PHILOSOPHICAL TRANSACTIONS.

XII. *Magnetical Experiments made principally in the South part of Europe and in Asia Minor, during the years* 1827 *to* 1832. *By the Rev.* GEORGE FISHER, *A.M. F.R.S.*

Received November 3, 1832. Read January 24, 1833.

I. *Experiments to determine the relative Magnetic Forces soliciting a Magnetic Needle, suspended horizontally.*

THE forces were determined by a comparison of the number of vibrations made by several needles at each place. They were vibrated in a box, in the vertical sides of which were fixed narrow strips of glass, having on each of them a fine vertical line drawn by means of a diamond; by the coincidence or parallelism of these lines with the silk fibres by which the needles were suspended, also by making their extremities coincide with two fixed points on the bottom of the box, their horizontal position was insured. The first semi-arc of vibration was ten degrees, and the last two.

As the magnetism of needles is increased as the temperature is diminished, and vice versâ, it becomes necessary to reduce the experiments to the same standard. But since the law or relation existing between the changes of temperature and the corresponding increments and decrements of the magnetic intensity is not precisely known, and will moreover in some degree vary with the shape, size, &c. of the needles employed; it is better to avoid as much as possible the necessity of any correction, by making the experiments at nearly the same temperature.

The principal objection to the use of horizontal needles for the purpose of determining the comparative magnetic forces in the direction of the dipping needle, arises from a knowledge of the dip being required. For although they admit of great delicacy of suspension, yet in high latitudes this objection is, for obvious reasons, insuperable, and their use inadmissible for this purpose.

The determination of the forces in the direction of the dipping needle was also effected by direct experiment, with three needles attached to an excellent dipping instrument made by DOLLOND. The first semi-arc of vibration in this instrument was 40°, and the last 10°; and the number of vibrations between these limits was generally about 80 with each needle. Many observers, I am aware, are in the habit of observing the vibrations of their needles in much smaller arcs, for the purpose of obtaining a greater number of vibrations, as well as making the times of vibrations approach nearer to isochronism, and thereby rendering corrections for the circular arcs less necessary. Desirable as these objects are, yet considerable experience in the use of these instruments has convinced me, that very little reliance can be placed on the vibrations of needles when the total arcs described are less than about 20°. Such, at least, has been the case with those which I have used, which have been very numerous, and of the best construction.

To those much accustomed to experiments with dipping instruments and other instruments for magnetical purposes, it may be needless to state the necessity of ascertaining by experiment, that the metal of which they are constructed exerts no assignable influence on the needle; at least such influence as may cause it to deflect from its true dipping position, or in any way affect the time of its completing a given number of vibrations. This can be readily ascertained by placing the instrument, with the centre-work removed if necessary, in a horizontal position, and by suspending within it either one of the needles belonging to it, or another of the same length, by means of a long fibre of raw silk. If it be found that the time of performing a given number of vibrations of the needle when thus placed within it, is the same as when the instrument is detached from it, we may infer that no such influence exists.

To avoid the objection arising from the influence of metal upon the needles, several dipping instruments have been constructed of late years of wood and card, some of which are of the usual form, and in others (in order that the friction which arises from the transverse axes of the needles when vibrating upon agate edges may be removed,) the needles are supported by fibres of silk, secured at each end of the axes by means of a small hook or notch, which having the degree of tension necessary for its support, and also by an arrangement of the instrument resembling the equatorial movement of astronomical instruments, the needles are made to vibrate in any plane at pleasure. Ingenious as these contrivances are, they are subject to several inconveniences; and a very material one arises from the effects of temperature and humidity upon the frame and centre-work of the instrument. That which I had of this construction was in Levant and Siroc winds perfectly immovable from this cause; which, together with the effect of torsion, rendered it little better than useless for the general purposes of a dipping instrument; and I could confirm these objections by the testimony and experience of an indefatigable observer employed on the coast of Africa.

