XXV. *On the effects produced in the rates of Chronometers by the proximity of masses of iron.* By Peter Barlow, *Esq. of the Royal Military Academy.* *Communicated by* John Barrow, *Esq. F. R. S.*

Read June 28, 1821.

It having been ascertained during the voyage made by Captain Buchan to the Arctic regions, in the year 1818, that the rates of the chronometers were considerably different on board and on shore, and this change having been attributed to the iron of the vessel,* I felt very desirous, first, of ascertaining whether the proximity of a mass of iron had actually any effect in changing the rate; and, secondly, supposing this to be the case, to determine, if possible, the laws and principles by which that action was governed.

I accordingly, through the kindness of some of my friends, procured the loan of six excellent chronometers, besides one or two others, which upon trial were found to have too wide and irregular rates for my purpose. Having procured these, and made the requisite preparations, I began my series of observations on them on the 11th of March of the present year, and continued them daily till the 25th of May; when, having obtained a considerable number of results, they were discontinued.† It will however be proper, before I proceed

* See a Memoir by Mr. Fisher, who accompanied Captain Buchan, in the Philosophical Transactions for 1820, Part II.

† I ought not to omit this opportunity of returning my best thanks to those

to the detail of particulars, to explain the views I had formed on the subject, and the principles upon which I conducted the experiments.

I conceived, that if such an effect as that described by Mr. FISHER, were generally produced on the rates of watches and chronometers, it must arise from the spring, or some part of the balance having become magnetic, and the consequent attraction of the iron upon it. But this would lead us also to conclude, that accordingly as the balance was placed in this, or that direction, with respect to any given mass of iron, the rate of the chronometer would be accelerated or retarded, and not uniformly accelerated, as would seem to be the case by Mr. FISHER's observations. Or rather perhaps I ought to say, that a different direction of the balance would alter the arc of its vibration, from greater to less, or from less to

friends who have, in these experiments, favoured me with their advice and assistance. To my late colleague, the Reverend Mr. EVANS, I am much indebted for the loan of his gold pocket chronometer by EARNSHAW, and by his procuring for me, through the kindness of Mr. PENNINGTON, an excellent box chronometer by that Gentleman, marked No. 4 in the following series. To my friend Captain LYNN I am under an equal obligation, by his having entrusted to my care his very fine box chronometer, marked No. 3, and by his having procured for me, from Mr. ARNOLD, the silver pocket chronometer No. 2. These two were selected out of a great number which the former Gentleman was employed in rating, in consequence of their being decidedly the most uniform in their action. To Captain COLBY and to Mr. ARTHUR BAILY, I am indebted for my introduction to Messrs. PARKINSON and FRODSHAM, who in the most liberal and handsome manner furnished me with the two chronometers No. 5 and No. 6. The latter of these is adjusted according to the new principle of these makers, and was made at the same time, and is in all respects similar to their chronometers No. 228, 253, 254, and 259, which were so much distinguished in Captain PARRY's late voyage. To these Gentlemen I am also much indebted for the means of making the experiments, reported in a subsequent page, on the detached chronometrical parts of such a machine.

greater; but it would still depend upon the original adjustment of the machine, whether the result would be to accelerate or to retard its action; that is to say, it would depend upon the contingency, whether the chronometer had a tendency to gain, or lose, in short arcs, which I am informed is nearly an equal chance, if it proceed from the hands of a scientific workman; but that, in general cases, the probability is, that the watch will lose in large arcs, and gain in small ones.

The experiments and observations which Mr. FISHER describes as having been made with a strong bar magnet, brought within two inches of the balance, I consider to be perfectly distinct in their nature from those which were made by him on board and on shore at Spitzbergen; for a magnet of such power, brought within the distance of two inches of any small piece of steel, will, whether the latter be previously magnetic or not, impress upon it a strong temporary derangement of its latent magnetism, and give to the part nearest the magnet, a contrary pole to that by which it is opposed; and consequently, there will exist between the balance and the magnet a strong power of attraction sufficient to cause that acceleration so strongly indicated in Mr. FISHER's experiments; and this will be the case whichever end of the magnet is opposed to the balance, and to whatever part of the latter the application is made; because, in this instance, the effect does not depend upon the previous magnetic state of the balance, but upon that temporary state excited by the proximity of the magnetic bar, and which ceases when the bar is removed.

This explanation will not, I conceive, apply to the action of plain unmagnetized iron; for notwithstanding, according to the present received doctrine of magnetism, every mass of soft iron becomes a temporary magnet by induction from the earth; yet I am not aware that ever any particular action has been discovered between two pieces of iron, whether hard or soft, which had not previously acquired a polar quality; the largest mass of iron, for instance, will not, that I am aware of, attract and give direction to the lightest and most freely suspended needle of soft iron, or of unmagnetized steel.

Now, if this be admitted, it necessarily follows, that plain unmagnetized iron can only be supposed to act on the balance of a chronometer, when that balance has acquired a polar or directive quality; and then, as I have already stated, it will have a tendency to produce an acceleration, or retardation, according to its position with respect to the balance, and the previous adjustment of the machine.

If this be actually the case, it may probably appear singular, that all Mr. Fisher's chronometers were accelerated; but it is not much less so, that five out of the six which I used in my experiments were as decidedly retarded. It will likewise, after examining my experiments, be difficult to account for that high degree of acceleration noticed by Mr. Fisher; for it will be seen that, although I approximated some of my chronometers to within two or three inches of the surface of an iron ball thirteen inches in diameter, the utmost effect which I could produce did not exceed 4″ per day; whereas Mr. Fisher makes *his* amount to 8″ or 9″ per day; and yet we can scarcely imagine that he brought his chronometers so closely within the immediate sphere of action of any mass of iron, more powerful than that described in my experiments; indeed we are led strongly to suspect, that the remarkable change in the rates of the nine chronometers of the Dorothea and Trent, reported by Mr. Fisher, must have been produced by some extraordinary cause, not commonly operating on ship board.

I have already observed, that, according to the idea I entertain of the action of iron on the balance of a chronometer, it is actually necessary to conceive, that part of the machine, or at least its spring, to have acquired a certain polar or directive quality, whereby, independent of any other power, the balance would have a tendency to assume a certain direction, when brought within the sphere of action of a given mass of iron; and the amount of that tendency might, I conceived, be estimated, by counting the number of vibrations which a small magnetized needle would make in a given time, in any assigned situation, near the iron, and comparing the result with the number it would make under like circumstances, and in the same time, when wholly removed from any attracting mass.

