ′	
CS. *PVC.*	51. 19.	9. 795891
T. *PV.*	27. 00.	9. 707166
T. *VR.*		9. 503057 = 17 40
		from 58 22
Then say,		Remnt 40 42 = *RC.*
	° ′	
CS. *VR.*	17. 40.	9. 979019
CS. *PV.*	27. 00.	9. 949880
CS. *RC.*	40. 42.	9. 879746
		19. 829626 ° ′
CS. *PC* =		9. 850607 = 44. 51.
		Ergo, Lat. 45. 9.

In order to find the Angle ☊ *PC*, or the Longitude of that Point where the Center of the Shadow departs out of the Disk of the Earth, from the Primary Meridian, proceed thus:

	° ′			° ′
S. CP.	44. 51.	9. 848345		
S. PVC.	51. 19.	9. 892435		
S. VC.	58. 22.	9. 930145		
		19. 822580		
S. QPC.	=	9. 974235	=	70. 27
			+	136 59
			=	207 26

And for the Angle VCP thus;

	° ′			
S. CP.	44. 51.	9. 848345		
S. PVC.	51. 19.	9. 892435		
S. VP.	27. 00.	9. 657047		
		19. 549482		
S. VCP.	=	9. 701137	=	30. 10.

Corollary. Hence the Angular Motion of the Center of the Eclipse about the Pole of the Earth, if there were no diurnal Motion, is 207°. 26′.

XII.

To find the Time in which the Center of the Shadow will go over the Diameter of the Lunar Circle.

Say, first, $35'_{L}3 : 60' :: 123_{L}26 : 209_{L}6$; *i. e.* As the Number of Minutes of a Degree pass'd over in an Hour: to an Hour :: So is the entire Diameter of the Disk from the Calculation : to the Number of Minutes for that Passage.

Then say, 10000 : 8514 :: $209'_{L}6 : 178'_{L}4$ *i. e.* As the Radius : to the Sine of 58° : 22′ = the Distance of the Lunar Circle from its Pole or Vertex :: So are the Minutes of the Passage over the entire Diameter : to the Minutes of the Passage over this Chord = 178′ 24″.

XIII.

To find the Proportion of the Velocities of the Center of the Shadow and of the diurnal Motion of the correſponding Point of the Earth at the Time of the Eclipſe:

Say thus; As $178'_L4$ to $829'_L6 = 207° 26'$, or as 1 to 4_L64, ſo is the Time of the Center of the Eclipſe's Motion over the Diameter of the Lunar Circle: to the Timeof the diurnal Motion's going from the entranceto the Exit of the Center.

Corollary. Hence the real Angular Motion of the Center of the Eclipſe about the Pole of the Earth, is no more than 162° 40′. For 4_L64 : 3_L64 :: 207° 26′ : 162° 40′.

XIV.

To find the *Latitude* of any Place, over or near which the Center of any Shadow paſſes, to any known *Longitude* or *Time* given. And, *vice verſa*, To find the *Longitude* or *Time* of the neareſt Approach to any ſuch Place to any known *Latitude*. This is no more than proceeding in the Calculations as hitherto; by taking any known Meridian or Time; or elſe any known Latitude for our Examples.

I ſhall therefore give three ſeveral Examples in both Caſes; becauſe of the great Dignity and Uſefulneſs of the *Problem*: *viz.* For *Greenwich* the Meridian of the Tables; for *Dublin* more *Weſtward*; and for *Paris* more *Eaſtward*.

Now I here ſuppoſe, from the Calculation and Conſtruction of Eclipſes, that the Middle of this general Eclipſe will happen *May* 11. 1724. 17′ paſt 5 a-Clock in the Afternoon; and that its Center will croſs the Meridian of *Greenwich* 41′ paſt 6. Upon which Hypotheſis I thus compute:

From

	°	′	°	′
From the Angle	100	15	=) 6h	41
Deduct the Primary Angle			40	44
There remains the Angle of the Pole ☋ PC =			59	31

Then proceed thus:

R.			10.
CS. ☋ PC.	59	31	9. 705254
T. PV.	27	00	9. 707166
T. PR. =			9. 412420 = 14 29

Say then,

CS. PV.	27	00	9. 949880
CS. PR.	14	29	9. 985974
CS. VC.	58	22	9. 719730
			19. 705704
CS. RC. =			9. 755824 = 55 15
Deduct RP =			14 29
Remains PC =			40 46
Ergo, Lat.			49 14

N. B. If we take Dr. *Halley*'s Time 6h 36′, and substract 40° 44′ out of 99° there remains 58° 16′; and the Calculation will stand thus:

R.			10.
	°	′	
CS. ☋ PC.	58.	16.	9. 720958
T. PV.	27.	0.	9. 707166
T. PR. =			9. 428124 = 15 0

Then

Then say,

		°	′				
CS.	*PV.*	27.	0.	9. 949880			
CS.	*PR.*	15.	0.	9. 984944			
CS.	*VC.*	58.	22.	9. 719730			
				19. 704674			
CS.	*RC.*			= 9. 754794	=	55	21
				Deduct *RP.*		15	0
				Rem^{t}. *PC.*		40	21
				Ergo, Lat.	=	49	39
				Diff.		00	25

N. B. My Calculation differs from Dr. *Halley*'s Scheme no less than a full Degree of a great Circle, in the Meridian; if our Difference of Time, which is about 5′, be allowed. And though we take the Doctor's own Time, yet do we differ in *Latitude* 25 Minutes or Miles; by which Quantity the Doctor's Scheme brings the Center of the Eclipse nearer to *London* and *Greenwich* than this Calculation. The reason of which Difference I by no means understand. Time will discover which Determination is most accurate.

Dublin is about 6° 22′ *Westward* in Longitude from *Greenwich*. Let us find the Latitude of the Center of the Shadow, when it crosses the Meridian of *Dublin*. We must proceed thus:

As 3L 64 to 4L 64 so is 6′. 22″ to 8′. 7″ Deduct then from the Angle at the Pole used for *Greenwich* this Difference of these Angles 59° 31′ — 8°. 7′ = 51° 24′. which is our Angle at the Pole for *Dublin*. So that if we use the former Figure with that Angle, we compute as before;

R.				10.			
		°	′				
CS.	♀*PC.*	51.	24.	9. 795101			
T.	*PV.*	27.	0.	9. 707166		°	′
T.	*RP.*			9. 502267	=	17.	38

The

Then say,

	°	′			°	′
CS. *PV.*	27.	0.	9. 949880			
CS. *RP.*	17.	38.	9. 979099			
CS. *VC.*	58.	22.	9. 719730			
			19. 698829		°	′
CS. *RC.*			= 9. 748949	=	55	53
			Deduct *RP.*		17	38
			Remnt PC.		38	15
			Ergo, Lat.		51	45

Paris is 2° 19′ more *Easterly* than *Greenwich*,
Say therefore 3.64 : 4.64 :: 2°. 19′ : 2°. 57′
Now 59°. 31′ + 2°. 57′ = 62°. 28′

Then, R. 10.

	°	′			°	′
CS. *QPC.*	62.	28.	9. 664891			
T. *PV.*	27.	0.	9. 707166		°	′
T. *RP.*			= 9. 372057	=	13	15

Say then,

CS. *PV*	27.	0.	9. 949880			
CS. *RP*	13.	15.	9. 988282			
CS. *VC.*	58.	22.	9. 719730			
			19. 708012		°	′
CS. *RC.*			9. 758132	=	55.	03
			Deduct *RP*	=	13.	15
			Remt. = *PC.*		41.	48
			Ergo, Lat,	=	48.	12

N. B. By such Calculations we may determine the Latitude of the Center of the Shadow's Way, from its entry upon, till its exit out of the Disk of the Earth, to every known Meridian. A Specimen of which I intend to give presently for the several *East* and *West Longitudes* from

from *London* in the Eclipse before us: And another Specimen in the Eclipse, *Sept.* 4. 1727.

If the *Latitudes* be given, as for the Meridian of *Greenwich* 49°. 14′; For *Dublin* 51°. 45′; For *Paris* 48°. 12′: The Case will be that of a Spherical Triangle, when all the Sides are given; and the *Longitude* or *Time* is an Angle sought. Thus in the foregoing Figure for *Greenwich*, $VC = 58°. 22'$ is the Side against the Angle sought. $VP = 27°. 0'$, and $PC = 40°. 46'$. From which *data* we thus discover the Angle QCP.

	°	′					
$VC =$	58	22	R.	10.			
$VP =$	27	00	S.	9.	657047		
$PC =$	40	46	S.	9.	814900		
Sum of 3 =	126	08	Sum	19.	471947		
½ Sum	63	4	S.	9.	950138		
Diff. of VC	4	42	S.	8.	913488		
Double Radius				20.			
The Sum				38.	863626		
The Remainder				19.	391679		
½ Remainder				9.	695839	= CS.	60 14

double	120.	28
from	180.	00
as before remains	59.	32
Add the Primary Angle	40.	44
Sum	100.	16
Equal in Time to	6^h.	41′

The Time past Noon of the Center's Transit over the Meridian of *Greenwich*. For

For *Dublin* thus:

	°	′			
V C =	58	22	R.	10.	
V P	27	00	S.	9. 657047	
P C	38	15	S.	9. 791756	
Sum of	3.123	37	Sum	19. 448803	
Half Sum	61	48 ½		9. 945159	
Diff. of *V C*	3	26 ½		8. 778383	
Double Radius				20.	
The Sum				38. 723542	
The Remainder				19. 274739	
Half the Remainder				9. 637369	C S. = 64° 18′

double 128. 36
from 180. 00
remains as before 51. 24.
To 51. 24.
Add 40. 44.
Sum 92. 08 = 6^h 8′

Which deducted from 6^h. 41′, leaves 32′½ for the Difference of the Angle at the Pole in Time. Say then 46L4 : 3L64 : : 32′L5 : 25′L4 which is the Difference in time of the Meridians of *Greenwich* and *Dublin*.

For

For *Paris* thus:

$VC = 58^\circ\ 22'$	R.	10.	
$VP = 27\ 00$	S.	9. 657047	
$PC = 41\ 48$	S.	9. 823821	
Sum of 3 127 10		19. 480868	
Half Sum 63 35		9. 952105	
Diff. of VC 5 13		8. 958670	
Double Radius		20.	
Sum		38. 910775	
Remainder		19. 429907	
Half Remainder		9. 714953	$= CS.\ 58^\circ.\ 45'$

double 117 30
As before, Remainder 62 30
Add, Primary Angle 40 44
Sum 103 11
In Time $6^h\ 52\frac{1}{2}$

From which deduct $6^\circ.\ 41'.$ the Remainder $11'\frac{1}{2}$ is the Difference of the Angle at the Pole in Time. Say then, $4_L 64 : 3_L 64 :: 11\frac{1}{2} : 9'.$ which is the Difference in Time, of the Meridians of *Greenwich* and *Paris*.

Corol. (1.) The latter Branch of the Problem determines the Hour and Minute when the Centre of the Eclipse crosses the Meridian at any assign'd *Latitude*; and by a very small Allowance when the very middle of the Eclipse, or of Total Darkness happens in any Place very near the same.

Corol.

Corollary (2.) The same Branch determines the true *Difference of Meridians* in all Places over or near which the Center of the Eclipse passes, and so the Distance *East* and *West* from any known Meridian whatsoever. Thus because the Meridians of *Paris*, *Greenwich*, and *Dublin* do hence appear to be different as to the Angles of the Pole from the Primary Meridian, in the foregoing Angles, 62°. 28′. 59°. 31′. and 51°. 24′. respectively; It is plain, that the respective *Longitude* of *Paris* and *Greenwich*, when reduc'd from Angles of the Pole to the Difference of Meridians, is 2° 19′. and that of *Greenwich* and *Dublin* 6°. 22′. and by Consequence of *Paris* and *Dublin* 8°. 41′. Which is no other than the Foundation of my grand *Problem* of *Discovering the Geographical* Longitude *of Places by Solar Eclipses*, *from the* Latitude *given*: Of which more hereafter.

XV.

To find the Duration of a Solar Eclipse, along or near the Path of the Moon's Center, in any Place whatsoever.

From the Motion of the Moon from the Sun gain the Duration of the entire Eclipse; or the Time of that Center's Passage over the Diameter of the Penumbra, if there were no diurnal Motion during that Time, thus:

As the horary Motion of the Moon from the Sun, which is in angular Measure 35°. 18′. and is given in the Calculation; to an Hour or 60′ in Time :: So let the Diameter of the Penumbra there given, also in angular Measure = 65°. 10′. be to a fourth Number: which will be the Number of Minutes requir'd. In Decimals thus:

$35'.3 : 60' :: 65'.17 : 110.8 = 1^h : 50\frac{1}{4}$.

But then, because the diurnal Motion of the Earth must be compounded with this rectilinear Motion of the Moon; and that as we have already stated it, this Eclipse will cross the Meridian of *Greenwich* 41′ past 6 a-Clock in the Evening; the one Part of the Duration of the Eclipse being before, and the other Part after that Time, both Intervals must be unequally affected by the diurnal Motion, and we must then take the former half-Duration 55′. 24″ distinctly. And since the diurnal Motion of *Greenwich* is in a larger Parallel than that of the Center of the general Eclipse; while its Obliquity to the Path of the Shadow's Center increases; their respective Motions will nearly keep the same Proportion all along; and so we may safely omit the Consideration of them both. We have also already discovered, that the Velocity of this Center's Motion is here, to that of the Velocity of the diurnal Motion, As 829,6 to 178,4. or as 4,64 to 1. And because the Eclipse begins about 14′ before 6, 14′ after 6 balances the same; and these 28 Minutes are almost all one, as if there were no diurnal Motion at all. So that we have only 27′ 24″ capable of Retardation in the first half: The middle Time of which will be about 30′ after 6. We must therefore look into the Table, *p.* 22,——26 for the *Arc* 97½, or its Supplement 82½, corresponding to 89½ of the Sines. Where the Difference of half a Degree is instead of 19,1, as about Noon, no less than 160, which multiplied by 4,64 comes to 7424. So that the Motion is here retarded a 39th Part. Say then, As 39 to 38, so is 27,4 to 26,7 which 26,7 or 26′ 42″ is to be added to the 28 before excepted, for the Duration of the former Part of the Eclipse = 54′ 42″. The Middle of the second Part will be about 73 = 18°½ backward

ward beyond 90°. that is, 71° $\frac{1}{4}$ of the Arc, which corresponds to 85° $\frac{1}{2}$ of the Sines, where the Difference of half a Degree is 61° $\frac{1}{2}$. This multiplied by 4,64 gives 285. So that the Retardation is as 19,1 to 285, or 1 to 14,9. Say then; As 14,9 to 13,9 : so is 55,4 to 51,7 = 51′ 42″, which is the Duration of the latter Part of the Eclipse, and added to the former Part of the Duration, gives us the whole Duration = 106′ 24″ = 1ʰ46′ 24″, without the Consideration of the Elevation of the Luminaries above the Horizon, which a small Matter enlarges that Duration : Of which hereafter.

N. B. If we would be still more precisely nice, we may distinctly allow for the Difference of the Parallels, and the different Obliquity of the Direction; of which *p.* 26, 27. before : Which yet are here omitted, as very inconsiderable.

XVI.

To find the Duration of the Total Darkness along the Path of the Moon's Center; if the Luminaries were in the Horizon.

Say, As the Moon's Motion from the Sun in an Hour, or 60′; in the Calculation = 35′ 18″ is to those 60′ : So is the Difference of the Diameters of the Sun and Moon in the same Calculation, = 1′ 38″ to a fourth Number : Which will be the entire Duration of the Total Darkness if the Luminaries were not at all elevated above the Horizon. In Decimals thus :

$$35'{,}3 : 60' :: 1'{,}62 : 2'{,}73 = 2'46''\tfrac{2}{3}.$$

XVII.

To find the Altitude of the Sun above the Horizon, when the Center of the Shadow crosses the Meridian at *Greenwich*. It

In the Triangle (*Fig.* 10.) ZPS, ZP is = Diſtance between the Zenith and Pole of the Earth: 38° 30′. PS is = Diſtance between the Pole of the Earth and Center of the Sun: = Complement of the Sun's Declination, or to 69° 28′. And the Angle ZPS = interval of Time, from the Meridian = 6ʰ 41′ = 100° 15′, whoſe Supplement is 79° 45′.

Say then,

R.			10.		
	°	′			
CS. ZPS	79	45	9. 250280		
T. ZP	38	30	9. 900605	°	′
T. PR =			19. 150885	= 8	3 = PR
				+ 69	28 = PS
				= 77	31 = RS

And,

	°	′			
CS. PR	8	3	9. 995699		
CS. ZP	38	30	9. 893544		
CS RS	77	31	9. 334766		
			19. 228310	°	′
CS. ZS =			9. 232611	= 80	10 = ZS
			Ergo, Altitude =	9	50

XVIII.

To find the Azimuth of the Sun at the ſame Time and Place.

In the former Triangle the Complement of the Altitude being now found = ZS = 80° 10′. Proceed thus:

	°	′			
S. PS	80	10	9. 993572		
S. ZPS	79	45	9. 993013		
S. PS	69	28	9. 971493		
			19. 964506	°	′
S. PZS = Suppl. =			9. 970934	= 69	16 = PZ
			From the *Weſt*	20	44

XIX.

XIX.

To find the Number of Minutes that any Solar Eclipſe extends to, in a plain Perpendicular to the Axis of the Penumbra.

When the Parallax of the Moon is 57′ 17″, which is near its mean Quantity; the Moon's Diſtance is 60 Semidiameters of the Earth: And one Second on the Diſk of the Earth as viewed at the Diſtance of the Moon; or on the Diſk of the Moon viewed at the Diſtance of the Earth, is exactly one geographical Mile. And 60″ or one Minute, is one Degree upon the Diſk of the Earth or Moon. But when the Moon's Parallax, as in the Calculation of this Eclipſe, is 61′. 48″ whoſe Sine is $\frac{17976}{1000000}$ or $\frac{1}{55.5}$ of the Radius nearly: One Second is leſs than a Mile; and that in the Proportion of 55.5 to 60. So that about 65 geographical Miles correſpond to 60″, or one Minute: And accordingly, 1781 ſuch Miles will correſpond to 32′ 35″, which in that Calculation, is the Semidiameter of the Penumbra, or the utmoſt perpendicular Extent of the Eclipſe.

N. B. We may always make uſe of the foregoing Tables, *pag.* 29, —— 34 for the perpendicular Diſtances from the Path of the Moon's Centre, at all Durations of the Eclipſes, and of Total Darkneſs, by ſtill calling the Radius of every *Penumbra* 2000 equal Parts or Miles, and the Radius of every *Umbra* or Total Shadow, 50 ſuch Parts or Miles; and uſing them accordingly. And this without any other Inconvenience than the Suppoſition of other than geographical Miles: Which Inconvenience, by the Reduction of them to geographical Miles afterwards, will always, as here, come to nothing.

XX.

XX.

To find the Alteration there is in the Extent and Duration of Eclipses, and of total Darkness, on Account of the Elevation of the Luminaries at that Time above the Horizon.

This is ever, as the Radius: to the Sine of the Sun's Altitude: As compared with the particular Distance of the Moon at that Time. Thus at the Middle of this Eclipse at *Greenwich*, the Altitude of the Sun has been found to be 9°. 50′, whose Sine is $\frac{1708}{10000}$, which divided by 55′,5 is equal to $\frac{1}{2}$ of the whole: And in the Semidiameter of the *Penumbra*, as well as *Umbra*, amounts to about 6 Miles every Way. Thus also at the Middle of the Eclipse in *North-America*, where 'tis Central at Noon, the Sun will be about 52° above the Horizon: whose Sine is $\frac{788}{1000}$, which divided by 55′,5 is $\frac{1}{70}$ nearly; which in the same Semidiameters, amounts to about 29 Miles every way. And for the Duration at *Greenwich* add to the common Duration already found, or to 1ʰ 46′ 24″ the $\frac{1}{324}$ Part of the same, or about $\frac{1}{3}$ of a Minute both ways: which is about $\frac{2}{3}$ in the whole; which will bring the entire Duration from 1ʰ 46′ 24″ to full 1ʰ 47′; and for Total Darkness will add about $\frac{6}{50}$ of the whole total Darkness = 20″, and increase the Duration from 2′ 46$\frac{2}{3}$ to 3′ 6″ $\frac{2}{5}$. But for the Alteration in *North America*, which is about $\frac{1}{70}$ both ways, or $\frac{1}{35}$ in the whole; this will there increase the entire Duration 4′ 12″, and from 1ʰ 46′ 24″ bring it to 1ʰ 50′ 36″, and for the total Darkness will add about $\frac{29}{50}$ of the whole, or bring the 2′ 46″ $\frac{2}{3}$ to 4′ 47″.

XXI.

XXI.

To find the Species and Dimensions of the Ellipsis made by the Total Shadow at the same Places and Altitudes.

The shorter Axis of the Ellipsis, (which is the same with the Diameter of the Conick Shadow it self, in a Plane Perpendicular to the Axis;) is to the Longer, as the Sines before-mentioned. Or at *Greenwich*, as 1708 to 10000; and at *North America*, as 788 to 1000: And since that shorter Axis is in the Calculation 98 Minutes or Miles, of 65 to a Degree; they must be equal to 90 Geographical Miles; which by the last Problem must be increas'd to 96 and to 119 respectively. The golden Rule will therefore soon shew the Length of the longer Axis of the Shadow in both Places.

	sine	rad.		miles	miles
For *Greenwich*	1708 :	10000	::	96 :	562.
For *North-America*	788 :	1000	::	119 :	151.

XXII.

To determine the central Point in the Elliptick Shadow for *Greenwich*, at the Middle of the same Eclipse.

By *Lemma* XIX. and in its Figure; As VB: to VA :: So is the Sine of $BAV = 9^\circ\ 34' = 166$: to the Sine of $ABV = 10^\circ\ 6' = 175$, and so is BC : to AC. And *componendo*, As $166 + 175 = 341$ to 175 :: So is $BC + CA = 562$ to CA, which therefore is equal to 289. Also As $166 + 175 = 341$ to 166 :: So is $BC + CA = 562$ to BC; which therefore is equal to 274.

For 341 : 175 :: 562 : 289.
And 341 : 166 :: 562 : 274.

Whence the Parts of the longer Axis being found, the larger $CA = 289$ Miles: the leſſer $BC = 274$ Miles. The half of which, DC is the Diſtance between the central Point of the Shadow D, and the Center of the Ellipſis C, $= 7\frac{1}{2}$ Miles.

XXIII.

To determine the Angle of Direction of the Total Shadow over the Meridian of *Greenwich*.

This to be done either by Conſtruction, upon drawing the Curve Line of this Motion, through the ſeveral Points where, by Calculation, the Center of the Shadow croſſes the Meridians of *Paris*, *Greenwich*, and *Dublin*; and meaſuring the Angle it makes with the ſeveral Meridians; or more exactly for *Greenwich* by ſolving the Triangle (*Fig.* 11.) PVO, where the Arc VO is equally diſtant *Weſt*, as *Paris* is *Eaſt* from *Greenwich*, is to be found by the Method already made uſe of; thus:

Paris Angle at the Pole $= 62° \; 28'$. Angle for OV at the Pole is leſs by twice the Difference of the Angles at the Pole for *Paris* and *Greenwich* $= 5° \; 54'$, And $62° \; 28' - 5° \; 54' = 56° : 34'$. First then find the Arc VO = Compl. Latitude for O, as in *Probl.* XIV. by this Analogy.

R.			10.		
	°	′			
CS. ∠ PC.	56.	34.	9. 741125		
T. PV.	27.	00.	9. 707166	°	′
T. PR.			9. 448291 =	15	41

Then ſay,

CS. PV.

	° ′			° ′
CS. *PV*.	27. 00.	9. 949880		
CS. *PR*.	15. 41.	9. 983523		
CS. *VC*.	58. 22.	9. 719730		
		19. 703253		
CS. *PC*		9. 753373	=	45. 29.
			Deduct	15. 14.
			Remt. *VO*.	39. 48.
			VG.	40. 46.
			VP.	41. 48.

Then in the Triangle *VOP* whose included Angle is 4° 38′, and whose two Sides are 39° 48′ and 41° 48′. Find the Arc *PR* as usual thus:

R.		10.			
	° ′			°	′
CS. *OVR*.	04. 38.	9. 998577			
T. *VO*.	39. 48.	9. 920733			
T. *VR*.		9. 919310	=	39	48
			from	41	42
			Remnt	2°	6′ = *PR*.

Then for the Angle *VPO*, say:

	° ′		
S. *PR*.	02. 06.	8. 563999	
S. *VR*.	39. 42.	9. 805343	
T. *OVR*.	04. 38.	8. 908719	
		18. 714062	
T. *VPO*.	=	10. 150063	= 54. 42.

And for *VOR*;

	° ′	
S. *VO*.	39. 42.	9. 805343
S. *VPO*.	54. 42.	9. 911763
S. *VP*.	41. 48.	9. 823821
		19. 735584
S. *VOP* =		9. 930241 = 58. 23
		+ 113 05
		Half 56 32½
		Compl. 33 27½

So that the Acute Angle *VGO*, which the Course of the Center of the Shadow makes with the Meridian of *Greenwich*, is 56° 32′ ½; And by consequence the Angle it makes with the Parallel of Latitude there is 33° 27′ ½. 5 or 6 Degrees more than in Dr. *Halley*'s Scheme.

Corollary. The longer Axis of the total Shadow at the Meridian of *Greenwich*, makes an Angle of 12° 43′ ½ with the Direction of the Shadow.

For if from the Angle that the Direction of the Center of the Shadow makes with the Parallel of *Greenwich*,	33 27½
We deduct the Angle that the longer Axis makes with the same Parallel, which is the Azimuth formerly discovered,	20 44
There remains this Angle	12 43½

XXIV.

To Determine the perpendicular Breadth of the Total Shadow, when that Shadow is nearest to *London*; or when the central Point is about the Meridian of *Padstow* in *Cornwall*.

This

This *Problem* is, In an Ellipsis of 96 Miles broad, and 562 Miles long; whose longer Axis makes an Angle with the Direction of the Shadow of 12° 43 ½; To determine the Length of the greatest Perpendicular that falls on that Diameter, along which the Direction of the Motion is. For twice that Perpendicular is the Breadth required. Now I have actually drawn this Ellipsis, or total Shadow, for my Map of this Eclipse. And I find by that Construction, that the Breadth of the total Shadow over *England* is about 155 Miles; or 30 Miles broader than in Dr. *Halley*'s Scheme. Time will probably discover which is nearest the Truth.

N. B. This total Shadow increases so greatly in Length as it goes *Eastward*, that it will reach from *Paris* to the utmost Boundary of the Sun-setting at once. And though the Center of the Shadow, by my Calculation, will end 8° ⅔ *East* of the Meridian of *London*, in the Latitude of 45° 9', or in the *Alps*, not far from *Milan* and *Turin*; Yet by reason of the Extension and Breadth of the total Shadow, and the Refraction of the Rays of Light near the Horizon, it seems probable to me, that all *Switzerland* and *Lombardy*, as far as *Trent*, *Mantua*, *Cremona*, and *Parma*; nay, perhaps, as far as *Venice*, *Padua*, *Bononia*, *Ferrara*, *Ravenna* and *Florence*; may at the same Time be invelop'd in the Total Shadow; and that the Sun may set eclipsed at all or most of those Places at once.

XXV.

To determine the Digits eclipsed, and the Duration of the Eclipse, or of total Darkness, at

any given Distance from the Path of the Moon's Center; and *vice versâ*. These Digits and Durations, if we do not consider the diurnal Motion, are immediately found to any given Distance in the Tables, P. 29,——34. Thus, if the Digits be 4, or Duration 80′ 24″, the first Table gives us the Distance of 1350 Miles. And, *vice versâ* if the Distance be known to be 1350 Miles, the same Table gives us 4 Digits and 80′ 24″ Duration. And the like is true of the total Shadow, and the Distance or Duration in the second Table. Thus also we learn from the Map of this Eclipse, that the nearest Approach of the total Shadow to *London* will be about 40 geographical Miles: Which 40 Miles, in this Obliquity of the Motion, is about 31 perpendicular Miles. So that $\frac{14}{1000} = \frac{13}{60}$ of a Digit, is the Quantity of the Rim of Light that will be seen at *London*, when the Eclipse is greatest: And by consequence the Digits there eclipsed will be $11\frac{48}{60}$. Nor does it appear to me, that the total Darkness will come nearer to *London*, than 40 Miles; although Dr. *Halley*'s Scheme brings it within 7 or 8 Miles. As for the Duration of the entire Eclipse here, it will be much the same as if it were Central: And has been already determined to 1^h 47′. And for the total Darkness along the Path of the Center between *Exeter* and *Plimouth*, its Duration will be, as before stated, 3′ 6″ $\frac{1}{2}$.

N. B. As to the Alterations which will arise in more considerable Distances from the Path of the Moon's Center, proceed thus: First, find the Minutes of Duration corresponding to any given Distance in Miles, *e.g.* 1350, thus; 2000 : 1350 :: 32′,63 : 22′,07. Or, As 2000 Miles, the Radius : to 1350 the Sine :: So are the Number of Mi-

Minutes for the Semidiameter of the Penumbra: to the Number of Minutes for that Sine. Now 32′ 19″ the present Length of the greatest Distance — 22′ 01″ = 10′ 18″. Then compute every Thing as if the Center of the Shadow were 10′ 18″, Latitude or nearest Distance; and as if the Chord of that Arc over the Earth's Disk were the Path of the Moon's Center: and the Chord of the Distance from the Center of the Penumbra were the Diameter of the Penumbra: And all will be discovered by the Rules before going; without any new Directions whatsoever. Only if this Distance be the contrary way to the present Example, we must here make use of Addition instead of Substraction.

N. B. Upon consulting the *French* Ephemerides of *Des Places*, recommended, in some Degree, by *Cassini* himself, I find that he determines the Eclipse at *Paris* thus.

	h	′	″
Beginning, *May* 22. (*N. S.*)	06	03	00
Middle	06	58	38
End	07	54	00
Whence the Duration there is	01	51	00
Digits eclipsʼd	10	$\frac{17}{20}$	
Latitude of the Moon at the Middle	39′	$\frac{1}{4}$	
Difference from me in Digits	01	$\frac{3}{20}$	
In Latitude	07	10	

If these Digits and this Latitude be right, Dr. *Halley*, and I, and those *English* Astronomers that have computed and constructed this Eclipse, who all, I think, do agree, that it will be total at *Paris*, and that for two or three Minutes also, are prodigiously mistaken. For if *Des Places* be in the right, *Copenhagen* and *Stockholm* will stand much fairer for the Pretence to a total Eclipse, than

than either *Dublin*, *London*, or *Paris*. Time will certainly determine who are in the right.

N. B. If we add the Duration of the Eclipse, consider'd without Regard to the diurnal Motion, to the Time of the Center of the Shadows passing over the entire Disk, we gain the entire Duration of the Eclipse in general, thus:

	h	′	″
To	1	50	48
Add	2	58	24
Sum	4	49	12

Therefore the general Eclipse by the Meridian of *London*,

	h	′	″
Begins II.		52	24
Middle V.		17	00
End VII.		41	36
Duration	4^h	49	12

Eclipse at *London*,

Begins V.		45	00
Middle VI.		41	00
End VII.		$32\frac{1}{2}$	00
Duration	1^h	$47\frac{1}{2}$	00
Digits eclipsed		11	$\frac{48}{65}$
Duration of Total Darkness between *Exeter* and *Plimouth*,		03	$6\frac{1}{2}$

N. B. Dr. *Halley*'s Times are still about 5′ sooner than mine, and his general Duration about 7′, and his Duration at *London* about 1′ longer.

N. B.

N. B. I cannot tell the Reaſon why my Original Calculation of this general Eclipſe, which has been carefully made according to Sir *Iſaac Newton*'s famous *Theory of the Moon*, does here ſo much differ from Dr. *Halley*'s Determination, as 5′ in Time; eſpecially ſince both thoſe Methods did very well agree, in the laſt celebrated total Eclipſe, *Apr.* 22. 1715. 'Tis Time alone that can determine between theſe two Methods of Calculation.

N. B. I have lately been ſhewed an exact Scheme of this next Eclipſe, according to Mr. *Flamſteed*'s own Tables and Determination, and made in his Life-time; wherein the Digits eclipſed are $11\frac{8}{60}$ exactly according to my Determination in this Paper.

L A PRO-

A PROPOSAL

For the Discovery of the LONGITUDE of the several Places of the Earth, by Total Eclipses of the Sun.

IT is humbly proposed, That Observations be made in all Places where Solar Eclipses are seen, of the exact *Duration* of the same; by either viewing the Beginning and Ending thereof through a Telescope, with a Glass smoaked in the Flame of a Candle, for saving the Eye of the Observer; or else by casting the Sun's Image through such a Telescope upon white Paper, and viewing the first and last Impression of the Moon's Shadow upon it. And that the Hour, Minute, and Second of some Pendulum Clock be carefully noted at the same Time: And that when the same Observations are transmitted for the Uses of Geography, the Latitudes of the Places be also set down and transmitted at the same Time: That the like Observations be also made in all Places where such Eclipses are total and visible, of the exact Beginning and Ending, with the Duration of Total Darkness; by the like Comparison of a Pendulum Clock, or other pendulous Body that vibrates Seconds, or half Seconds; and, with the Latitude be transmitted in the same Manner, and for the same Uses. How by the Help of these Ob-

Obſervations the *Longitude* may be diſcovered, I have already ſhew'd under *Problems* XIV, XV, and XXV. foregoing.

N. B. If the Latitude be exact, and the entire Duration of an Eclipſe of the Sun can be determined to one Quarter of a Minute in Time; and the Times of Beginning and Ending be not too remote from Noon; the Longitude of that Place may uſually be thence determined much nearer than to one Degree. And ſince 'tis certainly very practicable to obſerve the Duration of Total Darkneſs to three or four Seconds every where; if the Latitudes be exact, the *Longitude* of thoſe Places may commonly be determined much nearer than a Quarter of a Degree. Nor will the groſſer Way by the Duration of the entire Eclipſe, unleſs the Beginning or Ending be near the Horizon, be much inferior, as to Accuracy, to any Method now uſed by Aſtronomers for that Purpoſe; while it is withal much more eaſy and practicable, even by thoſe that underſtand little or no Aſtronomy, or that have no curious Aſtronomical Inſtruments, than any of them. And as for all ſuch Places as lie in the Trace of the Total Shadow, 'tis evident, that no other Way now uſed is in the leaſt comparable to this before us; either in Eaſe of Obſervation, or Accuracy of Determination therefrom.

N. B. Since this next total Eclipſe is ſo near the Evening, and the Motion of no ſmall Part of its Shadow's Paſſage over *North America*, and the *North-Weſt* Parts of *Europe* nearly parallel to the Equator; the general Eclipſe is much leſs fit for ſuch Obſervations, as are here neceſſary, than moſt others of the ſame Sort; though where a total Shadow paſſes, no Eclipſe can be wholly unfit for

it. However, if this be less favourable to us in general; the other which I have brought to Calculation also, 1727. is exceeding favourable; as not going very far over the *West* of *Africa*, 'till a good while in the Day; as going very oblique to the Parallels almost all the Way; and as reaching the *East-Indies* long before the Sun comes to the Horizon: On all which Accounts I venture to recommend it for that Purpose, and to say, That in case the Clouds generally favour us, and a sufficient Number of accurate and proper Observations be not wanting, the Geographical Longitude of Places in no small Part of the one half of the known World, may by that single Eclipse be very well determined.

N. B. The Calculations here made before-hand, with regard to both these Eclipses, are not themselves design'd for the actual Discovery of that Geographick Longitude of Places immediately; but only as Specimens how such Calculations may and ought to be more exactly made after the Eclipses are over, and their true State, and Time and Circumstances well known from the best Observations, but not otherwise.

N. B. If any curious Persons have a mind to examine very nicely any of the Eclipses which will be visible at *London* till *A. D.* 1740. they are these following; according to the Calculation of Mr. *Leadbetter*.

Solar Eclipses.

(1.) A Total Eclipses, *May* 11. 1724. 36′ past Six a-Clock at Night, of 11 ½ Digits at *London*.

(2.) An Eclipse, *Sept.* 14. 1726. 38′ past Five a-Clock in the Evening, of 6 Digits.

(3.) An

(3.) An Eclipse, *Sept.* 4. 1727. 27′ past Seven in the Morning, of $2\frac{1}{2}$ Digits.

(4.) An Eclipse, *July* 4. 1730. 26′ past Nine in the Morning, of 6 Digits.

(5.) A great Eclipse, *May* 2. 1733. 36′ past Six at Night, of $9\frac{8}{3}$ Digits.

(6.) A great Eclipse, *Feb.* 18. 1737. 25′ past Three in the Afternoon, of $9\frac{3}{4}$ Digits.

(7.) An Eclipse, *Aug.* 4. 1738. 58′ past Nine in the Morning, of $4\frac{1}{8}$ Digits.

(8.) A considerable Eclipse, *July* 24. 1739. 23′ past Four in the Afternoon, of $7\frac{1}{10}$ Digits.

(9.) An Eclipse, *Decemb.* 19. 1739. 49′ past Eight in the Morning, of $2\frac{1}{6}$ Digits.

Lunar Eclipses.

(1.) An Eclipse, *Octob.* 21. 1724. 9′ past Four in the Morning, of 7 Digits.

(2.) A great and total Eclipse, *Octob.* 10. 1725. 15′ past Seven at Night, of $21\frac{3}{5}$ Digits.

(3.) An Eclipse, *Sep.* 30. 1726. 4′ past Five in the Morning, of 5 Digits.

(4.) An Eclipse, *Feb.* 14. 1728. 14′ past Seven in the Morning, of $9\frac{1}{5}$ Digits.

(5.) A great and total Eclipse, *Feb.* 2. 1729. 44′ past Eight at Night, of $19\frac{1}{4}$ Digits.

(6.) A great and total Eclipse, *July* 29. 1729. 20 past one in the Morning, of $18\frac{1}{5}$ Digits.

(7.) An Eclipse, *Jan.* 23. 1730. 34′ past Three in the Morning, of $2\frac{6}{7}$ Digits.

(8.) An Eclipse, *June* 9. 1731. 55′ past One in the Morning, of $1\frac{6}{7}$ Digits.

(9.) A great and total Eclipse, *Novem.* 20. 1732. 59′ past Nine at Night, of $20\frac{1}{5}$ Digits.

(10.) An Eclipse, *May* 17. 1733. 56′ past Six at Night, of $8\frac{5}{7}$ Digits.

(11.) An

(11.) An Eclipſe, *Sept.* 21. 1735. 33′ paſt One in the Morning, of $5\frac{3}{5}$ Digits.

(12.) A great and total Eclipſe, *March*, 15. 1736. 52′ paſt Eleven at Night, of $21\frac{1}{4}$ Digits.

(13.) A great and total Eclipſe, *Sept.* 6. 1736. 2′ paſt Three in the Morning, of $20\frac{1}{2}$ Digits.

(14.) An Eclipſe, *Aug.* 29. 1737. 44′ paſt Three in the Morning, of $4\frac{3}{5}$ Digits.

(15.) An Eclipſe, *Jan.* 13. 1739. 47′ paſt Ten at Night, of $6\frac{1}{5}$ Digits.

(16.) A great and total Eclipſe, *Jan.* 2. 1740. 45′ paſt Ten at Night, of $20\frac{1}{2}$ Digits.

(17.) An Eclipſe, *Decemb.* 21. 1740. 49′ paſt Ten at Night, of $5\frac{4}{5}$ Digits.

Advertiſement.

Mr. *Whiſton* Propoſes to make an *Orery* for the Explication of the Motions of all the Planets and Comets; and a *Copernicus Improv*'d, for the eaſy Diſcovery of of all Solar Eclipſes whatſoever, from the Beginning of Aſtronomy, till *A D.* 2000. and for the natural and univerſal Exhibition of the ſame to the Eye in a few Minutes time, and this with a Globe of 30 Inches Diameter. Price of both 20 Guineas.

A Table of the Latitude *of the Center of the total Shadow at the Eclipse,* May 11. 1724. *to every* 10 *Degrees of the Angle about the* Pole, *and every* 7°L845. Longitude *from* London.

Angles at the Pole.			Longitude from *London.*	Latitde.	
°	′		° *East.*	°	′
70	19		8L577	45	9
69	23		7L845	45	34
			West.		
59	23		0000	49	17
49	23		7L845	52	19
39	23		15L690	54	42
29	23		23L535	56	29
19	23		31L380	57	43
09	23		39L225	58	13
00	00		46L600	58	38
00	37		47L070	58	38
10	37		54L915	58	21
20	37		62L760	57	36
30	37		70L605	56	18
40	37		78L450	54	27
50	37		86L295	51	59
56	22	Midk.	90L021	50	16
60	37		94L140	48	51
70	37		101L985	45	5
80	37		109L830	40	40
90	37		117L675	35	56
100	37		125L520	30	31
110	37		133L365	25	15
120	37		141L210	20	11
130	37		149L055	15	37
136	59		154L052	13	3

N. B. Here, as well as in the next Table, *The Angles at the Pole* differ by Ten Degrees; and the *Longitude from London* is found by the Proportion of 4L64 to 3L64. to be 7°L845 of Longitude from

from *London* for every such Ten Degrees. But if, as is generally most convenient, we would have the Differences of *Longitude from London* be even 10 Degrees; We must find the correspondent *Angles at the Pole* before we begin our Calculations by the inverse Proportion of 3,64 : 4,64 :: 10° : 12¼ the perpetual Addition of which Number will give us a Series for such a Calculation.

A Table of the Latitude of the Center of the total Shadow at the Eclipse, Sept. 4. 1717. *to every* 10° *Degrees of the Angle at the Pole; and every* 7°,167 *Longitude* from *London.*

Angles at the Pole.			Longitude from *London.*		Latitde.
°	′		° *West.*		° *North.*
11	33		12,248		30 18
4	28		7,167		30 20
			East.		
00	00		3,963		30 14
5	32		0,000		29 28
15	32		7,167		27 56
25	32		14,334		25 40
35	32		21,501		22 38
45	32		28,668		18 27
55	32		35,835		14 24
65	32		43,002		9 21
75	32		50,169		5 4
77	58	Midle.	51,903	Midle.	3 57
85	32		57,336		0 16
					South.
95	32		64,503		4 32
105	32		71,670		9 55
115	32		78,837		14 54
125	32		86,004		19 16
135	32		193,171		23 00
145	32		100,338		25 57
155	32		107,505		28 8
165	32		114,672		29 34
168	39		116,909		30 14

3,53 : 2,53 :: 10 : 7,167.
2,53 : 3,53 :: 10 : 13,952.

A Cal-

A Calculation of the Total Eclipse of the Sun, A. D. 1724.

May 11. *Post Meridiem.*

	M.'s mean Mo.	Motio of Apogee.	Motio of Node retr.
	s ° ′ ″	s ° ′ ″	s ° ′ ″
Anno Dom. 1701	10 15 20 00	11 8 20 00	4 27 24 20
Years 20	4 13 34 05	3 3 50 15	26 50 15
and 3	28 9 10	4 1 59 32	1 27 59 9
Leap-Y. *May*, Days 11	9 29 17 03	14 42 21	6 59 24
Hours 5	2 44 42	1 24	40
Minutes 15	8 14	4	2
(Mean Time.)			3 1 49 30
Moon's mean Motion	1 29 13 14	6 28 53 36	1 25 34 50
Sun's mean Anomal.	10 22 19 57	An.Eq.add 12 2	An.Eq.subst. 5 43
Physic. Parts substract	7 7	6 29 5 38	1 25 29 7
2d Equat. substract	2 31 9 38	Mean Pla. correct	Mean Pla. correct
3d Equat. add	10	2 1 38 45	2 1 38 45
6th Equat. add	2 6 2 16	Sun's true Place	Sun's true Place
Diff. substr.	7 22	7 2 33 7	6 9 38
Moon's mean Pl correct	1 29 5 52	Annual Argument	S's dist. from Node
True Pl. of Apog. substr.	7 9 14 38	10 9 0	Equat. add 18 56
Moon's mean Anomal.	6 19 51 14	Equat. add	1 25 48 3
Equat. add	2 31 7	7 9 14 38	True Pl. of Node
Moon's true Pl. in Orbit	2 1 36 59	True Pl. of Apogee	5 17 9
Sun's true Pla. substract	2 1 38 45	Eccentricity 6000	Inclinat. Limit.
Moon's dist. from Sun	11 29 58 14	′ ″	′ ″
Nodes true Pl. substract	1 25 48 3	M's h.mot. 37 42	S.mid. Sun 15 53
Argument of Latitude	5 48 56	Sun's 2 24	Sem. Moon 16 42
Reduction substract	1 30	M's fro. Sun 35 18	Sem. Penb.ra 32 35
Moon's tr. Pl. in Eclip.	2 1 35 29	35′ 18″ : 60′ : 1′ 46″ : 3′ 2″	Semi. Disc. 61 38
Moon's true *North* Lat.	32 14		Angle of the M's Way with the Ecliptick 5 36
At the Eclipse	32 19	Eq. time add 3 53	Diff. Diameter of the Sun & Moon, or Breadth of total Shad. 0 98
		Reduct. subst. 2 33	
		Diff. add 4 22	
		Ergo, Eclipse is 11d 5h 19′ 22″	
		Temp. appar. deduct the Error of the Tables about 2′ 22″	
		true Tim. 5h 17 0	

A Calculation of the Sun's Place for the same Time.

	Sun's mean Motion.	Motion of Perihelion.
	s ° ′ ″	s ° ′ ″
A. D. 1701	9 20 43 40	3 7 44 30
Years 20	9 4	28 0
And 3	11 29 17 0	3 9
Leap-Y. *May*, Days 11	4 10 6 19	23
Hours 5	12 19	
Minutes 15	37	3 8 9 2
(meanTime)		Place of Perihelion.
Sun's mean Motion	2 0 28 59	2 00 28 59
Equation add	1 9 46	Moon's mean Motion.
Sun's true Place	2 1 38 45	10 22 19 57
		Sun's mean Anom.

M A Cal-

A Calculation of the Total Eclipse of the Sun, A. D. 1727. Sept. 4. Mane.

		M's mean Mot.	Motion Apogee.	Mot^{n} of N^{ods} retr.
		s ° ′ ″	s ° ′ ″	s ° ′ ″
Anno Dom.	1701	10 15 20 0	11 8 20 0	4 27 24 20
Years	20	4 13 34 5	3 3 50 15	26 50 15
And	6	2 9 28 55	8 4 5 44	3 26 1 29
Sept. Days	3	1 23 35	27 24 23	13 1 37
Hours	20	10 58 49	5 34	2 39
Minutes	35	19 13	10	5
(Mean Time.)				5 5 56 5
Moon's mean Motion		5 21 4 37	11 13 46 6	11 21 28 15
Sun's mean Anomaly		2 15 32 16	An.Eq.sub. 18 59	An. Eq. add 9 7
Physical Parts add		11 3	11 13 27 7	11 21 37 22
2d Equat. substract		0 38	Mean Pl.Apo.cor.	MeanPl.of No. 01
6th Equat. add		1 57	5 21 52 53	5 21 52 53
Difference add		12 42	Sun's true Place	Sun's true Place
Moon's mean Pl. correct		5 21 17 19	6 8 25 46	6 0 15 31
True Pl. of Apog. subst.		11 16 23 44	Annual Argum.	S.'s dist.fro. Nod.
Moon's mean Anomaly		6 4 53 35	Eq. Ad 2 56 37	Eq. Ad. 0 48
Equation add		42 26	11 16 23 44	11 21 38 10
M.'s Correct.Pl. inOrb.		5 21 59 45	True Pl. of Apo.	True Pl. of Node
Sun's true Pla. substract		5 21 52 53	Eccentr. 66337	5 17 20
Moon's Dist. from Sun		6 52		Inclin. Limit.
Variation add		9	S.'s hor.mot. 2 26	
M.'s true Pl. in Orbit		5 21 59 54	Moon's 38 29	Semid. S. 16 1
Nodes tr. Pl. substract		11 21 38 10	M. fr. S. 36 2	Semid. M. 16 50
Argument of Latitude		6 0 21 44	36 ∠04 : 60 : :	Diff. = 00 49
Reduction substract		6	6.19 : 11 30.	Sum = 32 52
Moon's true Pl. inEclip.		5 27 51 48	*Ergo*, Eclipse will	Parallax M. Horizon 62 7
Moon's true *South* Latit.		1 54	be 20^{h} 23 34	Sun 10
At the Eclipse		1 23	Mean Time.	Semid. Dis. 61 57
			Eq.tim. ad. 4 38	Angle of the M.'s visible Way with the Ecliptick
			Reduct. substr. 9	5 36 20
			Diff. add 4 29	
			20^{h} 28 03	
			Appar. Time.	

A Calculation of the Sun's Place for the same Time.

		Sun's mean Motion.	Motion of Perihel.
		s ° ′ ″	s ° ′ ″
A. D.	1701	9 20 43 40	3 7 44 30
Years	20	9 4	21 0
And	6	11 21 33 8	6 18
Sept. Days	3	8 2 28 9	40
Hours	20	49 17	
Minutes	35	1 26	3 8 13 28
(Mean Time.)			Place of Perihel.
			5 23 44 44
Sun's mean Motion		5 23 44 44	Sun's mean Motion
Equat. substract		1 51 51	2 15 32 16
Sun's true Place		5 21 52 53	Sun's mean Anomaly.

Some

Some Account of Obſervations lately made with Dipping-Needles, in Order to diſcover the LONGITUDE and LATITUDE at Sea.

UPON the Receipt of the liberal Aſſiſtance of His moſt Excellent Majeſty, King *GEORGE*; their Royal Highneſſes the Prince and Princeſs of *Wales*, and many other of the Nobility and Gentry, my kind Friends; I ſent laſt Year Four ſeveral Dipping-Needles to Sea; with Frames hung near the Center of Motion in Gimbols, to avoid the Shaking of the Ship; and with proper Inſtructions to the Maſters of the Veſſels: And this, in order to diſcover the State of Magnetiſm in the ſeveral Parts of the Globe; and to find whether accurate Obſervations could be made at Sea, and to determine whether the fundamental Theory I laid down from former Obſervations would hold or not; *viz.* "That Magnetick Variation and Dip "are all deriv'd from one Spherical Magnet in "the Center of our Earth; with an irregular "Alteration of the Variation, according to the "different Degrees of Strength of the ſeveral "Parts of the Loadſtone, as compounded with a "very ſlow Revolution from *Eaſt* to *Weſt*: And "with a regular Alteration of the Dip, nearly "according to the Line of Sines, from the Mag-"netick Pole to the Magnetick Equator; the "Axis of that Equator being ſufficiently Oblique

"to its Plane: All which is the Case of Sphe-
"rical Loadstones here." Now having already received Four Journals from Four several Masters employ'd, I take this Occasion of returning my Benefactors hearty Thanks for their Assistance, and of giving them and the Publick some Account of the Success of these Observations; and what Consequences are naturally to be drawn from them; with the Difficulty hitherto met with in the Practice at Sea, and the proper Remedy for the same in future Trials.

Captain *James Folly* set out in *July*, 1722. for *Archangel*, with one of my Dipping-Needles on Board. He, for some time, met with such Difficulties in the Practice, as confin'd to the Frame I had given him, that he was not at first able to make any good Observations at all. But after some Time, he took the Needle into his own Cabin; and without any Approach to the Center of Motion, or any Contrivance for avoiding the Shaking of the Ship at all, having a clear and full Gale all along, but without any stormy Weather, He made me 28 very good Horizontal Observations, from the Latitude of 65 quite to *Archangel*: I say, *Horizontal Observations* only, as I desired him; the Needle, by an Accident before he went, being rendred incapable of making any other with sufficient Accuracy. In this Space the Needle altered its Velocity very greatly, as I expected it would: And 5 Vibrations which at first were perform'd in about 280″; beyond the *North-Cape* came to 250″; till towards *Archangel* it gradually returned to about 177″.

Captain *Othniel Beal* set out about the same Time for *Boston* in *New-England*, with the same

Instrument, and made Four Observations of the Dip, both by the Vertical and Horizontal Vibrations, and by the Dip it self; Three upon the open Sea, and One in the Haven of *Boston*: Which in some small Manner differed one from another, but in the main agreed, and kept the due Analogy I expected. He greatly complained of the Shaking of the Ship; till in *Boston* Haven he made a nice Observation both Ways, which did not greatly differ: Tho' the greatest Part of of his Observations by the Dip it self were somewhat more agreeable to Analogy than the other. The Reason was, I take it, that, as he assured me, he always took great Care to avoid the Shaking of my Frame; which Frame tho' it very much avoided the slower and greater Oscillation of the Ship, yet made a quicker but lesser Oscillation it self: Which Fault I was sufficiently sensible of just before the Ships were going away, but was not able then to obviate; as I am prepared to do hereafter. After Captain *Beal* had made and sent me these Observations, he pursued his Voyage to *Barbados*, and thence to *Charles Town* in *South Carolina*; at both which Places he made Observations; but the best at *Barbados*. For before he came to *Carolina*, he observed the Axis of the Needle to shake; which made him take the Dip there otherwise than he ought to have done; which is the natural Occasion that the Dip there did not so well agree to Analogy as the rest. However, upon my Receipt of his first Journal, with the Four first Observations, especially the exact one at *Boston*, I formed a more exact Theory of the Proportion of the Alteration of the Dip in the Spherical Magnet of the Earth; and found it at this Distance of the Earth's Surface, not far from that in my Spherical Loadstone, at the Distance

ſtance of about $\frac{2}{10}$ of an Inch from its Surface; *viz.* Not exactly as the Line of Sines, where at the Middle of the Line the Angles are 60 and 30; but rather as 66 to 24. Which Rule therefore is what I now propoſe as much nearer than the other. By which Proportion I determined long before-hand the Dip at *Barbados* of 43° or 44°, as many of my Friends can witneſs: And when Captain *Beal* delivered me the Paper of this Obſervation at *Barbados*, before I opened it, or in the leaſt knew what Dip it contain'd, I foretold to him from that Theory the very ſame Dip, which both himſelf and his Paper immediately aſſur'd me to be true; and whoſe Truth, as he inform'd me afterwards, was confirm'd by another Obſervation, made a little before in the open Sea, of about 45°.

Captain *Tempeſt* alſo, about the ſame Time, ſet out for *Antegoa* and *St. Chriſtopher's*, with the ſame Inſtrument and Frame. In his Letter, dated laſt *January*, he greatly complains of the Shaking of my Frame; and propoſes an Hint how it might be avoided: Which Method of its Avoidance I had long before thought of, and provided for accordingly; and which has been a full Year ready for Practice. Thoſe Obſervations of his, that I have yet received; for I have not heard from him ſince *January*, but hope ſoon to here farther; were but Three, and all at open Sea; and but one of them made both the Ways that I deſired: And, indeed, ſeem the leaſt agreeable to Analogy of any of the reſt. Only ſince that ſingle Obſervation, which was alſo made by the horizontal Vibrations and vertical Oſcillations, agrees very well to that Analogy; ſince they all three are about the ſame

Quan-

Quantity of 8 or 9 Degrees exceed that Analogy; and ſince very near the ſame Place, where the third Obſervation was made, I have a double Obſervation of Captain *Beal*'s to correct the ſame; I rather conclude, that Captain *Tempeſt* made a Miſtake, and placed the wrong Edge of the Needle upward in all the Three Obſervations: Which would naturally occaſion ſuch a Difference. When I receive the reſt of his Obſervations, or his Needle again, I ſhall be able to judge better of that Matter. However, even theſe Obſervations agree in groſs with all the reſt, to the gradual Decreaſe of the Dip as you go nearer to the Equator: Tho' as they ſtand at preſent, they do not determine the accurate Proportion of that Alteration ſo well as the others.

Captain *Michel* alſo, long after the reſt, ſet out for *Hamburgh* with the ſame Inſtrument; though now without the Frame, which he was not willing to incumber himſelf with: and I ſuſpected that in its preſent Contrivance it did more hurt than help the Nicety of the Experiments. I alſo by him, ſent a Letter to the Reverend Mr. *Eberhard*, who was the Occaſion of my ſtudying this Matter, and was then Paſtor of *Altona*, cloſe by *Hamburgh*; deſiring that he would there make the Experiment very exactly, and give me a particular Account of it. But I have not yet received his Anſwer.

Now the Obſervations here mentioned, as well as thoſe many others I had by me before, do ſeem to me in general evidently to afford us the following Inferences:

(1.) That there is one Spherical Loadſtone, and but one in the Center of our Earth; and that this Load-

Loadſtone, like other Spherical Loadſtones, has but one *Northern* Pole : Contrary to Dr. *Halley*'s Hypotheſis.

(2) That this *Northern* Pole is ſituated, contrary to the ſame Hypotheſis alſo, a great Way to the *Eaſt* of our Meridian : And indeed, as I before had determined, about the Middle of the Diſtance between the *North Cape* and *Nova Zembla*. Captain *Jolly*'s numerous Obſervations prove this moſt fully : While in Sailing towards that Point his horizontal Vibrations greatly increas'd in Number : And when he turned almoſt at right Angles, as he went down to *Archangel*, they ſoon diminiſhed ; and yet ſo little, after ſome time that it was evident he then ſailed not far from a Parallel to that *Northern* Pole ; and not very many Degrees from it neither ; exactly according to my Expectations.

(3.) That the abſolute Power of the internal Magnet is conſiderably different in different Places ; and that without any certain Rule ; as it is upon the Surface of our *Terrellæ* or Spherical Loadſtones here. This the various Number of Seconds to a vertical Oſcillations, and all the Accounts in the other Obſervations fully prove ; and by conſequence this muſt cauſe different Variations in different Places, as is the Caſe of our *Terrellæ*.

(4.) That there no where appears in open Seas any ſuch Irregularity in the Dip, as we ſometimes meet with near Shores, or at Land ; and by conſequence that Dr. *Halley*'s grand Objection againſt the Diſcovery of the Longitude by the Dipping-Needle, taken from an Obſervation of his own, concerning ſuch an Irregularity near the Shore at *Cape Verd* ; and from his own Hypotheſis of the four Magnetick Poles is utterly groundleſs.

less. Nor indeed shall I be at Rest, till I have sent a Dipping-Needle to *Hudson's Bay*, on purpose to determine this Dispute about the four Poles: For that Voyage being almost directly towards his second *Northern* Pole all the way, and about the same Distance all the way from mine; if this Voyage afford much the same Dip, it will demonstrate that there is but One *Northern* Pole; and that it is nearly where I place it: But if that Dip greatly *increase*, it will demonstrate a second Pole somewhere in those Parts of *America*, where Dr. *Halley* places it. And to this Decretory Experiment do I appeal for a final Determination of this Question. The Doctor seems to me to draw his Inferences from the *Variation*, which no Way proves any such double Poles; as being full as sensible on our *Terrella*, which have no more than single ones; while he avoids all Observations from the *Dip*, which are still against him; and which are alone capable of discovering the exact Place of such Poles, either upon the Surface of the Earth, or of *Terrella*. However, when one Set of Experiments with a Dipping-Needle, sent to *Hudson's Bay*, will certainly determine this Matter, 'tis a vain Thing to go on in the Way of Controversy about it.

In short, The Observations hitherto made, shew that the Foundations I go upon in this Discovery of the *Longitude* and the *Latitude* at Sea, are true and right: That the Terrestrial Magnetism is very regular and uniform, in the open Seas; that the Latitude in the *Northern* Parts may even, without any Avoidance of the Shaking of the Ship, in ordinary calm Weather, be in good Degree thereby discovered already; and that if I can sufficiently avoid the Shaking of the Ship, which I am now endeavouring, and have great

Hopes of performing, both *Latitude* and *Longitude* may by this Method be discovered in the greatest Part of the sailing World. I say nothing here of another Method of Trial, which I am also pursuing, and which depends, like this, on the avoiding the main Part of the Ship's Agitation; and if effected will be more easy and universal than this. But as to giving any farther Account of that to the Publick, unless it succeed, I have no Intention at all.

N. B. The original Journals are all in the Hands of my great Friend and Patron *Samuel Molyneux*, Esq; Secretary to his Royal Highness, the Prince of *Wales*, and Fellow of the Royal Society: Which Journals, when I have compleated the rest of the Observations I hope to procure, I intend to publish entire, for the more full Satisfaction of the curious,

A Table of the Angle of Inclination below the Horizon, in Dipping-Needles, *to every* $\frac{1}{90}$ *Part of their respective equal Distances from the Magnetick Poles and Equator.*

Dist. from the Pole.	Dip.		Dist. from the Equat	Dip.	
°	°	°	°	°	°
1	89	30	1	08	41
2	89	00	2	12	23
3	88	27	3	15	14
4	87	59	4	17	41
5	87	29	5	19	51
6	86	59	6	21	50
7	86	38	7	23	41
8	85	58	8	25	24
9	85	27	9	27	2
10	84	57	10	28	36
11	84	27	11	30	6
12	83	56	12	31	32
13	83	26	13	32	55

Di-

Dist. from the Pole.	Dip.		Dist. from the Pole.	Dip.	
°	°	°	°	°	°
14	82	55	14	34	15
15	82	24	15	35	33
16	81	54	16	36	50
17	81	23	17	38	4
18	80	52	18	39	16
19	80	21	19	40	28
20	79	49	20	41	37
21	79	18	21	42	45
22	78	47	22	43	54
23	78	16	23	44	58
24	77	44	24	46	2
25	77	12	25	47	6
26	76	41	26	48	9
27	76	8	27	49	10
28	75	36	28	50	12
29	75	4	29	51	12
30	74	32	30	52	12
31	73	59	31	53	11
32	73	26	32	54	9
33	72	54	33	55	6
34	72	20	34	56	1
35	71	47	35	57	0
36	71	14	36	57	56
37	70	39	37	58	52
38	70	5	38	59	47
39	69	31	39	60	41
40	68	57	40	61	35
41	68	22	41	62	49
42	67	47	42	63	22
43	67	12	43	64	15
44	66	36	44	65	8
45	66	00	45	66	0

N. B. I take the *Northern* Pole of the Terrestrial Magnet to be about the Meridian of *Archangel*, in the Latitude of $75\frac{1}{2}$. Its Equator to be nearly a great Circle, intersecting the Earth's Equator about $2\frac{1}{2}$ Degrees *Eastward* of the Meridian of *London*; and in its opposite Point. And that its utmost Latitude *Northward* is in the Gulph of *Bengall* about $12\frac{1}{2}$ Degrees; and as much *South* in the opposite Point, in the great *South Sea*. And that the *Southern* Pole is nearly circular; its Radius 40 Degrees of a great Circle, and its Center in a Meridian *Eastward* from *Ceilon* about $4\frac{1}{2}$ Degrees, and about $68\frac{1}{2}$ Latitude.

N. B. London is nearly $\frac{21}{84}L^5 = \frac{2}{90}L^6$ distance from the *North* Pole of the Magnet, whence its Dip will be at $74\frac{1}{2}$, which is certainly so in Fact. *Boston* in *New-England* is $\frac{51}{111} = \frac{41}{90}L^3$, whence its Dip will be about 68° 22′, which Captain *Beal* found to be so in Fact. *Barbados* is about $\frac{26}{100}L^5 = \frac{22}{90}L^5$ distant from the Equator of the Magnet, whence its Dip ought to be about 44° $\frac{1}{2}$, as Captain *Beal* also found it to be in Fact. *St. Helena* is about $\frac{14}{49} = \frac{25}{90}L^7$, whence its Dip ought to be about 47° 50′ as Dr. *Halley* found it to be in Fact. And so every where in the main Ocean, at considerable Distances from the Shores.

N. B. If the Dip of any Needles be somewhat different at *London*, add or substract a proportionable Part of the Dip elsewhere. And you will have nearly the true Dip at any other Place with that Needle Thus if your Needle differ from the other 2° or 120′, and shew the Dip at *London* 72° 45′ instead of 74° 45′, which is its proper Dip in this Table; and you require the true Dip by this Needle for

Boston in *New-England*, *Southward*; which in the Table is 68° 22′, proceed thus. Because the equal Distance of *Boston* from the Magnetick Equator is 49 Parts of 60 L 4, the like Distance of *London* from that Equator; deduct $\frac{49}{60}$ L 4 120′ = 97′ = 1° 37′ out of the Tabular Dip 68° 22′. The Remainder is 66° 45′, for the true Dip at *Boston* with that Needle. Thus if you want the true Dip, by the same Needle, at *Dronthem* in *Norway*, *Northward*: Because the equal Distance of *Dronthem* from the Magnetick Pole is 15 L 2 Parts of 29 L 6 the Distance of *London* from that Pole; deduct $\frac{15}{29}$ L 6 12′ = 62′ = 1° 2′ out of the Tabular Dip 82° 30′, and the Remainder, 81° 28′ is the true Dip at *Dronthem*, with that Needle: And so in all other Cases whatsoever.

N. B. The Table before set down, supposes that the true Dip differs according to such a Line of Sines, whose middle Point gives 66° on one Side, and 24 on the other; and is made by adding or substracting 8 to the Complement of the Dip found by the natural Sines for every $\frac{1}{10}$ of equal Distances from the Equator or Pole.

N. B. If any desire to calculate by Trigonometry the Distances of all Places from the magnetick Equator of Poles, and the Distances of that Equator and those Poles in every particular Case, both made use of in the foregoing Calculations, it is thus to be done:

In the (*Fig.* 12.) Triangle *BLA* we have *BL* the Co-Latitude of *London*; *BA* the Co-Latitude of the magnetick *North* Pole; and the included Angle, *ABL* = the Distance of the Meridian of that Pole from the Meridian of *London*; to find the Angle *QAM* and the Side *AL*. Then in

in the Triangle $\mathfrak{Q} A M$, we have the Angles $\mathfrak{Q} A M$ and $\mathfrak{Q} M A$, and the Side $A M$, = the Diſtance of the Magnetick Pole from the Magnetick Equator, to find $A \mathfrak{Q}$. So we have the Proportion of A L to $A \mathfrak{Q}$, $\mathfrak{Q}$. E. I.

But ſince the *Data* are not yet ſufficiently exact for the Calculation, meaſuring is ſufficient.

FINIS.

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Fig. 1.

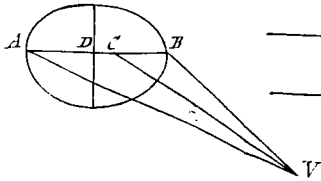


Fig. 2.

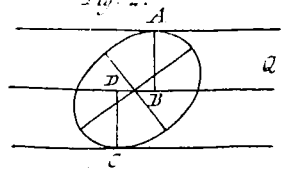
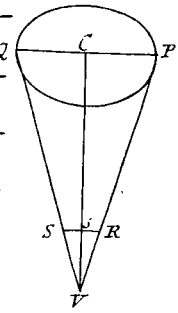
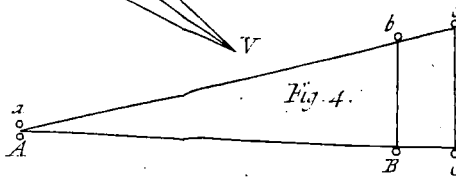


Fig. 3.





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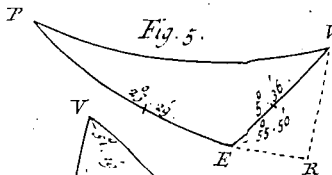
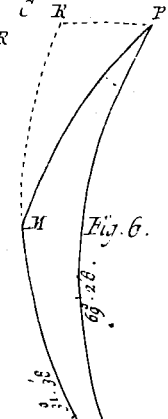


Fig. 5.

Fig. 7.



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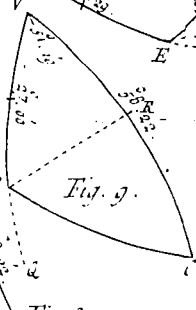

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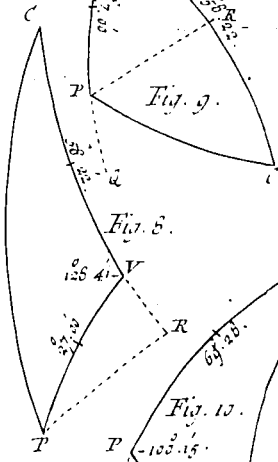

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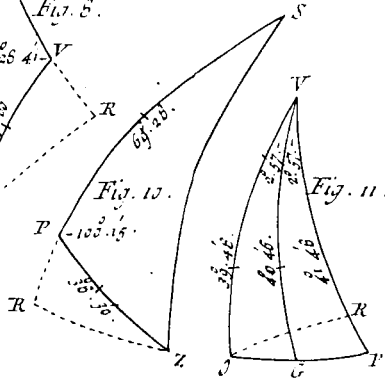


Fig. 10.

Fig. 11.

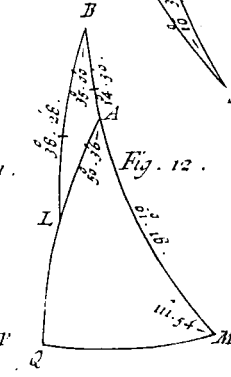


Fig. 12.

ERRATA.

PAge 1. *lines* 12, 13. *read*, 5 Leap Days; and with 11 Days when 4 Leap Days. *P.* 7. *over against* 21, &c. *read*, 53. 2. 55. 40. 58. 19. 60. 58. 63. 38. 66. 19. 69. 0. 71. 42. 74. 24. 77. 7. 79. 50. 82. 34. 85. 19. 88. 4. 90. 50. *P.* 10. *l.* 32. *read*, Summer. *P.* 13. *l.* 7. *r.* 10d. *l.* 8. *and* 10, *and* 16. *r.* 18. *P.* 13. *l.* 24. *r. Bern*, *Zurich*, and *Pillau* near *Koningsberg* in *Prussia*. *Dele p.* 16. *l.* 32. *to p.* 17. *l.* 10. *and instead of it read thus:* Its greatest Alteration therefore must be at the mean Distance; and is the Difference of the Equation belonging there to the Addition of $10^{\circ}.8 = 17$, which Space the Moon usually goes in about 36 of time. So that the Difference on this Account must, each Period, be usually less than 36′. And as to the Moon's own Motion, it has also its greatest Alteration at its mean Distance; and is the Difference of the Equation at $2^{\circ}.51.\frac{1}{2} = 17$. which the Moon usually goes in about 36′. of time. So that the Difference on this Account must, each Period, be usually less than 36′. also, and on both Accounts less than $1^{h}.12'$.

A

DISSERTATION

ON THE

General Properties

OF

ECLIPSES;

And particularly the enſuing ECLIPSE of 1748, conſidered thro' all its Periods.

By GEORGE SMITH, *Eſq*;

LONDON:

Printed for E. CAVE, at *St John's Gate*, and ſold at the Pamphlet Shops. 1748.

A DISSERTATION, *&c. on* ECLIPSES.

WE have no record of any *Eclipses* being obſerv'd 'till after *Nabonaſſar*'s days. This monarch having eſtabliſhed a ſchool of *Ægyptian* aſtronomers at *Babylon*, they began to collect a ſeries of theſe aſtoniſhing phænomena, in order to compleat their cæleſtial theory, and ſee if they could inveſtigate their cauſes, and aſſign their returns. Accordingly they obſerv'd one as early as 721 years before Chriſt, about 26 after the foundation of their College; but it does not appear, from all their regiſters, that they ever attain'd to the knowledge of their computations by previous calculation; tho' by the number of years aſſign'd for their return, which was eighteen, with 10 or 11 days, more or leſs, as the Biſſextile falls out, 'tis evident that they had made conſiderable progreſs before the deſtruction of *Babylon* by *Alexander*; yet we cannot think that they had tables for correcting the anomalies of that period, or computing ſucceeding eclipſes *a priori*.

Thales was the firſt of the *Grecian* aſtronomers, that foretold the ſolar eclipſe which happened in the fourth year of the 48th *O-*

lympiad, or the 580th before Chriſt; but 'tis moſt likely he had the prediction elſewhere, as we find no tables exiſtent till long after the redemption, which could with the leaſt certainty explain or foretel theſe appearances.

The *Chaldean* period of 18 years, with ten or eleven days, generally throws the eclipſe near eight hours later with regard to the time of day, ſo that if the firſt eclipſe happen about noon, the return of it after that interval will be near eight at night; and when theſe obſcurations happen about the ſummer ſolſtice, all the whole three periods may be ſeen in *Britain*, but in winter only one of theſe, ſo that the time of the year greatly affects the circumſtances of ſolar eclipſes.

As eight hours in three periods make juſt one day, ſo in 54 years and about a month, theſe returns will nearly correſpond to the time of day, and bring the eclipſe with much the ſame affections to every particular place, the difference lying chiefly now betwixt the greater or leſſer obliquity of the earth's axis, and the variation of the moon's node.

In eclipſes about the ſolſtices the parallels of latitude are cut at ſmall angles, and the difference of the latitudes of the central ingreſs and exit, depends altogether on the poſition of the axis of the lunar circle to the earth's. But in eclipſes about the equinoxes

noxes these latitudes are widely different, and the meridians cut at small angles, contrary to what happens in the solstices.

The shade generally has its most northern limit in the illuminated hemisphere, sometimes to the east and sometimes to the west of the general meridian.

After the shade arrives at its most northerly limit, it from thence declines continually southward, till it arrives at the opposite point of deflection, which two points are seldom or never in the disk at one time, except in some very particular cases.

In the present eclipse, for example, it enters the earth amongst the *French* settlements in *Canada* central, and passes continually more north, till it arrive in latitude 57° 38′; from that point it bends southward continually till its exit, near fort *St George* on the *Indian* continent; this point is to the west of *Britain*, because it crosses *Scotland* betwixt 56° and 57°, diminishing, which is less than its most northerly approach.

This contrary flexure is not occasioned by any irregularity of the lunar motions, but entirely by the position of the earth, and must be common to all eclipses, because of different situation of the earth's and moon's axes; and even when these co-incide, it will be at times when no parallelism can happen betwixt the path of the shade and place; for the last is always elliptical, except at the equi-

equinox, when the angle of the axis is 23° 29′ from the ecliptic, and that of the moon can never exceed 6 degrees. Now as the way of the ſhade is ſo near a ſtrait line, that we always delineate it as one on the diſk, and the path of the place is always a curve, except in the circumſtances ſpecify'd, of the elliptic kind, all right lines that cut any ellipſis in one point muſt paſs out of it again, and ſo the ellipſis of the moſt northerly contact will be no more touch'd by the moon's way, which will afterwards continually keep ſouth of it, till it would arrive at a point, of the moſt ſoutherly approach, if the progreſs continu'd till that time.

The compleat revolution of ſolar eclipſes will be a period nearly equal to half of the *Annus Magnus*, or 12,000 years, but 1000 of theſe, or about ſixty *Chaldean* periods, generally exhibit all their variety to this globe; the far greater part of that revolution is expended on the ætherial ſpaces of the univerſe, within the circumſcription of the ſhade, and never reach the earth at all: In ſome of theſe ſpaces every moment has a ſolar eclipſe ſince the creation of things, and the number of thoſe aſſign'd to the Earth are comparatively almoſt nothing to thoſe of the expanſum.

To illuſtrate this a little farther, we ſhall examine ſome of the moſt remarkable circum-

cumſtances of the returns of the eclipſe which happens *July* 14, 1748, about noon: This, after traverſing the voids of ſpace from the creation, at laſt began to enter the *Terra Auſtralis incognita*, about 88 years after the conqueſt, which was the laſt of king *Stephens*'s reign; every *Chaldean* period it has crept by degrees more northerly, but was ſtill inviſible to any part of the *Britiſh* iſles before the year 1622, when on the 30th of *April* it began to touch the ſouth points of *England* about 2 in the afternoon, its central appearance riſing in the *American* ſouth ſeas, and traverſing *Peru*, and the *Amazons* country thro' the *Atlantic* ocean into *Africa*, and ſetting in the *Æthiopian* continent, not far from the beginning of the Red Sea.

Its next viſible period was after three *Chaldean* revolutions in 1676, on the firſt of *June*, riſing central in the *Atlantic* ocean, paſſing us about 9 in the morning with four digits eclips'd on the under limb; this ſet in the gulph of *Cochinchina*, in the *Eaſt Indies*.

It being now near the ſolſtice, was, for reaſons already given, viſible the very next return in 1694 in the evening; and in two periods more, which was in 1730, on the 4th of *July*, was ſeen above half eclips'd juſt after ſun-riſe, and obſerv'd both at *Wirtemberg* in *Germany*, and *Peking* in *China*, ſoon after which it went off.

Eighteen years more afford us the eclipſe now

now to happen on the 14th of *July*, with the phænomena already deſcrib'd; and thoſe who deſire to look more narrowly into its particular affections, may conſult the annexed map of it over the earth, which illuſtrates by inſpection only. However, to ſatisfy the curious, I ſhall continue the revolutions till their expiration.

The next viſible return will happen in 1766, in the evening, about four digits eclips'd, *July* 25th; and after two periods more on *Auguſt* 16, 1802, early in the morning, about five digits, the centre coming from the north frozen continent by the capes of *Norway*, thro' *Tartary*, *China*, and *Japan*, to the *Ladrone* iſlands, where it goes off.

Again in 1820, *Aug.* 26, betwixt 1 and 2, there will be another great eclipſe at *London* above 10 digits, but happening ſo near the equinox, the centre will leave every part of *Britain* to the weſt, and enter *Germany* at *Emden*, paſſing by *Venice*, *Naples*, *Grand Cairo*, and ſet in the gulf of *Baſſora*, near that city.

It will be no more viſible 'till 1874, when 5 digits will be obſcur'd, the centre being now about to leave the diſk on *Sept.* 28. In 1892, the ſun will go down eclips'd at *London*, and again in 1928 the paſſage of the centre will be quite in the expanſum, tho' there will be 2 digits eclips'd at *London* *Oct.* the 31*ſt* of that year; and about the year

year 2090 the whole penumbra will be wore off, whence no more returns of this eclipſe can happen 'till after a revolution of 10000 years.

From theſe remarks on the entire revolution of this eclipſe, we may gather that 1000 years more or leſs (for there are ſome irregularities that may protract or lengthen that period 100 years) compleat the whole terreſtrial phænomena of any ſingle eclipſe; and ſince 20 periods of 54 years each, and about 33 days, comprehend the entire extent of their revolution, 'tis evident that the times of the return will paſs thro' a circuit of 1 year and 10 months, every return of the *Chaldean* period 10 or 11 days later, and of the equable appearances, about 32 or 33 days. Thus tho' this eclipſe happens about the middle of *July*, no other ſubſequent terreſtrial eclipſe of this period will return to the middle of the ſame month again, but wear conſtantly each period 10 or 11 days more forwardly, and at laſt appear in winter, but then it begins to ceaſe from affecting us.

Another concluſion from this revolution may be drawn, that there will ſeldom be any more than two great eclipſes of the ſun in the interval of this period, and theſe ſometimes follow next return, and often at greater diſtances. That of 1715 return'd again in 1733 very great, but this preſent eclipſe will not be great till the arrival of

of 1820, which is a revolution of four *Chaldean* periods, so that the irregularities of their circles must undergo new computations to assign them exactly.

Nor do all eclipses come in at the south pole; that depends altogether on the position of the lunar nodes, which will bring in as many from the expansum one way as t'other, and such eclipses will wear more southerly by degrees, contrary to what happens in the present case.

The eclipse, for example, of 1736, in *September*, had its centre in the expansum, and set about the middle of its obscurity in *Britain*; that will wear in at the north pole, and in the year 2600, or thereabouts, pass off into the expansum on the south side of the earth.

The eclipses therefore which happen'd about the creation, are little more than half way yet of their ætherial circuit, and will be 4000 years before they any more enter the earth. This grand revolution seems to have been wholly unknown to the antients.

I come now to consider them in another light, as it appears before their reduction to computation; their remarkable phænomena in the two great lights of the earth, afforded proper subject to the *Jewish* prophets to borrow allusions, and even make use of their revolutions to point out the ensuing issue of their prophecy.

This

This will be more evident, if we attend to the other prophetic threatnings as deduc'd, from the eſtabliſh'd laws of nature, either as fore-runners of ſome general calamity, or as penal ſufferings inflicted on the delinquencies of that people; ſuch as famine, peſtilence, war, dreams, earthquakes and the like; not that theſe ſignals were the cauſe of the evil, but certain diagnoſtics foreſeen by the prophets to precede it.

Again, the particular nation threatned had moſt frequently ſome one of its darling objects, taken either in knowledge, idolatry, or any other favourite ſcheme. Thus the images of *Moab* are threatned to be removed from them; the *Ægyptians* on the other hand had their *Nile*, the fountain of all their wealth ſpoke againſt, "to be ſmitten in all its ſeven channels", &c. the *Tyrians* their ſea, &c. as is evident from inconteſtable proofs in the *Jewiſh* writings.

Hence nothing could be fixt on by a prophet more emphatical to point forth the deſtruction of *Babylon*, than ſome aſtronomical phænomenon, as that was the principal ſtudy of theſe people; and nothing indicates the ſupernatural authority of the prophets more than foretelling theſe remarkable events, before there were the leaſt tables made for ſuch computations, or indeed before any mathematical hypotheſis was ſuffer'd about them, being looked on as the aſtoniſhing miracles

nature, and not to be accounted for by the then rational theory.

It muſt therefore be conſonant to the ſyſtem of prophecy, to prefigure the deſtruction of an aſtronomical city, by ſigns taken from their own theory. And this will appear the caſe, if we attentively examine thoſe prophets who particularly directed their menaces to *Babylon*; I ſhall at preſent only mention *Iſaiah*.

