XXI. *On magnetic influence in the solar rays.* *By* SAMUEL HUNTER CHRISTIE, *Esq.* M.A. *F.R.S. &c.*

Read June 19, 1828.

THE facts which I communicated in my former paper on this subject appeared so inexplicable on any known principle, that I am induced to present my subsequent observations to the Society, although I have not succeeded in ascertaining the causes of the singular effects which I have observed. From the experiments described in that paper, it appeared that a magnetized needle, when vibrated exposed to the sun's rays, will come to rest sooner than when screened from their influence: that a similar effect is produced on a needle of glass or of copper ; but that the effect upon the magnetized needle greatly exceeds that upon either of the others. To the experiments from which this was inferred, it might be objected, that the magnetized needle and the other metallic needle were not of the same weight, and that the effect upon an unmagnetized steel needle had not been compared with that upon a similar needle magnetized. I therefore, on the first opportunity, made these experiments in the most unexceptionable manner, and the results most decidedly confirmed those I had previously obtained. I endeavoured likewise to ascertain the effects that would be produced by the separate rays; but, possibly owing to the inefficiency of my apparatus, I obtained no very decided results: the violet rays appeared to produce the same effect as partially screening the needle; and the red rays, the greatest effect in diminishing the arc of vibration. The observations themselves will however best point out the nature of these effects.

My first object was to compare the effects on an unmagnetized steel needle with those on a magnetized needle, under circumstances as nearly as possible the same. For this purpose I made another needle of the same form and weight, and from the same piece of clock-spring, as the magnetized needle which I had already employed. Each needle had pasteboard glued to the

under side, to render it of precisely the same weight as two other needles of copper and of glass, which I had cut of the same form for the purpose of comparing the effects upon needles of different kinds. The length of each needle is 6 inches, and the greatest breadth 1.5 inch, the boundaries being circular arcs. The needles were vibrated by means of an apparatus, described in my former paper, from which metal was scrupulously excluded; the suspending wire being the only metal within several feet of the needle. This wire was of brass, and of such diameter, that the unmagnetized needles vibrated by the force of its torsion in very nearly the same time as the magnetized needle by the directive force of the earth. The observations are contained in the following table, where the terminal arc is, in all cases, the extent to which the needle vibrated beyond zero after completing the 100th vibration; and the terminal excess is the excess of the terminal arc when the needle vibrated in the shade above that when it vibrated exposed to the sun.

Needle vibrated.	Needle vibrated screened from the Sun.				Needle vibrated exposed to the Sun.					
	Extent of 1st Vibration.	Time of making 100 Vibrations.	100th or Terminal Arc.	Therm.	Extent of 1st Vibration.	Time of making 100 Vibrations.	100th or Terminal Arc.	Therm.	Terminal excess.	Difference of Temp.
	°	m s	°	°	°	m s	°	°		
Magnetized Steel Needle.	90+88	6 06.2	31.5	57.5	90+88	6 01.9	16.5	106		
Weight = 252¼ grains.	90+88.5	6 06.0	31.5	57.5	90+88	6 02.0	16.5	107		
	90+88	6 06.0	31.25	58.5	90+88	6 01.8	16.5	109		
Means...	90+88.2	6 06.1	31.4	57.8	90+88	6 01.9	16.5	107.3	14°.9	49°.5
	Apr. 19, from 9h A.M. to 9h 40m A.M.				April 19, from 9h 53m A.M. to 10h 17m A.M.					
Unmagnetized Steel Needle.	90+92.5	5 59.6	25	65	90+91.5	5 59.4	19	121		
Weight = 252¼ grains.	90+91.5	5 59.6	26.5	65	90+90.5	5 59.4	18.5	114		
	90+91.5	5 59.8	26.75	65	90+91	5 59.4	19	115		
Means...	90+91.8	5 59.7	26.1	65	90+91	5 59.4	18.8	116.7	7.3	51.7
	Apr. 21, from 23m P.M. to 52m P.M.				April 21, from 1h 07m P.M. to 1h 39m P.M.					