In order to illustrate this view of the subject a little more particularly, let A B C D (fig. 1. Pl. XXV.) represent the balance of a chronometer, s, s' its spring, and let D be that part of the rim which is attracted by the centre o, of an iron ball or shell. If now we conceive the spring to be detached from the fixed part of the machine, it will be free, with the balance itself, to take any position. The point D will therefore be attracted towards o; and if it be displaced from this position, it will have a tendency to oscillate on each side of the point D; and the number of vibrations which it would make in a given time would serve, if we could obtain such results, to estimate the intensity of action of the attracting body.

But although we cannot detach the balance for such an experiment, we may still form some idea of the intensity of action, by causing a small magnetized needle to oscillate in the place of the balance, and by counting the number of its vibrations as above described. Indeed there is not much difficulty in estimating, theoretically, the change of intensity due to a certain change in the position and distance of the attracting body; but I prefer experiment, as more satisfactory to those who may not be able to follow out completely the mathematical investigation on which such a computation must depend. With this previous view of the subject, I began with first ascertaining the time in which forty vibrations were made with a small magnetic needle in different situations with respect to an iron shell eighteen inches in diameter, and at eighteen inches distance from its centre; the weight of the shell being 496 lbs.

But as the degree of intensity, as well as the quantity of deviation, occasioned by the iron ball, has reference, not to the plane of the horizon, but to *the plane of no attraction*,* I proceeded with these experiments as follows:

Let S Q N Q′ (fig. 2. Pl. XXV.) represent the iron shell, or a sphere concentric with it; Q Q′ its magnetic equator, or plane of no attraction, and *ab*, *cd*, *ef*, &c. parallels of latitude answering to 60°, 45°, 30°, &c. H H′ the horizon, and S N the natural direction of the magnetic action in this place; the circle S Q N Q′ denoting the plane of the magnetic me-

* See "Essay on Magnetic Attraction," page 18.

ridian, agreeably to the division of the magnetic sphere, as described in my "Essay on Magnetic Attraction."

I now first placed the compass at Q, eighteen inches from the centre of the shell, and observed the number of seconds which the needle employed to make forty vibrations; then, still keeping the needle in the circle QQ′, I placed it 30° from Q towards E, or in longitude 60°. I then brought it 30° nearer to E, or into longitude 30°; then to E, or longitude 0°; and so on at every 30° through the whole circle. The same was then repeated in the circles *ab*, *cd*, *ef*, &c.; and by taking the mean of the results for each corresponding situation on each side of the meridian, I obtained the numbers given in the following table:

TABLE,

Showing the time of making ten vibrations with a fine magnetic needle in different situations, eighteen inches from the centre of an iron shell, eighteen inches in diameter, weighing 496 lbs.

Latitude.	Mean time of making 10 vibrations.						
	Long. 90° N	Long. 60° N	Long. 30° N	Long. 0°	Long. 30° S	Long. 60° S	Long. 90° S
°	″	″	″	″	″	″	″
90 N	30·25						
60 N	26·00	27·25	28·00	29·75	34·50	35·75	38·25
45 N	26·25	27·50	28·25	30·00	35·25	39·25	43·50
30 N	27·25	27·50	29·00	31·25	34·00	41·25	46·50
0	34·50	34·75	34·75	35·50	35·00	35·00	35·00
30 S	46·50	41·25	34·00	31·25	29·00	27·50	27·25
45 S	43·50	39·25	35·25	30·00	28·25	27·50	26·25
60 S	38·25	35·75	34·50	29·75	28.00	27·25	26·00
90 S							30·25
Mean time of making 10 vibrations detached from the iron ball 32″·50.							

These experiments were made with a small steel bar or magnetic needle, finely suspended with untwisted silk in a glass vessel, and some care was taken to get the time as accurately as seemed desirable for the purpose; but as the only intention of the experiments was to have some general ideas of those situations near the ball, where a compass needle would be the most affected in its vibrations, and where also, according to my ideas, the chronometer would be most affected in its rate, I did not conceive it necessary to carry these observations to the utmost degree of precision.

Every thing being thus prepared, I applied to my friend the Reverend Mr. Evans, to allow the experiments to be conducted at his observatory, in which was an excellent transit instrument by Troughton, and every thing requisite for conducting them with the greatest accuracy. To this request he very readily assented; and he superintended the observations with the utmost attention, from March 11 to April 30, when, being about to remove to another part of the country, he was obliged to dismantle his observatory, and the experiments, during the rest of the period, were carried on in the same way by myself, in the Observatory of the Royal Military Academy.

Explanation of the table of experiments.

In the *first* column is given the day of the month, and in the *second*, the state of the thermometer for each day at ten o'clock A. M.

The *third* column shows the rate of the observatory clock, as deduced from each two consecutive transit observations: it is of no other use than that of showing the degree of confidence which is due to the daily rates of the chronometers on those days on which the sun's transit could not be taken.

The *fourth* column gives the quantity which each chronometer was fast or slow of mean time every day at noon, and from which is drawn the daily rate indicated in the *fifth* column.

The *sixth* column shows the mean daily rate for each period while the chronometers remained in the same position; and in the *seventh*, is shown the gain or loss in each position; it is found by taking the difference between the actual observed daily rate, and the mean detached rate. By the *mean detached rate*, is to be understood the mean rate on all those days when the chronometers were not applied to the ball.

In order to ascertain whether any law subsisted between the gain or loss of the watch and the magnetic intensity of the place in which it was situated, the needle, described in a preceding page, was vibrated in every situation where a chronometer had stood, and the mean time of its making ten vibrations carefully noted and entered in the *eighth* column; and in the *ninth* is given the proportional magnetic intensity, assuming that due to the natural state of the needle at 100.

In the *tenth* and last column, is described the particular situation of each chronometer, *viz.* its azimuth, height from the floor, and distance from the centre of the ball. These situations are also reduced to their particular latitudes, longitudes, and central distances, as referred to the ideal sphere circumscribing the ball, and explained in a preceding page. I have also, in every case, noted the direction of the chronometer itself, by stating whether the 12 o'clock mark on the dial pointed to the north, south, east, or west.

The plate and pedestal mentioned in two instances, are the same as those described in my " Essay on Magnetic Attraction," page 87. See also fig. 3. Pl. XXV. of this Memoir. The plate was double, one foot in diameter, and weighed about 5 lbs. It was placed vertically, and at the distance of ten inches from the vertical through the centre of the dial, and its centre ten inches below that of the chronometer.