That writer having pointed out the pride of the *Chaldean* learning, the multitude of her aſtronomers and ſtar-gazers, in his 47th chapter, and their ridiculous pretenſions to prognoſticate the fate of nations by the aſſiſtances of ſuch ſciences, tells them, their own deſtruction was coming like a torrent, which they could not foreſee, though the ſign would be amongſt their ſtars, which they principally ſtudy'd, and their two grand lights. Your deſolation, ſays he, is coming from a far country, from the kingdoms of nations, and when you ſee theſe ſigns be ſure it will follow.

The ſtars of heav'n, to wit the קסילים (Keſilim) *thereof ſhall be hid, the ſun ſhall be darkned in his going forth, and the moon ſhall withdraw her light.* Iſaiah xiii. 10.

Accordingly the whole prophecy was literally compleated, the *Keſilim*, or *Hyades*, were eclipſed by the moon, the ſun was darkned totally over the *Babylonian* empire at his going forth

forth, or ſetting, and the moon was likewiſe totally eclips'd, all regularly after each other, in the 4th year of the 48th *Olympiad*, not many years before the deſtruction of that city. And as this was the ſolar eclipſe predicted by *Thales*, 'tis not difficult to conjecture whence that aſtronomer might gather his light; and tho' *Iſaiah* did not point out the particular year in his prophetical writings, we can hardly ſuppoſe him ignorant even of that, as he gives ſo many concurring circumſtances to ſtrengthen the event of his prediction.

The ſupernatural eclipſe at the paſſion of *Chriſt* ſeems very manifeſtly foretold by *Zechariah* xiv. 6. For as they were divinely inſpired, the miraculous accidents in nature were the ſame to them as thoſe which after ages might be capable of deducing from the eſtabliſhed theory of things, though impracticable to the aſtronomers of thoſe days.

Likewiſe the great ſolar and lunar eclipſe, which preceded the deſtruction of *Jeruſalem*, ſeems elegantly hinted at by *Chriſt*, *Mathew* xxiv. 29.

But notwithſtanding the prophets made uſe of thoſe phænomena as ſigns, they being no cauſe of the event, nor having any relation to the myſteries of futurity, nothing can now be made out from their particular tranſits, as divine inſpiration has ceaſed, even granting that they precede ſome diſaſter

to

to a particular people, becauſe we cannot argue from cauſes that have no viſible connection to events of a different nature. The *Jewiſh* prophets foretold the circumſtances that would go before, and the diſaſters that would follow; they even pointed out the nation that was to effect it, though frequently there was not the leaſt apprehenſion or ground for ſuch a concluſion. Thus *Iſaiah*, foretelling the deſtruction of *Tyre* and *Zidon*, ſays it would be from a people they little expected, a city that had no being 'till the *Aſſyrian* built it, that t'other day only the *Arabian* ſhepherds had pitched their tents where that miſtreſs was getting up that would be their end, even the city of the *Chaldeans*; *Iſaiah* xxiii. and elſewhere in his prophecies againſt *Tyre*. And when our modern Judicialiſts go as evidently to work with their concluſions, we may then give aſſent to their predictions; otherwiſe, *credat Judæus Apella*.

Nothing beſides, of any certainty, can be deduced from a phænomenon ſo uncertain in its riſe, progreſs, and exit. Many eclipſes come in on the ocean, in uninhabited countries about the north pole, and never reach the ſight of man at all, and no concluſion can be inferred to any people from theſe; but when minds are diſpos'd to imbibe enthuſiaſm, they will eaſily draw inferences from independent cauſes.

Thus

Thus, in 1724, the ſun went down totally eclips'd over *Genoa*; its cataſtrophe followed in 1747; at *Dantzig* the ſame, and in 1733 that city was taken by the *Ruſſians*; in 1737 the eclipſe came in at *Porto Bello*, that mart deſtroyed by admiral *Vernon* a few years after; the ſame came over *Scotland* ſoon after mid-day, the rebellion in 1745; ſet at the mouth of the river *Kimen* in *Finland*, that province ruined by the *Ruſſians*, and the river like to become a ſource of new contentions. Now if ſome great and ſignal calamity happen to *Quebec* and the *French* ſettlements in *Canada*, or to fort *St George* in the *Eaſt Indies*, the riſe and exit of the great enſuing eclipſe; and if the time of its completion be diſtinctly marked out, or the people that are to effect it, and the circumſtances that will attend it, ſomething may be done to ſtrengthen aſtrology; otherwiſe accumulations of myſtic ſentences, and ambiguous evaſions, look more like the heathen oracles, than the temple of *Zion*, and will never gain ground with the more judicious part of mankind, till better ſupported.

P.S. It is particularly to be noted, that eclipſes, which have happened many centuries ago, will not be found by our preſent tables to quadrate exactly with antient obſervations, by reaſon of the great anomalies in the lunar motions; which appears an incon-

inconteſtable demonſtration of the non-eternity of the univerſe. For it ſeems confirmed by undeniable proofs, that the moon abſolves her period in a ſhorter compaſs of time than formerly, and will continue by the centripetal law to accelerate in velocity as ſhe approaches the earth; nor will the centrifugal power be found ſufficient to compenſate the different gravitations of ſuch an aſſemblage of bodies as conſtitute this mighty fabric, which would ruſh to ruin of itſelf, without proper aſſiſtance to regulate and adjuſt it to its original motions.

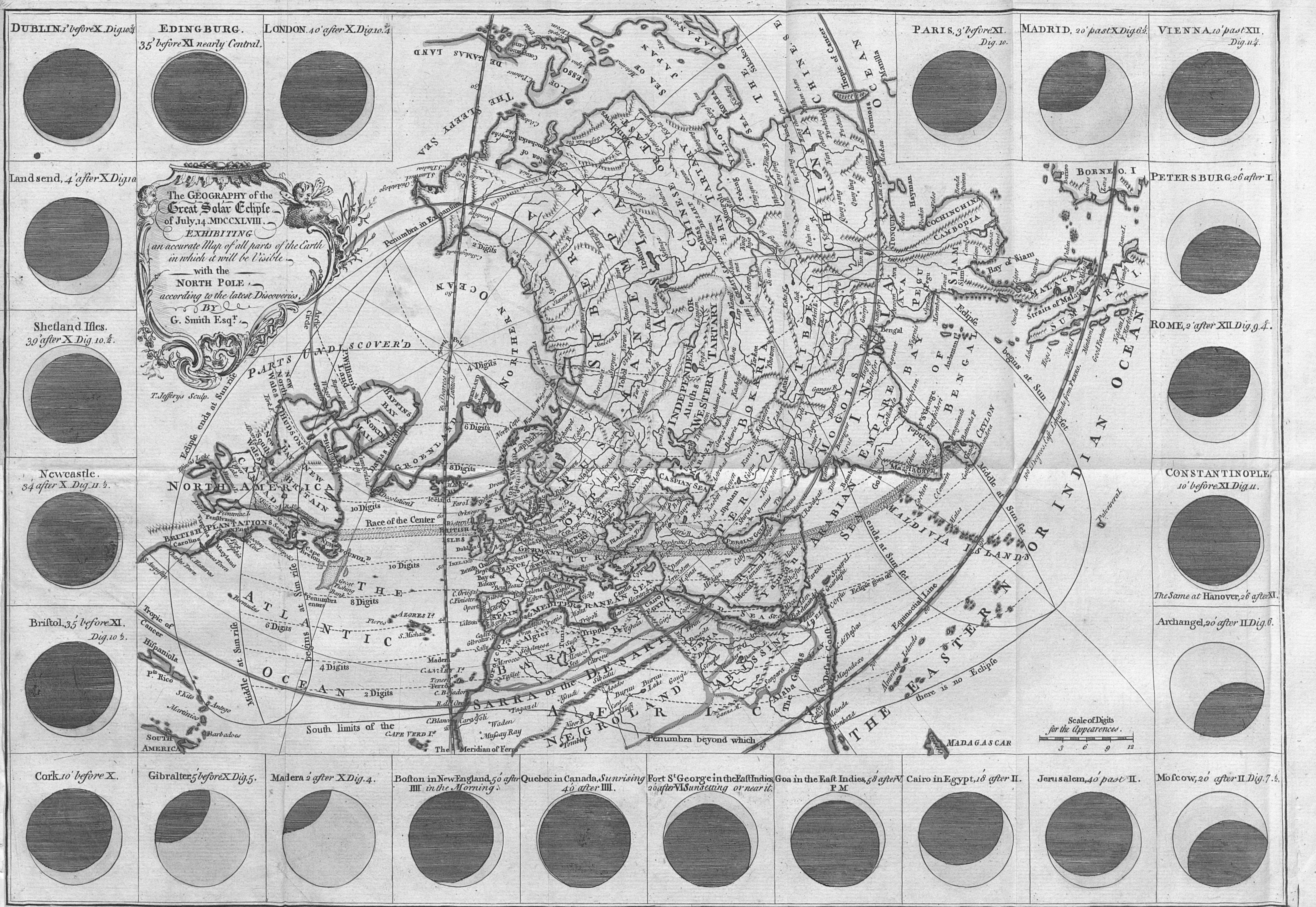
Thus we are credibly aſſured, from the teſtimony of the antients, that there was a total eclipſe of the ſun predicted by *Thales* to happen in the fourth year of the 48th *Olympiad*, either at *Sardis* or *Miletus* in *Aſia*, where this aſtronomer then reſided. That year correſponds to the 585th before *Chriſt*, when accordingly there happened a very ſignal one on the 29th of *May*, anſwerable to the preſent 10th of that month, central through *North America*, the ſouth parts of *France*, *Italy*, &c. as far as *Athens*, or the iſles in the *Ægean* ſea, which is the fartheſt that even the *Caroline* tables carry it, and conſequently make it inviſible to any part of *Aſia* in the total character, tho' I have good reaſons to believe that it extended to *Babylon*, and went down central over that city. We are not however to imagine that it was ſet before it paſt *Sardis*, and the *Aſiatic* towns where

where the predictor lived, becauſe an inviſible eclipſe could have been of no ſervice to demonſtrate his ability in aſtronomical ſciences to his countrymen, as it could give no proof of its reality.

For a farther illuſtration; *Thucydides* the hiſtorian relates, that a ſolar eclipſe happened on a ſummer's day in the afternoon, in the firſt year of the *Peloponneſian* war, ſo great that the ſtars appeared. *Rhodius* was victor in the *Olympic* games the fourth year of the ſaid war, being alſo the fourth of the 87th *Olympiad*, or the 428th before *Chriſt*. So that the eclipſe muſt have happened in the 431ſt before *Chriſt*, and by computation it appears that on the 3d of *Auguſt* (about the 17th of our preſent *July*) there was a ſignal eclipſe, which would have paſt over *Athens* central about ſix in the evening, but which our preſent tables bring no farther than the antient *Syrtes* on the *African* coaſt, above 400 miles from *Athens*, which ſuffering in that caſe but 9 digits, could by no means exhibit the remarkable darkneſs recited by the hiſtorian; the center ſeems therefore to have paſt *Athens* about ſix in the evening, and probably might go down about *Jeruſalem*, or near it, contrary to the conſtruction of the preſent tables. I have only obviated theſe things by way of caution to the preſent aſtronomers, in re-computing antient eclipſes, and refer them to examine the eclipſe of

Nicias

Nicias ſo fatal to the *Athenian* fleet, that which overthrew the *Macedonian* army, &c. from the annals of hiſtory, becauſe the tedious proceſs of calculations is foreign to my deſign. Mean time I ſhall note down 10 or 12 remarkable eclipſes, that will be viſible at *London* in the compaſs of 800 years, as they may ſerve for a future ſtandard to ſucceeding aſtronomers, in aſcertaining the quantity of this increaſed velocity of the lunar motions, for which a proper table may be compoſed, to regulate, with more certainty, eclipſes of great antiquity; as they will have larger opportunities to gratify their knowledge, and confirm this conjecture, from the numerous regiſters of thoſe phænomena daily publiſhed.



Revised and Published according to Act of Parliament Jan. 1. 1748. by E. Cave.

At *LONDON.*

Table of 12 *Solar Eclipses to happen in* 800 *Years.*

1842 *June* 26, 8′ before VI. manè Dig. 10 $\frac{1}{4}$ center to the ſouth.

1860 *Sept.* 26, 2′ after VIII. manè Dig. 11 $\frac{1}{4}$ center a little ſouth.

1927 *June* 16, 33′ paſt V. manè Dig. 11 center to the north.

1999 *July* 28, 4′ before XI. manè Dig. 11 $\frac{1}{2}$ center a little ſouth.

2075 *June* 30, 12′ before V. manè Dig. 9 $\frac{1}{2}$ center to the ſouth.

2093 *July* 10, 20′ before I. P. M. Dig. 10 $\frac{3}{4}$ center to the north.

2146 *Feb.* 26, 15′ paſt V. P. M. Dig. 9 $\frac{1}{2}$ center to the ſouth.

2187 *June* 22, 15′ after VII. manè Dig. 10 $\frac{1}{2}$ center to the ſouth.

2200 *March* 29, 18′ after V. P. M. Dig. 11 $\frac{3}{4}$ center a little north.

2381 *July* 6, 40′ after XI. manè Dig. central and total ferè.

2435 *Auguſt* 8, 10′ before X. manè Dig. 8, center to the north.

2551 *May* 19, 10′ after V. P. M. Dig. 6 $\frac{3}{4}$ center to the ſouth.

Computed from Leadbetter's *Tables.*

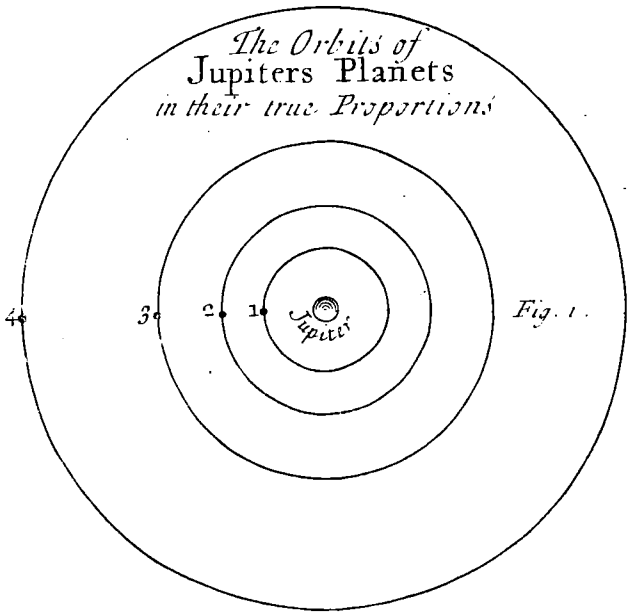

The Orbits of
Jupiters Planets
in their true Proportions
4
3
2
1
Jupiter

Fig. 1.

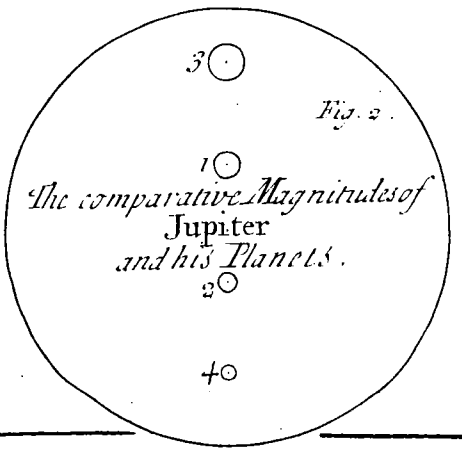

3
1
The comparative Magnitudes of
Jupiter
and his Planets.
2
4

Fig. 2.

THE

LONGITUDE

DISCOVERED

BY THE

ECLIPSES, OCCULTATIONS,

AND

CONJUNCTIONS

OF

JUPITER'S PLANETS.

WITH

DESCRIPTIONS of those Refracting and Reflecting TELESCOPES; and of those SECTORS, and that QUADRANT, which are the Instruments necessary for this DISCOVERY, both at Land and Sea.

To which is added,

An *EPHEMERIS* for the latter Half of the YEAR of our Lord 1738.

Containing the

CONFIGURATIONS of *Jupiter*'s PLANETS at Six a Clock every Evening, while *Jupiter* is to be any where seen. With those ECLIPSES, OCCULTATIONS, and CONJUNCTIONS that are useful for the DISCOVERY of the LONGITUDE, both at Land and Sea. Engraven on a Copper Plate.

Humbly Recommended to

The HONOURABLE the COMMISSIONERS appointed by Act of Parliament for the Discovery of the LONGITUDE at SEA.

By WILL. WHISTON, *M. A.*

Sometime Professor of the MATHEMATICKS in the University of *CAMBRIDGE*.

Και πᾶσαι πεδίοιο τρίβοι, καὶ τρήχεες ὄχθαι,
Οὔρεα θ' ὑλήεντα, καὶ ἄγρια κύματα πόντου
Εὔβατα δὴ, καὶ εὔπλοα ἔσται ἡμάσι κείνοις.

Orac. SIBYLL. L. III.

LONDON,

Printed for JOHN WHISTON, at *Boyle*'s Head, *Fleet-Street*.

MDCCXXXVIII.

To the HONOURABLE the

COMMISSIONERS

APPOINTED BY

ACT of PARLIAMENT

FOR THE

DISCOVERY

OF THE

LONGITUDE at SEA,

THIS

DISCOVERY

OF THAT

LONGITUDE,

Now, at length, rendered practicable at SEA,

IS,

With all due Submiſſion,

Humbly Dedicated by

The AUTHOR.

PREFACE.

AFTER all that has been propo-ſed to the Publick ſince the Act of Parliament paſs'd, twenty-four years ago, for providing a Re-ward to any who ſhould find out a practicable method for Diſcovering the Longitude at Sea, I believe it does at length appear, that none of them have ſo well deſerved the attention of the curious, and particularly of the Honour-able the Commiſſioners appointed for that purpoſe, as Mr. Harriſon's *at-*

tempt

tempt for making ſuch a Clock as may go true on ſhipboard; and Mr. Whiſton's *attempt for producing ſuch Refracting and Reflecting Teleſcopes as may ſhew the* Eclipſes, Occultations, *and* Conjunctions of *Jupiter*'s Planets, *and the* Occultations *of fixed Stars by the* Moon *there. Which laſt mentioned method includes the uſe of two New Inſtruments, called the* Longitude Sectors, *now firſt propoſed by Mr.* Whiſton, *as well as of Mr.* Barſton's Quadrant. *Which* Quadrant, *altho' it were at firſt intended by the Author for taking the* Latitude, *in which caſe it has met with great Approbation; yet does it moreover ſeem to be the beſt Inſtrument hitherto known for perfecting the Diſcovery of the* Longitude *alſo, whenever neither the riſing nor ſetting of the Sun, Moon, or Stars can*

be

be ſeen at Sea: which is a caſe but too common there alſo. For as this Inſtrument is known to take the Altitude of the heavenly bodies much better and quicker, even at Sea, than any other; ſo is that altitude, when the Horizon is not to be ſeen, the beſt means of knowing the time at the Ship. Without which Knowledge, all Clocks, or Obſervations of Jupiter's *Planets, or of the Appulſes of the Moon to fixed Stars,* &c. *muſt be to no purpoſe, as to the Diſcovery of the Longitude there.*

In order to the Explaining which methods by Jupiter's *Planets, and by the* Occultation *of fixed Stars by the* Moon; *the Author, Mr.* Whiſton, *offers theſe* XXXIV Lemmata, *or Preparatory Propoſitions; and the following* XI Problemata: *immediately including the*

the Discovery of the Longitude: ana that in the exact way of the Geometricians; for greater perspicuity, and evidence of Demonstration.

THE

AN HISTORICAL

PREFACE;

OR, AN

ACCOUNT

OF THE

Several Steps taken by the AUTHOR for the Discovery of the Longitude at Sea; from the Act of Parliament giving a Reward for that Discovery, passed *A. D.* 1714, till the Completion of that Discovery 1741.

IN *the Year* 1713, *Mr.* Humphrey Ditton *and myself hit upon a Method of discovering the Longitude at Sea, at least near the Coasts, by* Signals of Light and Sound, *which would determine the Bearing and Distance of the Ship from the Place whence the Light and the Sound were seen and heard. This Discovery was by us the next Year communicated to Sir* Isaac Newton; *and, at his Desire, to Dr.* Halley; *as also to Dr.* Samuel Clarke, *and Mr.* Roger Cotes; *and we soon had their Approbation so far as to encourage us to make Application to the House of Commons the same*

Year 1714, *for a Reward to be allotted to any ſuch as ſhould diſcover that Longitude. This Application was kindly received by the Houſe of Commons; a Committee was appointed to examine into the Matter; and the four Perſons already mentioned were ſummoned to attend. What was then ſaid and done appears, for the main, in the Report of the Committee to the Houſe in their Journals; which was received and agreed to by the Houſe unanimouſly on* June 11, *and a Committee was named to draw up a Bill accordingly. Which being paſſed in the Houſe of Lords, and by the Queen, is become a known Act of Parliament, with the Title of* An Act for providing a publick Reward for ſuch Perſon or Perſons as ſhall diſcover the Longitude at Sea; *wherein the Reward is* 10000 l. *if it extend only to one Degree of a great Circle, or* 60 *Geographical Miles:* 15000 l. *if to* 40: *and* 20000 l. *if to* 30 *ſuch Miles, With this Proviſo, that if any ſuch Method extend no farther than to* 80 *Miles adjoining to the Coaſts, the Propoſer ſhall have no more than one half of ſuch Rewards reſpectively. As alſo with another Proviſo, that any leſſer Diſcovery of the ſame Longitude may have a proportionably leſſer Reward. But all according to the Determination of the Commiſſioners therein named. But this will be more fully underſtood if I trace the Hiſtory of the Hearing it ſelf before the Committee, and ſet down Sir* Iſaac Newton's *Paper delivered in to that Committee: which*

which was directly the original Plan upon which the Act itself was founded: all which is preserv'd in the Journals of the House of Commons, a Copy of an Extract out of which Journals has been procured me by the Right Honourable the Speaker of the two last Houses of Commons, and lies now before me. As soon therefore as the Committee was set, which was a very large one, and had Mr. Clayton, *Member of Parliament for* Liverpool, *for its Chairman, the four Persons before mentioned appeared; and a Chair was set for Sir* Isaac Newton *near the Chairman, and I stood at the Back of it. What the rest had to say they delivered by word of Mouth; and the same appears in the Journals: but Sir* Isaac Newton *only delivered what he had to say in a Paper: which here follows, as it appears there* verbatim.

" *That for determining the Longitude at*
" *Sea, there have been several Projects, true*
" *in the Theory, but difficult to execute.*

" *One is by a Watch* [i. e. *a short Pendu-*
" *lum Clock, that has no striking Part:*] *to*
" *keep Time exactly. But by reason of the*
" *Motion of a Ship, the Variation of Heat*
" *and Cold; wet and dry; and the Diffe-*
" *rence of Gravity in different Latitudes, such*
" *a Watch hath not been yet made.*

" *Another is by the Eclipses of* Jupiter's
" *Satellites: but by reason of the length of Te-*
" *lescopes requisite to observe them, and the*
" *Motion of a Ship at Sea, those Eclipses can-*
" *not yet be there observed.*

" *A third is by the Place of the Moon:*
" *but her Theory is not yet exact enough for*
" *this Purpose. It is exact enough to determine*
" *her* [*the*] *Longitude within two or three De-*
" *grees, but not within a Degree.*

" *A fourth is Mr.* Ditton's *Project. And*
" *this is rather for keeping an Account of the*
" *Longitude at Sea, than for finding it, if at*
" *any time it should be lost: as it may easily*
" *be in cloudy Weather. How far this is prac-*
" *ticable, and with what Charge, they that*
" *are skilled in Sea-Affairs are best able to*
" *judge. In sailing by this Method, whenever*
" *they are to pass over very deep Seas, they*
" *must sail due east or west, without varying*
" *their Latitude: and if their way over such*
" *a Sea doth not lie due east or west, they must*
" *first sail into the Latitude of the next place,*
" *to which they are going beyond it, and then*
" *keep on due east or west, till they come at*
" *that place.*

" *In the three first ways there must be a*
" *Watch regulated by a Spring, and rectified*
" *every visible Sun-rise and Sun-set, to tell*
" *the Hour of the Day or Night.*

" *In the fourth way such a Watch is not ne-*
" *cessary. In the first way there must be two*
" *Watches; this, and the other mentioned above.*

" *In any of the three first ways, it may be*
" *of some Service to find the Longitude within*
" *a Degree: and of much more service to find*
" *it within forty Minutes; or half a degree*
" [*which is thirty Minutes;*] *if it may be;*

" *and*

" *and the Succeſs may deſerve Rewards ac-*
" *cordingly.*

" *In the fourth way it is eaſier to enable Sea-*
" *men to know their Diſtance and Bearing*
" *from the Shore* 40, 60, *or* 80 *Miles off, than*
" *to croſs the Seas: and ſome part of the Re-*
" *ward may be given when the firſt is per-*
" *formed on the Coaſt of* Great-Britain, *for the*
" *Safety of Ships coming home: and the reſt*
" *when Seamen ſhall be enabled to ſail to an*
" *aſſign'd remote Harbour without loſing their*
" *Longitude, if it may be.*"

Upon the reading of this Paper, how true and juſt ſoever, the Committee were at a Loſs, as not well underſtanding its Contents: and Sir Iſaac *ſitting ſtill, and ſaying nothing by way of Explication. This gave the Chairman an Opportunity, which it was perceived he wanted, of trying to drop the Bill. Which he did by declaring his own Opinion to be, that* " *Unleſs Sir* Iſaac Newton *would ſay, that* " *the Method now propoſed was likely to be* " *uſeful for the Diſcovery of the Longitude,* " *he was againſt making a Bill in general for* " *a Reward for ſuch a Diſcovery;*" *as Dr.* Clarke *had particularly propoſed to the Committee. Upon this Opinion of his, not contradicted by any other of the Committee; and upon Sir* Iſaac Newton's *Silence all the while, I ſaw the whole Deſign was in the utmoſt Danger of miſcarrying. I thought it therefore abſolutely neceſſary to ſpeak my ſelf: which I did nearly in theſe Words,* " *Mr.* Chairman; *the*

" *Occa-*

" *Occasion of the Puzzle you are now in, is* " *nothing but Sir* Isaac Newton's *Caution.* " *He knows the Usefulness of the present Me-* " *thod near the Shores,*" [*which are the Places of greatest Danger.*] " *Whereupon Sir* Isaac *stood up, and said, that* " *He thought this Bill* " *ought to pass, because of the present Method's* " *Usefulness near the Shores.*" *Which Declaration of his was much the same with what he had said in his own Paper, but which was not understood by the Committee, and determined them unanimously to agree to such a Bill. After this, all Opposition ceasing, a Proposal was offered how much the Committee would think fit to allow for Trials, as distinct from the Reward. One of the Members named* 500 l. *as, in his Opinion, sufficient for that Purpose. Mr.* Robert Walpole, *who was now come up to the sitting Members of the Committee, hearing so small a Sum named, shewed some Indignation at it; and boldly said, that* " *since so much* " *larger Sums were often given for much* " *smaller Designs, he thought it a Shame that* " *so noble a one as this should have no more* " *than* 500 l. *allotted for it. Let it, said he,* " *be* 2000 l." *Which Proposal was comply'd with, without any Hesitation: and* 2000 l. *is the Sum allotted for Trials accordingly in that Act of Parliament. Which Act or Bill was first drawn up, at General* Stanhope's, *by the General himself, by Mr.* Walpole, *Dr.* Clarke, *and my self; and put into Form by a Lawyer: and pass'd both Houses* Nemine Contra-

Contradicente. *However, it must be acknowledg'd, that as the Clause for a smaller Reward for any less accurate Discovery of the Longitude was my own Addition, and pass'd without the least Contradiction; so two other proper Clauses were omitted by us all: which had they been then thought of would, I persuade my self, have not been refused:* viz. *one to enable the Commissioners to apply part of the* 2000 l. *allotted for Trials to the settling the Longitudes and Latitudes of the Capes and Ports along the Coasts; without which all methods for discovering the Longitude at Sea are in a manner useless: The other for giving some Reward for any considerable Improvements in the finding even the Latitude it self; which hitherto is the main thing our Navigators are forced to have recourse to in their Distresses at Sea. As for the latter Omission, it was to be here taken notice of, because not very long after the passing of that Act, Mr.* Rowe *procured a meeting of the Commissioners for the* Longitude, *in order to desire some Reward for an Improvement he pretended to have made in the Discovery of the* Latitude. *Sir* Isaac Newton, *and Dr.* Halley, *were there; as well as the Lord* Trevor, *and other Commissioners. And altho' this Application appeared evidently beyond their Power, yet did he make his Pretensions so effectual at the Board of Admiralty, that a Bill was brought in by Admiral* Jennings *into the House of Commons,* 1720, *for a Reward in general to Improvements*

ments in Navigation, which it was ſuppoſed would have enabled the Commiſſioners to reward Mr. Rowe, *but it was rejected at the laſt reading: as Mr.* Plumptre *informed me from the Journals of that Houſe. However he was ſo far favour'd by the Admiral and the Board of Admiralty that they allotted him* 500 l. *out of the contingent Money for the Navy: as Dr.* Halley *had formerly had* 200 l. *out of the ſame contingent Money allotted him by the Lord* Pembroke, *when he was Lord High Admiral, for his moſt uſeful Survey of the* Britiſh *Channel: altho' I do not know that Mr.* Rowe's *Propoſal for finding the Latitude ever came to be practiſed at Sea ſince that Time. And thus much concerning this our firſt Attempt for diſcovering the Longitude* by Signals. *But ſince it has not been put in practice, either here, or abroad for that Purpoſe; tho' it has in ſome meaſure been put in practice, for ſtating the Geography of certain Places upon Land with good ſucceſs, as being very uſeful in ſuch Surveys, I refer the Reader to Mr.* Ditton's *and my own large Accounts of all ſuch Matters in our* New Method for diſcovering the Longitude both at Sea and Land, *firſt publiſhed* 1714, *and eſpecially its ſecond Edition, publiſhed the following Year* 1715, *particularly pag.* 85---88.

As for my own ſmall Attempt for procuring ſuch a Clock or Watch as ſhould go even on Shipboard, made me by Mr. Williamſon, *it was too inconſiderable in compariſon of Mr.* Har-

Harrison's *now proposed; and never brought to any Perfection. So I give no farther Account of it; but proceed to the* second *Method for discovering the Longitude at Sea, wherein I have been concerned. Take its History as follows.*

About the middle of November 1718 *came to me one Mr.* Eberhard, *a* German, *born at* Isleben *in* Saxony, *the very Town where* Luther *was himself born, with a Pretence to a Method for discovering the Longitude by a magnetick* Dipping Needle. *But as the other Mathematicians and Virtuosos could make nothing of Mr.* Eberhard's *Pretensions, which depended on the Dip being in or parallel to the Equator, and the magnetick Power exerting it self East and West, contrary to all Experience; so did I, after some time, find it to be wholly groundless. However, the Consideration of this* Dipping Needle, *an Instrument I had hardly ever seen, or indeed heard of to any purpose before, occasion'd many Experiments and Thoughts of my own; to see whether this Power of a magnetick Needle, when it vibrates in a vertical Plain, and descends beneath the Horizon, might not, by some proper Contrivance, be made use of at least for the Discovery of the Latitude, if not also for that of the Longitude, at Sea, as well as at Land. In the Progress of which Enquiries I went several hundred Miles my self, with Mr.* Barker, *and made a great number of Observations, with different Loadstones, and*

different Dipping Needles, in different Counties of this Land. I also procured many other to be made in several remote parts of the Earth and Sea; till the Hopes became tolerable, that both the Longitude and Latitude would at length be discover'd by such Dipping Needles, if they were sufficiently large, and exact, and well hung in the Ship. In the pursuit of which Enquiries I tired my self. And tho' I was thereby enabled greatly to improve the Knowledge of the Terrestrial, and other Magnetism, as Mr. Mafshenbroek *allows, and follows in his further Researches. Yet did three things at last extinguish almost all my Hopes of discovering the Latitude, and intirely all my Hopes of discovering the Longitude by this Instrument. The first was the Weakness of the magnetick Power: the second was the Concussion of the Ship: which I found prodigious hard to avoid so much as the Nicety of these Experiments requir'd: The third and principal was an hitherto unknown Irregularity in the Motions of all magnetick Needles, both horizontal and dipping, discovered, upon this Occasion, by Mr.* George Graham, *and soon confirmed by my own Observations. Whereby they, within about the Compass of a Degree vary uncertainly backward and forward, even sometimes in a few Hours Time, without the dependance on any visible Cause whatsoever. On which Accounts I was, after a world of pains and Charges, forced to desist; which Charges yet were plentifully made up to me by his Majesty*

jesty K. George I. *his present Majesty, then Prince of* Wales, *and the late Queen, then Princess of* Wales, *and many other my kind Friends and Benefactors. Of all which Matters see my* Longitude and Latitude found by the Inclinatory, or Dipping Needle, *published* 1721, *and the* Appendix *to the* Calculation of Solar Eclipses without Parallaxes, *published* 1724. *One thing only, of some Consequence, I must add, to what is there said, and it is This. Dr.* Halley *and I had been some time debating, whether the Earth's Magnet or Magnets, had only* one, *or not rather* two *northern Poles. I maintaining there was but* one *internal Magnet, and that it had but* one *northern Pole. While the Doctor asserted* two *such Poles, and determined the second Pole to be about* Hudson's Bay. *I thought this Debate would best be put an End to by sending a dipping Needle to* Hudson's Bay. *Which I did* A. D. 1723. *Yet hearing nothing of it till the Year* 1739. *I concluded the Ship, in which it was, to have been long ago cast away, and the Needle to have been long ago at the Bottom of the Ocean. But the last Year the curious Captain* Middleton, *who was then the Mate of that Ship in which my dipping Needle was sent, assured me the Ship was safe; and that he had himself tryed the Experiment* 79° *west of* London, *at* Cape Diggs, *in* Hudson's Streights; *and found that the Needle stood strongly perpendicular at that Place. Which certainly implies the Being of such a magnetick Pole there as Dr.* Halley *supposed. Nay, what*

is further very remarkable, such a Pole was known to be thereabout earlier than the Days of Dr. Halley. *Mr.* Barker *has since shew'd it me, noted by a Circle, and the Words* Polus magnetis, *on the Delineation of that part of the Globe, about the very Place assigned for it by Dr.* Halley, *in* Gerard Mercator's *Edition of* Ptolemy's *Maps in the Year* 1574. *And for the last Trial, I had in my Study lately that very Dipping Needle by which the Experiment was made. And this shall suffice for my* second *Attempt for discovering the Longitude; which was by the* Dipping Needle.

However, my Disappointment in these Attempts did not so far discourage me, but that I afterward joined my Endeavours with Mr. Haselden, *when a third Proposal was thought of, I mean that for improving Dr.* Halley's *Method of finding the Longitude by the Appulses of the Moon to fixed Stars. This had been indeed proposed about two Centuries ago by* Apian, *an Astronomer;* [*See* Blundevil's, Exercises, *pag.* 391.] *and has been long and earnestly pursued, and with much greater hopes of Success by Mr.* Flamsteed, *and Dr.* Halley; *especially by the latter: and that with Sir* Isaac Newton's *full Approbation, as appears above. Its Nature and Truth in Theory is well known; and, with other Methods, has been sufficiently described by others; especially by Mr.* Hodgson, *in his* System of the Mathematicks, Vol. I. Sect. 16. *and shall not be here enlarged upon. Now Mr.* Haselden *endeavoured*

deavoured to render this Method much more useful, by multiplying the Occasions of knowing the Moon's Place, and discovering the same: not only at its Appulse to fixed Stars; as in Mr. Flamsteed's *and Dr.* Halley's *Way; but by the small Interval of its rising and setting, from those of a known fixed Star, to be measured by a Pocket Watch: and by the Help of trigonometrical Calculations determining the unknown Place of the Moon, by the known Place of the fixed Star. To this Proposal I made certain Improvements my self: and took some pains in conquering the Difficulties that occur'd therein. But when, after all our Pains, it appear'd, that the very Points of Time of the rising or setting of even the larger fixed Stars were hardly visible at Sea; that the Inequalities in the Moon's Motion were not yet brought to Exactness; and that the Calculations necessary in this Way were, for all different Latitudes, almost innumerable; we found Cause to drop the further Prosecution of this Method. So far only did I follow this Intimation, as to try how near the Interval of the risinng or setting of two fixed Stars, of the first Magnitude, thus taken by a Watch would discover the* Latitude *it self: which I found it would do to great Exactness. But then as there are so many easier Ways of finding that Latitude; and very few Stars can be seen directly upon the Horizon, as I have noted already, I also at length intirely drop'd this Method, as almost unnecessary, and as usually impracticable also. However, a great part of my Dissertation*

tion upon this whole Proposal was read before the Royal Society, Feb. 20, 1728-9. *But then,*

On or a little before the Year 1730, *I light upon a* fourth *Method for the Discovery of the Longitude, much better than any of the former: and that is to enable Seamen to view the Eclipses, Occultations, and Conjunctions of* Jupiter's *Planets on Shipboard: which Eclipses, Occultations, and Conjunctions are well known by Astronomers to be the very best Ways of finding the Longitude, both at Land and Sea, could the Concussion of the Ship be avoided; or could such a Telescope be made as, notwithstanding that Concussion, those Phænomena might be still visible there. My first Thought was this: that in case the Tube of a* refracting Telescope *of nine or ten Foot long could be made so far tapering, pyramidal, or conical, as to bear a good number of Object Glasses, ground on the same or equal Tool, and by consequeuce of the same focal length; while the Eye-glass were very large, and but a single one also; the Concussion of the Ship would only make any lucid Point apparently to move from one Object-glass to another; but that still the Point would come to the Eye in the very same manner as if there were, as usual, but one Object-glass only. This, upon trial, proved to be Fact: and altho' when the fixed Stars are in general viewed thorough such a Telescope, different Stars appearing through the different Object Glasses are vastly numerous and entertaining; yet does the same Object, as suppose* Jupiter *with his Satellites, never appear at the same time,*

but

but through one of those Glasses only. This Telescope having seven Object-glasses, and one Eye-glass I have now by me: and this Telescope I exhibited before the Royal Society April 22, 1730. *the very same Evening when* Mercury *was expected to touch, or pass over the Disk of the Sun. Accordingly had the Evening been clear, I intended then to have viewed the Sun with it on the Leads of the Royal Society's House: but it proving very hazy, nothing could be done. However, on the following* Christmas *Eve, about Midnight, Capt.* Sotheby, *Mr.* Scarlet, *jun. and my self, took with it a View of* Jupiter *and his Planets, at Mr.* Scarlet's *small Observatory, near St.* Ann's *Church; which afforded us a Sight not unentertaining. For whereas at first we saw but two of these Planets, we, in a little time, saw three. One of the other parting it self into two; as having been in Conjunction, and now separating one from another. Which, by the way, is the only apparent corporal Conjunction of two of those Planets that I have yet heard of; and such as Mr.* Lynn *himself, in full* 30 *Years, confesses he never saw. Not long after I had laid this Telescope before the Royal Sooiety, there came a Friend to enquire of me; Whether I had not discovered the Longitude? assuring me that he had an Intimation of such a thing from a Friend in* Scotland, *who most probably had his Information from some of our Royal Society in* England; *who thought the Instrument I had lately shewn them would really make that Discovery.*

covery. I told my Friend, that " *I believed* " *I had discovered the Longitude: but that,* " *for certain Reasons, I did not think fit to* " *make it yet more publick.*" *Take those Reasons in the Words of that Memorial that was read before the Board of Admiralty* July 15, 1737, *and was two Days after laid before the* Trinity House: " *The main Reasons of my long* " *delay in producing this sort of Telescope* " *before this Board, or the Publick were* " *these two; because this Telescope had not* " *been tried on Shipboard; and because I hoped* " *a much shorter reflecting Telescope, with* " *one large reflecting Speculum, and many* " *small Eye-glasses might invert the Problem,* " *might be so fitted as to perform the same* " *with the other much longer refracting Tele-* " *scope. This I pitched upon, as a still better* " *Method,* A. D. 1731. *though I have not* " *hitherto been so happy as to bring that great* " *Improvement to Perfection.*" *And thus much concerning the Refracting Telescope, with many Object-glasses, and one broad Eye-glass: which I believe will readily discover the Longitude at Sea, by the means of the Eclipses, Occultations, and Conjunctions of* Jupiter's *Planets.*

I now come to my fifth and last, and, as I believe, a better and easier Method of discovering the Longitude at Sea by Telescopes; and that still by the means of the same Eclipses, Occultations, and Conjunctions; and this is by a reflecting Telescope *of my own Invention*

tion also. This Method has been, in a manner, already intimated from the Memorial laid before the Board of Admiralty July 15, 1737. *and its Discovery very soon followed that Intimation. For in another Memorial, dated* Aug. 2, *and laid before that Board* Aug. 12, *the same Year, I have this additional Clause; that* " *since the concave* Speculum *of a reflecting Telescope, of Mr.* Cassegrain's [*rather of* " *Mr.* James Gregorie's] *Form, whose lesser* " *Reflecter is round, broad, and plain; and* " *has its focal Distances* 4. *or* 6. *or* 8. *or* 10. " *Foot, requires a Tube of no more than* 2. *or* " 3. *or* 4. *or* 5. *Foot long; and the Eye-glass* " *need be but one, only not* [*very much*] *broader than the Hole in the* Speculum, *this reflecting Telescope will perfect the great Improvement before wanted; and will be easily manageable on Shipboard. And indeed* " *seems to me, by far, the best and surest of all* " *the astronomical Methods for discovering the* " *Longitude there. Which is accordingly proposed to this honourable Board, and to the* " *Commissioners for the Discovery of the Longitude; as what will bring that Discovery* " *to its utmost Perfection; and will be very* " *cheap, and very readily practised at Sea by* " *ordinary Seamen.*' *But of these two Methods I need say no more in this Preface; because in the Book it self both this and the former Telescope are fully described, with the other Instruments, and Tables of Astronomy, and Calculations belonging to them. Unto which I therefore refer the Reader.*

Upon the whole, I now look upon the Longitude in the open Sea to be discoverable by two sure methods of my own Invention, I mean by the Refracting Telescope, *with many Object-glasses; and by the double* Reflecting Telescope *with its one large concave Reflecter, and one small flat Reflecter; besides the Eye-glass, which is of course a Refracter in both Instruments. I mean this over and above my Discovery of the Place of a Ship near the Shores, or within* 80 *geographical Miles of the Coasts by Signals of Light or Fire: to which half the respective Rewards are allotted by the Act of Parliament: and over and above the Hopes there is, that Mr.* Harrison's *curious Clock may be able to weather Storms at Sea, and to go evenly through them, from* Europe *to* America. *Which, if it succeed, will be a third, or rather a fourth very valuable Method for discovering that Longitude also. I now proceed with my History.*

At the latter End of the last Year 1739 *I was very desirous to make some farther Progress in this Affair: and as I knew that Dr.* Halley's *Chart of the* Variation *of the magnetick Needle, made for* 1700, *was excellent in its kind, and would be still of very great Advantage to Navigation, if it were renewed, and fitted to the present Time; that Variation being altered, even in the* British *Channel, about eight degrees in these last* 40 *Years: and as I knew that both Mr.* Harrison's *Clock, and my Telescopes, discovering the Longitude in the open Seas, would be of little or no Advantage*

to

to Navigation till the Coasts were better determined; I desired Sir Charles Wager, *first Commissioner of the Admiralty, to call the Commissioners of the Longitude together, that I might lay these Matters before them. Which he readily did, and the Majority of the whole Number, then alive, being present at the Admiralty Board,* Nov. 24, 1739. *I laid the following Memorial before them; and added large Explications of several of its Parts by word of Mouth, for their more intire Information. The Memorial was as follows:*

" *To the Honourable the Commissioners ap-*
" *pointed by Act of Parliament for the*
" *Discovery of the Longitude at Sea.*

" *The Memorial of* William Whiston, *Clerk,*
" *sometime Professor of the Mathematicks*
" *in the University of* Cambridge.

" *Humbly Sheweth,*

" *THAT the Perfection of the Art of*
" *Navigation depends on the frequent*
" *Discovery of the Longitude and Latitude of*
" *Ships at Sea; and on the Knowledge of the*
" *Variation of the magnetick Needle, in all*
" *Places where Ships do sail. For want of the*
" *due Allowance for which Variation many*
" *Ships are believed to have been lost at Sea,*
" *especially in our* British *Channel.*

" *That before the Discovery of the Longi-*
" *tude at Sea can be throughly useful to Na-*
" *vigation, the Knowlede of the Longitudes of*
" *the Coasts, Headlands, Ports, and Havens,*

" *highly necessary; and that in many Places*
" *to a degree far exceeding what is hitherto*
" *known: and particularly in those of* Great
" Britain, *and* Ireland, *and the Plantations*
" *to them belonging. In which the* French *As-*
" *tronomers and Navigators are known to*
" *have greatly outdone those of our Nation:*
" *Altho' our Skill in astronomical Observations*
" *be not inferior, and our Trade and Navi-*
" *gation far superior to theirs.*

" *That the Longitude of such Places can al-*
" *most only be discovered by Observations made*
" *sometimes of the Appulses of the Moon to*
" *fixed Stars, and more frequently of* Jupiter's
" *Planets, when* Jupiter *is sufficiently remote*
" *from the Sun; and chiefly when he is in*
" *northern Signs. Which two Characters ex-*
" *cellently agree to the next five Months; and*
" *to about eight Months in each of the next*
" *five following Years.*

" *That there are several Instruments, rela-*
" *ting to the Discovery of the Longitude at*
" *Sea, and which promise great Advantages*
" *to Navigation, which ought to be throughly*
" *tried in the Ports on Shipboard: and may*
" *be easily tried there at the same time that*
" *the Longitudes and Latitudes of such Ports*
" *are determined. Such as Mr.* Hadley's *and*
" *Mr.* Smith's *Catadioptrick Quadrants:*
" *Mr.* Barston's *Quadrant: Mr.* Whiston's
" *refracting and reflecting Telescopes:* [*Capt.*
" Elton's *Quadrant:*] &c.

" *That*

" *That, at the same time, new and accurate*
" *Charts may be made of our Sea-coasts; for*
" *the Advantage both of Geography and Na-*
" *vigation.*

" *That Dr.* Halley *made a most useful Map*
" *of the Variation of the magnetick Needle,*
" *fitted to Year* 1700. *Which Variation is yet*
" *so greatly altered since that time, that the*
" *same may now greatly mislead such Ma-*
" *riners as do not carefully allow for that*
" *Alteration. Which Variation may be anew*
" *exactly observ'd on this Occasion at all our*
" *Ports, when their Longitude and Latitude*
" *are taken. And other Observations made*
" *since* 1700 *by Capt.* Middleton, *Capt.* Hox-
" ton, *and many others may be compar'd, in*
" *order to the forming a new Map of that*
" *Variation for the Year* 1740.

" *That by reason of this Variation of the*
" *Variation, it is very fit that a new Map of*
" *such Variation be made at least every ten*
" *Years; and placed in every Ship that goes*
" *to Sea: to prevent all future Inconvenien-*
" *ces, and Mistakes about such Variation.*

" *That Dr.* Halley, *the Royal Observer at*
" Greenwich, *may be desired to assist and di-*
" *rect some proper Person in making such a*
" *new Map, for* 1740. *And also to take care*
" *that, during the Observations of the Moon's*
" *Appulses and* Jupiter's *Planets on the Coasts,*
" *for settling the Longitude there, the like*
" *Observations of the same Appulses and Pla-*
" *nets be made every clear Night at* Green-
" wich. *It being by the* Comparison *of those*
" *Obser-*

" *Obſervations with the other made on the*
" *Coaſts that the Longitude of thoſe Coaſts*
" *muſt be determined; as all Aſtronomers do*
" *well know.*

" *Laſtly, It is humbly deſired, that the Par-*
" *liament having provided* 1500 l. *for ſuch*
" *preparatory Trials, as concern the Diſco-*
" *very of the Longitude, more than is to be*
" *applied to Mr.* Harriſon's *Clock, ſo much of*
" *that Sum may be applied to the providing*
" *Inſtruments, and paying the Charges of pro-*
" *per Perſons to make the neceſſary Trials and*
" *Obſervations aforeſaid, as the Commiſſioners*
" *ſhall judge neceſſary to thoſe Purpoſes; and*
" *ſuch Perſons employed therein as they ſhall*
" *think to be moſt able and willing to ſerve*
" *the Publick on theſe Occaſions.*"

Nov. 24, 1739. WILL. WHISTON.

Now when the Commiſſioners had conſidered of this Memorial, they fully and unanimouſly agreed that it was all right, and fit to be complyed with, as I deſired; and that the Government ought to be at the Charges. But upon the Speaker's reading the Clauſe in the Act of Parliament, which aſſigned 2000 l. *for ſuch preparatory Trials, he obſerved this very material and neceſſary Preliminary of* ſettling the Coaſts *was omitted: and ſo he, with the other Commiſſioners preſent, ſent the Secretary of the Admiralty, Mr.* Burchet, *out to tell me, that* " *They did not perceive they had*
" *Authority to aſſign that* 1500 l. *to the ſet-*
" *tling of thoſe Coaſts; but that I muſt apply*
" *elſe-*

" *elsewhere.*" *Accordingly Mr.* Burchet *farther told me, that* " *I ought to lay a larger* " *Memorial before the Board of Admiralty to* " *the same Purpose.*" *So far however the Commissioners did comply with my Desires, as to recommend to Dr.* Halley *the Care of making a new Map of the Variation for the present Time. I then drew up the following Memorial. And altho' it was not laid before that Board, as will appear anon, yet is it not improper to insert it in this Place:*

' *To the Right Honourable the Commissioners*
' *for executing the Office of the Lord*
' *High Admiral of* Great-Britain.

' *The Memorial of* William Whiston, *Clerk,*
' *sometime Professor of the Mathematicks*
' *in the University in* Cambridge.

Humbly Sheweth,

' *THAT your Petitioner did, on the*
' 24*th of* November *last, lay before* The
' Honourable the Commissioners appointed
' by Act of Parliament for the Discovery of
' the Longitude at Sea *a Memorial, which is*
' *hereafter copied* [viz. *that above*] *setting*
' *forth the great Advantages that would arise*
' *to the Navigation of* Great-Britain *from a*
' *more exact Determination of the Longitudes*
' *and Latitudes of our Coasts; as also from*
' *the making anew Dr.* Halley's *Map of the*
' *Variation of the magnetick Needle: The lat-*
' *ter of which Proposals was then recommend-*
' *ed to Dr.* Halley, *and is now undertaken to*
' *be prepared for his Review accordingly. Your*
' *Petit-*

' *Petitioner did then desire of those Commis-*
" *sioners, that* " *So much of the Sum of* 1500l.
" *which was more than was apply'd to Mr.*
" Harrison's *Clock, might be apply'd to the*
" *providing Instruments, and paying the Charge*
" *of proper Persons to make the necessary*
" *Trials and Observations as they should judge*
" *necessary to those Purposes; and such Persons*
" *employed therein as they should think to be*
" *most able and willing to serve the Publick*
" *on such Occasions.*" *Which Proposal, though*
' *it appear'd every way agreeable to those*
' *Commissioners, and highly fit to be provided*
' *for by the Publick, yet did they observe the*
' *Act of Parliament to be so deficient as to*
' *the settling of the Coasts, that they thought*
' *they were not enabled thereby to grant the*
' *Money desired of them for that Purpose;*
' *but that your Petitioner was to make his*
' *Application elsewhere. In consequence of*
' *which Determination he now applies himself*
' *to this honourable Board; and requests, that*
' *they would please to take the Scheme which*
' *he now lays before them into their serious*
' *Consideration; and that as soon as possible:*
' *that the advantagious Position of* Jupiter's
' *Planets, (by the Observation of whose Eclip-*
' *ses and Conjunctions, the Longitudes of those*
' *Coasts are chiefly to be discovered) the eight*
' *following Months, beginning with* August,
' *may not be neglected. Your Petitioner also*
' *begs of you to consider farther: that since*
' *the present Design of settling the Coasts of*
' Great-Britain *and* Ireland *may be perfected*

" *in*

" *in those eight Months Time, as appears by*
" *the Computation annexed, for about the Sum*
" *of* 800 l. [*but the Computation proving on*
" *trial to be much too little both as to Time*
" *and Expences, is here omitted:*] *Whether*
" *such a Sum can ever be more beneficially*
" *employ'd to the Navigation of* Great Britain,
" *which is peculiarly under the Care of this*
" *honourable Board, than it will be if this*
" *Proposal be comply'd with. Which has not*
" *been made but upon Consultation with Dr.*
" Halley, *and other Persons and Books pro-*
" *per for rendering it as compleat and ad-*
" *vantageous to the Publick as possible.*"

June 20, 1740. WILL. WHISTON.

This Memorial I intended to lay before the Board of Admiralty. *But as the like Proposal actually laid before the* Commissioners for the Longitude *was stopped, because it was supposed the Act of Parliament had not enabled those Commissioners to do what otherwise they owned to be very fit to be done; so did the Opinion of Sir* Charles Wager, *who is the first Commissioner of the Admiralty, that They had not properly any Power to disburse the Money desired out of the contingent Money of the Navy, as had been supposed it might have been, discourage me from laying it before them: Altho' Sir* Charles *did not deny there had been two or three Examples of the like Disbursements formerly. Yet did he, and every body that were capable of judging about such Mat-*

ters ſtill acknowledge, that the Propoſal was very fit to be provided for by the Parliament, in order to perfect their own Act. Accordingly He readily came into a temporary Subſcription of 50 l. *out of his own Pocket: as did the Speaker of the Houſe of Commons: and Mr.* Poynts, *for the Duke of* Cumberland, *of the like Sum alſo. And they have been followed by the Lord* Wilmington, *the Lord* Baltimore, *and Mr.* Townſhend, *in a Subſcription of* 25 l. *apiece for the ſame Purpoſes. The Receipt of which Sums has enabled me to prevent the Loſs of a Year, and to ſupport this Deſign till the Parliament has now enabled the Commiſſioners to diſburſe the Money out of the Navy-Office, as was before deſired. I ſhall now produce a Liſt of thoſe* xxxvii *ſeveral Places on our Coaſts, where the Obſervations either have already been made, or are to be made: together with a like Liſt of the* xiii *ſeveral Places on the Coaſts of our Weſtern Plantations, where the like Obſervations are to be made afterward.*

A List of xxxvii ſeveral Capes and Places on the Coaſt of *Great-Britain* and *Ireland*, where the Obſervations have already been made, or are to be made.

(1) North Foreland.
(2) South Foreland.
(3) Dengy Neſs.

(4) Beachy

(4) Beachy Head.
(5) Selſey Bill.
(6) Dun Noſe, *in the* Iſle of Wight.
(7) Race, *or* Bill of Portland.
(8) Start Point.
(9) Lizzard Point.
(10) Land's End.
(11) St. Agnes's Light-Houſe, *at* Scilly.
(12) Hartland Point, *at the Entrance of* Briſtol Channel.
(13) St. Ann's Point, *at the Entrance of* Milford Haven.
(14) Old Head Lighthouſe, *at the Entrance of* Waterford River.
(15) Ram's Head, *at the Entrance of* Cork River.
(16) Cape Clear.
(17) *The Entrance of* Limerick River; *either* Kerry Point, *or* Cape Lean, *or* Loophead.
(18) Black Head, *at the Entrance of* Galloway River.
(19) Dog's Head.
(20) Black Rocks, *or* Moors; *or elſe* Achil Head.
(21) North Iſle of Arran, *near* Ireland.
(22) Fair Foreland, *or* Fair Head *in* Ireland.
(23) St. Bee's Head, *in* Cumberland.
(24) Mull Iſle, *near* Scotland.
(25) Skye Iſle.
(26) Faro Head.
(27) Kirkwall, *in* Orkney.
(28) Sumborough Head, Schetland.
(29) Dunſby Head.

(30) Tarbet Point, *or* Neſſe, *in the* Firth *of* Murray.
(31) Buchan Neſſe.
(32) Fife Neſs.
(33) Tinmouth Caſtle, Northumberland.
(34) Flamborough Head, Yorkſhire.
(35) Cromer, Norfolk.
(36) Loweſtoff Lighthouſe, Suffolk.
(37) Landguard Fort, *by* Harwich, Eſſex.

A LIST of xiii ſeveral Capes and Places on the Coaſts of our Weſtern Plantations, where the Obſervations are alſo to be made.

(1) *The Mouth of the River* Altimaha, *in* Georgia.
(2) Cape Fair, *or* Cape Hatteres, *in* Carolina.
(3) Cape Charles, *at the Entrance of* Cheſapeak Bay.
(4) Cape May, *in* New Jerſey.
(5) Cape Cod, *in* New England.
(6) Cape Race, *in* Newfoundland.
(7) Port Antonia, *in* Jamaica.
(8) Port Royal, *in* Jamaica.
(9) St. Chriſtopher's Iſland.
(10) Iſle of Providence.
(11) Deebles Point, *or* Chriſt's Church, *in* Barbadoes.
(12) Iſle of Burmudas.
(13) Gibraltar.

[N. B. Hudſon's Bay, Baffin's Bay, *and the Ports in the way to, and in the* Eaſt Indies, *may be recommended to the ſeveral Companies and Merchants that trade thither.*]

I ſhall

I shall now add a Copy of those Directions I gave Mr. Renshaw *and Mr.* Birkbeck, *who were sent to make Observations round the Coasts. And they were as follows,* verbatim: *as they are set down in their Journal.*

Directions for the making Observations for discovering the Longitude, and Latitude, and Variation of the magnetick Needle, round the Coasts of *Great-Britain* and Ireland: given them by Mr. *Whiston, September* 23, 1740.

I. *First of all adjust your Royal Pendulum carefully, by several Days Observations, about Noon, that it may go true to the* mean time. *Adjust also your large Stop Watch, with Seconds, to go true to the same* mean time. *And note, that if this be accurately done at the first Station, a smaller Matter will keep the Clock and Watch thus adjusted afterward, especially in the* British *Channel, where the Latitude is not much altered.*

II. *Set that Pendulum and Watch, thus adjusted, by Mr.* Sisson's Instrument for Dialling, *the very first Day afterward, that you can see the Sun: And this at any time of the Day [tho' the nearer Noon the better:] using the supposed Latitude of your Place in the Maps. This is to be done frequently the same Day: and will set the Pendulum and Watch to half a Minute, or nearer.*

N. B. *The Pendulum and Watch must always be adjusted and kept to the* mean, *but not the*

the apparent *Time. Which Times are easily reduc'd from one to another by the common* Equation Table, *and are to be both set down in the Journal.*

III. *If you then can see the Sun about Noon, take its greatest Altitude by your Quadrants. This Altitude, when you have deducted the* Refraction *from Sir* Isaac Newton's *Table,* pag. 69. *of my last Book; and allow'd for the Sun's* Declination *north or south for the Time, from* Vol. I. pag. 505.——520. *of Mr.* Hodgson's *Book, will give you the* Elevation of the Equator, *and its Complement the* Elevation of the Pole, *or* Latitude of your Place.

IV. *The first clear Night take with your Quadrants the Altitude of the Pole Star six several times at least, at the Intervals of a quarter of an Hour: Noting the Times by the Clock or Watch. Correct these Altitudes, as before, by deducting the* Refraction *from Sir* Isaac Newton's *Table; and the Remainder will give the true Altitudes of the Pole Star. And then by Trigonometry, or the Table in my former Book,* pag. 101, 102, *corrected, find how much the Pole Star was then higher or lower than the Pole it self, (its Distance from that Pole being this Year* 1740 2° 5′ 6½″) *which Quantity add or substract as Occasion requires, and you will have the true* Elevation of the Pole, *or* Latitude of the Place. *This lesser Degree of Accuracy in the Time will be sufficient for the present Purpose, by reason of the very slow diurnal Motion of the Pole Star.* *The*

V. *The ſame firſt clear Night, take the greateſt or meridian Altitudes of as many of the more elevated bright Stars as you well can, at leaſt of ſix. The mean of thoſe Altitudes, when they are corrected by Sir* Iſaac Newton's Table of Refraction *already mentioned, and when their* Declinations, *north or ſouth, are allow'd for, from* pag. 70 *of my laſt Book, or from* Vol. II. pag. 516—519, *of Mr.* Hodgſon's, *will give the* Elevation of the Equator, *and, its Complement, the* Elevation of the Pole, *or* Latitude of the Place, *without any Regard to the Time of the Night when thoſe Obſervations are made.*

VI. *The true* Latitude *being thus found, the next clear Night take the Altitude of as many of the brighter fixed Stars as you can, near the prime vertical, eaſt or weſt; at the leaſt of ſix: noting the Times by the Pendulum, or Watch, as already adjuſted to the Time, tho' imperfectly. Then from each of thoſe Altitudes, firſt diminiſhed by the* Table of Refraction, *compute, by the two Rules of Trigonometry in* pag. 96—99 *of my laſt Book, the exact Times to the Meridian of your Place, to Minutes and Seconds, when thoſe Obſervations were ſeverally made; and correct your Clock and Watch accordingly. Which will now, and not till now, give you the juſt Time at your Meridian, with the greateſt Accuracy.*

VII. *And now the Shadow of a Plummet-line, or any erect ſtrait Line at Twelve a Clock, apparent Time, will give you a true Meridian,*

Meridian, for finding the Variation of your two magnetick Needles; to be set down accordingly. I need not add, that great Care must be taken that neither any Loadstone, nor Iron, be near these Needles at the Time of the Observations.

VIII. *You have now nothing to do but to make use of your* Refracting *and* Reflecting Telescopes, *and by them to observe, and that with the greatest Nicety you can, two or three* Eclipses *or* Conjunctions *of* Jupiter's *Planets; especially those of the first and second, which are noted in the Table at the End of my last Book; and to set them down with their Times as observed accordingly. The* Conjunctions *to be taken both at equal Distances from* Jupiter, *and at the cross Hair in a Meridian. Which when compar'd with the same* Eclipses *and* Conjunctions *to be observed at* Oxford, *and at* Southwick, *by Mr.* Bliss *and Mr.* Lynn, [*as also several of them at* Lyndon, *by Mr.* Barker,] *will afterward give the Difference of the Longitudes of the Places of Observation; and at length how much they are east or west of the Meridian of the Observatory at* Greenwich.

N. B. *The several Quadrants of Mr.* Hadley, *Mr.* Smith, *Capt.* Elton, *and Mr.* Barston; *together with my double reflecting Telescope, are to be frequently and carefully tried on Shipboard; and how well they perform to be truly noted accordingly.*

N. B. *The*

N. B. *The very Points where the ſeveral Obſervations are made are to be always ſpecified in your Journal, and noted on your Maps.*

N. B. *Original Obſervations are to be ſet down unaltered on the left hand Page; and the Reſult of the Calculations on the Right.*

Sept. 23, 1740. WILL. WHISTON.

But to proceed in my Hiſtory.

After the Obſervers Mr. Renſhaw *and Mr.* Birkbeck *were gone, and I was my ſelf retired to Mr.* Barker's *at* Lyndon, Rutland, *we had ſeveral Diſcourſes about the beſt Methods of aſcertaining the Longitude of Places by Land, and on the Coaſts; and whether a trigonometrical Method of Survey would not be more exact than what had hitherto been made uſe of, I mean the Eclipſes of* Jupiter's *Planets. It having been there obſerved, that by a compleat Catalogue of ſuch Longitudes diſcovered by thoſe Planets in the* Philoſophical Tranſactions, *it appeared ſuch Longitudes could not be more exactly determined thereby than to an intire Minute in Time, or in our Latitude to nine Miles. Nay, Dr.* Halley *aſſures me, that this Degree of Exactneſs is more than can be depended on in that Method. So that we can hardly depend on it in our Latitude near than to ten or twelve Miles. While the Latitude of Places can eaſily be taken much nearer, and ſometimes to a ſingle Mile or Minute of a Degree alſo. About which time I received a Letter from one of our Land Ob-*

 ſervers,

servers, Mr. Lynn *of* Southwick, *dated* November 10, 1740. *and containing a compleat Sett of his Observations of* Jupiter's *Planets fore the foregoing Month of* October: *and, what is most remarkable, It contained withal his Desire of my Opinion relating to a peculiar Method of his own for discovering the Longitude of different Places at Land, by Observations of the same falling Stars, which appear and disappear almost in an Instant of time. Which Instant of time, if it be compared with the different Instants of time in different Meridians where the same is seen, will truly give the Difference of those Meridians with great Exactness. This Method Mr.* Lynn *had formerly proposed to the Publick in the* Philosophical Transactions, N° 400. *And the like Use of that most amazing and sudden Meteor which was seen* March 19, 1718-19. *could its coming have been foreseen, whcih had been started by Dr.* Halley *himself, had given Occasion to Mr.* Lynn *to think of the falling Stars, as a* Succedaneum *thereto. This Use the Doctor inserted into his Account of that Meteor in the* Transactions, N° 360. *where he takes Notice, that,* ' *If any two Observers, by help of Pendulum Clocks, duly corrected by cælestial Observations, do exactly note at what Hour, Minute, and Second, such a Meteor is discharged, the Difference of those Times will be the Difference of the Longitude of the two Places.*' *Now as we were debating of these Matters,* Nov. 12. *it came into my mind that*

that we might have a much better Succedaneum *than that proposed by Mr.* Lynn *for Distances not too great, by making such Explosions of Shells or Balls of Fire. Which if if thrown up exactly at a known Point of Time, in a known Meridian, and observed* 100 *Miles every Way at a like known Time, in other Meridians, would ascertain the Difference of all such Meridians, which we call their respective Longitudes: in the same manner as Dr.* Halley *proposed with his Meteor. and this Method was agreed to by Mr.* Lynn, *And by all Men immediately. This Method I am now ready to exemplify in Balls of Fire to be thrown up from* Shooter's Hills, *by Signals deriv'd from Dr.* Halley's *Meridian, and to be observ'd at least* 100 *Miles every way. This Method was in part practised by my Direction, and recommended to publick Use* 26 *Years ago: as the Reader may find in Mr.* Ditton's *and my* New Method for the Discovery of the Longitude, *first published* A. D. 1714. *where are several Calculations and Tables proper to put it in Practice. And had it been thought of, and put in Practice at* Scilly, *before Sir* Cloudsly Shovel *perished there, he and his Ship had, in all Probability, escaped that terrible Calamity. Nay, had it but been put in Practice there and elsewhere, these last* 26 *Years, in which it has been known and recommended to the Publick, 'tis highly probable many hundreds of Lives, and many thousands of Pounds had been saved, which are*

now utterly loſt and periſhed. And I cannot but heartily wiſh that ſuch ſalutary Signals by Gunpowder might be hereafter made much oftener, than that other fatal Uſe which it is uſually put to for Mens Deſtruction; that ſo we might begin, in the ſacred Language, to * Beat our Swords into Plowſhares, and our Spears into pruning Hooks; that Nation might not lift up Sword againſt Nation, nor learn War any more, *Amen, Amen. However, ſo far it is plain, that becauſe every ſuch Signal may be given at a very determinate Time, as ſuppoſe* 20″ *before Ten at Night; that the Ball may be at the greateſt Altitude juſt at Ten; and becauſe 'tis not very difficult to find other Meridians within* 15″ *or a quarter of a Minute, this Method by Signals will find the Longitudes of Places four times as exactly as they can be found by* Jupiter's *Planets; or in our Latitude, to two or three Miles: which is abundantly ſufficient for the Purpoſes of Navigation. Nor is the geographical Uſes of the like Method by a Mortar placed at* 60 *Miles Diſtance over any Country, at all difficult to be conceived: and has not only been hinted at in the Treatiſe already quoted,* Introduct. pag. (2d Edition) 25. Book pag. 85—88. *But was actually put in Practice ſometime afterward by my ſelf and my Friends within* 20 *Miles of* Hamſtead *or* London; *and a Map drawn out of the Ob-*

* Iſ. ii. 4. Mic. iv. 3.

ſerva-

servations accordingly: Which tho' not yet published is still extant, and perhaps still not unworthy Publication. On which Occasion take these following Observations.

(1) *That such Balls of Fire thrown up along our Coasts may be easily seen over Sea to* Dunkirk *and* Ostend *in* Flanders; *to* Calice *in* France, *and all along the Promontaries and Islands of that Kingdom which extend into the* British *Channel. They may still more easily be seen from the* Isle of Man *into the northern Coast of* England, *the southern of* Scotland, *the northern of* Ireland, *and the northern of* Wales, *and will connect the Longitudes of those four Countries together. They may be also seen from the western Coast of* Wales *all along into the eastern Coasts of* Ireland, *and thereby connect the Longitudes of* England *and* Ireland *all the Way. And if the Balls be thrown up from the* Isle of Skie, *the Light will be well seen in the* Western Islands *adjoining, as well as in the northern Parts of* Scotland. *Lastly, If they be thrown up near* Faro Head, *and* Dunsby Head, *and* Buchan Nesse, *in the North of* Scotland, *they will be easily seen in the* Isles of Orkney, *and* Schetland *themselves: which are the remotest Parts of these Kingdoms, and so will connect them, as to their Longitude, for ever hereafter.*

Note (2) *That wherever these Balls are thrown up with this last Intention they ought to be continued for three or four Nights together, and to have*

have the Latitude of each Place ascertained also. Nay, indeed, if such Latitude be but taken with sufficient Accuracy at every County Town, or what is equivalent thereto, thro' Great Britain, *and* Ireland, *this will be abundantly sufficient for a new and actual Survey of these Kingdoms, and will afford the most perfect Materials for a new Sett of most compleat Maps of them; and that very far beyond all other actual Surveys and Setts of Maps that have been ever made thereof in any past Ages whatsoever.*

Note (3) *That this Method includes the other Method of a trigonometrical Survey also. Since the Distances between each Station of such a Mortar may be always as near as possible the same;* i. e. *sixty Geographical Miles: or may make together a Square equal to* 122400 *Yards nearly. And every Spectator who observes the Bearing of the Shell from his own Place or Meridian, has four Triangles, whose Angles are all given, and the remote Sides of each* 122400 *Yards given also. It is therefore most easy from each of those four Triangles to find the distinct Point in that Square where the Spectator himself stands: the mean of which Distances will be exceeding near to his true Position. And tho' any Spectator should chance to be in the same Meridian or Parallel with two of the Stations of the Mortar, yet will he have still three such Triangles whereby to discover that Distance in all Positions. Which are Circumstan-*

cumstances of very great Value in all such Cases whatsoever.

It now remains that I say something concerning Mr. Harrison's *Clock, and its Usefulness for the Discovery of the Longitude at Sea: And withal to compare the Advantages and Disadvantages of his Method with mine. Mr.* Harrison *has made two Clocks of this kind formerly; and is at present about a third. And they are, without Dispute, vastly preferable to all the Attempts that have been made of the same Kind from the Time of* Hugenius, *who first tried this Method, to this Day. 'Tis certainly true, as Sir* Isaac Newton *declares in his Paper already produc'd, that* '*If such a Clock or Watch, regulated by a* '*Pendulum* [*or otherwise*] *can be made, as* '*will keep time exactly at Sea; and another* '*Watch can be regulated by a Spring, and* '*any way rectified by the Sun* [*or Stars*] *so* '*as to tell the Hour of the Day or Night at* '*the Ship,*' *the Difference of those Times will give the Difference of their Longitudes in time; and by allowing* 15° *of the Equator to an Hour, will give the same Difference of Longitude in Degrees also, for all the Uses of Geography and Navigation. Of which see* pag. 94—99 *hereafter. So that in case Mr.* Harrison's *Clock be once regulated to a certain Meridian, and will bear the great Concussion of Ships in Storms, without being disordered, or its even Motion disturbed, the same Clock will always inform the Mariners what Hour*

it

it is at that Meridsan. So that they have then no more to do but to compare that Time with the Time at the Ship, known either from the Altitude of a fixed Star, by Mr. Hadleigh's, *or Mr.* Smith's, *or Mr.* Barston's, *or Capt.* Elton's *Quadrants, or from the rising or setting of the Sun, or any other astronomical method; and the* Difference *of those Times will give the Longitude required.*

'Tis certainly true also, that if we see any of Jupiter's *Planets,* Eclipses, *or* Occultations, *or* Conjunctions, *or proper* Appulses *of the Moon to fixed Stars on Shipboard, the Times of which Phænomena are ascertained to any meridian by Calculation, (as those of* Jupiter's *Planets are in the* Appendix *to this Book to the Meridian of* Greenwich, *for the Years* 1739, 1740, 1741, 1742,) *the Comparison of those Times with the Times at the Ship, will also give us the Longitude: as Sir* Isaac Newton *farther declares in the Paper before-mentioned. So that in case either or both my Telescopes will enable us to see those Eclipses, or Occultations, or Conjunctions, or Appulses of the Moon to fixed Stars on Shipboard, they will discover the Longitude at Sea also. And 'tis certainly the Interest of the Publick that all these Methods should succeed, and be brought to Perfection. Only it must be noted, that what Sir* Isaac Newton *says of Mr.* Ditton's *and my own first Method by* Signals of Light and Sound *above, is true of Monsieur* Huigen's, *and Mr.* Harrison's

Method

Method by Clocks or Watches also; that 'It is 'rather for keeping an Account of the Longi-'tude at Sea, than for finding it, if at any 'time it should be lost.' While my present Method by Telescopes is for finding it at any time, tho' it has been lost never so long. Which is a very material Difference between them. As also it must be noted, that these different Methods have several Advantages and Disadvantages peculiar to themselves; which I shall now consider. It cannot then be deny'd, that Mr. Harrison's *Method by a Clock has the Advantage of mine by Telescopes in these* three *Respects:*

(1) *The Clock equally serves for* all Months *in the Year: whereas* Jupiter, *with his Planets, is too near the Sun for about six Weeks in* 13 *Months to be seen by us; and for some Weeks before and after those six Weeks they are seen but a little while.*

(2) *The Clock gives the Time at the Meridian to which it is adjusted by* bare Inspection: *whereas a View of certain* Phænomena *in the Heavens is necessary in my Method by Telescopes.*

(3) *The Clock gives the Time at the Meridian to which it is adjusted* by day, *as well as* by night: *whereas the* Phænomena *I am concerned with appear only in the Night-time. Nor do I know of any other Advantages that Mr.* Harrison's *Clock has, properly speaking, over my Telescopes. For it cannot be deny'd*

that these Telescopes have the Advantage of his Clock in the seven *Respects following:*

(1) *My Telescopes are no way liable to any Harm from the* Carelessness of Seamen. *While if, in the longest Voyages, Mr.* Harrison's *Clock be once casually neglected, and not every Day wound up, which is no way impossible to happen, it becomes useless all the rest of that Voyage.*

(2) *My Telescopes, when they come to be made of Glass, as is intended, will no way become worse in length of time: which is impossible to be supposed of any Clock or compound Machine whatsoever.*

(3) Jupiter's *Planets will go as true* after *a Storm, as* before *it; and so the Observations will be in no Danger by such Storms. Whereas every very great Storm will endanger not only the Regularity of the Clock's Motion, but the Motion it self; and perhaps demolish sometimes several of its nicer Springs and Parts also for ever afterwards.*

(4) Jupiter's *Planets will afford us equally good Observations at the* End *of Voyages, when the Knowledge of the Longitude is most valuable, with those near their* Beginnings, *when it is hardly valuable at all. While any smaller Error in the Clock, tho' no more than* 1″ *or* 2″ *in a Day, may in time become so considerable, towards the Conclusion of a Voyage, that when they want Exactness* the most, *they can* the least *depend upon it.*

(5) *This Clock can be relied on little farther than for a two or three Month's Voyage; because*

cause any such small Error in a Day as 1″ *or* 2″ *may in several Months become so enormous as to be plainly intolerable.*

(6) *This Clock, with its* Apparatus, *for avoiding the motion of the Ship, will in all smaller Ships, especially those belonging to Merchants, take up so much Room as to be very troublesome. Whereas my Telescopes will require no such Room, but be laid by in a Corner without any such Inconvenience in any small Ship whatsoever.*

(7) *The Expences of this Clock, even tho' they should be reduced to less than one half of what the foregoing Specimens have cost, I mean to* 60 l. *will be, I suppose, ten times as great as those of one of my Telescopes; and so will exceed the Purses of no small Part of our Owners of lesser Ships and Traders. Which is a Circumstance greatly to the Disadvantage of this Clock, and greatly to the Advantage of my Telescopes.*

'Tis true, that in my Method there is to be a great deal of Calculation of the Eclipses, Occultations, and Conjunctions of Jupiter's *Planets every Year, to a certain Meridian; as the Reader may observe in the* Appendix: *Which Calculations are avoided by Mr.* Harrison's *Clock. But this I do not estimate here, because it is not to be done at Sea, but at Land: And for a small matter may be done by two different Hands, for greater Sureness, and may be put into annual* Ephemerides *and* Philosophical Transactions, *as they begin to be already. Nay,*

may be calculated many Years beforehand, as other Ephemerides frequently are. I say these Calculations *only are avoided by Mr.* Harrison's *Clock. For as to those Observations and Calculations that are necessary for knowing the* Time at the Ship, *without which the rest is in all Cases intirely useless, they are equally necessary in the one Method as in the other: and are the very same in both Cases without any Inequality whatsoever. All which Considerations render my Method, in a Manner, upon the Par with Mr.* Harrison's *Clock it self, even in this Particular of Calculations. 'Tis also true that Mr.* Harrison's *Clock will inform the Seamen what Time it is at the Meridian to which it is adjusted in* cloudy *Weather, as well as in* clear: *which my Telescopes will not do. This at first sight looks as if that Method would discover the Longitude in* cloudy Weather *also; which* Jupiter's *Planets cannot do. But then, since the Knowledge of the Time of the Day or Night* at the Ship *is as necessary as that* at the fore-mentioned Meridian, *which can never be exactly known but by the Sun, or Stars, and in* clear Weather, *I do not reckon this as any material Advantage in Mr.* Harrison's *Method at all. However, it is well known to Travellers and Navigators, that in those more southern Parts of the World where our Trade principally lies, the Air is nothing near so often cloudy as in our more northern Climates. It is also well known, that* cloudy Weather *is no greater an Objection against finding the* Longitude *by a Clock, or by Telescopes, than it is against finding the* Latitude *by any Instruments whatsoever: which can be no more done in cloudy Weather than the other. The Discovery of which* Latitude *yet is by no means on that Account deemed impracticable.*

As to the degree of Exactness our two Methods can pretend to, Experience will best determine the same.

same. I imagine that near the End of Voyages, when the Longitude will be most wanted, the best and some of the most frequent Instances in my Method, which are the Eclipses of Jupiter's *innermost Planet may claim the Advantage. For since the Calculations of these Eclipses does already come nearly within three Minutes of Time to our Observations, it will be next to impossible to expect any Security of a like Accuracy towards the End of Vopages in Mr.* Harrison's *Clock: tho' I own, as before, that for a few Weeks after it first sets out, or when the Knowledge of the Longitude is of little Use, that Clock will naturally afford us greater Accuracy than my Telescopes can pretend to.*

Upon the whole, I think it greatly for the Interest of the Publick that both these methods should be encouraged, and, as Occasion serves, be made use of at Sea. That all Admirals, Vice-Admirals, Rear-Admirals, and Commodores, who conduct numerous Fleets, who have the publick Purse, and want not room in their Ships, together with Dr. Halley's *Map of the Variation corrected to the present Time, should have both Mr.* Harrison's *Clock, and one of my Telescopes aboard, in order to compare the Observations made both ways, and to confirm or correct their Longitudes found by them upon all Occasions: As also that all private Traders have at least a corrected Map of the Variation, and one of my Telescopes for the Discovery of their Longitude at Sea. I conclude with a brief Account of what I delivered by word of mouth; and with that Memorial which I laid before the Commissioners of the Longitude in Writing* April 28, 1741.

Upon my appearing before the Commissioners at the Admiralty that Day, I first begged Leave to read over to them the Memorial *which I had laid before those Commissioners* Nov. 24, 1739. *which*

which is already set down pag. 19—22. priùs, *as the Foundation on which I had proceeded ever since. I then took notice that the grand Objection made at that Time against my Proposals,* viz. *That the Act for the Longitude had not made any direct Provision for the Settlement of the Coasts, was now superseded by the New Act made on purpose for that End. After which I offered to lay before them in general, as I had done to Dr.* Smith *in particular already, the Observations that had been made during the months of* October, November, December, January, February, March, *and Part of* April, *by Mr.* Bliss *at* Oxford, *by Mr.* Lynn *at* Southwick, *by Mr.* Barker *at* Lyndon, *together with those made on the Coasts at the* North Foreland, *the* South Foreland, Dengy Ness, Beachy Head, Selsey Bill, *and* Dun Nose *in the* Isle of Wight, *by Mr.* Renshaw *and Mr.* Birkbeck, *which I had brought with me. And I informed them these two last were already gone to the Isle of* Portland, *and were to go still farther in their Observations till the Beginning of* June, *when* Jupiter *will be too near the Sun till the Beginning of* Sept. *I withal took notice, that as* five *Things were necessary for the right Settlement of those Coasts,* viz. *(1) The Knowledge of the Time of each Observation at some one certain Meridian at Land, as of that of the Observatory at* Greenwich, *to which those of* Oxford, *at* Southwick, *and at* Lyndon, *are easily reduced. (2) The Knowledge of the like Time of each Observation on the Coasts. (3) The Determination of the Latitude of those Places on the Coasts where the Observations were made. (4) The trigonometrical Survey of the intire Coasts with Maps of the same. (5) The Quantity of the Variation of the magnetick Needle to be there noted all long;* " *Every one of which Particulars were* " *taken care of by my Agents in the present Under-*

" *taking.*

" *taking : And for all which I had given them spe-*
" *cial Directions in Writing, which I offered to lay*
" *before the Commissioners also; while only the first*
" *could possibly be performed by Mr.* Harrison's
" *Clock, how accurately soever it might go.*" [*The Use of one of which Clocks, belonging to the Publick, I the last Year earnestly desired in my own Undertaking, but could not by any means prevail with Mr.* Harrison *to allow it.*] *After which I informed the Commissioners, that I had already expended more than I had received of those Benefactors to me and to the Publick already named pag.* 26. priùs; *and desired I might now have a proper Sum out of the publick money toward repaying my self what I was out of Pocket* [*and for carrying on the Undertaking for the publick Benefit.*] *Hereupon the Number of Votes present being fewer than five, which yet are necessary in such a Case; and Dr.* Smith, *who was the only Mathematician of four that belonged to this Commission now present, desiring the farther Consideration of this matter might be defer'd till the rest could be consulted; and informing them that his own Affairs would not permit him to attend himself till above three months hence : It was agreed that the Secretary, Mr.* Corbet, *should write pressing Letters to those other members, and insist by all means on their Attendance the next Day of meeting, which was appointed to be on* Tuesday Sept. 1.