I have been led to these remarks by having witnessed a considerable degree of disappointment expressed by several persons, who in visiting foreign countries have laudably endeavoured by their exertions to add somewhat to the present stock of information upon this subject, and who have found upon their return, that they have in a great measure failed in their endeavours, either from some imperfection in the construction of their instruments, or in the methods of using them: and I cannot but consider, that an unqualified commendation of any instrument whatever, intended for foreign service, particularly for those places which, from many circumstances, can rarely be visited, without thoroughly examining its merits, to be productive of considerable mischief; since it is not only the cause of error, but tends to damp that zeal for the interests of science which travellers have it often in their power to promote.

As experiments of this nature are most frequently made at some of the principal sea-ports immediately before the embarkation of the needles, and at the same places upon their return, in order that the intervals of time may be as short as possible, which is desirable on account of the great variations which their intensities are subject to from rust and other causes; and as other experiments have generally been referred to London, it becomes necessary to know the relative forces between these places, that the requisite reductions may be made. For this purpose a series of experiments were made during the last summer by Captain Sir EVERARD HOME, Bart. F.R.S. near London, and at South Sea Castle near Portsmouth. With a similar view, another series had been previously made by myself at London and at Ryde (four miles from South Sea Castle) in 1830. The mean between both results is probably nearest the truth; from which the horizontal force at London is to the same at Portsmouth as 1 to 1·01755; and the forces in the direction of the dipping needle, as 1 to 1·00416. The dip at each place being 69° 40′ and 69° 23′ respectively.

Had the needles maintained precisely the same degree of magnetism during the whole period of these experiments, the forces might be at once obtained by comparing those made at each place with corresponding ones made in London; but as this was not the case, and moreover from the causes just mentioned will seldom happen in long voyages, it was necessary in this case to compare the experiments made at Gibraltar with those made at Lisbon; and also those made in the various places in the Mediterranean and Asia Minor with corresponding ones at Malta, obtained by means of short runs from this latter place. It is necessary to mention this, since by otherwise combining the experiments different results may be obtained, without attending to this circumstance.

Table I. contains the comparative horizontal forces by a mean of four needles at each place, with a small correction applied for difference of temperature. The last column of this Table contains the same, taking the horizontal force at London equal to unity. Table II. contains the comparative forces in the direction of the dipping needle determined by the experiments made with the horizontal ones; and also the results obtained by direct experiment with the dipping needles. The detail of the latter is omitted, since they are of less authority than the others, in consequence of their poles being constantly inverted for the purpose of obtaining the dip; for though their magnetism was not interfered with between the consecutive experiments, there was not that satisfactory evidence respecting any alteration in their intensities that possibly might have occurred during the intervals which is desirable: the means of both methods are therefore omitted, as the results would be vitiated by the same cause.

The dips contained in the column for that purpose, are the mean results obtained with three needles;—that at Malta, by a long series of experiments made in the years 1828-9: these were made, not only for the purpose of determining the dip with all possible precision, since the greater number of the experiments made in other parts were necessarily compared with those made at this place, but also for the sake of comparing the dip obtained by the different methods of vibration with that obtained in the usual way. The experiments at Malta are given at the end of this paper. In each of these experiments the poles are inverted; a precaution as essential in determining the dip by the methods of vibrations as in any other method.

II. *Experiments on the diurnal variation in the intensity of the Force soliciting a Magnetic Needle, suspended horizontally at Malta.*

These experiments were first commenced on the 27th of November 1828, with the horizontal needle No. 4. used in the foregoing observations, and having the usual silk suspension. It was firmly fixed on a strong table constructed for the purpose, and placed in the centre of a large stone room in Valette, beyond the direct influence of the sun's rays, and was vibrated in the box to which it was fitted. The first semi-arc of vibration was 10°, and the last 2°; and the time of completing one hundred vibrations was obtained by proportion. The times of commencing the 1st, 3rd, and 5th vibrations, also the corresponding ones at the end of the experiment, were observed as before with a chronometer; by which three intervals were obtained in the same experiment, and a mean of them taken for the result.