At the distance of from twelve to fourteen inches from such a plate, its action is equal to the mean effect of all the iron of a vessel of medium rate, at least on the compass; as I have ascertained by my experiments on board His Majesty's ship Leven and Conway; and as farther appears from the observations of Captain Ross in the Isabella, and of Captain PARRY in the Hecla. I had, therefore, intended to make farther observations on the effect of this plate, had it not been rather unexpectedly called away to be fitted on board the Fury, with a view of ascertaining its efficacy in correcting the local attraction of that vessel in her present interesting voyage.

TABLE I.

Experiments and observations on the rates of Chronometers in the vicinity of iron bodies, at the Observatory of the Rev. Mr. EVANS, *Woolwich Common. Lat.* 51° 29′ 8″ *North, long.* 4′ 10″ *East.*

No. I. *Pocket Chronometer in Gold Cases, by* EARNSHAW. *Detached rate* —3″·2.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten Compass Vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
From Mar. 1 to 12.	° ..	......	....	—3·2	3·2	″ 0·0	....	....	These rates were taken prior to the experiments by Mr. EVANS.
12	50	—1·4	″ +48·4	—3·2	—3·2	0·0	″ 32·5	100	These rates were taken before the Chronometer was applied to the ball.
13	51	......	+45·2	—3·2					
14	49	—1·1	+41·1	—4·1					
15	47	—1·5	+39·0	—2·1					
16	46	......	....		—5·6	—2·5	34·0	91	Chronometer to the South of the ball; 2·1 inches from the floor, and distant from the vertical, passing through the centre of the ball, 17·31 inches, corresponding to lat. 0°, long. 90°, and distance from centre 18 inches. 12 o'clock, South.
17	47	—0·9	+32·0	—3·5					
18	48	—1·05	+28·1	—3·9					
19	46	—0·9	+20·9	—7·2					
20	47	—1·05	+12·8	—8·1					
21	47	......	+ 5·0	—7·8					

This Chronometer was detached from the ball on the 21st, and its rate taken for a few days; but as it was very irregular, our observations on it were discontinued after the 24th. The mean rate of this Chronometer is assumed —3″·2.

TABLE II.

Experiments and observations on the rates of Chronometers in the vicinity of iron bodies, at the Observatory of the Rev. Mr.* EVANS, *Woolwich Common. Lat.* 51° 29′ 8″ *North, long.* 4′ 10″ *East.

No. II. Pocket Chronometer, in Silver Cases, by ARNOLD.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten compass vibrations.	Proportional Magnetic intensities.	Position of Chronometer, Remarks, &c.
Mar. 1st. to	- -	- - -	- - - -	+6″·0	+6″·0	- - - -	- - -	- - -	These rates were taken by Captain LYNN prior to the experiments.
Mar. 11th	- -	- - -	- - -						
12	50°	—1·4	+2′ 32″·1		+5·0	0·0	32·5	100	These rates were taken at Woolwich before the Chronometer was applied to the ball.
13	51	- - -	+2 37·0	+4·9					
14	49	—1·1	+2 42·1	+5·1					
15	47	—1·5	+2 47·1	+5·0					
16	46	- - -	- - - -	- - -	+6·5	+1·5	30·0	117	Chronometer placed above the ball; height from floor 23 inches, distance from vertical through the centre 6 inches, to the South; corresponding to lat. 90° South, and distance 18 inches: 12 o'clock, North.
17	47	—0·9	+2 59·6	+6·2					
18	48	—1·05	+3 6·5	+6·9					
19	46	—0·9	+3 13·1	+6·6					
20	47	—1·05	+3 19·8	+6·7					
21	47	- - -	+3 26·3	+6·5					
22	48	- - -	+3 32·1	+5·8	+5·8	+0·8	32·5	100	Detached from the ball.
23	45½	—1·4	+3 37·3	+5·8					
24	47	—1·4	+2 7·5	- - -					
25	48	- - -	+2 13·0	+5·5	+5·2	+0·2	32·5	100	The Chronometer was placed in a new situation on the 23rd; but in consequence of its being suffered to go down on the 23rd at night, it was kept detached till the 30th, to be re-rated
26	47	- - -	+2 18·2	+5·2					
27	49	—2·4	+2 24·1	+5·9					
28	48	- - -	+2 28·9	+4·8					
29	50	- - -	- - - - -	- - -					
30	48	—2·4	+2 39·1	+5·1					
31	49	- - -	+2 44·8	+5·7	+6·1	+0·9	33·5	94	Placed to the N. of ball; height 10½ inches; dist. from vertical 11·31, corresponding to lat. 0°, long. 90°, dist. from centre 12 in. 12 o'clock S.
April 1	48	—2·5	+2 51·0	+6·2					
2	51	—1·7	+2 57·3	+6·3					
3	50	- - -	+2 38	- - -	+4·7	—0·5	32·5	100	Detached again from the ball.
4	49	—1·9	+2 42·8	+4·8					
5	49	—2·5	+2 47·3	+4·5					
6	47	- - -	+2 52·8	+5·5	+5·0	—0·2	25·5	162	Placed above the ball; height from floor 17·3 inches; distance from vertical 4 inches, to the South; corresponding to latitude 90° South, and distance from centre 12 inches. 12 o'clock, South.
7	50	- - -	+2 57·4	+4·6					
8	- -	—1·9	+3 3·9	+6·5					
9	57	—1·9	+3 7·7	+3·8					
10	58	—1·7	+3 12·6	+4·9					
11	57	- - -	+3 16·8	+4·2	+4·0	—1·2	30·0	117	Same latitude, but at the distance of 18 inches, as on the 16th March. 12 o'clock, South.
12	55	—2·0	+3 20·5	+3·7					
13	53	- - -	+3 25·8	+5·3	+4·3	—0·9	32·5	100	As this chronometer appeared to be increasing its rate, or rather decreasing its losing rate, independent of the action of the iron, it was detached during these days, and our observations with it discontinued.
14	52	- - -	+3 29·9	+4·1					
15	50	- - -	+3 34·1	+4·2					
16	49	- - -	+3 38·6	+4·5					
17	49	—1·9	+3 42·4	+3·8					
18	51	—2·1	+3 46·3	+3·9					
19	53	- - -	+3 50·4	+4·1					

The numbers in column 7 are drawn from comparison with each preceding detached rate, and not from the mean detached rate, as is done in the following Tables.

TABLE III.

Experiments and observations on the rates of Chronometers in the vicinity of iron bodies, at the Observatory of the Rev. Mr.* EVANS, *Woolwich Common. Lat. 51° 29′ 8″ North, long. 4′ 10″ East.