The written Memorial read by me, and then delivered to the Board, was to this Effect.

Since Sir Isaac Newton's *Paper, delivered to the Committee of the House of Commons about the Longitude; upon the Plan of which Paper the Act about the Longitude was originally form'd, has these Words :* ' *In the fourth way* [*by Signals*] *it is ea-*
' *sier to enable Seamen to know their Distance and*
' *Bear-*

'Bearing from the Shore 40 *or* 60, *or* 80 *Miles off, 'than to croſs the Seas: And ſome Part of the Re-'ward may be given when the firſt is performed on 'the Coaſt of* Great-Britain, *for the Safety of Ships 'coming home:' And ſince the Law it ſelf enacts expreſsly, that 'One Moiety, or half Part of its 'Reward or Sum ſhall be due and paid when the 'Commiſſioners, or the major Part of them do agree, 'that any Method for diſcovering the Longitude at 'Sea extends to the Security of Ships within eighty 'geographical miles of the Shores, which are Places 'of the greateſt Danger:' And ſince it appears to be undeniable that any Method by Balls of Fire or Light, to be thrown up on the moſt elevated Parts of the Shore, from no larger a mortar than one of nine or ten Inches, will extend to the Security of Ships coming home farther than eighty geographical miles off thoſe Shores, As your Memorialiſt is ready to make appear upon any Trial you ſhall pleaſe to appoint: And ſince withal the Degree of* Determination *by ſuch Signals of Safety will always be a great way within thoſe thirty geographical miles, which the Act limits for its greateſt Reward of* 20000 l. *Your Memorialiſt hereby puts in his Claim to ſuch Moiety, or half Part of that largeſt Reward; and humbly hopes you will allow of his Claim accordingly.*

April 28, 1741. WILL. WHISTON.

N. B. *If an eight Inch Mortar be esteemed sufficient for making these Signals, every one of the* 50 *Headlands or Ports already mentioned, as well in* Europe *as in the* West Indies, *pag.* 26, 27, 28. priùs, *may have a Ball of Fire thrown up three quarters of a Mile high, and visible for above* 60 *geographical Miles, once every Night, for* 14 l. *a Year a Piece: amounting to little more than* 5000 l. *a Year in the Whole. If the Ball be thrown up at only the one half, or one quarter of those Places, the Charges will be but one half, or one quarter of the former. Nor in that Case will any Ship that sails within* 60 *Miles of those Coasts, in tolerably clear Nights, be very long out of the Sight of one of those Signals.*

N. B. *If these Mortars be within such Distances whence, in clear Weather,* Light-houses *are of Advantage to Seamen, the* Sound, *as well as the* Fire *or* Light *of the Signal, may be some direction to them, even when Fogs or Mists hinder the Sight of the said* Light-houses *also.*

N. B. *It is of small consequence what the Sky is at the place of each Mortar. Since those that are near it, do not want to know where they are by these Signals; which are intended for a Direction to those at a Distance at Sea only: And the Sky may be clear there, how cloudy or misty soever it be at the Mortars. For these Balls of Fire, in misty and cloudy Weather, pass quite through such Mists and Clouds, and return with the same degree of light through them again to the very Ground: And so may often be well seen at those remote Distances notwithstanding. However,*

N. B. *It will not be any great Inconvenience, if Ships, under Suspicion of Danger, cast Anchor in cloudy and misty Weather, and stay till a clear Night afford them better Satisfaction.*

N. B. *Since Shells thrown but a* quarter *of a Mile high may be seen* half *as far as those thrown a* Mile *high: Since small Quantities of Gunpowder will throw them much higher in Proportion than large ones: And since therefore the Charges in small Mortars are much less than in large ones, it may deserve to be tryed whether a six Inch Mortar may not, upon the Whole, be more useful in many Places, as they are certainly much more manageable than the other; especially in the Case of a Land Survey. Which I should think does not at all require a larger Mortar than that last mentioned. A few Trials will soon determine such Questions.*

N. B. *And now, after all, I desire it may be farther noted, that although there be already many* Light-houses *on the Coasts, near the Places whence these Balls are proposed to be thrown; which it may be supposed might, in that Case, be superseded; yet am I very unwilling to have any such thing done. I rather desire all the Helps that the Seamen already have may be continued; and that what Assistances are to be afforded them may be* additional, *and not* exclusive *of their former, all being not more than sufficient in many Cases of Distress for their Security.*

N. B. *As I have already preserved the Names of those who, to their great Honour, have layd down the 225 l. towards my present Design of settling the Coasts: So should I have been very ready to preserve the Names of those who, to their great Honour also, have lent Mr.* Harrison *any like Sum for the perfecting of his Clock, had I been equally acquainted with them, and the Sums they contributed; but as I am not, I must forbear.*

PRO-

PROBLEM

From the two following Tables, with the Obſervation of the intire Time a Shell is viſible, both in its Aſcent and Deſcent, to find the Diſtance of the Obſerver from the Mortar.

I. A Table of the Number of Feet that Bodies fall or riſe, as far as 25″ of Time.

″	feet
1	16,1
2	64,4
3	145
4	252
5	402
6	580
7	789
8	1030
9	1294
10	1610
11	1948
12	2318
13	2721
14	3156 = ½ mile
15	3622
16	4122
17	4653 = ¾ mile
18	5216
19	5812
20	6440 = a mile
21	7100
22	7792
23	8517 = 1¼ mile
24	9273
25	10062 = 1½ mile

II. A Table of Exceſs of the Secants in Feet above the Earth's Semidiameter, as far as 1° 46′.

miles	feet	miles	feet	miles	feet	miles	feet
1	1	28	695	55	2688	82	5974
2	4	29	745	56	2787	83	6121
3	8	30	798	57	2887	84	6272
4	15	31	853	58	2991	85	6422
5	23	32	909	59	3093	86	6573
6	34	33	968	60	3198	87	6726
7	45	34	1026	61	3305	88	6882
8	57	35	1088	62	3415	89	7039
9	71	36	1151	63	3526	90	7199
10	88	37	1216	64	3639	91	7360
11	107	38	1283	65	3755	92	7522
12	128	39	1352	66	3870	93	7686
13	151	40	1422	67	3988	94	7852
14	174	41	1493	68	4118	95	8020
15	199	42	1569	69	4229	96	8190
16	227	43	1642	70	4353	97	8362
17	256	44	1720	71	4479	98	8536
18	288	45	1800	72	4608	99	8611
19	321	46	1882	73	4735	100	8887
20	357	47	1963	74	4866	101	9066
21	393	48	2047	75	4998	102	9246
22	430	49	2134	76	5132	103	9429
23	470	50	2222	77	5269	104	9614
24	512	51	2312	78	5407	105	9799
25	556	52	2404	79	5546	106	9986
26	601	53	2497	80			
27	647	54	2592	81			

Take

Take out of the first Table the Number of Feet that stands over against half *the intire Time you observe the Rise and Fall of the Shell, out of* 3156, *or* 4653, *or* 6440, *according as the Mortar that you use is of the small, or middle or large Sort, (to which utmost Altitudes they are by Trials to be adjusted.) The Number in the second Table, which stands over against that Difference, corresponds to the Distance of the Observer from the Mortar in geographical Miles. Suppose the Observer sees the Shell* 22″ *in all, take the Number over against its Half, or* 11″, *which is* 1948 *out of* 3156, *or out of* 4653, *or out of* 6440, *according as you use the least, the middle, or the large Mortar. The Differences are* 1208, *or* 2705, *or* 4492. *Over against which Numbers, in the second Table, stand* 37, 55, *and* 71 *geographical Miles, which are the true Distances of the Observer from the Mortar in the same geographical Miles nearly; and so for ever.*

Now the Reason why I choose the Number 11″ *is because its Double or* 22″ *was the Mean between the Times during which the two Shells of about* 28 *pound Weight a Piece, sent up with* 1½ *pound of Powder, from a* 7 *Inch Mortar, were seen in* August 1715, *at* Lewes *in* Sussex. *As the like Shell in the like Circumstances had been before seen in* Oxfordshire, *during the great Eclipse* April 22. *the same Year, even after the Sun was come out of the total Darkness; altho' I had no Account how many Seconds it was there seen. See the* New Method for discovering the Longitude, *printed* A. D. 1715, pag. 52, 53, 54.

As to the Bearing *of this Signal, which ought always to be noted together with the Distance, it may be so exactly taken at Land by a* true Meridian; *and on Shipboard pretty nearly by an* Azimuth Compass, *which every Ship ought to be provided with, that I shall not insist on any more particular Directions about it.*

Lyndon, Rutland, WILL. WHISTON.
Aug. 10, 1741.

But to proceed in my History.

The next meeting of the Commissioners of the Longitude having been appointed, as has been noted already, for Sept. 1, 1741. *I came to* London *accordingly* Aug. 22, *in order to get every thing ready for that Day. But a sudden and dangerous Illness of my Wife, who was at* Lyndon *in* Rutland, *which I was informed of during this Interval, obliging me to post down to her, I was forced to desire Sir* Charles Wager *to put off that Meeting till I could return to* London; *or at least, if the Commissioners should meet on* Sept. 1, *I desired him to lay before them the Memorial following: Which was dated in* Rutland, Aug. 29, *but which yet, upon the putting off the Meeting, there was then no occasion for till* Saturday Jan. 16, 1741-2, *when they met, and when I was present myself, and laid it before them. The* Speaker *indeed, who had been somewhat indisposed, and was but just recovered, durst not venture abroad that Day: But seven other of the Commissioners met,* viz. *Lord* Monson, *Sir* Tho. Hanmer, *Sir* Charles Wager, *Sir* John Norris, Martyn Folkes, *Esq*; *Dr.* Smith, *and Mr.* Bradley. *Now after Mr.* Burchet *the Secretary, had, at my Desire, read the late Act of Parliament,* For surveying the chief Ports and Headlands on the Coasts of *Great-Britain* and *Ireland*, and the Islands and Plantations thereto belonging, in order to the more exact Determination of the Longitude and Latitude thereof, *The Memorial itself was read by me, and was as follows,* verbatim:

To the Honourable the Commissioners for the Longitude at Sea:

The Memorial of *Will. Whiston* Clerk, sometime Professor of the Mathematicks in the University of *Cambridge*.

Humbly sheweth,

" *THAT your Memorialist, at the Encourage-*
" *ment of several great and generous Persons,*
" *procured the last Year a Set of excellent astronomi-*
" *cal Instruments, with certain exact Observers at*
" *Land; and sent his Agents with those Instruments,*
" *to begin a Survey of the Coasts of* Great-Britain
" *and* Ireland, *as to Longitude, and Latitude, and*
" *the Variation of the Needle, and for the Trial of se-*
" *veral Methods of discovering the Time at Sea;*
" *which is necessary to be known in all the Ways of*
" *discovering the Longitude there. That the said*
" *Agents are long ago come back, with a considerable*
" *Set of Observations on the Coasts, and a Chart of*
" *those Coasts, as far as* Portland: *Which he hopes*
" *will be approved by all good Judges: and they in-*
" *tend to proceed in the same designs, if they may be*
" *paid what is now due to them, and secured as to*
" *what they shall deserve hereafter. That yet your*
" *Memorialist has not only disbursed all the Money hi-*
" *therto put into his hands, which was* 225 l. *but*
" *considerably more, out of his own Pocket. Which*
" *has indeed greatly distressed him: While part of the*
" *Instruments are not yet paid for, and a great part*
" *of the Allowances to the Observers and Agents is*
" *also behind-hand. All which ought to be disburs'd*
" *out of the Money allow'd by Parliament. That if*
" *this be not now allow'd, the noble Design so happily*
" *begun*

" *begun must be drop'd, and your Memorialist, with* " *the other Observers and Agents, very much damni-* " *fied, and distress'd: And this for no other reason* " *than their great Zeal for the Good of the Publick,* " *and the Benefit of Navigation.*

" *Your Memorialist therefore humbly desires, that* " *he may have at least five hundred Pounds allotted* " *to him for other Trials, and for the paying off* " *what is now owing, and for continuing this Survey,* " *as far at least as* Cape Clear *in* Ireland: *Which* " *will include much the most useful part of the entire* " *Design: And when it is done, will enable the Pub-* " *lick to judge how far it will be necessary to proceed* " *afterward. Your Memorialist also presumes to say,* " *that as the Discovery of the Longitude in the open* " *Seas will be of little or no Use before the Coasts are* " *ascertain'd, so does that method by Signals near the* " *Shores, which he laid before the Board the last* " *time, both in the Opinion of Sir* Isaac Newton, " *and of the Legislature seem to be equivalent to any* " *Method that may be practised in the open Seas:* " *Tho' all the Helps that can be given Seamen either* " *near to or far from the Coasts ought certainly to be* " *procur'd them. Nor had he been, perhaps, forced* " *now to insist on the lone of eight and ten inch Mor-* " *tars, as he particularly does, for the trial of his* " *Method by Signals, had that eight inch Mortar* " *which he borrowed of the Board of Ordnance, and* " *which his Agent began to use with very great Suc-* " *cess, been allow'd him for the last five Months:* " *Any sufficient Cause of which Discouragement to* " *so important an Experiment, does no way appear.* " *Tho' after all, the Shell fired at the great Eclipse* " *on* Hamstead-Heath 1715, *from a seven inch* " *Mortar, and seen in* Oxfordshire, *even after the* " *Sun was come out of total Darkness: With those* " *two others fired on one and the same Night from*

" *the same Mortar, and very plainly seen, the first* " *for* 25", *the last for* 19", *at* Lewes *in* Sussex, *by* " *Dr.* White, *in* August *the same Year, do abun-* " *dantly prove, that a Mortar of ten inch, if not* " *one of eight, would send up a Ball of Fire that* " *should be visible above eighty Miles. A Scheme of* " *which Distances of forty, sixty and eighty Miles,* " *mentioned by Sir* Isaac Newton, *I have here in-* " *closed. Nor do I insist on more than* 500l. *for the* " *next eight Months, which I shall endeavour to hus-* " *band to the best Advantage, and to give the Com-* " *missioners an Account how that Sum has been em-* " *ployed at the end of that term, and this particu-* " *larly in order to leave room for an additional Sum* " *of* 250l. *if the Commissioners so please, for Mr.* " Harrison's *Clock, who, I suppose, has been as much* " *distress'd as myself, and perhaps more. I being* " *very willing that his Design as well as mine, should* " *be provided for out of the Money allotted by Par-* " *liament for such Purposes.*

Aug. 29, 1741. WILL. WHISTON.

Now as I read this Memorial myself, when I came to those Clauses concerning the Observations made on the Coasts, *and the* Chart of those Coasts, *I produced three Tables of the Observations of* Jupiter's *Planets, made at Land during seven several Months, by Mr.* Bliss, *at* Oxford; *by Mr.* Lynn, *at* Southwick *near* Oundle, Northamptonshire; *and by my Grandson Mr.* Tho. Barker *at* Lyndon *in* Rutland: *Which were to be compared with the fourth Table, exhibited in the same Paper, containing the corresponding Observations which were made of the same Satellites by Mr.* Renshaw *along the Coasts, in order, by such Comparison, to discover the Longitude there. I also introduced Mr.* Renshaw *himself, with his Corrections of Dr.* Halley's Chart of the Chan-

nel

nel between England and France: *Which, as Dr.* Halley *himself informed us, and as the very Title of his Chart will inform every Reader, related only to the* Depth of the Sea, *the* Flowing of the Tides, *and the* Setting of the Current; *without any proper Instruments or Attempts for the Discovery of either the* Longitude, *or* Latitude, *or any new* trigonometrical Survey *of the adjoining Coasts: Which he confesses to have only delineated from the best former Surveys he could meet with, how imperfect soever: And wherein he took the Coast of* Cornwall *from Mr.* Carew's *Survey of that County. Altho' he confess'd that this Survey appeared afterward to have erred no less than fifteen intire Miles in the Situation of the Lands-End itself: Which ought to have been placed so much farther Westward than it stands both in that Survey and in Dr.* Halley's *Chart derived from it. And, by consequence the most dangerous Islands of* Scilly *beyond it, are placed fifteen miles false in that Chart also. Now upon Mr.* Renshaw's *producing this Chart, as amended by his own actual Survey, to the great Exactness of which no Objection had been made by Dr.* Halley, *when we waited upon him at* Greenwich *with it; nor by any of the Commissioners now assembled, nor indeed by any other, it appear'd, that as to several places Dr.* Halley's *Chart pretty well agreed with our new Observations: But that in many others it disagreed, and was in several egregiously false, even as to the* Latitude *itself: (For as to the* Longitude, *Dr.* Halley *did not so much as pretend to set it down any where in this Chart) Insomuch that at* Dengy-Nesse *that Latitude was about three, and at* Beachy-Head *no less than five Minutes or Geographical Miles erroneous in Excess; Which Quantities are, the first too inaccurate, and the last plainly intolerable.*

I then informed the Commissioners, that as we had already

already corrected the Errors of Dr. Halley's *Chart no farther Westward than* Portland, *so was the principal, very far the principal Part of the Work behind: Which was to make the like Corrections in the Chops of the* British *and* Bristol *Channels, from* Portland *to* Cape Clear, *where the Dangers of Ships is most frequent, and very often most fatal; especially near the* Scilly Islands *there situate, as the most shocking Loss of Sir* Cloudsley Shovel, *at those Islands, demonstrates to every one.*

After this I was desired to give the Commissioners an Account of my Receipts and Disbursements, relating to this Survey of the Coasts: Which I did accordingly in a distinct Paper. Whereby it appear'd, that I either had already paid in the Name of the Publick, or the Publick did still really owe (I mean over and above that Sum of 225 l. 4 s. *which I had already received and disbursed) about* 330 l. *For the Payment of which, and for the Continuation of this actual Survey through the* Start-Point, *the* Lizard-Point, *the* Lands-End, *the* Isle of St. Agnes *in* Scilly, *to* Cape Clear *on the Southwest Coast of* Ireland, *which was all I now intend, I only desired of the Commissioners the Sum of* 500 l. *which they unanimously granted me. Nor is there any particular Necessity now for surveying nearer to* Bristol *or to* Milford Haven: *Since that intire Coast of* Wales, *and much farther into* Scotland, *has not long since been carefully surveyed by Mr.* Eyes, *and that Survey has been made publick also. To say nothing of Captain* Joseph Southgate's *Survey, and fourteen Years Observations on the eastern Side of our Island, the most dangerous Parts of* Norfolk *and* Lincolnshire *Coasts; from* Fulness *on the* Norfolk, *to the* Sprone-Head *on the* Yorkshire *Coast. A Draught of which has been made public also. However I was cautioned by Sir* Charles Wager, *in the Name of the Commissioners, not to*

exceed

exceed that Sum of 500 l. *Which I willingly promised to take care not to do.*

It was indeed formerly proposed, at Dr. Halley's *Suggestion, to have extended this Survey much farther round* Great-Britain *than is here set down: As the Reader has seen* pag. 26, 27, 28, priùs. *But when it appeared that the Sum allotted by Parliament would by no means be sufficient for such an extensive Survey of the Coasts, and for Mr.* Harrison's *Clock also, the largest but much most inconsiderable part of my Design was to be drop'd, and I was obliged to confine it to the smallest, but far more useful part of it, which is the* British Channel, *from the* North-Foreland *in* Kent, *to* Cape Clear *in* Ireland: *Which includes I suppose, not less than nine parts in ten of the intire* British *Navigation. For as to the Places already noted in the* West-Indies *pag.* 28. *which ought by all means to be carefully surveyed, I hope when* Jupiter *shall be again in a proper Situation, which will not be till* October, *and the eight Months following, Care will be taken of that Matter also.*

As to my Complaint of a Mortar being taken from me, it was occasioned by the falling of one of my Shells near the duke of Montague's *House by* Black-Heath, *farther than was expected, while the Mortar was upon that Heath. Nor can I be at all sorry for that Accident, since no body was hurt: it having been the Cause of the Removal of our present Gun three Miles farther, to* Shooter's Hill: *and of placing it perpendicular, and sufficiently distant from all Houses. It has also been the happy Occasion of my discovering a new very useful Theorem in the Art of Gunnery, utterly unknown before: which I shall demonstrate after I have given some Account of the rest of the Acts of these Commissioners, and have exhibited four curious Experiments in Gunnery, made by General* Armstrong.

The Commissioners then allowed Mr. Harrison *for the perfecting of his Clock* 500 l. *provided he gave Security*

to

to put it together and in Motion by the first Day of Aug. *next; and in a Condition by* Aug. 1 1743, *to be placed on board one of the King's Ships, in order to the making Trial thereof. As also that he, or some proper Person by him appointed, shall actually proceed in that Ship to the* West-Indies, *to explain the Theory and Use of this Clock in that Trial: and on condition that he deliver this third, and his two former Clocks to the Use of the Publick: and that in case he obtains by this Clock any Part of the Reward for the Longitude, he shall deduct this* 500 l. *and what he had before received* (250 l.) *out of the same Reward.*

But, what I ought not to omit, the following Sum of 500 l. *was paid me* Feb. 12, *and the like Sum is to be paid to Mr.* Harrison *very soon, without the least deduction, by the Order of* Arthur Onslow, *Esq; Speaker of the House of Commons, and Treasurer of the Navy; and that in Defect of other Money in that Office unapplied to the Use of the Navy, out of what he might have taken to himself, as the Taxes on his Salary, which used to be excused to his Predecessors. He also set the first Example of* giving *the Sums abovementioned page twenty six, to me, or rather to the Publick by me, which I desired to be* lent *only. In which he has been generously followed by the rest also. So that in Reality, this whole money* 1225 l. *of which* 1050 l. *comes from the Speaker, is not to be esteemed as taken out of the Treasury, or out of the Nations publick money, but most generously contributed by private Persons, and chiefly by the Speaker as Treasurer of the Navy, to the Uses of Navigation. Which most noble Gifts deserve the highest Acknowledgements from the Publick, from Mr.* Harrison, *and from myself; which I here desire, sincerely, to pay in all our Names, as a monument of our gratitude for so signal Benefactions.*

The Commissioners did also meet again after an Adjournment, the next Saturday, *upon Sir* John Norris's *Suggestion: and took into Consideration Mr.*

Rich.

Rich. Graham's *great Improvement of what Monſ.* Fatio *had publiſhed* 1728, *of finding the Latitude by the Sun's Altitude at two ſeveral Times in the Day-time, with no more than the Interval of the Obſervations, meaſured by a Watch: of which Sir* John Norris *was exceeding fond. This being now to be done by a Globe mechanically and readily, without Monſ.* Fatio's *tedious Calculations. And they agreed to recommend this Method ſtrongly to* Trinity-Houſe, *and every where elſe; in order to the Introduction of it into general Practice at Sea. And I cannot but agree as to its Value, particularly as to our* Engliſh *Sailors; who unhappily confining themſelves, for the diſcovering the Latitude, to the Day-time, and to the Sun at Noon, which is often then under a Cloud, frequently loſe their much more numerous Opportunities of diſcovering the ſame in the Night, by the Stars. While by this Method, if the Sun do but ſhine clear any time in the morning and afternoon, they may readily diſcover the ſame.*

Fxperiments made at *Woolwich* out of the braſs 13 Inch Sea-Mortar, with the wooden Bed in the Bomb-Room, 26 *July*, 1738. By Brig. *Armſtrong*.

	Weight of Shells.		Elevation		Weight of Powder	Diſtance	Time of Flight
	Empty	Filled with Sand					
No. of Shells.	lb.	lb.	D.	M.	lb.	Yards.	Secds.
1	240	245	45	0	30	4100	
2	230	240	45	0	26	3600	25
3	226	235	45	10	30	3627	25½
4	231	231	45	15	30	3580	24½

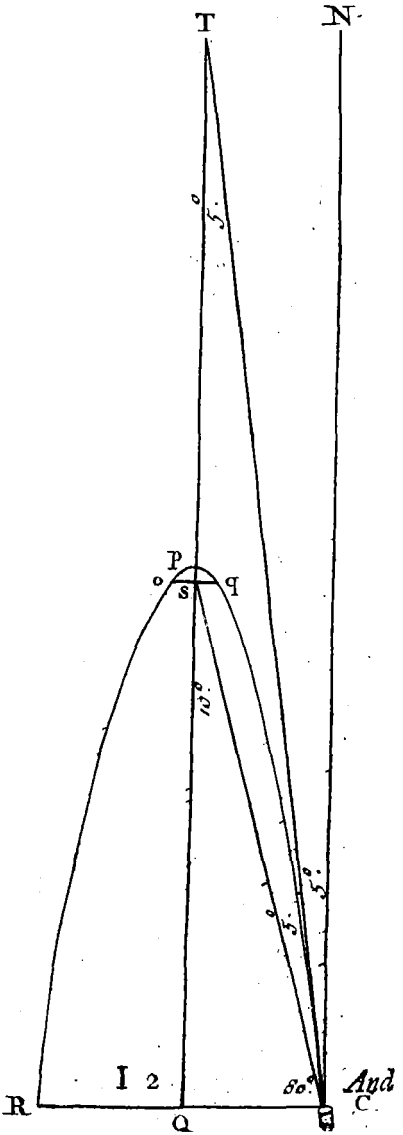
N. B. *Since it is well known that the ſame Force that can throw a Shell of any Weight to any Diſtance at* 45° *Elevation, which is the* utmoſt Random *in Gunnery, is able to throw the ſame Shell half as high perpendicular: And ſince the leaſt of theſe Diſtances is above two* meaſured *Miles,* = 3520 *Yards, and the greateſt above two* geographical *Miles* = 4080 *Yards; it follows, that had theſe Mortars been erected perpendicular on* Shooter's-Hill *or the like Elevation, theſe Shells had been thrown all above a meaſured Mile, and one of them above a geographical Mile high, and might have afforded the nobleſt Signals to all Ships within* 100 *meaſured or* 86 *geographical Miles of the Mortar whence they were thrown. Nor would it perhaps, be improper to have ſuch a glorious Signal as theſe would be, made every Midnight from St.* Agnes's *Iſland in* Scilly *for the Security of Navigation in that Place of moſt eminent Danger: Altho' in Places of much leſs Danger, much leſs Signals may ſuffice.*

PRO-

PROPOSITION.

If a Mortar be placed 5° from the perpendicular, the Horizontal Range of the Shell will be almost a third Part of its Altitude.

For when ST is equal to SC, the Line CT is the Tangent of the Parabola describ'd. Prælect. Physico-mathemat. *p.* 344. *To which point T the Mortar is directed. Hence the Angles NCT: STC: SCT are all equal or* 5° *and the external Angle QSC is double, or* 10° *and its Complement QCS* 80°. *Therefore, as the Radius* = 1000 *is to the Tangent of* 80° = 5671. *So is CQ to QS. And as double the Radius* = 2000. *is to the* 5671. *So is CR to QS, which is nearly as* 2 *to* 6, *or* 1 *to* 3. *And QS. being almost equal to QP, CR is nearly one third of QP. QED.*

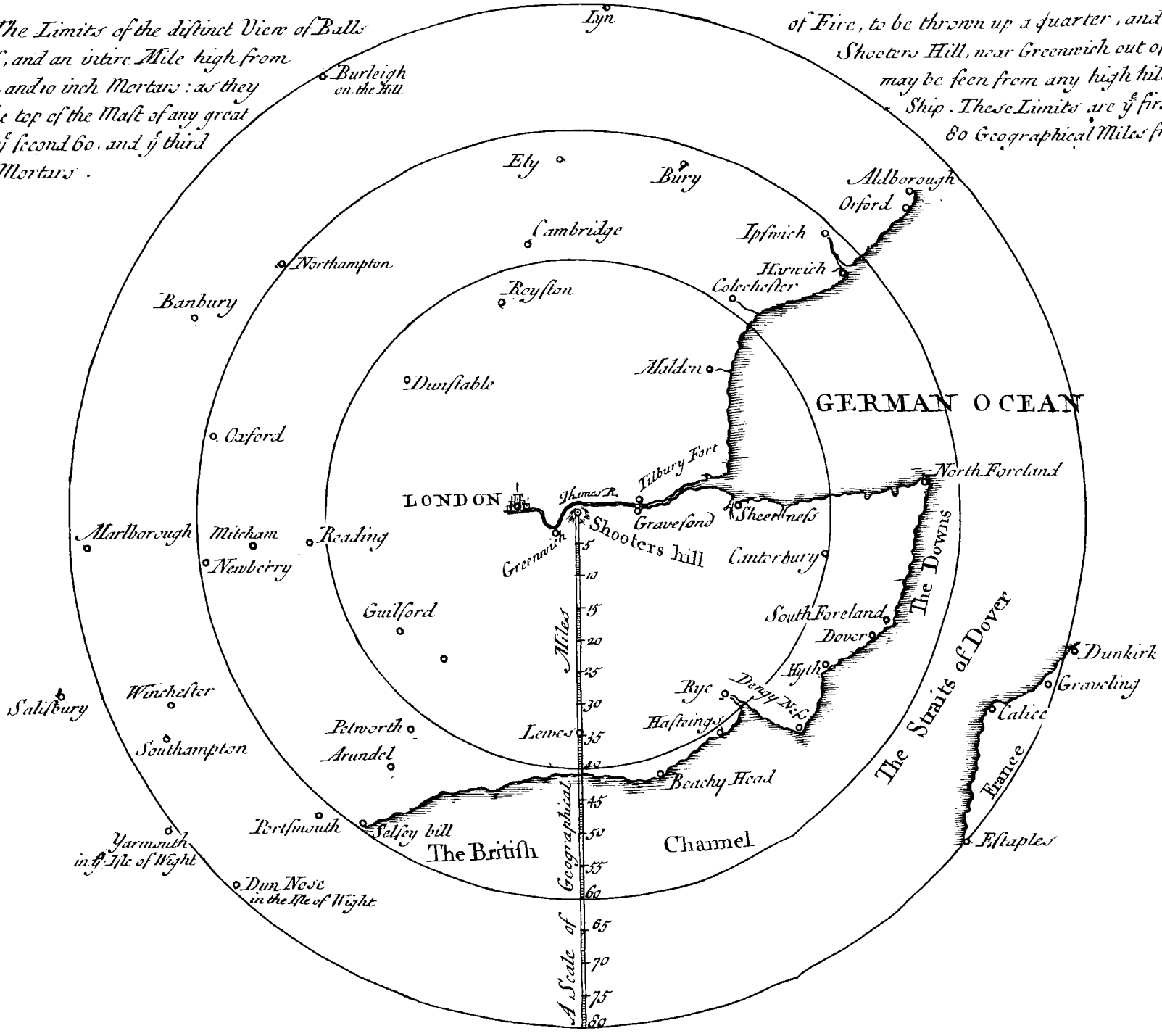


And now, I shall add somewhat farther concerning my own Reflecting Telescope *itself, for the finding the Longitude in the open Seas by* Jupiter's *Planets. This Discovery directly provides for what Dr.* Halley, *page* 61 *prius, declares to be hitherto wanting, when he requires an Invention of* shorter Telescopes *than ordinary, that may yet shew the Eclipses of* Jupiter's Satellites *at Sea. Now the* Reflecting Telescope, *which is now making for me by Mr.* Chaplain, *will be only four Feet focal length, or iucluded in a Tube of only two Feet long. It is to magnify about* 55 *Times in diameter, and yet to take in at once near three diameters of the Moon,* i. e. *six diameters of the farthest of* Jupiter's *Planets, or considerably more than is necessary for our present Purpose: as Mr.* Hadley *observes, page* 62 *priùs.*

As for the Spray of the Waves or Vapors on Shipboard, it may be avoided by the View of Jupiter *in my small Tube, through a larger Tube fixed by a Hand to the main Mast, or by looking through an Aperture from below Deck, or in a kind of Tent above Deck; or by the interposition of a very thin clear Glass at the end of the Tube, whose sides are parallel by refraction, or perhaps by looking at them on a flat metal or Looking-glass downward by reflection. Nor does the good Success of Mr.* King's *Experiment for seeing these Planets, and even discovering the Longitude by them in a Voyage with the Lord* Baltimore *to and from* Russia, *and this with a common Reflector made by the same Mr.* Chaplain, *which yet included not one tenth of the Space which mine is to include, and hardly magnified more than one half of what mine is to magnify, give us leave to doubt of the Success of my Telescope, which has so much the advantage of the other.*

Here follows a Scheme of the distances of Signals for 40, 60, *and* 80 *miles, mentioned in the foregoing Memorial.*

The Limits of the distinct View of Balls of Fire, to be thrown up a quarter, and half, and an entire Mile high from Shooters Hill, near Greenwich out of 6, 8, and 10 inch Mortars: as they may be seen from any high hill, or the top of the Mast of any great Ship. These Limits are ye first 40, ye second 60, and ye third 80 Geographical Miles from the Mortars.



THE

LONGITUDE

DISCOVERED

BY

Jupiter's PLANETS.

LEMMATA:

OR,

Preparatory PROPOSITIONS.

I.

THE true *Diſtances* of *Jupiter*'s Planets from his center, eſtimated by Semidiameters of *Jupiter*'s Body, and their decimals are theſe that follow: See Fig. (1).

		s. d.
I.	——	5,965
II.	——	9,494
III.	——	15,141
IV.	——	26,063

N. B. Their

N. B. Their old measures, derived from less accurate Observations, were determined to be these that follow:

		s. d.
I.	——	5,667
II.	——	9,017
III.	——	14,388
IV.	——	25,299

Yet does not this difference in the numbers at all affect the *proportions* of these Planets proper *Distances* from the center of *Jupiter*; but only the quantity of *Jupiter*'s own Diameter. Which, as it used to be stated at 40″, nearly; so, upon Mr. *Pound*'s exacter Observations, Sir *Isaac Newton* at last justly states it at no more than 37″ $\frac{1}{4}$: and thence corrects the old numbers, and gives us those that are more accurate. See his *Principia*, 3d Edition, pag 390, 391.

II.

The *Periodick Months* or Revolutions of these Planets about *Jupiter*, with regard to the fixed Stars, are these; as given us in the same place by Sir *Isaac Newton*.

		d.	h.	′	″
I.	——	1	18	27	34
II.	——	3	13	13	42
III.	——	7	3	42	36
IV.	——	16	16	32	9

III. The

III.

The *Synodick Months*, or Revolutions of these Planets about *Jupiter*, with regard to the Sun; as given us by all Astronomers, and particularly by Sir *Isaac Newton*, in his *System of the World*, in *English*, pag. 13. and in the first Edition of his *Principia*, p. 403. are these.

		d.	h.	′	″
I.	——	1	18	28	36
II.	——	3	13	17	54
III.	——	7	3	59	36
IV.	——	16	18	5	13

N. B. Because the three quarters; the halves; and the quarters of these *Synodick Periods* will be of great Use hereafter; I shall here set them down distinctly also.

		d.	h.	′	″
I.	$\frac{3}{4}$ =	1	7	51	27
II.	$\frac{3}{4}$ =	2	15	58	25
III.	$\frac{3}{4}$ =	5	8	59	42
IV.	$\frac{3}{4}$ =	12	13	33	54

		d.	h.	′	″
I.	$\frac{1}{2}$ =	0	21	14	18
II.	$\frac{1}{2}$ =	1	18	38	57
III.	$\frac{1}{2}$ =	3	13	59	48
IV.	$\frac{1}{2}$ =	8	9	2	36 $\frac{1}{2}$

		d.	h.	′	″
I.	$\frac{1}{4}$ =	0	10	37	9
II.	$\frac{1}{4}$ =	0	21	19	28 $\frac{1}{2}$
III.	$\frac{1}{4}$ =	1	18	59	54
IV.	$\frac{1}{4}$ =	4	4	31	18 $\frac{1}{2}$

 IV. The

IV.

The mean *Durations* and *Semidurations* of the Total Eclipses of these Planets, when they are not far remote from their Nodes, and describe Diameters over *Jupiter*'s Shadow, are as follows.

		h.	′			h.	′
Durations	I.	2	12	Semidurations	I.	1	6
	II.	2	49		II.	1	24½
	III.	3	32		III.	1	46
	IV.	4	46		IV.	2	23

V.

The like *Durations* and *Semidurations* of the same Planets, while they are under *Occultations* by the body of *Jupiter*, either on this, or the other side, when they are not far remote from their Nodes, and describe Diameters over *Jupiter*'s body, are as follows.

		h.	′		h.	′
Durations	I.	2	18	Semidurations	1	9
	II.	2	56		1	28
	III.	3	40		1	50
	IV.	4	54		2	27

N. B. Altho' these apparent Durations on this side *Jupiter* must be somewhat shorter than those beyond him, by passing over somewhat larger arcs of their own Orbits during their Occultations; yet are their Differences so small, as hardly to deserve any allowance in this place.

VI. The

VI.

The *Times* of these several Planets, while they are gradually entring the Penumbra, or imperfect shadow of *Jupiter*'s body, or emerging from it, in their Eclipses; as distinct from their Durations within the total shadow itself, are, by the Observations of Mr. *Lynn*, and many others, found to be nearly as follows. See *Philosophical Transactions*, N°. 393, 394, 396, 401, 402, and 440.

	′	″
I.	1	10
II.	2	20
III.	3	40
IV.	5	30

Only we must Note farther, that the Comparison of the Observations shews, that the quantities here set down admit of a good deal of variety; and are at some times considerably larger than at others.

VII.

It appears therefore, from the numbers under the III^d Lemma, that two *Synodick Periods* of the I^st Planet, are shorter than one Synodick Period of the II^d by 20′. 42″.

For	1	18	28	36	=One Period of the I^st.
+	1	18	28	36	=Another Period of the I^st.
=	3	12	57	12	
from	3	13	17	54	=One Period of the II^d.
remains	0	0	20	42	

As

As also it appears thence, that two *Synodick Periods* of the II^d are shorter than one *Synodical Period* of the III^d by 1 h. 23′ 48″.

For	3	13	17	54	=One Period of the II^d.
+	3	13	17	54	=Another.
=	7	2	35	48	
from	7	3	59	36	=Period of the III^d.
remains	0	1	23	48	

It appears farther, that two *Synodick Periods* of the III^d. are shorter than one such Period of the IVth by 2 d. 10 h. 6′ 1″.

	d.	h.	′	″	
For	7	3	59	36	=One Period of the III^d.
+	7	3	59	36	=Another.
=	14	7	59	12	
from	16	18	5	13	=One Period of the IVth.
remains	2	10	6	1	

Hence it follows, that these small quantities in excess are greatly diminished, and, in a manner, worn off in 26 Periods of the IVth, in 61 Periods of the III^d, in 123 Periods of the II^d, and in 247 Periods of the I^st, when the numbers will stand as follows:

		d.	h.	′	″
26	Periods of the IVth =	435	14	15	38
61	Periods of the III^d =	437	3	35	36
123	Periods of the II^d =	437	3	41	42
247	Periods of the I^st =	437	3	44	2

N. B.

N. B. Since Mr. *Pound*'s, Tables in every 43 days diminish a single Period of the I^st^ by 1″ and so in this whole Period 10″. I have set down but 2″ instead of 12″ under its 247 Periods; as this nicety requires.

Corollary. All these four Planets therefore return to their former situation, with respect to one another, and to the Sun, in about 437^d 3^h 40′ within 1^d 13^h 28′ 34″. Nay the three innermost do the same within the very small quantity of 8′ 26″. And accordingly the first three pass through all the varieties of their mutual situations, and return to their former places, with regard to one another, and to the Sun in this Period, of 437^d 3^h 40′, and that almost to the utmost nicety. Which therefore is the first *grand Period* to them belonging: and of which *grand Period* particular notice is taken by Mr. *Bradley* upon this occasion; as will be distinctly shewed under the first *Corollary* of the XIth *Lemma* presently.

VIII.

The Comparative magnitude of these Planets of *Jupiter*; tho' not hitherto sufficiently measured by the Micrometer, or otherwise, so far as I know, seems to be this.

The third is evidently the largest of them all: and, as I guess, about the bigness of the *Earth*, or *Venus*.

The first is the next in largeness; tho' certainly somewhat less than the former; and so not much bigger than *Mars*.

The

The second is a small matter lesser than the first; and so not a great deal bigger than *Mercury*.

The fourth is evidently the least of them all; and therefore not much larger than our Moon. See these Proportions represented in Fig. 2. Mons. *Cassini*, by stating the diameter of the first at the 20th Part of the diameter of *Jupiter*, fairly implies these determinations to be not far from the truth. See *Philos. Transact.* N°. 211.

IX.

The *Distances* of these Planets from *Jupiter*'s Center are these that follow; in our ordinary measur'd miles, nearly.

Distances	I.	— 218000	miles.
	II.	— 348000	
	III.	— 554000	
	IV.	— 972000	
Mean Distance of our moon from the Center of our Earth		— 240000	miles.

X.

The *Hourly motions* of these Planets about *Jupiter* are as follows, nearly.

Motions in an Hour	I.	— 32000	miles.
	II.	— 26000	
	III.	— 20000	
	IV.	— 15000	

Mean

Mean Motion of our Moon about our Earth in an Hour, nearly, — 2400 Miles.

Corollary. As therefore all these Moons, or secondary Planets about *Jupiter*, excepting the innermost, are farther off *Jupiter* than our Moon is from our Earth; so is their Velocity, if supposed at equal distances, very much greater. Nor could their projectile motions in any degree balance the vastly greater power of *Jupiter*'s Attraction, arising from his vastly greater magnitude than that of our Earth, had not their Velocities, and, by consequence, the squares of those Velocities, at equal distances, to which that Attraction is always proportional, been vastly greater also.

XI.

The motions of the I^st^, III^d^, and IVth Planets are tolerably even, and regular. While the motion of the II^d^ is, by far, the most uneven, and irregular of them all: as our Astronomical Observers agree.

Corollary (1.) Since therefore the IVth Planet is both the smallest and remotest of them all; Its Attractions cannot very much influence or alter the motions of the three innermost; and their irregularities must chiefly arise from their own mutual attraction or gravitation, acting upon one another: as Sir *Isaac Newton* has demonstrated the Sun, Moon, Planets, and Comets perpetually do. And since withal the

Grand Period of these three, which we have seen to be $437^d\ 3^h\ 40'$, brings them still back to their former situation, we thence learn the true occasion of a kind of Revolution, or Return of their former inequalities in half that Period; or in about 218 days $= 7\frac{1}{2}$ months: which Mr. *Bradley* affirms they do. His words are published, and are these: " I presume, says he, that the " irregular motion of the first Satellite chiefly " arises from the gravity of the other Satellites " towards it: [or rather from its own gravity " towards those others.] For altho' the effect " of the influence that the Satellites have on " each other is most remarkable in the II^d, " whose motion will sometimes be accelerated " or retarded thereby as much as amounts to " 30′ or 40′ in time, in the space of about 7 " months; or in half the period in which the " three innermost Satellites return to have " nearly the same position, with respect to them- " selves, and to the shadow of *Jupiter*; yet the " first seems also liable to inequalities that can- " not well be accounted for but from some " such cause as is before mentioned: the effect " of which will not easily be reduc'd to any " rule but from a long and exact Series of Ob- " servations." *Philos. Transact.* N°. 394.

Corollary (2.) When therefore we shall have once obtained a compleat sett of Observations of these three Planets for a few of their grand Periods of $14\frac{1}{2}$ months, we shall, probably, be thereby enabled nearly to perfect their Theories, and to compose much exacter Tables than have been

been uſed hitherto for all their *Eclipſes:* As alſo for all their *Occultations*, and *Conjunctions.* For which purpoſe it is, in good part, that I now publiſh this Treatiſe, and the *Ephemeris* or Scheme of *Configurations* thereto belonging; even before I can reduce my diſcoveries to that compleat perfection which I aim at in this matter. Which is indeed hindred by nothing ſo much at preſent as by the inaccuracy of the Theories of theſe Planets; and particularly by the great inequalities in the motion of the II^d.

Corollary (3.) Yet, becauſe all the other Planets, primary and ſecondary, as well as the Comets; that is all the reſt of the bodies in our intire Solar Syſtem; appear to be more, or leſs *Eccentrical*, this rational ſuppoſal of *mutual influences* ought not to prevent the Obſervations proper for diſcovering their *Eccentricities* alſo. Eſpecially ſince Mr. *Bradley* has already diſcovered ſuch an Eccentricity of the IVth, as affords its greateſt Equation equal to that of *Venus*, or not leſs than 48′, and that its Apſis, or greateſt diſtance from *Jupiter*, was, at the beginning of A. D. 1717. 8 degrees of *Piſces:* Nay, and that the ſame Apſis goes forward 36′ in a year; or two ſigns in 100 years. He has alſo diſcovered, that in the years 168$\frac{2}{3}$, 169$\frac{4}{5}$, and 1718, at the diſtances of *Jupiter*'s revolutions about the Sun, of almoſt 12 years; the Eclipſes of the I^ſt Planet continued at leaſt 2^h 20′, while yet in 1677, and 1689, in the middle of ſuch Periods, they did not continue longer than 2^h 14′, which difference of Durations

seems plainly to imply, that, in the former years, this innermost Planet was eclipsed near its *greatest*; and in the latter near its *least* distance from the center of *Jupiter*. Which fairly implies some Eccentricity in its Orbit also. And as the irregularity of the II^d is far the greatest of them all, it is no way unreasonable to suppose, that part of this great irregularity may be owing to its Eccentricity also. Nor can we, with any Assurance, affirm the Orbit of the III^d to be intirely free from such Eccentricity: tho' it may be comparatively of a very small quantity

N. B. As to the *Inclinations* of the several Plains of the Orbits of these Planets to the Plain of *Jupiter*'s own Orbit; or, which is not very far different, from the Plain of our Ecliptick: (for the former Plain is but 1° 20′ different from the other;) together with the places of their *Nodes*; the knowledge of which is necessary to the perfect understanding of their Theories; take them from Mr. *Bradley*'s determinations, in his Tables of these Planets; which, by the favour of Dr. *Halley*, I am now in possession of. " As to the Lati-
" tudes of these Planets, says he, It plainly ap-
" pears by our later observations, that the As-
" cending *Node* of the IVth is now 11°½ in *Aqua-*
" *rius*, and its descending *Node* 11°½ in *Leo*;
" and that the *Nodes* of the III^d are very near
" the same places. For which reason we place
" the *Nodes* of the two innermost there also,
" because the Observations do no way forbid
" us

" us so to do: But if these *Nodes* were 40 years
" ago 15° in *Aquarius* and *Leo*, as *Cassini* af-
" firms,(nor have we any other authority equal-
" ly valuable) they must have gone backward
" about one degree in every period of *Jupiter*
" of 12 years. As for the Inclination of the
" plains of these orbits to the plain of *Jupiter*'s
" own orbit, as it is determined by *Cassini*, *i. e.*
" 2° 55′, we still retain it in the other Planets,
" but affirm that the plain of the IVth Orbit
" has not quite so great an inclination, and is
" no more than 2° 42′." Altho' it must be confess'd that Mr. *Derham* found the Latitude of the III^d about *Sept.* 1703 greater than either Mr. *Flamsteed*, or Monsieur *Cassini* had conjectured; and saw it in the *Penumbra*, or imperfect shadow of *Jupiter*, a long while, at the very Pole of *Jupiter*'s body; and took notice that its duration in *Jupiter*'s shadow was no more than two hours; instead of 3^h 32′, which is its proper quantity, when it describes a diameter over that shadow: as has been already observed, under the IVth Lemma foregoing. Tho' as to the Nodes and Inclination of the II^d Planet, I have, I confess, met with no farther particular determination about them. However, in my *Ephemeris*, or Scheme of *Configurations*, I have endeavoured to follow these determinations, and to set each Planet a little northward or southward of *Jupiter*'s center, as their true positions require; that so the careful Observer may the better know the several Planets asunder; and may take notice

at

at what point of *Jupiter*'s body any of them ought to be waited for at their *Emersions* from it.

XII.

If we subſtract from, or add to, any of the times of *Jupiter*'s Planets coming to their Heliocentrick or Geocentrick *Oppoſitions*, half their Synodick Periods, we ſhall gain their foregoing, or following Heliocentrick or Geocentrick *Conjunctions*. The practice of this will be exemplify'd hereafter.

XIII.

If we ſubſtract from the places of any of theſe Planets, counted from their Geocentrick Oppoſition, at any given time, *one* quarter, or *three* quarters of a Synodick Period; or their places at any given time from *one* quarter, or *three* quarters of ſuch a Period; we ſhall gain the times of their *Utmoſt Elongations*. The reaſon is plain: becauſe theſe *Utmoſt Elongations* are always diſtant *one* quarter, or *three* quarters of ſuch a Period from the time of the Planets poſition at their Geocentrick Oppoſition. The practice of this will be exemplify'd hereafter.

XIV.

If we ſubſtract from, and add to the times of theſe Planets poſition at their *Heliocentrick* Oppoſitions, their true *Semidurations* in *Jupiter*'s ſhadow; we ſhall gain the times of thoſe their *Immerſions* and *Emerſions* which are ſtiled their

their *Eclipses*. The practice of this will be exemplify'd hereafter.

XV.

If we also substract from, and add to the times of these Planets position at the *Geocentrick* Oppositions and Conjunctions, their *Semidurations* under their *Occultations*, either beyond, or on this side of the body of *Jupiter*, we shall gain the times of their *Occultations*, of *Immersions*, or *Emersions* with regard to his body. The practice of this will be also exemplify'd hereafter.

XVI.

Altho' those Eclipses of our Moon which we call *Total* are not strictly such; because the Moon never comes nearer to the *total Shadow* of the Earth than about 80,000 Miles: yet are these Eclipses of *Jupiter*'s Planets every one strictly Total. They going very deep into that *total Shadow* of *Jupiter* in every one of their Eclipses. Only we must except the IVth Planet, about its greatest Latitude: which cannot then come into his shadow at all, for a long time.

Thus, in Fig. (3) let *AC* represent the Diameter, and *AB* the Semidiameter of the Sun. Let *ac* represent the Diameter, and *ab* the Semidiameter of *Jupiter*. Let the lines *Aae* and *Cce* be tangents of the Sun, and of *Jupiter*; meeting in the vertex of the cone of the shadow of *Jupiter* at *e*, supposing he had no atmosphere: and containing the angle *aec*,

or

or *AeC*: and its half, *aeb*, or *AeB*. Let *ad* and *cd* represent the rays of the Sun twice refracted through the bottom of *Jupiter*'s atmosphere; and meeting at *d*, the vertex of that cone of the total shadow: and containing the angle *adc*, and its half *adb*. Draw the lines *aS* and *as* parallel to the axis *eb*, the former for the distance of the Sun and *Jupiter*: and the latter for the distance of *Jupiter*'s IVth or outermost Planet from his center. Draw also the line *gh* to represent the passage of that IVth Planet over the total shadow of *Jupiter*. Then run the following analogies, in order to find the lengths *eB* : *eb* : and *ed* : with the quantities of the angles *aeb*, and *adb*. While *as* : the difference of half the passage of the IVth Planet over the Shadow, from the semidiameter of *Jupiter*, is given from the Observations.

Now if we suppose, with Mr. *Flamsteed*, and Sir *Isaac Newton* formerly, that the Sun's Parallax is no more than 10″ the Earth's distance from the Sun will be about 81,000,000 measured Miles, and *Jupiter*'s distance from him (which is to that, as 52 to 10) will be about 421,000,000 such miles. But if, with Sir *Isaac Newton* at last, we takethat Parallax to be 10″$\frac{1}{2}$ (which is the mean between Mr. *Pound*'s many and most accurate Observations; which always proved to be between 9″ and 12″) the Earth's distance from the Sun will be but 77,000,000, and *Jupiter*'s distance from the Sun but 400,000,000 nearly. In this case the analogies will stand thus:

As

As is *AS*, the difference of the Sun's and *Jupiter*'s Semidiameters, = 9003 Parts : to *Sa*, the diſtance of *Jupiter* from the Sun, = 400,000,000 :: So is *AB*, the Sun's ſemidiameter, = 10000 parts: to *Be* = 444,000,000 miles, nearly: which is therefore the length of the intire axis.

From this *Be* thus found, ſubſtract *as*, or *Bb* = 400,000,000 : the difference will be *be*, or the axis of *Jupiter*'s ſhadow, if he had no atmoſphere, = 44,000,000 miles, = $\frac{1}{10}$ *Be*, nearly. Then proceed, and ſay:

As 52 : to 10 :: or as AS the diſtance of *Jupiter* from the Sun : to the diſtance of the Earth from the Sun :: So is the ſine of the Sun's apparent ſemidiameter at the earth, = 16′ : to the ſine of its apparent ſemidiameter at *Jupiter*. Or, in ſuch very ſmall angles, :: So is the angle itſelf at the Earth, = 16′ : to the angle at *Jupiter* = 3′ 5″. Again, As *Be* : to *Bb* :: or nearly as 10 : to 9 :: So is that apparent ſemidiameter of the Sun at *Jupiter*, = 3′ 5″ to its apparent ſemidiameter at the vertex *e* = 2′ 46″ = ſemiangle of the cone *aeb* or AeB. Proceed then farther, and ſay, As *as* the difference of the ſemiduration of the IVth Planet, either behind, or on this ſide *Jupiter*, and of *fg*, his ſemiduration in the total ſhadow, or, from the Obſervations, as 4′ : to 147′ :: So is *sg* = 26,63 ſemidiameters of *Jupiter*, to *bd* = 978 ſuch ſemidiameters : = 35,794,800 miles. Take that number out of 44,000,000 the difference will be 8,205,200 miles, = *ed*. Say then

farther, As $bd, = 3579$: to $de = 820$: So is the angle $aeb = 1' 46''$, to the angle $ead, = 38' \frac{1}{2}$ = double the greatest horizontal refraction of the rays of light through the bottom of *Jupiter*'s Atmosphere. Which refraction is therefore no more than $19'' \frac{1}{4}$.

Corol. (1) This Refraction therefore through the bottom of *Jupiter*'s atmosphere : is to the parallel horizontal refraction through our Earth's atmosphere :: as $19'' \frac{1}{4}$: to $33' \frac{3}{4} = 2025''$ :: *i. e.* nearly, as 1 to 100.

Corol. (2) Since therefore it is well known that the density of our Earth's atmosphere at 22 or 23 miles height, is only the 100th part of its density on the earth's surface: and, by consequence, its refractive power but the 100th part of the other; it follows, that the density and refractive power of *Jupiter*'s atmosphere on *Jupiter*'s surface, is nearly equal to that of ours at 22 or 23 miles altitude: or not much more than the 100th part of the density and refractive power of our atmosphere on the Earth's surface.

Corol. (3) Since the $5' \frac{1}{2}$ duration of *Jupiter*'s IVth Planets continuance in the penumbra, or imperfect shadow of *Jupiter*, both in his central *Immersions*, and *Emersions*; as under *Lemma* VI before; is a greater quantity than those 4, by which the passage over the breadth of half the total shadow in Eclipses is less than the passage over *Jupiter*'s bare semidiameter in *Occultations*; it thence appears, that *Jupiter*'s atmosphere makes a sensible shadow somewhat beyond those 4', and indeed must be as high,

at

at leaſt, as the 30th part of his ſemidiameter. Which is the caſe of the Earth's atmoſphere alſo.

Corol. (4.) Since the Obſervations ſhew, that the durations in *Jupiter*'s penumbra, or imperfect ſhadow, admit of conſiderable variations; as has been already noted under the VIth *Lemma* already: it appears thence that *Jupiter*'s atmoſphere is, at ſome times, much clearer than it is at others. Which is the caſe of our own atmoſphere alſo.

N.B. That I may do Juſtice here to thoſe Aſtronomers who have the moſt contributed to the application of theſe Eclipſes of *Jupiter*'s Planets to the diſcovery of the Longitude, either at land, or ſea, I muſt inform my Readers, that our own worthy countryman Mr. *Rook*, Profeſſor of Aſtronomy at *Greſham*-College, is the very firſt that I have ever met with who thus applied them; and, I ſuppoſe, the very firſt that made Obſervations of them for that purpoſe: altho' he died A. D. 1662, juſt upon his finiſhing thoſe Obſervations, and ſo never lived to perfect his deſign. Nor did he particularly recommend any of their phænomena, but only the *Immerſions* of the firſt and third, to be made uſe of; and thoſe only for the perfecting the Geography at land: and this by the compariſon of the ſame *Immerſions* as obſerv'd in different Meridians. Which method, tho' enlarged ſince to *Emerſions*, as well as *Immerſions*; and not wholly confin'd to thoſe two Planets; has been, and is ſtill the very ſame which has been

made use of by all Astronomers, but most frequently by those of the *French* Nation, for that purpose, to this very day. However, the Calculation of those Eclipses being then so very imperfect, as hardly to come nearer than to a whole hour, Mr. *Rook* saw no possibility of coming at the *Longitude at Sea* by such Eclipses. Of all which matters the Reader may see a full account in Bishop *Sprat*'s History of the Royal Society, *pag.* 183—189.

Not many years afterward, Mons. *Cassini* set about making many more, and much better Observations of these Eclipses; and made much exacter Tables for them all; and in particular contrived and published such excellent Tables for the Eclipses of the I', as will render his name famous to all Astronomical posterity. These Tables are the same which have been improv'd, and corrected, and republished by Dr. *Halley*, in the *Philosophical Transactions*, N° 214. and then by myself, in my Astronomical Lectures at *Cambridge*, *pag.* (*Edit. Lat.*) 219—224, and 372—380, and have since been reduced to an easier form by Mr. *Pound*, and printed in the *Philosophical Transactions*, N° 361. and are those that are made the most general use of at this day.

'Tis true also, that Mr. *Flamsteed* himself made no small number of Observations, and composed Tables for all the Eclipses of these Planets; and contrived a mechanical Instrument for finding their situations at any time. See *Philos. Transact.* N° 178.

'Tis

'Tis farther true, that his Relation and Assistant Mr. *Hodgson*, has preserved those Tables of Mr. *Flamsteed*'s, and has, in some measure, improv'd them; and from them has now, for several years, given us very valuable Calculations of all their Eclipses, in the *Philosophical Transactions*. Which Calculations have been of great use to me in composing this Treatise about them, as the Reader will perceive hereafter.

'Tis true withal, that Mr. *Bradley* has from *Cassini*'s, and Mr. *Pound*'s, and his own and others Observations composed and printed about 19 years ago a sett of Astronomical Tables, for these secondary Planets about *Jupiter*, and given them to Dr. *Halley*, as an Appendix, or second part of his Astronomical Tables, the publication whereof hath been very long, and very much desired by the Astronomical World.

I must however do justice to Mr. *Derham*, and to several foreigners, whose Observations of many of these Eclipses have been published in our *Philosophical Transactions*, or elsewhere; and especially to our own long and accurate observer of them, Mr. *Lynn*, of *Southwick*, near *Oundle* in *Northamptonshire*: who will be farther taken particular notice of presently; as having, I think, first of all suggested to the Astronomical World that Phænomenon of these Planets which is the best of all other for the discovery of the Longitude: altho' for the want of sufficient accuracy in several of their Theories, the use of that Phænomenon can be hitherto but rarely of considerable advantage to us.

XVII.

XVII.

Altho' the *Eclipses* of *Jupiter*'s Planets have been hitherto principally considered, and observed by Astronomers; Nay, even few of these Eclipses but those of the I^st^ have been thought of for the Discovery of the Longitude, either at land or sea; yet do the *Occultations* of them by the body of *Jupiter*, both before and after their central Oppositions, and Conjunctions, but especially in the latter case, highly deserve their consideration, and observation for that purpose. These *Occultations* are usually in number three for one of the Eclipses. And since two of these three are between us, and the body of *Jupiter*; and are therefore no way subject to any penumbra, or refraction through *Jupiter*'s Atmosphere; they are, on that account, to be better observed than the Eclipses themselves. Nor ought these Occultations therefore, tho' they require somewhat sharper eyes, and longer Telescopes than those Eclipses, to be wholly neglected when we aim to discover the Longitude by these Planets. The middle times between *Immersions* and *Emersions* being somewhat more easily calculated, and giving us Observations not less fit for our present purpose, than the Eclipses themselves.

XVIII.

There is also another very remarkable Phænomenon belonging to these Planets, which has been less considered and observ'd than even those

those *Occultations:* I mean their apparent mutual opposite *Transits*, by, or in *Conjunction* with one another. These, by meeting each other, double their natural respective velocities; and determine the times of such their apparent *Transits*, or *Conjunctions* more nicely than either the *Occultations*, or *Eclipses* themselves. These *Transits*, or *Conjunctions* also are usually free from *Jupiter*'s penumbra, and refraction, and too great neighbourhood. All which are known to be great obstructions to the advantageous view of these Planets. Accordingly Mr. *Derham* several times complains of the difficulty of observing these Eclipses near the Opposition of *Jupiter* to the Sun; by reason of the glaring brightness of *Jupiter* himself, just by them at that time: and which most and longest affects those of the innermost, which otherwise are both the best and most numerous of them all. *Philos. Transact.* N° 402. These *Transits*, or *Conjunctions* are in number, compared with the Eclipses, nearly as 3 to 2. They may also be observed to less than a single minute in time: nay, when belonging to the I^st^ and II^d^, and not too remote from *Jupiter*, they may sometimes be observed to half a minute, or nearer; as our accurate observer of them Mr. *Lynn* informs us, *Philosoph. Transact.* N°. 393. where he moreover, first of all, fairly proposes them to be made use of in the Discovery of the Longitude also. And this very justly; because, when the Theories of these Planets come to be perfected,

ed, they will determine that Longitude nearer than either the *Occultations*, or *Eclipses* themselves.

N.B. The Observations of *Jupiter*'s Planets hitherto made, having been almost wholly confin'd to their *Eclipses*; as has been already noted, which are always near their Oppositions beyond *Jupiter*: The Observations of the *Occultations*, now proposed, being withal ever near their Conjunctions, or Oppositions, either on this, or the other side of *Jupiter*, afford us no Observations about the Quadratures and Octants: which yet ought to be known in order to compleat their Theories. But then, these mutual *Transits*, or *Conjunctions* being sometimes near their Quadratures, and frequently at or near their Octants, will supply the former defect; and afford Astronomers very exact Observations for those Quadratures and Octants, in order to their perfecting those Theories. Nor ought we to forget, that by the means of these mutual *Transits*, or *Conjunctions*, the first, the third, and the fourth Planets, which move more evenly, will already assist us in stating the motions of the second, which are so much more irregular, better than formerly: to the great advantage of this curious part of Astronomy.

XIX.

Since, as we have taken notice before, there are commonly three Occultations for every Eclipse of these Planets: and three Conjunctions for two Eclipses: And since the first Planet is

is eclipſed 13 times in 23 days, as Mr. *Pound* truly informs us, *Philoſoph. Tranſact.* N° 361, and the ſecond, half as often, or $6\frac{1}{2}$ times: the third, a quarter as often, or $3\frac{1}{4}$ times: and the fourth once, and all in the ſame 23 days: The whole ſum of *Eclipſes*, *Occultations*, and *Conjunctions*, capable of being made uſe of in the diſcovery of the Longitude; I mean this aſſoon as the Theories and Tables of theſe Planets are brought to perfection, will be above five times and an half as many as there are days of the year. For 13 and $6\frac{1}{2}$ and $3\frac{1}{4}$ and 1 are $23\frac{3}{4}$ Eclipſes: to which add about 36 Conjunctions, and about 70 Occultations, the ſum will be in all about 130 Phænomena for 23 days, or above $5\frac{1}{2}$ to each day; I mean, through ſuch parts of the year as *Jupiter* and his Planets can be ſeen. Of which the next *Lemma* will treat particularly.

XX.

Altho' therefore we make a reaſonable allowance (1.) for thoſe 6 weeks in 13 months when *Jupiter* and his Planets are too near their Conjunction with the Sun to be ſeen at all by any: (2.) for that day time when we cannot ſee them, tho' they be ſufficiently diſtant from the Sun, and above our horizon: (3.) for ſuch parts of the night time as they are themſelves beneath our horizon: and (4.) for the interpoſition of clouds; which too often, eſpecially in theſe northern regions obſcure the ſight of them: Yet ſhall we ſtill in general, and one with another, have near as many opportunities for view-

ing one or other of these Phænomena, and for discovering the Longitude by them, as there are days in the year. I mean this still assoon as their Theories are brought to perfection: of which presently. But more of this matter under the IVth Problem hereafter.

XXI.

From the premisses it is justly to be expected, that a pretty compleat Theory of these Planets may be obtained, upon *proper* and continual *Observations* of all those their *Eclipses*, *Occultations*, and *Conjunctions*, which are visible, in 14 $\frac{1}{2}$ month; that being, as we have already demonstrated, the grand Period of the motions of those three innermost, which are chiefly to be regarded in these Observations for the discovery of the Longitude. In order to prepare the way for which *proper Observations*, I proceed to the Lemmata following.

XXII.

If an eye be placed vastly remote from *Jupiter*, and his Planets; as every eye upon our earth always is: And if that eye be in, or very near the same plain with those Planets; as every such eye is: And if that eye view those Planets, as they revolve about *Jupiter*'s center, in circles, concentrical to *Jupiter*; which is very nearly the case of every such eye also: Those Planets will appear to such an eye to move backwards and forwards along those Diameters of their several Orbits, which are perpendicular

pendicular to the line of the earth's diſtance from *Jupiter:* and their even circular motions, will be truly repreſented by the uneven diviſions made upon ſuch diameters, according to lines of *Sines*, and not otherwiſe. Thus, in Fig. (4.) to an eye at E: at a vaſt diſtance from *Jupiter* at C: altho' each of theſe Planets be really placed in its own circular circumference MRNS, yet will it appear to our eye, which cannot perceive the difference of the diſtances on this or on the other ſide of the Diameter RS, no otherwiſe than if the Planet were placed in that Diameter. And their apparent diſtances from *Jupiter*'s center will be the *Sines* of the angles of their real motions from or to *Jupiter*'s center; or, which comes to the ſame, from or to their Oppoſitions at *M*, and Conjunctions at *N*, and not otherwiſe. Thus, *Ad* $\alpha\delta$ on one ſide: as alſo *ad* $\alpha\delta$ on the other ſide, are *Sines* of the angles DCA : DCα : and of dCα: And the Planet at *A*, or *a*, at *a* or α, will appear to the eye at *E*, no otherwiſe than if it really were placed at *B* and β: at *b* and β. Now, ſince *AD* is equal and parallel to *BC* and $\alpha\delta$ equal and parallel to βC: as alſo *ad* equal and parallel to *bC:* and $\alpha\delta$ equal and parallel to βC: and ſince the former are no other than the very *Sines* of their arcs and angles, from or to their Oppoſitions and Conjunctions, the latter, which are equal and parallel to them reſpectively, are alſo the *Sines* of the ſame arcs and angles, and ſo every where. This is ſo obvious a Propoſition, as needs no farther illu-

ſtration: and is throughly confirmed by all our Obſervations of thoſe Planets.

XXIII.

If we add or ſubſtract the Time belonging to the *Parallax of the* annual *Orb*, to, or from the Time of the Poſition of any of theſe Planets at the *Heliocentrick* Axis; we gain the Time of their Poſition at the *Geocentrick* Axis: And *vice verſâ*.

Thus if in Fig. (5) *S* repreſent the Sun, *I* the Body of *Jupiter*, and *E* the Earth, in any particular Poſition, the Line *S A* is the *Heliocentrick* Axis: and the Line *E A* the *Geocentrick*. And the Difference between them is the Angle *E I S*, or its Equal, *A I a:* which is called the *Parallax of the* annual *Orb:* and by addition or ſubſtraction reduces the poſitions at one Axis, to thoſe of the other at the ſame Time. So that if one be given, the other is eaſily diſcovered alſo.

Corollary (1). Since the *Heliocentrick* and *Geocentrick* places of *Jupiter* are conſtantly ſet down in our vulgar *Ephemerides*, ſuch as thoſe of Mr. *Parker* and Mr. *Weaver*, their *difference*, or the *Parallax of the Orb* is eaſily found by ſubſtracting the leſſer from the greater.

Coroll. (2). Since this difference or Parallax vaniſhes both in *Jupiter*'s Oppoſition to, or Conjunction with the Sun, at thoſe times we allow nothing for this Parallax. But then, we are to *ſubſtract* the Parallax out of the *Heliocentrick* place, for 6 ½ months; from the Oppoſition

position to the Conjunction: And from the Conjunction to the Opposition we are to add it, for 6 ½ months: in order to gain their *Geocentrick* places. And it may be noted, that as the last Opposition of *Jupiter* to the Sun was at the end of *August*, 1737. so was the last Conjunction *March* 16th, 173⅞, and the next Opposition will be *October* 7th following, as those Ephemerides inform us. An example or two will make this matter easy.

November 2d. 1737. at 6 in the evening, the Heliocentrick place of *Jupiter* was, by the forementioned Ephemerides, in ♓ 13°. 38′. His Geocentrick place was then, ♓ 24°. 15′. Their difference therefore was 10°. 37′. which was the *Parallax of the Orb* at that time. So *November* 18th the same year, at 6 in the evening also, the Heliocentrick place of *Jupiter* was ♓ 14°. 21′. His Geocentrick place was then, ♓ 25°. 48′. their difference was 11°. 27′. which was then the *Parallax of the Orb* also.

But because the angular motion of these Planets is sufficiently unequal, this Parallax must be still reduced to its different intervals in all the four Planets. Thus the first Parallax of 10°. 37′. is gone over by the several Planets in the intervals following:

		h.	′
I.	in	1	15½
II.	in	2	31
III.	in	5	6
IV.	in	11	50

Thus

Thus the ſecond Parallax, of 11°. 27′. is gone over in the intervals following:

		h.	′
I.	in	1	20
II.	in	2	40
III.	in	5	25
IV.	in	12	55

As a conſtant direction for which allowance, the Reader may conſult the following Table.

Degrees

Degrees of the Parallax of the Orb; with the hours and minutes correſponding to them: in order to find the *Geocentrick* places of *Jupiter's* Planets, from their *Heliocentrick* places given.

grad.	1	2	3	4	5	6	7	8	9	10	11	12
	h ′	h ′	h ′	h ′	h ′	h ′	h ′	h ′	h ′	h ′	h	h ′
I	0 7,1	0 14,16	0 21,2	0 28,3	0 35,4	0 42,5	0 49,6	0 56,6	1 3,7	1 10,8	1 17,8	1 25
II	0 14,2	0 28,4	0 42,6	0 56,8	1 11	1 25,2	1 39,4	1 53,6	2 7,8	2 22	2 36,2	2 50
III	0 28,7	0 57,4	1 26,1	1 54,8	2 23,5	2 52,2	3 20	3 49	4 18	4 47	5 15,7	5 44
IV	1 7	2 14	3 21	4 28	5 35	6 42	7 49	8 56	10 3	11 10	12 17	13 24

		°	h		°	h	′		
These Numbers are thus found	I	360 :	42,5	::	1 :	,118	=	7,1
	II	360 :	85,28	::	1 :	,237	=	14,2
	III	360 :	172	::	1 :	,477	=	28,7
	IV	360 :	402	::	1 :	1,117	=	1^h 7′.

N. B. The finding the firſt number gives all the other numbers: which are only 2, 3, 4, *&c.* times thoſe firſt numbers. And as for the inſertion of them upon the *Longitude Sector*, of which preſently, *there is* no difficulty in it: ſince the very ſame numbers which exhibit the *Sines* of the 12 firſt degrees, give the quantities of this *Parallax* alſo. The diviſions being *in a manner equal all the way.*

XXIV.

The ways by which the Eccentricity of the Orbits of these Planets may be discovered, are these three: (1.) *That* of noting their greatest errors, with regard to the Calculations from their mean motions: (2.) That by measuring their *Utmost Elongations* from *Jupiter*, by Micrometers: and (3.) That by the different durations of their Occultations, and chiefly those on this side *Jupiter*. These durations in circular motions would be all equal, but in eccentrick and elliptick ones will be as the squares of their different distances from *Jupiter*'s center, reciprocally: and by consequence will be very fit for the accurate determinations of the quantity of such eccentricity. While no more than an hundredth part of difference in eccentricity, becomes a fiftieth part in apparent motion.

N. B. It may be here remarked, that the *Utmost Elongations* are at present taken notice of here: Not with any intention of discovering the Longitude by them: for which they are not at all fit; but to afford opportunities at present to such as have very long Telescopes, and very good Micrometers belonging to them, for discovering the *eccentricity* of their Orbits, in order to the perfecting their Theories. After the attainment of which perfection the noting such *Utmost Elongations* may be intirely omitted.

XXV. A

XXV.

A Description of the Longitude Sector. Fig. (4.)

Take two ſmall planks or boards of deal, each of them ſomewhat above 6 feet long, and full 5 inches broad. Join them ſo by hinges, that they may open and ſhut, as common Sectors do. Paſte good white paper upon thoſe inward ſides that are to cloſe one upon another: and thereon draw four double ſtrait parallel lines, at proper diſtances from one another, for ſo many ſemidiameters of the Orbits of *Jupiter*'s Planets; to be afterward divided according to ſo many lines of *Sines:* as has been already explain'd. Then determine a radius, or ſemidiameter for each of their Utmoſt Elongations, both ways; in the proportions that agree to their true diſtances from the center of *Jupiter*. The Radius for the firſt, or innermoſt muſt then be 16,184 inches: and its intire diameter, when the Sector is opened, 32,368 inches. That for the ſecond muſt be 25,76,and its diameter 51,52. That for the third muſt be 41,08, and its diameter 82,16. That for the fourth or outmoſt muſt be the whole length of the half Sector 72,24, and its diameter 144,48. Beſides the ſemidiameter for *Jupiter*'s body, to be determined by a line drawn croſs the inſtrument on both ſides, at the diſtance of 2,71 inches from the center; and ſo containing 5,42 inches for his intire diameter.

 Theſe

Theſe meaſures will always repreſent the Orbits of theſe Planets truly, as to their *proportions*, with which we are chiefly concern'd: altho' when the Earth is nearer to, or farther from *Jupiter* and his Planets, than at their mean diſtance, they repreſent what is conſiderably unequal in apparent diameter, or angular meaſure: with which we are very rarely concerned. Then divide each of theſe double lines, or rather a middle line between them, according to the line of Sines: as will be more fully directed preſently. All this is to be done by occult lines, without Ink, or with the leaſt uſe of it poſſible; that the numbers may be no hindrance when the hours, half hours, and quarters, or even the minutes themſelves are to be determined by them. For that is what muſt be done in the next place: I mean to ſet the hours, half hours, quarters, &c. *within* each line, in their proper places; and to note them with black Ink: that they may be ſeen, and uſed upon all occaſions; as will be more fully directed preſently. After which you are to divide the two edges of the Sector, on the ſame plain with the reſt, and on both ſides the center, into inches, and decimals of an inch alſo. But you are ſtill to begin all your numbers for the hours, *&c.* from the middle of the Sector, on the upper of the two lines; or from the Oppoſition beyond *Jupiter:* and to count from your right hand, to your left; till you come to its firſt Utmoſt Elongation: but are then

then to turn, and count backward, along the lower of the two lines, from your left hand, to your right, till you come to the ſecond Utmoſt Elongation: and then are to return, and, according to the order of nature, to count from your right hand, to your left, till you come to the middle where you began. And thus are you to proceed diſtinctly with the hours, *&c.* of every one of theſe Planets. And all this becauſe, if we could ſee the motions of theſe Planets about *Jupiter* with our naked eyes, they would then appear to go thus, from Weſt to Eaſt perpetually; and would take their conſtant courſes in a way perfectly analogous to that before us.

N. B. Becauſe this Scale, which was to include the intire Orbits of all theſe Planets, will not be exact enough for determining their mutual *Conjunctions*; which are of the greateſt conſequence in our preſent deſign; we ought to mark other hours, with the very minutes belonging to them, upon the *outſides* of the forementioned double parallel lines, tho' in the parts neareſt the center only. This ſecond Scale ought to be three times as large as the former: and need not reach quite ſo far as the Orbit of the ſecond Planet in the firſt. For as beyond the third there can be no ſuch mutual *Conjunctions* at all; ſo beyond the ſeconds Orbit there cannot be very many, nor very good ones; becauſe of the length of the Periods of the third and fourth: and becauſe of the comparative

slowness of their motions there. Whence this neglect of the outmost parts, that are almost useless; will permit us to have a larger Scale for the parts most useful: which are always those not far from *Jupiter*. Not less indeed than will give us intire leave to note every single minute of time, in almost every one of these Planets; without any confusion: and this almost in the very remotest parts here made use of. Which advantages will abundantly compensate the forementioned small disadvantage in the omission, under this Scale, of those parts of the Orbits of the second, third, and fourth Planets which are most remote from the center. This only we are to take care of, that we sufficiently distinguish the divisions belonging to this Scale, from those belonging to the other: which will be best done by marking both the Sines, and the hours and minutes thereto belonging with *red* Ink; as the other are supposed already to be marked with *black*.

N.B. We may also, if we please, make distinct marks upon the *Sines* of the first 12 degrees of this Scale for the *Parallax of the Orb:* and this distinctly both ways from the center, and for every one of these Planets, and with the same *red* Ink also: That *Parallax* requiring no new divisions: and properly belonging to the parts nearest the center, as this Scale for these parts of the Orbits do. Its use is to denote the place where the perpendicular falls from every Planet upon that diameter on which the

the Sines are noted: and by the ſubſtraction or addition of their ſemidurations at its poſition in the Heliocentrick Axis in the total ſhadow of *Jupiter*, to indicate the times of the *Immerſions* or *Emerſions* in thoſe Eclipſes; to be compared with the ſame times found by calculation; and to prevent all poſſible error in ſuch calculations.

N. B. Becauſe of this double Scale, I ſhall preſently ſet down a double Table of Sines; the latter thrice as large as the former; in order to the ready inſertion of the hours and parts of an hour in their proper places, diſtinctly by each Scale, altho' the Tables for the hours and parts themſelves require no ſuch double Table: but only that each hour and its parts, without any confuſion, be applied to the diviſions in its proper Scale.

XXVI.

Tables of Sines, *for dividing the ſemidiameters of theſe Planets on the Longitude Sector, in the proportions already determined. The latter numbers of inches and decimals belonging to the larger Scale, noted with* red *Ink; and being always just thrice as large as the former numbers, for the ſmaller Scale, noted with* black: *and all to be meaſured from the center.*

Radius.	Inches.	Radius.	Inches.
I. - - -	16,184	I. -	48,552
II. - -	25,76	II.	beyond the Sector.
III. -	41,08	III.	beyond it.
IV. -	72,24	IV.	beyond it.

Sines

Sines of 5 Degrees.

	Inches.		Inches.
I. - - -	1,41	- -	4,23
II. - -	2,24	- -	6,72
III. -	3,58	- -	10,74
IV. -	6,29	- -	18,87

Sines of 10 Degrees.

I. - - -	2,81	- - -	8,43
II. - -	4,47	- -	13,41
III. -	7,22	- -	21,66
IV. -	12,54	- -	37,62

Sines of 15 Degrees.

I. - - -	4,19	- -	12,57
II. - -	6,66	- -	19,98
III. -	10,63	- -	31,89
IV. -	18,61	- -	55,83

Sines of 20 Degrees.

I. - - -	5,53	- -	16,59
II. - -	8,81	- -	26,43
III. -	14,06	- -	42,18
IV. -	24,71	- -	74,13

Sines of 25 Degrees.

I. - - -	6,84	- -	20,52
II. - -	10,89	- -	32,67
III. -	17,37	- -	52,11
IV. -	30,53	- -	beyond the Sector.

Sines

Sines of 30 Degrees: or half the Radius.

	Inches.		Inches.
I.	8,09		24,27
II.	12,88		38,64
III.	20,54		61,62
IV.	36,12		beyond the Sector.

Sines of 35 Degrees.

I.	9,28		27,84
II.	14,77		44,31
III.	23,56		70,68
IV.	41,43		beyond it.

Sines of 40 Degrees.

I.	10,4		31,2
II.	16,56		49,68
III.	26,4		beyond it.
IV.	46,43		beyond it.

Sines of 45 Degrees.

I.	11,44		34,32
II.	18,22		54,66
III.	29,05		beyond it:
IV.	51,08		beyond it.

Sines of 50 Degrees.

I.	12,04		37,02
II.	19,73		59,19
III.	31,54		beyond it.
IV.	55,34		beyond it.

Sines

Sines of 55 Degrees.

	Inches.	Inches.
I. - - -	13,25	- - 39,75
II. - -	21,1	- - 63,3
III. -	33,65	- - beyond it.
IV. -	59,14	- - beyond it.