The experiments were continued without intermission until the 24th of January following, when I found upon examination, that I was unable to trace the least appearance of any progression in the results, as indicating a maximum or minimum, or indeed any change whatever, excepting what appeared to be the errors of experiment: still I was induced to continue them until I had completed three hundred sets of vibrations at different periods of the day and night, in hopes, that having made so great a number of experiments, and by taking a mean of all those made about the same time, the small errors of observation would be so far eliminated as to indicate some result of this kind. In this I was again disappointed, as many of these means were nearly identical, that is, to the nearest tenth of a second. It was evident, therefore, that the daily change of intensity, if any existed, was so exceedingly small as not to be apparent in experiments with this needle, much less the periods of maximum and minimum.

On the 25th of March following, I began another series for the third time, with a much larger needle (one belonging to the dipping instrument), and suspended by a single fibre of raw silk eighteen inches in length; the first semi-arc of vibration was reduced to 5°, and the last semi-arc to 2°; and between these limits the number of vibrations was about two hundred and thirty. In these the commencement of the 1st and every odd vibration to the 29th inclusive, were observed; and at the end of the experiments, the commencement of the 201st, 203rd, &c. to the 229th inclusive: by this means, the time of completing two hundred vibrations was obtained by a mean of fifteen independent observations.

In these, as in the former ones, very little progression appears in any one day's experiments. The differences indeed are so exceeding small, as to render them in some degree a test of the regular going of the chronometer. I will not, however, attempt to assign the degree of accuracy to which a chronometer will measure so small an interval, but merely observe, that every precaution was taken to insure accuracy, by using alternately one of three chronometers by ARNOLD; which were wound up at different periods of the day. A very small correction for the daily rate of each was applied. In one of them, which had the largest rate (—12″), the correction of the measured interval amounted to only one tenth of a second. The following are the mean results, taken as before, about the same period of the day.

Time.	Time of 200 Vibrations.	Therm. FAHR.	No. of Experiments.
h m	″	°	
2 20 A.M.	855·68	65·7	6
8 0	855·27	65·1	18
10 30	855·02	65·4	11
0 30 P.M.	855·15	65·8	11
2 30	854·86	67·3	13
6 0	855·28	67·0	12
10 0	855·58	65·6	11

In these observations, although they do not amount to more than one third the number of the former ones, yet when thus taken in groups, there appears in the means a regularity which was not visible in the former ones. From these it appears that the least horizontal intensity took place about 2^h A.M., and the greatest about 2^h P.M., in April and May 1829. The variation is so very minute, that I offer this conclusion with some diffidence, though I have but little doubt that it will be confirmed by the subsequent experiments of others. I regret that my own were not more extensive.

I have now to mention a source of irregularity which may possibly arise during a series of experiments of this nature, and materially vitiate the results; that is, storms of thunder and lightning. They cause, as far as my experience goes, in general, a diminution in the magnetic intensity of the needles. The observations just mentioned are fortunately exempt from this, from a continuance of fine weather during the experiments.

I had reason on several occasions to suspect this, but as I never had corresponding experiments made immediately previous to a violent storm, to compare with similar ones made subsequently, I was unable to assign with accuracy the period at which this diminution took place, and thereby identify the cause. A violent storm which took place at Malta on the 7th of December 1829, attended with considerable mischief, afforded me this opportunity. I had fortunately, the day before, made a great number of observations with all the needles, for the sake of a comparison with similar ones that I intended to make in other parts of the Mediterranean to which I was about to proceed. I availed myself therefore of the opportunity of ascertaining, during the storm, the effect produced upon the needles. In the results which were obtained, it appears that all of them were affected in a similar way, that is, they all suffered a permanent diminution of their intensities.

III. *On the diurnal Oscillations in the direction of a Magnetic Needle, suspended horizontally at Malta.*

The needle employed in these experiments was twelve inches in length. Every precaution was taken to avoid the influence of iron; and to secure the whole apparatus from damp, and to equalize the temperature around it, it was fixed, and the needle adjusted within it, six weeks before an observation was registered.