No. III. Box Chronometer by BARRAUD *(No. 749) Mean detached rate* +0.6.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten compass vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
Mar. 1st. to Mar. 11th.	- -	- - -	- - - -	+0″·3	+0″·3	- - - -	- - -	100	These rates were taken by Captain LYNN, at his observatory in town, prior to the Experiments.
12	50°	—1·4	+1′ 15″·1	- - -	—0·4	- - - -	32·5	100	These rates were taken at Woolwich, before the Chronometer was applied to the ball.
13	51	- - -	+1 14·9	—0·2					
14	49	—1·1	+1 14·4	—0·5					
15	47	—1·5	+1 13·9	—0·5					
16	46	- - -	- - - -	—0·9	—0·9	—1·5	29·0	126	Chronometer placed to the south of the ball; height from the floor 11·3 inches; distance from vertical through the centre of the ball 17·3 inches, corresponding to lat. 35° 16′ S. long. 90°, and distance from centre 18 inches. 12 o'clock, South.
17	47	—0·9	+1 12·1	—0·9					
18	48	—1·05	+1 11·7	—0·4					
19	46	—0·9	+1 10·9	—0·8					
20	47	—1·05	+1 10·1	—0·8					
21	47	- - -	+1 8·4	—1·7					
22	48	- - -	+1 7·5	—0·9					
23	45½	—1·4	+1 6·8	—0·7	—0·9	—1·5	30·0	117	Placed above the ball; height from floor 23 inches; distance from vertical through the centre of the ball 6 inches, to the South; corresponding to the lat. 90° S. and central distance 18 inches. 12 o'clock, South.
24	47	—1·4	+1 6·3	—0·5					
25	48	- - -	+1 4·9	—1·4					
26	47	- - -	+1 3·9	—1·0					
27	49	—2·4	+1 3·2	—0·7					
28	48	- - -	+1 2·0	—1·2					
29	50	- - -	- - - -	- - -					
30	48	—2·4	+1 0·2	—0·9					
31	49	- - -	+0 59·6	—0·6	—0·2	—0·8	25.5	162	Same situation as the above, but the distance reduced to 12 inches from the centre. 12 o'clock, South.
April 1	48	—2·5	+0 59·0	—0·6					
2	51	—1·7	+0 59·3	+0·3					
3	50	- - -	+0 59·5	+0·2					
4	49	—1·9	+0 58·3	—1·2	—0·9	—1·5	35.5	84	Placed to the East of the ball; height 6·5 inches; distance from vertical 12 inches, or lat. 0°. long. 0°. distance 12 inches. 12 o'clock South.
5	49	—2·5	+0 57·7	—0·6					
6	47	- - -	+0 56·7	—1·0					

This Chronometer being so little affected by the action of the iron, our observations on it were discontinued after the 6th, on which day it was returned to town; and by comparison with Greenwich time by Captain LYNN, on the 28th of April, its rate was found to have been 1″·0 per day gaining, which makes the mean rate, as stated above, +0·6.

TABLE IV.

Experiments and observations on the rates of Chronometers in the vicinity of iron bodies, at the Observatory of the Rev. Mr. Evans, *Woolwich Common. Lat.* 51° 29′ 8″ *North, long.* 4′ 10″ *East.*

No. IV. *Box Chronometer in Glass Case, by* Pennington. *Detached rate* + 1″ ·5.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each Position.	Gain or Loss per day in each position.	Time of ten Compass Vibrations.	Proportional Magnetic Intensity.	Position of Chronometer, Remarks, &c.
	°		′ ″	″					
March 24	47	—1·4	—0 25·5		—0·5	—2·0	29·0	126	Placed the Chronometer to the South of the ball; height from the floor 11·4 inches; distance from the vertical passing through the centre of the ball 17·3 inches, corresponding to lat. 35°16′ S, long. 90°, and central distance 18 inches. 12 o'clock, South.
25	48	......	—0 24·7	+0·8					
26	47	......	—0 26·0	—1·3					
27	49	—2·4	—0 26·4	—0·4					
28	48	......	—0 26·8	—0 4					
29	50	......	....	—0·9					
30	48	—2·4	—0 28·6	—0·9					
31	49	......	—0 27·0	+1·6	+2·1	....	32·5	100	Detached from the ball in order to obtain the natural rate.
April 1	48	—2·5	—0 25·5	+1·5					
2	51	—1·7	—0 22·6	+2·9					
3	50	......	—0 20·3	+2·3					
4	49	—1·9	—0 20·8	—0 5	—0·3	—1·8	33 5	94	Placed to N. of ball; height 10 5 inches; distance from vertical 11·3 inches; or lat. 0°; long. 90°, central distance 12 inches. 12 o'clock, South.
5	49	—2·5	—0 20·9	—0 1					
6	47	......	—0 21·1	—0·2					
7	50	......	—0 20·8	+0 3	+0·3	—1·2	33·5	94	Same situation. 12 o'clock, West.
8	.....	—1·9	—0 19·6	+1·2					
9	57	—1·9	—0 20 3	—0·7					
10	58	—1·7	—0 19·5	+0·8	+0·8	—0·7	33·5	94	Same situation. 12 o'clock, East.
11	57	......	—0 19 2	+0·3					
12	55	—1·7	—0 18·0	+1·2					
13	53	—2·0	—0 16·6	+1·4	+0·6	—0·9	33·5	94	Same situation. 12 o'clock, North.
14	52	......	—0 16·1	+0·5					
15	50	......	—0 15·6	+0 5					
16	49	......	—0 15·7	—0·1					
17	49	—1·9	—0 15·1	+0 6					
18	51	—2·1	—0 14·9	+0·2	—0·6	—2·1	33·5	94	Same situation, but with the 12 o'clock, South, as on the 4th, 5th, and 6th.
19	53	......	—0 14·4	+0·5					
20	55	......	—0 15·0	—0·6					
21	57	......	—0 16·4	—1·4					
22	56	—2·4	—0 17·9	—1·5					
23	56	—2·4	—0 18·1	—0·2	+0·2	—1·3	*	......	Placed this Chronometer on pedestal, South of the plate; distance from vertical through the centre of plate 10 inches; height above centre 10 inches. 12 o'clock, South. See Description of plate, page 365.
24	60	—1·5	—0 17·7	+0·4					
25	63	......	—0 17·2	+0·5					
26	65	—0·8	—0 14·8	+2 4	+1·3	....	32·5	100	The Chronometer was detached during these days, to ascertain whether it would return to its former detached rate.
27	63	—0·3	—0 13·5	+1·3					
28	62	—0·5	—0 12·4	+1·1					
29	60	—0 9	—0 11·6	+0·8					
30	56	......	—0 10·9	+0·7					

* Not taken for the reason assigned in page 376.