Sines of 60 Degrees.

I. - - -	14,02	- - 42,06
II. - -	22,3	- - 66,9
III. -	35,57	- - beyond it.
IV. -	62,55	- - beyond it.

Sines of 65 Degrees.

I. - - -	14,66	- - 43,88
II. - -	23,35	- - 70,05
III. -	37,23	- - beyond it.
IV. -	65,46	- - beyond it.

Sines of 70 Degrees.

I. - - -	15,2	- - 45,6
II. - -	24,2	- - beyond it.
III. -	38,6	- - beyond it.
IV. -	67,7	- - beyond it.

Sines of 75 Degrees.

I. - - -	15,63	- - 46,89
II. - -	24,89	- - beyond it.
III. -	39,68	- - beyond it.
IV. -	69,72	- - beyond it.

Sines

Sines of 80 Degrees.

	Inches.	Inches.
I.	15,94	47,82
II.	25,37	beyond it.
III.	40,46	beyond it.
IV.	71,23	beyond it.

N. B. The Sines of 90 Degrees are the ſame with the *Radii*, or *Sinus Toti* already ſet down.

N. B. The intermediate Sines have their differences ſo nearly equal, that they hardly ſtand in need of diſtinct Calculations.

N. B. This Table is thus made, by the Logarithms.

As Radius	= 10,00000
To Sin. 5°	= 8,94030
So Log. of 16,184 inches	= 1,20809
To Log.	= 0,14838 =

1,41 inches, as in the Sine of 5° of the *black* Ink, in this Table. And ſo for ever.

XXVII.

A Table of the hourly motions of Jupiter's *Planets, in degrees, and decimals of a degree, for dividing their Orbits into* hours *and* minutes; *upon the foundation of the foregoing diviſions by the* Sines.

I^ſt Planet's horary motion in degrees and decimals of a degree.

h	°	h	°
1 =	8,475	3 =	25,425
2 =	16,950	4 =	33,9
		5 =	42,375

h	°	h	°
5 =	42,375	8 =	67,8
6 =	50,850	9 =	76,275
7 =	59,375	10 =	84,75 = 90° — 5,25

Say then, 8,475° : 60′ :: 5,25° : 37,2′.

Now 10ʰ 37,2′, taken 4 times, gives 42ʰ, 28,6′ = Period of this Planet, and itself is a quadrant to the first utmost Elongation.

N. B. These numbers are found thus: 1ʰ = 60′. Then say, 42ʰ, 28,6′ : 360° : : 1ʰ : 8,475°, and that number added to itself, as far as 10 times, gives all the other numbers, which serve for dividing the first quadrant from the Geocentrick Opposition.

IIᵈ Planet's horary motion, in degrees, and decimals of a degree.

h	°	h	°
1 =	4,22	12 =	50,64
2 =	8,44	13 =	54,86
3 =	12,66	14 =	59,08
4 =	16,88	15 =	63,30
5 =	21,10	16 =	67,52
6 =	25,32	17 =	71,74
7 =	29,64	18 =	75,96
8 =	33,76	19 =	80,18
9 =	37,98	20 =	84,42
10 =	42,20	21 =	88,66 = 90° — 1,34°
11 =	46,42		

Then say as before, 4,22° : 60′ :: 1,34° : 19′½.

And 21ʰ with 19′½ taken 4 times, gives 85,18 = 3ᵈ 13ʰ 18′ = Period of this Planet: and itself is a quadrant to the first utmost Elongation.

IIIᵈ Pla-

III[d] Planet's horary motion, in degrees, and decimals of a degree.

h		°	
1	=	2,0931	
2	=	4,1862	
3	=	6,2793	
4	=	8,3724	
5	=	10,4655	
6	=	12,5586	
7	=	14,6517	
8	=	16,7448	
9	=	18,8379	
10	=	20,9310	
11	=	23,0241	
12	=	25,1172	
13	=	27,2103	
14	=	29,2034	
15	=	31,3965	
16	=	33,4896	
17	=	35,5827	
18	=	37,6758	
19	=	39,7689	
20	=	41,8620	
21	=	43,9551	
22	=	46,0482	
23	=	48,1413	
24	=	50,2344	= I day.
1	=	52,3275	
2	=	54,4206	
3	=	56,5137	
4	=	58,6068	
5	=	60,6999	

 6 = 62,7930

h	°
6 =	62,7930
7 =	64,8861
8 =	66,9792
9 =	69,0723
10 =	71,1654
11 =	73,2585
12 =	75,3516
13 =	77,4447
14 =	79,5378
15 =	81,6309
16 =	83,7240
17 =	85,8171
18 =	87,9102 = 90° — 2,0898° = 59′,54″

And 1 day, 18^h 59′ 54″ taken 4 times, is = 171^h 59′ 36″ = 7^d 3^h 59′ 36″ = Period of this Planet, and itself is a quadrant to the first utmost Elongation.

IVth Planet's horary motion in degrees, and decimals of a degree.

h	°
1 =	0,89534
2 =	1,79068
3 =	2,68602
4 =	3,58136
5 =	4,47670
6 =	5,37204
7 =	6,26738
8 =	7,16272
9 =	8,05806
10 =	8,95340
11 =	9,84874

12 =

h		o	
12	=	10,74408	
13	=	11,63942	
14	=	12,53476	
15	=	13,43010	
16	=	14,32544	
17	=	15,22078	
18	=	16,11612	
19	=	17,01146	
20	=	17,90680	
21	=	18,80214	
22	=	19,69748	
23	=	20,59282	
24	=	21,48816	= I day.
1	=	22,38350	
2	=	23,27884	
3	=	24,17418	
4	=	25,06952	
5	=	25,96486	
6	=	26,86020	
7	=	27,75554	
8	=	28,65088	
9	=	29,54622	
10	=	30,44156	
11	=	31,33690	
12	=	32,23224	
13	=	33,12758	
14	=	34,02292	
15	=	34,91826	
16	=	35,81360	
17	=	36,70894	
18	=	37,60428	
19	=	38,49962	

20 =

h		o	
20	=	39,39496	
21	=	40,29034	
22	=	41,18568	
23	=	42,08102	
24	=	42,97636	= II days.
1	=	43,87170	
2	=	44,76704	
3	=	45,66238	
4	=	46,55772	
5	=	47,45306	
6	=	48,34840	
7	=	49,24374	
8	=	50,13908	
9	=	51,03442	
10	=	51,92976	
11	=	52,82510	
12	=	53,72044	
13	=	54,61578	
14	=	55,61112	
15	=	56,40646	
16	=	57,30180	
17	=	58,19614	
18	=	59,09148	
19	=	59,98682	
20	=	60,88216	
21	=	61,77740	
22	=	62,67274	
23	=	63,56808	
24	=	64,46342	= III days.
1	=	65,35876	
2	=	66,25410	
3	=	67,14944	

4 =

h	o
4	= 68,04478
5	= 68,94012
6	= 69,83546
7	= 70,73080
8	= 71,62614
9	= 72,52148
10	= 73,41682
11	= 74,31216
12	= 75,20750
13	= 76,10284
14	= 76,99818
15	= 77,89352
16	= 78,78886
17	= 79,68420
18	= 80,57954
19	= 81,47488
20	= 82,37022
21	= 83,26560
22	= 84,16094
23	= 85,05628
24	= 85,95162 = IV days.
1	= 86,84696
2	= 87,74230
3	= 88,63764
4	= 89,53298 = 90 — 0,46702

Then say as before, 0,89534° : 60′ : : 0,46702° : 31′ $\frac{1}{4}$.

And $4^d\ 4^h\ 31'\ 15''$ taken 4 times gives $402^h\ 5' = 16^d\ 18^h\ 5'$ = Period of this Planet: and itself is a quadrant to the first utmost Elongation.

N. B. These

N. B. These Tables are sufficient for dividing the first quadrants, where the hours begin at the center; and by allowing the difference of those hours from the center in the second quadrants, as the Planets appear to return along the same Semidiameters, will serve for the divisions of that also. But then the third quadrants, not beginning with compleat hours, and having no divisions parallel to them yet made for their guidance, must have distinct Tables made for them, as follows. In order to which find the parts of the first hours thus, for the several Planets.

	′ degrees.		degrees.		degrees.
I.	60 : 8,475	::	45,7	:	6,455
II.	60 : 4,22	::	21	:	1,47

III. Begins naturally with an hour very nearly, so the numbers for the first quadrant serve for this also.

IV. 60 : 0,89534 :: 57,4 : 0,85555

To which last numbers those for an hour are to be still added, as follows.

I.

h		°
1st	=	6,455
	+	8,475
2d	=	14,930
3d	=	23,405
4th	=	31,88
5th	=	40,355
6th	=	48,830
7th	=	57,305

8th =

h		°
8	=	65,780
9	=	74,255
10	=	82,730
	+	2,020
	=	84,75 = 90° — 5,25°

Then ſay, as before, 8,475° : 60′ : : 5,25° : = 37,2′, which, with half the Period 21^h 14′ 18″ and the 10 hours, are = 1^d 7^h 51′ 27″ and very nearly equal to three quarters of the Period of this Planet: and itſelf is a quadrant, to the ſecond Utmoſt Elongation.

II.

h		°
1	=	1,47
	+	4,22
2	=	5,69
3	=	9,91
4	=	14,13
5	=	18,35
6	=	22,57
7	=	26,79
8	=	31,01
9	=	35,23
10	=	39,45
11	=	43,67
12	=	47,89
13	=	52,11
14	=	56,33
15	=	60,55
16	=	64,77
17	=	68,99

h		°
18	=	73,21
19	=	77,43
20	=	81,65
21	=	85,87

Now 85,87 + 422 = 90,09° and 90,09° — 1,47° = 88,62° = 90° — 1,38°.

Then say, as before: 4,22° : 60′ :: 1,38° : 19′ 36″, which, with half the Period 1^{d} 18^{h} 38′ 57″, and the 21^{h} is 2^{d} 15^{h} 58′ 33″, and is very nearly equal to three quarters of the Period of this Planet; and itself is a quadrant to the second Utmost Elongation.

III.

h		°
1	=	2,093
	+	2,093
2	=	4,186
3	=	6,279
4	=	8,372
5	=	10,465
6	=	12,558
7	=	14,651
8	=	16,744
9	=	18,837
10	=	20,930
11	=	23,023
12	=	25,116
13	=	27,209
14	=	29,302
15	=	31,395
16	=	33,488
17	=	35,581

18 =

h		o	
18	=	37,674	
19	=	39,767	
20	=	41,860	
21	=	43,953	
22	=	46,046	
23	=	48,139	
24	=	50,232	= I day.
1	=	52,325	
2	=	54,418	
3	=	56,511	
4	=	58,604	
5	=	60,697	
6	=	62,790	
7	=	64,883	
8	=	66,976	
9	=	69,069	
10	=	71,162	
11	=	73,255	
12	=	75,348	
13	=	77,441	
14	=	79,534	
15	=	81,627	
16	=	83,720	
17	=	85,813	
18	=	87,906	
19	=	89,999	

So 1^d 19^h taken four times is 7^d 4^h which is very nearly equal to the Period of this Planet: and itſelf is a quadrant to the ſecond Utmoſt Elongation.

IV.

h		°	
1ft	=	0,85555	
	+	0,89534	
2	=	1,75089	
3	=	2,64623	
4	=	3,54157	
5	=	4,43691	
6	=	5,33225	
7	=	6,22759	
8	=	7,12293	
9	=	8,01827	
10	=	8,91361	
11	=	9,80895	
12	=	10,70429	
13	=	11,59963	
14	=	12,49497	
15	=	13,39031	
16	=	14,28565	
17	=	15,18099	
18	=	16,07633	
19	=	16,97167	
20	=	17,86701	
21	=	18,76235	
22	=	19,65769	
23	=	20,55303	
24	=	21,44837	= I day.
1	=	22,34371	
2	=	23,23905	
3	=	24,13439	
4	=	25,02973	
5	=	25,92507	

6 = 26,

h		o
6	=	26,82041
7	=	27,71575
8	=	28,61109
9	=	29,50643
10	=	30,40177
11	=	31,29711
12	=	32,19245
13	=	33,08779
14	=	33,98313
15	=	34,87847
16	=	35,77381
17	=	36,66915
18	=	37,56449
19	=	38,45983
20	=	39,35517
21	=	40,25051
22	=	41,14585
23	=	42,04119
24	=	42,93653 = II days.
1	=	43,83187
2	=	44,72721
3	=	45,62255
4	=	46,51789
5	=	47,41323
6	=	48,30857
7	=	49,20391
8	=	50,09925
9	=	50,99459
10	=	51,88993
11	=	52,78527
12	=	53,68061
13	=	54,57595

14 = 55,

h		o	
14	=	55,47129	
15	=	56,36663	
16	=	57,26197	
17	=	58,15731	
18	=	59,05265	
19	=	59,94799	
20	=	60,84333	
21	=	61,73867	
22	=	62,63401	
23	=	63,52935	
24	=	64,42469	= III days.
1	=	65,32003	
2	=	66,21537	
3	=	67,11071	
4	=	68,00605	
5	=	68,90139	
6	=	69,79673	
7	=	70,69207	
8	=	71,58741	
9	=	72,48275	
10	=	73,37809	
11	=	74,27343	
12	=	75,16877	
13	=	76,06411	
14	=	76,95945	
15	=	77,85479	
16	=	78,75013	
17	=	79,64547	
18	=	80,54081	
19	=	81,43615	
20	=	82,33149	
21	=	83,22683	

22 = 84,

h		o
22	=	84,12217
23	=	85,01751
24	=	85,91285 = IV days.
1	=	86,80819
2	=	87,70353
3	=	88,59887
4	=	89,49421 = 90 — ,50579

Then ſay, $0,89534^{\circ} : 60' :: 50579^{\circ} : 33' 51''$ which with half the period in days and hours $8^{d}\ 9^{h}\ 0'\ 00\frac{1}{2}''$ and theſe $4^{d}\ 4^{h}$ are $= 12^{d}\ 13^{h}\ 33'\ 51''$ and very nearly equal to three quarters of the Period of this Planet: and itſelf a quadrant, to the ſecond Utmoſt Elongation.

N. B. Theſe latter Tables are ſufficient for dividing the third Quadrants, where the hours do not begin at the center: and by allowing the difference of theſe hours from the center in the fourth Quadrants, as the Planets appear to return along the ſame ſemidiameters, they will ſerve for the diviſions of that alſo.

XXVIII.

A Deſcription of the Longitude Refracting Teleſcope.

This is no other than ſuch a Refracting Teleſcope, of nine foot long, which has *ſeven* Object Glaſſes inſtead of *one*, all of the ſame focal length, as ground together on the ſame tool; and placed in the ſurface of a ſphere of the ſame radius. It has, like other Teleſcopes, only

only one Eye Glass, but that a very broad one, of 2 $\frac{1}{2}$ inches diameter. Its Tube is much wider at the Object Glasses, than at the Eye Glass. Its intention is to bring *Jupiter* and his Planets to the eye, notwithstanding the rolling of a ship at sea. For that rolling can do no more than remove those Objects apparently from one Object Glass to another; while they still come all to the eye through some one of them, and through the single Eye Glass; in the very same manner as if there were but a single Object Glass also; as in other Telescopes. Whether we shall be ever obliged to have more than seven Object Glasses, as we easily may, experience only can fully determine. I believe that if we can procure a considerably broader Eye Glass, as one of three inches, instead of this of 2 $\frac{1}{2}$ inches: which I have not hitherto been able to do: we should have no great occasion for more than the present number of seven. For since common Telescopes of this length have usually Eye Glasses little or nothing broader than one inch; this Telescope, of seven Object Glasses, and one Eye Glass of three inches broad; has about 63 times the advantage for finding and keeping an Object, which the other have. Since by its seven Object Glasses those advantages become sevenfold; and by the square of three to the square of one no less than ninefold. Now $7 \times 9 = 63$.

N. B. It is to be here noted farther, that this Telescope being too long and unweildy to be

be managed by the bare arms of the Obſerver, muſt be placed on a ball and ſocket, or what is equivalent thereto; muſt be placed near the ſhip's center of motion; (which is where the ſurface of the ſea produced would interſect the main maſt;) and muſt be prudently guided by the Obſerver, that it may be as little as poſſible diverted from *Jupiter*, during the times of Obſervation.

XXIX.

A Deſcription of the Longitude Reflecting Teleſcope.

This is a new ſort of *Reflecting Teleſcope*, of Mr. *Gregory*'s, or Monſ. *Caſſegrain*'s form, ſo much uſed of late: The *focal length of my* former large Reflecter, which was of Metal, was ſeven foot, or 84 inches; and, by conſequence, the length of its Tube, lined with black velvet, little above half ſo long, or 3 ½ foot, whoſe breadth or Diameter was 4 ½ inches: and its back aperture, with its ſmall Reflecter and Eye Glaſs, were all of them about 1 ½ inches in Diameter, and the focal length of the Eye Glaſs was the ſame. They were alſo circular: and the Reflecter was a circular plain. Theſe meaſures were ſo large on purpoſe, in order to take in as great an area in the heavens as might be, without loſing the great advantage of *reflections* above *refractions*. That former Teleſcope took in a full degree of a great circle at once, in diameter: or a circular ſpace about four times as large as the Sun, or Moon, *i. e.* in diameter

four times, and in area sixteen times as large as the circle of *Jupiter*'s remotest Planet: whose apparent diameter is little or nothing above half the apparent diameter of the Sun or Moon.

The corrected measures I now pitch upon, after some trials of the former, are these. The focal length of the large Reflecter is to be five feet, or 60 inches: and, by consequence, the length of its Tube 2 $\frac{1}{2}$ feet, or 30 inches. Its breadth, or diameter, is to be full 6 inches. The breadth of its back aperture, and Eye Glass, not less than 1 $\frac{1}{2}$ inch, and the *charge*, or focal length of the Eye Glass about one inch: Its small Reflecter is to be a flat circle, as before, but at least 2 inches in diameter. This Telescope will then magnify objects in diameter 60 times, and will be abundantly sufficient for our Observations of *Jupiter*'s Planets, and of the Occultations of the fixed Stars by the Moon: such a Telescope taking in above three diameters of the Sun or Moon at the same time; or including a circular space above nine times as large as is the area of either of their bodies. Nor will this breadth of the small reflecter intercept more than a ninth part of the rays of light which would otherwise fall upon the great one; while, even the common reflecters, which can view nothing far from the axis of vision, intercept about a sixteenth part of them.

N. B. One thing must here be farther explained; and it is this; that because, as Sir *Isaac Newton* grants, when he was explaining the great advantages of Reflection above Refraction

fraction in Telescopes, that still more rays of light are transmitted in refractions through glass, than are sent back by metal in reflections, *Philos. Transact.* N° 80. and N 82. the breadth of the great reflecter ought to be as large as can conveniently be ground, and used, that so the *charge*, or power of magnifying by a small Eye Glass, may not want a sufficient quantity of rays to shew these Planets with sufficient clearness. Tho' I suppose this great breadth of the principal reflecters might be spared, if they could be made of glass; which has been often attempted, but never yet brought to perfection.

N. B. That these Eclipses of *Jupiter*'s Planets have been esteemed the best method for discovering the Longitude; and that these Refracting and Reflecting Telescopes are capable of discovering those Eclipses, Occultations, and Conjunctions of *Jupiter*'s Planets, with sufficient accuracy, even at Sea, assoon as the Ports are settled, take the following testimonies of Mr. *Flamsteed*, Mr. *Witty*, or Mr. *Hodgson*, Dr. *Halley*, and Mr. *Hadley*; all Persons of great skill in these matters.

Mr. *Flamsteed*'s words are these: *Philos. Transact.* N° 151. " The Eclipses of *Jupiter*'s " Satellites have been esteem'd, and certainly " are, a much better expedient for the disco- " very of the Longitude, than any yet known; " by reason that they happen frequently; and " are easily observable with a [refracting] Te- " lescope of 12 feet, or, for need, with one

" of 8." Mr. *Witty*'s, or Mr. *Hodgson*'s words are these, in Mr. *Hodgson*'s *System of the Mathematicks*, Vol. I. pag. 378. " When we " consider the great number of these Eclipses " every year; there being more visible in one " year, than there are days in it; and, conse- " quently, but few nights when *Jupiter* may " be seen, and which is near eleven months in " the year; but that an Eclipse of one or other " happens; and sometimes two or three in a " night: the easiness with which these Obser- " vations may be made; there requiring only " a Telescope of eight or ten foot in length; " which may be almost managed with the " hand: and the little likelihood there is of " missing the times of ingress or egress; they " being in a manner instantaneous: and, lastly, " the great exactness to which they would " give the difference of Longitude: it being " certainly as exact as the Latitude at present " can be taken: It is much to be wonder'd at, " that the more skilful part of our Seamen " have so long neglected them; and especially " in the several ports into which they sail." Dr. *Halley*'s words are these: *Philos. Transact.* N° 214. " The method the *French* have used " to determine the Longitude of their places, is " by the Observation of the Eclipses of the first " Satellite of *Jupiter*; which they find almost " instantaneous; and, with good Telescopes, " discernable almost to the very opposition of " *Jupiter* to the Sun. And it may be said, " that this account of the Longitudes observed,

" has

" has put it paſt doubt, that this is the very beſt " way, could portable Teleſcopes ſuffice for the " work." Dr. *Halley* adds, " However, before " Sailors can make uſe of this art of finding the " Longitude, it will be requiſite that the coaſt " of the whole ocean be firſt laid down truly: " for which work this method, by the Eclip- " ſes of *Jupiter*'s Satellites, is moſt appoſite. " And it may be hoped, that either a true " Geometrick Theory of the Moon may be " diſcovered, by the time the Charts are com- " pleated; or elſe that ſome invention of " ſhorter Teleſcopes may ſuffice to ſhew the " Eclipſes of the Satellites at Sea." And in the Appendix to the 2d Edition of *Street*'s *Caroline Tables*, the ſame Dr. *Halley* aſſures us, that " He had found it only needed a little " practice, to be able to manage a five or ſix " foot Teleſcope, capable of ſhewing the Ap- " pulſes or Occultations of the fixed Stars by " the Moon, on ſhipboard, in moderate wea- " ther:" And elſewhere; *Philoſ. Tranſact.* N° 191. and *Abridgment*, Vol. I. pag. 647. " It " will be fit to give the Reader this informa- " tion; *viz.* that the moments of theſe Eclip- " ſes may be, with ſufficient diſtinctneſs, ob- " ſerved, with a Tube of eight, or even ſeven " feet, which is eaſily portable: and more " eſpecially in the outer Satellites. I mean " this in caſe the Aperture of the Object Glaſs " be 2 ½ or three inches. For by that means " a very great quantity of the refracted rays " of light will come to the Eye; which will

" render

" render those little stars visible, even in the " neighbourhood of *Jupiter*, which otherwise " might be obscured by its overmuch light. " And though they may, in this case, be co- " loured, and *Jupiter*'s limb may appear dull; " yet when our only design is to observe the " moment of the loss, or recovery of their " light, we have no other concern, but to in- " crease that light as much as possible, that " they may become more certainly visible." Mr. *Hadley*'s words are these: *Philos. Transact.* N° 430. " I have been informed, that an " Object may be kept in view, without much " difficulty, even in pretty rough weather, " through a [refracting] Telescope magnify- " ing about ten times; which Telescopes sel- " dom comprehend an area of much more " than one degree in diameter; or at most " one degree, twenty minutes." [While I propose, even a Reflecting Telescope that will take one degree, and considerably above thirty minutes, or above three diameters of the Sun or Moon.]

XXX.

A Description of Mr. Barston's *Quadrant.* *See* Fig. (7.)

This Quadrant is no other than one of the usual form, very exactly divided into degrees; whose Pendulum is considerably heavy, and is inclosed between two plains; in order to prevent all disorders from the wind. That Pendulum is connected to, and governs a train of wheel-

wheel-work, within the quadrant; adjusted nicely to the division of the Instrument into *degrees*; and shewing, by its Index, without, the *minutes* belonging to these degrees. This train of wheel-work may be readily stop'd by the hand of the Observer, by means of a tricker, upon the first direction of its sights to the Object: (which are at the distance of an intire diameter, and upon a semicircle.) By this Quadrant, the true altitude of the Sun, or Moon, or fixed Stars, or Planets, or Comets, may be, at any time, taken, both at Sea, and at Land, as has been frequently experienced, nearly to a single minute. Which altitude of the heavenly Bodies is always the best way of finding the *Latitude* directly: as it is frequently the best way of finding the time at the Ship also: without which the *Longitude* itself cannot be discovered, either by Clocks, or by the Eclipses, Occultations, and Conjunctions of *Jupiter*'s Planets; or by the Appulses of the Moon to the fixed Stars, as all Astronomers do very well know. Nor indeed do I at all differ from Mr. *Witty*, or Mr. *Hodgson*, in the value of such an Instrument; when it is affirmed (System of the Mathematicks, Vol.I. *p.*382, 383.) that "He "who can contrive any way to take the height "of any fixed Star at Sea, to a minute, or two, "may fairly be intituled to a share of the dis- "covery of the Longitude; and ought to have "a proportionable reward.

XXXI.

A Description of the other Longitude Sector, *taken from Dr.* Halley's Zodiack.

This is only that Zodiack, as publiſhed by Mr. *Senex*, cut into three parts; and ſo paſted upon a Sector, like the former, as to exhibit, when opened, the intire Ecliptick, in one length. Its uſe is, by putting very ſmall pins into the places of the Moon, at every noon, for a month, at the Meridian of *Greenwich*, from Mr *Parker*'s, or Mr. *Weaver*'s *Ephemeris*, and ſtretching a fine ſilver thread along thoſe pins, to trace the true courſe of the Moon, without Parallax, and as it would appear to an Eye from the Earth's center, among thoſe fixed Stars that are inſerted upon that Zodiack: and thereby to know thoſe Stars which the Moon makes its tranſits over in ſuch a poſition: and to determine, very nearly, the times of thoſe Stars Immerſions and Emerſions in the ſame poſition at their Occultations by the Moon. Its uſe is alſo, upon proper allowance for the Parallax, to exhibit the ſame things to an Eye at the Earth's ſurface alſo. This method of uſing Dr. *Halley*'s Zodiack will greatly improve the advantages to be reaped from it, in general: and, in particular, will ſupply the curious part of our ſeamen with a tolerable method for diſcovering the Longitude, during thoſe ſix weeks, when *Jupiter* and his Planets are inviſible. Of all which more fully hereafter.

N. B. Since

N.B. Since both my Refracting and Reflecting Teleſcopes, eſpecially the latter, enable us to ſee ſomewhat ſmaller fixed Stars, and Stars nearer the full Moon, than thoſe uſed by Dr. *Halley*, and others on ſhip-board hitherto: It will be a deſirable thing, that as many more of thoſe ſmaller fixed Stars as can be now viſible, may be obſerved and inſerted into this Zodiack: that ſo the opportunities for diſcovering the Longitude this way may be more frequent, and advantageous to us. Tho' it muſt be confeſs'd, after all, that the opportunities of diſcovering the Longitude by *Jupiter*'s Planets, are much more frequent, the Calculations much more eaſy, and the Determations much more exact than thoſe of the other.

XXXII.

New Tables for the Equation of Light: *fitted to Mr.* Bradley's *Astronomical Tables for* Jupiter's *first Planet, published in the* Philosophical Transactions, N° 361. *as well as to be republished at the end of Dr.* Halley's *own Astronomical Tables: where they are called the* second *and* third Equations.

N. B. The reason of the insertion of these New Tables for the Equation of Light is this; that since the publication of those Tables, which suppose this Equation to be but 7′, and its double 14′. Mr. *Bradley* has certainly discovered it to be no less than 8′ 13″, and doubled 16′ 26″. See *Philos. Transact.* N° 406.

Secundæ Æquationes Conjunctionum Primi Satellitis cum Jove.

N. B Æq.	0		100		200		300		400		500		600		700		800		900	
	Æq.		Æq.		Æq.		Æq.		Æq.		Æq.		Æq		Æq.		Æq.		Æq.	
	′	″	′	″	′	″	′	″	′	″	′	″	′	″		″	′	″	′	″
0	16	26	15	5	11	30	6	27	1	53	0	0	1	53	6	27	11	30	15	5
4	16	26	14	58	11	18	6	14	1	46	0	0	2	2	6	40	11	40	15	9
8	16	25	14	52	11	6	6	1	1	38	0	1	2	11	6	52	11	50	15	13
12	16	24	14	45	10	54	5	48	1	31	0	2	2	20	7	4	12	0	15	18
16	16	23	14	39	10	42	5	35	1	23	0	3	2	30	7	16	12	11	15	23
20	16	22	14	32	10	30	5	22	1	15	0	4	2	40	7	28	12	21	15	29
24	16	21	14	24	10	19	5	12	1	7	0	6	2	50	7	40	12	31	15	34
28	16	19	14	16	10	8	5	1	0	59	0	9	3	0	7	53	12	41	15	39
32	16	17	14	8	9	56	4	50	0	52	0	12	3	10	8	6	12	51	15	44
36	16	15	14	0	9	44	4	39	0	46	0	15	3	20	8	19	13	0	15	49
40	16	13	13	52	9	32	4	28	0	40	0	18	3	30	8	32	13	10	15	54
44	16	11	13	44	9	19	4	14	0	35	0	22	3	41	8	44	13	19	15	58
48	16	8	13	36	9	8	4	4	0	30	0	25	3	52	8	56	13	27	16	1
52	16	4	13	27	8	56	3	52	0	25	0	30	4	4	9	8	13	36	16	4
56	16	1	13	19	8	44	3	41	0	22	0	35	4	14	9	19	13	44	16	8
60	15	58	13	10	8	32	3	30	0	18	0	40	4	28	9	32	13	52	16	11
64	15	54	13	0	8	19	3	20	0	15	0	46	4	39	9	44	14	0	16	13
68	15	49	12	51	8	6	3	10	0	12	0	53	4	50	9	56	14	8	16	15
72	15	44	12	41	7	53	3	0	0	8	0	59	5	1	10	8	14	16	16	17
76	15	39	12	31	7	40	2	50	0	6	1	7	5	12	10	19	14	24	16	18
80	15	34	12	21	7	28	2	40	0	4	1	15	5	22	10	30	14	32	16	20
84	15	29	12	11	7	16	2	30	0	3	1	23	5	35	10	42	14	39	16	22
88	15	23	12	0	7	4	2	20	0	2	1	31	5	48	10	54	14	45	16	24
92	15	17	11	50	6	52	2	11	0	1	1	38	6	1	11	6	14	52	16	25
96	15	11	11	40	6	40	2	2	0	0	1	46	6	14	11	18	14	58	16	26
100	15	5	11	30	6	27	1	53	0	0	1	53	6	27	11	30	15	5	16	26

Tertiæ Æquationes Addendæ.			
Num. A	Æquationes		Num A
	′	″	
0	4	6	0
20	4	5	980
40	4	2	960
60	3	58	940
80	3	52	920
100	3	45	900
120	3	34	880
140	3	24	860
160	3	13	840
180	3	0	820
200	2	46	800
220	2	33	780
240	2	19	760
260	2	4	740
280	1	47	720
300	1	30	700
320	1	16	680
340	1	2	660
360	0	48	640
380	0	37	620
400	0	26	600
420	0	16	580
440	0	9	560
460	0	4	540
480	0	2	520
500	0	0	500

N.B. The first of these Tables properly supposes *Jupiter* and his Planets to be at their mean distances from the Sun and Earth; as they were at the end of the year 1731, and will be again before the end of 1743. But because the *Eccentricity* of *Jupiter*'s own Orbit is equal to *one quarter* of the Semidiameter of the Earth's Orbit; this requires another Table: because that *Eccentricity* alters that Equation of Light one quarter as much as the other; or 2′ 3″, which quantity is therefore to be *added* at their greatest distance in *Jupiter*'s Aphelion; and *substracted* at their least distance in *Jupiter*'s Perihelion, which is provided for in this second Table. However, in Mr. *Pound*'s Method, all is done by Addition. Accordingly I have made the proper allowance for both their Epochas in each of these Tables; and do all by Addition also. Nor do we indeed properly stand in need of a distinct Table for this second Equation of Light, as here and in the Transactions: because the same number A is the

the Index for this, as well as for the first or principal Equation. And the addition of their Equations together in the Tables, would somewhat facilitate our calculations afterward.

N. B. The Eccentricity of the Earth's Orbit would itself also afford another correction of the Equation of Light. But this hardly ever amounting to a quarter of a minute in time; and being generally not near so much; neither Mr. *Pound*, Mr. *Bradley*, nor I have made any allowance for it.

XXXIII.

Sir Isaac Newton's *Table of Refraction.*

This is published by Dr. *Halley* in the *Philos. Transact.* N° 368. The great use of it will appear under the Xth Problem hereafter, when we come to find the true time at the Ship by the *apparent* altitude of the Sun, Moon, and Stars; which cannot be reduc'd to calculation, till, by the use of this, or the like Table, the *apparent* altitudes be reduced to the *real* ones, as will be exemplified hereafter.

Tabula

Tabula Refractionum Siderum ad altitudines apparentes.

Al. ap. gra.	Al. ap. m.	Refract. m.	Refract. sec.	Al. ap. grad.	Al. ap.	Refract. m.	Refract. sec.	Al. ap. grad.	Al. ap.	Refract.	Refract. sec.
0	0	33	45	16	0	3	4	46	0	0	52
0	15	30	24	17	0	2	53	47	0	0	50
0	30	27	35	18	0	2	43	48	0	0	48
0	45	25	11	19	0	2	34	49	0	0	47
1	0	23	7	20	0	2	26	50	0	0	45
1	15	21	20	21	0	2	18	51	0	0	44
1	30	19	46	22	0	2	11	52	0	0	42
1	45	18	22	23	0	2	5	53	0	0	40
2	0	17	8	24	0	1	59	54	0	0	39
2	30	15	2	25	0	1	54	55	0	0	38
3	0	13	20	26	0	1	49	56	0	0	36
3	30	11	57	27	0	1	44	57	0	0	35
4	0	10	48	28	0	1	40	58	0	0	34
4	30	9	50	29	0	1	36	59	0	0	32
5	0	9	2	30	0	1	32	60	0	0	31
5	30	8	21	31	0	1	28	61	0	0	30
6	0	7	45	32	0	1	25	62	0	0	28
6	30	7	14	33	0	1	22	63	0	0	27
7	0	6	47	34	0	1	19	64	0	0	26
7	30	6	22	35	0	1	16	65	0	0	25
8	0	6	0	36	0	1	13	66	0	0	24
8	30	5	40	37	0	1	11	67	0	0	23
9	0	5	22	38	0	1	8	68	0	0	22
9	30	5	6	39	0	1	6	69	0	0	21
10	0	4	52	40	0	1	4	70	0	0	20
11	0	4	27	41	0	1	2	71	0	0	19
12	0	4	5	42	0	1	0	72	0	0	18
13	0	3	47	43	0	0	58	73	0	0	17
14	0	3	31	44	0	0	56	74	0	0	16
15	0	3	17	45	0	0	54	75	0	0	15

N.B. Because in the discovery of the *Latitude* by Mr. *Barston*'s Quadrant, the seamen will frequently want a Table of the Sun's *Declination*

clination at noon: And, because, in our present way of discovering the time at the Ship for the *Longitude*, we shall always want a Table of the Sun's *Right Ascension* for six in the evening: In the margin of my *Ephemeris* I have added both those Tables; and that for the Meridian of *Greenwich:* for which Meridian all my other Calculations are made also.

XXXIV.

A Table of the Right Ascension, *both in degrees, and in time; and of the* Declination, *North, or South of fourteen of the principal fixed Stars; fitted to the year* 1740, *and serving for several years before, and after it: In order to the discovery of the time at the Ship, by Mr.* Barston's *Quadrant. Of which more hereafter.*

	Right As. in deg. °	′	Right As. in time. h	′	Declination. °	′	
(1.) *Mencar*, in the Mouth of the Whale.	42	14	2	49	3	2	N.
(2.) *Aldebaran*, or Bulls Eye.	65	16	4	21	15	58	N.
(3.) *Orion*'s left foot, *Rigel.*	75	38	5	2½	8	32	S.
(4.) In his right Shoulder.	85	18	5	41	7	21	N.
(5.) The Great Dog, *Syrius.*	98	34	6	34	16	20	S.
(6.) The Little Dog, *Procyon.*	111	29	7	26	5	56	N.
(7.) The Lyon's Heart, *Regulus.*	148	39	9	54½	13	16	N.
(8.) The Lyon's Tail.	174	0	11	36	16	15	N.
(9.) The Virgin's Spike.	197	55	13	12	9	45	S.
(10.) *Arcturus.*	211	4	14	4	20	40	N.
(11.) Scorpion's Heart, *Antares.*	243	19	16	13	25	45	S.
(12.) Bright Star in the Eagle.	294	34	19	38	8	12	N.
(13.) Wing of *Pegasus*, *Marcab.*	343	3	22	52	13	51	N.
(14.) Head of *Andromeda.*	358	47	25	55	27	48	N.

N.B. Some Stars of Southern Declination are here set down, for the use of Ships sailing beyond the Line. Otherwise those are not so useful on this side of it: as never coming to the east or west points of the Compass: near to which the best Observations for our present purpose are to be always made.

PRO-

PROBLEMATA.

I.

To find the true time of the Heliocentrick Oppositions *of* Jupiter's *Planets, for the Meridian of* Greenwich.

This is to be done for the first Planet, by a Calculation from Mr. *Pound*'s Tables, published in the *Philosophical Transactions*, N° 361. but still as corrected by both the Equations for the velocity of the rays of light, mentioned under the XXXII^d *Lemma* foregoing. According to which rules I have myself made new Calculations for my *Ephemeris*, for the latter half of the year 1738.

For example. On *November* 2. 1737. the Heliocentrick Opposition of this first Planet is to be found by the method following.

	d	h	′	″	A.	B.
I^st A.D. 1737.	1	6	55	33	389	880
Novemb.	0	9	59	5	70	758
						19
Conjunct. Med.	1	16	54	38	459	657
Equat I.			28	33		
II.			4	18		
III.				4		
Novemb.	1	17	27	33	=Mean time of ☉.	
+ Equation of Time			15	12		
=	1	17	42	45	=True time of ☉.	

For

For another example of this first Planet, on *November* 18th the same year, 1737.

	d	h	′	″	A.	B.
Ist A.D. 1737.	1	6	55	33	389	880
Novemb.	16	8	16	29	74	799
						19
Conj. Med.	17	15	12	02	463	688
Equat I.			29	44		
II.			6	21		
III.				4		
Novemb.	17	15	48	11	Mean time of ♂.	
+ Equat Time			10	58		
=	17	15	59	9	True time of ♂.	

Corollary. If the *Semidurations* of the Planets in the total Shadow of *Jupiter* be *substracted* from, or *added* to these *Heliocentrick Oppositions*, they give us the true times of those their *Immersions* and *Emersions:* which we call their *Eclipses.* The former of which are alone visible from *Jupiter*'s *Conjunction* with the Sun, to his *Opposition:* and the latter from his *Opposition*, to his *Conjunction.* Examples of these Eclipses will be given presently.

N. B. In my *Ephemeris*, or Scheme of Configurations, I esteem each day to be a vulgar day, current; beginning at midnight, and ending at the midnight following; and adjust my numbers accordingly. So that the former 18 hours of it are supposed to be over at that six in the evening, to which I have fitted the Planets places; and the remaining 6 hours till XII o'-clock at night to belong to the same day. And, Note, that

to avoid the ambiguity of the ſame numbers of the hours, as II in the morning and II in the afternoon, V in the morning and V in the afternoon, *&c.* I imitate the reſt of the Aſtronomers, and call the morning hours with them, as if the day began not at midnight, as in common uſe, but at the noon foregoing. Thus II in the morning is by the addition of XII called XIV, and V is called XVII, and ſo in all parallel caſes. Which the Reader is ever to bear in mind in the uſe of theſe Calculations, and the *Ephemeris.*

N. B. No properly correct Aſtronomical Tables for the other three Planets being yet publiſhed; at leaſt not in ſo eaſy a method as are thoſe of Monſ. *Caſſini*'s for the firſt; we muſt find the time of the ſeconds coming to its Heliocentrick Oppoſition, by Mr. *Hodgſon*'s annual Calculations of its Eclipſes, out of Mr. *Flamſteed*'s Tables, corrected by himſelf, and inſerted of late into the *Philoſophical Tranſactions*, as well as we can: and either *ſubſtract*, or *add* their *ſemidurations.* Thoſe Tables are fitted to the true time: and the Calculations for both the foregoing examples here follow;

	d	h	′	
II[d] *Novemb.*	2	3	7	= true time of Emerſion.
—Semiduration about		1	$24\frac{1}{2}$	
	= 2	1	$42\frac{1}{2}$	= true time of ☌.

For the ſecond Example.

Novemb.	16	8	8	= true time of Emerſion.
—Semiduration about		1	$24\frac{1}{2}$	
	= 16	6	$53\frac{1}{2}$	= true time of ☌.

N. B. The III[d] and IVth Planets have here both their *Immerſions* and *Emerſions* ſet down by Mr. *Hodgſon*: we may therefore, with greater

 aſſurance,

assurance, take the middle time between them for the true time of their *Heliocentrick Opposition:* (always here reckon'd from the Noon preceding) and proceed thus, in the first Example;

	d	h	′	
III[d] From *Octob.*	28	10	50	= true time of Emersion.
Take *Octob.*	28	7	49	= true time of Immers.
remains	0	3	1	
Whose half is	0	1	30 $\frac{1}{2}$	
Add the second number	28	7	49	
Sum	28	9	19 $\frac{1}{2}$	= true time of ☌.

For the second Example.

From *Novemb.*	11	18	51	= true time of Emersion.
Take *Novemb.*	11	15	52	= true time of Immers.
remains		2	59	
Whose half is		1	29 $\frac{1}{2}$	
Add the second number	11	15	52	= true time of ☌.
Sum	11	17	21 $\frac{1}{2}$	

IVth From *Octob.*	26	9	35	= true time of Emersion.
Take *Octob.*	26	7	12	= true time of Immers.
remains	0	2	23	
Whose half is	0	1	11 $\frac{1}{2}$	
Add the second number	26	7	12	
Sum	26	8	23 $\frac{1}{2}$	= true time of ☌.

For the second Example.

From *Novemb.*	12	3	25	= true time of Emersion.
Take *Novemb.*	12	1	15	= true time of Immers.
remains	0	2	10	
Whose half is	0	1	5	
Add the second number	12	1	15	
Sum	12	2	20	= true time of ☌.

II.

To find the true Times of the Geocentrick Opposition *of* Jupiter's *Planets, for the Meridian of* Greenwich.

This is to be done by substracting or adding the *Parallax of the Orb*, from, or to the true time

time of *Heliocentrick Oppoſition* already found; as follows,

In the firſt example, which only needs to be produced in ſo eaſy a caſe.

	d	h	′	″	
Iſt *Novemb.*	1	17	42	45	= true time of Heliocentrick ☾.
Parallax Subſtract	0	1	15	0	
remains	1	16	27	45	= true time of Geocentrick ☾.
IId *Novemb.*	2	1	42	30	= true time of Heliocentrick ☾.
Parallax Subſtract		2	31	0	
remains	1	23	11	30	= true time of Geocentrick ☾.
IIId *Octob.*	28	9	19	30	= true time of Heliocentrick ☾.
Parallax Subſtract	0	5	6	0	
remains	28	4	13	30	= true time of Geocentrick ☾.
IVth *Octob.*	26	8	23	30	= true time of Heliocentrick ☾.
Parallax Subſtract	0	11	50	0	
remains	25	20	33	30	= true time of Geocentrick ☾.

N. B. If the *Geocentrick Oppoſition* be given, the *Heliocentrick* is eaſily found, by the reverſe of this practice: *i. e.* by *adding* the Parallax, inſtead of *ſubſtracting:* and by *ſubſtracting* it, inſtead of *adding.* This needs no farther examples.

III.

To find the places *of any of theſe Planets at any given time.*

This is to be done by *ſubſtracting* the time of the *Geocentrick Oppoſition*, from the *time given.*

Thus we may find all their places on *November* 2d, at ſix in the evening, as follows: One example in each of the Planets will be ſufficient.

	d	h	′	″	
Iſt From *Novemb.*	2	6	0	0	
Take *Novemb.*	1	16	27	45	= true ☾.
remains		13	32	15	= true place.

	d	h	′	″	
II[d] From *Novemb.*	2	6	0	0	
Take	1	23	11	30	= true ☾.
remains	0	6	48	30	= true place.
III. From *Novemb.*	2	6	0	0	
Take *Octob.*	28	4	13	30	= true ☾.
remains	5	1	46	30	= true place.
IVth From *Novemb.*	2	6	0	0	
Take *Octob.*	25	20	33	30	= true ☾.
remains	7	9	26	30	= true place.

N.B. The time here and elſewhere given, is ſuppos'd to be at the Meridian of *Greenwich*: to which the Tables we make uſe of are fitted. But this time is not the ſame in other Meridians: becauſe at 15, 30°, 45°, *&c.* eaſtward, this ſix a clock is 7, 8, 9 a clock, *&c.* As it is, but 5, 4, 3, *&c.* at Meridians as far weſtward. Which ought always to be borne in mind on ſuch occaſions.

IV.

To find the Eclipſes, *or* Immerſions *and* Emerſions *of theſe Planets, with regard to the total ſhadow of* Jupiter.

This is to be done by ſubſtracting, and adding the *ſemidurations* of theſe Eclipſes, from, or to their *Heliocentrick Oppoſition*; as follows,

The Mark for ſubſtractions and additions, is this: ∓

		d	h	′	″	
I. *Novemb.*		1	17	42	45	= true ☾.
	∓	0	1	6	0	= mean ſemiduration.
	=	1	16	36	45	= Immerſion inviſible.
	=	1	18	48	45	= Emerſion viſible.
II. *Novemb.*		2	1	42	30	= true ☾.
	∓	0	1	24	30	= mean ſemiduration.
	=	2	0	8	0	= Immerſion inviſible.
	=	2	3	7	0	= Emerſion viſible.

III. *Octob.*

		d	h	′	″	
III. *Octob.*		28	9	19	30	= true ☾.
	∓	0	1	46	0	= mean ſemiduration.
	=	28	7	33	30	= Immerſion viſible.
	=	28	11	5	30	= Emerſion viſible.
IV. *Octob.*		26	8	23	30	= true ☾.
	∓	0	2	23	0	= mean ſemiduration.
	=	26	6	0	30	= Immerſion viſible.
	=	26	10	46	30	= Emerſion viſible.

N. B. Theſe calculations ſuppoſe the Planets to paſs either over the center of *Jupiter*'s ſhadow, or very near it: as they do when they are not too remote from their Nodes. At other times theſe mean ſemidurations are too long; and the *Immerſions* happen later, and the *Emerſions* ſooner than is here determined.

N. B. The former ſpecies of theſe Eclipſes, or the *Immerſions*, can be ſeen commonly for about 6½ months; from *Jupiter*'s Conjunction with the Sun, to his Oppoſition. And the latter ſpecies of the ſame Eclipſes, or the *Emerſions*, for about 6½ months from his Oppoſition, to his Conjunction, I mean this, when the light of the Sun does not hinder us from ſeeing either theſe Planets, or even *Jupiter* himſelf: which is our unhappy caſe for about three weeks before, and as many after their Conjunctions with the Sun. Nor will the weeks immediately before, and after thoſe ſix weeks afford many opportunities for obſerving them. Which opportunities yet will be more and more as the time before and after is farther diſtant from that *Conjunction*, and moſt numerous of all about their *Oppoſition*, as laſting then all the

the night long. *Jupiter*'s own situation has also a great hand in affording fewer, or more such opportunities. These being in southern signs fewer, and in northern signs more numerous. I mean this with regard to us who live in the northern Hemisphere. The reverse of which is true in the southern.

N.B. Since therefore *Jupiter* is now ascending from the southern to the northern signs; where he will continue near six years: those six years will peculiarly afford the Astronomers, Geographers, and Navigators of *Europe* the most frequent and valuable opportunities for perfecting the Theories of these Planets; and for making use of those Theories in their discovery of the Longitude, both at land and sea. Which I accordingly do earnestly recommend to them; and heartily wish they may not be neglected by them.

V.

To find the Occultations, *or* Immersions, *and* Emersions *of these Planets, both beyond, and on this side the body of* Jupiter.

This is to be done by substracting, or adding the *semidurations* of these Planets, under this their obscurity, to their Geocentrick Oppositions or Conjunctions. Only the Reader must take notice, that the *Conjunctions* are easily found when the *Oppositions* are given: *viz.* by substracting, or adding half a Synodick period of each of these Planets from, or to the *Geocentrick*

trick Oppositions. One example in each Planet shall suffice here.

		d	h	′	″	
I^st *Novemb.*		1	16	27	45	= true ☉.
	∓	0	1	9	0	= Semiduration.
	=	1	15	18	45	= Im. invisible.
	=	1	17	36	45	= Em. visible.
+ ½ Period to the first		0	21	14	18	
	=	2	13	42	3	= true ♂.
	∓		1	9	0	= Semiduration.
	=	2	12	33	3	= Im. invisible.
	=	2	13	42	3	= Em. visible.
II^d *Novemb.*		1	23	13	0	= true ☉.
	∓	0	1	28	0	= Semiduration.
	=	1	21	45	0	= Im. invisible.
	=	2	0	41	0	= Em. visible.
+ ½ Period to the first		1	18	38	57	
	=	3	17	51	57	= true ♂.
	∓	0	1	28	0	= Semiduration.
	=	3	16	23	57	= Im. visible.
	=	3	19	19	57	= Em. visible.
III^d *Octob.*		28	4	13	30	= true ☉.
	∓	0	1	50	0	= Semiduration.
	=	28	2	23	30	= Im. invisible.
	=	28	6	3	30	= Em. visible.
+ ½ Period to the first		3	13	59	48	
	=	31	18	13	18	= true ♂.
	∓	0	1	50	0	= Semiduration.
	=	31	16	23	18	= Im. visible.
	=	31	20	3	18	= Em. visible.
IVth *Octob.*		25	20	33	30	= true ☉.
	∓	0	2	27	0	= Semiduration.
	=	25	18	6	30	= Im. invisible.
	=	25	23	0	30	= Em. visible.
+ ½ Period to the first		8	9	2	36½	
= *Novemb.*		3	5	36	6½	= true ♂.
	∓	0	2	27	0	= Semiduration.
	=	3	3	9	6½	= Im. visible.
	=	3	8	3	6½	= Em. visible.

VI. *To*

VI.

To find the nearest Utmost Elongation of these Planets from the body of Jupiter.

If the time given be that of the Geocentrick Opposition or Conjunction, the bare addition and substraction of one quarter of a Period gives the times of the two nearest *Utmost Elongations*, and needs no examples. But if, as usual, that time be any other, as that of six in the evening, the solution is thus:

Substract *one*, or *three* quarters of a Period from the given place; or the given place from *one*, or *three* quarters of a Period, the lesser number from the greater: the remains will be in the former case the first, and in the latter the second nearest Utmost Elongation. The use of the *Longitude Sector*, and of the *Scheme of Configurations* derived from it, will here prevent any mistakes; and will itself solve this Problem very nearly. However, take the following examples in numbers. Suppose that *November* 18th, 1737, at six in the evening, true time, the place of the Ist Planet has been found to be 0^{d}, 15^{h}, 19′. Of the II^{d}, 2^{d}, 1^{h}, 43′ $\frac{1}{2}$. Of the III^{d}, 6^{d}, 18^{h}, 3′, and of the IVth, 6^{d}, 16^{h}, 35′. It is required to find when they did severally come to their next *Utmost Elongation*. See *Lemma* III^{d} before.

	d	h	′	
I. From $\frac{3}{4}$ of a Period	1	7	51 $\frac{1}{2}$	
Take the place	0	15	19	
remains	0	16	32 $\frac{1}{2}$	after 6, or 10^{h}, 32′ $\frac{1}{2}$ the next day.

II. From

	d	h	′	
II. From $\frac{1}{4}$ of a Period	2	15	$58\frac{1}{2}$	
Take the place at 6	2	1	43	
remains	0	14	$15\frac{1}{2}$	after 6, or 8^h, $15'\frac{1}{2}$ the next day.
III. From the place at 6	6	18	3	
Take $\frac{3}{4}$ of a Period	5	8	$59\frac{1}{3}$	
remains	1	9	$3\frac{1}{3}$	before 6.
IV. From $\frac{3}{4}$ of a Period	12	13	34	
Take the place at 6	6	16	35	
remains	5	20	59	after 6.

See the Note after *Lemma* XXIV before.

VII.

To make a Table for every day of any month, or year, &c. *of the* Geocentrick Places *of every one of these Planets at any time given: as here for six a clock in the evening; true, or common time.*

Take the examples following: which are no other than consequences of the III[d] Problem foregoing: and are obtained by addition of equal days motions, till they amount to more than a Period: when that Period is to be substracted, and the remainder still solves the Problem.

	I.	d	h	′	″	
Novemb.	18 at 6 gives us	0	15	18	44	
	19 - - -	1	15	18	44	
	20 - - -	2	15	18	44	
	—	1	18	28	36	
	=	0	20	50	8	
	21 - - -	1	20	50	8	
	—	1	18	28	36	
	=	0	2	21	32	
	22 - - -	1	2	21	32	&c.

II.

		d	h	′	″	
Novemb. 18 at 6 gives us		2	1	43	30	
19 - - -		3	1	43	30	
20 - - -		4	1	43	30	
	—	3	13	17	54	
	=	0	12	25	36	
21 - - -		1	12	25	36	
22 - - -		2	12	25	36	
23 - - -		3	12	25	36	
24 - - -		4	12	25	36	
	—	3	13	17	54	
	=	0	23	7	42	
25 - - -		1	23	7	42	&c.

III.

Novemb. 18 at 6 gives us		6	18	3
19 - - -		7	18	3
	—	7	4	0
	=	0	14	3
20 - - -		1	14	3
21 - - -		2	14	3
22 - - -		3	14	3
23 - - -		4	14	3
24 - - -		5	14	3
25 - - -		6	14	3
26 - - -		7	14	3
	—	7	4	0
	=	0	10	3
27 - - -		1	10	3 &c.

IV. *No-*

	IV.	d	h	′
Novemb.	18 at 6′ gives us	6	16	35
	19 - - -	7	16	35
	20 - - -	8	16	35
	21 - - -	9	16	35
	22 - - -	10	16	35
	23 - - -	11	16	35
	24 - - -	12	16	35
	25 - - -	13	16	35
	26 - - -	14	16	35
	27 - - -	15	16	35
	28 - - -	16	16	35
	29 - - -	17	16	35
	—	16	18	5
	=	0	22	30
	30 - - -	1	22	30 &c.

N.B. This Table is thus far made from the mean motions of these Planets only; without the allowance for any Equations arising from the difference of the Parallax of the Orb; or from the successive motion of Light, or from the inequality of *Jupiter*'s own motion: which yet ought to be allow'd for in the Astronomical Calculations of these Planets, and is allow'd for in the I^st, II^d, and III^d, in the large Table of those places made for the Longitude Sector: (a specimen of which shall be set down presently.) If therefore we at any time proceed in this way, we must frequently make new Calculations. Otherwise we shall soon err, and that very considerably also.

N. B. The Reader is to be farther informed, that in this Specimen for the latter half of 1738. I have had use of Mr *Hodgson*'s Calculations of the Eclipses of the second and third, as they stand in the *Philosophical Transactions* for this year, N° 443. Yet have I made those of the I^st^ myself, and compared them with both his, and Mr *Weaver*'s Calculations; and hope they will nearly correspond to the Observations. But the fourth Planet having no Eclipses, neither in this nor the following year, the calculations and places of that Planet in my *Ephemeris* must needs, at present, be very gross. However, I hope, against the next year, to procure such helps as will enable me to place that Planet much more exactly.

A Table

A Table of the places of *Jupiter*'s Planets, as seen from the Earth, for the latter end of *November*, and for *December* 1737, at six a Clock in the evening, true time.

	I.			II.			III.			IV.		
Nov.	d	h	′	d	h	′	d	h	′	d	h	′
18	0	15	19	2	1	43½	6	18	3	6	16	35
19	1	15	19	3	1	43½	0	14	3	7	16	34
20	0	20	50	0	12	25	1	14	3	8	16	31
21	0	2	21½	1	12	25	2	14	3	9	16	29
22	1	2	21½	2	12	25	3	14	3	10	16	28
23	0	7	52	3	12	27	4	14	3	11	16	26
24	1	7	52	0	23	10	5	14	3	12	16	25
25	0	13	23	1	23	10	6	14	3	13	16	23
26	1	13	23	2	23	10	0	10	4	14	16	22
27	0	18	54	0	9	52	1	10	4	15	16	20
28	0	0	25	1	9	52	2	10	4	16	16	19
29	1	0	25	2	9	52	3	10	4	0	22	12
30	0	5	56	3	9	52	4	10	4	1	22	11
Dec. 1	1	5	55	0	20	35	5	10	5	2	22	9
2	0	11	27	1	20	35	6	10	5	3	22	7
3	1	11	26	2	20	35	0	6	5	4	22	5
4	0	16	58	0	7	18	1	6	5	5	22	2
5	1	16	59	1	7	19	2	6	6	6	22	0
6	0	22	31	2	7	20	3	6	7	7	21	54
7	0	4	4	3	7	21	4	6	7	8	21	48
8	1	4	5	0	18	4	5	6	8	9	21	42
9	0	9	37	1	18	5	6	6	8	10	21	36
10	1	9	37	2	18	6	0	2	9	11	21	30
11	0	15	10	0	4	49	1	2	9	12	21	24
12	1	15	11	1	4	50	2	2	10	13	21	18
13	0	20	44	2	4	51	3	2	10	14	21	12
14	0	2	17	3	4	52	4	2	11	15	21	6
15	1	2	17	0	15	33	5	2	11	0	2	54
16	0	7	49	1	15	34	6	2	12	1	2	48
17	1	7	48	2	15	34	7	2	12	2	2	42
18	0	13	19	0	2	16	0	22	9	3	2	36
19	1	13	18	1	2	16	1	22	5	4	2	30
20	0	18	49	2	2	17	2	22	0	5	2	24
21	0	0	20	3	2	17	3	21	57	6	2	18
22	1	0	18	0	12	59	4	21	53	7	2	12
23	0	5	48	1	12	59	5	21	50	8	2	6
24	1	5	48	2	13	0	6	21	47	9	2	0
25	0	11	20	3	13	0	0	17	42	10	1	54
26	1	11	20	0	23	24	1	17	37	11	1	48
27	0	16	50	1	23	24	2	17	34	12	1	42
28	1	16	49	2	23	24	3	17	30	13	1	36
29	0	22	21	0	10	6	4	17	26	14	1	30
30	0	3	52	1	10	6	5	17	22	15	1	24
31	1	3	51	2	10	6	6	17	18	16	1	20

VIII.

To find the places of these Planets by the Longitude Sector, *at any given time, at the Meridian of* Greenwich.

Take this Sector, and lay it open before you. Then take four common pins, of the larger sort, and place them, by such a Table as has been just now exemplified, at their several places, for 6 a clock in the evening, on the day you propose to know those places. Remove each pin along its own Orbit, as many hours and minutes as the time given is different from 6 a clock: *backward*, if that time be *before*; 6 and *forward*, if it be *after* 6. Then will the four pins, representing these four Planets, stand true, and rightly determine their places at the time given.

Thus if it be required to find the places of these Planets by the *Longitude Sector* at 7 a clock at night, the 18th of *November*, and the 31st of *December*, 1737. [the former being the day when the Moon came very near to *Jupiter:* and the latter the day when there were four Conjunctions of *Jupiter*'s Planets in a few hours time.] In the first place, write down their places at 6 a clock on both those days, out of the foregoing Table, which are these.

Nov. 18.

		d	h	′			d	h	′
Nov. 18.	I.	0	15	19	*Dec.* 31.	I.	1	3	51
	II.	2	1	43 ½		II.	2	10	6
	III.	6	18	3		III.	6	17	18
	IV.	6	16	35		IV.	16	1	20

Then ſet thoſe four large pins in theſe their ſeveral places, at 6 a clock, which will then exhibit theſe Planets ſtanding two over againſt your right hand, or weſtward, and two over againſt your left hand, or eaſtward, from the body of *Jupiter*, upon *Nov.* 18. but all over againſt your right hand, or weſtward, upon *Dec.* 31. and will have the following diſtances from *Jupiter*'s center, in inches, and decimals of an inch.

		inch.			inch.
Nov. 18.	I.	12,3	*Dec.* 31.	I.	13,7
	II.	12,5		II.	23,2
	III.	14,5		III.	15,6
	IV.	42,8		IV.	18,5

And thus are they to be truly repreſented in miniature at 6, in a Scheme of *Configurations*, ſuch as I have by me for thoſe months. Then remove each pin one hour forward, for 7 a clock, the time requir'd; when they will ſtand thus.

		inch.			inch.
Nov. 18.	I.	10,5	*Dec.* 31.	I.	15,1
	II.	14,2		II.	24,0
	III.	13,2		III.	13,3
	IV.	42,0		IV.	17,5

Corollary

Corollary (1.) If you desire to know farther when any of these Planets will come to an *Occultation* by the body of *Jupiter*, from which it is not too remote, remove its pin forwards, from its place at 6 a clock, till it cross one of the tangents of *Jupiter*, and observe how many hours and minutes you have removed it. That interval, as before, added to 6 a clock, gives you the time of such *Occultation*. Thus if we take the foregoing examples, we shall soon see, both on the Sector more exactly, and on a Scheme of Configurations nearly, that in the former example the II^{d} and IVth are, the one going away from *Jupiter*, and the other too remote from him: and that in the second example the Ist and II^{d} are going away from *Jupiter*; and in the second, the III^{d} and IVth are going towards *Jupiter*, and will not be very long ere they come to him: And by removing the several pins, that represent their places at 6 a clock, those two evenings will cross the nearest tangent of *Jupiter*, and will afford *Immersions*, by being removed forward.

		h				h	
Nov. 18.	I.	4	47½.	*Dec.* 31.	III.	8	50
	III.	8	7.		IV.	14	10

As also that they will cross the second Tangent, and afford *Emersions*, by being removed one intire duration of such Occultations farther, *viz.*

Nov.

		h ′			h ′
Nov. 18.	I.	2 . 18.	*Dec.* 31.	III.	3 . 40.
	III.	3 . 40.		IV.	4 . 54.

Which are therefore very near the true times of ſuch *Occultations*, of ſuch *Immerſions* and *Emerſions* reſpectively, *i. e.* upon the ſuppoſition that theſe Planets were then near their Nodes, but not otherwiſe; as has been already obſerved under the Vth Lemma foregoing.

Coroll. (2.) If you deſire to know when any of theſe Planets will come to one of its *Utmoſt Elongations*, that is not too remote, remove its pin to ſuch Elongation; and take notice, as before, how many hours and minutes you have removed it forward, or backward. That interval, as before. added to, or ſubſtracted from 6 a clock, gives you nearly the true time of ſuch Elongation. Only it muſt be noted, that the Sines near ſuch *Utmoſt Elongation* differ little from one another; and that therefore ſuch time cannot be determined by the Sector to any exactneſs. In that caſe the former method by numbers, as under Problem VI. before, anſwers this enquiry with much greater accuracy. However, to go on with the ſecond example: (the other affording us no ſuch Elongation near.) If we remove the pins repreſenting the I^st^ and II^d^ Planet forward from 6 a clock, the hours and minutes following, they will then be each of them very near their utmoſt Elongations.

		h	′
Dec. 31.	I.	4	0.
	II.	5	24.

Coroll. (3.) If you desire to know when any two of these Planets, which are not at 6 a clock very remote from each other, have met, or will meet one another, to our eye, and be in *Conjunction*; you must remove each pin that represents any such two of them, forward, or backward, till you see them at an equal distance from the center of *Jupiter*, and in the same cross perpendicular. That interval, added to or substracted from the hour of 6, gives you the true time: and this, when the Planets Theories shall be perfected, to great exactness also.

Thus if we now make use of the red lines, and the larger scale, we shall find that by removing, in the first example, the II^{d} and III^{d} forward; and in the second, by removing the II^{d} and III^{d}, the II^{d} and IVth backwards: as also by removing the Ist and III^{d} and the Ist and IVth forward, as far as to bring them to their *Conjunctions* respectively, those *Conjunctions* will be found thus,

Nov. 18. ☌ II^{d} and III^{d} at 6^{h}. 38′. or somewhat before the approach of the moon to *Jupiter*.

		h	′	
Dec. 31.	☌ II^{d} and III^{d} at	2	46	before Sun-set.
	☌ II^{d} and IVth at	3	42	
	☌ Ist and III^{d} at	6	39	after Sun-set.
	☌ Ist and IVth at	8	20	

In

In which latter example, the laſt day of the old year, there was ſuch a cluſter of theſe Planets, and number of *Conjunctions* together, as very rarely happens; the two latter of which, as well as the firſt on *Nov.* 18 ^{h}, were viſible, and were accordingly well obſerved at Mr. *Lynn*'s at *Southwick*, *Northamptonſhire*, and at Mr. *Barker*'s at *Lyndon*, *Rutland*.

N B. It muſt be here farther remark'd, that this branch of the Problem before us is of the greateſt conſequence to my preſent deſign; and that it cannot, without great difficulty, be ſolved by numbers, as the other may; and this by reaſon of the continual inequality of theſe apparent motions, and the four different ſemidiameters to which the Sines, Hours, and Minutes are to be accommodated. While the *Longitude Sector* ſolves it with the greateſt eaſe, accuracy, and ſatisfaction.

IX.

To compoſe a Scheme of the Configurations *of theſe four Planets, for any number of months, for an intire year; or for any number of years required, by the uſe of the* Longitude Sector.

This is the principal and highly valuable uſe of this Sector, and what will render the diſcovery of the exact times when the ſeveral *Occultations* and *Conjunctions* of theſe Planets are to be both computed and obſerved, for the diſcovery of the *Longitude*, very eaſy, very cheap, and very familiar.

In order to the obtaining which advantages, you must proceed as follows.

Place the Sector open before you. Then set the four pins, representing the four Planets, in their proper places, according to such a Table as has been already exemplify'd under Problem VII. before, for six in the evening. Lay a rule perpendicularly across the four double lines, drawn upon the Sector, for the Orbits of these Planets, distinctly, at each of those pins: Look upon the divisions near both the edges of the Sector, and note how many inches and decimals of an inch each of those pins is from the Center or Axis of the Sector, and whether to the right hand, or to the left. Take with your compasses either $\frac{1}{100}$, or $\frac{1}{10}$, or $\frac{1}{5}$ of those inches and decimals, and set one of its points upon your paper, (already ruled, and prepared for the daily insertion of these Configuration) from the Center, or Axis to the right hand, or to the left, as the pins on your Sector do direct you The other point will determine the true place of the Planet concern'd, that evening at 6 a clock. Do this distinctly for every pin or Planet, and for every day of the year that *Jupiter* is visible. You will then have before you a true representation of the situation of every one of *Jupiter*'s Planets, at that time of the evening, for every day of the year, at the meridian of *Greenwich*.

Corollary. If all these pins be once removed to the hour and minute when any of them come to either of the Tangents of *Jupiter*, for

for *Occultations*; or to its greateſt diſtance from the center for *Utmoſt Elongations*; or to the place of their mutual meetings, for their *Conjunctions*, as already directed; and the intervals of time for ſuch removals be noted; you will have the ſituation of all theſe Planets at the times of ſuch *Occultation*, *Utmoſt Elongation*, or *Conjunction*. And if the $\frac{1}{10}$, or $\frac{1}{15}$, or $\frac{1}{20}$ of ſuch removals be imitated on ſuch a Paper of *Configurations*, the paper will then repreſent, in miniature, the ſame ſituations alſo.

N. B. I have noted in my Scheme of theſe Configurations, not only thoſe Eclipſes that are any where viſible, with the true place, at 6 a clock, but the preſent *direction* of each Planet, at that time, by a very ſmall line, imitating the point of an arrow, drawn from the very ſmall circle that ſtands for ſuch a Planet. This is a circumſtance of no ſmall advantage, tho' commonly omitted in the like Schemes of their Eclipſes hitherto.

N. B. I need not here inform my Aſtronomical Readers, that when that ſmall line points *eaſtward*, the Planet thereby repreſented, and denominated by its number 1, 2, 3, and 4, is *beyond* Jupiter; and when it points weſtward, it is *on this ſide* of him. Nor need I inform him that moſt of thoſe Teleſcopes, by which we view theſe Planets, contradict my own, and nature's repreſentation, by *inverting* all their objects; and exhibiting what is really on the

left

left hand of *Jupiter*, as on his right: and what is *beneath* the center of *Jupiter*, as *above* it, and *vice versa*. But all Obſervers of the Heavens by Teleſcopes are ſo perpetually uſed to this inverſion, and make ſuch conſtant allowance for it, that I need add no more about it in this place.

X.

To find the Longitude of a Ship at Sea, by any of the Eclipſes, Occultations, *or* Conjunctions *of* Jupiter's *Planets, obſerved there.*

To ſolve this GRAND PROBLEM, which is the main deſign of the former *Lemmata* and *Problemata*, let ſome ſkilful Obſerver, who has a ſharp eye and dextrous hands, take either the refracting or reflecting Teleſcope, already deſcribed, and obſerve by one of them, either an *Eclipſe*, or *Occultation*, or *Conjunction*, (which will almoſt always be one of thoſe noted in my Scheme of *Configurations*, and whoſe time, in all Meridians, may be near enough gueſs'd at by the Scheme, to forewarn Obſervers to expect them:) And let this be done with all poſſible accuracy. At the very ſame moment of time, as near as poſſible, let ſome other like Obſerver take, by Mr *Barſton*'s Quadrant, or otherwiſe, the altitude of ſome one of thoſe 14 bright Stars noted in the Table under Lemma XXXIV foregoing. Then, by the Rules to be ſet down preſently, find the hour and minute at the Ship, and this alſo to the greateſt nicety poſſible. Compare the hour and minute for that *Eclipſe*,

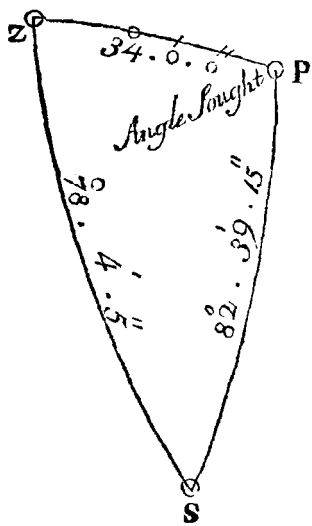
Eclipse, *Occultation*, or *Conjunction* in the ſcheme of Configurations, with the hour, and minute at the ſhip; the *difference* between that time in the ſcheme, and the time by obſervation, gives you the *difference* in time between the meridian of *Greenwich*, and the meridian of the Ship at the time of the obſervations; which *difference* is no other than the *Longitude* of *Greenwich*, to which the time of the Configurations is accommodated, from the *Longitude* of the Ship, whereon the Obſervations are made. And, by allowing 15 degrees to an hour, gives you the ſame *Longitude* in degrees and minutes of the Equinoctial alſo.

N. B. If ſuch *Eclipse*, or *Occultation*, or *Conjunction* of *Jupiter*'s Planets cannot be conveniently obſerv'd at the very ſame time with the altitude of the Star, let ſome of the watches on ſhipboard be ſet exactly, when ſuch Obſervation of the Planet's *Eclipse*, *Occultation*, or *Conjunction* is made, to the hour and minute noted in the ſcheme of Configurations for that appearance. Thoſe watches will then, for an hour, or more, inform the ſeamen exactly enough what a clock it was at the time of that Obſervation by the Meridian of *Greenwich*. As ſoon as this is done, let the ſame, or another ſkilful Obſerver take the altitude of ſome one of thoſe 14 Stars, already noted, by Mr. *Barſton*'s Quadrant, or otherwiſe: Then, by the rules to be ſet down preſently, let them find the time of the Ship from that Obſervation, as exactly as may be. Compare thoſe times together;

together; I mean that at *Greenwich*, shewn by the watch; and that at the Ship, shewn by the calculation from the Star's altitude, and this exactly at the taking of that altitude. The *difference* of those times is the *Longitude of the Ship from* Greenwich *at that time.* And Note, that the *later* hours and minutes shew meridians more *easterly*, and the earlier more *westerly*, than the meridian of *Greenwich*.

Now the Calculation of the time of the Ship from the Star's altitude is to be thus made

Let us suppose that the bright Star in the right shoulder of *Orion* was observed *December* 31st, 1737. in the evening, on shipboard, in the *Latitude* of 56° north, to be not far off the east point of the compass, and just 12° high above the Horizon. And this at the very same time that a *Conjunction* of *Jupiter's* Ist and III Planet was seen also, it is required to find the time at the Ship at that *Conjunction*. The refraction by the air at this altitude of 12° from Sir *Isaac Newton's* Table already set down under Lemma XXXIII foregoing is 4. 5″. which is to be substracted from the apparent altitude



altitude of 12°. The remainder is 11° 55′ 55″, and is the real altitude of the Star at the time of its Obſervation. Now in order to diſcover the true or common time at the Ship from theſe *data*, we muſt reſolve the foregoing oblique angled ſpherical Triangle, whoſe three ſides are given, I mean the diſtance between the Pole of the World and the vertex or zenith; which is equal to the complement of the Latitude = 34°, the complement of the Star's north Declination from the Equinoctial = 82° 39′ 15″, and the Star's diſtance from the vertex or zenith; which is equal to the complement of its altitude = 78° 4′ 5″ by which the Angle ZPS, which the Star makes with the meridian, is to be diſcovered. This requires the following proceſs. Noting withal, that it appears by the proper Tables, that the Sun's Right Aſcenſion was, at 6 in the evening, the laſt day of *December*, in time 19ʰ 23′, and the Star's Right Aſcenſion, by the Table under the XXXIVᵗʰ Lemma foregoing in time 5ʰ 41′.

Let P be the North Pole: and Z the Vertex, or Zenith of the Ship: and S the place of the Star, when its altitude was obſerved. Where ZS is the *baſe*, and ZP and PS the *ſides*, including the angle ſought. The numbers will ſtand thus:

		°	′	″			
ZS the baſe	=	78,	4	5			
PS a ſide	=	82	39	15	=	Log. Sine	9,99642
PZ the other ſide	=	34	0	0	=	Log. Sine	9,74756

	°	′	″			
Sum of all three	= 194	43	20		=	19,74398
The half Sum	= 97	21	40			
(Its supplement	82	38	20)	Log. Sine	=	9,99642
Difference of ZS, and the half Sum	19	17	35	Log. Sine	=	9,51903
Log. of the Radius doubled					=	20,00000
Sum of the last three numbers					=	39,51545
Remainder, or difference of the former Sum, and this:						19,77147
Half that remainder:					=	9,88573
				= Cosine of	39°	46′
Its double is ZPS the angle sought					= 79	32
Which in time corresponds to					= 5^h	18′
The Stars Right Ascension was in time					= 5	41
Add to it 24 hours, the Sum is, in time					= 29	41
Take out of it the Sun's Right Ascension					= 19	23
Remainder					= 10	18
From which subtract the time, that answers to the angle now found					= 5	18
The remainder is the time at the Ship					= 5	0

Which 5^h is, in the last place, to be subtracted from the time at *Greenwich:* which, by the Scheme of Configurations, was 6^h 39′. The Difference or Remainder is 1^h 39′, and is no other than the Longitude of the Ship from *Greenwich* in time; or in degrees 24° 45′ Westward.

N.B. You are only then to add 24^h, or a whole circle, to the Stars Right Ascension, when it is *lesser* than that of the Sun. But remember that when the Star is observed near the *West* point of the Compass, you must not *subtract*, but *add* the Suns and the Stars Right Ascensions together, in order to gain the time at the Ship. As also it must be noted, that this

this time is not the mean or equal, but the true or common time.

But becauſe this Problem is of ſuch great importance in the diſcovery of the Longitude, I ſhall produce another method of trigonometrical calculation: that by its agreement, the former calculation may be confirm'd, and that both of them may be ſtill made uſe of at Sea upon all occaſions; to prevent any poſſibility of error therein. The Proceſs will ſtand thus;

					°	′	″
Complement of the altitude ZS				=	78	4	5
Complement of the Declination PS				=	82	39	15
Complement of the Latitude				=	34	0	0
Sum of thoſe three ſides				=	194	43	20
Half Sum ——— ZS				=	19	17	35
Half Sum ——— PS				=	14	42	25
Half Sum ——— PZ				=	63	21	40
Add together	°	′	″				
Log. of the Sine of	14	42	25	=	9,40463		
And Log. of the Sine of	63	21	40	=	9,95126		
And Double the Radius				=	20,00000		
All three				=	39,35589		
Add alſo together Log. Sine of PS = 82° 38′ 20″				=	9,99642		
And Log. of the Sine of 19° 17′ 35″				=	9,51903		
Theſe two equal to				=	19,51545		
Take this ſecond Sum out of the firſt: the remainder is				=	19,84044		
Its half is				=	9,92022		

= Tangent 39° 46′ as before.

Accordingly its double = 79° 32′ is the angle ZPS, which was ſought: and in time, as before 5^h 18′.

N.B. In my *Ephemeris* or Scheme of Configurations, I had not room for the ſetting down the *Utmoſt Elongations* of theſe Planets. So I

 have

have omitted them there intirely. And indeed, they being of no particular use to any but to some few curious Astronomical Observers, who are furnished with very long Telescopes, and very good Micrometers, and this at Land, and for a little time only; it was no way necessary to insert them. As for the *Eclipses*, they are to be all noted there. Those of the first are from my own calculations: which almost always very nearly agree with Mr. *Weaver*'s, so far as I have tried them by Mr. *Pound*'s Tables: but corrected, as already explain'd. The calculations of the II^d and III^d are taken from Mr. *Hudson*'s Catalogue of them, lately published in our *Philosophical Transactions* for this year. The *Conjunctions* of those Planets are also noted: all those I mean that are not beyond the Scale of my Longitude Sector, nor very remote from *Jupiter:* The rest are very few, and of little use for the discovery of the Longitude. And this indeed, is, I think, the very first time that ever those *Conjunctions* have been foretold by Astronomers. And as for the *Occultations*, I have done what the Scale of my *Scheme of Configurations* would admit; I mean, I have set down the times of all the Geocentrick *Conjunctions* on this side *Jupiter:* which is the middle time between their *Immersions* and *Emersions*, which are alone visible; and which, upon the Substraction, and Addition of their *Semidurations*, as stated under the Vth *Lemma* foregoing, directly give the times of

of those *Occultations.* As do the *Oppositions,* there always noted also, by the like substractions and additions of *Semidurations,* give their *Immersions* and *Emersions* beyond *Jupiter* also. I mean, all this is actually noted on the *Ephemeris,* or *Scheme of Configurations,* without any farther trouble of Calculation on shipboard whatsoever. Which *Ephemeris* therefore I look on as one of the principal advantages that can be proposed, in order to facilitate this great discovery of the Longitude, both at Land and Sea.

N. B. We have no occasion for Mr. *Barston's* Quadrant in the discovery of the Longitude, but when the horizon is so hazy, or has what the Seamen call such a *bank* of vapours, as hinders them from seeing the Sun, Moon and Stars, either rise or set. Otherwise the time at the Ship, is best of all known by those risings or settings: which is at no altitude from the horizon, or at 90° from the Zenith (allowing the refraction) and is readily found by the foregoing, or the like trigonometrical Calculations: which are well known to those that have learned the art of Navigation. Nor will it be improper to use the Longitude or other Telescopes in those cases: since those Telescopes will afford a view of those risings and settings oftener, and more nicely than when the bare eye, how sharp soever, is trusted in such Observations.

XI. *To*

XI.

To find the Longitude of a Ship at Sea, during those six weeks in thirteen months, while Jupiter *and his Planets are invisible to us.*

This is to be done, in general, by the *Appulse* of the Moon to any fixed Star in Dr. *Halley's Zodiack*, or by any of their *Occultation* by the Moon, in the manner following. Having placed the 28 pins, at the places of the Moon on this *Zodiack*, as they were each day, at noon, in the Meridian of *Greenwich*, taken from Mr. *Parker's* or Mr. *Weaver's Ephemeris*. Note what time the Moon's center will arrive at the Star you intend to observe, supposing the Moon had no Parallax; and this by measuring the distance of the Star from the Noon foregoing, and comparing it with the intire distance then from noon to noon, by the like measure; according to the following analogy. As the number of Inches belonging to the intire Day: is to 24 hours, or 1440 Minutes therein contained :: so is the number of Inches from the foregoing Noon, to the place of the Star: to the number of Hours and Minutes from the Noon foregoing to the time of the Moon's Conjunction with the Star. After this, take your Zodiack, of the largest scale, as including a portion of 15 degrees only, and place thereon the Star, or a point to represent it, from the Table of the Longitudes and Latitudes

tudes of these Stars exhibited on the backside of that portion of the Zodiack, and, by moving its larger fictitious Moon, correct the former time of Conjunction: which time will usually be six times as exact as the first time, because of this scale six times as large as the other; then will you have the very hour and minute of their Conjunction, so far I mean as the Moon's present Theory can afford it. And all this upon the supposition of no parallax; or when the Moon is in the Zenith of the ship, at which time all such Parallax intirely vanishes. And so far my *Ephemeris* of Configurations will guide you; because I shall insert the time of such Conjunctions into it, during the Interval between the disappearing of *Jupiter*, and his appearing again, for the Meridian of *Greenwich*. The rest must be done on shipboard, as under the Note following.