The radius of the arc described by the needle was increased from six to ten inches by light pieces of cedar attached to each end of it, and carrying upon their extremities small pieces of ivory, extending to about 4° of arc, and subdivided to every 5′. Opposite to each end of these divided extremities, were placed three vertical hairs, at the distance of 1° apart, and as near to them as could be without touching them. The coincidence of these vertical lines, with the divisions on the white ground of the ivory behind, was observed with extreme distinctness by means of a compound microscope. By this means, the subdivisions of 5′ were again subdivided to single minutes, and by a mean of the six (which constituted an observation), to within a few seconds.

The observations were commenced on the 5th of January 1829, and carried on every hour, from 9^h A.M. to 4^h P.M., to the 21st of the same month: during this period a maximum occurred in the westerly variation, at $0^h\ 30^m$ P.M. nearly. They were recommenced on the 24th of March following, and continued until the 31st, and the needle observed every half-hour, with a few exceptions, from 7^h A.M. to 4^h P.M.; during this interval, the maximum occurred at about $1^h\ 30^m$ P.M., and the minimum at $9^h\ 30^m$ A.M. These results are obtained by taking the means of all the observations made at the same hour, and considering these means as representing the true variation at those hours. They are contained in a Table at the end of the paper. On the 1st of April, another series was commenced, and continued to the 15th. They were made from 7^h A.M. to $4^h\ 30^m$ P.M., every half-hour, and as frequently during the night as could conveniently be done, considering the great labour and want of rest attending experiments of this nature, particularly as they were accompanied by corresponding observations of the times of vibration of another needle.

From these it appears that the maximum westerly variation takes place about $1^h\ 45^m$ P.M.; from this period of the day, it gradually diminishes until about $10^h\ 0^m$ P.M.; from about this time to about sun-rise, it is nearly stationary; after this period a still further diminution takes place, and the minimum westerly variation happens at about $8^h\ 45^m$ A.M., when it again increases to about $1^h\ 45^m$ P.M., and reaches its maximum as before.

The difference between the mean maximum and minimum variation, or the mean amount of the diurnal movement of the needle, in April, was 10′ 12″.

During these observations, several oscillations, or tremulous motions in the needle were observed; and as they are occasionally registered by others, I mention three days on which they were most apparent. January 15, 1829, at $10^h\ 30^m$ A.M., the north end of the needle moved to the westward about 2′ 15″ in ten minutes; the needle exceedingly tremulous; from this period of the day, it moved gradually back to the eastward until 3 P.M., when it again moved suddenly 2′ to the westward, and shortly afterwards back again to the eastward. The mean variation on this day was less than usual. On the 26th of March 1829, at 3^h P.M., the needle was very tremulous, and on the 29th following, at 8^h and 9^h P.M., oscillated considerably.

IV. *Experiments on the bases and edges of the craters of Vesuvius and Etna, and also on Gibraltar Rock and the neutral ground below.*

It has been observed by Baron HUMBOLDT, in describing his experiments to determine the magnet dip, that the heights of the places of observation seem to have a sensible influence on the results; and moreover, that the magnetic forces appear to be modified by the proximity of lavas. He found at Cumana, the capital of New Andalusia, that the dip before the earthquake was invariably 43°·65 (cent. div.); but he was astonished to find three days after the violent shocks of earthquake, that it was no more than 42°·75, and a year afterwards still 42°·80, although the intensity of the magnetic forces had not varied the whole time.

With respect to the influence of height, he observes that BORDA is the only traveller who has compared in an accurate manner the dip at Santa Cruz with that determined at the top of the Peak of Teneriffe*, where he found it greater than at the bottom, which result Baron HUMBOLDT observes was exactly conformable to what he has several times obtained among the Andes; and he suggests, that it probably depends upon some system of local attraction.