Observations on No. IV. continued at the Royal Military Academy.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten Compass Vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
From Ap. 30 to May 6.	... ...	* +1·06	....	+1·2	+1·2		32·5	100	Detached, the farther observations being transferred to the Royal Military Academy.
6	60	+1·06	—0 3·9	....					
7	59	......	—0 3·1	+0·8					The Chronometer, during this interval, was placed to the East of the ball, 2 inches from the floor, and distance from the vertical through the centre of the ball 11·1 inches, corresponding to lat. 20° 45′, long. 7° 45′, central distance 12. 12 o'clock, South.
8	59	......	—0 3·3	—0·2					
9	57	—0·7	—0 4·5	—1·2					
10	57	......	—0 4·5	—0·0	+0·2	—1·3	33	97	
11	57	......	—0 4·0	+0·5					
12	60	......	—0 3·5	+0·5					
13	56	—0·25	—0 3·0	+0·5					
14	54	—0·0	—0 2·5	+0·5					
15	54	......	—0 0·9	+1·6					
16	54	......	+0 0·6	+1·5	+1·5	....	32·5	100	Again detached from the ball.
17	54	......	+0 2·3	+1·7					
18	55	—0·1	+0 3·3	+1·0					
19	56		+0 3·55	+0·25					Placed to the South of the ball, 1 inch from the floor, 10 inches from the vertical, or lat. 9° 19′ N. long. 90° central dist. 11·4 inches. 12 o'clock, South.
20	55		+0 5·4	+1·75	+1·1	—0·4	41·0	63	
21	55	—0·25	+0 7·15	+1·75					
22	53		+0 7·95	+0·8					Same situation, but the 12 o'clock turned to the North.
23	50		+ 9·65	+1·7	+1·3	—0·2	41·0	63	
24	50	—0·2	+ 11·05	+1·4					
25	51		+ 12·35	+1·3					

* The clock rates from April 30th, are for the Astronomical Clock at the Royal Military Academy, by PENNINGTON.

TABLE V.

Experiments and observations on the rates of Chronometers in the vicinity of iron bodies, at the Observatory of the Rev. Mr. EVANS, *Woolwich Common. Lat.* 51° 29′ 8″ *North, long.* 4′ 10″ *East.*

No. V. Box Chronometer, by PARKINSON *and* FRODSHAM. *Mean detached rate* +0·23.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten Compass Vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
	°		′ ″						
March 25	48	......	—0 36·1	....					
26	47	......	—0 35·0	+1·1					These rates were taken before the Chronometer was applied to the ball. This Chronometer had not been wound up since October 18, 1820; its rate was then —0·8.
27	49	—2·4	—0 34·5	+0·5					
28	48	......	—0 34·2	+0·3	+0·9	....	32·5	100	
29	50	......	....	+1·2					
30	48	—2·4	—0 31·7	+1·2					
31	49	......	—0 35·5	—3·8					Placed to the South of ball; height 9·8 inches from floor; distance from vertical 11·3 inches, or lat. 35° 16′ S. long. 90°, central distance 12 inches. 12 o'clock, South.
April 1	48	—2·5	—0 39·8	—4·2	—3.4	—3 6	27·2	143	
2	51	—1·7	—0 42·2	—2·4					
3	50	......	—0 45·3	—3·1					
4	49	—1·9	—0 47·9	—2·6					
5	49	—2·5	—0 51·0	—3·1	—3·3	—3·5	27·2	143	Same situation. 12 o'clock, North.
6	47	......	—0 55·1	—4·1					
7	50	......	—0 58·3	—3·2					Same situation. 12 o'clock, West. Not wound up on the 7th.
8	....	—1·9	—0 16·2	....	—2·5	—2.7	27·2	143	
9	57	—1·9	—0 17·9	—1·7					
10	58	—1·7	—0 16·4	+1 5					
11	57	......	—0 14·8	+1·6	+0·7	+0·5	27·2	143	Same situation. 12 o'clock, East.
12	55	—1·7	—0 15·9	—1·1					
13	53	—2· 0	—0 18·3	—2·4					Same situation; but the 12 o'clock turned back to the South, as on March 31st, April 1st, and 2nd.
14	52	......	—0 21·9	—3·6					
15	50	......	—0 25·5	—3·6	—3·9	—4·1	27·2	143	
16	49	......	—0 31·3	—5·8					
17	49	—1·9	—0 35·5	—4·2					
18	51	—2·1	—0 41·5	—6·0					Placed on pedestal to the South of the plate; height above the centre of the plate 10 inches; and distance from vertical through centre of plate, 10 inches. 12 o'clock, South. See description of plate, page 365.
19	53	......	—0 45·0	—3·5					
20	55	......	—0 47·6	—2·6	—3·2	—3·4	*	......	
21	57	......	—0 49·0	—1·4					
22	56	—2·4	—0 51·5	—2·5					
23	56	—2·4	—0 53·2	—1·7					
24	60	—1·5	—0 52·8	+0·4					
25	63	......	—0 52·6	+0·4					
26	65	—0·8	—0 49·4	+3·2					Detached both from ball and plate, to ascertain whether it would return to its former detached rate.
27	63	—0·3	—0 48·0	+1·4	+0·4	....	32·5	100	
28	62	—0·5	—0 48·7	—0 7					
29	60	—0·9	—0 46 6	+2·1					
30	56	......	—0 48·3	—1·7					

* The intensity in this case was not taken, in consequence of the plate having been sent on board the Fury, Captain PARRY, for the purpose of correcting the local attraction of that vessel, before it was recollected that this datum had not been obtained.