The circumstances under which the observations with the two needles were made, were as nearly the same as I could expect to have them; and the results show that the effect produced by the sun's rays on a steel needle, when vibrated exposed to their influence, is most decidedly increased when that needle is magnetized. The small differences which are to be noticed in the extent of the first arc of vibration would have little influence on the terminal arc, the

diminution in the large arcs being so much greater than in the small ones: for instance, the needle vibrating 90° beyond zero in the first vibration, in the second it would not vibrate to 88°; whereas the 100th vibration being 26°, the 101st would be $25\frac{1}{2}$° beyond zero. This remark applies to all the observations which I have made.

In making these observations, I first noticed that time appeared to be required, in order that the full effect arising from exposure to the sun should be produced. Thus the last observation in the shade with the magnetized needle being concluded at $9^h\ 40^m$, the screen was immediately removed, and I commenced an observation in the sun at $9^h\ 43^m$, which gave the terminal arc 23°; and the next observation in the sun, commencing at $9^h\ 53^m$, gave the terminal arc $16\frac{1}{2}$°. With the unmagnetized needle, the last in the shade being concluded at $0^h\ 52^m$, I commenced an observation in the sun at $0^h\ 53^m$, which gave the terminal arc 22°; the terminal arc in the next observation commencing at $1^h\ 07^m$ was 19°: and again the needle being screened at $1^h\ 39^m\ 45^s$, an observation in the shade, commencing at $1^h\ 39^m\ 30^s$, gave the terminal arc $24\frac{1}{2}$° instead of 26°, which I had obtained previously. I ought to mention, that during the observation with the magnetized needle in the sun to which I have referred, the power of the sun was diminished by a haze which produced a halo round it; and the extent of the terminal arc might partly be attributed to this circumstance. I have, however, observed the same effect on other occasions where no such cause operated.

In the following table, are contained similar observations, which I made with these steel needles and two others, the one of copper, and the other of glass. The four needles were of the same form and weight, and vibrated nearly in the same time; the unmagnetized steel needle, the copper needle and the glass needle being suspended by the same wire as I had used in the foregoing experiments with the unmagnetized steel needle.

Needle vibrated.		Time of commencing Observation.	Extent of first Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer. Exposed to Sun.	Thermometer. In Shade.	Remarks.
Glass Needle. Weight 252¼ grains.	Screened from the Sun.	July 2nd. h m	° °	m s	°	°	°	
		10 02	90+88	6 01.0	29.5	124.5	74	Sun shining clear.
		10 12	90+88	6 01.0	29.0	132.0	75	Sun shining clear.
		10 21	90+88	6 01.0	29.0	118.0	73.5	Clouds over sun.
		Means...	90+88	6 01.0	29.17		74.2	
	Exposed to the Sun.	10 38	90+87.5	6 01.0	23.0	123.0	74.8	Sun clear.
		0 46	90+88	6 01.6	22.0	132.0	78.5	Sun clear: dew on the glass of the instrument.
		0 56	90+88.3	6 01.6	23.5	141.5	79.0	Sun clear: dew on the glass of the instrument.
		Means...	90+87.9	6 01.4	22.83	132.2		Terminal excess = 6.34°; {diff. of temp. in sun and in shade.} = 58°
Copper Needle. Weight 252¼ grains.	Exposed to the Sun.	3 35	90+90	5 57.4	29.0	136	80.0	Sun clear.
		3 45	90+89.5	5 57.2	27.5	140	80.6	Sun clear.
		3 53	90+89.3	5 57.2	28.0	141	80.4	Sun clear.
		Means...	90+89.6	5 57.27	28.17	139		
	Screened from the Sun.	4 03	90+90.5	5 57.2	32.75	142	80.0	Sun clear.
		4 12	90+91.0	5 57.2	34.0	143	80.0	Sun clear.
		4 20	90+89.0	5 57.0	33.0	142	80.0	Sun clear.
		Means...	90+90.2	5 57.13	33.25		80.0	Terminal excess = 5.08°; {diff. of temp. in sun and in shade.} = 59°
Unmagnetized Steel Needle. Weight 252¼ grains.	Screened from the Sun.	July 3rd.						
		9 15	90+87	6 00.2	28.5	135	74.7	Sun clear.
		9 25	90+88	6 00.4	29.25	136	75.3	Sun clear.
		9 34	90+89	6 00.4	29.5	138	76.0	Sun clear.
		Means...	90+88	6 00.33	29.08		75.3	
	Exposed to the Sun.	9 43	90+88	5 59.8	25.25	136	76.0	Sun clear. } These two observations are not included
		9 52	90+89	5 59.6	23.5	141	78.0	Sun clear. } in the mean.
		10 02	90+87.5	5 59.2	22.0	147.8	79.0	Sun clear: dew on the glass of the instrument.
		10 11	90+89.5	5 59.0	22.0	148	79.4	Sun clear: dew on the glass of the instrument.
		10 20	90+87	5 59.0	21.0	149	80.0	Sun clear: dew on the glass of the instrument.
		Means...	90+88	5 59.07	21.67	148.3		Terminal excess = 7.31°; {diff. of temp. in sun and in shade.} = 73°
Magnetized Steel Needle. Weight 252¼ grains.	Screened from the Sun.	0 38	90+87	6 12.3	29.5	142	86	Sun clear.
		0 48	90+88	6 12.6	29.5	140	85.7	Sun clouded for 50s.
		1 04	90+87.5	6 12.2	29.5	122	85.4	Sun clouded.
		Means...	90+87.5	6 12.37	29.5		85.7	
	Exposed to the Sun.	1 16	90+88	6 12.4	21.5	141	86.2	Sun clear. Not included in the mean.
		1 26	90+88	6 12.4	17.5	149.8	87.6	Sun clear.
		1 35	00+88.3	6 13.9	16.0	155.0	88.8	Sun clear.
		Means...	90+88.1	6 13.15	16.75	152.4		Terminal excess = 12.75°; {diff. of temp. in sun and in shade.} = 66.7