* It appears also from a manuscript account of BORDA's voyage to the Canaries, that he found the card attached to his horizontal needle made a given number of vibrations in 97″ at the summit of the Peak, while at Santa Cruz (bearing E. 29° N.) it was 94″, indicating a less intensity on the summit than at the bottom. At the brink of the crater, he observed the westerly variation to be 19° 40′; at Santa Cruz 15° 50′; and at Gomera 15° 45′; which observations indicate a considerable deflection of the needle from the magnetic meridian, arising from some disturbing force.

HANSTEEN found the force soliciting a needle on the top of the round tower at Copenhagen, at the height of one hundred and twenty-six feet, to be much less than in a garden below, which he ascribes to polarity in the building. Similar experiments made at the Pagoda at Kew (which is a brick building of the same height,) by Professor RIGAUD, Sir EVERARD HOME, Bart., and myself, give no such result, nor indicate any assignable difference, either in the dip or in the magnetic force, whether observed on the top or at the bottom.

From whatever cause these differences proceed, whether from the attraction of lavas containing iron ores, from the influence of height alone, or from both causes conjointly; it is evident, that while such extraordinary discrepancies exist, either in the direction of the needle, or in the intensity of the force soliciting it, it will be impossible to reconcile the results of magnetical experiments by means of mathematical formulæ.

With a view of observing these anomalies in experiments of this nature, as well as to gratify my own curiosity, I was induced to make similar ones on Vesuvius, Etna, and Gibraltar Rock. The experiments at Vesuvius indicate a remarkable difference in the variation, observed on the top and at the bottom.

	°	′
By the sun's azimuth at the crater, variation	12	19 W.
By the bearing of St. Francazzo at the crater, variation .	12	5½
——————— Arcera at the crater, variation . . .	12	51½
Mean variation at the crater	12	25⅓

By a great number of observations in the neighbourhood of Baia and Naples, the westerly variation, by the same instrument, was $15° \, 20\frac{1}{2}'$, differing 3° from that observed on the crater at the height of 3400 feet.

The magnetic force on the western edge of the crater was the same as that observed at Naples. That observed half-way up the mountain, at the hermitage on the west side, was a little less.

On the south-eastern edge of the crater of Etna, at the height of 11,000 feet, the westerly variation, by means of the sun's azimuth, was $18° \, 35'$ west. At Catania, on the southern foot of the mountain, it was $16° \, 28'$; and at Messina, on the north-eastern side, it was $17° \, 12'$, with the same instrument.

The magnetic force on the crater of Etna was much greater than either at Catania or at Messina, both with a horizontal needle, and one in the direction of the dipping needle.

At Gibraltar, the experiments on the summit, at the height of 1300 feet, indicate a greater intensity than on the neutral ground below; though one of the needles, probably from some error of observation, appeared to give discordant results. The different periods of vibration are given with the other experiments, in a Table, at the end of the paper.

Upon reviewing the observations made in different parts of the Mediterranean, contained in this paper, a great irregularity will be seen in the numerical results. In proceeding from Malta to Naples, by way of Etna and Messina, it appears that an increase of the whole magnetic force took place in the first half of the distance, which we might have expected; but from Messina to Vesuvius and Naples, a considerable diminution of the intensity was observed; whereas, from their relative geographical positions, we might have concluded otherwise. Upon the whole, as we proceed eastward as far as Constantinople, there appears to be a decrease in the intensities at places having the same dip, similar to what has been observed in the western hemisphere, if we except the observations at Naples and Vesuvius.

Whether these irregularities arise from any inequalities in the distribution of the terrestrial magnetism, or from any active agency of a volcanic nature, I dare hardly venture an opinion. The deflections or deviations of the needle from the magnetic meridian, on the summits of Vesuvius and Etna, confirm the latter idea; although, on the other hand, experiments made in several places in the neighbourhood of Vesuvius, from their near agreement with each other, indicate nothing of the kind.