Observations on No. V. continued at the Royal Military Academy.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten Compass Vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
From Ap. 30 to May 6.	°	* 1·06	....	—0″·6	—0·6	....		100	Detached. The farther observations transferred to the Royal Military Academy.
7	59	......	+0 50·4	—1·7	—1·4	—1·6	27·0	150	Placed to North of ball on the floor; height 1 inch; distance from vertical 12 inches, or lat. 44° 8′ N. long. 90°, central distance 13·2 inches. 12 o'clock, South.
8	59	......	+0 49·2	—1·2					
9	57	—0·7	+0 48 0	—1·2					
10	57	......	+0 46·5	—1·5	—2·1	—2·3	30·0	117	Placed to the North of ball; height from floor $6\frac{1}{2}$ inches; distance from vertical 10 inches, corresponding to lat. $19\frac{1}{2}$° N. long. 90°, central distance 10 inches. 12 o'clock, South.
11	57	......	+0 45·5	—1·0					
12	60	......	+0 42·5	—3·0					
13	56	—0 25	+0 40·5	—2·5					
14	54	—0·0	+0 37·5	—2·5					
15	54	......	+0 36·2	—1·3	—1·7	—1·9	23·0	199	Placed to the South of ball; height 8 inches, distance from vertical 10, or lat. 28°·2′ S. long. 90°. central dist. 10·1 inch.; 12 o'clock, S.
16	54	......	+0 34·3	—1·9					
17	54	—0.1	+0 32·5	—1·8					
18	55	......	+0 29·9	—2·6	—2·3	—2·5	22·5	208	Placed South of ball; height 12 inches; distance 10 inches, corresponding to lat. 48° 30′ S. long. 90°, central distance 11·4 inches. 12 o'clock, South.
19	56	......	+0 26·7	—3·2					
20	55	......	+0 24·7	—2·0					
21	55	—0·25	+0 23·2	—1·5					
22	53	......	+0 19·6	—3·6	—1·7	—1.9	22·5	208	Same situation, but with the 12 o'clock turned to the East.
23	50	......	+0 18·4	—1·2					
24	50	—0·20	+0 17·2	—1·2					
25	51	......	+0 16·5	—0·7					

* The clock rates from April 30th, are for the Astronomical Clock at the Royal Military Academy, by PENNINGTON.

TABLE VI.

Experiments and observations on the rates of Chronometers in the vicinity of iron bodies, at the Observatory of the Rev. Mr. EVANS, Woolwich Common. Lat. 51° 29′ 8″ North, long. 4′ 10″ East.

No. VI. Box Chronometer, by PARKINSON *and* FRODSHAM. *Mean detached rate* —0·39.

Days.	Thermometer.	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten Compass vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
April 9	57°	—1·9	+3′ 16·7″		+0·2		32·5	100	These rates were taken before the Chronometer was applied to the ball.
10	58	—1·7	+3 17·0	+0·3					
11	57	.....	+3 17·1	+0·1					
12	55	—1·7	+3 17·2	+0·1					
13	53	—2·0	+3 17·2	0·0	—1·3	—0·9	33	97	Placed to the East of ball; height from floor 2 inches; distance from vertical 11·1 inches, corresponding to lat. 20°45′ N. long. 7° 45′, distance from centre 12 inches. 12 o'clock, South.
14	52	......	+3 15·7	—1·5					
15	50	......	+3 14·2	—1·5					
16	49	......	+3 12·4	—1·8					
17	49	—1·9	+3 10·5	—1·9					
18	51	—2·1	+3 9·2	—1·3	—1·5	—1·1	33	97	Similar situation, and at the same distance to the West of the ball. 12 o'clock, South.
19	53	......	+3 7·1	—2·1					
20	55	......	+3 5·6	—1·5					
21	57	......	+3 4·2	—1·4					
22	56	—2·4	+3 2·9	—1·3					
23	56	—2·4	+3 0·5	—2·4	—1·6	—1·2	30·5	127	Placed to the North of the ball; height 2 inches, distance 14 inches; or lat. 37°20′ N. long. 90°, central distance 14·6 inches. 12 o'clock, South.
24	60	—1·5	+2 59·5	—1·0					
25	63	.....	+2 58·2	—1·3					
26	65	—0·8	+2 57·0	—1·2	—0·6		32·5	100	Detached; and the farther observations transferred to the Royal Military Academy.
27	63	—0·3	+2 57·3	+0·3					
28	62	—0·5	+2 57·6	+0·3					
29	60	—0·9	+2 56·8	—0·8					
30	56	.....	+2 55·2	—1·6					

Observations on No. VI. continued at the Royal Military Academy.

Days.	Thermometer	Clock Rate.	Chronometer + or — at Noon.	Daily Rate of Chronometer.	Mean Rate in each position.	Gain or Loss per day in each position.	Time of ten Compass vibrations.	Proportional Magnetic intensity.	Position of Chronometer, Remarks, &c.
	°		′ ″						
From Ap. 30 to May 6.	60	* +1·06	+1 34·6	—0·5	—0·5	....	32·5	100	Observations begun at the Royal Military Academy.
7	59	....	+1 31·9	—2·7	—1·9	—1·5	34	91	Placed to the South of the ball; height 1 inch distance from vertical 12 inches, or lat. 5° 8′ N. long. 90°, central distance 13·2 inches 12 o'clock, South.
8	59	....	+1 30·2	—1·7					
9	57	—0·7	+1 29·0	—1·2					
10	57	....	+1 27·5	—1·5	—1·4	—1·0	24	183	Placed still to the South; height 6½ inches, distance from vertical 10 inches, or lat. 19° 30′ S long. 90°, central distance 10 inches. 12 o'clock, South.
11	57	....	+1 26·0	—1·5					
12	60	....	+1 25·0	—1·0					
13	56	—0·25	+1 23·5	—1·5					
14	54	0·0	....	....	—1·4	—1·0	25	169	Placed to the North of the ball; height 1 inch distance 10 inches from vertical, or lat. 48° 18′ N. long. 90°, central distance 11·4 inches 12 o'clock, South.
15	54	....	+1 21·2	....					
16	54	....	+1 19·6	—1·6					
17	54	—0·1	+1 18·5	—1·1					
18	55	—0·1	+1 17·9	—0·6	—1·2	—0·8	56	33	Placed still to the North; height 13 inches distance from vertical 9 inches, or lat. 16° 20′ S. long. 90°, central distance 11 inches. 12 o'clock, South.
19	56	....	+1 16·6	—1·3					
20	55	—0·25	+1 15·6	—1·0					
21	55	....	+1 13·6	—2·0					
22	53	....	+1 12.9	—0·7	—1·0	—0·6	56	33	Same situation, but with the 12 o'clock turned to the North.
23	50	....	+1 11.7	—1·2					
24	50	—0·20	+1 10.7	—1·0					
25	51	....	+1 9.5	—1·2					

* The clock rates from the 30th, are for the Astronomical Clock of the Royal Military Academy, by PENNINGTON. The above chronometer is corrected according to the new principle of Messrs. PARKINSON and FRODSHAM. The rate of this chronometer for days, after its return, was —0″·39.

Practical deductions from the results of the preceding experiments.

The first general conclusion which may be drawn from the foregoing experiments, is, that the rate of a chronometer is undoubtedly altered by its proximity to iron bodies.