This table exhibits in the clearest manner the difference between the effect on a magnetized needle and that on any other, when vibrating exposed to the influence of the sun's rays. Had the time during which the magnetized needle vibrated been 6^m instead of $6^m\ 13^s$, the terminal excess would have been $12°.3$ nearly, supposing it to be nearly proportional to the time. However, to render the time in which this needle made one hundred vibrations more nearly equal to those of the others, I remagnetized it; and four hours afterwards made the following observations.

Needle vibrated.		Time of commencing Observation.	Extent of the first Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer. Exposed to Sun.	Thermometer. In the Shade.	Remarks.
Magnetized Steel Needle. Weight 252¼ grains.	Screened from the Sun.	July 4th. h m 0 10	° ° 90+88	m s 6 01.1	° 29	° 149	° 84.5	Sun clear.
		0 28	90+87.75	6 01.3	29	150	84.6	Sun clear.
		0 37	90+88	6 01.4	29	149.6	83.0	Sun clear.
		Means	90+87.9	6 01.27	29		84.0	
	Exposed to the Sun.	0 46	90+88	6 02.4	18	149.0	83.5	Sun clear. At 6^m $02^s.4$, terminal arc = $18°$
		1 00	90+88	6 05.8	16.75	146	83.2	Sun clear. At 5 58.5 or 98^{th} vib. arc = 17.25
		1 12	90+87.75	6 06.4	16.5	147	83.0	Sun clear. At 5 59.1 or 98^{th} vib. arc = 17.0
		1 24	90+87.75	6 06.8	15.5	145	83.4	Sun clear. At 5 59.5 or 98^{th} vib. arc = 16.0
		Means	90+87.9	6 05.35	16.7	146.75	83.3	Time = 5^m 59.98^s, arc = 17.06
	Screened from Sun.	1 33	90+87.75	6 07.6	24.5	145.0	83.8	Sun clear. { At 6^m 0.0^s or 98^{th} vib. arc = 24.75 Not included in the mean.
		1 46	90+87.75	6 08.8	27.5	144.0	83.8	Sun clear. At 6 01.4 or 98^{th} vib. arc = 28.25
		1 55	90+87.75	6 09.0	27.75	140.8	82.8	Sun clear. At 6 01.6 or 98^{th} vib. arc = 28.5
		Means	90+87.75	6 08.9	27.62		83.3	Time = 6^m $01^s.5$, arc = 28.38
		Taking the mean of the arcs in the shade, and in the sun, when the time of vibrating was the same, we have, Terminal Excess = 11°.5; Difference of temperature in sun and in shade = 63°.1.						