N. B. In order to gain the visible place of the Moon, and the true time and duration of this visible *Conjunction* or *Occultation*, even upon the allowance for the Parallax, in all places whatsoever, proceed after the following manner. Take a celestial Globe, and mark on it the point where the Moon is supposed to be at her Conjunction with the Star from the Zodiack, according to the largest scale; then rectify your Globe to the Latitude of the Ship, and, as near as you can, to the time of the night at the meridian of the Ship when that Conjunction would happen, without allowance

for

for the Parallax. Draw an occult line from the Pole of the Ecliptick through that point downward, as also another from the Zenith the same way: Measure that Angle, and make an Angle equal to it with the line perpendicular to the Ecliptick, and either eastward or westward as the position of the Ecliptick on the Globe will direct you, and this through the corresponding point on that portion of the Zodiack, and towards the Horizon. Note the distance of the point representing the Star from the Zenith; then set on this Line from the point representing the Star the intire Parallax of the Moon belonging to that distance from the Zenith. This will determine the very point of the apparent place of the Moon's center, on allowance for her Parallax; take that distance parallel to the Ecliptick, or rather to the Moon's way, which near the Nodes may be a small matter different from the other. This will be the *Parallax in Longitude*, and apply it to the proper scale for minutes of degrees in an hour of time, in proportion to the Moon's velocity in degrees or minutes belonging to that day; which is easily gathered from Mr. *Parker*'s, or Mr. *Weaver*'s *Ephemeris:* Add, or substract this difference, as the Globe will direct you, to, or from the time found before, and you will gain the true time of the Moon's apparent Central Conjunction with the Star at the Ship; and, by moving your fictitious Moon both forward and backward, you will gain

gain the true times of the *Immersion* and *Emersion* of the same Star; which true time of the central Conjunction, when compared with the true time at the Ship, to be gained, as before, by Mr. *Barston*'s Quadrant, or otherwise, will give you your *Longitude from Greenwich.* But a very few hours instruction, *vivâ voce*, with the proper Instruments before you, will make this practice much easier to every curious Mariner, than any bare words whatsoever.

N. B. Concerning these methods of discovering the Longitude in general, both at Land and Sea; and how necessary it is that the Charts of the Sea Coasts be first of all corrected by the same methods; take Mr. *Witty*'s, or Mr. *Hodgson*'s words, in Mr. *Hodgson*'s *System of the Mathematicks*, Vol. I. pag. 384, 385. It is well known, says that Author, that "If "never so easy methods for finding the Lon- "gitude at Sea were proposed, they could not "be put in practice with any desirable success, "till the Longitude of the Sea Coasts were "better determined. For most certain it is, "that the surer any man is of the Longitude "of the place he is in at Sea, the surer he is "to miss the place he is design'd for, if the "Longitude of that place be not truly deter- "mined. So that if the worst of the methods "hitherto proposed be not practicable at Sea, "yet it cannot be denied but that they are "practicable at Land; and therefore the first "thing necessary to be done is to have all our

" Sea Coasts better settled, and new Sea Charts " form'd. Let them attempt this first, and I " doubt not but the Success will encourage " them so much, that they will readily find " means to put it in practice at Sea. For " things that we are unacquainted with gene- " rally seem more difficult than really they " are; and Use very often renders those things " easy, which at first sight we thought impos- " sible."

" 'Tis to the *French* Missionaries chiefly that " we owe the knowledge we have of most of " the Sea Coasts, but more especially the *East* " *Indies*, and the coasts of *China*. — And is it " not a severe Reflection upon us, who want " no means, and who trade almost to every " part of the habitable World, that in three " seven years scarce three Observations have " been made by which the true Longitude of " any of the places they have been in can be " truly determined?"

— " I have often heard the Government " blamed, for not sending two or three ships " abroad to put the methods that have been " proposed in practice, and thereby bring us " such a treasure of Observations, as might " enable us to draw new Maps of the Sea " coasts."

Take also Dr. *Halley*'s words, to the same purpose, out of *Philos. Transact.* N° 354. which are these. " Of all the methods hither- " to proposed for finding the Longitude of

" places

" places for Geographical uſes, none ſeems
" more adapted to the purpoſe than that by
" the *Occultations* of the fix'd Stars by the
" Moon, obſerved in diſtant parts. For thoſe
" *Immerſions* of the Stars, which happen on
" the dark ſemicircle of the Moon, and their
" *Emerſions* from the ſame, are perfectly mo-
" mentaneous, without that ambiguity to
" which the Obſervations of the Eclipſes of
" the Moon, and thoſe of *Jupiter*'s Satellites
" are ſubject. Beſides, whilſt the Moon is
" horned, and her weaker light leſs dazzling,
" an ordinary ſhort Teleſcope, ſuch as by ex-
" perience is found to be manageable on ſhip-
" board, ſuffices to obſerve theſe moments,
" even in the Occultation of very minute
" Stars. On which account this way ſeems to
" bid faireſt for the deſired Solution of the
" grand Problem of finding the Longitude at
" Sea. But ſince it would be needleſs to en-
" quire exactly what Longitude a ſhip is in,
" when that of the port to which ſhe is bound
" is ſtill unknown, it were to be wiſhed that
" the Princes of the Earth would cauſe ſuch
" Obſervations to be made in the ports, and
" on the principal Headlands of their domi-
" nions, each for his own, as might once for
" all ſettle truly the limits of the Land and
" Sea."

Take alſo the ſame Dr. *Halley*'s words at the bottom of his *Zodiack*. " The principal
" deſign of this Map is to foreſee the Appli-

" cations of the Moon to the fixed Stars. " These being duly observed on shore, would " be of great use to ascertain the Longitude " of places, and to verify the Charts of the " coasts of the Ocean; and until that be done, " the Longitude at Sea (for which the Parlia- " ment of *Great Britain* has provided so ample " a reward,) if found, would be of little ser- " vice. But the Sea Charts being thus once " perfected, the same Appulses of the Moon " to the fixed Stars would determine, by the " only practicable method, the true bearing " and distance of a ship at Sea from her Port, " without any regard to reckoning; which is " the thing required."

N. B. If, after all, the Reader be desirous of knowing to what degree of exactness these two methods by *Jupiter*'s Planets, and by the Moon's Appulse to the fixed Stars, are already capable of discovering the Longitude at Sea; and to what farther degree they may probably be advanc'd hereafter; I venture to say, as to the former method, by *Jupiter*'s Planets, that since Mons. *Cassini*'s own original Tables, published by Dr. *Halley*, in the *Philosophical Transactions*, N° 211. upon the comparison of the Theory of the I^st or innermost Planet, with many good and certain Observations, scarce ever then err'd above 3′ or 4′ of time: since Sir *Isaac Newton* has inform'd us long ago, from Mr. *Flamsteed*'s Letters to him, that the Eclipses of the same Planet never then differed from his Theory by 2′ of

2′ of time: that in the outmoſt the error was little greater; and in the outmoſt but one ſcarcely three times greater: [or ſcarcely 6′.] *Syſtem of the World, Eng. Ed. pag.* 16. Since Mr. *Hodgſon* has, long after that, aſſured us, from the compariſon of 244 of its Eclipſes, with his Tables, for 54 years together, that 74 of them do not differ 1′ from the Tables he makes uſe of; that 127 do not differ 2′; that 181 do not differ 3′; that 214 do not differ 4′; and that the reſt do not differ above 5½. *Philoſ. Tranſact.* N° 436. [wherein above half are within 2′, and almoſt 8 out of 9 within 4′.] Since Mr. *Bradley* alſo reckons no more than 5′ 10″, error in the ſame Eclipſes, *Tranſact.* N° 394. And ſince Mr. *Bradley* informs us farther, that the errors of the III^d Planet are alſo ſmall: ſince they therefore do all agree that none but the II^d errs much from the Tables: And ſince withal it now appears that the *Conjunctions* of theſe Planets with one another are more numerous, and more nicely to be diſcovered and obſerved than the *Eclipſes* themſelves; I conclude, that this method, if followed with due care, and if the II^d Planet be not yet made uſe of, may generally diſcover the Longitude; at leaſt *in the Latitude of Great-Britain*; within one degree of a Great Circle, or 60 Geographical Miles already, which is here within 7′ of time. And there is great reaſon to hope, that after good Obſervations of a few intire Periods of the three innermoſt, or

in

in a few 14½ months. (See *Corollary* (2.) after the XIth Lemma foregoing) the same Longitude will be hereby gradually discoverable to 50, nay, to 40, nay, to 30, nay, perhaps, at length, to 20 such miles; which last number implies a degree of exactness almost beyond the utmost desires and expectations of Astronomers.

As to the latter method, the Appulse of the Moon to the fixed Stars, take its present degree of exactness from Dr. *Halley*'s own words, at the bottom of his Zodiack; which are these: " In this method we must suppose the inequa- " lities of the Moon's motion known. When " perhaps the best numbers we hitherto have " may err a few minutes; tho' scarce ever e- " nough to produce in practice an error of " above 40 Leagues [= 120 miles.] And " this, 'tis likely, may be amended if diligent " Observations be made. Of which this Zo- " diack is very proper to notify the occa- " sion."

And after all, I shall, myself venture to add this farther; that if once the Theory of the Moon's motions be brought to perfection, (to which Mr. *Flamsteed*'s and Dr. *Halley*'s labours have greatly contributed;) this method by the Moon may, by degrees, be not much inferior in accuracy to the other by *Jupiter*'s Planets. Yet that the Period of the motions of these Planets necessary to be intirely observed, being no more than 14½ months, as we have already proved under

under Lemma VII. foregoing: while that of the Moon is known to be full eighteen years: the Theory of *Jupiter*'s Planets is likely to be brought to perfection much sooner than that of the Moon. It is also to be farther remarked, that the Opportunities for observing either an *Eclipse*, or *Occultation*, or *Conjunction* of *Jupiter*'s Planets will always be much more numerous, than those for observing the Appulse of the Moon to fixed Stars; and on that account will ever be much more advantageous to us in the discovery of the Longitude, both at Land and Sea.

I conclude the whole, as I have done upon two former attempts for the discovery of this *Longitude*, with my hearty wishes, *as a Man*, that this my design may tend to the common benefit of *Mankind*; as a *Briton*, that it may tend particularly to the honour and advantage of this my *Native Country*; and as a *Christian*, that it may tend to the propagation of our *Holy Religion*, *in its original purity*, throughout the World.

London, July 6.
1738.

WILL. WHISTON.

ERRATA.

PAG. 23. line 3. dele *in* and read *Conjunctions*. pag. 26. line 14. read *in: a few periods of* 14½ *months*. pag. 65. line 16. read *Determinations*. pag. 96. line 12. Add this (A gross solution being first made by the Celestial Globe, if any such be in the Ship, to prevent all fundamental mistakes:) pag. 62. line 24. add, I mean this on account of the breadth of the Eye-Glass of 1½ inch only. While the breadth of the small reflecter, of 2 inches, affords us room for near 4 degrees more; without our losing the sight of Jupiter and his Planets.

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1739

EMERSIONS.

January.

D.	H.	M.	S.
2	7	44	40
4	2	12	55
5	20	41	10
7	15	9	24
9	9	36	50
11	4	5	16
12	22	34	41
14	17	3	14
16	11	31	47
18	6	0	20
20	0	29	0
21	18	57	40
23	13	26	19
25	7	55	12
27	2	24	25
28	20	52	57
30	15	21	52

February.

1	9	50	47
3	4	19	40
4	22	48	40
6	17	17	30
8	11	46	42
10	6	15	44
12	0	44	48
13	19	13	58
15	13	43	29
17	8	12	20
19	2	41	32
20	21	10	48
22	15	40	6
24	10	9	28
26	4	38	47
27	23	8	6

1739

EMERSIONS.

March.

D.	H.	M.	S.
1	17	37	23
3	12	6	43
5	6	36	3
7	1	5	22
8	19	34	44
10	14	4	6
12	8	33	28
14	3	2	4
15	21	30	40
17	16	1	32
19	10	30	52
21	5	0	12

Jupiter near the Sun.

IMMERSIONS.

May.

7	21	55	37
9	16	24	13
11	10	52	49
13	5	21	26
14	23	49	52
16	18	18	16
18	12	46	41
20	7	14	53
22	1	43	5
23	20	11	41
25	14	40	0
27	9	8	15
29	3	36	33
30	22	4	51

June.

1	16	33	9
3	11	1	26
5	5	29	34
6	23	57	42
8	18	25	49

1739

IMMERSIONS

June.

D.	H.	M.	S.
10	12	53	53
12	7	21	57
14	1	50	22
15	20	18	37
17	14	46	52
19	9	15	7
21	3	43	11
22	22	11	35
24	16	39	49
26	11	8	1
28	5	36	13
30	0	4	26

July.

1	18	32	29
3	13	0	57
5	7	29	49
7	1	57	52
8	20	25	54
10	14	54	29
12	9	23	40
14	3	51	12
15	22	19	43
17	16	48	9
19	11	16	47
21	5	45	8
23	0	13	30
24	18	42	22
26	13	11	6
28	7	39	50
30	2	8	36

August.

0	20	37	12
2	15	6	6
4	9	34	5
6	4	3	26

1739

IMMERSIONS.

August.

D.	H.	M.	S.
7	22	32	18
9	17	1	10
11	11	30	2
13	5	58	58
15	0	27	54
16	18	57	3
18	13	25	57
20	7	54	15
22	2	23	44
23	20	52	47
25	15	21	50
27	9	50	52
29	4	19	55
30	22	48	58

September.

1	17	13	1
3	11	47	6
5	6	16	1
7	0	45	18
8	19	14	22
10	13	43	26
12	8	12	28
14	2	41	29
15	21	10	30
17	15	39	31
19	10	8	36
21	4	37	41
22	23	6	46
24	17	35	40
26	12	5	21
28	6	33	21
30	1	2	18

October.

1	19	31	36
3	14	0	12
5	8	29	7
7	2	58	59

Immersions.

October.

D.	H.	M.	S.
8	21	27	4
10	15	55	47
12	10	24	24
14	4	52	12
15	23	22	32
17	17	50	44
19	12	19	19
21	6	47	55
23	1	16	31
24	19	45	9
26	14	13	45
28	8	42	14
30	3	10	22

November.

0	21	39	12
2	16	7	31
4	10	35	33
6	5	4	9
7	23	32	45
9	18	0	19
11	12	28	55

Jupiter in Opposition to the Sun.

Emersions

11	14	36	56
3	9	5	32
15	3	34	8
16	22	2	12
18	16	30	16
20	10	58	19
22	5	26	16
23	23	54	13
25	18	22	13
27	12	50	5
29	7	17	21

Emersions.

December.

D.	H.	M.	S.
1	1	46	3
2	20	14	2
4	14	42	1
6	9	9	59
8	3	37	52
9	22	5	45
11	16	33	37
13	11	1	29
15	5	29	25
16	23	57	19
18	18	25	20
20	12	53	21
22	7	21	36
24	1	49	45
25	20	17	54
27	14	46	3
29	9	14	19
31	3	42	35

1740.

Emersions.

January.

1	22	10	28
3	16	38	49
5	11	7	10
7	5	35	31
9	0	3	54
10	18	32	17
12	13	0	40
14	7	29	3
16	1	57	26
17	20	26	9
19	14	54	44
21	9	23	19
23	3	51	54
24	22	20	47
26	16	49	40
28	11	18	32
30	5	47	28

Emersions.

February

D.	H.	M.	S.
1	0	16	10
2	18	45	9
4	13	14	10
6	7	43	9
8	2	12	15
9	20	41	21
11	15	10	27
13	9	39	36
15	4	8	45
16	22	37	57
18	17	7	13
30	11	36	29
22	6	5	44
24	0	35	3
25	19	4	22
27	13	33	40
29	8	3	6

March

2	2	32	32
3	21	2	2
5	15	31	25
7	10	0	47
9	4	30	12
10	22	59	34
12	17	28	56
14	11	58	19
16	6	27	38
18	0	56	54
19	19	26	35
21	13	56	1
23	8	25	27
25	2	54	52
26	21	24	11
28	15	53	30
30	10	22	50

April.

1	4	52	7
2	23	21	24

Emersions

April.

D.	H.	M.	S.
4	17	50	42
6	12	19	54
8	6	49	6
10	1	18	19
11	19	47	27
13	14	16	33
15	8	45	37
17	3	14	41
18	21	43	44
20	16	12	41
22	10	41	38
24	5	10	36
25	23	39	29
27	18	8	22
29	12	37	14

May.

1	7	6	30
3	1	34	55
4	20	3	36
6	14	32	17
8	9	0	59
10	3	29	35
11	21	58	11

Jupiter near the Sun.

Immersions.

June.

19	18	9	44
21	12	38	1
23	7	6	18
25	1	34	37
26	20	2	50
28	14	31	5
30	8	59	19

1740.

Immersions.

July.

D.	H.	M.	S.
2	3	27	30
3	21	55	41
5	16	24	23
7	10	52	48
9	5	21	13
10	23	49	37
12	18	18	8
14	12	46	39
16	7	15	11
18	1	43	41
19	20	12	11
21	14	40	43
23	9	9	17
25	3	37	51
26	22	6	37
28	16	35	20
30	11	4	3

August.

1	5	32	46
3	0	1	28
4	18	30	16
6	12	59	5
8	7	27	56
10	1	56	47
11	20	25	38
13	14	54	32
15	9	23	32
17	3	52	26
18	22	21	26
20	16	50	26
22	11	19	14
24	5	48	16
26	0	17	32
27	18	46	3
29	13	15	5
31	7	44	7

1740.

Immersions.

September.

D.	H.	M.	S.
2	2	13	10
3	20	42	9
5	15	10	58
7	9	40	8
9	4	9	8
10	22	38	8
12	17	7	10
14	11	36	7
16	6	5	4
18	0	34	3
19	19	3	0
21	13	31	57
23	8	0	53
25	2	30	4
26	20	58	55
28	15	27	26
30	9	56	14

October.

2	4	25	2
3	22	53	50
5	17	22	31
7	11	51	12
9	6	19	54
11	0	48	33
12	19	17	12
14	13	45	50
16	8	14	21
18	2	42	52
19	21	11	22
21	15	39	45
23	10	8	6
25	4	36	31
26	23	4	48
28	17	33	5
30	12	1	21

November.

1	6	29	29
3	0	57	37

1740.

Immersions.

November.

D.	H.	M.	S.
4	19	25	46
6	13	53	52
8	8	21	58
10	2	50	5
11	21	17	59
13	15	45	53
15	10	13	47
17	4	41	39
18	23	9	29
20	17	37	22
22	12	5	27
24	6	33	32
26	1	0	35
27	19	28	26
29	13	56	17

December.

1	8	24	6
3	2	51	45
4	21	19	24
6	15	47	2
8	10	14	41
10	4	42	20
11	23	9	56
13	17	37	42
15	12	5	28

Jupiter in Opposition to the Sun.

Emersions.

15	14	19	38
17	8	47	25
19	3	15	13
20	21	43	1
22	16	10	52
24	10	38	45
26	5	6	38
27	23	34	30

1740.

Emersions.

December.

D.	H.	M.	S.
29	18	2	26
31	12	30	22

Eclipses of the 2d. Planet.

1739

Emersions.

January.

D.	H.	M.	S.
2	15	17	23
6	4	35	36
9	17	53	30
13	7	9	50
16	20	28	7
20	9	46	25
23	23	4	49
27	12	23	12
31	1	42	27

February.

3	15	0	43
7	4	19	40
10	17	38	38
14	6	57	10
17	20	16	32
21	9	36	15
24	22	55	56
28	12	15	30

March.

4	1	35	5
7	14	54	41
11	4	14	18
14	17	13	51
18	6	53	25
21	20	13	2

Immersions.

May.

6	22	47	18
10	12	5	12
14	1	23	10

1739

Immersions.

May.

D.	H.	M.	S.
17	14	40	54
21	3	58	37
24	17	16	6
28	6	33	34

June.

0	19	50	55
4	9	8	16
7	22	25	29
11	11	42	42
14	23	59	55
18	14	17	7
22	3	33	55
25	16	51	42
29	6	9	4

July.

2	19	26	26
6	8	43	59
9	22	1	27
13	11	19	14
17	0	37	0
20	13	54	53
24	3	12	49
27	16	30	46
31	5	48	44

August.

3	19	7	21
7	8	25	58
10	21	44	32
14	11	3	7
18	0	21	22
21	13	40	37
25	2	59	30
28	16	18	21

1739

Immersions.

September.

D.	H.	M.	S.
1	5	37	25
4	18	56	29
8	8	15	22
11	21	34	13
15	10	53	8
19	0	12	5
22	13	31	0
26	2	49	55
29	16	8	37

October.

3	5	27	19
6	18	45	50
10	8	4	21
13	21	22	35
17	10	40	48
20	23	58	51
24	13	16	64
28	2	34	39

November.

0	15	52	24
4	5	9	58
7	18	27	33
11	7	44	37

Emersions.

14	23	36	55
18	12	53	54
22	2	10	52
25	15	27	43
29	4	44	34

December.

2	18	1	15
6	7	17	56
9	20	34	39

1739

Emersions.

December.

D.	H.	M.	S.
13	9	51	21
16	23	8	10
20	12	24	58
24	1	41	52
27	14	58	45
31	4	15	44

1740.

Emersions.

January.

3	17	33	39
7	6	51	25
10	20	8	40
14	9	26	26
17	22	44	12
21	12	2	20
25	1	19	56
28	14	39	6

February.

1	3	57	50
4	17	16	34
8	6	35	35
11	19	54	36
15	9	13	51
18	22	33	6
22	11	52	34
26	1	12	1

March.

0	14	31	38
4	3	51	14
7	17	10	52

EMERSIONS.

March.

D.	H.	M	S.
11	6	39	28
14	19	50	10
18	9	9	52
21	22	29	30
25	11	49	17
29	1	8	36

April.

1	14	28	4
5	3	47	25
8	17	6	45
12	6	25	50
15	19	44	54
19	9	3	46
22	22	22	36
26	11	41	6
30	0	59	35

May.

3	14	18	3
7	3	36	30
10	16	54	44

Jupiter is near his Conjunction with the Sun till *June* 22.

IMMERSIONS.

June.

D.	H.	M.	S.
22	5	42	29
25	19	0	23
29	18	18	17

July.

2	21	34	20
6	10	51	19
10	0	9	16
13	13	26	50
17	2	44	40
20	16	2	34
24	5	20	24
27	18	38	31
31	7	56	37

August.

3	21	14	56
7	10	33	15
10	23	51	40
14	13	10	5
18	2	29	8
21	15	47	20
25	5	5	56
28	18	24	32

IMMERSIONS.

September.

D	H.	M	S.
1	7	43	20
4	21	2	6
8	10	20	52
11	23	39	37
15	12	58	16
19	2	16	53
22	15	35	22
26	4	53	50
29	18	12	48

October.

3	7	31	43
6	20	49	16
10	10	6	48
13	23	24	42
17	12	42	35
21	2	0	29
24	15	18	23
28	3	35	7

November.

0	17	52	24
4	7	9	10
7	20	26	0
11	9	42	47

IMMERSIONS.

November.

D.	H.	M.	S.
14	22	59	12
18	12	15	37
22	1	32	13
25	14	48	47
29	4	4	37

December.

2	17	20	25
6	6	36	27
9	19	52	30
13	9	8	40
16	22	24	43
17	1	12	21

EMERSIONS.

20	14	28	15
24	3	45	6
27	17	1	30
31	6	18	54

Eclipses of the 3d. Planet.

1739

IMMERSIONS. AND EMERSIONS.

January.

D.	H.	M	S.
Im. 1	9	11	55
Em. 1	11	23	25
Im. 8	13	11	52
Em. 8	15	23	8

1739

Im.	15	17	12	46
Em.	15	19	23	54
Im.	22	21	13	22
Em.	22	23	24	10
Im.	30	1	15	34
Em.	30	3	26	16

February.

Im.	6	5	17	35
Em.	6	7	28	1

1739

Im.	13	9	20	44
Em.	13	11	31	7
Im.	20	13	23	46
Em.	20	15	33	58
Im.	27	17	27	31
Em.	27	19	37	41

March

Im.	6	21	31	20
Em.	6	23	41	24

1739

Im.	14	1	35	7
Em.	14	3	45	7
Im.	21	5	38	55
Em.	21	7	48	57
Im.	28	9	41	33
Em.	28	11	50	52

Jupiter is near his Conjunction with the Sun till *May* 10.

Immersions And Emersions.

May.

D.	H.	M.	S.
Im.	10	9	59	33
Em.	10	12	10	27
Im.	17	13	57	9
Em.	17	16	8	23
Im.	24	17	54	45
Em.	24	20	6	8

June.

Im.	0	21	54	6
Em.	1	0	5	54
Im.	8	1	53	12
Em.	8	4	5	20
Im.	15	5	51	37
Em.	15	8	4	7
Im.	22	9	50	55
Em.	22	12	3	18
Im.	29	13	49	28
Em.	29	16	2	42

July.

Im.	6	17	49	19
Em.	6	20	2	44
Im.	13	21	48	23
Em.	14	0	2	23
Im.	21	1	49	11
Em.	21	4	3	26
Im.	28	5	48	48
Em.	28	8	3	58

August.

Im.	4	9	50	29
Em.	4	12	5	52
Im.	11	13	50	57
Em.	11	16	7	13
Im.	18	17	52	58
Em.	18	20	9	38
Im.	25	21	53	51
Em.	26	0	11	15

September.

D.	H.	M.	S.
Im.	2	1	56	59
Em.	2	4	14	41
Im.	9	5	58	54
Em.	9	8	17	32
Im.	16	10	1	44
Em.	16	12	20	43
Im.	23	14	3	1
Em.	23	16	23	17

October.

Im.	0	18	5	2
Em.	0	20	25	34
Im.	7	22	5	59
Em.	8	0	27	19
Im.	15	2	7	16
Em.	15	4	28	57
Im.	22	6	7	8
Em.	28	8	29	54
Im.	29	10	7	21
Em.	29	12	30	37

November.

Im.	5	14	6	8
Em.	5	16	30	22
Im.	12	18	5	7
Em.	12	20	29	21
Im.	19	22	2	28
Em.	20	0	28	20
Im.	27	2	0	30
Em.	27	4	26	46

December.

Im.	4	5	57	43
Em.	4	8	25	13
Im.	11	9	55	19
Em.	11	12	23	9
Im.	18	13	53	40
Em.	18	16	22	46
Im.	25	17	55	4
Em.	25	20	20	32

January.

D.	H.	M.	S.
Im.	1	21	47	58
Em.	2	0	18	38
Im.	9	1	45	44
Em.	9	4	17	24
Im.	16	5	45	57
Em.	16	8	18	37
Im.	23	9	47	9
Em.	23	12	19	49
Im.	30	13	46	36
Em.	30	16	20	56

February

Im.	6	17	48	20
Em.	6	20	23	36
Im.	13	21	50	2
Em.	14	0	26	16
Im.	21	1	52	41
Em.	21	4	29	47
Im.	28	5	55	18
Em.	28	8	33	18

March.

Im.	6	9	56	13
Em.	6	12	37	11
Im.	13	14	1	10
Em.	13	16	41	4
Im.	20	18	4	4
Em.	20	20	44	57
Im.	27	22	7	1
Em.	28	0	48	39

April.

Im.	4	2	9	29
Em.	4	4	52	7
Im.	11	6	12	0
Em.	11	8	55	36
Im.	18	10	14	38
Em.	18	12	58	15
Im.	25	14	17	18
Em.	25	16	58	54

May.

D.	H.	M.	S.
Im.	2	18	20	30
Em.	2	20	58	30
Im.	9	22	24	30
Em.	10	0	58	6

June.

Im.	21	22	8	18
Em.	22	0	59	6
Im.	29	2	6	52
Em.	29	5	0	52

July.

Im.	6	6	3	26
Em.	6	8	58	2
Im.	13	10	2	27
Em.	13	12	58	57
Im.	20	14	1	28
Em.	20	16	58	4
Im.	27	18	0	25
Em.	27	20	57	55

August.

Im.	3	22	1	23
Em.	4	0	59	47
Im.	11	2	2	17
Em.	11	5	1	33
Im.	18	6	3	11
Em.	18	9	3	19
Im.	25	10	4	3
Em.	25	13	5	7

September.

Im.	1	14	4	56
Em.	1	17	6	44
Im.	8	18	6	●
Em.	8	21	8	52
Im.	15	22	7	4
Em.	16	1	11	0
Im.	23	2	7	37
Em.	23	5	12	15
Im.	30	6	8	10
Em.	30	9	13	30

1740.

IMMERSIONS. AND EMERSIONS.

October.

	D.	H.	M.	S.
Im.	7	10	8	20
Em.	7	13	14	30
Im.	14	14	8	30
Em.	14	17	15	30
Im.	21	18	9	6

1740.

October.

	D.	H.	M.	S.
Em.	21	21	17	6
Im.	28	22	5	40
Em.	29	1	14	38

November.

Im.	5	2	3	10
Em.	5	5	12	46
Im.	12	6	0	39
Em.	12	9	10	53

1740.

November.

	D.	H.	M.	S.
Im.	19	9	57	15
Em.	19	13	8	11
Im.	26	13	53	17
Em.	26	17	4	57

December.

Im.	3	17	49	3
Em.	3	21	1	33
Im.	10	21	44	49

1740.

December.

	D.	H.	M.	S.
Em.	11	0	58	9
Im.	18	1	41	33
Em.	18	4	54	53
Im.	25	5	36	51
Em.	25	8	51	37

Heliocentrick Oppositions, and *Eclipses* of the 4th Planet.

1739

Heliocentrick Oppositions.

January.

D.	H.	M.	S.
5	2	48	50
21	21	2	14

February.

7	15	18	43
24	9	37	56

March.

13	3	58	44

May.

19	5	6	40

June.

4	23	16	54
21	17	25	41

July.

8	11	34	7
25	5	46	40

Heliocentrick Oppositions.

August.

D.	H.	M.	S.
11	0	0	33
28	18	16	33

September.

13	12	32	28
30	6	48	13

October.

17	1	1	38

November.

2	19	2	16
19	13	19	29

December.

6	7	24	28
23	1	28	56

1740

January.

8	19	35	35
25	12	44	50

Heliocentrick Oppositions.

February.

D.	H.	M.	S.
11	6	58	47
28	2	18	59

March.

15	20	31	54

April.

1	13	48	26
18	8	45	57

May.

5	3	14	24

Jupiter is near his Conjunction with the Sun till June 24.

Eclipses of the 4th.

IMMERSIONS. AND EMERSIONS.

June.

Im.	24	8	47	33
Em.	24	10	18	35

IMMERSIONS. AND EMERSIONS.

July.

	D.	H.	M.	S.
Im.	11	2	44	31
Em.	11	4	32	29
Im.	27	20	44	58
Em.	27	22	47	18

August.

Im.	13	14	47	22
Em.	13	17	2	12
Im.	30	8	53	15
Em.	30	11	19	41

September.

Im.	16	2	59	52
Em.	16	5	34	56

October.

Im.	2	20	56	3
Em.	2	23	44	5
Im.	19	15	5	43
Em.	19	18	2	13

November.

Im.	5	9	4	53
Em.	5	12	10	11

Immersions. And Emersions.				Immersions. And Emersions.				Immersions. And Emersions.			
November.				*December.*				*December.*			
D.	H.	M.	S.	D.	H.	M.	S.	D.	H.	M.	S.
Im. 22	2	41	31	*Im.* 8	20	54	11	*Im.* 25	14	48	19
Em. 22	5	55	3	*Em.* 8	24	15	23	*Em.* 25	18	16	49

A Table of the *Occultations*, the *Immersions* and *Emersions* of Jupiter's 1st. Planet into, and from Jupiter's Body: with the *Parallax of the Orb*, for every Day of the Years 1739, and 1740, while Jupiter is visible.

Days of *January.*	Parallax of the Orb.	1739	Days of *February.*	Parallax of the Orb.	1739
		H. M. H. M. H M.			H. M. H. M. H. M.
1	11 22	*Im.* 6 59. *Em.* 9 13.	1	10 9	Im. 6 28 Eclipse.
2	11 23	*Im.* 4. 13. Eclipse.	2	10 4	Im. 3 42. Em. 5 56
3	11 23	*Im.* 1 27. *Em.* 3 41. *Im.* 22 41.	3	9 59	Im. 0 59 Eclipse, Im 22 12
4	11 24	Eclipse, *Im.* 19 56. *Em.* 22 10.	4	9 55	Em. 0 26 Im. 19 28 Eclipse,
5	11 24	*Im.* 17 10 Eclipse.	5	9 50	Im. 16 42 Em. 18 56
6	11 23	*Im.* 14 24. *Em.* 16 38.	6	9 44	Im. 13 57 Eclipse
7	11 22	*Im.* 11 38. Eclipse.	7	9 38	Im. 11 12 Em. 13 26
8	11 21	*Im.* 8 52. *Em.* 11 6.	8	9 32	Im. 8 28 Eclipse
9	11 19	*Im.* 6 6 Eclipse.	9	9 26	Im. 5 43 Em. 7 57
10	11 18	*Im.* 3 20. *Em.* 5 34.	10	9 20	Im. 2 59 Eclipse
11	11 17	*Im.* 0 34 Eclipse. *Im.* 21 49.	11	9 15	Im. 0 13 Em. 2 27 Im. 21 29
12	11 15	*Em.* 0 3. *Im.* 19 4 Eclipse.	12	9 11	Eclipse Im. 18 43 Em. 20 57
13	11 13	*Im.* 16 18 *Em.* 18 33.	13	9 5	Im. 15 59 Eclipse
14	11 10	*Im.* 13 33 Eclipse.	14	8 58	Im. 13 14 Em. 15 28
15	11 7	*Im.* 10 48 *Em.* 13 2.	15	8 52	Im. 10 30 Eclipse
16	11 5	*Im.* 8 3 Eclipse.	16	8 46	Im. 7 44 Em. 9 58
17	11 2	*Im.* 5 17 *Em.* 7 31.	17	8 40	Im. 5 0 Eclipse
18	11 0	*Im.* 2 31 Eclipse *Im.* 23 46.	18	8 34	Im. 2 14 Em. 4 29 Im. 23 30
19	10 58	*Em.* 2 0. *Im.* 21 1.	19	8 28	Eclipse Im. 20 45 Em. 22 59
20	10 55	Eclipse *Im.* 18 15 *Em.* 20 29.	20	8 22	Im. 18 1 Eclipse
21	10 52	*Im.* 15 30 Eclipse.	21	8 15	Im. 15 16 Em. 17 30
22	10 48	*Im.* 12 44 *Em.* 14 58.	22	8 8	Im. 12 32 Eclipse
23	10 46	*Im.* 9 59 Eclipse.	23	8 2	Im. 9 47 Em. 12 1
24	10 42	*Im.* 7 14 *Em.* 9 28.	24	7 55	Im. 7 3 Eclipse
25	10 39	*Im.* 3 29 Eclipse.	25	7 47	Im. 4 17 Em. 6 31
26	10 35	*Im.* 1 43 *Em.* 3 57 *Im.* 22 59.	26	7 40	Im. 1 33 Eclipse Im. 22 48
27	10 32	Eclipse *Im.* 20 13 *Em.* 22 27.	27	7 33	Em. 1 2 Im. 20 4 Eclipse
28	10 28	*Im.* 17 28 Eclipse.	28	7 27	Im. 17 18 Em. 19 32
29	10 23	*Im.* 14 42 *Em.* 16 56.	*Mar.*		
30	10 18	*Im.* 11 58 Eclipse.			
31	10 13	*Im.* 9 12 *Em.* 11 26.			

March	Par:	H. M.	H. M. H. M.
1	7	19	Im. 14 35 Eclipse
2	7	11	Im. 11 49 Em. 14 3
3	7	3	Im. 9 6 Eclipse
4	6	54	Im. 6 21 Em. 8 35
5	6	48	Im. 3 37 Eclipse
6	6	43	Im. 0 51 Em 3 5 Im. 22 8
7	6	36	Eclipse Im. 19 21 Em 21 36
8	6	28	Im. 16 39 Eclipse
9	6	22	Im. 13 53 Em. 16 7
10	6	14	Im. 11 9 Eclipse
11	6	6	Im. 8 24 Em. 10 38
12	5	57	Im. 5 41 Eclipse.
13	5	49	Im. 2 55 Em. 5 9
14	5	41	Im. 0 11 Ecl. Im. 21 25 Em. 23
15	5	32	Im. 18 41 Eclipse (39
16	5	24	Im. 15 56 Em. 18 10
17	5	16	Im. 13 14 Eclipse
18	5	8	Im. 10 28 Em. 12 42
19	5	0	Im. 7 44 Eclipse
20	4	52	Im. 4 59 Em. 7 15
21	4	44	Im. 2 16 Eclipse Im. 23 30
22	4	36	Em. 1 44 Im. 20 47 Eclipse
23	4	28	Im. 18 1 Em. 20 15.
24	4	19	Im. 15 18 Eclipse
25	4	11	Im. 12 32 Em. 14 46
26	4	3	Im. 9 49 Eclipse
27	3	55	Im. 7 3 Em. 9 17
28	3	48	Im. 4 20 Eclipse
29	3	40	Im 1 34 Em. 3 48 Im. 22 51
30	3	32	Eclipse Im. 20 5 Em. 22 19
31	3	24	Im. 17 21 Eclipse
May			*Jupiter near the Sun.*
18	3	40	Eclipse Em. 15 24
19	3	48	Im. 10 24 Em. 12 37
20	3	56	Eclipse Em. 9 54
21	4	5	Im. 4 54 Em. 7 8
22	4	14	Eclipse Em. 4 24 Im. 23 24
23	4	22	Em. 1 38 Eclipse Em. 22 55
24	4	31	Im. 17 55 Em. 20 9
25	4	40	Eclipse Em. 17 25
26	4	48	Im. 12 25 Em. 14 39
27	4	56	Eclipse Em. 11 55
28	5	4	Im. 6 55 Em. 9 9
29	5	12	Eclipse Em. 6 24
30	5	19	Im. 1 25 Em. 3 39 Eclipse
31	5	27	Em. 0 54 Im. 19 55 Em. 22 9

June	Par.	H. M.	H. M. H. M.
1	5	35	Eclipse Em. 19 24
2	5	43	Im. 14 25 Em. 16 39
3	5	51	Eclipse Em. 13 54
4	5	59	Im. 8 55 Em. 11 9
5	6	8	Eclipse Em. 8 24
6	6	14	Im. 3 24 Em. 5 39 Eclipse
7	6	23	Em. 2 54 Im. 21 54
8	6	30	Em. 0 8 Eclipse Em. 21 24
9	6	38	Im. 16 24 Em. 18 38
10	6	45	Eclipse Em. 15 53
11	6	52	Im. 10 53 Em. 13 8
12	6	59	Eclipse Em. 10 23
13	7	6	Im. 5 22 Em. 7 37
14	7	13	Eclipse Em. 4 53 Im. 23 53
15	7	20	Em. 2 7 Eclipse Em. 23 23
16	7	27	Im. 18 23 Em. 20 37
17	7	34	Eclipse Em. 16 52
18	7	42	Im 11 52 Em. 14 7
19	7	49	Eclipse Em. 12 22
20	7	55	Im. 7 22 Em. 9 36
21	8	2	Eclipse Em. 6 51
22	8	8	Im. 1 51 Em. 4 6 Eclipse
23	8	15	Em. 1 21 Im. 20 21 Em. 22 35
24	8	21	Eclipse Em. 19 51
25	8	28	Im. 14 51 Em. 17 5
26	8	34	Eclipse Em. 14 20
27	8	40	Im. 9 20 Em. 11 34
28	8	46	Eclipse Em. 8 50
29	8	52	Im. 3 50 Em. 6 4.
30	8	59	Eclipse Em. 3 19 Im. 22 19
Jul.			
1	9	5	Em. 0 34 Eclipse Em. 21 49
2	9	11	Im. 16 49 Em. 19 3
3	9	17	Eclipse Em. 16 18
4	9	23	Im. 11 18 Em. 13 32
5	9	29	Eclipse Em. 10 48
6	9	34	Im. 5 48 Em. 8 3
7	9	39	Eclipse Em. 5 18 (23 47
8	9	44	Im. 0 18 Em. 2 32 Ecli. Em.
9	9	49	Im. 18 47 Em. 21 1
10	9	54	Eclipse Em. 16 8
11	9	59	Im. 11 18 Em. 13 32
12	10	4	Eclipse Em. 12 46
13	10	10	Im. 7 46 Em. 10 1
14	10	15	Eclipse Em. 7 15
15	10	20	Im. 2 15 Em. 4 29 Eclipse
16	10	24	Em. 1 45 Im. 20 45 Em. 22 59
17	10	28	Eclipse Em. 20 1[illegible]

		H. M.	H. M. H. M.
July	Par.		
18	10	31	Im. 15 14 Em. 17 28
19	10	35	Eclipse Em. 14 43
20	10	39	Im. 9 43 Em. 11 58
21	10	43	Eclipse Em. 9 12
22	10	47	Im. 4 12 Em. 6 27
23	10	51	Eclipse Em. 3 42 Im. 22 42
24	10	54	Em. 0 56 Eclipse Em. 22 11
25	10	57	Im. 17 11 Em. 19 25
26	11	0	Eclipse Em. 16 40
27	11	4	Im. 11 46 Em. 13 55
28	11	7	Eclipse Em. 11 10
29	11	10	Im. 6 10 Em. 8 24
30	11	13	Eclipse Em. 5 39
31	11	15	Im. 0 39 Em. 2 54 Eclipse
Aug.			
1	11	18	Em. 0 8 Im. 19 8 Em. 21 23
2	11	20	Eclipse Em. 18 38
3	11	22	Im. 13 38 Em. 15 52
4	11	24	Eclipse Em. 13 6
5	11	26	Im. 8 6 Em. 10 20
6	11	28	Eclipse Em. 7 36,
7	11	30	Im. 2 36 Em. 4 51 Eclipse
8	11	31	Em. 2 5 Im. 21 5 Em. 23 19
9	11	32	Eclipse Em. 20 34
10	11	33	Im. 15 34 Em. 17 48
11	11	34	Eclipse Em. 15 3
12	11	35	Im. 10 3 Em. 12 17
13	11	36	Eclipse Em. 9 36
14	11	36	Im. 4 32 Em. 6 47
15	11	36	Eclipse Em. 4 1 Im. 23 1
16	11	37	Em. 1 16 Eclipse Em. 22 31
17	11	37	Im. 17 30 Em. 19 45
18	11	37	Eclipse Em. 16 59
19	11	36	Im. 11 59 Em. 14 14
20	11	36	Eclipse Em. 11 28
21	11	35	Im. 6 28 Em. 8 42
22	11	34	Eclipse Em. 5 57
23	11	33	Im. 0 57 Em. 3 11 Eclipse
24	11	32	Em. 0 26 Im. 19 26 Em. 21 40
25	11	31	Eclipse Em. 18 55
26	11	29	Im. 13 54 Em. 16 9
27	11	27	Eclipse Em. 13 23
28	11	25	Im. 8 23 Em. 10 37
29	11	23	Eclipse Em. 7 52
30	11	21	Im. 2 52 Em. 5 6 Eclipse
31	11	18	Em. 2 20 Im. 21 20 Em. 23 35

		H. M.	H. M. H. M.
Sept.	Par.		
1	11	16	Eclipse Em. 20 49
2	11	13	Im. 15 49 Em. 18 4
3	11	10	Eclipse Em. 15 17
4	11	6	Im. 10 17 Em. 12 32
5	11	3	Eclipse Em. 9 46
6	10	59	Im. 4 45 Em. 7 0
7	10	55	Eclipse Em. 4 14 Im. 23 14
8	10	50	Em. 1 28 Eclipse Em. 22 42
9	10	46	Im. 17 42 Em. 19 57
10	10	42	Eclipse Em. 17 10
11	10	38	Im. 12 10 Em. 14 25
12	10	34	Eclipse Em. 11 39
13	10	29	Im. 6 38 Em. 8 53
14	10	24	Eclipse Em. 6 7
15	10	18	Im. 1 6 Em. 3 21 Eclipse
16	10	12	Em. 0 34 Im. 19 34 Em. 20 49
17	10	7	Eclipse Em. 19 2
18	10	1	Im. 14 2 Em. 16 17
19	9	55	Eclipse Em. 13 30
20	9	48	Im. 8 30 Em. 10 44
21	9	41	Eclipse Em. 7 58
22	9	34	Im. 3 58 Em. 5 12 Eclipse
23	9	27	Em. 2 25 Im. 21 25 Em. 23 40
24	9	20	Eclipse Em. 20 53
25	9	13	Im. 50 52 Em. 18 7
26	9	5	Eclipse Em. 15 21
27	8	57	Im. 10 20 Em. 12 35
28	8	49	Eclipse Em. 9 47
29	8	42	Im. 4 47 Em. 7 2
30	8	33	Eclipse Em. 4 15 Im. 23 14
Oct.			
1	8	25	Em. 1 29 Eclipse Em. 22 42
2	8	16	Im. 17 42 Em. 19 56
3	8	5	Eclipse Em. 17 9
4	7	56	Im. 12 8 Em. 14 23
5	7	47	Eclipse Em. 11 36
6	7	38	Im. 6 35 Em. 8 50
7	7	29	Eclipse Em. 6 4
8	7	19	Im. 1 3 Em. 3 18 Eclipse
9	7	9	Em. 0 30 Im. 19 29 Em. 21 44
10	6	59	Eclipse Em. 18 57
11	6	48	Im. 13 56 Em. 16 11
12	6	37	Eclipse Em. 13 23
13	6	27	Im. 8 22 Em. 10 37
14	6	16	Eclipse Em. 7 48
15	6	5	Im. 2 47 Em. 5 4 Eclipse
16	5	54	Em. 2 16 Im. 21 16 Em. 23 31

Octob. Par.	H. M.	H. M. H. M.
17	5 42	*Eclipse Em.* 20 42
18	5 30	*Im.* 15 41 *Em.* 17 56
19	5 18	*Eclipse Em.* 15 8
20	5 6	*Im.* 10 7 *Em.* 12 22
21	4 54	*Eclipse Em.* 9 34
22	4 42	*Im.* 4 33 *Em.* 6 48
23	4 30	*Eclipse Em.* 4 0 *Im.* 22 59
24	4 17	*Em.* 1 14 *Eclipse Em.* 22 27
25	4 4	*Im.* 17 26 *Em.* 19 41
26	3 51	*Eclipse Em.* 16 52
27	3 38	*Im.* 11 51 *Em.* 14 6
28	3 25	*Eclipse Em.* 11 18
29	3 12	*Im.* 6 17 *Em.* 8 32
30	3 0	*Eclipse Em.* 5 43
31	2 49	*Im.* 0 42 *Em.* 2 58 *Eclipse*
Nov.		
1	2 36	*Em.* 0 10 *Im.* 19 9 *Em.* 21 24
2	2 23	*Eclipse Em.* 18 36
3	2 10	*Im.* 13 35 *Em.* 15 50
4	1 57	*Eclipse Em.* 13 1
5	1 43	*Im.* 8 1 *Em.* 10 15
6	1 30	*Eclipse Em.* 7 26
7	1 17	*Im.* 2 25 *Em.* 4 41 *Eclipse*
8	1 4	*Em.* 1 52 *Im.* 20 52 *Em.* 23 7
9	0 50	*Eclipse Em.* 20 18
10	0 37	*Im.* 15 17 *Em.* 17 33
11	0 24	*Eclipses.*
12	0 9	*Im.* 9 37 *Em.* 11 52
		Jupiter in Opposition to the Sun.
13	0 4	*Im.* 6 51 *Eclipse*
14	0 17	*Im.* 4 6 *Em.* 6 21
15	0 30	*Im.* 1 18 *Eclipse Im.* 22 33
16	0 44	*Em.* 0 48 *Im.* 19 44 *Eclipse*
17	0 58	*Im.* 16 58 *Em.* 19 13
18	1 12	*Im.* 14 9 *Eclipse*
19	1 26	*Im.* 11 23 *Em.* 13 38
20	1 39	*Im.* 8 34 *Eclipse*
21	1 52	*Im.* 5 49 *Em.* 8 3
22	2 6	*Im.* 3 59 *Eclipse* (*Eclipse*
23	2 19	*Im.* 0 13 *Em.* 2 28 *Im.* 21 25
24	2 32	*Im.* 18 39 *Em.* 20 55
25	2 45	*Im.* 15 49 *Eclipse*
26	2 57	*Im.* 13 4 *Em.* 15 19
27	3 9	*Im.* 10 15 *Eclipse*
28	3 21	*Im.* 7 29 *Em.* 9 44
29	3 34	*Im.* 4 39 *Eclipse*
30	3 48	*Im.* 1 54 *Em.* 4 9 *Im.* 23 5

Dec. Par.	H. M.	H. M. H. M.
1	4 0	*Eclipse Im.* 20 20 *Em.* 22 35
2	4 12	*Im.* 17 31 *Eclipse*
3	4 24	*Im.* 14 45 *Em.* 17 0
4	4 36	*Im.* 11 56 *Eclipse*
5	4 48	*Im.* 9 11 *Em.* 11 26
6	5 1	*Im.* 6 22 *Eclipse*
7	5 13	*Im.* 3 36 *Em.* 5 50
8	5 24	*Im.* 0 47 *Eclipse Im.* 22 2
9	5 35	*Em.* 0 17 *Im.* 19 13 *Eclipse*
10	5 46	*Im.* 16 27 *Em.* 18 42
11	5 57	*Im.* 13 38 *Eclipse*
12	6 9	*Im.* 10 52 *Em.* 13 8
13	6 20	*Im.* 8 4 *Eclipse*
14	6 31	*Im.* 5 18 *Em.* 7 33
15	6 41	*Im.* 2 29 *Eclipse Im.* 23 44
16	6 51	*Em.* 1 59 *Im.* 20 55 *Eclipse*
17	7 1	*Im.* 18 10 *Em.* 20 25
18	7 12	*Im.* 15 21 *Eclipse*
19	7 22	*Im.* 12 35 *Em.* 14 51
20	7 31	*Im.* 9 48 *Eclipse*
21	7 40	*Im.* 7 2 *Em.* 9 17
22	7 49	*Im.* 4 13 *Eclipse*
23	7 58	*Im.* 1 28 *Em.* 3 43 *Im.* 22 40
24	8 7	*Eclipse Im.* 19 54 *Em.* 22 10
25	8 15	*Im.* 17 6 *Eclipse*
26	8 23	*Im.* 14 21 *Em.* 16 36
27	8 31	*Im.* 11 33 *Eclipse*
28	8 39	*Im.* 8 47 *Em.* 11 2
29	8 47	*Im.* 5 59 *Eclipse*
30	8 55	*Im.* 3 14 *Em.* 5 29 (*Em.* 23 56
31	9 3	*Im.* 0 26 *Eclipse Im.* 21 49
Jan.		1740.
1	9 10	*Im.* 18 52 *Eclipse*
2	9 17	*Im.* 16 6 *Em.* 18 22
3	9 24	*Im.* 13 20 *Eclipse*
4	9 31	*Im.* 10 35 *Em.* 12 50
5	9 38	*Im.* 7 47 *Eclipse*
6	9 44	*Im.* 5 1 *Em.* 7 17
7	9 50	*Im.* 2 13 *Eclipse Im.* 23 27
8	9 55	*Em.* 1 43 *Im.* 20 40
9	10 1	*Eclipse Im.* 17 54 *Em.* 20 10
10	10 7	*Im.* 15 7 *Eclipse*
11	10 11	*Im.* 12 22 *Em.* 14 38
12	10 16	*Im.* 9 35 *Eclipse*
13	10 21	*Im.* 6 49 *Em.* 9 5
14	10 26	*Im.* 4 2 *Eclipse*
15	10 30	*Im.* 1 16 *Em.* 3 32 *Im.* 22 30
16	10 34	*Eclipse Im.* 19 44 *Em.* 22 0

		H. M.	H. M. H M.
Jan.	Par.		
17	10	38	*Im.* 16 58 *Eclipse*
18	10	41	*Im.* 14 12 *Em.* 16 28
19	10	45	*Im.* 11 25 *Eclipse*
20	10	48	*Im.* 8 40 *Em.* 10 56
21	10	51	*Im.* 5 54 Eclipse
22	10	54	*Im.* 3 8 *Em.* 5 24 (*Em.* 23 52
23	10	57	*Im.* 0 22 Eclipse *Im.* 21 36
24	11	0	*Im.* 18 50 Eclipse
25	11	2	*Im.* 16 4 *Em.* 18 20
26	11	4	*Im.* 13 18 Eclipse
27	11	6	*Im.* 10 33 *Em.* 12 49
28	11	8	*Im.* 7 47 Eclipse.
29	11	10	*Im.* 5 1 *Em.* 7 17
30	11	12	*Im.* 2 15 Eclipse, *Im.* 23 30
31	11	13	*Em.* 1 46 *Im.* 20 44 Eclipse
Feb.			
1	11	13	*Im.* 17 58 *Em.* 20 14
2	11	14	*Im.* 15 13 Eclipse
3	11	14	*Im.* 12 27 *Em.* 14 43
4	11	15	*Im.* 9 42 Eclipse
5	11	15	*Im.* 6 56 *Em.* 9 12
6	11	15	*Im.* 4 10 Eclipse
7	11	15	*Im.* 1 25 *Em.* 3 41 *Im.* 22 40
8	11	15	Eclipse *Im.* 19 54 *Em.* 22 10
9	11	14	*Im.* 17 9 Eclipse
10	11	14	*Im.* 14 23 *Em.* 16 39
11	11	13	*Im.* 11 38 Eclipse
12	11	13	*Im.* 8 52 *Em.* 11 8
13	11	12	*Im.* 6 7 Eclipse
14	11	10	*Im.* 3 21 *Em.* 5 38
15	11	8	*Im.* 0 37 Eclipse *Im.* 21 51
16	11	6	*Em.* 0 7 *Im.* 19 6 Eclipse
17	11	5	*Im.* 16 20 *Em.* 18 37
18	11	3	*Im.* 13 35 Eclipse
19	11	1	*Im.* 10 50 *Em.* 13 7
20	10	59	*Im.* 8 5 Eclipse
21	10	56	Im. 5 20 Em. 7 36
22	10	54	Im. 2 35 Eclipse Im. 23 50
23	10	52	Em. 2 6 Im. 21 5
24	10	50	Eclipse Im. 18 19 Em. 20 35
25	10	47	Im. 15 36 Eclipse
26	10	44	Im. 12 49 Em. 15 6
27	10	40	Im. 10 5 Eclipse
28	10	37	Im. 7 19 Em. 9 36
29	10	34	Im. 4 36 Eclipse

		H. M.	H. M. H. M.
Mar.	Par.		
1	10	30	Im. 1 50 Em. 4 6 Im. 23 5
2	10	26	Eclipse Im. 20 20 Em. 22 36
3	10	22	Im. 17 36 Eclipse.
4	10	18	Im. 14 50 Em. 17 6
5	10	14	Im. 12 6 Eclipse
6	10	10	Im. 9 20 Em. 11 37
7	10	6	Im. 6 36 Eclipse
8	10	1	Im. 3 50 Em. 6 6
9	9	56	Im. 1 6 Eclipse Im. 22 21
10	9	51	Em. 0 37 Im. 19 37 Eclipse
11	9	47	Im. 16 51 Em. 19 8
12	9	43	Im. 14 7 Eclipse
13	9	38	Im. 11 21 Em. 13 38
14	9	33	Im. 8 37 Eclipse
15	9	28	Im. 5 52 Em. 8 8
16	9	22	Im. 3 8 Eclipse
17	9	17	Im. 0 22 Em. 2 39 Im. 21 38
18	9	11	Eclipse Im. 18 53 Em. 21 9
19	9	6	Im. 16 9 Eclipse
20	9	0	Im. 13 23 Em. 15 40
21	8	54	Im. 10 40 Eclipse
22	8	48	Im. 7 54 Em. 10 10
23	8	42	Im. 5 10 Eclipse
24	8	37	Im. 2 25 Em 4 41 Im. 23 41.
25	8	31	Eclipse Im. 20 55 Em. 23 12
26	8	25	Im. 18 12 Eclipse
27	8	18	Im. 15 26 Em. 17 43
28	8	12	Im. 12 42 Eclipse
29	8	6	Im 9 56 Em. 12 13
30	7	59	Im. 7 13 Eclipse
31	7	53	Im. 4 27 Em. 6 44
Apr.			
1	7	46	Im. 1 44 Eclipse Im. 22 59
2	7	39	*Em.* 1 15 Im 20 14 *Eclipse*
3	7	32	Im. 17 28 *Em.* 19 45
4	7	25	Im. 14 45 *Eclipse*
5	7	18	Im. 11 59 *Em.* 14 16
6	7	12	Im. 9 15 *Eclipse*
7	7	5	Im. 6 30 *Em.* 8 46
8	6	58	Im. 3 46 *Eclipse*
9	6	51	Im. 1 0 *Em.* 3 17 Im. 22 17
10	6	44	*Eclipse* Im. 19 31 *Em.* 21 48
11	6	37	Im. 16 47 *Eclipse*
12	6	30	Im. 14 2 *Em.* 16 19
13	6	23	Im. 11 18 *Eclipse*
14	6	15	Im. 8 32 *Em.* 10 49

	H. M.	H. M. H. M.
Apr.	Par.	
15	6 8	Im. 5 48 Eclipse
16	6 0	Im. 3 3 Em. 5 20
17	5 52	Im. 0 19 Eclipse Im. 21 33 Em.
18	5 45	Im. 18 50 Eclipse (23 50
19	5 37	Im. 16 4 Em. 18 21
20	5 29	Im. 13 21 Eclipse
21	5 21	Im. 10 35 Em. 12 52
22	5 13	Im. 7 51 Eclipse
23	5 5	Im. 5 5 Em. 7 22
24	4 57	Im. 2 22 Eclipse Im. 23 36
25	4 49	Em. 1 53 Im. 20 52 Eclipse
26	4 40	Im. 18 7 Em. 20 24
27	4 31	Im. 15 23 Eclipse
28	4 22	Im. 12 37 Em. 14 54
29	4 13	Im. 9 54 Eclipse
30	4 7	Im. 7 8 Em. 9 25
May.		
1	3 58	Im. 4 24 Eclipse
2	3 48	Im. 1 39 Em. 3 56 Im. 22 56
3	3 38	Eclipse Im. 20 9 Em. 22 26
4	3 29	Im. 17 25 Eclipse
5	3 22	Im. 14 40 Em. 16 57
6	3 16	Im. 11 56 Eclipse
7	3 7	Im. 9 10 Em. 11 27
8	2 58	Im. 6 26 Eclipse
June		Jupiter near the Sun
18	2 53	Em. 2 17 Im. 21 13 Em. 23 3
19	3 1	Eclipse Em. 20 48
20	3 9	Im. 15 44 Em. 18 2
21	3 17	Eclipse Em. 15 17
22	3 25	Im. 10 13 Em. 12 31
23	3 33	Eclipse Em. 9 46
24	3 41	Im. 4 43 Em. 7 1
25	3 49	Eclipse Em. 4 17 Im. 23 13
26	3 57	Em. 1 31 Eclipse Em. 22 47
27	4 5	Im. 17 43 Em. 20 1
28	4 13	Eclipse Em. 17 17
29	4 21	Im. 12 13 Em. 14 31
30	4 30	Eclipse Em. 11 46
July.		
1	4 38	Im. 6 42 Em. 9 1
2	4 46	Eclipse Em. 6 16
3	4 54	Im. 1 12 Em. 3 31 Eclipse
4	5 2	Em. 0 46 Im. 19 42 Em. 22 1

	H. M.	H. M. H. M.
July	Par.	
5	5 10	Eclipse Em. 19 16
6	5 18	Im. 14 13 Em. 16 31
7	5 26	Eclipse Em. 13 47
8	5 34	Im. 8 43 Em. 11 1
9	5 42	Eclipse Em. 8 17
10	5 50	Im. 3 13 Em. 5 31 Eclipse
11	5 57	Em. 2 47 Im. 21 43
12	6 4	Em. 0 1 Eclipse Em. 21 17
13	6 12	Im. 16 13 Em. 18 31
14	6 19	Eclipse Em. 15 47
15	6 27	Im. 10 43 Em. 13 1
16	6 34	Eclipse Em. 10 17
17	6 40	Im. 5 13 Em. 7 32
18	6 47	Eclipse Em. 4 47 Im. 23 43
19	6 54	Em. 2 1 Eclipse Em. 23 17
20	7 1	Im. 18 13 Em. 20 31
21	7 8	Eclipse Em. 17 47
22	7 15	Im. 12 43 Em. 15 2
23	7 22	Eclipse Em. 12 17
24	7 29	Im. 7 13 Em. 9 32
25	7 36	Eclipse Em. 6 47
26	7 44	Im. 1 43 Em. 4 2 Eclipse
27	7 52	Em. 1 18 Im. 20 14 Em. 22 32
28	8 0	Eclipse Em. 19 48
29	8 6	Im. 14 44 Em. 17 2
30	8 12	Eclipse Em. 14 18
31	8 18	Im. 9 14 Em. 11 32
Aug.		
1	8 24	Eclipse Em. 8 48
2	8 29	Im. 3 43 Em. 6 2
3	8 34	Eclipse Em. 3 18 Im. 22 14
4	8 39	Em. 0 32 Eclipse Em. 21 47
5	8 45	Im. 16 43 Em. 19 2
6	8 50	Eclipse Em. 16 17
7	8 55	Im. 11 13 Em. 13 32
8	9 0	Eclipse Em. 10 47
9	9 6	Im. 5 43 Em. 8 2
10	9 12	Eclipse Em. 5 17
11	9 18	Im. 0 13 Em. 2 32 Ecli. Em.
12	9 23	Im. 18 43 Em. 21 2 (23 47
13	9 28	Eclipse Em. 18 18
14	9 33	Im. 13 13 Em. 15 32
15	9 38	Eclipse Em. 13 17
16	9 43	Im. 8 43 Em. 11 1
17	9 48	Eclipse Em. 7 18
18	9 52	Im. 2 13 Em. 4 32 Eclipse
19	9 56	Em. 1 48 Im. 20 43 Em. 23 2

Aug.	Par.	H. M.	H. M. H. M.
20	10	0	Eclipse Em. 20 17
21	10	4	Im. 15 13 Em. 17 32
22	10	8	Eclipse Em. 14 47
23	10	12	Im. 9 43 Em. 12 1
24	10	16	Eclipse Em. 9 17
25	10	20	Im. 4 12 Em. 6 31
26	10	24	Eclipse Em. 3 47 Im. 22 42
27	10	28	Em. 1 1 Eclipse Em. 22 16
28	10	32	Im. 17 12 Em. 19 31
29	10	36	Eclipse Em. 16 46
30	10	39	Im. 11 42 Em. 14 1
31	10	42	Eclipse Em. 11 16
Sept.			
1	10	45	Im. 6 11 Em. 8 30
2	10	47	Eclipse Em. 5 45
3	10	50	Im. 0 41 Em. 3 0 Eclipse
4	10	52	Em. 0 11 Im. 19 5 Em. 21 29
5	10	54	Eclipse Em. 18 40
6	10	57	Im. 13 36 Em. 15 59
7	10	59	Eclipse Em. 13 14
8	11	2	Im. 8 9 Em. 10 28
9	11	4	Eclipse Em. 7 43
10	11	5	Im. 2 39 Em. 4 58 Eclipse
11	11	6	Em. 2 13 Im. 21 8 Em. 23 27
12	11	7	Eclipse Em. 20 42
13	11	8	Im. 15 37 Em. 17 56
14	11	9	Eclipse Em. 15 11
15	11	10	Im. 10 6 Em. 12 25
16	11	11	Eclipse Em. 9 44
17	11	12	Im. 4 35 Em. 6 55
18	11	12	Eclipse Em. 4 9 Im. 23 5
19	11	13	Em. 1 24 Eclipse Em. 22 38
20	11	13	Im 17 34 Em. 19 53
21	11	13	Eclipse Em. 17 7
22	11	12	Im. 12 2 Em. 14 22
23	11	11	Eclipse Em. 11 36
24	11	11	Im. 6 31 Em. 8 50
25	11	10	Eclipse Em. 6 5
26	11	9	Im. 1 0 Em. 3 20 Eclipse
27	11	8	Em. 0 34 Im. 19 29 Em. 21 48
28	11	7	Eclipse Em. 19 2
29	11	6	Im. 13 57 Em. 16 16
30	11	4	Eclipse Em. 13 31
Oct.			
1	11	2	Im. 8 26 Em. 10 45
2	11	0	Eclipse Em. 7 59

Octob.	Par.	H. M.	H. M. H. M.
3	10	57	Im. 2 54 Em. 5 13 Eclipse
4	10	55	Em. 2 27 Im. 21 22 Em 23 42
5	10	53	Eclipse Em. 20 56
6	10	50	Im. 15 51 Em. 18 10
7	10	47	Eclipse Em. 15 24
8	10	44	Im. 10 19 Em. 12 38
9	10	40	Eclipse Em. 9 52
10	10	36	Im. 4 47 Em. 7 6
11	10	32	Eclipse Em. 4 19 Im. 23 14
12	10	29	Em 1 34 Eclipse Em. 22 47
13	10	25	Im. 17 42 Em. 20 2
14	10	21	Eclipse Em 17 15
15	10	16	Im. 12 10 Em. 14 29
16	10	11	Eclipse Em. 11 43
17	10	6	Im. 6 38 Em. 8 57
18	10	1	Eclipse Em. 6 10
19	9	56	Im. 1 5 Em. 3 25 Eclipse
20	9	50	Em. 0 38 Im. 19 32 Em. 21 52
21	9	44	Eclipse Em. 19 5
22	9	38	Im. 14 0 Em. 16 19
23	9	31	Eclipse Em. 13 32
24	9	26	Im. 8 26 Em. 10 46
25	9	20	Eclipse Em. 7 59
26	9	14	Im. 2 53 Em. 5 13 Eclipse
27	9	6	Em. 2 26 Im. 21 20 Em. 23 40
28	8	58	Eclipse Em. 20 53
29	8	50	Im. 15 47 Em. 18 7
30	8	43	Eclipse Em. 15 19
31	8	37	Im. 10 14 Em. 12 34
Nov.			
1	8	29	Eclipse Em. 8 46
2	8	20	Im. 3 41 Em. 6 0
3	8	12	Eclipse Em 4 12 Im. 23 7
4	8	4	Em. 1 27 Eclipse. Em. 22 39
5	7	55	Im. 17 33 Em. 19 53
6	7	45	Eclipse Em. 17 5
7	7	36	Im. 12 59 Em. 14 19
8	7	26	Eclipse Em. 11 30
9	7	16	Im. 6 25 Em. 8 44
10	7	6	Eclipse Em. 5 57
11	6	58	Im. 0 51 Em. 3 12 Eclipse
12	6	49	Em. 0 23 Im. 19 18 Em. 21 38
13	6	39	Eclipse Em. 18 49
14	6	29	Im. 13 43 Em. 16 3
15	6	18	Eclipse Em. 13 50
16	6	7	Im. 8 9 Em. 10 29
17	5	56	Eclipse Em. 7 40

			H. M.	H. M.	H. M.
Nov.	Par.				
18	5	45	Im. 2 35	Em. 4 55	Eclipse.
19	5	33	Em. 2 6	Im. 21 0	Em. 23 20
20	5	21	Eclipse	Em. 20 31	
21	5	9	Im. 15 25	Em. 17 45	
22	4	57	Eclipse	Em. 14 57	
23	4	47	Im. 9 51	Em. 12 11	
24	4	37	Eclipse	Em. 9 23	
25	4	25	Im. 4 17	Em. 6 37	
26	4	13	Eclipse	Em. 3 47	Im. 22 42
27	4	1	Em. 1 2	Eclipse	Em. 22 13
28	3	47	Im. 17 7	Em. 19 27	
29	3	35	Eclipse	Em. 16 38	
30	3	24	Im. 11 32	Em. 13 52	
Dec.					
1	3	11	Eclipse	Em. 11 3	
2	2	58	Im. 5 57	Em. 8 18	
3	2	45	Eclipse	Em. 5 28	(Em. 23 53
4	2	32	Im. 0 23	Em. 2 43	Eclipse
5	2	20	Im. 18 47	Em. 21 7	
6	2	8	Eclipse	Em 18 18	
7	1	56	Im. 13 13	Em. 15 33	
8	1	42	Eclipse	*Em.* 12 43	
9	1	30	Im. 7 37	*Em.* 9 57	

			H. M.	H. M.	H. M.
Dec.	Par.				
10	1	17	Eclipse	*Em.* 7 8	
11	1	4	*Im.* 2 2	*Em.* 4 22	*Eclipse*
12	0	19	*Em.* 1 33	*Im.* 20 27	*Em.* 22 47
13	0	37	*Eclipse*	*Em.* 19 58	
14	0	24	*Im.* 14 52	*Em.* 17 13	
15	0	10	*Eclipse*	*Em.* 14 23	
			Jupiter in Opposition to the Sun.		
16	0	3	*Im.* 9 17	*Em.* 11 38	
17	0	16	*Im.* 6 28	Eclipse	
18	0	29	*Im.* 3 42	*Em.* 6 2	
19	0	43	*Im.* 1 52	Eclipse	*Im.* 22 7
20	0	57	*Em.* 0 27	*Im.* 19 19	Eclipse
21	1	12	*Im.* 16 34	*Em.* 18 54	
22	1	24	*Im.* 13 43	Eclipse.	
23	1	36	*Im.* 10 57	*Em.* 13 17	
24	1	47	*Im.* 8 8	Eclipse	
25	2	1	*Im.* 5 22	*Em.* 7 42	
26	2	12	*Im.* 2 33	Eclipse	*Im* 23 47
27	2	22	*Em.* 2 8	*Im.* 20 59	Eclipse
28	2	33	*Im.* 18 13	*Em.* 20 34	
29	2	48	*Im.* 15 25	Eclipse	
30	3	2	*Im.* 12 39	*Em.* 14 59	
31	3	15	*Im.* 8 50	Eclipse	

A TABLE of the *Conjunctions* of Jupiter's Four Planets with one another, for every Day of the Years 1739, 1740; while Jupiter is visible.

	1739.	1739.	1739
Jan.		Feb.	Mar.
1	d. d. h. m.	ft. d.	d. d.
2	2 & 3 : 14 12 ! 1 & 2 :	1 & 2 : 20 13	2 & 3 : 13 0 (14 7
3	(21 5		1 & 3 : 15 19 ! 2 & 4 :
4	2 & 4 : 8 59		(1 & 2 : 21 34
5	2 & 3 : 10 32		
6	1 & 2 : 8 26	1 & 2 : 9 25 (12 33	1 & 3 : 17 14
7	1 & 2 : 15 41	1 & 2 : 16 27 ! 1 & 4 :	1 & 2 : 10 44
8	1 & 3 : 9 33		1 & 2 : 18 6
9		2 & 3 : 7 36	
10			
11	1 & 3 : 11 52		1 & 4 : 7 56
12	1 & 3 : 10 0		2 & 4 : 7 12
13	1 & 2 : 10 44	1 & 2 : 11 51	1 & 2 : 17 8
14			
15	1 & 3 : 12 21	2 & 4 : 10 18 : 1 & 4 : 15	
16		(32	
17			
18		1 & 2 : 8 6	1 & 2 : 1 21
19	1 & 3 : 13 34		
20	1 & 2 : 13 5		1 & 3 : 13 53
21	2 & 4 : 18 39		1 & 4 : 7 48
22	2 & 3 : 8 2 ! 1 & 3 15 10		
23			1 & 3 : 15 40
24			1 & 2 : 3 45 ! 1 & 3 : 7 0
25	1 & 2 : 9 20		
26	1 & 3 : 16 55		
27	1 & 2 : 15 26		1 & 3 : 16 52
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29	2 & 3 : 11 29		1 & 4 : 10 50
30	1 & 4 : 14 53		1 & 3 : 19 50
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4		1 & 2 : 10 36	
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12		1 & 2 : 13 3 (9 12	
13		1 & 3 : 12 58 ! 2 & 3 :	
14		1 & 3 : 10 56 ! 1 & 2 :	2 & 3 : 10 6
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17	1 & 2 : 7 38
18	1 & 2 : 15 31 ! 2 & 3 :
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22	1 & 2 : 4 40 ! 1 & 3 :
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29	1 & 3 : 10 48 ! 2 & 4 :
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July 1	
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8	1 & 4 : 9 13 ! 1 & 2 : 15 5
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July 16	
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12	1 & 4 : 2 38 ! 1 & 3 : 5 5
	(2 & 4 : 7 45 ! 2 & 3 :
13	1 & 2 : 2 52 (9 24
14	1 & 2 : 9 20
15	1 & 3 : 5 54
16	1 & 2 : 16 5
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16	1 & 3 : 18 53
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19	1 & 3 : 19 37
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1739.

Oct.

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Nov.

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Nov.

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Jan.

1740

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1740

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Feb.

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18	1 & 2 : 13 14 (16 10
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22	1 ☌ 3 : 5 28 ! 2 ☌ 3 :
23	1 ☌ 2 : 1 31
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25	1 ☌ 3 : 5 52 (14 41
26	2 ☌ 4 : 10 37 ! 1 ☌ 2 :
27	1 ☌ 2 : 21 44
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30	1 ☌ 2 : 3 56
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June 24	(15 22
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26	1 & 3 : 8 6 ! 3 ☌ 4 :
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27	1 ☌ 4 : 23 59
28	1 ☌ 4 : 0 23
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11	1 ♃ 3 : 4 0
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13	1 ♂ 2 : 7 15 ! 2 ♂ 4 :
14	1 ♂ 4 : 10 27 ! 3 ♂ 4 :
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15	1 ♃ 3 : 6 12
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18	1 ♃ 2 : 4 37 ; 1 ♂ 3 :
19	(6 55
20	1 ♃ 2 : 9 50
21	1 ♃ 2 : 17 48 : 2 ♂ 3 :
22	2 ♂ 4 : 2 4 (22 46
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24	1 ♂ 3 : 5 54
25	1 ♃ 2 : 6 58 ! 1 ♂ 3 :
26	(9 52
27	1 ♃ 2 : 12 24
28	1 ♃ 2 : 20 8
29	2 ♂ 3 : 2 3 ! 1 ♃ 3 :
30	1 ♃ 4 : 15 47 (12 4
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Sept. 1	1 ♂ 2 : 9 16 ! 1 ♂ 3 :
2	(12 46
3	1 ♂ 2 : 14 53
4	1 ♃ 2 : 22 24 (14 52
5	2 ♃ 3 : 5 56 ! 1 ♃ 3 :
6	(19 0
7	1 ♂ 2 : 4 4 ! 1 ♂ 4 :
8	1 ♃ 2 : 11 34 ! 2 ♂ 4 :
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19	2 ♂ 3 : 11 59

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28	1 ♃ 2 : 11 8
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Oct.	
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3	(18 24 ! 3 and 4 :
4	1 and 4 : 6 9 ! 2 and 3 :
5	1 and 2 : 13 23
6	1 and 2 : 20 30
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8	1 and 3 : 3 10 ! 2 and 3
9	1 and 2 : 2 32 (7 2
10	1 and 2 : 9 34
11	1 and 3 : 4 34 ! 1 and 4
12	(8 43
13	1 and 2 : 22 40
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15	1 and 3 : 6 12
16	1 and 2 : 4 40
17	1 and 2 : 11 45
18	1 and 3 : 7 10
19	1 and 4 : 12 58 ! 2 and 4 :
20	(17 18 ! 1 and 2 : 17 47
21	1 and 4 : 14 40
22	(13 15
23	1 and 3 : 9 0 ! 2 and 3 :
24	1 and 2 : 6 50
25	1 and 2 : 13 50
26	2 and 3 : 3 37
27	(20 55
28	1 and 4 : 17 8 ! 3 and 4
29	1 and 3 : 11 38 ! 2 and 3
30	1 and 2 : 8 24 (16 46
31	1 and 2 : 15 55.

Nov.	(12 1[illegible]
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4	1 and 2 : 3 58 (19 11
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6	2 and 4 : 1 23 ! 1 and 2 :
7	1 and 2 17 5 (10 56
8	2 and 3 : 9 26 ! 1 and
9	(3 : 14 43
10	
11	1 and 2 : 6 58
12	1 and 3 : 16 37 (20 39
13	1 and 2 : 12 57 ! 1 and 4
14	2 and 4 : 16 58 ! 1 and
	(2 : 19 59
15	2 and 3 : 12 16 ! 1 and
	(3 : 17 10
16	2 and 4 : 16 50
17	1 and 2 : 2 0
18	1 and 2 : 8 56
19	1 and 3 19 1
20	1 and 2 : 14 56
21	1 and 2 : 21 58
22	2 and 3 : 15 4 ! 1 and 3 :
23	(19 38 ! 3 and 4 : 20 7
24	1 and 2 : 3 55
25	1 and 2 : 10 26
26	1 and 3 : 21 28
27	2 and 3 : 3 32
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Dec.	(5 50
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4	2 and 3 : 6 12 ! 1 and
5	(2 : 18 50
6	2 and 3 : 20 30
7	(4 : 11 18
8	1 and 2 : 7 44 ! 2 and
9	1 and 4 : 6 0 ! 1 and 2
10	(14 47
11	1 and 3 : 1 48 ! 2 and
12	(3 : 8 45
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1740		1740		1740	
Dec.		Dec.		Dec.	
14		20	1 and 2 : 5 42	26	
15	1 and 2 : 9 38	21		27	1 and 2 : 7 36
16	1 and 2 16 42	22	1 and 2 : 11 34	28	
17	2 and 4 : 2 36 / 3 and 4 (18 32	23	1 and 2 : 18 39	29	1 and 3 : 6 55
18	2 and 3 : 11 30	24	(14 12	30	1 and 2 : 20 38
19		25	1 and 4 : 9 7 / 2 and 3	31	

ERRATA.

*** TABLE, 1st. of the 2d. Planet for *March*, 14 16 16 51, read 14 17 33 51, and for *June* 14 23 49 55, read 15 1 0 0.

OBSERVATIONS.

(1) THE original *Tables*, on which the present Calculations are founded, are those of Mr. *Bradley*, Professor of Astronomy at *Oxford*, printed 20 Years ago, but not yet published; as reduc'd to an easier Form by his Uncle Mr. *Pound*, by Dr. *Bevis*, and Mr. *Caleb Smith*. Only I always make use of those exacter Tables for the *Equation of Light* which are exhibited above Page 66. 67. instead of those more imperfect ones in use hitherto. Which Correction amounts sometimes to no less than 1 Minute 13 Seconds, which, in Errors of 4 or 5 Minutes only, as are those of the first Planet, is by no means an inconsiderable Correction.

(2) The *Meridian* to which these Tables and Calculations are all fitted, is that of the Royal Observatory at *Greenwich*; which hardly differs half a Minute from that of *London*, Eastward.

(3) The Time in these Tables is not *mean*, or *equal*; but *common* or *apparent* Time, as determined by a true Meridian, or Sun-Dial at Noon; or else by a good Watch, or Clock regulated thereto.

(4) The *Days* are here *Astronomical* and begin on the foregoing Days at Noon, and continue till the Noon of the Days over-against which the Numbers stand. Thus *Jan.* 2 Days, 7 Hours, 44 Minutes, and 40 Seconds, 1739. Means 7 Hours, 44 Minutes, and 40 Seconds compleat, after our 2d of *January* 1739, at Noon. And *December* 31 Days, 12 Hours, 30 Minutes, and 22 Seconds, 1739, denotes 12 Hours, 30 Minutes, 22 Seconds compleat;

pleat, after Noon, on our *December* 31, 1739, which we call 30 Minutes 22 Seconds after Midnight or in the Morning of the first of *January* 1740. And so in all other Instances whatsoever.

(5.) The *Eclipses* of all the four Planets are set down in the first Table to Seconds, as being more exactly known than the *Occultations* in the Second, or *Conjunctions* in the 3d Table; while both these last are only set down to the nearest whole Minutes: which is abundantly sufficient at present for their Observation.

(6) In the *Occultations* of the first Planet, exhibited in the 2d Table, the Planet it self, by Reason of its Diameter, measur'd by Mr. *Bradley*, a 24th Part of that of *Jupiter*, is not less than 5 Minutes 46 Seconds of Time during its *Immerging* into, and *Emerging* from the Body of *Jupiter*. Accordingly we are still to allow the *Durations* of such *Occultations* to be from the Entry and Exit of its *Center*, given in the Table, 2 Minutes 53 Seconds, or near 3 Minutes after it first, and before it last touches the Body: while in the *Eclipses* of all these Planets, we ever estimate those *Durations* to be only from their *last* Appearances at *Immersions*, to their *first* Appearances at *Emersions*. And note farther, that altho' the *Eclipses* and *Conjunctions* of all the four Planets are set down in the first and third Tables, as being of good Use in Astronomy, yet are these *Occultations* in the *second* Table confin'd to the *first* Planet only. Since too many Difficulties occur in calculating and observing the *Occultations* of the rest to permit us to expect any considerable Advantage therefrom.

(7.) At the earnest Desire of Mr. *Lynn* I have, in a 3d Table added the mutual opposite *Conjunctions* of all the four Planets one with another, for these two Years, at any tolerable nearness to the Body of Jupiter, or where they can be of any considerable Use to us. See Page 35. 36. prius. For altho', on account of the present Imperfection of the Theories of the 3d and 4th. but chiefly of the 2d. these *Conjunctions*, so easily to be observed every where, cannot yet be useful for the Longitude at Sea; because in that Case the *Observations*, how exact soever, can only be compared with imperfect *Calculations*; yet may they be very useful already for the same Discovery at *Land*; and particularly for setling the *Longitude* of the *Ports* and *Havens*: (which is the first Thing to be done in order to that Discovery at Sea:) while the *actual Observations* are still to be compar'd with other *actual Observations* of the very same *Conjunctions* seen elsewhere. They may also be very useful for the Correction of the Theories of the three remoter Planets; and so for making all such *Conjunctions* useful for the Discovery of the Longitude at Sea hereafter. Of which Matter see Page 22— 26. prius.