Secondly; it appears that it is by no means a general case, that iron necessarily accelerates the rate of a chronometer, as would appear from Mr. FISHER's observations; for five out of the six chronometers which I have made use of, were obviously retarded in every situation in which they were placed. In one instance only, viz. chronometer No. II, there is an indication of acceleration in one situation; but it is more doubtful than the retardation in all the other five.

It is also very obvious from the experiments on Nos. IV. and V., that much depends on the direction of the balance with respect to the iron: thus, No. IV. lost nearly 2″ per day when its 12 o'clock hour mark was turned to the South, and only seven tenths when it was placed to the East; but as soon as the chronometer was returned to its old direction, the loss again became 2″·1 daily. The same occurred in the case of No. V., which lost 3″·6 per day in one direction, and gained 0″·5 in another at right angles to it; and on returning it again to its former direction, the losing rate became 4″·1 per day, viz. rather stronger than at first. It must be admitted, however, that the same striking difference in the rate, as depending upon direction, was not observed in another instance, when a similar experiment was repeated on the same chronometer. Speaking generally, it also appears, that the greatest effect is produced in those instances where the change in the magnetic intensity is the greatest; but there does not seem to be that uniformity of relation in these cases, that we should naturally have anticipated.

As a practical conclusion, it is obvious, that on ship-board, great care ought to be taken to keep the chronometers out of the immediate vicinity of any considerable mass, or surface of iron; on which account, they ought not to be kept in the cabins of the gun-room officers, which are on the sides of the vessel; and probably a strong iron knee, or even a gun, will be found at a very inconsiderable distance from the spot where the watch is most likely, in this case, to be deposited.

In short, it appears from the preceding experiments, that a chronometer ought to be kept as carefully at a distance from any partial mass of iron, as the compass itself. And, as much of the iron of a ship is hidden, the best way of detecting it, and of ascertaining a proper situation for a chronometer, will be to set down a compass in any place designed for the former, and to observe and compare the direction of its needle with that of the azimuth compass on deck, while the vessel is on different tacks; and if the disagreement between the two be very considerable, another situation ought to be selected.

When I made my experiments on local attraction, on board His Majesty's ship Leven, we placed several compasses in different parts of the vessel, some of which were very powerfully affected under different directions of the ship's head; in consequence, no doubt, of their being within the influence of partial action arising from some near, but hidden, mass of iron.

In support, and in confirmation of the necessity of taking the above precautions, it may not be amiss to state the following fact. A very intelligent seaman, many years a Master in the Navy, and at present an officer in the Dock-yard at Woolwich, to whom I was describing the nature of my experiments, immediately exclaimed, that they explained a circumstance which he had remarked when he was master of a first rate. He informed me, he always found that his chronometer, which was a very excellent one, had a different rate on board and on shore, amounting to 5″ per day; but as he well remembered that the birth he had selected for it was in his cabin, nearly in contact with an iron knee, he now saw that it was the action of that mass of iron which had caused all his perplexity.

Lastly; since it is rendered obvious by the experiments with the plate of iron on Nos. IV. and V. that the power of the iron to disturb the action of the chronometer resides (as in the instance of the compass), on the surface, and as we know, generally, the distance and direction of such a plate, so that its power may be equal to the mean action of the iron of the vessel, we have thence a ready method of ascertaining, before a chronometer is sent on board, whether the effect of the ship's iron will be to accelerate or retard its going; and probably, a very near approximation to the actual quantity of that change may also be predicted.

For this purpose, it is only necessary to have a box or pedestal, as shown in Figure 3, Plate XXV., in the side of which a brass pin, *a b*, may be fixed, to carry the iron plate P, and on the top of the box a convenience for placing the chronometer. Then, having taken its rate in the usual way, let it be taken again while the chronometer is placed on the pedestal, keeping the plate, generally, at the distance of about twelve inches from the vertical through the centre of the dial, and its centre about the same depth below the plane of the balance, and the rate thus obtained will be a very close approximation to the ship rate of the instrument, provided care be taken, when it is removed on board, to keep it out of the immediate action of any partial mass of iron. The plate for this purpose should be a double one, such as I have described in my "Essay on Magnetic Attraction," and if it weigh about 5lbs. it will be sufficient to prevent any partial action.

It should be observed, that the plate is meant as a substitute for the iron forward; and therefore the chronometer, when on board, should be placed in the same direction in reference to the ship's head, as it had with respect to the iron plate when its rate was determined; that is, if the 12 o'clock mark of the dial be turned towards the iron plate on shore, then must the same be turned towards the ship's head when taken on board.

Experiments on the detached parts of a chronometer.

As some of the results of the preceding experiments were not precisely what I had anticipated, nor quite consistent with the ideas I had formed of the nature of the action between the iron and the balance, I was desirous of making some experiments on the detached chronometrical parts, in order, if possible, to trace the irregularity to its source.

Having mentioned my wish on this subject to Mr. FRODSHAM, he very cordially and earnestly entered into my views, desirous, not of avoiding, but of meeting openly every difficulty which presented itself in the construction of such a machine, the most delicate, perhaps, of any in the entire circle of the mechanical arts.

We accordingly went into his work-shop, and having detached a balance from a chronometer, we suspended it very nicely in its frame, and brought it near a piece of iron of some magnitude, which happened to be at hand, and an action between it and the balance was rendered immediately obvious; and it was of that kind which seemed to imply, that it proceeded from the magnetism of the balance, or of the spring which remained attached to it; that is, if the motion which we gave to the balance terminated in a certain place, a trifling recoil, or repulsion, might be distinguished; but if the opposite side of the balance was nearest to the iron when the motion ceased, then, a slight degree of attraction was equally distinguishable; and Mr. FRODSHAM had no doubt that such an action as we then noticed, was amply sufficient to change the rate of the chronometer, of which the balance formed a part, when brought within the sphere of attraction of any such iron mass.

The above experiment was made with the balance and frame placed near the bottom of the piece of iron; it was now repeated near its upper part, and a similar action was distinguishable; but it appertained to the reverse extremities of the balance.

I have said, that these results were such as indicated the presence of magnetism in the balance or spring; and it may not be amiss to advert here to this subject a little more particularly, and to explain how I imagine we may always distinguish between the magnetism of the balance, and that of the attracting body.

1st. If the balance have a polar, or directive quality, and the iron is pure and free from it (except that which is due to position); then, if the balance be kept below the *plane of no attraction*, the south pole of the former will be attracted, and its north pole repelled; but if the balance be placed above the plane of no attraction, the reverse will take place; that is to say, that part of the balance which was before repelled will be attracted, and that which was attracted will be repelled; and the same will happen, whichever of the ends or parts of the iron be turned downwards.