Some of these observations again appear to indicate, that the full effect of diminishing the terminal arc was not produced immediately on exposing the needle to the sun's rays, nor was the full effect of increasing it immediately produced on screening the needle from their influence. The first observation with the unmagnetized needle exposed to the sun, commenced immediately that the screen was removed, and the terminal arc was $25\frac{1}{4}°$; in the next observation the terminal arc was $23\frac{1}{2}°$; but in those which followed, it was

reduced to 22° and 21°, which appeared to be the limit. The observations with the magnetized needle give similar results. The terminal arc was $21\frac{1}{2}°$ in the first observation with the needle exposed to the sun, which commenced immediately that the screen was removed; and this arc was only $17\frac{1}{2}°$ and 16° in the subsequent observations. The result was similar in the first observation in the sun on the 4th of July; although the difference between the terminal arc in this and the following observations was not so considerable: but in the first observation when the needle was screened, after having been exposed to the sun, and which commenced immediately that the needle was screened, the terminal arc was only $24\frac{3}{4}°$ instead of 29°, which it had been in the shade previous to exposure to the sun. This circumstance would appear to indicate that the diminution of the terminal arc, on exposure to the sun, was caused by the heat which it imparted; but subsequent observations clearly showed that this was not the case, and that the effect was only so far dependent on the heat of the sun, that this appeared in some instances to measure the intensity of the action which produced the diminution. These observations in July, compared with those in April, appear to indicate that the effect of the sun's rays on the magnetized needle in April was greater than in July; although their intensity, measured by the heat imparted, was much less in the former case than in the latter. If, however, such is really the case, nothing but observations carefully made and repeated during a series of years, would satisfactorily establish such a fact. It may appear that I have unnecessarily multiplied observations all pointing to the same conclusions: my object in making them was, in the first instance, to satisfy myself that the effects which I observed invariably took place under certain circumstances; and I, in all cases, give these repeated observations, that others may be enabled to draw their own conclusions from them, should they doubt the correctness of mine.

In order to determine how far the vibrations of a needle are influenced by the separate rays, I placed a glass cylinder, ground plane on the under edge, upon the plate of glass covering the compass-box; and I proposed, by having fluids of different colours in this cylinder, to transmit only particular rays to the needle. Owing, however, to the irregularities on the sides of the cylinder, so much light was lost in transmission through the cylinder even when empty, that the effect was considerably diminished; and after a few trials I gave up

this method of observing, as before I could have procured another cylinder better adapted to my purpose, I should no longer have been able to devote the requisite time to the inquiry. The only effect which I observed was, that transmitting the rays through half an inch of the sulphate of indigo very much diluted, appeared to be nearly equivalent to intercepting them altogether. Another method which I adopted for transmitting only particular rays, was by placing circles of glass painted with different transparent colours over the compass; but in this manner I obtained no very determinate results as respected the effects of rays of different colours. Although I failed in the particular object I had in view, the observations led to one important conclusion, which I have already noticed, that the diminution in the terminal arc was not produced by the heat imparted by the sun, either to the needle or the medium in which it vibrated.