It will not, however, appear very extraordinary that volcanic products should exert considerable influence on the needle, when we consider how very generally iron ores enter into the composition of the different lavas. Upon submitting each specimen contained in a collection of lavas (made by SALVADORE, the Vesuvian guide,) to a light needle, suspended by a fibre of silk, I found that sixty-eight out of one hundred and twenty-four specimens exerted considerable influence upon it; most of them attracting each end indiscriminately, while others had decisive features of distinct polarity. Whether the difference between the intensity on the summit of Etna and that observed below, proceeds from the same cause, or from the influence of height alone, is alike difficult to determine.

Table A.

Experiments to determine the dip at Malta by the usual method.

The results with the poles inverted are connected with the others by brackets.

Needle, No. 1.			Needle, No. 2.			Needle, No. 3.		
Date.	Dip, each 12 Observations.	Means.	Date.	Dip, each 12 Observations.	Means.	Date.	Dip, each 12 Observations.	Means.
1828.	° ′ ″	° ′ ″	1828.	° ′ ″	° ′ ″	1828.	° ′ ″	° ′ ″
Nov. 7.	53 25 30 / 56 59 45	55 12 37	Nov. 7.	58 48 15 / 52 48 15	55 48 15	Nov. 8.	50 31 30 / 56 22 45	53 27 7
11.	56 42 45 / 53 13 0	54 57 52	11.	52 59 30 / 55 31 15	54 15 22	10.	56 10 30 / 52 2 0	54 6 15
1829. Jan. 24.	56 39 0 / 52 59 0	54 49 0	Dec. 31.	56 2 15 / 52 57 0	54 29 37	Dec. 10.	51 57 15 / 55 52 45	53 55 0
Mar. 6.	52 26 0 / 56 6 0	54 16 0		55 49 0 / 52 47 0	54 18 0	30.	52 7 0 / 55 53 0	54 0 0
7.	56 21 0 / 52 29 0	54 25 0	1829. Mar. 7.	52 19 0 / 55 25 0	53 52 0	1829. Mar. 6.	51 37 20 / 55 37 20	53 37 20
Mean		54 44 6	Mean		54 32 39	Mean		53 49 10
Mean of the three Needles .... 54° 21′ 58″.								

Table B.

Experiments to determine the dip at Malta.

Date.	Time of 100 Vibrations in Meridian (t).	Time of 100 Vibrations perpendicular to Meridian (t').	Dip (Δ).	Means.	Needle.
	″	″	° ′	° ′ ″	
1829. Jan. 1.	147·6 / 151·7	161·63 / 170·15	56 50 / 52 39	54 44 30	No. 3
3.	162·5 / 156·45	184·1 / 172·57	51 11 / 55 17	53 14 0	2
14.	150·4 / 151·4	163·65 / 169·02	57 38 / 53 21	55 29 30	3
24.	154·65 / 151·57	178·02 / 166·7	49 0 / 55 46	52 23 0	1
Mar. 5.	157·0 / 153·87	173·82 / 173·07	54 41 / 52 13	53 27 0	2
6.	154·75 / 161·07	171·25 / 182·4	54 45 / 51 14	52 59 30	1
Mean of the three Needles				53 42 55	

Formula employed.... $\sin\Delta = \left(\frac{t}{t'}\right)^2$

Table C.

Experiments to determine the dip at Malta.

Date.	Time of 100 Vibrations in Meridian (t).	Time of 100 Vibrations, horizontal (h).	Dip (Δ).	Means.	Needles.
	″	″	° ′	° ′ ″	
1829. Jan. 1.	156·6	200·8	52 32	54 24 30	No. 3
	147·3	197·7	56 17		
3.	156·45	211·95	56 59	55 14 0	2
	159·25	206·45	53 29		
14.	151·4	196·16	53 26	54 56 30	3
	145·7	195·98	56 27		
27.	155·4	201·65	53 34	54 45 0	1
	148·48	198·4	55 56		
Mar. 5.	157·0	208·25	55 22	54 30 0	2
	153·87	197·5	52 38		
6.	154·75	206·5	55 50	53 58 30	1
	161·07	205·55	52 7		
Mean of the three Needles				54 38 5	

Formula employed.... $\text{Cos}\ \Delta = \left(\frac{t}{h}\right)^2$

Table D.