(8.) The *Number* of the *Eclipses* and *Occultations* set down in the 2d Table, every one belonging to the *first Planet*, and *every one useful for the Discovery of the Longitude at Sea already*, is 4. in 42 Hours and a half. Which, in these two Years, amount to no fewer than 1472. See Page 25. 26. and Page 94. —99 prius.

(9.) The *Number* of the *Eclipses* of the other three Planets, set down in the first Table, is no fewer than 392 in the same time.

(10.) The *Number* of the *Conjunctions* in the 3d Table, during the same time, is no fewer than 506. The total Sum is 2370.

(11.) Since the *Eclipses* of the 1st Planet, in the first Table, are more nicely to be found, both by Calculation and Observation, than its *Occultations*, in the second, They are more carefully to be watched and observed, and depended on than the other. For as by these *Occultations*, how carefully soever observ'd, we can, at present, hardly pretend to come at the *Longitude at Sea* nearer than to 5 or 6 Minutes in time; so by these *Eclipses* may

may we usually come already within 3 or 4 Minutes. And when Mr. *Bradley* has made his Correction in the Numbers of the first of about another Minute, which he is prepared to do, we may expect thereby to come within 2 or 3 Minutes. To say nothing of Mr. *Machin*'s Hopes of discovering and correcting the Errors of all the secondary Planets arising from their mutual Influences upon each other, a *priori* also: which is indeed the only thing still wanting in order to bring all their Theories to the utmost Perfection.

(12.) As it has appeared already from Mr. *Derham*'s Observations, mention'd Page 13 before, that the *Inclination* of the Plain of the 3d Planet is somewhat greater than these Tables suppose it to be; so does it appear from *Kirchius*'s Annotations on Monsieur *D'L'Isles* Calculations of these *Eclipses* for the last 5 Years, and made from Mr. *Bradley*'s Tables, that the Nodes of the 4th Planet are a few Degrees erroneous. And whereas all those Nodes have been hitherto supposed to be in the same Place of the Heavens, which would afford *corporal Conjunctions* when *Jupiter* and his Planets were in those Nodes; Mr. *Lynn* informs me, that, in his long Course of observing them, he could never find that verify'd; nor could ever see such a *corporal Conjunction* of any two of them, in any such Circumstances whatsoever.

N. B. The *Parallax of the Orb* is set down here all along in the 2d Table, for the use of such as have a mind themselves to examine the *Heliocentrick* Phænomena of these Planets, and reduce them to their *Geocentrick*. Which Reduction entirely depends on the Allowance for that *Parallax*. See Page 28. — 31. prius.

N. B. The *Eclipses* of the 4th Planet were of necessity to be here omitted, till Midsummer 1740. because that Planet passes wide of *Jupiter*'s Shadow till that time.

(13.) Since Dr. *Smith*'s admirable Book of Opticks is now publish'd; and Mr. *Mac-Laurin* therein assures us, Remarks Page 80. 81. That Mr. *Short* of *Edinburgh* has not only so much improv'd the Method of grinding Metalline Specula, as thereby to enable very sharp Eyes, in a very clear Sky to discern all *Saturn*'s Planets with a focal Length of fifteen Inches only; but has render'd the grinding of *Glasses* for such reflecting Telescopes very practicable also; I cannot but be highly pleased with the mighty Improvement hereby afforded to this my reflecting Telescope. For as Mr. *Scarler*, several Years ago, fail'd in grinding me such a Glass Speculum; and so forced me, utterly against my own Inclinations, to have recourse to Mr. *Hearne*'s Metalline Reflecter, in this Design; so do I now very gladly return to my first Intentions. I now hope to procure, from Mr. *Short*, such *Glass Reflecters* as will be much cheaper; much lighter; and, by consequence, more easily managable at Sea, than those of Metal; and such as, above all, will never rust or tarnish in any Place whatsoever. This I look upon as the utmost Improvement this Telescope for the Sea is capable of: and what, I hope, will render the Observations to be there made by it very easy, very accurate, and very acceptable to all Astronomers and Navigators. How such Observations are to be made; and how the Calculations therefrom are to be manag'd, in order to the Discovery of the Longitude, has been already explained at large, Page 94. — 101. prius, and need not be here repeated.

N. B. The correct Measures for the reflecting Telescope I, at length, pitch upon are these. The *focal Length* of the larger Reflecter is to be 5 Feet, or 60 Inches; and, by consequence, the *length of the Tube* no more than two Feet and a half, or 30 Inches. The Breadth or *Diameter* of the Reflecter is to be 5 Inches. The Breadth or *Diameter* of its *Back Aperture*, and of its *Eye-Glass*, is to be 1 Inch and an half. The *Charge*, or focal Length of

of the Eye-Glass, is to be about one Inch. Its smaller Reflecter is to be a flat Circle, very little more in Breadth or Diameter than the Back Aperture, or than one Inch and an half. This larger Reflecter is to be truly centred, and the smaller accurately adjusted and kept parallel thereto. The Telescope will then take in about 3 Diameters of the Moon, or 6 Diameters of the Orbit of *Jupiter*'s remotest Planet at once; and will magnify Objects about 60 times in Diameter. If the larger Reflecter be ground intirely spherical, or even a little parabolical; and that very near to the Edges, as Mr. *Short* is able to do; the Image will be very distinct; and the smaller Reflecter will intercept little or nothing more than the eleventh part of the Light that would otherwise fall on the larger: which is but little more than our common reflecting Telescopes intercept already. See Dr. *Smith*'s Opticks, Page 148, and Remarks Page 80. 81. 104. 105. When Mr. *Short* has procur'd himself as good an *Apparatus* of Tools for this focal Length of 5 Feet, as he has already for 9 and 15 Inches, he will, I believe, be able to furnish me and the Seamen with such reflecting Telescopes, as will, with great Ease, shew all those *Eclipses*, *Occultations*, and *Conjunctions* of *Jupiter*'s Planets, which are necessary for the Discovery of the Longitude at Sea.

Lyndon, Rutland,
March 12,
1738-9

Will: Whiston.

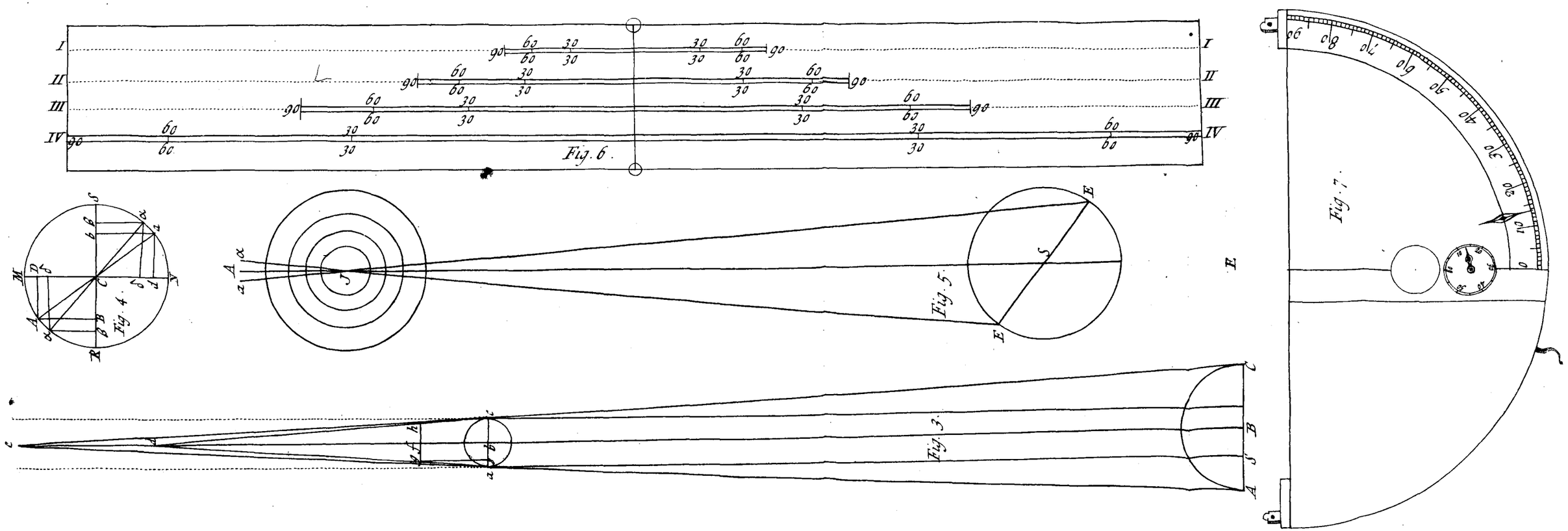


Fig. 6.
Fig. 4.
Fig. 5.
Fig. 3.
Fig. 7.

THE LONGITUDE AND LATITUDE Found by the INCLINATORY OR *Dipping Needle*;

Wherein the

Laws of Magnetism are also discover'd.

To which is prefix'd,

An *Historical Preface*; and to which is subjoin'd, Mr. ROBERT NORMAN's *New Attractive*, or Account of the first *Invention* of the *Dipping Needle*.

By WILL. WHISTON, M. A.

Sometime Professor of the Mathematicks in the University of CAMBRIDGE.

Καὶ πᾶσαι πεδίοιο τείχοι, καὶ πρόχεες ὄχθαι,
Οὔρεα θ' ὑλήεντα, καὶ ἄχρια κύματα πόντου
Εὐβοίη δὴ, καὶ ἔυστεφὲς ἔσεται ἤματι κείνοις.
Orac. Sibyll. III. v. 715, 716, 717.

LONDON:

Printed for J. SENEX, at the *Globe* in *Salisbury-Court*; and W. TAYLOR, at the *Ship* in *Pater-Noster-Row*.

MDCCXXI.

TO

The Right Honourable THOMAS *Earl of* Pembroke *and* Montgomery.

The Right Honourable JAMES *Earl of* Berkley, *First Commissioner of the Admiralty.*

The Right Honourable THOMAS *Earl of* Westmorland, *First Commissioner of Trade.*

The Right Reverend Father in God PHILIP *Lord Bishop of* Hereford.

The Right Honourable THOMAS *Lord* TREVOR.

Sir GEORGE BYNG, *Kt. Admiral of the* Red, *and First Commissioner of the Navy.*

Sir JOHN JENNINGS, *Admiral of the* White.

Sir JOHN NORRIS, *Admiral of the* Blue.

Sir WILL. SANDERSON, *Master of* Trinity-House.

Sir THOMAS HANMER, *Bart.*

Sir

Sir ISAAC NEWTON, *President of the* Royal Society.

SPENCER COMPTON, *Esq*; *Speaker to the Honourable House of Commons.*

WILLIAM LOWNDS, *Esq*;

Dr. EDMUND HALLEY, *Astronomer Royal, and Savilian Professor of Geometry.*

Dr. JOHN KEILL, *Savilian Professor of Astronomy.*

Mr. NICHOLAS SANDERSON, *Lucasian Professor of the Mathematicks.*

Mr. THOMAS SMITH, *Plumian Professor of Astronomy.*

Commissioners appointed by Act of Parliament for the Discovery of the LONGITUDE.

This METHOD for that Discovery is, with all due Submission, humbly Dedicated by

The AUTHOR.

AN
Historical PREFACE:

Giving some ACCOUNT of the Invention of Magnetick Needles; especially of the Inclinatory or Dipping Needle; and the gradual Improvements therein made, till the Discovery of the Longitude thereby.

HOW long it is since the Magnet *or* Loadstone *has been taken notice of, and distinguish'd from other Mineral Stones, is not now known. 'Tis mention'd frequently, since the Time of* Plato; *and several little Attempts have been anciently made to solve its Appearances. But then all this came to no more than the Knowledge of the Magnet's* Attractive *Power, with relation to other Magnets, or to Iron: while its* Directive *Power, disposing its Poles nearly*

 along

along the Meridian of every Place; and occasioning all Needles, Wires, or long Pieces of Iron touch'd by it, to point nearly North *and* South, *which is by much its principal Property, was entirely unknown. Nor does it appear that before the latter Part of the Thirteenth Century, one Syllable occurs in the old Books relating to that matter. About* A. D. 1260, *as some say,* Paulus Venetus *brought in the* Mariners Compass, *and applied it to the Uses of Navigation; altho' not as an Invention of his own, but as deriv'd from the* Chinese: *who are pretended to have had it still more anciently. Yet has the very Learned* Renaudot *given such Reasons against this Antiquity of the* Mariner's Compass *in the Oriental Parts, both as to* Arabia *and* China, *that 'tis much more probable they knew nothing of this* Compass, *till the* Europeans *brought it to them. Others therefore, with much greater Probability, ascribe this noble Invention, which is one of the the greatest for the Uses of Mankind that ever was yet made, to a* Neapolitan, John Goia *by Name,* A. D. 1300, *who is, however, owned to be the First that apply'd it to the Guidance of Ships in the* Mediterranean. *Nor is that unlikely, which Dr.* Wallis *conjectures; That this* Nautical Compass *came to its Perfection*

Dissert. of the Chinese Sciences, &c. p. 287. — 294, & 380.

tion by Steps, and by several partial Discoveries and Improvements, before any one was able to apply it to the business of Navigation. Take his Notion in his own Words: "*Where Inventions* "*creep in by degrees, says the Dr. it* "*must not be thought strange if it be not* "*easy to say who is the first Inventor.* "*In the present Case, he who first Observ'd* "*(I know not by what accident) that* "*the* Magnet *hath a* Polarity, *or Incli-* "*nation Northward, made the* First Step "*towards this Invention. This, I think,* "*was at First wont to be shewed by* "*putting a* Magnet *into a little Boat,* "*Swimming on Water; when it was* "*observ'd that the* Magnet *would of* "*it self so Steer this little Boat, as that* "*a certain Point in the* Magnet *would, if* "*not hindred, turn towards the* North: "*which Point was thereupon called the* "Magnet's North Pole. *He that after-* "*wards observ'd that this Verticity or* "*Polarity was communicable to a piece of* "*Iron or Steel, rubbed on a Magnet,* "*added a further Step towards the business* "*in Hand. And he who contrived a* "*Way to set a Needle or Piece of Steel,* "*(so touched,) on a sharp Pin, so as* "*(in the Air) to move Horizontally* "*thereon, so as (of it self) to find out* "*the* North *and Point towards it, as*

Philos. Transact. N°. 278.

" *(before) the ſwimming Magnet (in its*
" *Boat) had done on the Water, had now*
" *diſcovered a New Experiment in Na-*
" *tural Philoſophy, very ſurprizing. But*
" *this cannot yet be called* Circulus Nau-
" ticus, *(or the* Mariners Compaſs, *)*
" *till they had further contrived a Way*
" *how to put a Needle, (thus pois'd,)*
" *into a Box, with a Compaſs or Circle*
" *round it, ſo divided as to denote the*
" *Azimuthal Points of the Horizon: (or,*
" *as they be now called,* the Points of the
" Compaſs; *) and ſo commodiouſly to*
" *fix this Box, (ſo prepared,) to the Ship,*
" *as thereby to inſtruct the Mariner (or*
" *Steers-man) towards what Point of the*
" *Compaſs the Ship moved; that (by the*
" *help of the Rudder) he might put it*
" *into ſuch a Courſe, as was proper for*
" *his Voyage. And it was now indeed*
" Pyxis Nautica, *or* Circulus Nauticus,
" *(the* Mariners Box, *or* Compaſs) *but*
" *not till then. And he who Firſt con-*
" *triv'd this Application did* Compleat
" *the Invention of* Circulus Nauticus.
" *But all thoſe antecedent Diſcoveries*
" *were Steps towards it, and Parts of the*
" *Invention. Thus far Dr.* Wallis. *Who*
alſo there endeavours to claim this Inventi-
on to the Engliſh *Nation, from the* Engliſh
Names Compaſs; *and* Box *or* Boxel;
which are imitated by moſt other Nations
uſed

used to Navigation. However, thus far is certain, that this Noble Invention was made and applied to Navagation a little before our Countryman John Wiclif *appeared in the World, and so before the First direct Origin of the Protestant Reformation in* Europe. *But still it appears all along the* 14*th and* 15*th Centuries, that there was no Apprehension that such a Magnetical Horizontal Needle pointed, any where, to any other than the* North *and* South *Points of the Horizon: And when any Declination therefrom appear'd, it was supposed to be from some Error or Defect in the placing of the Wires, or the ill Make of the particular Compass; and not to the real Variation of such a Needle, when good, and well hung, from that Direction.* Sebastian Cabot, *a* Venetian, *is generally allow'd to have been the first who discovered that* Variation to be real, *and the same in the same Place in all the Needles. And this was* A. D. 1500. *just before* Luther *arose in* Germany; *and occasion'd that great Event of an actual* Protestant Reformation, *both there and elsewhere. Yet was it still thought, even by Mr.* Norman *and Mr.* Burrows *themselves, the first exact Observers of the* Inclination *and* Variation, *that the Declination from the Meridian was only different in different Places and Countries:*

Norman's *New Attract. c.* 9. Burrows's *Variation, c.* 10.

While

While it was, after all, supposed to be one and the same during all Ages, in the same Place or Country, notwithstanding. It being then commonly supposed owing to certain Magnetick Continents, or Mountains, or the like Originals; which continuing the same for all Generations, might naturally occasion such a Declination: different indeed in several Countries, but in the same Country invariably the same. But still, to use Dr. Wallis's *Words here, instead of my own,* " *I think it is now* " *agreed on all hands, that (what we* " *call)* the Variation of the Variation, *is* " *an* English *Discovery, (of Mr.* Gellibrand, " *if I mistake not; one of Sir* Thomas " Gresham's *Professors, at* Gresham *College,) about the Year* 1625. *Who also, as the Doctor there informs us,* " *caused a great Concave Dial to be erected* " *in the* Privy-Garden *at* Whitehall, " [*which is still remaining, as to the* " *main Body of it*] *with great Care to* " *fix a true Meridian Line, and with a* " *large Magnetick Needle, shewing its* " *Variation from that Meridian from* " *time to time*". *And where, give me leave to add, Mr.* Bond *informs us, that Variation was taken* A. D. 1665. *and found to be,* June 8. 1°. 22′. 30″. West. *And there again, I do not doubt, it was taken, as he informs us, in* June, A. D. 1666,

Philos. Transact. N°. 276, *and* 278.

Long. Found. p. 13, 14.

1666. *and found to be* 1°. 35'. 36''. *and that by ſome of the beſt Obſervers of that Age: Tho', alas! the Remains of that Noble Concave ſtand now wild and batter'd; with the Braſs generally gone; and no Tidings of that large Magnetick Needle, no leſs than Three Feet in Diameter, as the Diameter of the Concave it ſelf, ſtill remaining, implies; or of the Nicety of thoſe Diviſions, or of the Exactneſs of thoſe Contrivances, whereby, even in an Horizontal Situation, the Angle was taken nearer than to a ſingle Minute, and this in Agreement to Analogy in the foregoing and ſucceeding Obſervations of others alſo. A Loſs the more to be lamented, becauſe this Degree of Nicety has been ſince ſo far forgot, that the Learned will hardly believe it ever had been, or ever can be brought to that Degree of Perfection, which this Concave, and the Obſervations formerly there made, do ſuppoſe. I hope ſome of our curious Virtuoſo's about the Court will take care to have this noble Monument of the Care and Accuracy of the laſt Age for Magnetick Experiments of this Kind recovered, and put to its original Uſe: that we may be able there to ſhew this, and the following Ages, not only the* Variation *of the* Horizontal Needle, *as before; but alſo the* Inclination *of the* Dipping Needle

to

to the same Degree of Accuracy, which the last Age here shew'd the Variation. *But to leave this Digression, and to proceed.*

Longitude found, p. 2. —9.

Some time after this, about A. D. 1663, *Mr.* Bond, *already mentioned, embraced the Hypothesis of Moveable Magnetick Poles, and suppos'd them in, or above, our Air; and from that Motion of theirs, which he estimated to be* Westward, *and to make its Revolution in* 600 *Years, he computed a Table of the Variation for* London, *from* 1663 *to* 1715, *extant in the* Philosoph. Transactions. *Which, tho' it agreed well enough with the Observations till the Beginning of this Century, has since too far disagreed from them; and so has discovered some Error or Defect in that Hypothesis on which it was founded.*

Philos. Transact. N°. 40.

However, this Notion in general of Moveable Magnetick Poles, *has always seemed so probable, or rather necessary, ever since the* Variation *has been it self found to* Vary, *and this after a certain regular manner also; that Mr.* Philips, *before Mr.* Bond, *asserted the same; and stated the Revolution to be in* 370 *Years. And after all, our Learned Dr.* Halley, *who has far outdone every body upon this Subject, has determined it to be so. Only he has thought himself obliged to add the Hypothesis of two other fixed Poles: and from the joint Effects of all Four Poles,*

Apud Bond. *Longitude found, p. 7, &c. Philos. Transact. N°. 148.*

Poles, and from thoſe only has he been able to bring this Variation of the Variation *to ſome kind of Syſtem, agreeable to the Obſervations. He has alſo been obliged to lengthen the Period of the moveable Poles Revolution: and, as Mr.* Bond *had enlarged Mr.* Philips's *Number, from* 370 *Years to* 600: *So has Dr.* Halley *enlarg'd the ſame farther from* 600 *to* 700 *Years. Take the Subſtance of Dr.* Halley's *Notion, which was the Reſult of many and accurate Obſervations, in his own Words, as they ſtand in the* Philoſophical Tranſactions, N°. 148.

" *Theſe Obſervations, ſays the Doctor,* " *plainly demonſtrate the Impoſſibility of* " *reconciling theſe* Variations *by the Theo-* " *ry of* Bond: *which is by* Two Magne- " tical Poles, and an Axis, inclined to " the Axis of the Earth. *From whence* " *it would follow, that under the ſame* " Meridian *the* Variation *ſhould be in all* " *Places the ſame way.* ——*They may* " *ſerve as a ſure Foundation for this* " Theory, That the whole Globe of the " Earth is one great *Magnet*; having " Four *Magnetical Poles*, or Points of " Attraction: Near each *Pole* of the " *Equator* Two; *and that* in thoſe Parts " of the World which lie near adjacent " to any one of thoſe *Magnetical Poles*, " the *Needle* is governed thereby: the

" nearest *Pole* being always predominant
" over the more remote. *The Parts of*
" *the Earth, wherein these* Magnetical
" Poles *lie, cannot as yet be exactly de-*
" *termined, for want of sufficient* Data *to*
" *proceed* geometrically. *But, as near*
" *as Conjecture can reach, I reckon that*
" *the* Pole, *which is at present nearest to*
" *us, lies in, or near the* Meridian *of the*
" Land's End *of* England, *and not above*
" 7 Degrees *from the* Pole Arctick. *By*
" *this* Pole *the* Variations *in all* Europe,
" *and* Tartary, *and the* North Sea, *are*
" *principally governed; tho' with regard*
" *to the other* Northern Pole, *whose Si-*
" *tuation is in a* Meridian *passing about*
" *the Middle of* California, *and about*
" 15 *gr. from the* North Pole *of the*
" *World. To this the* Needle *has chiefly*
" *respect in all the* North America, *and*
" *in the* Two Oceans *on either side there-*
" *of, from the* Azores, *Westwards, to*
" Japan, *and farther. The* two Southern
" Poles *are rather farther distant from*
" *the* South Pole *of the World; the one*
" *about* 16 *deg, therefrom is in a* Merid.
" *some* 20 *deg. to the Westward of* Ma-
" gellan's Streights, *or* 95 *deg.* West
" *from* London. *This commands the*
" Needle *in all the* South America, *in*
" *the* Pacifick Sea, *and the greatest Part*
" *of the* Æthiopick Ocean. *The Fourth*

" *and*

" *and last* Pole *seems to have the greatest*
" *Power, and largest Dominions of all*;
" *as it is the most remote from the* Pole
" *of the* World, *being little less than* 20
" *deg. distant therefrom: In the* Meridian
" *which passes through* Hollandia Nova,
" *and the Island* Celebes, *about* 120 *deg.*
" East *from* London. *This* Pole *is pre-*
" *dominant in the* South *Part of* Africa,
" *in* Arabia, *and the* Red Sea, *in* Persia,
" India, *and its Islands*; *and all over the*
" Indian Sea, *from the Cape of* Good
" Hope, *Eastwards, to the Middle of the*
" *Great* South Sea, *that divides* Asia
" *from* America. *This seems to be the*
" *present Disposition of the* Magnetical
" Virtue *throughout the whole Globe of*
" *the Earth.* ——*Now considering the*
" *Structure of our Terraqueous Globe,*
" *the only way to render this Motion in-*
" *telligible and possible, is to suppose it*
" *possible to* turn about the Center of the
" Globe, having its Center of Gravity
" fix'd and immoveable in the same com-
" mon Center of the Earth. *And there*
" *is yet requir'd, that this moving* Inter-
" nal *Substance be* loose, *and detach'd*
" *from the* External *Parts of the Earth*
" *whereon we live. So then the* Exter-
" nal *Parts of the Globe may well be*
" *reckoned as the Shell, and the* Internal *as*
" *the* Nucleus *or* Inner Globe, *included*

" *within ours, with a fluid Medium be-*
" *tween. Which, having the ſame com-*
" *mon Center, and Axis of Diurnal Ro-*
" *tation, may turn about with our Earth*
" *each* 24 Hours. *Only this* Outer
" *Sphere having its turbinating Motion*
" *ſome ſmall Matter either ſwifter or*
" *ſlower than the* Internal Ball; *and a*
" *very minute Difference in length of*
" *Time, by many Repetitions, becoming*
" *ſenſible; the* Internal *Parts will by de-*
" *grees recede from the* External, *and,*
" *not keeping pace with one another, will*
" *appear gradually to move either Eaſt-*
" *wards or Weſtwards, by the Difference*
" *of their Motions. So that if this* Ex-
" terior *Shell of Earth be a* Magnet,
" *having its* Poles *at a diſtance from the*
" Poles *of* Diurnal Rotation; *and if the*
" Internal Nucleus *be likewiſe a* Magnet,
" *having its Poles in two other Places,*
" *diſtant alſo from the Axis, and theſe*
" *latter, by a gradual and ſlow Motion,*
" change *their Place in reſpect of the*
" External; *we may then give a reaſona-*
" *ble Account of the* Four Magnetical
" Poles; *as likewiſe of the* Changes *of*
" *the* Needle's Variations, *which, till*
" *now, hath been unattempted. The*
" Period *of this Motion being wonderful*
" *great, and there being hardly an hun-*
" *dred Years ſince thoſe* Variations *have*
" *been*

" *been duly observ'd, it will be very hard*
" *to bring this* Hypothesis *to a* Calculus.
" ——*The* Period *of this Motion ap-*
" *pears, by all Circumstances, to be of*
" *many Centuries of* Years. ——*We may*
" *with some reason conjecture,* —*that the*
" *whole* Period *thereof is performed in*
" 700 Years, *or thereabouts*". *Thus far* Dr. Halley's *own Account. To whose entire Discourse in that Transaction, and the excellent Map of those Variations published afterwards, I must still refer the curious Reader.*

Thus far concerning the gradual Improvements made in the Knowledge of the Magnetick Horizontal Needle's Variation, *and the Consequences thence deducible. I now proceed to what I mainly intend in this Preface, I mean an Account of the Invention of the* Inclinatory *or* Dipping-Needle; *the Observations hitherto made with it; and the great Uses it may be apply'd to: Which are no less than the compleat Discovery of the Longitude and Latitude, both by Sea and Land.*

Now the first Inventor of the Inclinatory *or* Dipping-Needle *was, without all question, an* Englishman, Robert Norman *by Name, a Compass-maker at* Wapping, *in the Suburbs of* London, *on or about* A. D. 1576. *as is attested not only by his own Account in his* New Attra-

ctive,

ctive, *dedicated to Mr.* Burrows, *a very good Mathematician, and great Sailor at that Time; but at the same time was allow'd to be his Invention by Mr.* Burrows; *as well as by Dr.* Gilbert, *the Father of Magnetical Philosophy soon afterward, in these Words:* "*This is that* "Robert Norman, *that skilful Seaman,* "*and ingenious Artificer, who first found* "*out the Inclination of the Magnetick* "*Needle*". *Mr.* Bond *also assures us, about a Century after this Invention,* "*That himself saw an Inclinatory Needle* "*of one Dr.* Merret's, *which was made* "*by this* Robert Norman, A. D. 1578. "*and which he fitted up for the Doctor's* "*Use*". *Take the History of this Original Invention in Mr.* Norman's *own Words, which you will meet with in the* IIId Chapter *of that* New Attractive: *which is added at the End of these Papers.*

Burrows of *Variation, Pref.*

Gilbert de Magnete, l. 1. c. 1.

Long. found, p. 11.

Having, *says he*, made many and divers compasses, and using alwaies to finish and end them before I touched the needle, I found continually, that after I had touched the yrons with the Stone, that presently the north point thereof would bend or *Decline*, downwards under the Horizon in some quantitie: insomuch that to the Flie of the Compasse, which before was made equall, I was still constrained to

to put ſome ſmall peece of waxe in the South part thereof, to counterpoiſe this *Declining*, and to make it equall againe.

Which effect hauing many times paſſed my hands without any great regard thereunto, as ignorant of any ſuch propertie in the Stone, and not before having heard nor read of any ſuch matter: It chaunced at length that there came to my hands an Inſtrument to bee made, with a Needle of ſixe inches long, which needle after I had polliſhed, cut off at juſt length, and made it to ſtand levell upon the pinne, ſo that nothing reſted but only the touching of it with the Stone: when I had touched the ſame, preſently the North parte thereof *Declined* downe, in ſuch ſort, that being conſtrayned to cut away ſome of that part, to make it equal again, in the end I cut it too ſhort, and ſo ſpoiled the needle wherein I had taken ſo much paynes.

Hereby beeing ſtroken into ſome choller, I applyed my ſelf to ſeeke further into this effect, and making certayne learned and expert men (my friends) acquainted in this matter, they adviſed me to frame ſome Inſtrument, to make ſome exact tryall, how much the Needle touched with the Stone would *Decline*, or what greateſt Angle it would make with the Plaine of the Horizon. *Thus far Mr.* Norman. *But*

But what is here chiefly remarkable as to us, is the exact Quantity of the Inclination of this Needle at London *then*, A.D. 1576. *noted here by Mr.* Norman, *about* 71°. 50'. *as also the like exact Quantity of the Variation there about the same time, noted by himself, and by his Friend and Patron Mr.* Burrows, 11°. 15'. *Eastward. Which Observations of those two Angles are, for certain, the oldest and best now extant in the World: And which I take to be Original Standards for the* Inclination *and* Variation *of Magnetick Needles, with their several Variations, in all future Ages; as the Lunar Eclipses, noted at* Babylon *by the ancient* Chaldeans, *are Original Standards for the Periods and Motions of the Sun and Moon, with their several Inequalities, for all future Ages. Nor will these Observations of the* Inclination *and* Variation *be perhaps hereafter of less Use in* Navigation, *than the other have ever been in* Astronomy.

Norman's *New Attract.* c. 4, 7, 9. Burrows's *Variation*, c. 3, 7, 9.

Nor may we pass over another Notion advanc'd by Mr. Burrows *at that time*; viz. *That the Magnetick Poles of the Earth were different from the Poles of the* Equator: *Whose Distance he also endeavoured to find; with good Skill as to the Mathematick Part, but with ill Success in the Practice. His* Data *being too uncertain,*

Variation, c. 8.

tain, and the Poles mutable; neither of which he was then acquainted with. However, had the succeeding Ages but adher'd to Mr. Burrows's *Opinion, that the Poles of the Terrestrial Magnet were different from the Poles of the Earth, and by consequence their Equator and Parallels different from the Earth's Equator and Parallels, they had hardly so generally confin'd their Thoughts to the discovery of the* Latitude *by the Inclinatory Needle, as the contrary Mistake oblig'd them to do: But might probably have thought of discovering the* Longitude *thereby also. Tho' indeed the weak and precarious Methods made use of by Dr.* Gilbert, *Dr.* Ridley, *Mr.* Bond, *and many others, after the Days of Mr.* Norman *and Mr.* Burrows, *for that Discovery of even the Latitude by this Needle; a thing so easy in it self, had they gone by Observations and Facts, instead of Notions and Hypotheses; give one but a small Opinion of their Capacities for the Discovery of the Longitude thereby. Which, tho' in its own Nature very fit for such a Purpose, yet requiring more and nicer Observations than the other, 'tis no great Wonder the Discovery of the Longitude escaped their Notice at that Time.* Cabeus *indeed at* Ferrara, *did wish he could try the Angle of Dip on a* Terrella *or Spherical Load-*

Gilbert, l. 5. c. 6. Ridley's *magnetick Motions.* l. 20. c. 36, 37, 38. Bond's *Caroline Tables.*

Cabeus, *de Magnet.* l. 22.

 stone;

ſtone; but wanted one ſufficient for his Purpoſe. He alſo endeavour'd to procure actual Obſervations of that Dip at Sea, in a Southern *Voyage; but the Perſon employed dying before his return, he got but a very imperfect Account thereof. About* A. D. 1608, *Mr.* Hudſon, *a famous Sailor, and Diſcoverer of unknown Countries, from whom* Hudſon's Bay *takes its Name, ſailed towards the Pole, beyond the* North Cape: *and took with him a good* Inclinatory Needle; *with which he made ſeveral highly valuable Obſervations of the Angle of Inclination, from the Latitude of* 61°. 11'. *to that of* 75°. 22', *or from* 79 *of ſuch Inclination then, to* 89½. *and ſo almoſt to the then* Northern *Magnetick Pole it ſelf. Which Obſervations we meet with in Vol. III. of* Purchas's Pilgrim, *or Collection of ſuch Voyages; and which are of the greateſt Conſequence to my preſent Deſign. About the ſame Time Mr.* Henry Philips, *in his* Seaman's Calendar, *as is already mentioned, approved of moveable Magnetick Poles; and computed their Period to be in* 370 *Years.*

After him, tho' not very long, Mr. Henry Bond, Sen. *a Teacher of Navigation in* Ratcliff, *near* London, *began to entertain Thoughts of Magnetick moveable Poles, placed above the Earth,*

and

and revolving in 600 Years, of which before. He also, after Nautonier *and* Linton, *whose Books I have not seen, entertained Thoughts of discovering the Longitude by the Knowledge of their Position and Motion, and by the Consequent Angles of Inclination of the Dipping Needle, in the several Parts of the World. He first wrote, as himself tells us, in his* Seaman's Kalendar, *published about* A. D. 1645. "*That, without* "*Doubt, the Longitude would be found* "*by the Observation of something below the Moon.*" *He afterwards,* A. D. 1676. *published a distinct Treatise in 4to, intituled,* The Longitude found: *which has* King Charles II. *Royal Privilege before it: and which, as the Book it self informs us, was examined by Six of the most competent Judges about the Court at that Time. Who then seemed to hope that Mr.* Bond *had some great Secret, and would discover the Longitude. However, Mr.* Bond *gives us not in that Book, any particular Account of the Facts he went upon, as to the Inclination of the Dipping Needle: there being, that I remember, but two such Observations set down in all his Book: the one in the* East, *and the other in the* West-Indies: *Together with the Inclination at* London, *to be collected from the pointing of that*

Ridley pref. Hook. op. posthum. p. 482, 483.

Long found, p. 3.

p. 17, 18, 19. &c.

Needle in his Scheme thereof. Nor does he give us any particular Rules or Examples of the Manner how he would discover the Longitude by that Needle. Nay, when on the Reverse, he attempted to find that Inclination from the Longitude given, he built upon such precarious and inconsistent Hypotheses, as real Facts; and withal made such Mistakes in his Trigonometrical Calculations; (which were soon demonstrated to be such by Mr. Blackborough, *in his* Longitude not found;) *that 'tis a Wonder the Publick took so much Notice of it. Tho' it was indeed great Pity, that when so noble a Thought was started for the Discovery of the Longitude, and so fair an Occasion given, for considering the entire magnetick Power, the truly Learned did not better examine into that Matter, and cause more authentick Observations of the Inclination of the Dipping Needle to be made for that Purpose: but left all to stand or fall by Mr.* Bond's *own Hypothesis and Calculations. The Consequence of this great Disappointment seems to have been, at least with us, an almost intire Disuse of Dipping Needles ever since: as will appear in the following History.*

Colonel Windham, *a very curious and inquisitive Gentleman, indeed, did both in, and ever since the Days of Mr.* Bond,

Bond, *cultivate this magnetick Part of Philosophy; and particularly made considerable Use of the Dipping Needle, both by Sea and Land: from whose Observations made about* A. D. 1672. *with the Allowance of the Increase since that Time, I have determined the Dip at* Salisbury *in my little Map prefixed to this Treatise: and from whose other Observations, made at Sea, and on the* French *Coast, I would willingly have determined the like Dip at those Places also, could he have recovered the Papers wherein they were set down. But they being not yet found, I could not do it. That great Mathematician and Philosopher also Mons.* Fatio, *just now assures me, that the Honourable Mr.* Boyle *had a* Terrella, *and a little Inclinatory Needle; both which he lent him, above Thirty Years ago. That he tried a great Number of Experiments with them, and that they were consonant to what I have tried since my self. He also intimates, that He was sensible that some Use might be made of this Dipping Needle, in order to discover the Longitude; tho' he freely acknowledges, that* "My Theory of the "Properties of Magnetism, beside the "actual Observations, has a Degree of "Ripeness and Simplicity, which he "knew nothing of.

A. D.

A. D. 1700, *Dr.* Halley *went to Sea, on purpose to compleat his Observations of the Variation, with an Horizontal Needle only. Whereas if he had taken a large and good Dipping-Needle with him also at the same time, and had observ'd, with equal Exactness, the* Inclination, *as the* Variation, *it was next to impossible he should have missed of discovering the Longitude thereby; as will appear in the Sequel. The very same Year did our great Astronomer of* Wanstead, *the Reverend Mr.* Pound, *in Company with Mr.* James Cunningham, *take a Voyage to* China; *and most part of the way they made Observations of the Inclination by a Dipping-Needle which they had with them: Which Observations have been published, from Mr.* Cunningham's *Journal, in the* Philosophical Transactions. *But, by what hard Fate I know not, their Dipping-Needle prov'd so bad, and the Observations so disagreeable the one to the other, and most of them so different from the Analogy of all other such Observations, in or near the same Seas, that, excepting the gross general Correspondence, of affording an Horizontal Situation somewhat beyond the Equator; the Increase of that Dip Southwards; and the Return to the Horizontal Situation near the* Western *Coast of* China, *in which all Needles conspire,*

N°. 292.

ſpire, no particular Degrees of Inclination can be at all depended on in this whole Collection.

A. D. 1706, Pere Noel, *of the Society of* Jeſus, *when he ſailed from* Lisbon *to the* Eaſt Indies, *as a Miſſionary, had along with him a good Inclinatory Needle; and all the way made accurate Obſervations of the Angle of Inclination, as far as* Fort St. George: *Which, with many other curious Obſervations, and an Hypotheſis of his own with reſpect to Two large Magnets he ſuppoſed to be within the Earth, he publiſhed at* Prague *in* Bohemia *ſome time afterward. And indeed, I eſteem this to be the principal Set of Inclinatory Obſervations that I have yet ſeen; eſpecially as they appear to have been carefully made, and with a good Inſtrument, and to contain the true Dip over ſo large a Part of the World.*

A little after this, about A. D. 1708, *Monſieur* Feuillee, *a very curious and obſerving Perſon, when he was got beyond* South America, *to* Lima *in* Peru, *procur'd himſelf a good Dipping-Needle there: and therewith obſerv'd the Inclination, with great Care and Exactneſs, from* 13°. *to* 36°. *of* South *Latitude; or from* 18°. *of Dip to* 55°.

The Knowledge of theſe laſt Obſervations, I owe to that curious and diligent Natural-

liſt

ralist and Mathematician, Samuel Molineux, *Esq*; *who had them collected out of Monsieur* Feuillee's *Account of that Voyage: Who also the first of all thereupon intimated his Hopes to me, that by such Observations of the Variation and Dip compar'd together, the Longitude would, one time or other, be someway discovered; tho' at that time I had not the least Thoughts of any such thing.*

Hitherto therefore, or till about the latter End of the Year 1718, *I had no Notions of discovering the Longitude by the Way now propos'd. Nor was it possible I should have, since I did not then distinctly know what a Dipping-Needle was: nor indeed do I remember that, before That Time, I had ever seen such an Instrument in my Life. But the Occasion which turned my Thoughts this way, was as follows: About the Middle of* November, A. D. 1718, *came to me one Mr.* Eberhard, *a* German, *born at* Illeben *in* Saxony, *the very Town where* Luther *was himself born; who pretended to have a Method for discovering the Longitude by the* Dipping-Needle; *which he had been several Months proposing to the other Mathematicians and Virtuoso's in Town; tho' without being able to satisfy any of them, that he had made any such Discovery. Upon my Examination into his Method, which*

at

at first I thought might admit of some Mystery, which he conceal'd; I found at last, when he sent me Pere Noel's *Book, it was little more than that Author's Hypothesis, already mentioned, of Two Internal Loadstones, and the Imitation thereof by the Insertion of small Loadstones under Maps, and within Terrestrial Globes: With some hopes he had, that Nature would afford a sort of Magnetick Needle, which should point* East *and* West, *as the ordinary ones pointed* North *and* South: *While yet he confessed he did not know that there was such a Power in Nature, as most certainly there is not: And yet without such a Power, all his Expectations must come to nothing.*

Being thus disappointed in Mr. Eberhard's *Proposal of discovering the Longitude, I could not, however, forbear to think of this, to me, wholly new Instrument, the Dipping-Needle it self: Nor did I know but it might possibly be applied to this Purpose, if well understood. Whereupon I had a strong Inclination to see a real Dipping-Needle, and to try some Experiments therewith: For those that Mr.* Eberhard *had shewed me were so very small, that they were entirely unfit for Philosophical Experiments. Nor did I well understand, by what I saw there, even the common Nature or Use of such*

an Instrument. Accordingly, to satisfy my Curiosity, I soon enquired for such an Instrument, and found that Colonel Windham *had one, tho' it was small; which upon my Application he readily lent me; and as readily shew'd me the way of using it: He inform'd me also what Observations he had made by a larger Instrument of that Kind; how the Dip stood when he was young; and how much it had increas'd in his Time: For which, and other the like Kindnesses ever since, I and the Publick are greatly obliged to him. For as soon as I had got this Dipping-Needle, I began to try some Experiments with it: Which tho' they immediately shewed that Mr.* Eberhard's *Hopes were ill grounded, yet seemed to promise somewhat considerable this way, could a practicable Method of Application be hit upon.*

Now as I was musing of this Matter, and when I could think of no other way, Dr. Halley's *Map of the Variation, already mentioned, came very seasonably to my mind: And I considered, that by such an inartificial way of describing the Curve Lines of equal Variation, how irregular soever, upon a Map, he had already given some Help for the Discovery of the Longitude, at least near the* Cape of Good Hope: *tho' the Quickness of the Mutation of those Lines, and their different*

Posi-

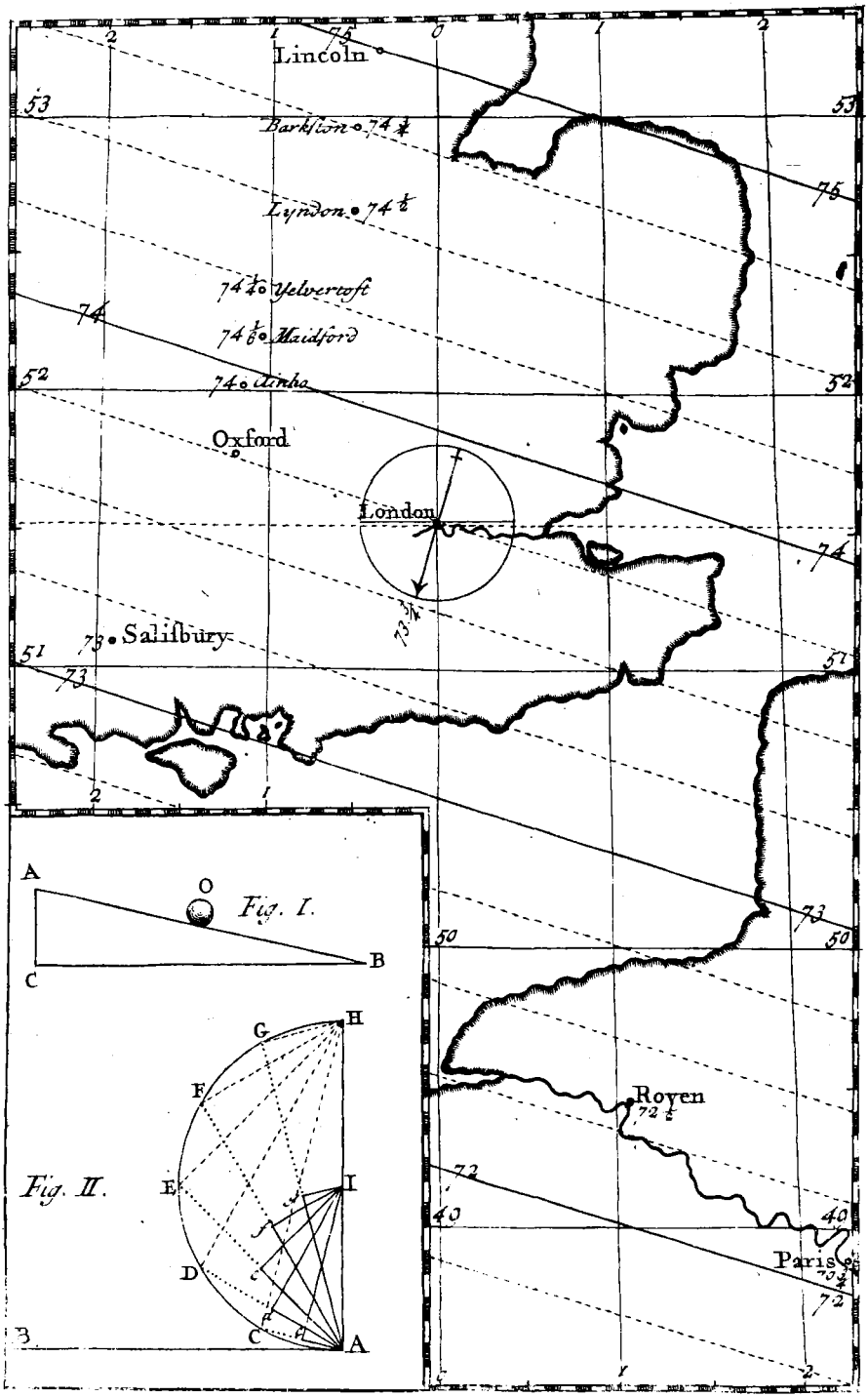
Position in the rest of the World, rendred that Method of short Use there, and almost wholly useless elsewhere. When therefore I considered, that the Lines of equal Dip could hardly be more irregular than those of the Variation; and well knew that their Mutation was a great deal slower; and that these might probably be useful over all the World; I conceived great hopes, that this way of Application of the Power before us might very probably discover the Longitude. And from this Time, and not before, do I properly date this my Discovery. But then, in what manner I immediately laid the Proposal before the Commissioners appointed by Parliament for the Longitude; what diligent, but usually fruitless, Searches I made both here, and in France, *for more good Inclinatory Observations; what Charges I have been at, and Difficulties I have met with, in the Mechanical Part of making and using this Instrument; what other Discouragements I met with; or what Assistances and Encouragements I have hitherto had; especially from the Right Honourable the Lord* Paisley, *and the free Use of his Loadstones; and from Col.* Windham's *Informations, and former Experiments: What Magnetical Trials I have my self first made, and afterward exhibited, before the best and most compe-*

tent Judges; and this in order to bring both this Theory and Practice to Perfection; it may not, perhaps, be proper here minutely to relate: any farther, I mean, than the following Papers, which contain the Success and Result of the whole, will inform the Reader. In the mean time, I hope the whole Sailing World will receive no little Benefit by these my Labours; and that the Publick will not, in any Nation, deny me those Rewards, which have been on purpose set apart for so useful a Discovery. I shall end this Historical Preface, in the Words which my dear Friend, Mr. Humphry Ditton, *since deceas'd, and my self, used on a like Occasion formerly.*

" *I conclude all with my hearty Wishes,*
" *as a* Man, *that this my Design may*
" *tend to the common Benefit of* Mankind:
" *as a* Briton, *that it may tend particu-*
" *larly to the Honour and Advantage of*
" *this my* Native Country: *and as a*
" Christian, *that it may tend to the Pro-*
" *pagation of our* Holy Religion, in its
" Original Purity, *throughout the*
" *World.*

London, Feb. 26. 17$\frac{19}{20}$.

Will. Whiston.


Lincoln
Barkston
Lyndon
Yelvertoft
Maidford
Oxford
London
Salisbury
Roven
Paris
Fig. I.
Fig. II.
A
B
C
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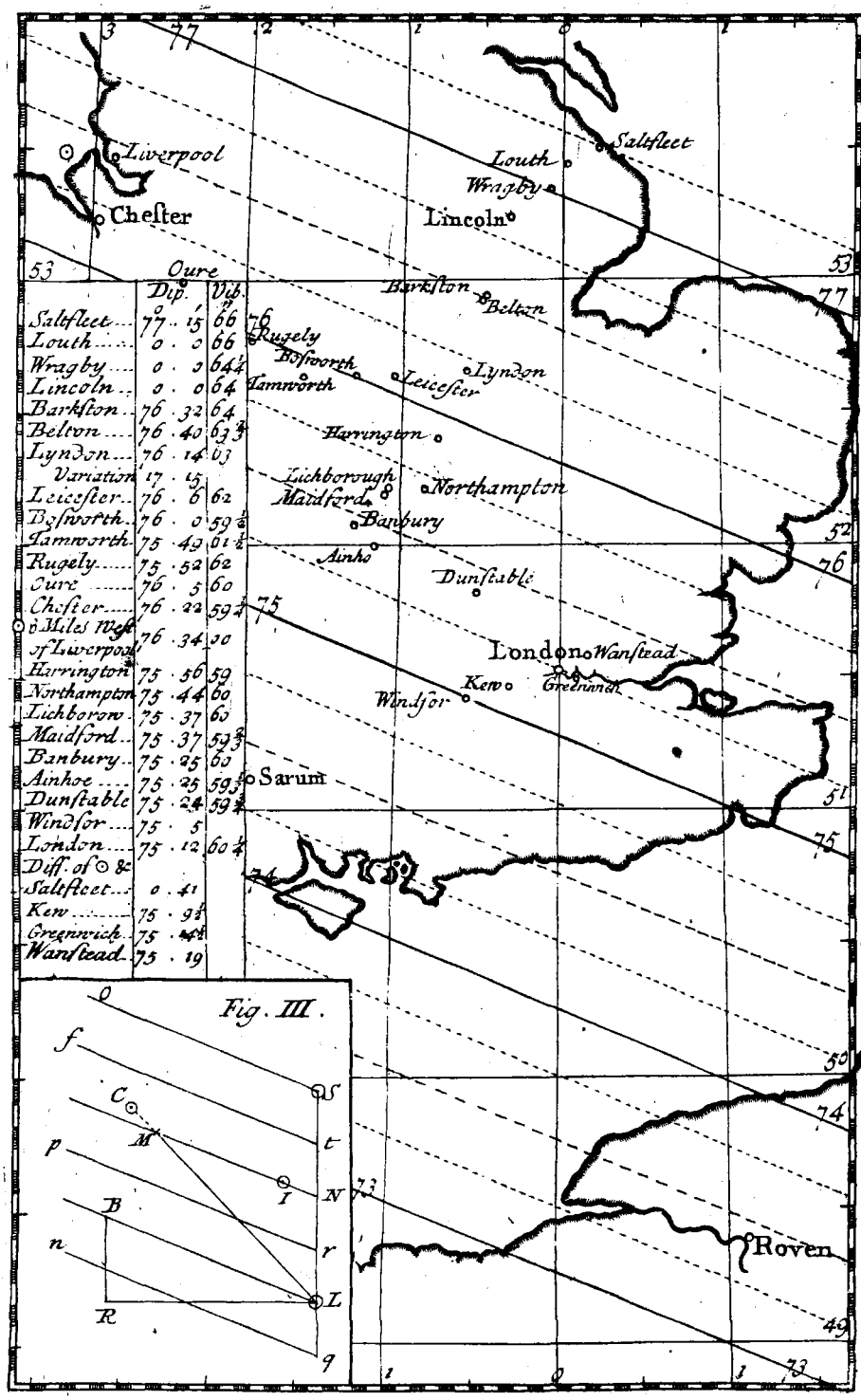
I



	Dip. °	′	Vib. °	′
Saltfleet	77	15	66	
Louth	0	0	66	
Wragby	0	0	64	1/2
Lincoln	0	0	64	
Barkston	76	32	64	
Belton	76	40	63	3/4
Lyndon	76	14	63	
Variation	17	15		
Leicester	76	6	62	
Bosworth	76	0	59	1/2
Tamworth	75	49	61	1/2
Rugely	75	52	62	
Oure	76	5	60	
Chester	76	22	59	1/2
8 Miles West of Liverpool	76	34	00	
Harrington	75	56	59	
Northampton	75	44	60	
Lichborow	75	37	60	
Maidford	75	37	59	2/3
Banbury	75	25	60	
Ainhoe	75	25	59	1/3
Dunstable	75	24	59	3/4
Windsor	75	5		
London	75	12	60	1/4
Diff. of ☉ & Saltfleet	0	41		
Kew	75	9	1/2	
Greenwich	75	4[illegible]		
Wanstead	75	19		

The LONGITUDE *and* LATITUDE *found by the* INCLINATORY *or* DIPPING NEEDLE.

DEFINITION.

AN Inclinatory or Dipping Needle, is a long and ſtrait piece of Steel, every way equally pois'd upon its Center, and afterwards touch'd with a Loadſtone; but ſo contriv'd, as not to play on the Point of a Pin, as does the common Horizontal Needle; but to Swing in a Vertical Plain, about an Axis, parallel to the Horizon; and this in order to diſcover the exact Tendency of the Power of Magnetiſm.

N. B.

N. B. As to the Sort of Iron or Steel which is beſt for Magnetical Needles, Dr. *Ridley* gives us Direction in theſe Words, which I ſuppoſe are agreeable to Experience.

Of Magnetical Motions, c. 17.

" Needles and Wires of Steel, " heated to an height, and redu-" ced back to a blewiſh Colour, will receive " a ſtronger Touch, and retain it ten times " longer, than Iron will, howſoever it be " hardened: yet Iron is beſt for Caps placed " near the Stone.

N. B. If you would have a ſtrong Touch, which ſhould not be laſting, it may be beſt ſometimes to touch the Needle with the Cap or Armature of the Loadſtone; but if you deſire a ſtrong and durable Touch, you muſt, by all means, touch it on the Stone it ſelf, and that as near as may be to the Poles thereof; the *North* End of the Needle on the *South* Pole, and the *South* End on the *North* Pole; and that a dozen or twenty times together: Tho' as to this Repetition of the Touch, which is every where now ſo frequent, hear Dr. *Gilbert*, under the following Note.

N. B. Dr. *Gilbert*'s Direction for touching of Needles is this: " When you would touch a " Needle with the Loadſtone, you are to be-" gin at the Middle of the Needle, and draw " it to the End of it: And towards the End, " con-

" continue that Touch gently, or by a tender " Application, for some time; I mean for one " or two Minutes of an Hour: But do not re- " iterate the Motion from the Middle to the " End, (as the Custom is,) for thereby its " directive Power is perverted. *L.* III. *c.* 17.

OBSERVATIONS.

I. The true Tendency of the *North* or *South* End of every Magnetick Needle, is not at all towards that Place in the Horizon whither the Horizontal Needle points, but towards another directly under it, in the same Vertical; and in different Degrees under it, in different Ages and Countries. *Ex. Gr.* At *London* this Tendency is now of the *North* End of the common Needle, about 73° 45′ below the Horizon. Whereas *A. D.* 1576, when this Property was first discovered, it was about 71° 50′, as Mr. *Norman* assures us, in his *New Attractive*; which I have added at the End of this Paper.

This Observation is also manifest in all Tryals of common Magnetick Needles; which though exactly pois'd in an Horizontal Position, before they are touch'd with the Loadstone; do yet, after that Touch, tend towards this Direction: And when contriv'd so as to swing in that Vertical Plain, will never rest in any other Position,

Position, without some other Force to counterbalance that Tendency. And indeed, by this Alteration of the Equilibrium of Horizontal Needles, upon the Touch, it was, that Mr. *Norman*, at *Wapping*, first discovered and made the Dipping-Needle; in or about *A. D.* 1576, as himself informs us in his forementioned *New Attractive*: of which in the Preface.

II. This Line of the Needle's Tendency is therefore to be considered, when we treat of the Power of Magnetism, in the very same Manner as is the Line of Direction towards the Earth's Center, when we treat of the Power of Gravity. This Magnetick Power appearing to be equally constant and uniform in this Direction, as is the Power of Gravity in the other.

III. The Angle of Dip, or Inclination below the Horizon, is then only the true one, or the least of all; and the Angle of the Needle from the Nadir the greatest; when the Plain of the Needle's Oscillations is directly along the Magnetick Meridian, or when the Intersection of the Plain with the Horizon is the true Variation of the Needle in that Place.

IV. When that Plain is at right Angles with the former, or in the Magnetick *East* and *West*, this Angle of Dip or Inclination is a right Angle;

Angle; and the Needle does not at all aſcend from the Nadir.

Corollary. When therefore the Dipping Needle ſtands exactly perpendicular to the Horizon, the Interſection of that Plain with the Horizon, makes an Angle with the true *Eaſt* and *Weſt* Line, equal to the Variation of the Needle at that Place.

N. B. Becauſe, as we ſhall ſee hereafter, the Alteration of the Aſcent of the Needle is according to the Degrees on the Line of Sines; which at firſt differ very much, but at laſt exceeding little; this Angle of the Variation is diſcover'd beſt by the Dipping Needle, in this Poſition of its Plain, and not in that along the Magnetick Meridian.

N. B. If the Plain of the Needle therefore be but within Three, Four, or even Five Degrees of the Magnetick Meridian, the Angle of Inclination will be almoſt as exact as if it were perfectly along that Line. The Reaſon is obvious: For the Sine of 85° differing from that of 90° not quite the 250th Part of the Radius; this Difference can hardly ever come to more than one Third of a Degree, or 20′, and with us never comes to more than 4′. And the Sine of 87° ½ differing from that of 90°, not quite the 1000th Part of the Radius, or but one Quarter of the former Dif-

 ference,

ference, this Error can hardly ever come to more than 5′, and with us never comes to more than 1. Which Thing is of great Advantage for Practice, in finding the true Angle of Inclination with Dipping Needles: Though it has not indeed any Place in the finding the Angle equal to the Variation; which admits of no ſuch Allowance for Inaccurrcy as is here mentioned.

V. Great Exactneſs is neceſſary in the Poiſe and Situation of the Dipping Needle; *viz.* that it be equally ballanced when either Edge is upward, that its Plain be exactly Vertical, or Perpendicular to the Horizon: And that the Beginning of the Diviſions be perpendicularly under the Axis of Motion; which, in ſmall Needles, are beſt provided for by a large circular Pedeſtal, with three Screws; and thoſe adjuſted by a Spirit Level, whoſe Plain is parallel to the Horizon. By which means, the Angles of Inclination will be equal, if either Side of the Inſtrument be turned *Eaſtward*: which otherwiſe will not happen.

N. B. Long Needles which will turn, in ſome degree, with the 120th or 130th Part of a Grain, and will ſtand in a perfect Equilibrium both horizontally and perpendicularly, will yet do ſo in no oblique Situation whatſoever. This is certain in fact; and plainly ariſes from a ſmall and uſually unperceiv'd Bending of the Needle, which makes the Center of Gravity a very ſmall matter different from the Center of Motion,

Motion, as Monſ. *Fatio* ſuggeſted to me. We muſt therefore correct this Inequality before we touch or uſe ſuch Needles: Which is eaſily done by a ſmall Poiſe of Braſs circular Wire, or any like ſmall Weight, placed on the lower Part of the Needle, and to be remov'd higher and lower, as Experience ſhall direct. For if you thus ballance this Power, the ſame Poiſe on a due Removal to its correſpondent Mark on the Needle, will ſerve for all other Inclinations. Thus my longer Needle of Four Feet was ballanc'd by a Poiſe of 1L77 Grains, and the other of Three Feet 11 ½ Inches by 2L44 Grains.

N. B. The Want of the diſtinct Knowledge of this Inequality, and of providing for its Poiſe, has rendred moſt of our Obſervations hitherto inaccurate, and the Angle of Inclination has been ſtated too ſmall. Accordingly the Dip at *London*, which by my former Needles of one Foot long, unpois'd, was only 73° ¾, is in reality by theſe of four Foot pois'd, 75 ⅙. Nay, theſe laſt, when unpois'd, differ from themſelves when pois'd not leſs than 30 degrees; and make the Dip at *London* leſs than 45.

Corollary. Hence all Dipping Needles that pretend to Exactneſs, and that are to belong to the ſame Sea Chart, ought to be nicely adjuſted to the ſame Standard, both as to the Accuracy of their Poiſe, and Quantity of Dip at one certain Place; otherwiſe they will groſsly deceive the Obſervers.

LEMMATA:

Or Preparatory PROPOSITIONS; *Wherein the Laws of Magnetiſm are diſcovered.*

I. THE Loadſtone has both an *Attractive*, and a *Directive* Power united together: While Iron, touch'd by a Loadſtone, has the *Attractive*, but little or no *Directive* Power at all. I mean, that the Loadſtone not only *attracts* Needles, or Filings of Steel; but *directs* them to certain different Angles with reſpect to its own Surface and Axis. While Iron, touch'd therewith, does little or nothing more than *attract* them; and ſtill ſuffers them to lie along, or ſtand perpendicular to its Surface and Edges in all Places, without any ſuch ſpecial Direction.

This is a Matter of Experiment, and appears to be ſo upon Trial.

N. B. Neither the *ſtrongeſt*, nor the *largeſt* Loadſtones give a better Directive Touch to Needles, than thoſe of a more ordinary Virtue and Bigneſs; as I have found upon Trial: The Quickneſs of the uſual Vibrations not having been ſenſibly altered by ſuch Loadſtones. And Monſ. *Fatio* aſſures me, he has formerly experienc'd the ſame thing. Colonel *Windham* alſo has himſelf obſerv'd this, "That all Load-"ſtones have two Qualities, *viz.* an Attra-

" ctive and a Directing Quality; neither of
" which depend on, or are an Argument of
" the Strength of the other.

N. B. The *Attractive* Power of Loadstones and of Iron, will greatly increase or diminish the Weight of Needles upon the Ballance; nay, will overcome that Weight, and support other additional Weights also: while the *Directive* Power seems to have much smaller Effect. I say only *smaller* Effect, not none at all, as Mr. *Norman*, *Gassendus*, with *Mersennus*, and, as it seems, Dr. *Gilbert* also found: For they assure us, that, upon the nicest Trials they could make, a Needle weigh'd neither more nor less after it was touch'd with the Loadstone, than it did before. But this was only because their Needles were too small to find that Difference of Weight. For as to my own exacter Trials, my longer Needle of Four Foot, which weighed before 4584 $\frac{1}{8}$ Grains; being presently weighed again, after the Touch, with the same Scales and Weights, weighed Two Grains less than it did just before; and my shorter of 3 Feet 11 $\frac{1}{2}$ Inches, which weighed before 4015 Grains, weighed afterwards 2 $\frac{5}{8}$ Grains less: Contrary to all our Expectations. Another Needle also of 14792 $\frac{1}{2}$ Grains, and 8 Foot long, which I tried afterwards, lost 2 $\frac{1}{2}$ Grains; and one still much heavier of 65726 Grains Weight, and 7 $\frac{1}{2}$ Foot long, lost no less than 14 Grains.

Norman's *New Attract.* C. V.
Gassend. Op. Tom. II. *p.* 129.
Gilbert de Magnete, III. 3.

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e

The Fact is evident; the Needles having been weighed both before and after with the ſame Weights, by our very accurate and skilful Operator Mr. *Haukſbee*. But as for the Cauſe of this Diminution of Weight, I leave it to the further Conſideration of the Inquiſitive; tho' my own Conjecture, as to this matter, will appear under the next Note but one.

N. B. Perhaps Iron is almoſt wholly made up of the *Attractive* Particles; and the Loadſtone of both the *Attractive* and *Directive* compounded together; and probably mixed with other heterogeneous Matter alſo: It having never been purged by the Fire, as Iron has been. And perhaps hence it comes to paſs, that Iron, after it is touch'd by a Loadſtone, and its Virtue excited, will lift up ſo much greater Weights than the Loadſtone it ſelf, which touched it; nay will, upon Contact, take away Needles or Filings of Steel from the ſame Loadſtone; as is well known in Magneticks.

N. B. The Quantity and Direction of Magnetick Powers communicated to Needles, is not properly, after ſuch its Communication, owing to the Magnet which gave the Touch, but to the Goodneſs of the Steel that received it; and to the Strength and Poſition of the Terreſtrial Loadſtone, whoſe Influence alone theſe Needles are afterward ſubject to, and directed by. So that all ſuch good Needles move with the ſame Strength, and point to the ſame Angle, what good Loadſtones ſoever they were excited by,

as

as we have in part already noted. Nor does the *Touch* ſeem to do much more in Magnetick, than *Friction* in Electrical Caſes; I mean, rub off ſome obſtructing Particles that adhere to the inward and outward Surfaces of the Steel, and open the Pores of the Bodies touch'd, and ſo make way for the Entrance and Exit of ſuch Effluvia, as occaſion or aſſiſt the Powers we are now ſpeaking of.

N. B. The *Directive* Power of Loadſtones ſeems not to be Immechanical, as Gravity is; but Mechanical, and deriv'd from Magnetick Effluvia, circulating continually round the Loadſtone: Of which Circulation there ſeem to be very evident Indications in Magnetick Experiments; tho' it muſt be confeſſed, the Magnetick Effluvia themſelves have never yet been rendred ſenſible, as the Electrick Effluvia begin to be. However, as to the *Attractive* Power, it ſeems to me as perfectly immechanical as Gravity it ſelf; of which more hereafter.

N. B. No natural Bodies whatſoever are found to hinder, or divert, or retard the Magnetick Effluvia, but Iron or Steel: which ſtill turn the ſame Lengthways, and receive their Power from them.

II. The Abſolute Attractive Power of different Armed Loadſtones to ſupport Weights, is, *cæteris paribus*, according to the Quantity, not of their Diameters or Solidities, but of the *Surfaces* of the Loadſtones, or in the duplicate Proportion of their Diameters.

This

This Propoſition has been very lately diſcovered by the Right Honourable the Lord *Paiſley*, the great Reviver and Encourager of the Knowledge of Magnetiſm among us: Who upon this Principle alſo has ſo far improv'd the Attractive Power of his beſt *Terrella*, or Spherical Loadſtone, of 1 ¼ Inches Diameter, that whereas it would ſupport little more than 14 Pounds when his Lordſhip bought it; it now ſupports about 22 Pounds. Nor is it any great Wonder, that a Power which acts chiefly on the Surfaces of Loadſtones, and of Iron, ſhould ſtill act in Proportion to thoſe Surfaces.

III. The equal Power of good Loadſtones unarmed, not ſenſibly unequal in Strength, ſimilar in Figure and Poſition, but unequal in Magnitude, is ſometimes a little greater, ſometimes a little leſs, than that of their ſimilar *Diameters*.

This is a Matter of Experiment; and I have found it ſo upon ſeveral Trials. Only the Difficulty is ſo great in determining when quite different Loadſtones, or indeed different Parts of the ſame Loadſtone when ſeparated therefrom, are equally good, that 'tis very hard to come at any degree of Exactneſs in this Experiment.

IV. The Loadſtone equally attracts Needles which have been already touch'd, at a farther Diſtance than thoſe that have not been touch'd; and this at the Diſtance of about 5 to 2; or where its Power is, as we ſhall ſhew preſently, about the Tenth Part of the other.

This has been found ſo upon Trial.

N. B. Both Poles of a Loadſtone do equally attract Needles, till they are throughly touch'd; and then it is, and then only, that the one Pole will begin to attract the one End of Needles, and to repel the other: tho' ſtill the repelling Poles will attract upon Contact, nay at a very ſmall Diſtance, notwithſtanding.

V. The Attractive Power of Loadſtones, in their ſimilar Poſition to, but different Diſtances from, Magnetick Needles, is in the *ſeſquiduplicate* Proportion of the Diſtances of their Surfaces from thoſe Needles *reciprocally*; or as the middle Proportionals between the Squares and the Cubes of thoſe Diſtances *reciprocally*: or as the ſquare Roots of the Fifth Powers of thoſe Diſtances *reciprocally*.

Thus, becauſe 1. 2. 4. 8. are in Geometrical Progreſſion; and the Square Root of $4 \times 8 = 32$. which is nearly, 5,65 is the middle Proportional between 4. the Square; and 8. the Cube of 2: I affirm, that the Magnetick Power of Attraction at *twice* the Diſtance from the Surface of the Loadſtone, is between a fifth and a ſixth Part of that Power at the firſt Diſtance. Thus alſo, becauſe 1. 3. 9. 27. are alſo in Geometrical Progreſſion; and the Square Root of $9 \times 27 = 243$. which is nearly $15\frac{1}{2}$. is the middle Proportional between 9. the Square; and 27 the Cube of 3: I affirm, that the Magnetick Power at *thrice* the Diſtance from

 the

the Surface of the Loadſtone, is in the Middle between the Fifteenth and the Sixteenth Part of the ſame Power at the firſt Diſtance. Thus alſo at 4 times the Diſtance, the Power will be 32 times as ſmall: At 5 times the Diſtance, the Power will be almoſt 56 times as ſmall: At 6 times the Diſtance, the Power will be a little more than 88 times as ſmall: And if the Diſtance of one be to that of the other as 7 to 9, the Power at the fartheſt Diſtance will be to that of the neareſt, as the Square Roots of the fifth Powers, or almoſt as 130 to 243, and ſo for ever.

N. B. I here take the Diſtances, not, as in the Law of Gravity, from the *Center*; but from the *Surface*: becauſe, as all Experience aſſures us, the Magnetick Power is chiefly at the *Surfaces* of Loadſtones, and of Iron: and indeed ſeems to have no particular Relation to any Centers at all.

Philoſ. Tranſact. N°. 344. Hauksbee's *Experiments*, 2d *Edit.* p.322 —328.

N. B. That Excellent Mathematician, Dr. *Brook Taylor*, late Secretary of the Royal Society; and Mr. *Hauksbee*, Sen. their Operator, Perſons very fit for making ſuch Experiments, have, not long ſince, at the Society's Recommendation, tried the Power of Three ſeveral Loadſtones, in order to diſcover the Law of Magnetick Attraction at ſeveral Diſtances; whoſe Numbers are

are extant. But becauſe they made the Experiments without preſerving a ſimilar Poſition of the Line of the Magnet's Motion to the Needles, which was neceſſary to have been obſerv'd; the Experiments, how exact ſoever, have proved of little Uſe. Nor did either of them in the leaſt hint what Conſequences might be drawn from thoſe Obſervations, in order to diſcover this Law of Magnetiſm. I was therefore obliged to make new Obſervations of my own for that purpoſe. For tho' the Knowledge of this Law muſt needs be one of the firſt Principles of Reaſoning in Magneticks, yet has it hitherto been almoſt entirely neglected. Our great Sir *Iſaac Newton* indeed has demonſtrated, that ſuch a Power muſt decreaſe in more than a *duplicate* Proportion of the Diſtance; and has intimated, from *ſome groſs Obſervations*, [poſſibly he means thoſe above-mentioned: for I know of no others extant] (Col. *Windham* having never publiſhed any of his Obſervations relating to Magnetiſm at all;) that it decreaſes in an almoſt *triplicate* Proportion of that Diſtance: Yet does the real Proportion, which I have diſcovered, ſo conſiderably differ from both the *duplicate* and the *triplicate*, that theſe Determinations, which yet are the *beſt*, if not the *only* ones extant, cannot be acquieſced in, without further Enquiry, and new Experiments: Which Experiments I was therefore obliged to make my ſelf, as they follow preſently.

Princip. L. I. Sect. 13. Prop. 85. L. III. *Prop. 6. Corol. 5.*

N. B. In these Experiments, I made use of my Lord *Paisley*'s larger *Terrella*, of 2 8 Inches Diameter. I generally exposed the *South* Pole of the Stone to the *North* End of the Needle, and that ever so as to keep the Line of the Loadstone's Motion at right Angles with that Needle. I also used sometimes a short Needle of 4 ½ Inches; sometimes a long one of 4 Feet: Both which, till the Loadstone came near the Needles, agreed well enough. But because the Concern of one Pole of the Loadstone with one End of the Needle was most distinct and undisturb'd in the long Needle; and because that Needle afforded Angles more agreeable to Analogy, I preferred the Experiments made thereby. Only at the greatest Distances, the small Needle would be moved when the Weight and Friction of the larger made its Motion scarce sensible. And indeed, I was forced to set down three or four of the fartheſt Numbers, rather from Analogy to the rest, than from any exact Observations. Nor is the Reader ever to expect greater Accuracy in such remote Numbers than 10′ or 20′, as Mr. *Hauksbee* has justly observ'd, in the Place above referred to. The Reason of which is plain; That there the Friction bears the greatest Proportion to the Magnetick Power of the Needle, and so the most interrupts the Freedom of its Motion.

N. B. The Reader is to remember, that in such Experiments the Force is to be measur'd by

by the *Chords* of those Arcs, by which it makes the Needle decline from its natural Direction: To which Chords it is ever proportional; as I have elsewhere demonstrated. I have therefore set down Half the Chords, or the Sines of Half those Arcs of Declination, as the true Measures of the Power of Magnetism.

Mathemat. Philos. Prop. 7.

Distance in Inches.	Degrees of Declin.	Sines of the $\frac{1}{2}$ Arcs.
3	0	
6	0	
$6\frac{1}{2}$	90	7071
9	27	2334
12	13	1132
15	$9\frac{3}{4}$	848
18	$6\frac{3}{4}$	588
21	$4\frac{1}{2}$	392
24	3	262
27	2	174
30	$1\frac{5}{6}$	160
33	$1\frac{1}{2}$	131
36	$1\frac{1}{4}$	109
39	$0\frac{5}{6}$	73
42	$0\frac{3}{4}$	65
45	$0\frac{2}{3}$	58
48	$0\frac{1}{2}$	44

Now if we take out of this Table the Sines for any Numbers of Inches *double* to each other; as for 9 and 18, they are 2334 and 588; which are nearly as the Squares, or as 4 to

to 1. The Sines for 12 and 24 are 1132, and 262: Theſe are in a greater Proportion than the Squares, or than 4 to 1; but in much leſs than the Cubes, or than 8 to 1. The Sines to 15 and 30 are 848, and 131. Theſe are in a much greater Proportion than the Squares, or than 4 to 1; but in a leſs than the Cubes, or than 8 to 1. The Sines to 18 and 36, are 588 and 109. Theſe are nearly in the Mean, between the Squares of the Cubes, or as 5L65 to 1. The Sines to 21 and 42 are 392 and 73; thoſe to 24 and 48 are 262 and 44; the former a little *under*, and the latter a little *above*, that mean Proportional. The remoter and exacter Diſtances alſo in Mr. *Hauksbee*'s Experiments, at 30 and 60 Inches Diſtance; which gave the Angles of 13°. 20′. and 2°. 15. whoſe Sines of the half Arcs are 1161 and 196, and are very near to the Proportion of 5L65 to 1. So that this *Seſquiduplicate* Proportion appears, by theſe double Diſtances, to be ſtill the true one. The ſame Proportion is more ſenſible, if we take Diſtances *triple* to one another: as 9 and 27. whoſe Sines are 2334 and 174: or 12 and 36. whoſe Sines are 1132 and 109; the one of which is *over*, and the other *under*, that ſeſquiduplicate Proportion; which requires about 15½ to 1. That Proportion is ſtill more ſenſible, if we take one Diſtance *quadruple* to the other; as 6½ and 26. whoſe Sines are 7071 and 204, or 9 and 36. whoſe Sines are 2334 and 109; or 12 and 48. whoſe Sines are 1132 and 44; the

the firſt of which *exceeds*, and the other two *want of*, that ſeſquiduplicate Proportion, which requires 32 to 1. So that the Mean is ſtill on all Accounts this very ſeſquiduplicate Proportion, and no other.

N. B. Take here the Numbers found at another more accurate Tryal; where many curious and conſiderable Perſons were preſent.

Diſt. in Inches corrected.	Degrees of Declinat.	Sines of $\frac{1}{2}$ Arcs.	Rat. ſeſquidupl.
20	2°	175	466.
$14\frac{8}{9}$	4	349	216.
$13\frac{5}{8}$	6	523	170.
$12\frac{3}{8}$	8	697	138.
$11\frac{1}{8}$	10	871	105.
$10\frac{1}{4}$	12	1045	87.
$9\frac{1}{4}$	14	1219	70.

N. B. The Reverend Mr. *Benjamin Worſter*, a skilful Mathematician and Philoſopher, has propoſed another very good Way of finding the Law of Attraction in Magnets, which is built on my Method of comparing Vibrations and Oſcillations of Needles with the Oſcillations of a Priſmatick Pendulum, of the ſame Radius, moving by the Force of Gravity, and it is well worth our Conſideration: *viz.* to count the Number of Vibrations or Oſcillations in a given Time at ſeveral Diſtances of the Magnet, and take the Force as the Squares of thoſe Numbers *directly*;

directly: or as the Squares of the Times of an equal Number of those Vibrations or Oscillations *reciprocally*. Provided only, that that Part of the Force which arises from the Magnetick Power of the Earth, be substracted from the entire compounded Force, to give the single Power of the Loadstone. According to which Method, we found the Numbers following, upon an exact Trial, made before many curious and considerable Persons; each Experiment being tried thrice over.

N. B. The Needle vibrated once in $3''_{L}2$. being near 4 ½ Inch long.

N. B. We used at first Mr. *Rose* the Jeweller's *Terrella*, of 1 ⅛ Inches Diameter.

N. B.

Inches diff.	Numb. Vibr.	Seconds.	50 Vibrat.	Vibrat. by Magnet alone.	50 Vibrat. in	Sesquidup. Proportion.
1	50	in 17″ $\frac{1}{3}$ in 17 $\frac{1}{4}$ in 16 $\frac{1}{8}$	17″	47	18″	5.
2	50	in 34 in 33 $\frac{3}{4}$ in 33 $\frac{5}{8}$	33L7	39	43L2	1L2.
3	25	in 26 $\frac{9}{10}$ in 28 $\frac{1}{4}$ in 27 $\frac{3}{4}$	55	33	83L3	2L0.
4	20	in 29 in 29 $\frac{1}{2}$ in 29	73	27	135	2L87.
5	20	in 35 $\frac{3}{4}$ in 33 $\frac{1}{2}$ in 30	88L7	22	202	3L80.

N. B. We also afterward used the Lord *Paisley*'s best *Terrella*, 5 Ounces, 16 pw. and 11 Gr. in Weight; and in Diameter 1 $\frac{3}{4}$ Inch. The Success was as follows.

1	50	in 11 $\frac{1}{4}$ in 12 $\frac{1}{8}$ in 11 $\frac{3}{4}$	11L5	46	12L5	5.
			[10	47	10L6]	
2	50	in 21 $\frac{3}{4}$ in 21 $\frac{1}{4}$ in 21 $\frac{1}{4}$	22L5	43	26L2	1L2.
3	50	in 33 $\frac{1}{4}$ in 33 in 33 $\frac{3}{4}$	33L3	40L6	41L6	2L0.
4	50	in 46 in 46 in 46 $\frac{1}{8}$	46L1	36	64	2L87.
			[44L6	36	62]	
5	40	in 45 in 44 $\frac{7}{8}$ in 45	56	32	87	3L80.

N. B. If we obſerve, that the Friction is moſt conſiderable at the greateſt Diſtances of the Loadſtones, and does there prolong the Time of the Vibrations; and that, in the laſt Set, the Loadſtone ſeems to have been a ſmall matter too remote from the Needle in the Second and Fourth Trials, as the Analogy of the reſt implies; all theſe Obſervations will nearly agree; and will farther demonſtrate, that the true Proportion of the Magnetick Power's Decreaſe, is the *ſeſquiduplicate* of the Diſtance; as all the other Obſervations have alſo proved.

N. B. I have tried the ſame Experiment in one Magnetick Needle with relation to another; and I find, that the Decreaſe of the Attraction is in the ſame *ſeſquiduplicate* Proportion of the Diſtance, in this Caſe alſo.