Therefore, when such action as that above described takes place, we may infer that the balance is magnetic, but that the iron, or attracting mass, is free from any polar quality, except that which it derives from position.

2. If the iron and balance were both magnetic, then we should have attraction and repulsion, as above described; but it would have no reference to the plane of no attraction; and by inverting the position of the iron, the effects of it upon the balance would be reversed also.

3. Again; if the iron possess the polar quality, but the balance and spring are free from it, then in every situation, either side or part of the balance, which is nearest to one of the poles of the attracting body, will be attracted, and no repulsion will in such case be observed.

4. Lastly; I am of opinion (although it is here, as in most other cases, difficult to prove a negative) that no action whatever will take place between the balance and iron, provided they are both free from any fixed polar quality.

As we were not prepared to pursue our enquiries any farther at this time, Mr. Frodsham proposed to provide himself with certain parts of a chronometer, and to appoint a day to come to Woolwich, and make such experiments as might suggest themselves to him or to me in the interval. He therefore prepared for the purpose a new compensation balance, in which, of course, the usual care was taken to prevent the excitement of any local magnetism; he also brought with him a brass balance, with two springs of different tempers, which might, either of them, be affixed to the balance in the usual way; he had likewise, beside the proper frame for suspending these parts, constructed a brass stand, whereby the whole might be nicely adjusted to horizontality.

Our first experiment was on the new compensation balance; but although it was brought almost in contact with the iron ball, and at that place where, by means of our experiments, page 370, the intensity was known to be the greatest, no action whatever could be discovered. We afterwards repeated the same experiments in several other places, but without producing the least apparent effect. The weights of the balance were now removed, in order to render it more light and sensible; but no species of action could be discerned.

We now detached the balance entirely from the ball, and presented to it the north end of a bar magnet; and then, giving the balance a very slight motion, it stopped after a short time, and arranged itself, so that the cross steel bar was directly in a line with the magnet; and immediately, upon being disturbed from its position, it returned to it again. The balance being now turned half round, so that the other end of the bar was directed towards the magnet, the same effect was produced. We now turned the magnet end for end, but found the attraction still the same between either end of the magnet, and on each end of the steel bar of the balance; and in no case could there be obtained the slightest indication of repulsion; from which we may conclude, that the balance itself was free from any polar magnetic quality, and that every part of it was alike susceptible of the power of the magnet, although it was wholly insensible to the action of the iron ball. A chronometer, therefore, with such a balance, and with a spring equally free from magnetism, would, I conceive, preserve the same rate both on shore and on shipboard, although it might be as sensibly affected with a magnet as any of those experimented upon by Mr. FISHER.

We now took the brass balance, and having suspended it in its frame, applied to it the end of the bar magnet, in order to ascertain whether any magnetic quality could be discovered in the brass of which it was composed; but no action of that kind could be rendered sensible. One of the springs being now attached to it, it was applied to the ball, whereby a small, but sensible, effect was produced by the action of the iron; and by repeating the experiment in various ways, it was obviously of that kind which indicated magnetism in the spring; and a very similar action was discoverable with the other spring.

Each of these was now applied, at a short distance, to a very light and sensible compass needle; when the polar quality of both was rendered manifest in a very peculiar manner, but which it is not necessary to detail in reference to the present enquiry.

All we learn from these experiments appears to be, that when a balance, or its spring, acquires a magnetic quality, the rate of the chronometer, of which it forms a part, will experience a change when brought within the action of a mass of iron; and, *a fortiori*, when it is approximated to a magnet; but, if the balance and its spring are both free from magnetism, then the chronometer will preserve its rate, notwithstanding the proximity of iron; but it will still be acted upon by a magnet.

I think it however highly probable, that the form and office of the spring, are precisely those the most likely to create magnetism in it, and that when once acquired in this part of the machine, it will be soon transmitted to the balance itself, and consequently, that there are but few chronometers, which have been long in use, that have not their balances impregnated with this subtle fluid, and which are therefore liable to a change of rate, more or less considerable, when taken on ship-board, or within the influence of a mass of iron.

I must acknowledge, however, that there is still some mystery hanging over this enquiry: the only reason that can be assigned for the effect produced by the iron in these cases is, that it has a tendency to increase or diminish the vibratory motion of the balance, which we must, I conceive, assimilate to the oscillations of a horizontal needle; from which it only appears to differ in its degree of directive intensity. But it will have been observed, that the nearest approach I could make to the iron, did not increase or diminish the intensity of this action so much, as in the ratio of 2 to 1, notwithstanding which a sensible effect was produced on the rate of the chronometers; whereas from Captain PARRY's and Captain SABINE's observations at Melville island, it appears, that the directive power of the needle was reduced to $\frac{1}{13}$th of what it is in London, and yet no change, or a very inconsiderable one, was

Fig. 1.

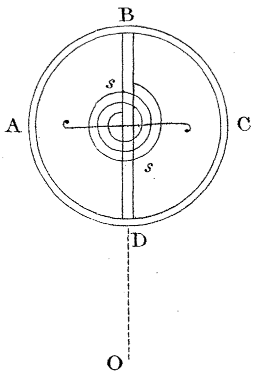


Fig. 2

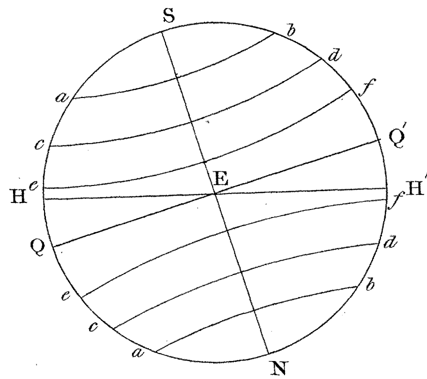
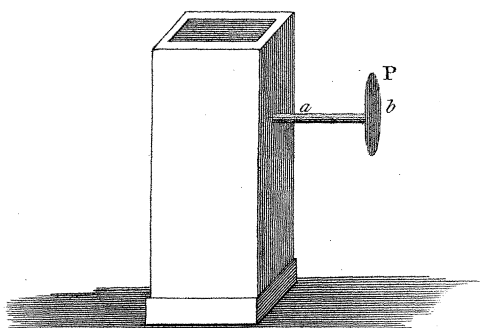


Fig. 3



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observed in the rates of the chronometers ; and this change, from the results of the preceding table of experiments, would rather appear to be due to the action of the iron on board, than to any other cause.

On the other hand, the change of rate reported by Mr. FISHER, is so much greater than our experiments would give us reason to expect, that we cannot help considering his case as an anomalous one, and as depending upon some cause not commonly operating on ship-board.