Experiments to determine the dip at Malta.

Date.	Time of 100 Vibrations perpendicular to Meridian (t').	Time of 100 Vibrations, horizontal (h).	Dip (Δ).	Means.	Needles.
	″	″	° ″	° ′ ″	
1829. Jan.14.	169·02	196·16	53 25	54 46 0	No. 3
	160·62	195·98	56 7		
16.	181·0	208·85	53 5	54 19 0	2
	168·15	203·0	55 33		
22.	161·97	198·8	56 25	54 26 0	3
	173·5	197·9	52 27		
23.	176·47	205·25	53 32	54 40 0	2
	172·9	209·7	55 48		
28.	163·85	199·7	56 3	54 34 30	1
	169·25	195·15	53 3		
Mar. 5.	173·82	208·25	55 8	53 48 30	2
	173·07	197·5	52 29		
	171·25	206·5	55 29	53 38 0	1
	182·4	205·55	51 47		
Mean of the three Needles				54 18 51	

Formula employed.... $\text{Tan}\ \Delta = \left(\frac{h}{t'}\right)^2$

Table E.

Places and Dates.		Time of 100 horizontal Vibrations, with				Comparative horizontal Forces.		
		Needle No. 1.	Needle No. 2.	Needle No. 3.	Needle No. 4.	Between the places connected by brackets.	Assuming force London equal to Unity.	
London .... 1827–8.	61	″ 266·4	″ 238·7	″ 243·0	″ 195·0	1·0000	1·0000	
Lisbon .... ——	61	239·7	215·7	219·7	177·3	1·2232	1·2232	Mean 1·2608
* —— .... 1831–2.	66	294·9	313·35	279·68	275·77	1·2761	1·2985	
Portsmouth ...... ——	65	333·67	352·7	314·85	313·22	1·0000		
Lisbon .... 1828.	61½	238·9	215·8	219·7	176·8	1·0000		
Gibraltar .... ——	68	235·5	212·0	215·0	172·0	1·0424	1·3143	
——, summit .. ——	70	231·75	208·25	212·4	173·25	1·0621	1·3391	
Portsmouth .... ——	61½	268·6	239·8	242·6	196·9	1·0000		
Malta .... ——	63	220·1	196·9	202·2	160·6	1·4788	1·5047	Mean 1·5071
—— .... 1830.	60	227·2	201·3	206·5	167·0	1·4835	1·5095	
Portsmouth .... ——	64	276·3	244·5	252·5	203·5	1·0000		
*Malta .... 1829.	59	218·5	195·0	199·02	161·27	1·0000		
Messina .... ——	51	220·1	196·5	201·1	161·25	0·9844	1·4836	
Naples .... ——	46	232·7	207·6	212·5	171·5	0·8779	1·3231	
Vesuvius, half-way up ——	48	....	....	....	172·5	0·8670	1·3067	
——, edge of crater ——	18	....	....	....	170·6	0·8781	1·3234	
Baia .... ——	66	235·9	210·5	216·3	173·5	0·8591	1·2947	
*Malta .... ——	64½	218·75	....	....	....	1·0000		
Syracuse .... ——	67½	221·54	....	....	....	0·9760	1·4709	
Catania .... ——	70	225·65	....	....	....	0·9413	1·4186	
Etna, summit ...... ——	32	216·75	....	....	....	1·0074	1·5181	
*Malta .... ——	68	221·5	197·95	201·62	163·05	1·0000		
Vourla .... ——	70	223·55	199·5	203·32	164·41	0·9833	1·4819	
Constantinople .... ——	72	227·5	202·95	207·1	167·5	0·9487	1·4298	
Egina and Athens .. ——	78	225·5	200·5	205·1	165·5	0·9691	1·4605	
Plains of Troy...... ——	79	229·0	204·0	209·1	169·0	0·9346	1·4085	

* The experiments marked * are means between the periods of vibration observed *before* and *after* those made at the places with which they are compared and bracketed with.