A TABLE *of Magnetick Power, from this* ſeſquiduplicate *Proportion, at different Diſtances from Loadſtones.*

Diſtance from the Loadſtone.	Magnetical Power in Proportion.
1	1.25
1.73	1.00
2	1.44
3	4.0
4	8.2
5	14.4

6

6 —————— 22L6
7 —————— 33L6
8 —————— 46L6
9 —————— 62L4
10 —————— 81L7
11 —————— 102L0
12 —————— 128L4
13 —————— 153L8
14 —————— 185L0
15 —————— 219
16 —————— 256
17 —————— 295
17L1 —————— 300
18 —————— 361
19 —————— 413
20 —————— 467
21 —————— 524
22 —————— 586
23 —————— 655
24 —————— 729
25 —————— 801
26 —————— 882
27 —————— 961
28 —————— 1050
29 —————— 1149
30 —————— 1253
31 —————— 1347
32 —————— 1452
33 —————— 1552
34 —————— 1656
35 —————— 1781
36 —————— 1910

37 ——

37	2034
38	2162
39	2294
40	2440
41	2632
42	2788
43	2959
43 $\frac{1}{4}$	3000
44	3136
45	3341
46	3564
47	3795
48	4045
49	4277
50	4516
51	4761
52	5013
53	5271
54	5535
55	5576
56	5926
57	6304
58	6577
59	6806
60	7123
70	10322
80	14042
90	19238
100	26018

Corol-

Corollary (1.) If therefore we know the Power of any Loadſtone at any one Diſtance from its Surface, we can readily find it at any other Diſtance. *e. g.* becauſe the Square Root of the Fifth Power of 10 is little above 300. If a Needle of a Foot long, at 5 Inches Diſtance, be equally drawn by Magnetiſm, as by Gravity; (and we ſhall hereafter prove, that the Power of Gravity is, in that Caſe, to the Power of the Magnetiſm of the Earth, as 300 to 1) it will begin to be lifted up at ſomewhat farther Diſtance than half one Inch: Which Experience does alſo atteſt. Thus alſo, if we ſuppoſe a Needle of a Foot long, 10 times ſo near the internal Magnet as we are here; the Power of that Loadſtone there, would be ſomewhat greater than the Power of Gravity here: But of that more hereafter.

N. B. Becauſe the Magnetick Force in Needles of the ſame length ſeems, by the Experiments, to be nearly equal; whether they be larger and broader, or leſſer and narrower towards the Ends; it ſeems as if the Magnetick Effluvia paſſed along the Needle, ſo as ſtill to confine themſelves within its Edges; or by running, like a River, ſo much ſwifter as the Needle or Paſſage is narrower, and ſo much ſlower as it is wider; whereby the Quantity of Motion and of directive Power becomes nearly equal in all thoſe Caſes.

PRO-

VI. A Pendulum, whose Center of Suspension is distant from the Center of Oscillation 39L12 Inches, makes every Swing in the least Arc of a Circle in one Second, or 60'''.

This is well known by all that make long Pendulum Clocks; or have try'd Experiments with other Pendulous Bodies.

N. B. I say here, every Swing, in the *least* Arc only; for so is the Fact. In Cycloids indeed, the Swings or Oscillations are all exactly equal, be the Arcs never so unequal: But in Circles they are not so: The larger Arcs requiring still a longer Time than the shorter, and the Quadrantal Arc requiring so much more Time than the smallest, as 34 is more than 29; which the famous Monsieur *Huygens* has demonstrated

VII. A Pendulum, whose Center of Suspension is distant from the Center of Oscillation Four Inches, describes very small Arcs in a little less than one Third Part of a Second, or exactly in 19L2'''. And one 32 Inches long in 54''';

This

This is eafily found, by extracting the Square Roots of the former Numbers, 39,12, and 4, which are 6,25, and 2. It being well known in Mechanicks, that the Lengths of Pendulums are as the Squares of their Times of Oſcillation: Or, which is all one, that the Times are as the Square Roots of thoſe Lengths. Whence the Analogy will run thus, 6,25. : 2. :: 60″. : 19,2‴.

VIII. A Priſmatick, or Cylindrick Solid and Pendulous Body Six Inches long, ſwinging about one End as a Center, performs each Oſcillation in the ſame Time with a common Pendulum or Plummet, hung by a Thread of Four Inches; that is in 19,2‴. As does alſo ſuch an one of Four Feet, or 48 Inches long, oſcillate in the ſame time with a common one of 32 Inches long; *i. e.* in 54‴, or 1,9″.

This is well known by the Place of the Center of Oſcillation in all Cylindrick and Priſmatick Bodies; which is demonſtrated to be at $\frac{2}{3}$ of the whole Length: And by Experiments purpoſely made with ſuch Bodies, which fully confirm that Demonſtration.

IX. An Inclinatory or Dipping Needle of Six Inches Radius, and of a Priſmatick or Cylindrick Figure, when it oſcillates along the Mag-

Magnetick Meridian, performs here every mean Oscillation in about 6″ or 360‴. And every small one in about 5″ $\frac{1}{2}$, or 330‴. And the same Sort of Needle 4 Foot long, makes every mean Oscillation in about 24″, and every small one in about 22″.

This is a bare Matter of Fact: And I have my self often found it to be so upon Tryal.

N. B. I use the Words *mean* and *small Oscillation* here, because in these Magnetick Oscillations, as well as those derived from Gravity, the large Arcs require longer Time than the small ones: And, by my Trials, in the same Proportion. So that when we compare their Velocities and Motions together, we must take Similar Oscillations, as I generally take the small ones for my Calculations. And indeed the Equality of the Oscillations in such Cases will, on all Sides, be secured better, by beginning with those much less than 30 Degrees from the true Dip, where they are almost equal; than with the largest, which are more unequal.

X. The Force of Gravity, or of any uniform Power, in Plains oblique to the Direction of that Power, is always as the Cosines of the Angles made by the Direction of that Power, and the oblique Plain: And the Times in which

which equal Lines are deſcribed, are in the ſubduplicate Proportion of the ſame.

Thus the Power of Gravity, which it ſelf tends only along the Perpendicular A C: to accelerate the Body O along the oblique Plain A B, is ever as the Coſine A C, to the Radius A B. and the Times of the Deſcription of equal Lines, as the Square Roots of the ſame. *Fig.* I.

Thus if A C be one Quarter of A B; the Force along A B, and the Line deſcribed in equal Time along A B, will be one Quarter of the Force and Line along A C. and the Times of the Deſcription of equal Lines as 2 to 1. If A C be $\frac{1}{9}$ of A B, the Force along A B, and the Line deſcribed in equal Time along A B, will be $\frac{1}{9}$ of the Force and Line along A C, and the Times of the Deſcription of equal Lines, as 3 to 1, and ſo for ever: As I have demonſtrated in my *Mathematical Philoſophy*; and as is now well known in Mechanicks. *Coroll.* 2. poſt Leg. Mot. xxiii.

Corollary (1.) If therefore the ſame Pendulum, finely Poliſhed, do oſcillate both in a Vertical Plain, and upon a Glaſs Plain, inclin'd to the Horizon, the Times of each ſimilar Oſcillation, or of any equal Number of ſuch

Oſcillations, will be to each other reciprocally, as the Square Roots of the Numbers expreſſing the Proportion of the Coſine A C, to the Radius A B. I mean this, with no greater Inequality than muſt ariſe from Friction in the oblique Glaſs Plain, which has no Place in the Vertical Plain. Thus when I tried the Experiment with a Pendulum Four Inches long, which, as we have ſeen, oſcillates in the Vertical Plain, in $19\frac{1}{2}''$, yet upon a Glaſs Plain ſo inclin'd, that A C was one Quarter of A B, and where, by Conſequence, had there been no Friction, the Time would have been only Double, or $38\frac{1}{4}''$, it was ſomewhat longer, or above $42''$. Which however is ſufficiently near to this Rule; and is accordingly a real Confirmation of it.

XI. The entire Power of Gravity, is to the entire Power of Magnetiſm, in this Country, as it affects Needles a Foot long, nearly as 300 to 1; and as it affects Needles of 4 Foot long, as 600 to 1.

This is a plain Corollary from the Eighth, Ninth, and Tenth Propoſitions foregoing. For ſince equal Arcs of equal Circles, are deſcribed by theſe Two Powers in unequal Times, which Times are to one another, upon Tryal, in Needles of one Foot long, as $330''$ to $19\frac{1}{2}''$ their Squares, which are 108900, and 368, will give

us

us the Proportion of the Powers themſelves: which is nearly the ſame with that of 300 to 1. And by a like Calculation in Needles of Four Foot long, the Proportion of Gravity to Magnetiſm is nearly as 600 to 1.

Corollary. This Power therefore affects Needles in the ſubduplicate Proportion of their Lengths, reciprocally; and is only of half the ſame Quantity in a 4 Foot Needle; and of one third the ſame Quantity in a 9 Foot Needle.

XII. The Quantity of Magnetick Power accelerating the ſame Dipping Needle, as it oſcillates in different Vertical Plains, is ever as the Coſines of the Angles made by thoſe Plains, and the Magnetick Meridian, taken upon the Horizon.

Let A I repreſent the greateſt Force, along the Magnetick Meridian, as the Semidiameter of a Circle. *Fig.* II.
[A being the Point where the Dipping Needle would cut the Horizon, when it ſtands Perpendicular thereto, and ſwings along the Tangent AB: and I, being the Point in the Line of Sines, applied to the Circle, where the ſame Needle, hanging from the ſame Center, would cut the Horizon in its proper Inclination, along the Magnetick Meridian.] Let the Angles at A be drawn at Random,

or, for greater Eaſe, as here, exceeding each other by 15 Degrees. Draw the Chords A C, A D, A E, A F, and A G. Then will Ac, Ad, Ae, Af, and Ag, be the Coſines of the Angles made by the Line of greateſt Force A I; and the ſeveral Plains, here repreſented by the Chords A C, A D, A E, A F, and A G. Theſe Coſines therefore, as compar'd with the Radius A I, expreſs the true Proportion of the Power of Magnetiſm in all theſe oblique Situations, juſt as A C expreſſed that of Gravity along AB, in Propoſition X. foregoing.

Corollary (1.) Since the Aſcents of the Dipping Needle from the Nadir A, taken along the Circle of the Dipping Needle, muſt needs increaſe till they come neareſt to the Power at I, *i. e*, as far as c, d, e, f, and g, in that Line of Sines applied to the Circle, which are the Length of the Coſines above-mentioned; At which neareſt Points alone, the Needle can reſt: 'Tis evident that theſe Aſcents, or Complements of the Dips below the Horizon, will be ſtill in the Proportion of thoſe Coſines reſpectively.

Corollary (2.) Becauſe the Sine of 30° is half the Radius, the Aſcent of the Dipping Needle along the Line, or Plain A D, at 60 Degrees Diſtance from the Magnetick Meridian A I, will be one Half of the utmoſt Aſcent; and is the moſt eaſily tried by every body. Thus,

Thus, becauſe at *London*, the utmoſt Aſcent along the Magnetick Meridian is in Needles of a Foot long 16 $\frac{1}{4}$, and in one of 4 Foot 14 $\frac{1}{2}$, the Aſcent at 60 Degrees therefrom, on either Side, will be 8° $\frac{1}{8}$ in the firſt, and 7° $\frac{1}{4}$ in the ſecond Caſe, and ſo every where. Accordingly I have ſeveral times tried this Experiment, and always found it to anſwer the Demonſtration, not in that Angle only, but in the others alſo.

Corollary (3.) If the former Conſtruction be ſuppos'd in a Plain Perpendicular to the Horizon, upon the ſame AI, as ſtill the Semidiameter of the ſame Circle; and it be ſuppos'd to be plac'd from the Center of the Dipping Needle, along the Magnetick Direction; that ſo the Sines Ac, Ad, *&c.* may repreſent the oblique Forces as before: We may thence eſtimate the Quantity of thoſe Forces, both in the Horizontal and Vertical Situation of Needles: The one exhibiting the Force of the Horizontal Needle; the other of the Vertical Dipping Needle, whoſe Plain is along the Magnetick *Eaſt* and *Weſt*.

Thus, if we would Eſtimate the Quantity of Force at *London* in the Vertical Plain here mentioned, in Needles of a Foot long, we ſhall find, that it is to the entire Force along the Magnetick Meridian, as the

the Sine of 73 $\frac{1}{4}$ to the *Sinus Totus*; or as 96 to 100; and by Consequence, that their Times of Oscillation are in the subduplicate Proportion of those Numbers; *i. e.* nearly as 98 to 100, or 49 to 50, which agrees to Experience. Thus also in Needles Four Foot long, this Force is as the Sine of 75 $\frac{1}{2}$ to the *Sinus Totus*; or as 968 to 1000, and their Times as 984 to 1000.

Thus also, if we would estimate the Quantity of Force here in the Horizontal Plain, we shall find it is to the same entire Force above-mentioned, in Needles of a Foot long, as the Sine of 16° $\frac{1}{4}$ to the *Sinus Totus*; or as 28 to 100; and in those of 4 Foot, as the Sine of 14 $\frac{1}{2}$ to the *Sinus Totus*, or as 25 to 1000, or 1 to 4; and by Consequence, that the Times of their Vibrations, and Oscillations, which are in the subduplicate Proportion of those Numbers; are, in the first Case, as 52,9 to 100; and in the last, as 500 to 1000, or 1 to 2, or as 11 $\frac{1}{3}$ to 6″; which also agrees to Experience.

N. B. The Power by which all Horizontal Needles are governed, and all our Navigation directed, in these Parts of the World, is but one Quarter of the Power by which the Dipping Needle is moved, and

and the Longitude and Latitude of Places are now propoſed to be diſcovered.

Corollary (4.) Hence we learn a new and ſure way of finding the true Angle of Inclination of the Dipping Needle, even without immediately obſerving it; and that by one ſingle Analogy, thus: As the Square of the Time of any Number of Vibrations in the Horizontal Plane, to the Square of the Time of the ſame Number of Similar Oſcillations in the Vertical Plane, along the Magnetick Meridian: So is the *Sinus Totus*, to the Coſine of the Angle of Inclination.

Let us ſuppoſe that our Needle be one Foot long, and that 100 of theſe mean Vibrations are to 100 Similar Oſcillations; or, which is the ſame thing, one Vibration to one Oſcillation, as $11'' \frac{1}{3}$ to $6''$; or that the ſame Needle, when playing horizontally, takes up $11'' \frac{1}{3}$ in one Vibration, and when playing Vertically takes up but $6''$; Then will the Analogy run thus: $11'' \frac{1}{3} q : 6'' q :: 128 : 36 :: 100 = \text{Rad} : 28 = \text{Sin.}$ $16° \frac{1}{4}$.

Thus alſo, as the Square of $86_{L}8'$, the Time of 2 ſmall Vibrations in an Horizontal Needle of Four Foot long, to the Square of $44''$, the Time of the like Number of Vibrations of the ſame Needle uſed as a

Dipping Needle: So is 10000=Radius: to 2560=Sine 14° ½. And so in all other Cases whatsoever.

N. B. Altho' it may be convenient to count the Oscillations and Vibrations by a Pendulum of 9,8 Inches long, which gives half Seconds precisely; yet will any other Pendulum, either longer or shorter, do, in case it be equally used with both the Vibrations of the Horizontal, and the Oscillations of the Dipping Needle.

N. B. These Oscillations in Dipping Needles, must be made without their Poizes; and about the Place where they dip naturally; or where the Magnetick and the other Power are in a perfect Equilibrium: Nor must the Angle be taken above 6 or 7 degrees on either side; lest the Mixture of the other Power too much disturb the Vibrations.

N. B. Where the Angle of Inclination is less than 45°, it will be best to find its Complement, the Angle of Ascent, by comparing the Oscillations along the Magnetick *East* and *West*, with those along the Magnetick Meridian: Which will be done by the foregoing Analogy.

N. B. If the Power of Magnetism were as nearly the same every where on the Earth's

Earth's Surface, as is that of Gravity, the forementioned Angle might be found by the Horizontal Needle alone, from the ſame Analogy. The Firſt and Third Terms in that Caſe being ſtanding Quantities; and there being Occaſion for nothing but counting the Number of Seconds in an equal Number of Vibrations of the Horizontal Needle. However, this Method by Calculation ought every where to be put in Practice, together with the direct Obſervation of the Dip it ſelf; that ſo the Angle may be confirm'd, or, on any Error happening therein, corrected, for the greater Security of Navigation.

N. B. One eaſy way of diſcovering the true Angle of Inclination in long Needles, is to obſerve the Needles Oſcillations by a Plummet or Watch that ſhews half Seconds, when they are not above one Degree wide; and to note that Point for the true Dip, where the Arcs and Vibrations of the ſame Number of half Seconds on each Side meet in the Middle; for there both the Arcs and Times are in a manner equal on both Sides; and the Middle of that entire Arc and Time gives the true Angle of Inclination.

Corollary (5.) Since the Horizontal Needle is moved only by a Part of the Power which moves the Dipping Needle; and that it only points to a certain Place in the Horizon, because that Place is neareſt its Original Tendency; whenever the Dipping Needle ſtands exactly perpendicular to the Horizon, the Horizontal Needle will not reſpect one Point of the Compaſs more than another, but will wheel about every way uncertainly.

And whereever it happens that this Needle does ſo, as it has ſometimes done, it is evident the Dipping Needle is there exactly perpendicular to the Horizon: Though indeed that perfect Equilibrium, ariſing from ſuch an exact Perpendicularity, can reach but to a very ſmall Compaſs of Ground; and ſo muſt be a very rare thing in Obſervation.

XIII. The Times of Oſcillation and Vibration, in Dipping and Horizontal Needles, equally good, is that of their Lengths directly: and the actual Velocity of their Points along their Arcs always equal. Thus, the Time of a ſmall Oſcillation in both my Needles, of one Foot long, was about 5″ ½; and the like Time in both my Needles of 4 Foot long, is about 22″. which Numbers are as 1 to 4; and conſequently the Points move a fourfold Arc in fourfold Time, and an equal Arc in equal Time.

Corol.

N. B. Becauſe ſome Steel takes a better Touch than others; and ſome Needles do thereupon conſiderably differ from this Proportion, tho' they all keep the ſame Angle of Direction; This Rule muſt be taken with that Limitation.

Corol. (1.) Hence Magnetick Needles are, *cæteris paribus*, ſtill better the longer they are; and that in the ſame Proportion with their Lengths. For ſince their Points for Obſervation move along their Arcs with equal Swiftneſs in all Caſes; and thoſe Arcs are ſo much exacter, as their Semidiameters are larger; it follows, that Needles are ſo much the better, as thoſe Semidiameters, or, which is all one, their Lengths and Diameters are larger. Thus, a Dipping or Horizontal Needle of Four Foot long, is four times as good as thoſe One Foot long: And thus thoſe of 8 Foot will be twice as good as thoſe of 4, and ſo on.

Coroll. (2.) Hence the Longitude and Latitude, if they depend on Magnetick Needles, may be found to what Degree of Exactneſs we pleaſe: there being, that I find, no more a Limit in Nature in the Caſe of Magnetick Needles, than in that of Aſtronomical Inſtruments: Which are alſo known to be better, *cæteris paribus*, in exact Proportion to their Semidiameters.

XIV. A Dipping Needle of a Foot long will plainly ſhew an Alteration of the Angle of Inclination, in theſe Parts of the World, in half a Quarter of a Degree, or 7 ½ Geographical Miles; I mean this, if we go along, or near to a Meridian.

The former Part of this I have found my ſelf upon Trial, in travelling the laſt *Autumn* from *Lincoln* to near *Oxford*; and the ſame, or a greater Exactneſs, appears practicable not only from my own Obſervations here with Needles of 4 Foot, but alſo from thoſe in Mr. *Norman* and Mr. *Bond*, when there were good Needles, and Care was taken to be accurate in the Obſervations.

N. B. If therefore this Alteration be viſible in theſe Parts of the World, along or near a Meridian, within ⅛ of a Degree, or 7 ½ Miles, with Needles of one Foot: and within 2′ or 3′ or Miles with thoſe of 4, where yet the Dipping Needle alters not nearly ſo faſt as the Latitude; or where we muſt go above 100 Geographical Miles, for the Difference of 75′: Such an Alteration will be viſible in a much leſs Space of Ground, in moſt other Parts of the World: Where 'tis not only common that the Minutes of the Dipping Needle alter as faſt as the Geographical Miles of Latitude, but that, in the

the Torrid Zone especially, those Minutes alter much faster than the other; as will appear hereafter.

Corollary. Hence it is plain, that the Latitude may generally with Ease be discovered by the Dipping Needle, though it be no more than a Foot long, when we travel along or near a Meridian, more nicely than to 7′ ½, or Miles, and that it may be discovered with the like Ease, by one of Four Foot, as near as 2′ or 3′, or Miles; that is, much nearer than it is now usually known at Sea by Celestial Observations.

XV. A Dipping Needle of Four Foot long, in these Parts of the World, will shew an equal Alteration along a Parallel, that one of a Foot long will shew along a Meridian: That is, This will with equal Exactness shew the Longitude, as That the Latitude, both by Sea and Land.

This depends upon the Position of the *Lines of equal Dip*, in these Parts of the World; which are found, upon Tryal, to lie about 14 or 15 Degrees from the Parallels: Or where the intercepted Parts along a Meridian, are about one quarter of those along Parallels: As the View of my small Map hereto prefixed, which is made from the best Observations, will readily demonstrate.

Corol-

Corollary (1.) Since therefore we can obſerve an Alteration in the Dipping Needle of one Foot long, when we go nearly *North* and *South*, in 7 ¼, Geographical Miles Space; we can do the ſame with one of Four Feet, when we go *Eaſt* or *Weſt*: *i. e.* We can by ſuch a Needle diſcover our Longitude to half a quarter of a Degree, or 7 ½ Miles, even here, and much nearer in other Parts of the World.

Corollary (2.) Since, as we have ſhewn, we can have Needles of 5, nay 6, 7, 8, or more Feet long; which will move with Strength ſufficient for exact Obſervations: And ſince, by the Uſe of Microſcopes, in viewing the ſmall Diviſions of Degrees on the Limb of our Inſtrument; we can ſtill greatly improve the Exactneſs of ſuch Obſervations; It is evident, that it is no way impoſſible, with moderate Care, to diſcover, at Land, by a Dipping Needle, our Longitude, nearer than to Four Miles.

Corollary (3.) Since many Obſervations have been already made at Sea, and on Shipboard, with Dipping Needles, by Mr. *Hudſon*, Mr. *Noel*, Mr. *Pound*, Mr. *Cunningham*, Monſieur *Feuillee*, Col. *Windham*, and others; which have determined the Dip uſually within a Degree; ſometimes within one half, or one third of a Degree, or nearer; *i. e.* about half

half as exactly as at Land; and this with small Needles of 5 or 6, or at the most 9 Inches long: 'Tis évident, that at the same Rate, and with the like Care, we may determine this Dip, even at Sea, much nearer than to half a quarter of a Degree, and the Longitude usually still nearer; even without any farther Improvements of the way of making such Observations there: Which yet are justly to be expected, when the Consequence of such Exactness shall appear to be so very considerable. Nor do I hereby determine, how much greater Accuracy may still be expected from that very exact Way before-mentioned by the Number of Vibrations, or by better avoiding the Shaking of the Ship; but here compute the Nearness that may be arriv'd at by a common Observation of the Angle of Inclination it self only.

XVI. Needles, Inclinatory or Horizontal, when touch'd with Loadstones, of whatsoever Kinds, of whatsoever Country, of whatsoever Strength, and in whatsoever Parts of the Loadstones, do all tend exactly to the same Points, whether of Dip or Variation, respectively.

This is not only clear from the Nature and Cause of those Directions, which as they must be singly deriv'd from one and the same internal Loadstone of the Earth, and its Effluvia, of which presently, and must therefore, all of them, be affected thereby in the same manner; but

but from direct Experiments. Which take in the Words of Mr. *Norman*, for the *Inclinatory*: and of Mr. *Sellers* for the *Horizontal Needle*; as follows. " All these Stones, " [of several Countries] says " Mr. *Norman*, are different one " from another, as well in Force, as " in Colour and Weight; yet all of one Operation in the Needle, shewing one Point Attractive; as I have proved my self by three " sundry Sorts of them, which I have. To " this Dr. *Gilbert* also agrees. And, says Mr. *Seller*, " I have " often made Trial with many " Needles, touching them in each " Hemisphere of the Stone, with all Variety " of Ways I could imagine, to find, if it were " possible, by that Means to cause any of those " Needles to vary in its Direction; but all of " them conform'd to the Magnetical Meridian; " standing *North* and *South*, as other Needles " that were touch'd upon the very Pole of the " Stone. All Needles touch'd upon different " Loadstones of several Bigness, and different " Virtue, in all Parts of the World, agree in " this Magnetical Harmony, that they all give " the same Directions.

New Attract. c. 1.

Gilbert de Magnet. V. 5.

Philos. Transact. N°. 23.

XVII. The Earth upon which we live, includes within it a vast Spherical Magnet, concentrical thereto; with its own Poles, Meridians, Equator, and Parallels: And all much of the

the ſame general Nature with thoſe ſmall *Terrellæ*, or Spherical Loadſtones, which are in the Poſſeſſion of the Curious with us.

That this is true in general, no one can deny, who has duly conſidered the known Phænomena of the *Direction*, *Variation*, and *Inclination* of all Needles, touched with a Loadſtone, in all the ſeveral Parts of the World: Which are indeed, in a manner, the very ſame which ſuch Needles exhibit to us, not only on ſuch a Magnet's own Surface; but on the Outſide, nay at a good Diſtance from, any Caſe, or Box, wherein ſuch a *Terrella* or Spherical Loadſtone is included. Nor is the Evidence for the one much different from, or inferior to that of the other. I mean at leaſt in ſuch Circumſtances, where the Spectators are not permitted to open the Caſe, or Box, and ſee the Magnet it ſelf within: Of whoſe Preſence yet they may be abundantly ſatisfied by thoſe Phænomena, without ſuch ocular Demonſtration. And that this Loadſtone is concentrical to the Earth, and Spherical, farther appears by the invariable Situation of the Earth's Center of Gravity, notwithſtanding this Loadſtone's perpetual Alteration of Place; of which preſently.

XVIII. The Power of a good *Terrella*, or Spherical Loadſtone, as it affects a Needle of a Foot long, is equal to the Magnetick Power of that internal Loadſtone, about $2\frac{1}{2}$ or 3 Diameters of ſuch Loadſtone.

In order to demonstrate this, the Reader must remember, that we have prov'd, that the Magnetick Power of the Earth, or internal Loadstone, on Needles of one Foot long, is nearlythe 300th Part of the Power of Gravity with us: And must observe, that the Chord of 16′ is nearly the 300th Part of the Chord of 90; or that the Power of a Magnet, when it can draw a Needle, hung by a Thread perpendicularly, to 16′ from that Perpendicular, is equal to the 300th Part of our Power of Gravity. This being suppos'd, the Proposition will be soon prov'd by the Experiments following.

Prop. XI. prius.

The Lord *Paisley*'s larger *Terrella*, of 2 L 8 Inches diameter, draws a small Needle 16′, or a full Quarter of a Degree from the Perpendicular, at the Distance of about 5 Inches; and his smaller, but vastly stronger *Terrella* of 1 ¾ Inches Diameter, draws it as far at about 7 ½ Inches. So that by Consequence the former would affect a Needle of one Foot long equally with the Power of Gravity, at about 4 Inches Distance, or at about 1 ½ of its Diameter: and the latter at about 6 Inches, or at about 3 ½ of its Diameter. So that our Determination of the Distance of a Foot Needle from any Spherical Loadstone, when its Force is the 300th Part of our Power of Gravity, must be suppos'd, by the Experiments hitherto made, to be, in a Mean, about 2 ½ or 3 Diameters of that Loadstone.

Corol.

Corol. (1.) Upon this Hypothesis we may determine the Quantity of Magnetick Attraction at all Distances from the internal Loadstone; and that by the Use of the Table, *p.* 22, 23, 24. above, for Needles of a Foot in Length. For the Column of the Powers will shew the Proportion of those Attractions, at all such Distances: *e. g.* Let us suppose the Surface of our internal Loadstone to be at the Distance of 3400 Miles from the Earth's Surface; I desire to know in what Proportion the Magnetick Power, upon a Needle of a Foot long, is stronger 2900 Miles deep, or about 500 Miles Distance from the Surface, and about 1060 Miles from the Center of the Earth; I mean as compar'd with that Power here, or with the 300th Part of our Power of Gravity. The Distances therefore being nearly as 1 to 7, the Number over-against $43\frac{1}{4} = 300$, is to the Number over-against $\frac{1}{7}$ of that Number or $= 6\frac{1}{12}$, or $\frac{10}{24}$, as 300 to $\frac{10}{24}$. So that at such Distance the Power of the internal Magnet, instead of being, as here, only the 300th Part, is between the half and the third Part of our Power of Gravity: And the Calculation is alike for all other Distances, and all other Lengths of Needles, whatsoever.

N. B. If we then take the Proportion of the Diameters for the true one of equal Force, and suppose that the Power is the same we here find it at thrice the Length of its

Diameter from its Surface; this Diameter of the internal Loadstone must be about 1150 Miles, and its Semidiameter 575 Miles; as every one will readily find upon Calculation.

Corol. (2.) Since Sir *Isaac Newton* has demonstrated, that the Power of Gravity diminishes within the Earth; and is nearly lesser there, than at its Surface, in the Proportion of its greater Nearness to the Center: That Magnetick Power, at 2900 Miles Distance from us, and nearly 1060 from the Earth's Center, which is $\frac{19}{24}$ of the Power of Gravity here, will be somewhat greater than the Power of Gravity there. A little above which Place therefore, is a Limit well deserving our Attention; it distinguishing the respective Quantity of the two Powers in the superior and inferior Regions: In the former of which, Gravity is stronger than Magnetism; and in the latter, Magnetism is stronger than Gravity; I mean as it affects Needles of one Foot Diameter.

Princip. L. I. Prop. 73. *and* L. III. Prop. 9.

Corol. (3.) At that Limit, near the Magnetick Poles at least, Iron of a Foot long will be twice as heavy, or fall twice as fast, as any other natural Body whatsoever, *viz.* by the Union of these two equal Powers, Gravity and Magnetism: And by Consequence, above that Limit, such an Iron will be less than twice as heavy: below it, more than twice as heavy as all other natural Bodies whatsoever.

XIX. The

XIX. The Earth's internal Loadstone is not fixed to our upper Parts, but is, respectively thereto, moveable; and actually revolves, upon the Earth's Axis, from *East* to *West*, in a certain long Period of Time.

This our Learned Dr. *Halley* has proved beyond reasonable Contradiction, from the constant *Variation of the Variation* of the Horizontal Needle *Westward*; and it may be confirm'd by the still more regular Increase of the Inclination of the Dipping Needle here at *London* also: Where alone it has been long and accurately known; while *A. D.* 1576. it was here 71° 50′, as Mr. *Norman* himself assures us: Where it was about 24 Years afterward almost 72°. as Mr. *Wright* assures us: Where, *A. D.* 1613. it was between 72° and 73°; but nearest 72°, as Dr. *Ridley*'s Two Schemes of the Dipping Needle, with one of his Tables of its Inclination, imply: Where it was, *A. D.* 1676. about 73°. 30′. as Mr. *Bond*'s Scheme of the Dipping Needle informs us: And where it was the last Year, and is this, by a Needle of one Foot, not pois'd, 73°. 45′. but by one of 4 Foot pois'd, above 75. (which is also the true Dip of the smallest Needles;) as I have my self frequently and exactly observed. Only it must

Philos. Transact. N°. 148.

New Attract. C. IV. VII. Gilbert de Magnete: Encomium. Ridley *of Magnetick Motions*, C. 35, 39, 40.

muſt be particularly remark'd, that this Revolution of the internal Magnet from *Eaſt* to *Weſt*, is not abſolute or real; but reſpective only: that is, it revolves not yet quite ſo faſt from *Weſt* to *Eaſt*, as does the upper Earth on which we live. Which ſlower Motion one way, muſt needs occaſion with us a reſpective or apparent Motion the other way; as every one will readily underſtand, upon the leaſt Conſideration.

Corol. (1.) Hence it is clear, that the Diurnal Motion belongs to the Earth, and not to the Heavens. For we ſee here, that Part of this abſolute Diurnal Motion from *Weſt* to *Eaſt*, remains yet uncommunicated to the internal Central Loadſtone: and is indeed the proper Occaſion of its reſpective Diurnal Motion from *Eaſt* to *Weſt*, to this very Day.

Corol. (2.) Hence it is evident, in Dr. *Halley*'s own Words, " That the only " Way to render this Motion in- " telligible and poſſible, is to ſup- " poſe it poſſible to turn about the Center of " the Globe; having its Center of Gravity " fix'd and immoveable in the ſame common " Center of the Earth: And that this moving " internal Subſtance is looſe, and detach'd from " the external Parts of the Globe; and may " well be reckon'd as the Shell, and the internal " as a *Nucleus* or Inner Globe, included within " ours; with a fluid Medium between": Exactly

Philoſ. Tranſact. N°. 148.

actly as I had collected from the other *Phænomena* of Nature, compar'd with the *Mosaick* History of the Creation, long ago, in my *New Theory of the Earth.*

Corol. (3.) Hence also, in the same Dr. *Halley*'s own Words, 'tis plain, Ibid.
" That this Motion is *Westward:*
" And, by Consequence, that the aforesaid
" *Nucleus* has not precisely attained the
" same Degree of Velocity with the exte-
" rior Parts in their Diurnal Revolution;
" but so nearly equals it, that in 365 Revolves
" the Difference is scarce sensible: And that
" this, most probably, has arisen from the
" Impulse, whereby this Diurnal Motion was
" impress'd on the Earth; being given to the
" external Parts, and from thence, in time,
" communicated to the internal": Exactly also as I had asserted in the same *New Theory.*

Corol. (4.) Since therefore the Communication of the Diurnal Motion from the external to the internal Parts of the Earth, appears to be mechanical, and done gradually, according to the Laws of such Communication of Motion among Bodies; it is also most probable, that this first Impression on the external Parts of the Earth was also mechanical, and done by the oblique Impulse of some other Body: Which is the only Way of impressing such a Diurnal Rotation from one Body to another.

Corol.

Corol. (5.) Since therefore no other Bodies in the Visible Universe are capable of approaching to, and Obliquely impelling any of the Planets, but only the Central Solids of Comets; which indeed continually pass through the Planetary System; and, as Dr. *Halley* truly says, may make a *Collision* with these Planets: 'Tis most probable, that this Diurnal Motion, thus mechanically impress'd on the outer Earth, was deriv'd from no other Cause than the oblique Collision of a Comet: as I have also long since conjectured, in the same *New Theory*. Which will be farther confirm'd hereafter, when we come to calculate the Velocity of this Diurnal Rotation, and to compare it with the Velocity of Comets.

Halley de Cometis: In calce.

XX. This internal Magnet has one *Central Pole, Northwards*, in the Nature of the Poles of our common Loadstones. But its *Southern* Pole appears not to be *Central*, but *Circular* rather; and that at a great Distance from the *Southern* Pole of the Earth.

This is proved, as to the former Part, by the Famous Mr. *Hudson*'s Observations, made *A. D.* 1607, and 1608. of the Inclination of the Dipping Needle, in one of his *Northern* Voyages: Whence it appears, that he once, about the

Purchas Pilgrim. *Vol.* III.

the Latitude of 75°. 22'. came within about a Degree of the *Northern* Magnetick Pole; or near 89°. or 89°. ½ Inclination of the Dipping Needle below the Horizon: And that he twice came to the ſame Dip of 84°. at the Diſtance of about 12 or 13 Degrees of a great Circle; once before he came to the *North Cape*; and again afterward, at *Nova Zembla.*

The other Part of this Propoſition is proved by *Pere Noel*'s Obſervations, in his Voyage to the *Eaſt Indies*, *A. D.* 1706. where it is evident that his Ship ſailed, about 1200 Miles together, very near the ſame Dip of 89° ½ and 90°. or near the ſame *Southern* Magnetick Pole. As alſo by Monſieur *Feuillee*'s Obſervations beyond *South America:* Which do, by Analogy, imply that the Polar Inclination of 90°. had he proceeded to mak Obſervations ſufficiently *Southwards*, would have fallen in or near the very ſame Circle alſo. As the Lines of equal Dip, drawn by me, from all the beſt Facts yet publiſhed, or by Analogy to them, upon Mr. *Molyneux*'s Terreſtrial Globe, will demonſtrate.

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XXI. The *Northern* Magnetick Pole is ſituate now about the Latitude of 76° ½, or 13° ½ from the *North* Pole of the Earth; and about 30°. *Eaſtward* from the Meridian of *London.*

 This

This is proved ſeveral ways; as *by* Mr. *Hudſon*'s Obſervation of the Dip of 89° ½. which, upon Allowance made for that Pole's Motion ſince, comes near this Point: *By* the Interſection of the Meridians to that Pole, which are the Perpendiculars to the Magnetick Parallels of equal Dip in the Map hereto belonging, and interſect the Parallel of 76° ½ about this very Point: *By* the Alteration of the Variation of the Horizontal Needle, an entire Point of the Compaſs, or between 11 and 12 Degrees, in a very ſmall Diſtance; particularly noted thereabout by one that accompanied Mr. *Hudſon*, when he went the *Northern* Voyage already mentioned. And, laſtly, *by* the remarkable Circumſtance, noted near that Place by a *Dutch* Sailor, that the Compaſs, or Horizontal Needle, fail'd them there, as to its uſual Direction; and would turn to any Point of the Horizon indifferently: Which could only happen over the very Magnetick Pole it ſelf.

Vid. De Stair Phyſiolog. *p.* 487.

XXII. The *Southern* Magnetick Circular Pole has its Center, or Central Pole, nearly in the Parallel of 60°. or at 30 Degrees from that Pole: And in a Meridian paſſing along the *Eaſt* Coaſt of *Borneo*, about 117°. *Eaſtward* of *London*. Its Radius is alſo an Arc of a great Circle, of about 44 Degrees.

Theſe

Theſe are natural Conſequences from *Pere Noel's* and Monſieur *Feuillee's* Obſervations, already mentioned; eſpecially when they are placed rightly on a Terreſtrial Globe; and when the Center of that Circular Pole is juſtly determined.

N. B. Mr. *Benj. Worſter*, already mentioned, is poſſeſs'd of a Loadſtone that gives great Light to this Linear or Circular Pole: For it has both its Edges or Lines Polar; without any ſuch ſingle Central Pole therein, as we ordinarily ſee in other Loadſtones. Nor are we, who live in the *Northern* Regions, which have an internal Central Pole, and no other, ſo likely to have many Loadſtones of the Linear or Circular Sort, as the *Southern* People; who alone have any ſuch Linear or Circular Magnetick Pole within the Earth.

N. B. The Situation of this *Southern* Circular Pole, which is very oblique to the *Axis* of our *Northern* Part of the internal Loadſtone, muſt needs greatly diverſify the Length of the Magnetick Meridians; and cauſe an uncommon Poſition to the Magnetick Equator and Parallels, from thoſe in our ordinary *Terrellæ* or Spherical Loadſtones. The oblique Section of a Cone, or Egg, will give us ſome tolerable Repreſentation of the ſpecial Poſition of theſe Lines. But this will beſt be underſtood from the View

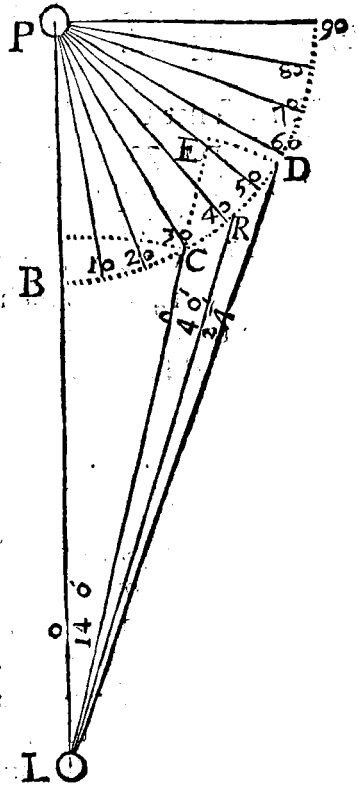
of the ſeveral Magnetick Poles, Parallels, and Equator, on Mr. *Molyneux*'s Terreſtrial Globe; which I have drawn according to the beſt Facts and Obſervations: and to which I muſt refer the Inquiſitive Reader.

N. B. This great Inequality of the Meridians of the internal Magnet ought the leſs to be wondred at, ſince we ſee Inequalities of the very ſame Nature in our *Terrellæ* or Spherical Loadſtones here: Their Equators being by no means equidiſtant from their two Poles, but ſomewhat oblique to their Axes; as Experience ſhews.

XXIII. *Problem.* To find the Velocity of the reſpective Motion of the Magnet within the Earth; or particularly of its *Northern* Pole.

Let P repreſent the *North* Pole of the Earth: L *London*: PB an Arc of the Meridian of *London* of 13° ½. BL the remaining Arc of that Meridian of 25°. BCRD the Parallel along which the Pole of the Magnet revolves from *Eaſt* to *Weſt*, or from D towards B. C the Place of the Magnet's Pole now, determin'd, as above, at 30 Degrees from B. Or where the Line LCE makes with the Meridian of *London* an Angle of about 14 Degrees; and ſo cuts its Parallel at 30° Diſtance from the former Meri-

Meridian. Now in order to discover the Place of the Magnetick Pole 144 Years ago; and, by Consequence, to discover the Arc DC described in that Term of Years, we have these *Data*: That the Dip from Mr. *Norman*'s and my own Observations, was then 3° 40′ of the Magnetick Inclination, or 5 ½ of a great Circle of the Earth less than it is now: Or that CE + CL = 27L7 + 5L5 = DL = 33L2.



Draw therefore the Arc ED from the Center L; and with the Radius LE. That Arc will cut the Parallel BCRD in D, the Place of the Magnetick Pole at the former Time: Whereby we truly discover the Point D, where the Pole was *A. D.* 1576, or 144 Years ago; and, by Consequence, the Arc CD, which that Pole has gone in the same Interval. Which therefore appears to be full 27°. 0′. or that it goes forward above one Degree in 5 Years, or an entire Revolution

volution in 1920 Years; which is much slower than Mr. *Philips*, Mr. *Bond*, or Dr. *Halley* have supposed.

N. B. That the Alteration of the Variation in the former 72 Years of that Term, was to the same Alteration in the latter 72 Years, (as Dr. *Halley*'s Table of those Observations shews) nearly as 10°. to 14°. Which is, in general, here agreeable to the natural Inequality of the Angles DLR and RLC, whose Arcs DR and RC are equal.

Philos. Transact. N°. 148.

Corol. (1.) As the Number of Days in the Upper Earth's Diurnal Revolution, to the Number of Days in the Revolution of the internal Magnet; or as 1 to 700000; so is the respective Motion of this Magnet from *East* to *West*, to the real Motion of the Upper Earth from *West* to *East*: or, to speak strictly, so is the Difference of their Motions from *West* to *East*, to the entire Motion of the Upper Earth the same way.

Corol. (2.) This external fixed Earth has therefore communicated almost all its Motion already to the inward and moveable Parts; and can communicate no more than this Difference of their Motion; and that only in an infinite Term of Years: Or, in other Words, this real internal Motion can never be the 700000th Part swifter than it is at present. *Corol.*

Corol. (3.) This internal Motion therefore began upon the Commencement of the Diurnal Motion of the upper Earth; or as soon as there were Days and Nights, in Distinction from Summer and Winter; and has gone still faster and faster, by the Communication of that Diurnal Motion of the upper Earth, through the intermediate Fluid, to the internal Magnet, in all the past Ages of the World, since it came into its present State.

Corol. (4.) Since therefore, by Sir *Isaac Newton*'s Third General Law of Motion, Action and Reaction are ever equal, and tend to contrary Parts; this internal Loadstone, thus accelerated by the upper Earth, must have all along retarded that upper Earth, and made the Diurnal Rotation, or the true Duration of each Sydereal Day, still slower and slower; and this ever since the Commencement of that Diurnal Rotation.

Princip. *p.* 13. *Ed.* 2.

Corol. (5.) The Length of a Sydereal, and, by Consequence, of a Solar or common Day, has been therefore somewhat different in all the past Ages, since the present State of the World began: And the same annual or menstrual Periods must anciently have contained more, and of late fewer Days, the one than the other.

Corol.

Corol. (6.) This Acceleration on one Side, and Retardation on the other, was very great at the firſt Beginning of the Diurnal Motion; when the Difference of their Motions was equal to the entire Motion it ſelf; but muſt become leſs and leſs, as the one went ſlower, and the other faſter; and thereby their Difference of Motion, which is the ſole Cauſe of this Acceleration and Retardation, became leſs and leſs continually. So that as they began, in Proportion to their Quantity of Matter, to affect each other; ſo the ſame Quantities continuing of each Side, muſt have gone on to affect one another in the ſame Proportion: *i. e.* the entire Impreſſions on both Sides, or the Difference of thoſe Motions, muſt have been all along in a Geometrical Progreſſion.

Corol. (7.) If therefore we knew, *a priori*, the exact Proportions of the Quantity of Matter in the upper fixed Earth, to the moveable internal Fluid and Magnet; with the Nature of the Surfaces above and below the Fluid, and the particular Quantity and Tenacity of that Fluid; it would be poſſible, from the known Difference of their Velocity now, which is nearly as 1 to 700000 to go backward, and find thoſe Differences and Quantities of Motion themſelves, *à priori*, in all the paſt Ages; and ſo geometrically or mechanically to determine, how long it has been ſince this Difference of the

the Diurnal Revolution from a Circle vanifhed away, and the internal Loadftone had no Diurnal Motion at all. Nay, if we any way knew the Velocity of the firft Diurnal Rotation of our upper Earth it felf, we might then geometrically or mechanically determine, *à priori*, how long ago that Rotation began; or how ancient the prefent State of our Earth was.

Corol. (8.) However, fo far we are fure, that the Earth on which we live has not been from all Eternity, in its prefent State; but at a certain Period backward, this Diurnal Motion, or our Day and Night, as diftinct from Summer and Winter, really began; as all ancient Tradition and Records whatfoever do agree: and as Dr. *Halley* himfelf is very free to confefs. *Philof. Tranfact.* N°. 344.

Corol. (9.) Nor is this Geometrical or Mechanical Method of determining the Origin of our Diurnal Motion, capable of the Suppofal of thofe 365000, or any like vaft Number of Years, which fome Pagan Nations pretend to have Traditions about. For no Geometrical Series can be taken, confiftently with the Phænomena of Nature, which can admit any thing like thofe extravagant Numbers; nor can we fhew any thing like fuch a parallel Velocity of a Diurnal Rotation, as muft then have obtained at firft, in the whole Univerfe. If any of thefe Numbers had been true, the firft Diurnal Ro-

tation must have gone vastly swifter than the Annual Motion of a Comet; which yet is the only possible Mechanical Cause of any such Diurnal Motion of a Planet; nay so swift, that it would have exceeded the mutual Gravitation of its Parts, and the Earth would, by Consequence, have dissolved it self, and scattered those Parts into the Ether, without any Possibility of a Reunion into a Planet again. Nor do I believe, by what he has said already, that Dr. *Halley* himself will pretend to justify such prodigeous Numbers, from any Phænomena of present Nature whatsoever.

Ibid.

Corol. (10.) The same Reasoning is confirm'd from all the Records of Antiquity now extant; which never mention an Annual Period of more than 365 ¼ Days, or a menstrual Period more than 30 Days. Whereas any such vast Numbers, do, for certain, suppose that the Year and Month must have been of old more than so many Centuries of Days, as the Records ascribe to them single Days: And that Days and Nights, as distinct from each other, must have been at first hardly a few Minutes long; Which would be absolutely inconvenient for Mankind, and utterly without Example in the whole visible Universe.

Corol. (11.) But tho' we cannot, with sufficient Exactness, calculate *à priori*, or from direct Geometrical and Mechanical Reasoning, How long ago the Diurnal Motion, or Day and Night.

Night, began upon our Earth; yet may we, *à posteriori*, come very near to that Epocha: I mean by observing the Proportion of the Effects of this Retardation of the Diurnal Motion, or Lengthning of the Day, in the several Ages of the World; or by discovering how many Days have gone to a Month, or a Year, in all the several past Ages. For if the World has been a very great Number of Thousands of Years old in its present State, and without any great Change by a Deluge, we shall find that the Old Year must have been 1000 Days long, then 500, then 400, then 390, then 380, then 370, and at last only 365¼; and the Month in Proportion: Contrary to all the ancient Accounts, Records, or Traditions Sacred and Prophane: Which, on the other hand, ever assure us, that the oldest Year of all, and the almost only Year heard of till these last 3000 Years, was of fewer Days than the present; and indeed of no more than 360: And that the eldest Month of all, and the only one heard of till the same last 3000 Years, was of no more than 30 Days: As my Learned Friend Mr. *Allen* has fully proved in my *New Theory*. Near to which they are at this Time also.

Corol. (12.) The Comparison therefore of the present Phænomena of Nature with all the ancient Records, implies, that the Year it self has been lengthened, since the Time that the ancient Year contained 360 Days: And that before that Time, the Number of Days had

been more and more, or that the Day had been ſhorter and ſhorter.

Corol. (13.) Since therefore no other Mechanical or Natural Cauſe could change the Length of the Year, but the Acceleration by a Comet; which would alſo naturally cauſe a general Deluge of Waters on the Earth; It is plain that theſe Phænomena of Nature, as compar'd with ancient Hiſtory, greatly confirm what I have long ſince ſuppos'd, and almoſt demonſtrated from other Evidence, in my *New Theory*, *viz.* That there was above 4000 Years ago a general Deluge of Water on the Earth; and that by ſuch a Cauſe as did lengthen the Year; and did alſo anſwer to all the Deſcription of that Flood in *Moſes*'s Hiſtory, and to the other Phænomena of Nature and of Antiquity. Which Account I ſhall therefore admit here as true; and make uſe of it in order to determine more exactly the Antiquity of our Diurnal Motion, or of the preſent State of our Earth; and in order to compare that Determination with the Sacred Chronology, and try its Veracity thereby.

Corol. (14.) Since therefore we now know, that the Difference of our Two Diurnal Motions is about the $\frac{1}{700000}$ Part of the whole Circle; that this Difference has ariſen according to a Geometrical Progreſſion; that the Difference of the preſent Day, from the ancient Day, at any determinate Period of Time backward, muſt be

be proportionable to that Difference, and proceed in the ſame Geometrical Progreſſion therewith: Since alſo we know, that about 5000 Years ago, 354 of our Days was nearly equal to the ſame annual Space, which was then meaſured by no fewer than 360 Days; or that the Day was then about 20′, or a 73d Part ſhorter than it is now: And ſince, laſtly, we alſo know, that the Day has not been conſiderably altered for theſe laſt 2400 Years; as the Compariſon of the oldeſt Eclipſes and Equinoxes with the preſent, does certainly demonſtrate: Since, I ſay, we have all theſe *Data*, as the Foundations of our Calculations, we may thence determine, in ſome meaſure, How long it has been ſince the Day had any Number of Minutes leſs than it has now; and ſo, very nearly, when that Diurnal Rotation, or the Day and Night firſt began: According to the following Series; where $\frac{1}{73}$ cannot be far off $\frac{1}{7}$, or the Year of 360 Days far off the Beginning of the Diurnal Motion.

By which it appears, that tho' we ſuppoſed the Earth to have had no Deluge by the Approach of a Comet, it could not ſtill be very much older than the 360 Days to a Year. Nor at all conſiderably older, without having had 370, 380, 390, 400, 500, and 1000 Days to a Year: for which we have not the leaſt Authority. That

in

in Caſe we allow of a Deluge by the Approach of a Comet, it cannot be ſuppos'd older than Scripture affirms, without the ſame ill-grounded Hypotheſis, of the Year's containing ſuch a great Number of Days: But that in Caſe we allow of the Deluge by the Approach of a Comet, and determine, what all Antiquity demonſtrates, that the Ancient Year before the Flood contained 360 Days, and no more; the preſent State of our Earth will be the ſame Number of Years old, and no more, which the Sacred Scriptures do aſſure us it really was.

N. B. If Dr. *Halley*'s ſhorter Period of the Magnet's reſpective Revolution of about 700 Years, were the true one; it would imply, that the World were ſtill of a ſhorter Date, by ſome Hundreds of Years, as the Reader may eaſily obſerve, by beginning with 250000 inſtead of 700000. Nor can any Computation agree to the internal Motion before us, and to the ancient Year of 360 Days, but it muſt ſuppoſe that there has been a Deluge; that the Year has been chang'd at that Deluge; that I have truly aſſign'd the Cauſe of that Change at the Deluge, in my *New Theory*; and that the internal Conſtitution of the Earth there deſcribed, is alſo the true one: Every ſuch Computation will alſo certainly eſtabliſh the Bible Chronology; and demonſtrate, that the preſent State of the Earth has been of that very Antiquity,

and

and no other, which *Moses* affirms concerning it in the Book of *Genesis*: which Corollary highly deserves the Consideration of every one, who desires to know the Truth, and to examine the Credit of the Sacred Scriptures by all proper Methods of Enquiry.

N. B. This Antiquity of the present State of the World, of about 6200 Years, (which, as I shall shew in my *Essay to restore the true Text of the Old Testament*, is the only original Scripture Chronology thereof) is grearly confirm'd from two most valuable Fragments of Heathen Antiquity, when connected together, as they are by the late Bishop *Cumberland*, in his Valuable and Curious Discourses not yet published, *Of the most Ancient Antiquities of the World*, corrected: I mean from the ancient Idolaters Genealogies in *Sanconiathon*, drawn down from the Beginning of the World till a little after the Days of *Misor* and *Taaut*, or of *Misraim* and *Thoth*, the two first Kings of *Egypt* after the Flood; and thence from the *Laterculus* of those *Egyptian* Kings, beginning with *Menes* and *Athothes* I. or the same *Mizraim* and *Thoth*, preserv'd by *Eratosthenes* the great *Egyptian* Mathematician, and Keeper of the famous Library of *Alexandria*, and allowed by the Learned to be of the greatest Authority of all others. Which entire Series, thus connected together, affords us an Heathen Chronology entirely independent on the Bible Chronology, and

and yet perfectly agreeable thereto; as I could here distinctly shew, were it my present Design; and would it not too much prevent the Reverend Mr. *Pain*, the Worthy Son-in-Law to Bishop *Cumberland*, who, with very great Labour, has retriev'd those last Remains of that very Learned Bishop, and intends in a little time to communicate them to the World. But to return.

Corol. (15.) What Dr. *Halley* has first asserted, and Sir *Isaac Newton* from him afterwards embrac'd, That since the oldest Observations of Astronomers, the Motion of the Moon, as compar'd with the Diurnal Motion of the Earth, has been a small matter accelerated, may, not improbably, be entirely owing to this small Inequality of the Days, of which we are now discoursing, and to nothing else. We now know, from certain Fact, that the Day must, in some degree, have been shorter formerly than it is now: We do not at all know in Fact, that the Moon has sensibly altered its Velocity: 'Tis therefore more reasonable to suppose, that this small Acceleration of the Moon is not real, but apparent only; and that the somewhat shorter Days by which its Periods ought to have been measur'd, but of which, 'till now, we were wholly ignorant, do give us the true Solution of that seeming Inequality; which is a necessary Consequence

Philos. Transact. N°. 218. *Princip. Edit.* 2. *p.* 481.

quence therefrom. I wish Dr. *Halley* had prosecuted that Matter farther, as he promised to do, and had given us an Account, how much this seeming Acceleration has amounted to; because that Quantity would have been very valuable to me, in stating the Earth's Diurnal Motion for the several past Ages; and for want of which, among other Things, I have not been able to determine particular Numbers of Years to the Geometrical Progression above-mentioned.

Corol. (16.) There is however no Occasion to wait many Centuries of Years, in order to discover the Antiquity of the Earth, in its present State, from Natural Philosophy, or to introduce any uncertain Hypothesis about the gradual Saltness of the Ocean, and of certain Seas, as Dr. *Halley* proposes for a Calculation thereof: Since we have here at hand a much surer Method, and this not built on a bare Hypothesis, but on Fact, for discovering the same already; and that even from Dr. *Halley*'s own Concessions of the moveable Magnetick Poles of the Earth also.

Philos. Transact. N°. 344. ut priùs.

Corol. (17.) Since therefore it is evident from Natural Philosophy, especially as compar'd with all the oldest Records of Mankind, that the present State of this Earth on which we live, is of no other Antiquity than the Bible

 informs

informs us: And since the present Numbers of Men upon it could not have arisen from a single, or a few Pairs, as all the ancient Records agree they really did, according to the usual Proportion of their Increase and Doubling, if their Lives had been of their present Brevity; 'tis plain, that the Sacred Writings have given us a true Account here also; and that the first Parents of Mankind, both before and after the Flood, lived much longer, and so doubled much quicker than we now do: Which Thing is fully confirm'd in all prophane Antiquity also.

Corol. (18.) Since therefore it is evident, from the still remaining slower Revolution of the Earth's internal Loadstone, that, in Dr. *Halley's* Words above recited, "the Diurnal "Revolution has, most probably, arisen from "the Impulse whereby this Diurnal Motion "was impress'd on the Earth; being given to "the external Parts, and from thence, in Time, "communicated to the Internal; and since, as Dr. *Halley* well knows, no other Body in the visible World is capable of giving such an Impression, but the Central Solid of a Comet; which I have conjectured in my *New Theory*, to have been the instrumental Origin of the Diurnal Motion: Let us see how the particular Velocity here assigned to this Earth at first, I mean between a 30th and 40th Part greater than it now has, will agree with the Velocity of Comets. Our Great Sir *Isaac Newton* has demon-

demonſtrated, that the proportionable Velocities of all Comets, at the Diſtances of any Planets from the Sun, are nearly one and the ſame; *i. e.* ſo much greater than the annual Velocity of every Planet, as the Diagonal is greater than the Side of a Square; or nearly as 10 is more than 7. It is alſo certain, that ſuch a Velocity is here to our Diurnal at the Equator, (along which alone that Diurnal Motion muſt have been at firſt impreſs'd) as about 77 to 1. If therefore that Comet's Central Solid had been as big as the upper Earth, and had hit againſt all its outward Parts directly; this Velocity would have been equally diſtributed between them both; and therefore would have been the one half of the Velocity of Comets; *i. e.* between 38 and 39 times the preſent Velocity. But then, becauſe this Motion was very oblique to the Earth, and ſo rather graz'd upon the outſide, than hit againſt the whole Maſs that was to be moved, otherwiſe a Diurnal Motion could not have ariſen thence; this Velocity would be ſtill much leſs conſiderable. And as Comets Central Solids alſo are frequently very much leſs than the Earth; ſo might they have impreſs'd a ſtill much leſs Quantity of Motion upon it. So that we can only hence certainly tell, that the Diurnal Velocity impreſs'd muſt have been much leſs than 77, moſt probably much leſs than 38 times the preſent Diurnal Velocity of our

Princip. L. I. Prop. XVI. Corol. 7. *and* L. III. Prop. XL. Corol. 3.

Equator; but cannot tell that it was at all greater.

Corol. (19.) Let us therefore leave this more uncertain Way, *à priori*, which cannot afford us any greater Accuracy; and proceed to another, *à posteriori*, from the Diurnal Revolutions of the rest of the Planets; which in all Reason they every one at first obtain'd in the same way; whether that Way were Immechanical or Mechanical, which is of no Consequence in this Corollary. And let us here see what Proportion any of them bear to the Diurnal Velocity of our Earth. For Fact is our surest Guide in such Matters: And 'tis the safest Way to suppose our Diurnal Velocity never to have much exceeded the Diurnal Velocity of one or other of the rest of our Fellow-Planets. Now if we proceed thus, we shall soon find, that all Degrees of Angular Velocity much beyond double the present Diurnal Motion of our Earth, is without all Example in the whole System; and that the greatest Part of the Instances are of Motions much slower than its own. To say nothing then of the Sun, which is near a Month in revolving round: The Moon herself revolves in no less than a Month's Time. Nay, *Mars* on one Side of us, and *Venus* on the other, which are the nearest and best Instances, revolve little differently from our Earth at present; the former in 24 $\frac{2}{3}$ hours, the latter in 23. *Saturn* and *Mercury* are not yet certainly known to revolve

revolve about their own Axes at all. *Jupiter* alone is known to revolve a good deal quicker than our Earth at present: Its Day being no longer than 9 Hours 56′. Which angular Motion is between twice and thrice as swift as the like angular Motion in *Mars*, the *Earth*, and *Venus*. So that, if we go the surest Way, that of Fact; and chiefly by the nearest and best Instances; the Earth's Original Angular Motion, must not have been near thrice so swift as at present, and much the most probably but little swifter; *i. e.* its present State cannot, by the Phænomena and Series above, have been very much older; but with much the greatest Probability, was not at all older than the Bible affirms: Which several coincident Methods of Examination, all of them coming to the same main Conclusion, highly deserve every one's serious Consideration.

Corol. (20.) Tho' we could not before with sufficient Exactness, *à priori*, fix the Proportion, which the upper solid or consistent Parts of our Earth, bear to the lower moveable Parts thereof; yet may we now, *à posteriori*, nearly determine the same. For since the Proportion of the quickest Motion of the Earth to that of the slowest, is the same with that of the whole Earth, which at last is moved to the upper Earth, which communicates that Motion to the rest, according to the known Laws of the Communication of Motion in such Bodies: And

And since that Proportion is as the Time of revolving at last, when the Motion is all communicated, to the Time of revolving at first, when none was communicated; or, as we have seen, as about 365 to 355, or 36 to 35; (the Lengthening of the Year at the Deluge being not here concern'd;) it thence appears, that the entire Earth is to the upper solid Earth, as 36 to 35; and the Difference, or Quantity of the lower moveable Earth, consisting of the Central Magnet, and interposed Fluid, is to that upper solid Earth, as 1 to 35. Since therefore an outward Concave Sphere 2800 Miles thick, is to an inward Sphere of 1200 Miles Radius, nearly as 35 to 1; we may well state those Parts of the Earth accordingly. Tho' indeed what Proportion the internal Magnet bears to the upper Earth or interposed Fluid, we cannot exactly determine till we have better Observations. Only we may, if we please, reckon the Depth of the interposed Fluid not much different from the Semidiameter of the Central Loadstone.

Corol. (21.) Upon better Observations, it will not, perhaps, be wholly impossible, *à posteriori*, to determine hereafter, within some Latitude, the Nature and Density of the interposed Fluid, by which a given Motion, at first impress'd on the upper Earth, has, in a given Time, been communicated to the internal Loadstone: Which Knowledge of that Fluid would be

be highly acceptable to the Inquisitive; and make way for the farther Discovery of such Uses, as it may serve to in the Course of Providence, besides that of the Communication of this Motion.

Corol. (22.) Perhaps therefore that Fluid may prove such as is fit for Animals to live in; I mean either on the inner Surface of the upper Earth, or outward Surface of the Central Loadstone, or else in the very Fluid it self, also; which last is the Case of the upper Surface of our Earth, and of the fluid Air above us. Nor does this Place, I confess, seem to me to be any other than the ἄδης of all Antiquity, Sacred and Prophane; of which it is not proper here to treat more largely. However, the Reader is desired to consult what I have elsewhere said to this Purpose in my *Astronomical Principles of Religion*, Part V, and VII. and to understand those Notions according to these Discoveries, and not otherwise.

Corol. (23.) Hence we may exactly compute the Inclination of the Dipping Needle for *London*, during the next 320 Years, till *A. D.* 2040, or 160 Years before and after the Magnetick Pole will come to the Meridian of *London*; which will not be till *A. D.* 1880, as in the following Table.

A. D.

A. D.		A. D.	Inclin.	
1720	and	2040	75°.	10′.
1725	and	2035	75.	17.
1730	and	2030	75.	23.
1735	and	2025	75.	30.
1740	and	2020	75.	36.
1745	and	2015	75.	42.
1750	and	2010	75.	48.
1755	and	2005	75.	55.
1760	and	2000	76.	00.
1765	and	1995	76.	05.
1770	and	1990	76.	09.
1775	and	1985	76.	13.
1780	and	1980	76.	17.
1785	and	1975	76.	21.
1790	and	1970	76.	24.
1795	and	1965	76.	27.
1800	and	1960	76.	30.
1805	and	1955	76.	33.
1810	and	1950	76.	36.
1815	and	1945	76.	38.
1820	and	1940	76.	40.
1825	and	1935	76.	42.
1830	and	1930	76.	44.
1835	and	1925	76.	45.
1840	and	1920	76.	47.
1845	and	1915	76.	48.
1850	and	1910	76.	49.
1855	and	1905	76.	50.
1860	and	1900	76.	51.
1865	and	1895	76.	52.
1870	and	1890	76.	53.
1875	and	1885	76.	54.
1880	and	1880	76.	55.

N. B.

N. B. That this Table being made from the Hypothesis, That the Revolution of the Magnet is even, and will be no slower the next three Centuries than it was this last; which is not strictly true; the real Times answering to each Dip are to be supposed somewhat later than those here set down: But how much later cannot yet be exactly determined: And therefore I have not here made any Allowance for that Inequality.

N. B. Since it will hereafter appear, that the *Variation* of Magnetick Needles from the Azimuth of the Meridians of the internal Magnet, is deriv'd from the Difference of the Strength of the several Parts of the internal Magnet's Surface, which is no way to be known but by Experience; we cannot, with any Assurance, foretel that Variation as to our own Meridian's long before-hand. Unless where we have good Accounts, how that Variation from the internal Magnet's Meridian has been, in any Parallel, for the Ages foregoing. Which being not yet to be met with, even as to the Parallel of *London*, much less as to any other Parallel, I dare not venture at all to predict that *Variation*, as I have here done the *Inclination*: Only that it may probably still return round, and be every where the same in any Year of the next Revolution of the internal Magnet, that it has been in the like Year of any former Revolution

 thereof;

thereof; or will it ſelf have a Revolution in ſomewhat above 1920 Years.

XXIV. Thoſe Two Magnetick Poles which Dr. *Halley* firſt introduc'd, and ſuppoſed fixed in our upper Earth; and that as neceſſary to ſolve the Irregularity of the Variation of the Horizontal Needle from the Meridians of the moveable Magnet within the Earth, of which in the Preface, have no juſt Foundation in Nature, but ought to be wholly rejected.

The Reaſon of this is very plain; that ſuch Irregularity of Variation belongs to our common *Terrellæ* or Spherical Loadſtone, as well as to the Earth's internal Loadſtone; as Dr. *Gilbert* has long ago obſerv'd; and as every body may ſoon ſatisfy himſelf upon Trial. Thus that *Terrella* which I have chiefly made uſe of, affords us but ſeldom a Direction ſtrictly along the Meridians; while the Needles vary ſometimes *Eaſtwards*, ſometimes *Weſtwards*: Inſomuch that between its *North* Tropick and Polar Circle, that Variation amounts, in one place, to above 30 Degrees; which is a Quantity rarely known upon the Earth it ſelf. Nor is the Reaſon thereof obſcure, *viz.* that Loadſtones have never been purified in the Fire, as Iron has; but are uſually ſtill compos'd of Parts of very different Degrees of Strength and Perfection; as all that cut them know very well: And that therefore where any Parts

De Magnet. L. IV.

Parts are weaker than the reſt, the ſtronger neighbouring Parts prevail, and draw the Needles that way; as is the Caſe notoriouſly at the Place of greateſt Variation on the *Terrella* above-mentioned. Nor is Dr. *Gilbert*'s Notion of prominent or concave Parts, like Hills and Valleys, upon ſuch *Terrellæ*, as Occaſions of ſuch Variations, perhaps wholly unapplicable to the internal Loadſtone: Tho', I confeſs, I rather think the forementioned unequal Strength of its ſuperficial Parts to be generally the Cauſe of the Needle's Variation upon the Earth; as it evidently is ſo upon our *Terrellæ*.

N. B. This Variation, as to the Azimuth of Magnetick Needles, ſeems nothing at all to affect their Angle of Inclination or Dip; as I have exactly tried on the Place of greateſt Variation in the *Terrella* above-mentioned: Which Property is very wonderful, and highly remarkable; and what gives a vaſt Preference to Dipping Needles above Horizontal ones, in all ſuch Attempts for diſcovering both of Longitude and Latitude thereby. Dr. *Gilbert* indeed aſſerts the contrary. But V. 10. ſince I perceive he did not diſtinguiſh between the *Strength* of the Magnet in the Elevation of a longer heavy Needle, and the *Angle it ſelf* of that Elevation, which in that Caſe is beſt ſeen in a ſhorter and a lighter one, he is therein evidently miſtaken. Accordingly I find, that in theſe Parts of the World, where the Varia-

tion on the Azimuth is 25 or 26 Degrees *Westward* from the Meridians of the internal Magnet, yet is the Angle of Inclination below the Horizon the very same that our Distance from the *Northern* Pole of that internal Loadstone requires; without any sensible Inequality at all on account of such Variation. Which thing, as I said, is *very wonderful*, and *highly remarkable*.

XXV. The Intervals between the Lines of equal Dip, taken in any equal Number of Degrees, as 10°. 20°. 30°. 40°, *&c.* are regular, and nearly, if not exactly, observe the Proportion of the Sines of such Angles; whose Radius is a Quadrantal Arc, and begins where the Dip is perpendicular to the Horizon. The Lines themselves also of such equal Dip, approach to parallel Circles, about the Magnetick Poles of the Earth.

This Proposition is proved both *a Priori*, and *a Posteriori*: From the Experiment of the Situation of small Needles, and their equal Dips, upon the Surface of Spherical Loadstones; and from the Fact of the Distance and Position of such Lines upon the Surface of the Earth, found by Observation there.

As to the former Proof, *a Priori*, I have myself exactly tried it upon Two *Terrellæ*, or Spherical

Spherical Loadstones; I mean those in the Possession of the Right Honourable the Lord *Paisly*: And have found that the Dip of the small End of a Needle, below its Surface or Horizon, is at 22° ½ from its Equator, 41 ⅔ Degrees: at 45° from it, 60 Degrees: And at 67 ½ from it, 75 ½ Degrees: While at the Equator, this small Needle lies along that Surface; and at each Pole stands perpendicular thereto. And in general, I find the Angles well enough answer to the following Table, made according to the Line of Sines, and beginning from the Poles.

	Sines equally different.	Inclination.	
		°.	'.
0.	0000.	90.	0
9.	1000.	84.	15
18.	2000.	78.	28
27.	3000.	72.	32
36.	4000.	66.	25
45.	5000.	60.	0
54.	6000.	53.	7
63.	7000.	45.	34
72.	8000.	36.	52
81.	9000.	25.	50
90.	10000.	0.	0

All which the Nature of the Line of Sines, and of no other Line, does exactly require.

The

The Lines of equal Dip are thereon alſo no other than the Parallels to the Equator; as all our Trials demonſtrate; and as every body uſed to Spherical Loadſtones will readily agree.

As to the latter Proof, *a Poſteriori*, it is to be taken, as to both Parts, from the Situation and Diſtance of theſe Lines of equal Dip, upon a Terreſtrial Globe or Map, made from the beſt Obſervations, whereon I have drawn them; and which, in both Caſes, do nearly and generally agree to this Propoſition.

N. B. The Quantity of this Angle of Inclination made by the Needle and the Horizon of a *Terrella* has been long ſought, but never found before. Dr. *Gilbert* thought, that at 45° the Needle pointed to the Pole, and that this Angle was there by Conſequence 67°. 30′. inſtead of 60°. and the reſt commonly followed him, without any ſufficient Experiments.

Lib. IV.

Corol. (1.) It appears from the Facts, that the proportional Diſtances of the Lines or Circles of equal Dip, taken along the Meridians of the internal Loadſtone; and from its Poles on each Side, are 360° of Dip in 272° of a great Circle on the Earth: I mean this as taken in groſs, and one with another; altho' ſometimes the Inequality will be on one ſide, and

and ſometimes on the other; as the Nature of the Line of Sines does require.

Corol. (2.) In order to the deſcribing theſe Lines or Circles of equal Dip upon a Globe, we muſt draw them through three obſerved Points where they can be had: or elſe through 2, or at leaſt 1 obſerved Point, and where we want them, through the Diviſions of the Meridians already mentioned, according to the Line of Sines: Reſpect being ſtill had to the Analogy of thoſe that are drawn through 3 obſerved Points: According to which Rule, I have drawn the Principal of them upon Mr. *Molyneux*'s Globe, for the eaſier Comprehenſion of the Curious.

Corol. (3.) Since it appears from Obſervation, that the Poles of the internal Magnet are conſiderably diſtant from the Poles of the Earth, theſe Parallels, or Lines of equal Dip, will very rarely be coincident with the Parallels of the Earth's Equator: Which yet is the only poſſible Caſe, where this Method will diſcover no more than the Latitude.

N. B. This Coincidence with our Parallels, ſeems now to be between *Europe* and *America*, near 30° *North* Latitude: To which alone, of all the Places now frequented in Navigation, this Imperfection of our preſent Method appears to belong. However, as the Uſe of very long Dipping Needles will reduce that Space to a ſmall Breadth, on each Side of ſuch coincident

dent Parallels; so will it be easy to avoid the Inconvenience arising therefrom. For since the Longitude may still be found along other Parallels at a small Distance both *North* and *South*, Pilots may easily sail along one of those Parallels, where the Longitude can be found, till they come to the Meridian of the Place they sail to: And then they may run along that Meridian till they arrive there. Which will be the more easily done, because the Parallel of that Place will, in this Case, be found by our Dipping Needle in the greatest Perfection. Nor will the Length of this Course be considerably greater than the usual one by the Rumb Line.

Corol. (4.) Where we have several good Observations of the Angles of Inclination or Dip, at considerable Distances from each other, we may nearly find the rest now, by Analogy to the Line of Sines, without waiting for other Observations. Nor will Sea Charts made from such *Data*, be wholly useless at Sea, even at present; because the Observations to be made at some particular Places, especially as join'd to the Use of the Line of Sines, will soon enable the Pilots to correct those Lines of equal Dip upon their Charts, and to guide themselves, in some measure, the rest of their Voyage, by such corrected Lines also. Though it must be confess'd, that such Charts cannot but require many more, and much nicer Observations, than

we

we yet have, in order to their utmoſt Perfection.

Corol. (5.) The Perpendiculars to theſe Magnetick Parallels muſt be nearly the Meridians of this internal Magnet, and paſs not far off its *Northern* Pole.

N. B. Since the Quantity of the Inclination of the Dipping Needle has varied here at *London*, [the only Place in the World where it has been long enough known to determine that Alteration,] not much above 3 Degrees in 144 Years: (As appears by Mr. *Norman*'s Original Quantity 71° 50′, compar'd with that now, 75° 10′;) and will alter much more ſlowly for a long time hereafter, as our Table in *Pag.* 76, ſhews: 'Tis certain, that Charts made with theſe Lines of equal Dip upon them, will ſerve, at leaſt in theſe Parts of the World, many Years, without any Neceſſity of Alteration, or any conſiderable Inconvenience to Navigation.

XXVI. *Problem.* From Three Obſervations given, to find the Poſition of the Magnetick Parallels, or Lines of equal Dip, to the Parallels of the Earth, in every Country.

Let L be the Place of the Firſt Obſervation: S of the Second: and C of the Third. The Poſition of the *Fig.* III.

Lines L S and L C being given with regard to L R a Parallel of the Earth: Take the Distances L M, L N, as is the Number of Geographical Miles corresponding to the Alteration of one Degree of Dip along the Line L C; to the Number of Miles corresponding to the Alteration of one Degree of Dip along the Line L S. Draw the Line MN, with its Parallels L B and S O. These are Magnetical Parallels, or Lines of equal Dip; and determine the Angle B L R, which is their Inclination to the Earth's Parallels in that Country.

Thus, if with us L be *London*; where the Dip is 75° 10′. S be *Saltfleet*, at the Sea-side in *Lincolnshire*, in or very near the Meridian of *London*, and at the Distance of about two Degrees, or 120 Geographical Miles; where the Dip is 77° 15′. and C be *Chester*, in an Angle of about 42 Degrees from the *North*, *Westward*; and at the Distance of about 150 such Miles, where the Dip is 76° 22′. L M will be to L N, as 130, the Number of Miles for the Alteration of one Degree of Dip along the Line L C, to 58, the Number of Miles for the Alteration of one Degree of Dip along the Line L S; or nearly as 22 to 10. The Angle B L R, which is the Inclination of the Parallels, will be about 22°. And the *First* and *Principal Magnetick Parallel*, or Line of equal Dip passing through *London*, will also pass nearly through *Calais*, *Dover*, *Woodstock* or *Blenheim*, *Hereford*, *Aberistwith* in *Wales*, and 20 Miles *South* of *Dublin* in *Ireland*. *Q. E. I.*

Corol-

Corollary. Since BR, is to RL, or the Change of the Dip along our Parallels, to the Change of the Dip along our Meridians [see either of the Maps] as 4 to 10. The Longitude may with us be discovered between the one half, and one third Part, as exactly as the Latitude, or in the Proportion of 4 to 10.

Corol. (2.) Since therefore 'tis easy in Fact to discover the Dip to 4", as I have found by frequent Experience, 'twill be alike easy to discover our Latitude to 4 Miles, and our Longitude to 10 Miles.

N. B. The Poise made use of in these Observations is so necessary in our Needles of the ordinary Shape, that my Needles of one Foot, unpois'd, differed from the true Dip of those of four Feet rightly pois'd here at *London*, no less than 1°. 25'. and those of four Feet themselves, when unpois'd, still differ from themselves, when poised, in the same Place, not less than 30 Degrees.

N. B. However, a small Error in the placing of this Poise, is of almost no Consequence as to the altering of the true Angle of Inclination. Thus if here in *England* we mistake an entire Quarter of a Degree, in the true Place of the Poise, we shall err only Two Minutes in the Angle of Inclination. And the like is to be supposed in other Places.

A General Observation.

It may possibly be here expected, that, after the Discovery of so many and so strange Phænomena of the Loadstone, I should offer some Philosophical or Mechanical Hypothesis for their Solution. Nor have I been wanting in my Thoughts and Endeavours that way. But not being able to satisfy my self at all in any such Hypothesis, I shall not propose any thing of that Nature to others. Sir *Isaac Newton* himself, in the 2d Edition of his most famous *Philosophiæ Naturalis Principia Mathematica*, after he had made the vastest and most amazing Discoveries about the Power of *Gravity*, and given us his Thoughts concerning *God*, in an admirable *Scholium*, is content to conclude his Work, without being able to give any Philosophical or Mathematical Account of that Power of Gravity; nay indeed very justly speaks so, as gives us the greatest Reason to suppose he believed it was not Mechanical, but deriv'd from the immediate Power of God himself, the Great Author of Nature. Nor did the very Learned Dr. *Bentley*, nor that Excellent Mathematician, the Editor, Mr. *Cotes*, at all mistake him, or the direct Tendency of his Discoveries; when the former in his *Boyle's Lectures*, and the latter in his *Preface* to that Edition, all along own and plead for the same Thing. Accordingly I am

P. 481—484.

driven, by the like Neceſſity, to Confeſs, that I can no way ſolve the Phænomena of Magnetiſm mechanically; nor can I ſo much as deviſe any ſuch Motion of a ſubtil Fluid belonging to the Loadſtone, as ſhall account for an Attractive Power in the Seſquiduplicate Proportion of the Diſtance reciprocally: Nor indeed, if I could deviſe any ſuch Motion of a Fluid, would that be a ſufficient Reaſon to determine, that ſuch a Fluid was the real Cauſe of thoſe Appearances, as Mr. *Cotes* has well obſerv'd in the like Caſe, in that Preface. Nay indeed, tho' I could prove the Being of ſuch a Fluid, and deviſe a proper Motion of that Fluid, and make it probable, that ſome hitherto unknown Property of that moving Fluid, made it certainly capable of ſolving theſe Phænomena mechacically; yet would this do no more than remove the immediate Power of the Supreme Being one Degree farther. It ever appearing that the laſt Reſort, the final Reſult of all ſuch Mechanical Principles whatſoever, always do, always will, and always muſt be reſolved into the Immechanical Power and Efficiency of God himſelf, the Firſt and Continual Cauſe; the Firſt and Continual Mover; the Firſt and Continual, moſt Wiſe and Powerful Author, Diſpoſer, and Governor of the Univerſe: *In whoſe World we live*; and without whoſe conſtant Interpoſition and Providence, that *World of his in which we live*, would immediately diſſolve into a Chaos of Confuſion, if not be reduced into its firſt State

of

of Annihilation, or Non-Existence. I shall therefore chuse to end all in the honest Words of the first Inventor of the Dipping Needle, *Robert Norman*, relating to this Matter: " Now, " says he, peradventure you will ask me, How " this Stone hath this Power, and how it is in- " gendred? I am no more able to satisfy you " therein, than if you should ask me, How " and by what Means the Celestial Spheres are " moved? But that God, in his Omnipotent " Providence, hath appointed it so to be: Which " may serve for a general Answer to all such " curious Searchers of the secret Works of God " in his Creatures. ——Now therefore, as di- " vers have whetted their Wits, yea and dul- " led them, so have I mine: and yet in the " End have been constrained to fly to the Cor- " ner Stone, I mean God; who hath given " Power to this Stone, which was received at " his mighty Hand in Creation.

New Attract. C. VIII.

PRO-

PROBLEM

To find the Longitude or Latitude by the Dipping Needle.

IF the Lines of equal Inclination or Dip below the Horizon, be drawn upon Maps and Charts, from good Obſervations, it will be very eaſy from the Longitude known, to find the Latitude; and from the Latitude known, to find the Longitude; and this both at Sea and Land.