TABLE F.

Places.	Lat. N.	Long.	Variation W.	Dip.	Comparative horizontal Forces.	Comparative whole Forces.	Remarks.
	° ′	° ′	° ′	° ′			
London	51 30	0 9W.	....	69 40	1·0000	1·0000	
Portsmouth	50 47	1 5	....	69 23	1·0175	1·0042	
Lisbon	38 42	9 10	22 23	63 30	1·2608	0·9819	Whole force with dipping needles = 0·9426.
Gibraltar	36 5	5 4	....	60 49	1·3143	0·9366	
————, summit..	——	——	....	......	1·3391	......	Height, 1300 feet.
Malta............	35 54	14 29E.	15 15	54 17⅓	1·5071	0·8972	Whole force with dipping needles = 0·9113.
Messina..........	38 12	15 30	17 12	56 29½	1·4836	0·9338	
Naples	40 53	14 15	15 20	58 28⅓	1·3231	0·8792	
Vesuvius, half-way up W. side....	40 49	14 26	....	......	1·3067	......	Height, 1900 feet.
————, W. edge of crater......	——	——	12 25	......	1·3234	......	Height, 3400 feet.
Baia	40 50	14 5	15 20	......	1·2947		
Syracuse	37 3	15 10	16 40	......	1·4709		
Catania	37 30	15 5	16 28	......	1·4186		
Etna, summit......	37 44	15 0	18 35	......	1·5181	......	Height, 11,000 feet.
Vourla, near Smyrna	38 24	26 38	10 36	54 34	1·4819	0·8882	Whole force with dipping needles = 0·9152.
Egina and Athens..	37 48	23 32	....	......	1·4605		
Plains of Troy	39 51	26 7	....	......	1·4085		
Constantinople	41 2	28 54	....	56 18	1·4298	0·8954	

Table G.

Mean westerly variation of the Needle at different hours of the day, at the Island of Malta, 1829.

Time.	January.		March.		April.	
	Variation.	No. of Obs.	Variation.	No. of Obs.	Variation.	No. of Obs.
h m	° ′ ″		° ′ ″		° ′ ″	
1 0 A.M.	....	......	14 60 15	2	14 51 19	4
2 0	....	......	58 0	2	51 27	5
4 0	....	......	58 0	2	51 30	2
5 0	....	......	59 45	2	50 7	2
7 0	....	......	59 12	7	50 30	11
7 30	....	......	59 5	7	49 38	9
8 0	....	......	58 52	7	50 25	4
8 30	....	......	58 42	7	47 15	3
9 0	14 34 46	11	58 40	9	48 14	11
9 30	35 3	11	58 33	9	49 3	11
10 0	35 19	11	58 42	9	50 30	11
10 30	35 33	11	58 45	9	52 19	11
11 0	35 48	11	59 15	9	53 46	11
11 30	36 9	11	59 28	8	55 10	13
Noon.	36 20	11	59 50	9	55 55	12
0 30	36 16	11	59 55	9	57 16	10
1 0	36 10	11	60 5	9	57 49	8
1 30	35 53	11	60 8	9	57 36	10
2 0	34 50	11	60 3	9	58 12	12
2 30	34 24	11	59 53	9	57 7	9
3 0	34 9	11	59 53	9	55 48	9
3 30	34 1	11	59 45	9	54 49	8
4 0	33 44	11	59 30	9	53 40	10
7 30	....	......	....	9	52 45	3
8 0	....	......	....	9	52 30	2
8 30	....	......	....	9	53 0	3
9 0	....	......	59 4	2	52 41	5
9 30	....	......	59 22	2	51 40	5
10 0	....	......	59 22	2	51 56	5
Midnight.	....	......	60 0	2	51 30	4
	Maximum at about 0^h 30^m P.M. Minimum ——— ?		Maximum at about 1^h 30^m P.M. Minimum ——— 9 30 A.M.		Maximum at about 1^h 45^m P.M. Minimum ——— 8 45 A.M.	