Thus in that firſt Sketch of a Map for ſome Parts of *England* and *France*, here exhibited, where I either have my ſelf obſerved the Inclination with a Dipping Needle of one Foot unpois'd, the laſt Year 1719. or procur'd former Obſervations; *viz.* one at *Sarum*, made by Col. *Windham*; and another at *Rouen* in *Normandy*, extant in Dr. *Power*:

Suppoſe we are travelling or ſailing along the Meridian of *London*, and we find the Angle of Dip or Inclination, with a Needle of one Foot unpois'd, to be 75°. 'Tis evident, that this Meridian, and the Line of this Dip, can meet no where but in the Latitude of 53°. 11′. which is therefore the *Latitude* ſought. Or

Or ſuppoſe we are travelling or ſailing along the Parallel of *London*, *i. e.* in 51°. 32′. *North* Latitude; and we find the Angle of Dip or Inclination to be 74°. This Parallel, and the Line of this Dip, can meet no where but in 1°. 46′. of *Eaſt* Longitude from *London*, which is therefore the *Longitude* ſought. But the ſmall Map hereto prefixed, makes this Method ſo very eaſy by bare Inſpection, that I need ſay no more about it.

N. B. The Caſe is the very ſame in the Second ſmall Map, containing the Obſervations I made this Year, 1720. with a Magnetick Needle of 47½ Inches rightly poiſed; and needs no farther Explication. Nor is the great Difference between the Dips in theſe Two Maps any Objection againſt this Method; becauſe when the ſeveral Needles come to have every one their proper Poiſe, and to be all adjuſted to one Standard, as they ought to be, that Difference will entirely ceaſe. And if we conſider the firſt Map, we ſhall find that the ſame Poſition of the Lines of equal Dip, which agrees to the Obſervations this Year, *viz.* that of 22 Degrees from the Parallels of the Equator, do alſo beſt agree to Two of the remoteſt and beſt Obſervations ſet down in the other Map, I mean thoſe at *Sarum*, and *Roven*; as will be obvious on a little Attention.

Corol. (1.) Hence we may find the Place where we are at Sea, by the Dipping Needle, even without the Knowledge of the Latitude.

For

For if either we know the Number of Leagues we have ſailed, or the Angle from the Meridian in which we have ſailed from any known Place, which may one or both be uſually done pretty nearly; the Interſection of a Circle of the given Diſtance, or of a ſtrait Line drawn in the given Angle, with the Line of the true Dip, will determine our Place, and at once give us both its Latitude and Longitude.

Corollary (1.) Hence we may correct all our Sea-Charts, and Geographical Maps of Countries, with their Ports, and that to great Exactneſs; thoſe of the Land eſpecially, where there can be no Difficulty in making the niceſt Obſervations.

Corol. (2.) Hence alſo, by the Help of a very few more good Obſervations, to be made at the *Lands-End*, *Scilly*, *Exeter*, *Dublin*, *Carliſle*, *Aberdeen*, *Uſhant*, *Limmerick*, *Yarmouth*, the *Texel*, and the like convenient Places, we may ſoon draw the Lines of equal Dip in our Coaſting Charts; which, uſed with a Dipping Needle of Four Foot long, will preſerve the Ships near *Great Britain* and *Ireland*; and particularly near *Scilly* Iſlands, from all Danger, for want of knowing their Longitude; or even their Latitude ſometimes alſo. Which Thing I would therefore humbly recommend to the Right Honourable, and others the Commiſſioners appointed by Act of Parliament for the Diſcovery of the Longitude, as the firſt Thing proper for their Conſideration.

Rules of Practice for the Management of the Dipping Needle, in order to the Discovery of the true Angle of Inclination.

(1.) RUB your Needle, the Edges on which it revolves, (which must be strait Lines, exactly horizontal, and nicely polished) and its Pivots playing thereon, with a clean Cloth or Handkerchief, that no Dust or Dirt may cleave to them, or alter the true Poise; and that the Needle may move easily and freely.

(2.) By the means of the three Screws, adjust the Situation of the Pedestal, or Frame, to the Perpendicular; which a Spirit Level will exactly discover at Land; and which the Frame it self at Sea cannot vary from, by its original Contrivance.

(3.) Remove the Poise to that Division upon the Needle from the Center, which you expect the true Dip will have below the Horizon; as at *London* to 75° 10: because the Dip is there 75° 10 below the Horizon; and so every where. If you find, upon Trial, that your Dip is a small matter different from what you expected, remove your Poise a little, till it agree with the true Dip, as near as possible.

(4.) Set a small Compass, or Horizontal Needle, on, or parallel to the Direction of your Instru-

Inſtrument; and remove your Inſtrument, till its principal Direction lies parallel to your ſmall Needle: For then, and then only is it in that Magnetick Meridian, and rightly diſpoſed to ſhew the true Angle of Dip or Inclination.

(5.) Put your Dipping Needle into its Place, the right Side or Edge upwards, and guide it within a few Degrees of that Situation, where you expect it will ſhew the Inclination: And, letting it freely oſcillate ſeveral times, note all along by the middle Point of Time, (from your Watch, or Pendulum, or Pulſe;) and alſo by the middle Point of the ſmalleſt Arc deſcrib'd, the middle Angle of each Oſcillation: Then ſet down that Angle in a Paper, as the true Angle of Inclination, by this firſt Method; as at *London* 75° 10.

(6.) Take off the Poiſe, and let the Needle find its own Equilibrium. Then remove the Needle about 6 Degrees on either Side; and count 4, 8, or 12 of thoſe Vibrations by your Watch or Pendulum; and ſet down the 4th, 8th, or 12th Part of that Number of Oſcillations, to be made uſe of preſently.

(7.) Then place the ſame Needle, without any Poiſe at all, in an Horizontal Situation; and count, in like manner, the Number of Seconds in half the Number of Vibrations here, as you did of Oſcillations there, (the half of theſe, if you pleaſe, with one, and the other half with the other Side upward:)

beginning ſomewhat above 30 Degrees on either Side the natural Direction of the Needle; and ſet down the one half the 4th or 6th Part of this Number alſo.

(8.) Then having firſt ſquared both the Numbers, work by the Rule of Three, thus: As the Square of the larger Number of Seconds, of the Vibrations; to the Square of the ſmaller Number of Seconds, of the Oſcillations: So is the Radius to be to a fourth Number: which will be the Coſine of the Dip. *E. G.* at *London* thus: $43''.4\ q = 1890''.6 : 22''\ q = 484 :: 10000 : 2560 :=$ Coſine $75°.10'$. Now if theſe two Ways of diſcovering the true Dip agree within about a Quarter, or however within Half a Degree, you may ſecurely take the former Dip, found directly, for the true one. But if they differ more than that, 'tis probable ſome Error has been committed in the Experiment, by reaſon of ſome Iron or Loadſtone too near the Needle; or becauſe the Frame was either not exactly Horizontal, or not truly in the Magnetick Meridian, as it ought to have been: In which Caſe the Experiment is to be repeated, for greater Satisfaction.

N. B. Since this Second Method cannot come near to the ſame Exactneſs with the Firſt, and is more difficult to be put in Practice, I rather *recommend* it to the curious Seaman, when he

he has any particular Doubt as to his Longitude or Latitude, or when he is near the Shoar, or when he has ſome reaſon to ſuſpect his Needle to be out of Order; than *require* it in the ordinary Courſe of his Practice. And indeed, if he will but make the other Obſervation at Noon, or at a ſet Time, every Day; there will be ſuch a natural Harmony and Analogy between theſe Angles of Inclination, as appearing upon his Journal, when carefully obſerv'd; and ſuch Diſcord and Diſagreement when careleſsly noted, that he will not be much liable to any conſiderable Error ariſing from this Head: Any particular Error of the Obſervation in one Day, being naturally corrected by the better Obſervations of the foregoing and following Days.

N. B. Since the Latitude, when we ſail within a Point or two of the *North* or *South*, is moſt exactly diſcoverable by this Method, as well as the Longitude ſomewhat leſs exactly, when we ſail along, or very near a Parallel, by even or proportional Alterations of the Dip every Day; in ſuch Caſes the obſerving Sailor will diſcover his Place originally, even without recourſe to his Chart, or to any other Method of Obſervation whatſoever.

N. B. Yet ſince the Courſe is very frequently upon other intermediate Points of the Compaſs; in which Caſe, the natural way of diſcovering

covering the Longitude is by the Interſection of the Lines of equal Dip, with the Parallels of Latitude; 'tis certain, that the oftener and the exacter we can take our Latitude at Sea, the more accurately ſhall we know our Longitude. Whence that neweſt and beſt Contrivance of the very Ingenious Mr. *Rowe*, whereby he can much more frequently, and ſomewhat more exactly than formerly take that Latitude, will be of great Uſe here; and will enable us to diſcover even our Longitude from this Method, to a greater Degree of Accuracy than we could otherwiſe do. To ſay nothing here of an Improvement of my own, to the like Purpoſe; of which more preſently.

N. B. The beſt Place and beſt Way for uſing the Dipping Needle on Shipboard, I take to be theſe. That in or near the Lower Deck, as cloſe to the main Maſt as may be, or exactly where the Center of the Ship's Motion is, which is eſteemed by the Ship-Builders to be, where the Surface of the Sea produc'd would cut the main Maſt, (which Place muſt have no Iron at all within a Foot or two; and no great Quantity of Iron within a Yard or two of it:) a round and ſtrong Hole be made, of about two Foot Diameter; that in this Hole be a ſtrong Circular Horizontal Table hung, within a very ſtrong Circle of Braſs, which has two Axes, at right Angles one to another, in the way of Sea Compaſſes; that to the Bottom of this

this Table be firmly join'd, and, if need be, brac'd, a long and heavy *Pendulum*; as I may call it, (tho' ſomewhat improperly: for 'tis the Ship it ſelf, and not this, that principally oſcillates, in the way of a real *Pendulum*:) in order to keep the Circular Table Horizontal. Upon this Table place your Inſtrument, with its ſmall Needle to guide it to the Magnetick Meridian; and with its Spirit Level, if there be Occaſion, to guide it to the Horizontal Situation. For in this Method, as I have frequently tried my ſelf, and ſhewn it to many curious and exact Obſervers alſo, the ſhaking of the Ship is almoſt wholly avoided, and the Angle of Inclination is found near as exactly as it is at Land; where there is no Concuſſion at all.

N. B. Upon ſuch an Horizontal Table we may place Pendulum Clocks, Large Hourglaſſes, or the like equal Movements, for the exacter Meaſure of Time, at leaſt for ſome Days, if not Weeks, in order to the Diſcovery of the Longitude by any other Methods which require it. Upon the ſame Table alſo may Inſtruments be plac'd for the exacter Diſcovery of the Latitude; at leaſt when the Sun ſhines at Noon: All which Methods have hitherto been too impracticable, for want of ſuch an Horizontal Table. And tho' this Table will not be free from all Degrees of Motion; yet will that Motion be very ſmall, where the Pendulum is 3 or 4 Foot long; and will ſtill be

be equally below the Horizon on one Side, and above it on the other: Which will hardly incommode the Accuracy of ſuch Movements and Obſervations at all.

N. B. I once thought to have ſhewn in this place, how the Inclination of the Dipping Needle might alſo have been found at Sea, without any Concuſſion from the Ship at all, in the Places of greateſt Danger, or within 80 or 90 Miles of the Shores, which the Seamen call the *Soundings:* I mean, by deſcending in a *Cloſe Chamber* or *Diving Bell*, to the Bottom of the Sea; and there making the Experiment: Which thing is by no means impracticable, as Dr. *Halley* well knows: [He having been One of Five at the Bottom, even in an *Open Diving Bell*, in 9 or 10 Fathom Water, for above an Hour and a half at a time, without any ſort of ill Conſequence, as himſelf informs us, *Philoſ. Tranſact.* N°. 349.] But becauſe I find, upon Trial, that there will ſeldom or never be Occaſion for ſo troubleſome and chargeable a Method, I omit what I had written on that Head.

N. B. Whether this, or any other Method, either for Longitude or Latitude, can be put in Practice in a very great Storm at Sea, I do not know: Only this I will ſay, that if, on the Expectation of ſuch a Storm, the Longitude and Latitude be known; and if, as ſoon as

ſuch a Storm is over, the ſame be alſo known, which ſuch a Storm can no ways hinder, there can be no great Inconvenience in not knowing either of them, during the Storm it ſelf; when the Seamen, to be ſure, are otherwiſe employ'd; and when it frequently happens, that ſuch their Knowledge would be of no Advantage to them: It being to ſmall purpoſe to know anew where the Ship is, or whither they are to guide her, at a time when ſhe either lies at Anchor immoveable, or elſe drives before the Wind, without ſubmitting at all to the Guidance of her Pilot.

Addenda & Corrigenda.

N. B. THAT in the Title Page, all the Copies of the *Sibylline* Oracles, as well as *Theophilus*'s Copy, have ὑλήεντα, a Word not known in the *Greek* Language, instead of λήεντα.

PREFACE.

Page 20. *Line* 2. *for* particular, *read* but precarious.

Line 29. *Add:* However, I must not here omit that highly valuable Attempt which was made by Captain *John Wood*, a very Inquisitive and Judicious Sailor, for the Discovery of those Things by Theory and Practice together, which Mr. *Bond* was chiefly trying to do by Theory. For about this very Time, or *A. D.* 1676. this Captain *Wood* sailed *North*, in order to discover the *North-East* Passage. Where one of the Reasons that induced him to this Voyage, as he tells us himself, was this: 'That he 'having for some Years past framed an Hypo-'thesis of the Motion of the Two Magnetical 'Poles; (for, says he, Two such there be:) 'And having by the Observations of all or 'most that writ of that Subject, with his 'own Observations, and costly Experiment, 'upon a great many Places of the Superficies 'of the Terrestrial Globe, found out their

'Motion

' Motion very near : [The *Northern* Pole, he had juſt told us, ' he was certain was not the ' ſame with the Pole of the World.] Where- ' by the Inclination of the Magnetick Needle ' under the Horizon in all Latitudes and all ' Longitudes ; and Variation of the Compaſs ' might be found in any Place in this World, ' without the Aſſiſtance of any other Lumina- ' ry : He wanted to come nearer the Pole, in ' order to better Satisfaction. Tho', as he ' tells us afterward, when he intended to have ' given a more full and nice Account of all the ' Experiments he had and ſhould have made ; ' eſpecially thoſe of the Magnet, which he ' forbears to mention, becauſe he intended to ' publiſh them in a Treatiſe by themſelves ; ' He, alas! with his Ship, loſt all his Papers, ' and with them all that he had in the World ' beſide '. See Sir *John Narborough*'s Voyages, *pag.* 150, 151. and *pag.* 195, 196. And this indeed ſeems to have been the laſt and beſt Attempt that has been made in this Kind to this very Day. And Pity, great Pity it was that it had no better Succeſs ; and that it was not ſeconded by ſome other fit Perſon, or by the Publick afterward ! Mr. *Bond* indeed once appeals to this Captain *John Wood*'s Obſervation in the Streights of *Magellan*, for the Confirmation of his Hypotheſis : But what that Obſervation was in particular, he does not inform us. I imagine he may mean that of his ſuppoſed Dip

In Initio.

there, of 65°. 26′. which is not very remote from my own Determination of the ſame, deriv'd from other Obſervations.

Page 22. *L.* 11. *Add*: Dr. *Halley* did alſo himſelf make ſome uſe of a ſmall Dipping Needle, near the Iſlands of *Cape Verd*, and found that it there lay Horizontal, contrary to all other Analogy: as if there were ſome Rocks of Loadſtone there. But when he made the like Obſervation at the Iſland of St. *Helena*, he found the Dip there to be regular, and in a near Agreement with the beſt of the other Obſervations thereabouts, and to my own Theory.

Page 23. *Line* 3. *Add*: Only this they found, that near the Iſland of *Jerſey*; and in the *Eaſt Indies*, both very near the great *Cardomum* Iſland, in the *Streights* of *Malacca*; and on a Rock at *Pulo Condore*, their common Compaſs would turn ſeveral ways; and ſo muſt either have been over a Pole of the internal Loadſtone, or near ſome Magnetick Rocks: The latter of which Mr. *Pound* juſtly thinks to have been the Caſe in all thoſe Places. And indeed what Grounds of Suſpicion ſoever there may be as to certain Coaſts and Iſlands, where the Longitude cannot be wanted; and where, in caſe it were wanted, a ſmall Removal of the Ship would give it as before; there is not, that I know of, any certain Examples of Irregularity of the Dip in the open Seas; where alone we have the principal Occaſion for that Longitude; either from Iron Mines, which indeed make little

little or no Impreſſion upon Magnetick Needles, even placed in the very Middle of them; or from Magnetick Rocks, or any other Cauſe whatſoever. Upon which Occaſion, Hear the moſt authentick Teſtimony of Mr. *Pound* himſelf, who has made Obſervations with a Dipping Needle in more remote Regions than any other Perſon whomſoever; and who has aſſured me by his Letters, 'That I was miſinformed, 'when I ſuppoſed he had affirm'd, concerning 'the Horizontal Needle, that it was ſo irregu-'lar in a certain Place of the *Open Seas*, that 'it would turn every way. And He declares, 'that it did ſo only in the forementioned Places 'between Iſlands, and on Rocks; (which might 'be great Loadſtones.) He adds, That he 'had made Obſervations with the Dipping 'Needle in ſeveral Places at Land, [in the '*Eaſt Indies*,] which he eſteemed pretty good, 'and agreeable to one another; tho' they were 'all loſt at the Deſtruction of the Factory at '*Pulo Condore*', and his Memory does not now enable him in any Degree to recover them. The Obſervations themſelves alſo, which he and Mr. *Cunningham*, as well as Mr. *Hudſon*, Mr. *Noel*, and Mr. *Feuillee*, made in their ſeveral Voyages, already mentioned, give no certain Indications of any ſuch Irregularity at all.

Line 11, *&c. Dele:* and an Hypotheſis of his own, with reſpect to two large Magnets, which he ſuppoſed to be within the Earth.

Page

Page 25. *Line* 4, 5. *read*; than an Hypothesis, suppos'd to be deducible from that Author's Observations, of two, *&c.*

At the End of the Preface add: Since this Preface was printed off, I have received Information from Mr. *Campbel*, a very inquisitive Friend of mine, That the Mariner's Compass was, in some sort, for certain, known in the *Southern* Parts of *France* above a Century sooner than *John Goia* is generally suppos'd to have first applied it to Navigation in the *Mediterranean.* Of which Discovery I will give the Account in my Friends own Words, as follows: ' The following Lines are found in ' an old provincial Poet, commonly call'd, *Guyot* ' *de Provins*, who flourish'd before the End of ' the 12th Century. And by the Date of his ' Work, they appear to have been wrote in the ' Year 1180. And they contain so very clear ' and plain a Description of the Mariner's ' Compass, as puts it past all doubt that 'twas ' known at that time.

Jcolle estoile ne se muet
Un art font, qui Montir ne puet
Par vertu de la Marinette
Une pierre laide & noirette
Ou li fer Volontiers se joint.

' I have put them down exactly as they stand ' in the Original, according to the Orthogra- ' phy and Spelling us'd at that Time. I shall ' now

‘ now give you their Tranſlation very near li-
‘ terally.

There is a Star that never moves; (meaning the
And there is an Art that never deceives (Polar one.
By vertue of the Compaſs,
And an ugly black Stone,
That always attracts Iron.

‘ Thoſe Lines are cited by Mr. *Fauchet*, a
‘ famous *French* Antiquary, who liv'd in the
‘ Reign of *Lewis* 13th, in his Book, entituled,
‘ *Lés Antiquités de la France*; And from him
‘ by Mr. *Perrault*, in his Parallel of the An-
‘ cients and Moderns with reſpect to Arts and
‘ Sciences, *T.* 3. And the Age of this Poet
‘ is as certainly known among his Countrymen,
‘ as we know that of our *Chaucer*.

BOOK.

Page 1. *Line ult. Add: N. B.* A good Needle of 4 Foot long ought, before it is touch'd, to be ſo nicely poiſed, that it will feel the 120th or 130th Part of a Grain in the horizontal Situation; and, as near as may be, in the perpendicular Situation alſo: Which laſt, as it is very much harder to do, ſo on its being well done depends the greateſt Accuracy of every Needle.

Page 3. *Line* 16. *read:* Of the pois'd Needle, about 75°. 10′.

Page 4. *Line* 9. *Add:* *N. B.* This Power of Magnetick Inclination in the horizontal Situation of my two long Needles, the one of 4582 $\frac{1}{8}$. and the other of 4012 $\frac{1}{8}$ Grains Weight, was ballanced, the former by about 1 $\frac{1}{4}$, and the latter by 1 $\frac{1}{8}$ Grains: Which is by a little above the 3000th Part of their entire Weight: I mean when hung at the *Southern* Extremity of each Needle.

Page 7. *Line* 14. *Add:* But if we make the Needles themſelves much broader and ſtronger in the Middle than towards the Ends; as has been ſometimes done formerly; we ſhall avoid the greateſt Part of this Power. Nay, perhaps it will not be impoſſible to avoid it ſo far, that we may not have Occaſion for ſuch a Poiſe at all. Any little Error that ſhall ſtill thence ariſe being eaſily allow'd for in the Charts belonging to this Method; which may be fitted exactly and ſolely to ſuch Needles, and not to thoſe that, by being truly pois'd, are more regular. I mean this only in caſe they be all made of one Length, Weight, and Standard. And perhaps this will be the beſt way for ordinary Practice at Sea. Experience will ſoon determine between theſe two Methods.

N. B. All ſuch Dipping Needles ought to be made ſo heavy, that by their Weight they may fix themſelves to certain Places of the Edges whereon they lie, to prevent their Removal any way. And a fourfoot Needle ought to be conſiderably above a Pound Weight for this purpoſe.

Page

Page 9. change the Places of the two Numbers 4584 and 4015.

Page 26. *Line* 3. *read* 39$\frac{1}{2}$2. *Page* 27. *Line* 3. *read* 39$\frac{1}{2}$2. *and* 626. *And Line* 10. *read* 626.

Page 33. *Line* 4. *read* 14$\frac{5}{8}$. *And Line* 7. *read* 7$\frac{5}{12}$.

Page 34. *Line* 8. *read* 75$\frac{1}{8}$ to the *Sinus Totus:* or as 9667 to 10000. *Line* 17, 18. *read* 14$\frac{1}{8}$ to the *Sinus Totus:* or as 2560 to 10000. which is nearly as 1 to 4. *Line* 23, *and* 24. *read* nearly as 500. and nearly as 1 to 2. *Line* 24. *dele* or as 11$\frac{1}{3}$ to 6.

Page 53. *Line* 15. *add*: By Mr. *Norman*'s Observation, Chap. *ult.* where he tells us, 'He 'had heard many say that had travelled far to 'the *Southwards*, that the horizontal Compass 'hath seemed to lose his Force, and to wax 'weak and dull'. Which is necessarily so, whenever we are somewhat near a Pole, and no where else. By Mr. *Pound*'s and Mr. *Cunningham*'s Observations also; which, tho' made with a Needle not equally pois'd or hung, shew that their greatest Angles of Inclination altered not very much in above 2400 Miles, near the same Road with the other; which could only happen in the Neighbourhood of such a Circular Pole. *Line* 21. *add*: And, lastly, by Captain *Tasman*'s Observations, made *A. D.* 1642. where not very far *West* from *Van Diemens Land*, his Horizontal Needle would not stand still upon any particular Point

of the Compaſs: Which was a Sign it was then over the *Southern* Pole of the internal Loadſtone, as we have already remark'd, *pag.* 38. *priùs.* See Sir *John Narborough*'s Voyages, *pag.* 132.

Page 54. *Line* 15. *read*, and either two or four Points, by Mr. *Norman* himſelf, C. 9. See alſo *Gilb. de Magnet.* IV. 16.

Page 54. *Line* 22. *add: N. B.* This Propoſition, and thoſe that depend on it, as to the Exactneſs of the Numbers, relies on the Truth of Mr. *Hudſon*'s greateſt Dip; which both in the Text and Margin is ſaid to be 89½. tho' in Figures only: While the Analogy of the reſt of his own Numbers ſeems plainly to requireus to read rather 86½. Nor do my own Obſervations this Year, 1720. contained in the Second ſmall Map, well agree to that larger Number. So that till we have more exact Trials beyond the *North Cape*; or can find the very Place of the *Northern* Magnetick Pole more nicely ſome other way; the Reader is to ſuppoſe ſuch Numbers and Calculations to admit of a conſiderable Latitude. *Line* 25. *read* 69. or at 21. *Line* 26, 27. *read*, by *Ballaſore* about 90. *Line* 29. *read* 40.

Page 55. *Line* 2. *add:* Mr. *Pound*'s, and Mr. *Cunningham*'s, and Captain *Taſman*'s Obſervations.

Page 56. *Line* 13. *add:* What the State of the Magnetick Power of the Earth, or internal Loadſtone, beyond, or within the *Southern* Circu-

Circular Pole, is, does not yet fully appear by any Facts that I know of. Very few, if any, besides Mr. *Pound* and Mr. *Cunningham* having ever made Observations either of the Variation or Inclination there. Only it seems to me somewhat probable, that the Dipping Needle will lie Horizontally at the Center, as it certainly stands perpendicularly at the Circumference of that Circle; or if it be otherwise, that the Dip will be perpendicular to the Horizon within that entire Circumference. But the Determination of this Matter must be left to future Trials.

Page 57. *Line ult. read*, almost.

Page 58. *Line* 12. *add:* *N. B.* This Proposition is directly fitted to the Observations I made 1719. while those I have made this Year 1720. require the Angle B L C, to be rather 22 Degrees; and by Consequence the Angle B P C above 50 Degrees; and the Arc gone by the Pole in 144 Years hardly 25 Degrees; and its whole Period not less than 2000 Years. Farther Observations will determine between all such Numbers.

Page 74. *Line* 23. *add*: *N. B.* All this Reasoning considers the *Upper Earth*, here mentioned, as including that *Fluid*, near the Top, which in my *New Theory* I have, from other Evidence supposed to be there: Which being *denser* than the superior Parts, would so suddenly receive and communicate the Diurnal Rotation, that it may here be well included under

that entire *Upper Earth* of which I am here treating, as distinct from the much lower, and vastly rarer Fluid, and from the Central Load-stone, therewith encompassed. Nor indeed, will any such Quantity as 50 or 100 Miles of such a dense Fluid; encompassed perhaps with 100 or 200 Miles of an *Upper*, and about 2500 or 2600 Miles of a *Lower* solid Earth, deserve much other Consideration in this Place, than if the entire *Upper Earth* were supposed to be throughout one continued solid Earth, without the Interposition of such a Fluid.

Page 80. *Line* 9. *add:* *N. B.* The Difference of this *Strength* of the Magnetick Power, from its *Direction*, is most visible in my Second Map hereto prefix'd: Where I have all along set down the Seconds wherein my Needle perform'd a single horizontal Vibration, at about 120 Degrees from the Magnetick Meridian, in most Places: Whose Squares, when Allowance has been made for the different Obliquity of the several Directions as to our Horizon, will give us the different *Strength* of that Magnetick Power at those several Places: As does the Angle of Dip give us the different *Direction* of the same Power there. Now at the first Sight, the former there appears to be irregular, and the latter regular; as is the Case also of our *Terrellæ*.

Page 82. *Line* 27. *read* 280.

Page 85. *Line* 6. *add:* *N. B.* Tho' the *Terrellæ* seem to give us these Angles exactly enough,

enough, on their Surfaces, according to the Line of Sines; yet may both they, and the *Earth's Loadſtone* alſo, at great Diſtances from ſuch Surfaces, admit of ſome Variation of that Proportion; as Dr. *Gilbert* has particularly obſerv'd in the former Caſe: and as many of the Obſervations on the Earth ſeem to require in the latter. Experience alone can determine this Matter. Nor is it of any great Conſequence, as to the Diſcovery of the Longitude or Latitude, How it is determined. For whatever this Proportion proves to be, when it is once known, it will be almoſt equally advantageous to ſuch Experiments.

Pag. 100. *Line* 4. *add: N. B.* The true Reaſon why the round Table guided by a Pendulum, will not oſcillate with the Ship; and why the Magnetick Needle will not vibrate either with the Ship or Pendulum, is evidently this; that the ſeveral Times of each of theſe Oſcillations, or Vibrations, are ſo entirely different, that their beginning Motions do mutually hinder their Influences upon each other, as do Diſcords in Muſick. Thus a Ship rolling in 7″, when compar'd with a Pendulum oſcillating in 2″, or a Magnetick Needle oſcillating in 17″ or 22″, or vibrating in 44″, are ſo diſſonant and diſagreeable, that they cannot conſiderably influence each others Motions; which Diſagreement, or Diſſonancy of the Motions, muſt therefore ever be taken exact Care of, in all Caſes of this Nature. And as

to

the Degree of this Avoidance of the Ship's Motion by the Pendulum, and of the Exactness of the Needle's Vibrations notwithstanding that small remaining Motion, I Appeal to Mr. *Molyneux*, Dr. *Desaguliers*, and Mr. *Machin*, all Worthy Members of the Royal Society, and Eye-witnesses; who I doubt not will do me Justice in this Matter.

N. B. The Reader is to remark, that it having hitherto been easy to poise Needles in their Horizontal, and very hard to poise them in their Vertical Situation, it has been much easier to find the Equator, than either of the Poles of the Internal Magnet by the Dipping-Needle: And that the other Method, by the Horizontal Needle, when it will turn every way equally over such a Pole, is almost the only one that will still find it exactly. However, the Observation is evident in Fact, that while several Dipping-Needles have hitherto considerably differ'd near the Magnetick Poles, they have agreed much better about their Equator: as they must needs do in their present Construction.

POSTSCRIPT.

AFter all my other Trials with Brass or Steel Edges, or Cylindrical Needles, for the Pivots of my Dipping-Needle to play

 upon,

upon, I have at laſt tried almoſt the ſame with Mr. *Norman*'s own firſt propoſed Method; *viz.* that of the plain Surface of Coach-Glaſs; which I find to be, at leaſt, twice as exact, and as ſure as any of the reſt; which Method therefore I intend ever to put in Practice for the future; and which I find will diſcover the Latitude, even in theſe Parts of the World, to *two* Minutes or Miles, and the Longitude to *five*.

I have alſo very lately been ſhewn by Mr. *Hutchinſon*, a very Curious and Inquiſitive Perſon, a Copy of a MS. Map of the World, made about 80 Years ago, taken by himſelf from an Original, wherein the Variation is reduc'd to a Theory, much like that which Dr. *Halley* has ſince propoſed; and in general exactly agreeing to his Obſervations, as he freely confeſſes; but with this Advantage, that therein the *Northern* Pole of the internal Loadſtone is much better ſtated than it is by Dr. *Halley*: And indeed is here plac'd almoſt in the very ſame Parallel and Meridian, wherein, by my other Obſervations, it muſt have been at that Time: Its Place then being, according to this unknown, very curious and ſagacious Author, about the Meridian of *Moſcow*, and the Latitude of 78 $\frac{1}{4}$ Degrees. Which ancient and authentick Determination of its Place, I deſire the Reader particularly to obſerve, in Confirmation of my foregoing Theory.

LONDON,
Jan. 28. 17$\frac{10}{11}$.

Will. Whiſton.

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THE *ASTRONOMICAL YEAR:*

OR, AN

ACCOUNT

Of the many remarkable

CELESTIAL PHÆNOMENA

OF THE

GREAT YEAR MDCCXXXVI.

Particularly of the

LATE COMET,

Which was foretold by Sir *ISAAC NEWTON*, and appeared at its Conclusion.

By *WILLIAM WHISTON*, M. A.

Ego nostris non assentior. Non enim existimo Cometen subitaneum ignem, sed inter æterna naturæ opera. —— Nondum sunt anni mille quingenti ex quo Græcia —— *Stellis numeros, & nomina fecit.* —— Veniet tempus, quo ista quæ nunc latent, in lucem dies extrahet, & longioris ævi diligentia. —— Veniet tempus, quo posteri nostri tam aperta nos nesciisse mirentur. —— Erit qui demonstret aliquando, in quibus Cometæ partibus errent, cur tam seducti à cæteris eant; quanti, qualesque sint. *Senec. Quæst. Natural.* L. VII.

LONDON:

Printed for JOHN WHISTON, at Mr. *Boyle's Head*, *Fleetstreet.* 1737. (Price 6*d.*)

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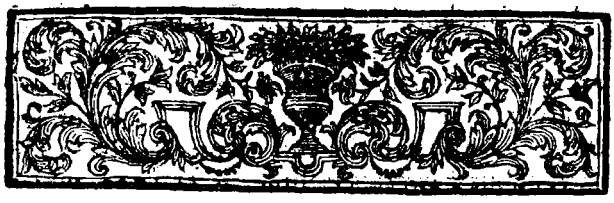

AN ACCOUNT OF THE ASTRONOMICAL YEAR, &c.

IN order to proceed regularly to this account; I muſt obſerve, in the firſt place, that, beſides the intimations relating to this great year 1736. given a century ago by Mr. *Mede:* and ſince by Bp. *Lloyd*, Dr. *Allix*, Monſ. *Daubuz*, &c. And beſides the intimations given by myſelf thirty years ago, in the *Eſſay on the Revelation of St. John*, pag. 213, 215, 216, 221, 222, 223, 234, and 270. And more fully among the *corrections* thereto belonging, eleven years ago, in my *Literal Accompliſhment of Scripture Prophecies*, pag. 95, 96, 99, 101, 102, 103, 104, 105, 110, and 113. I ſix years ago, in the *Memoirs of the Life of Dr. Clarke*, pag. 92. of the 2[d] Edition, gave far-

ther intimations concerning the ſame year, as the grand period of the ten kingdoms of tyranny and perſecution in the *Roman* Empire; or of the laſt antichriſtian State of the *Roman* Monarchy, under ten Kingdoms; and that this year would be remarkable for great Eclipſes of the Moon. I alſo, at the end of my Reply to Dr. *Sykes*, about *Phlegon*'s Eclipſe, *A. D.* 1733. which is the III[d] of my VI. *Diſſertations*, added, that the ſame year would be famous alſo for a great many Eclipſes of the Sun, in the words following, "that 1736. the grand period of the ten "Kingdoms, or of the laſt ſtate of the *Roman* "Monarchy, would be peculiarly remarkable "for great Eclipſes of the Moon, as well as for "the uncommon number of Eclipſes of the Sun." Moreover, in the IVth of thoſe VI. *Diſſertations*, pag. 261. I farther enlarged upon this matter, in the following words:

"*N. B.* Since there will be an annular Eclipſe "of the Sun on *Feb.* 18. *A. D.* 173$\frac{6}{7}$. of about "ten digits at *London*; and whoſe centre will "paſs nearly from north of *Dublin*, to *Edin-* "*burgh*, with a ring of light round the Moon "all the way: which path of the center is very "nearly the utmoſt weſtern limit of the *Roman* "Empire: and whoſe partial ſhadow will ex- "tend over the *Roman* Empire as far as *Eu-* "*phrates*, (of which ſee my eight Eclipſes "drawn on the Map of *Europe*) we may, with "the old *Romans*, [and with the *Jews*] begin "the year with [the New Moon in] *March*; "and take this Eclipſe into our conſideration "alſo. Which if we do, we ſhall find, that in "the ſame year 1736. there will be ſeen, in one "place or other, [and generally in the *Roman* "Empire] no fewer than five Eclipſes of the "Sun:

" Sun: On *March* 1. and *March* 31. On *Aug.* " 25. On *Sept.* 23. and *Feb.* 18. besides the " two great Eclipses of the Moon [on *March* 15. " and *Sept.* 9.] seven in all. Which is a greater " number of Eclipses than I have ever met " with in any of those 72 years, for which I " have computed them. Nay, if we take in " but five days farther, in *March* $173\frac{6}{7}$. we shall " have, somewhere or other, no fewer than " eight such Eclipses; five of the Sun, and three " of the Moon. There will also be a very small " Eclipse of the Sun, or a transit of *Mercury* " over the Sun the same year, *Octob.* 31. 10^h $53'$ " *manè*, and visible over all the *Roman* Empire " also. Which number of Eclipses cannot but " render this year exceeding remarkable to A- " stronomers. That number of Eclipses having " hardly ever been *equalled*; to be sure never " *exceeded* in any one year since the creation." Moreover, in the beginning of that year, I republished my open Sheet of the *Transits of* Venus *and* Mercury *over the Sun*, for $2\frac{1}{2}$ centuries: with an addition of XXIV *Eclipses of this great year, beginning with* March. Which are there all set down in order: though in gross only, and without the exact calculation of any of them.

About the same time I was informed by a learned friend, that Mons. *Cassini* had observed the tail of a Comet, at *Bononia*, in *Italy*, in the constellation called *The whale*, about the end of *February* 1668. Old Stile. And I soon found several accounts of the Comet itself, as well as its tail in our *Philosophical Transactions*, N°. 35. I also was then shewed a Chronological Dissertation about it, written by Mons. *Vignoles*, in the *Miscellanea Berolinensia*, printed in the year 1710.

pag.

pag. 251 —— 260. upon the ſuppoſition that this Comet was the ſame with that which *Ariſtotle* ſaw on the 373[d] or 372[d] year before the *Chriſtian* Æra: as *Caſſini* believed: and upon this farther ſuppoſition, that its period was no more than 34 years, as the ſame great Aſtronomer had determined alſo. Beſides which, *Maraldi*, an Aſtronomer, then at *Rome*, ſaw ſuch a ſtrange light in *the whale*, about the end of *February*, *A. D.* 1702. as was deemed to be the tail of the ſame Comet, though we no where hear of the Comet itſelf. Which, upon the former determination of a 34 years period, was alſo expected to return, about the end of *February* 173$\frac{5}{6}$. All which Hypotheſes and Expectations ſeemed to come to nothing, upon the failure of ſuch Comets return at that time.

However, I was informed about the ſame time by a friend of mine, Col. *Guiſe*, that He had himſelf heard Sir *Iſaac Newton* declare, that "Though he would not ſay he was ſure of it, "nor would publiſh it, he had ſome reaſon to "believe a Comet would return about the latter "end of 1736." And that he afterward added, that "Such a Comet had appeared formerly: "although the Colonel could not remember what "year it was when Sir *Iſaac* ſaid it had ſo ap-"pear'd." He alſo, at the firſt, informed me, that Mr. *Howard*, another acquaintance of mine, had alſo heard Sir *Iſaac Newton* ſay the ſame thing. All which I communicated to the Queen, on *March* 15. when I waited upon her Majeſty, to give her ſome account of the great Eclipſe of the Moon, which was to be that night; as well as of thoſe other numerous Eclipſes and Occultations that were coming on the ſame year. And when Mr. *Howard* was afterward aſked

about it by another friend of mine, and at my desire, he remembered it immediately: and added, upon the question, that "Col. *Guise* was "not with him, when Sir *Isaac Newton* said so "to him." But that when he was once at dinner, at Mr. *Tollett*'s, at the *Tower*, with Sir *Isaac*, and Dr. *Gregory*; Sir *Isaac* said, that "He "expected the appearance of a Comet [1735 "or] 1736. or thereabout." And that upon his putting some questions to him about it, "Sir "*Isaac* seemed to draw back: as sorry that he "had said so much: but still could not deny he "had such an expectation." All which Mr. *Howard* hath lately confirmed to myself also. Both which informations I have communicated, during the course of this last year, to great numbers of my auditors and acquaintance: and on their account have been long in some expectation of the coming of such a Comet, during the same year. This being premised, I shall now come to my account of all these Eclipses, and Occultations of the Planets, and of the Hyades; or particularly of the Occultation of *Aldebaran*, *Palilicium*, or the *Bulls Eye*, which is the principal of them; as well as of the appearance of the Comet itself, foretold by Sir *Isaac Newton:* and every one according to the order of time.

(1) On the first day of this year then, according to my estimation, or *March* 1. 173$\frac{5}{6}$. there was an Eclipse of the Sun, seen in the most northern parts of the Earth; though to us invisible.

(2) The second was a very great, total, and almost central Eclipse of the Moon, *March* 15. 173$\frac{5}{6}$. just before midnight: and seen over all the *Roman* Empire: beginning, as Mr. *Wright* truly

truly foretold in his Scheme, about 9′ after ten o' clock. Was in the greateſt darkneſs about 58′ after eleven; and ended about 46′ after one: and ſo laſted about 3^h 37′. This Eclipſe happened near the Moon's Perigee: and, by conſequence, left the Moon almoſt as dark in the center as it is poſſible for it to be. The Earth's atmoſphere ſtill admitting ſo many rays to fall upon it, by refraction, that it never can be totally obſcured in any ſuch Eclipſe whatſoever. And by reaſon of the quickneſs of the Moon's motion near the ſame Perigee, this Eclipſe did not laſt ſo long as we ſhall ſee its next Eclipſe in *September* did, near its Apogee. This I ſaw, and almoſt every body elſe, by reaſon of the air's clearneſs; and the early hour of the night for its beginning.

(3) The next Eclipſe was that of the Sun, on *March* the 31st about ſeven in the morning. But viſible only in the remoter ſouthern parts of the Earth, and inviſible to us in *Europe*.

(4) The next viſible Eclipſe, or Occultation, was that of *Aldebaran* by the Moon, *April* the 3^d about eight at night: and viſible over all the *Roman* Empire: which I, and ſome friends ſaw, as far as was poſſible to be ſeen. The latitude of the Moon then allowing it to paſs through the other Hyades; but not permitting it to reach this Star itſelf: though it came within about $2\frac{1}{2}$ Minutes of it.

N. B. I ſhall hereafter take no particular notice of ſuch occultations of this Star as were inviſible here: or happened in the day time, which occultations yet come once every periodical month, when the Moon arrives at 6°. 5′ longitude in *Gemini:* during this and the three next years ſucceſſively. See the VI. *Diſ-*

ſertations,

sertations, pag. 227, 228. where like occultations of the Hyades, as foretold by the Prophet *Isaiah*, are brought to a calculation, and shewed to have been exactly fulfilled accordingly.

(5) The next Eclipse, or Occultation was that when the Moon passed over *Venus*, *April* 27th. It was visible over all the *Roman* Empire. At *London* it was a very bright day: and I, with a skilful friend, tried to see it through a smoaked glass, and a telescope. But that brightness, and the inconvenience of our station, hindered us from seeing either *Venus* or the Moon. It was, by the best calculation, to begin at half an hour after twelve at noon; and to end three quarters after one.

(6) The next visible Eclipse, or Occultation was that of *Aldebaran* by the Moon, *July* 21st between three and four a clock in the morning, and visible over all the *Roman* Empire. This happened at such an unseasonable time of the night, that I did not attempt to see it.

(7) The next Eclipse was that of the Sun upon *August* 25th between eight and nine in the morning; but invisible in *Europe:* and only seen in the southern parts of the Earth.

(8) The next was that very great, total, and almost central Eclipse of the Moon, visible over all the *Roman* Empire, on the 9th Day of *September*, early in the Morning: beginning, by Mr. *Wright*'s calculation, $5' \frac{1}{2}$ after one a clock: at the greatest darkness about $11' \frac{1}{2}$ after three: and ending at $17' \frac{1}{3}$ after five. Which implies its lasting about $4^h\ 12'$. This long duration was occasioned by the slowness of the Moon's motion, near its Apogee, at that time. Nor could the Moon be near so dark at the centre,

as it was in *March*; by reason of its greater distance from the Earth at this time. Now although this was at so inconvenient a time of night, and the air was cloudy in *Rutland*, where I then was, when I went to bed; yet did I rise more than once out of bed to see it: and found the air cleared up, and the Eclipse very visible; both when it was partial, and when it was total. Though indeed I did not sit up, nor attempt to make any nicer observations about it.

(9) The next Eclipse was that of the Sun, *Sept.* 23[d] a little before, and at Sun-setting. The common Almanacks told us this Eclipse would be invisible with us. While the many calculations in the *Ladies Diary*; and Dr. *Halley's* own calculation shew'd that it would be visible at *London*, and above 4 digits in quantity there. We made some preparation in *Rutland*, where I then was, to observe it. But the sky grew too thick and hazy to afford us the sight of it.

(10) The next Eclipse, or Occultation was that of *Mars*, by the Moon, *Octob.* 8th between two and three a clock in the morning; and visible over all the *Roman* Empire. I was then in *Rutland* also: and saw the Moon going to make that occultation, before I went to bed: for the night was then very clear: but I did not sit up long enough to see the occultation itself.

(11) The next Eclipse, or Occultation was that of *Aldebaran*, by the Moon, between *Octob.* 11th and 12th a little before midnight; and visible over all the *Roman* Empire. But it was so cloudy in *Rutland*, where I still was, that no sight of it could be had by any body there.

(12) The

(12) The next ſmall Eclipſe, if I may ſo call it, was that curious Phænomenon, the tranſit of *Mercury* over the Sun; viſible over all the *Roman* Empire. With the explication of which, and of the great uſe ſuch tranſits may ſometimes be, in order to diſcover the parallax and diſtance of the Sun, I began my Aſtronomical Lectures this laſt Winter. This tranſit happened *Octob.* 31st. It began about 9^h 25′. and was at its middle about 10^h 48′ $\frac{1}{4}$. and ended about 12^h 11′ $\frac{1}{2}$. and ſo laſted about 2^h 46′ $\frac{1}{2}$. And although the day was, for the main, cloudy with us at *London*, yet did ſome careful obſervers ſee, very nearly, both the ingreſs and egreſs of the planet: though they could not ſee a great deal of its paſſage over the ſun it ſelf. By the favour of one of which obſervers, I had the ſatisfaction of ſeeing it my ſelf in *Fleetſtreet*, through a ſmoaked glaſs, and a good teleſcope, ſoon after *Mercury* was come upon the body of the Sun. As I, and many more had ſeen it, for a great while together, upon that body, *Octob.* 29. 1723. till Sun-ſetting. And as the curious in Aſtronomy may hope to ſee it upon the Sun again *April* 25. 1753. and *Venus*, *May* 26. 1761. As the forementioned ſcheme will inform them. The principal uſe of which tranſits, already mentioned, with its demonſtration, is fully given in that ſcheme.

(13) The next Eclipſe, or Occultation was that of *Aldebaran*, by the Moon, *Jan.* 2. $173\frac{6}{7}$. about 40′ paſt one in the morning: and was viſible over all the *Roman* Empire. But it was too cloudy to be ſeen with us at *London*. Though this and all the reſt of ſuch Phænomena were probably well ſeen in other parts of *Europe* and *Aſia*, within the bounds of that Empire.

 (14) The

(14) The next Eclipse was that famous one of the Sun, *Feb.* 18. $173\frac{6}{7}$. visible over all the *Roman* Empire. It began at *London* about 26′ past two in the afternoon; and ended about $3' \frac{1}{2}$ past five: and was in its middle about $44' \frac{3}{4}$ past three, and ended about $3' \frac{1}{2}$ past five: and so lasted about $2^h\ 37' \frac{1}{2}$. It was here scarcely 10 digits: but in *Rutland* at least $10 \frac{1}{3}$ digits. While, in the north of *Ireland*, and a little north of *Edinburgh* in *Scotland*, the utmost north-western limit of the *Roman* Empire, there was a most uncommon and curious sight: about half a digit round the body of the Sun being not Eclipsed by the Moon; which was then too small to cover it all over: and so there appeared an *annulus* or *ring* of light round the body of the Moon. Whence such Eclipses are denominated *annular* Eclipses. This sight, as very few of mankind ever see, so have not we of *London* seen it, I think, for several generations. Nor are any here, I believe, likely to see it, till *March* 21. 1764. about 40′ after ten in the morning. When the centre of such an annular shadow will pass near *Lisbon*, and *London*: and when the breadth of the annular light will be larger than it hath been any where in the Eclipse before us. Now although this Eclipse *Feb.* 18th could be no where total, yet would its shadow reach as far as *Euphrates*; and exhibit a partial Eclipse of the Sun to all the regions within the bounds of the *Roman* Empire, as I have already noted. These two annular Eclipses of the Sun are so remarkable, that they are among those eight eminent Eclipses, whose paths I drew upon a Map of *Europe*, and published *A. D.* 1733. To which I refer

refer the inquisitive Reader, who desires to know more about them.

(15) The next Eclipse or Occultation was that of *Aldebaran*, *Feb.* 25th about six in the evening. It was a clear night, and the occultation was well observ'd. It began 5′ later, and ended 5′ sooner than the best calculation had determined beforehand. Which shews that the Moon's Latitude hath not yet arrived at the utmost accuracy of determination. Which indeed appears to be true also by the observation of the foregoing Eclipse at *Edinburgh*; when, as I am informed, the path of the centre went sensibly north of that city: whereas it was rather expected to have passed somewhat south of it.

(16) I now proceed to give some account of that Comet; which was the only curious phænomenon wanting to render this great year sufficiently remarkable: and which I was accordingly all along very desirous of seeing, for that reason. I do not mean to give here an account in general of the *Theory of Comets*. That I have several times done already, from Sir *Isaac Newton*, and Dr. *Halley*, in my *New Theory*, and its *Appendix*: in my *Lectures* at *Cambridge* upon Sir *Isaac Newton*'s Philosophy: in my *Solar System*: and in my *Astronomical Principles of Religion*: To which I must therefore refer the inquisitive Reader. But to come now to the historical account of the Comet before us.

This Comet, as I have already said, was foretold to come about this time by Sir *Isaac Newton* many years ago. The first appearance of it, that I have yet heard of, was on *Jan.* 29th last: when it was seen both at *Gibraltar* and *Lisbon*. At the latter of which places it was observed

obſerved at 6^h 49′ p. m. to have had 5°. 15′ altitude: when *Venus* had 20°. 40′ altitude: and was 18°. 5′ diſtant from the Comet. Whence its place was computed to be ♓ 13°. 38′. and its latitude north to have been 3°. 59′ 40″. Though a ſomewhat leſs latitude agrees better with other obſervations. The tail was then like a bruſh, of ſome conſiderable length: and all was ſeen by the naked eye. It was alſo ſeen by the naked eye, and through a ſhort teleſcope, in the weſt of *England*, from *Feb.* 4. And was there on *Feb.* 12. ſeen about 6 or 7 degrees below *Venus*; and a little on the ſouth ſide of a perpendicular from *Venus* to the Horizon. When the length of its tail was eſtimated to be about 2 ½ or 3 degrees. It was alſo ſeen by an aſtronomical friend of mine at *Weſt Horſely* in *Surrey*, *Feb.* 5. It was then ſo ſituate, as to be almoſt exactly under *Venus*, and about 10 or 11 degrees from it: and was ſeen both by the naked eye, and through an 18 foot teleſcope. It was in the ſame place ſeen, *Feb.* 12th. much nearer to *Venus*; and tending to the ſouth; but near a ſmall teleſcopick ſtar: which in two day's time it deſerted, and left at ſome diſtance behind it. It was there ſeen alſo every clear evening through the teleſcope till the 25th. and even on the 26th and 27th. which were clear evenings alſo, it ſtill appeared; though very obſcurely; by reaſon of the neighbourhood and brightneſs of the Moon. And the tail, which had at firſt appear'd about 2°. long, was now become very ſhort; and the nucleus very obſcure alſo. The ſame Comet was ſeen by more than one curious obſerver of my acquaintance *Feb.* 15th. when it paſſed a little north of the principal ſtar or knot in that *linum* or *rib-*

band

band which joins the two northern fishes together: as also it was noted then to make nearly a right angle with *Mencar*, in the mouth of the *whale*; and with *Venus:* which was then about 21°. in *Aries*, and about 1°. 45′ north latitude. It was farther observ'd at *Newcastle*, *Feb.* 22d. to pass between the stars γ and ξ in the *whale:* and to cover the intermediate star ν, which is nearly 4°. in *taurus*, and about 9°. $\frac{1}{4}$ south latitude. On *March* 4th it was seen by another astronomical friend of mine near *London:* and that when it made nearly an equilateral triangle with the *Pleiades* and *Aldebaran*. On *March* 7th it was seen by another astronomical friend on *Tower Hill*, with an eight foot telescope; but very obscurely. On which evening I had a great deal of company with me; and tried hard both to see it myself, and to shew it my auditors: and this chiefly with my Longitude Telescope, of about nine foot long, and seven object glasses; and one very broad eye glass. But all was in vain. The following evenings were too cloudy or misty at *London* to afford a sight of so small a remainder of this Comet as was then in being. However, on *Saturday* evening, *March* 12th. which was very clear, I took two of my sons with me, and two other persons, and went to the purer air of *Hampstead*, and made all the essays possible, with the forementioned Longitude Telescope, to discover what remained of this Comet: but still all in vain. Yet was it seen at *Oxford*, by an accurate observer, so lately as the 20th about 4°. in *Gemini*, and that as going directly to the stars in the head of *Orion*; which is, I suppose, the last time it will be seen at this time. Nor has our famous Astronomer Royal

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at *Greenwich*, Dr. *Halley*, been ever able to ſee it; any more than my ſelf. He was forced, in ſome meaſure, as well as I, to look for it through the vapours of *London*, in this Comet's weſtern ſituation from him, and was not ſufficiently apprized where to look for it neither. Which I ſuppoſe to have been the proper occaſions of his not diſcovering the ſame alſo. And ſo much for the bare hiſtorical part.

The reſult of the whole is this: that the Comet has been ſeen, in clear evenings, which yet have not been very many with us, for fifty days together, from *Jan.* 29th to *March* 20th. that during this time, it paſſed, in its aſcent from the Sun, about 80 degrees of a great circle, along its own orbit, to appearance: that is it went about 1°. 36′ in a day: and this from the 14th of *Piſces*, through the ſigns *Aries*, and *Taurus*, to the 4th of *Gemini*. That therefore its courſe was direct; or according to the order of the ſigns: and that it made an angle with the Ecliptick of about 13 degrees and that its deſcending Node was about the 22d of *Piſces*: or but 8 degrees from the point of the vernal Equinox itſelf: and that it has been viſible over all the *Roman* Empire.

It remains now to enquire, When this Comet came before? and whence it was that Sir *Iſaac Newton* was able to foretel its return ſo long beforehand?

Now here it muſt be allow'd, that this is none of thoſe 24 Comets whoſe catalogue we have in Dr. *Halley*'s famous *Cometographia*; and whence their orbits are deſcribed in my *Solar Syſtem*. It muſt alſo be allow'd, that Sir *Iſaac Newton* could no other way foretel the return of this Comet, than as he ſome way had diſcovered

covered its having formerly appear'd, at more than one certain interval of time backward: which neither Dr. *Halley*, nor perhaps any other Aſtronomer had obſerved. It has indeed been propoſed, that the characters of the Comet of 1556. which is in Dr. *Halley*'s Catalogue, and thence in my *Solar Syſtem* might be examined. I have examined them accordingly. And find, that although this Comet be *direct*, as that was: and although this has its *Nodes* in, or very near the ſame places; yet is the angle which this orbit makes with the Ecliptick, of hardly 13°. ſo different from the angle of the others orbit, of above 32°. that we cannot ſuppoſe them to be the ſame Orbit, or the ſame Comet.

Nor could that Comet in 1556 be viſible ſo high as 4 degrees in *Gemini*, as this has been. So that this Comet cannot be the ſame with that. There was indeed a Comet that appeared *A. D.* 1530. and after twice 69 years another Comet appear'd *A. D.* 1668. which laſt has been already mentioned, as having its Tail ſeen by *Caſſini* and others; and the Comet itſelf by ſome in the more ſouthern parts alſo. And this has now appeared nearly after another 69 years. If theſe two former Comets were one and the ſame, there will be little reaſon to doubt but this is one and the ſame with them. But then, the former of them firſt appearing in the morning in *June*, and afterward in *Auguſt* and *September* in the evenings; and running through *Cancer*, *Leo*, and *Virgo*; and not diſappearing till it was gotten into *Libra*, could not, I think, be the ſame Comet with either that in 1668. or this in 173$\frac{6}{7}$. which have been chiefly confined to the *Whale*, and to the ſigns of *Aries* and *Taurus* thereto belonging. But then, that Comet which

Aristotle saw A°. 372. before the Christian Æra, has been justly supposed by the great *Cassini* to have been the same with that which was seen 1668. and this from their magnitude, figure, motion, and situation among the stars. And that this last Comet is the same with that seen by *Fracastorius* in *September*, *October*, and *November*, *A. D.* 1532. of which he gives us a full and distinct account in † the words set down in the margin, will be very plain upon the comparison. They both took the same direct course

† "The second Comet that I saw, says *Fracastorius*, *Homocentr.* Sect. III. *Cap.* 23. pag. 211, 212. "was *A. D.* 1532. "It always rose before the Sun. Its star was thrice as large "as *Jupiter*. Its hair or beard was of the length *brachionem duorum, of two ells*. It was first seen the 22d day of "*September:* and lasted till the 3d of *December:* which were "about 71 days. [Or rather to the 4th of *November* only; which were about 42 days.] Now from the time "that we began to observe it with instruments, the Comet "was at first about 5 degrees in *Virgo*, with 6 degrees south "[north] declination from the Equinoctial: and 15 [5] "degrees latitude from the Ecliptick. Soon afterward it "appear'd in the 7th of *Virgo*, with 3 [6] degrees of declination from the Equinoctial: and 14 [4] degrees of latitude from the Ecliptick. After some time it appeared "about the 11th degree of *Virgo*, with 1°. 31′. south declination from the Equinoctial [latitude from the Ecliptick] "and 12 [5°] from the Equinoctial. After some time it "was 12 degrees in *Virgo:* and afterward 17. and then appear'd 4 degrees north of the Equinoctial, and 3 degrees "south of the Ecliptick. But on *Octob.* 12th it was 21 degrees in *Virgo*, and 3°. 30′. north of the Equinoctial; but "with no latitude from the Ecliptick. On the 14th [24th] "it was 12 degrees in *Libra*, and 2°. north of the Ecliptick: "but 2°. south of the Equinoctial. On *Novemb.* 4th it appear'd 8 degrees in *Scorpio*, and 6 degrees south of the Equinoctial. But it was now small, and almost vanished "away. And on *Decemb.* 3d. it was intirely gone." [Some parts of this description want great corrections, which I have made in brackets accordingly, from the analogy of the rest.]

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in the heavens. They both made much the ſame angle with the Ecliptick: they both have had their Nodes about the very ſame places of the Ecliptick: their tails were the one longer and brighter, near the Sun; and the other ſhorter and duller when more remote from him, as ought to be expected. Their velocity was ſomewhat greater than that of *Venus*, or 63°. in about forty two days for the former: and 80°. in fifty days for the latter. And the ſigns they went through the very ſame ſigns that a Comet deſcending about *October*, compared with the ſame Comet aſcending about *February*, ought to paſs over, becauſe in theſe caſes the earth was on different ſides of that orbit. Nor is there much reaſon to doubt but they are both the ſame Comet that appeared to *Ariſtotle* and *Caſſini*; excepting the change to be made in *Caſſini*'s period: which is much more likely to be 68 years, than barely 34. Nor have we any example of ſo ſhort a period: nor could one that came twice round in the compaſs of the life of one man be well ſuppoſed to be ſo very ſeldom ſeen as this has been. Nor is it known upon what foundation *Caſſini* could ſuppoſe a Comet that came only 2039 years before, ſhould have ſo very ſhort a period as only 34 years, and that without any deficient or redundant months or days alſo. It is much more agreeable to the analogy of the other Comets, to ſuppoſe its period to be twice 68 years, or 136. than half of them, or only 34. But here *Caſſini* is to be in part excuſed, if he wrote before Sir *Iſaac Newton* and Dr. *Halley* had diſcovered that Comets have certain periods; and thoſe from 575 years of the longeſt, to 75 or per-

haps now to 68 years of the ſhorteſt period. But then, if this objection be made, that however the former 30 periods, from the days of *Ariſtotle*, to the days of *Caſſini*, may be 68 years very nearly; yet this laſt period muſt be 68 years, and above 10 months: which will not well agree to the reſt; Take the Anſwer from Dr. *Halley:* who obſerves a ſtill greater inequality of periods in that Comet, which he eſteems to have returned *A. D.* 1456. 1531. 1607. and 1682. and which he confidently expects again 1758. See the *Latin* Edition of my *Lectures upon Sir* Iſaac Newton's *Philoſophy*, pag. 358, 359. where the ſecond period is above a year larger than any of the reſt. And yet he juſtly gathers, from the agreement of all the other characters, that it was the very ſame Comet: and ſhews how ſmall an attraction from other celeſtial bodies may occaſion ſuch errors in the periods of Comets, as that of a ſingle year only. But ſtill, if the queſtion be aſked, upon the ſuppoſition that Sir *Iſaac Newton* believed, with *Caſſini*, that the Comet ſeen by *Ariſtotle*, and by *Caſſini* were one and the ſame; and upon the ſuppoſition that the Comet ſeen by *Fracaſtorius* was the ſame with them both; which hypotheſes ſeem to me highly probable: why he ſhould prefer the period of 68 years, before its double 136 years? ſince it was ſo long between the former times of this Comet's appearance, *A. D.* 1532. and the next of 1668. (for we hear nothing of it in, or about the intermediate year 1600.) I gueſs his true reaſon to have been this, that he thought it more likely that it paſſed by unobſerved in the year 1600. and that it would come to ſignalize this great year 1736. than be deferred

deferred till the common year 1804. Though I ſuppoſe his uncertainty about thoſe two periods occaſioned his caution in determining the ſame: and made him almoſt ſuppreſs his diſcovery of any expectation he had of its coming about this time.

N. B. The Orbit of this Comet, upon the compariſon of *Fracaſtorius*'s and our preſent obſervations, ſeems to be very nearly in the poſition of that moſt eminent one of 168$\frac{4}{5}$. Only its plane is not near ſo oblique to the plane of the Ecliptick as the other. Nor did it come by any means ſo near to the Sun in its perihelion as that did: nor is it, by conſequence, near ſo narrow a parabola as that was. See my *Solar Syſtem.*

N. B. So far as we yet know, Sir *Iſaac Newton* is the very firſt man; and this the very firſt inſtance; when the coming of a Comet has been predicted beforehand; and has actually come according to that prediction; from the creation till this very day.

(17) The next Eclipſe, which I add as an *Appendix* to thoſe of the foregoing year, was that of the Moon, on *Saturday*, the fifth of this month of *March:* and ſtill in the ſame year 1736. according to our Legal and Eccleſiaſtical computation: between four and five a clock in the afternoon: and was over a little before the Moon roſe at *London*, and ſo was to us inviſible. But then this Eclipſe was ſtill viſible to all the eaſtern parts of the *Roman* Empire: and the Moon roſe to them under the Eclipſe itſelf. Where alſo ſomewhat above one half of the Moon's diameter was darkened.

(18) The

(18) The laſt Eclipſe, or Occultation that any way belongs to this year, and with which I ſhall conclude, is the occultation of *Aldebaran*, juſt at midnight, between the 24th and 25th day of this month of *March*, and viſible over all the weſtern part of the *Roman* Empire: though the clouds have hindered us from ſeeing it at *London*. So that the old legal or eccleſiaſtical year 1736 went out; and the new year 1737 comes in, during the time of this occultation itſelf. Which is a remarkable aſtronomical memorial of the exit of this great year, in its utmoſt duration, to all poſterity.

N. B. It is worth our while here alſo to take notice of the very uncommon ſituation of the heavens at the exit of this great year. The Moon having very lately been in conjunction with the Pleiades, and next with the evening ſtar, *Venus*; then applied itſelf to the Hyades: and about midnight, paſſed over, and eclipſed their principal ſtar, *Aldebaran*. A little after which it came to a conjunction with *Saturn*: and ſoon afterward with the Comet, juſt becoming inviſible: and then with *Mars*. Inſomuch that a ſmall circle, of about 14 degrees radius, will then include no fewer than four of the ſeven Planets, with the Pleiades, and Hyades, and the Comet itſelf alſo. Which is ſuch a collection of celeſtial bodies cloſe together, as is not to be paralleled in many generations.

N. B. It is worth our while to obſerve farther, that all the conſtellations mentioned in ſcripture: either in the *Kings*, in *Job*, in *Iſaiah*, or in *Amos*, were then, and have been for ſome time very viſible every night ſouth-weſtward. I mean the *crooked Serpent*, or *Draco*: *Kimah*, or the *Pleiades*:

Pleiades: *Kesilim*, or the *Hyades*: *Hash and his sons*, or *Orion*: and *Mazeroth*, or the *Great Dog star*. See the IVth of my VI. *Dissertations*, pag. 221. Nor was there ever a more glorious prospect of this kind to be seen in the sky, than every clear evening has lately presented us withal, southwest, and westward: and which hath continued for some time, even past the next full Moon, till the length of the days, and of the twilight, do now gradually diminish that their glorious appearance.

N. B. I say little of those *northern lights* which have in former ages been so rare, but are of late become so frequent, as to be little regarded. Nor can I tell why several of them about *November* and *December* were of so unusual a red and fiery colour. No more than I can say any thing in particular to the unusual number of double Halos, mock suns, inverted rainbows, *&c.* observed about the same time. Nor indeed can I tell whether what I call the Sun's *Milky way*, mentioned by Mr. *Childrey*, and visible now near a century, be a new phænomenon; or was in being, but not noted, in ancient times. All which things I only mention, as deserving not to be wholly overlooked by considering men: and particularly not by me, now I am upon such natural and astronomical, but still most remarkable phænomena of this great year. Time will discover whether these be not providential also. See *Josephus*, *Of the Jewish War*, L. VI. *C.* 5.

But now, as to the principal point I have all along in view; and the main use I would make of the numerous and extraordinary astronomical phænomena of this great year 1736. for the

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marking out some great designs of providence; the foundation of what I have to say is contained in an observation of very great consequence, made by me several years ago. Which take in my own words, from the IVth of my VI. *Dissertations*, pag. 248. as follows:

" XXIII. I observe, that as the downfall of " the first, *i. e.* of the *Assyrian* or *Babylonian* " Monarchy; with the several captivities of the " ten, and of the two tribes of *Israel*, were fore- " told by *Amos*, *Isaiah*, and *Jeremiah*, as hav- " ing both frightful Eclipses, and sometimes " terrible earthquakes also, as signals of their " approach; and all still about 38 *years before-* " *hand:* which we have already seen: so do " we find, that both the *partial* and the *total* " downfalls or destructions of every one of the " four Monarchies, the *Assyrian* or *Babylonian*, " the *Medo-Persian*, the *Grecian*, and the *Ro-* " *man* were ushered in, and sometimes, in part, " occasioned by the like Eclipses *immediately* " *beforehand*; sometimes in a natural, sometimes " in a supernatural way. And so that the in- " termediate *breaches* made upon the several " Empires were constantly introduced by *great* " *Eclipses of the Sun:* and their final *periods* by " great Eclipses of the Moon, still visible over " the same Monarchies. As the calculations there set down do demonstrate.

Take also this additional Note out of the same treatise: which follows the several astronomical calculations, *pag.* 262.

" *N. B.* That such a regular correspondence " of Eclipses, *Total Eclipses of the Sun*, just be- " fore the *grand breaches* upon every one of the " four Monarchies; and those all visible through " those

" those Monarchies: as also, That such a re-
" gular correspondence of Eclipses, total Ec-
" lipses of the Moon, just before the *Ends* of
" every one of the same four Monarchies: and
" those all visible through those Monarchies:
" should be all *by chance*, and *without design*, is
" plainly incredible. And if that be incredi-
" ble, this correspondence can be no other
" than directly *supernatural* and *providential*.
" *Known unto God are all his works from the be-*
" *ginning of the world.* Act. xv. 18."

N. B. It would be invidious and offensive to many, if I should here declare too particularly my own thoughts or suspicions concerning the purport and meaning of the several providential correspondencies relating to this great year. They shall be, for the main, reserved for the second Edition of my *Essay on the Revelation of St.* John; which has been now almost a year ready for the press: and which I intend ere long to republish, with great corrections and improvements. Only I do not at all scruple letting my greatest and best friends so far know my opinion, that these phænomena all seem to me to conspire as happy *signals, of the End of all persecution in* Great Britain. However, it can be no way offensive to take notice, that during the introduction of the Protestant Religion into *Germany*, and thence into other Parts of *Europe*, *A.D.* 1530. 1531. 1532. and 1533. there appeared no fewer than six Comets: one of which proves to have been the very same with this before us: and to wish that the return of this Comet at the end of this great year, may be, among the rest of the astronomical phænomena thereto belonging, introductive of the old primitive Christian Religion

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into *Britain*; and the other parts of *Europe*: that so gradually the *Kingdoms of this world may become the Kingdoms of our Lord, and of his Christ; and he may reign for ever and ever. Amen. Amen.*

April 15. 1737.

WILL. WHISTON.

FINIS.

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5. Præ-

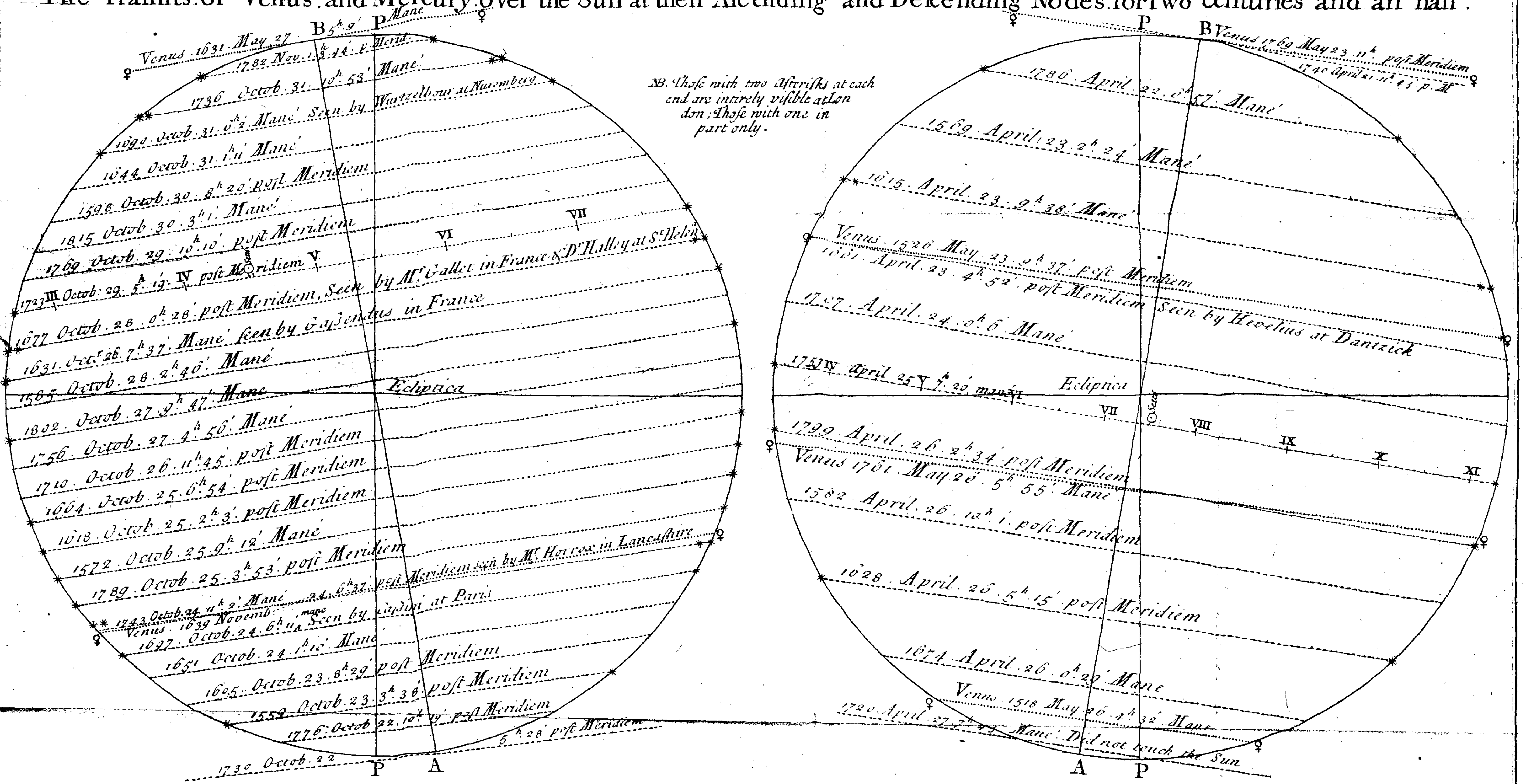
There, Good Reader, against the Transit of Mercury October the 31st Present thee with Two Schemes; containing all the Transits both of Mercury and Venus over the Sun during 2½. Centuries; as they are nicely stated by our Great Astronomer Dr Halley, in ye Philosophical Transactions No 193 and No 348 and Epit. Vol. I. p. 427 – 436. The principal Cycles or Periods of such Transits are. in Mercury 13. 46 and 263 Years. In Venus 8. 235. and. a Period made up of those two. of 243 years; with one made up of ye two last of 178 years. These Transits are no other than very small. but very remarkable Eclipses of ye Sun. and are among the most curious Phænomena of Astronomy: Especially as thus reduc'd to regular Periods; and exhibited to the View of the Reader in a proper order. without any Difficulty of Calculation. which method might also be made use of for the very remarkable Cycle or Period of the Revolution of Solar and Lunar Eclipses. mention'd by Pliny. and containing 223 Lunations. or 18y. 11d. 5h. 43′⅓ of which I treat more largely in my Paper about Eclipses formerly publish'd. The great Use of these Transits of Mercury and Venus; I mean especially of those at the Descending Nodes; is no less than the Compleat Discovery of the Magnitudes and Distances of all the Heavenly Bodies whatsoever. by the exact determination of the **Suns Parallax.** or Angle which the semidiameter of the Earth subtends to an eye at ye Sun. on which they all intirely depend: And that; at least in the Transit of Venus 1761. as Dr Halley has proved; to the 500th part of ye: Parallax. A degree of Accuracy this not to be in the least hoped for from any other method whatsoever. Tis true. Dr. Halley. in a manner discards Mercury, and confines his hopes for the next age to that Transit of Venus 1761. For which I see. very little foundation. And I Venture to say, that if this method had been put in practice, even since the invention of Telescopes, at the Transit of Mercury 1601; or especially at that 1707 we had not been now to seek for the exact solution of this famous Problem.

Nor need we. I think waite quite so long as that Transit of Venus 1761. since that of Mercury, 8 years sooner, 1753 is capable of abundantly satisfying the curious as to that discovery. Venus indeed affords us a greater Parallax than Mercury: and is on that account better fitted to this purpose. But then, At the descending Node its Parallax is not double to that of Mercury. And when I consider that Mercury. as Dr. Halley himself Observes, is free from all inequality of motion from the other Planets; that it is somewhat longer in the duration of its Transit; That the place of its Nodes, and the inclination of its Orbit. are by several the like observations. better known than those of Venus: that the instantaneous appearances of its entrance and its exit have been tried; which has not been done in the other; and that Mercury in 1707 did go; and in 1753 will go much nearer to the Suns Center than Venus 1761; I confess I know not whether. all things consider'd. these Transits of Mercury are not better fitted for the discovery of the Suns Parallax than the other. As it is very plain they cannot come very short of them. Accordingly I have Particularly fitted the following Demonstration to the same Transit of Mercury 1753: altho it will with a little variation extend to all the like Transits. of either Mercury or Venus whatsoever. —

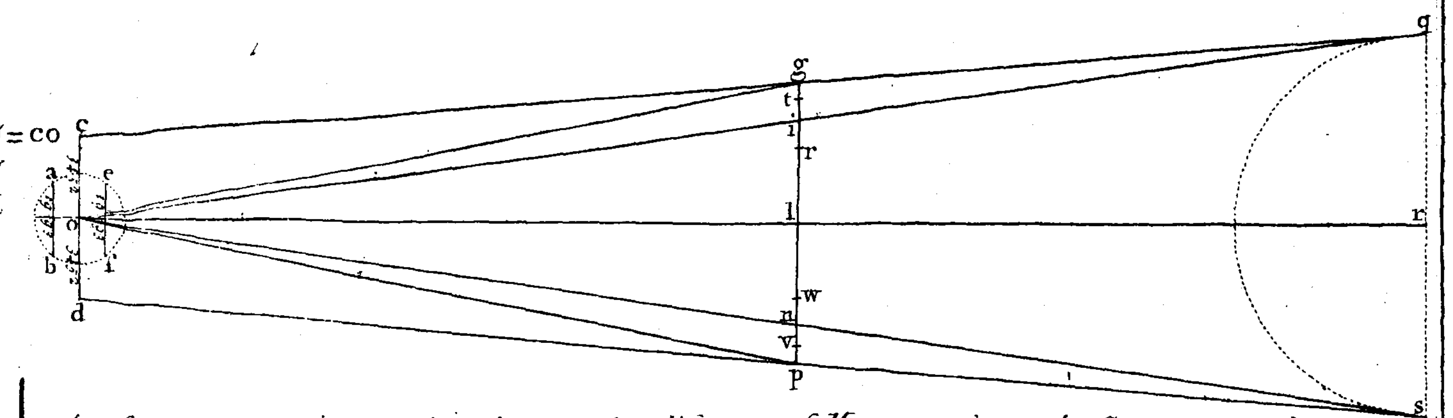
The XXIV Eclipses of the great Year 1736 beginning with March: for the Meridian of London.

1 ☉ March	1 . 2 . 36	p.m.	invisible		9 ♂ Octob.	6 . 2 . 30	mane.	visible		17 Hyades August	17 . 9 . 44	mane.	invisible	
2 ☽ March	15 . 11 . 58	p.m.	total	3h 37	10 ☿ Over the Sun	31 . 10 . 53	mane.	visible	2h ¾	18 Hyades Sept.	14 . 4 . 57	p.m.	invisible	
3 ☉ March	31 . 7 . 0	mane.	invisible		11 Hyades March	7 . 2 . 26	p.m.	invisible		19 Hyades Octob.	11 . 0 . 10	mane.	visible	
4 ☉ August	25 . 9 . 0	mane.	invisible		12 Hyades Apr.	3 . 9 . 39	p.m.	visible		20 Hyades Nov.	7 . 7 . 23	mane.	invisible	
5 ☽ Septemb.	9 . 3 . 11	mane.	total	4h 12	13 Hyades May	1 . 14 . 52	mane.	invisible		21 Hyades Dec.	5 . 2 . 36	p.m.	invisible	
6 ☉ Septemb.	23 . 5 . 37	p.m.	4 digits		14 Hyades May	28 . 0 . 5	p.m.	invisible		22 Hyades Ian.	1 . 9 . 49	p.m.	visible	
7 ☉ Febr.	18 . 2 . 31	p.m.	10 digits		15 Hyades June	24 . 7 . 16	p.m.	invisible		23 Hyades Ian.	28 . 5 . 2	mane.	invisible	
8 ♀ April	27 . 1 . 0	p.m.	visible		16 Hyades July	21 . 2 . 31	mane.	visible		24 Hyades Feb.	25 . 0 . 15	p.m.	invisible	
NB. 1737 ☽ March	5 . 0 . 35	p.m.	invisible											

The Transits of Venus and Mercury over the Sun at their Ascending and Descending Nodes for Two Centuries and an half.



Now The Parallax of the Sun is by this Transit thus to be discovered, in imitation of the Diagram of Hipparchus. Let the Semidiameter of the Earth be supposed, as it is, 3985 English statute Miles. Let eabf be the Parallel of 60, whose radius is therefore 1993 such miles. Let ab and ef be Chords each of 8 hours. or 120 degrees = co = 3452 miles. qs is the Suns Chord or Diameter: gp the line of the transit of Mercury over that Chord or Diameter. from g towards p. Tis then evident that if there were two Spectators at c and d. without any Diurnal motion, they would have ye same Angle for the apparent Chord or Diameter of the Sun with a Spectator at the Earths center; qos = 31′. 54″ = 1914″. and the same Duration of the Transit from i to n as suppose 8h = 480′ = 28800″. of time. But since the Spectator at a in Hudsons streights, westward, after he has seen the ingress at t before Sunsetting, during those 8 hours will be carried by the diurnal motion of the Earth, to b. to see the egress after Sun rising at v: and He at f. in the Meridian of Pekin, Eastward. that saw the ingress at r in the forenoon will be thereby carried in contrary direction to e. to see the egress at w in the afternoon. Here will be a double Parallax. answerable to the time and angle of ye transit along tr and vw. the one in excess; the other in defect; and both the very same as if a single spectator had seen the ingress when He was at c. at ye point g: and the other when he was at d. at the point p: as compar'd with a Spectator. that continued at the center o all that time. Let us then suppose in the Half Sum of their two durations, and angles to be as before. 28800″ of time: and 1914″ of angular measure (for their additions and substractions being equal. those quantities will not be altered:) And Let us suppose their difference 2gi to be 4′ = 240″: of time. Say then, As 28800″ of time; to 240″ of time :: so is 1914″ of Angular measure. = ion : to 16″ = 2goi and goi = 8″ which with ye Angle gqo. (bearing



the same proportion to this that gq the distance of Mercury from the Sun = 453 bears to go ye distance of ye Earth from Mercury. = 557 = cgo = 9″. 46‴. is 17″⅔ which is ye angle of the Parallax of Mercury. as subtended by 3452 miles. Now if this be increas'd as ye Earths semidiameter 3985 to 3452. we shall have Mercurys true Parallax at that time = 20″½ And by consequence, The Suns Parallax; which is in ye reciprocal proportion of their distances; or as 453 to 1010 will on this hypothesis be = 9″. 12‴. QEI. NB. The exactness of ye angle goi here. depends on ye exactness of ye time of ye observation of ye first and last thread of Light between Mercury and ye Suns limb: which, as Dr. Halley at St Helena. found upon trial; is instantaneous. and to be noted nearer than to a single second: that is nearer than to ye 15th part of a second in angular measure: while in any other Astronomical Observation of such angles whatsoever. we think it sufficiently exact. if it secure us within five or even 10 intire seconds. Will: Whiston. Feb: 21. 1735/6

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