The difference made in the apparatus was, that the compass-box was nine inches in diameter, to contain a graduated circle of paper eight inches in diameter; so that the needle having bristles in the direction of its axis projecting 1.5 inch beyond its extremities as indexes, I was enabled to read the direction of the needle, although it was hid by the coloured glass placed over the glass top of the instrument. In order that I might have a tolerably correct measure of the temperature within the compass-box during the different observations, I placed inside, a small spirit thermometer, graduated on ivory, and having the tube fixed to the scale by narrow bands of paper. I likewise employed a powerful lens eleven inches in diameter to concentrate the rays on the space in which the needle vibrated. I attempted also to bring the focus of the lens within the compass-box, but the heat was so great that it burned part of the apparatus; and I desisted, lest by injuring the essential parts I should put an end to my experiments. The coloured glass consisted of two semicircles, each having a small concentric semicircle cut out, so that they fitted each other round the tube carrying the suspending wire. Having clearly ascertained the fact that the effect produced on the magnetized needle was different from that on any other, the observations which I now made were on the vibrations of a magnetized needle alone; and I employed that which I had already used, removing however the additional weight of paper which had been fixed to it, so that its weight was now only 197 grains, and its time of vibration was likewise diminished. The following are the observations which I thus made.

Circumstances under which the Needle vibrated.	Time of commencing the Observation.	Extent of the first arc of Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer. Within the Compass-box.	Thermometer. Exposed to the Sun.	Thermometer. In Shade.	Remarks.
	July 29th. h m		m s					
Screened from the Sun.	9 15	90°+84°.5	5 31.0	19°.8	72°.5	123°.0	61°.4	Sun clear.
	9 30	90+84.8	5 31.5	21.5	73.0	110.6	60.8	Sun clear.
	9 40	90+84.8	5 31.1	20.5	73.0	126.0	63.0	Sun clear.
Exposed to the Sun.	9 50	90+84.8	5 30.0	9.8	100.0	134.0	65.0	Sun clear. The full effect appears to have been produced almost immediately.
	10 04	90+84.8	5 30.4	14.8	95.5	104.0	64.6	Sun obscured by dark clouds.
	10 15	90+84.8	5 29.8	9.3	102.9	120.0	64.8	Sun clear.
	10 23	90+84.8	5 31.1	14.3	102.5	108.4	64.6	Sun obscured by dark clouds, $165^s + 35^s$.
	10 35	90+84.5	5 29.8	9.3	117.7	127.4	66.0	Sun clear.
Sun's rays concentrated by lens: Needle beyond the focus of lens: two semicircles of blue glass over.	11 20	90+84	5 33.4	18.5	114.5	143.0	68.8	Sun clear.
	11 29	90+86	5 34.0	17.3	107.5	140.0	69.5	Sun obscured, 120 sec.
	11 40	90+86.5	5 34.3	18.5	107.4	147.0	69.8	Sun obscured, 15 sec.
	11 58	90+85.5	5 34.0	20.8	104.5	142.5	70.0	Sun clear.
	0 10	89.5+83	5 32.6	19.5	109.0	143.0	72.0	Sun clear.
Blue glass removed	0 22	90+84.8	5 34.4	10.5	128.0	141.0	73.0	Light haze with coloured halo round the sun.
Lens edgewise to the Sun . .	0 44	90+84	5 33.8	15.5	113.9	115.3	73.0	Sun scarcely seen; obscured by dense haze.
Lens removed .	0 58	90+84.8	5 34.2	17.5	111.0	108.2	74.0	Sun cast a very faint shadow.
Screened from the Sun.	1 11	90+84.8	5 34.3	20.5	104.6	122.4	74.6	Sun not clear; faint haze over.
	1 21	90+85.3	5 33.6	21.5	97.0	132.7	73.6	Sun clear at intervals.
	1 35	90+85.3	5 33.7	20.5	91.7	113.6	71.8	Sun hid entirely by a hazy cloud.
			Time of making 98 vibrations.					The intensity of the needle had been so much reduced by having the rays concentrated on it in some attempts with the lens, that the time of vibration was increased.
Exposed to the Sun.	3 15	90+85.3	5 34.1	16.0	101.3	127.2	74.0	Sun obscured by a light hazy cloud.
	3 24	90+85	5 34.7	13.0	111.5	128.7	74.0	Sun slightly obscured by very light haze.
	3 45	90+85	5 33.8	15.0	117.0	132.2	74.0	Sun slightly obscured by very light haze.
Screened from the Sun.	3 56	90+85	5 34.4	20.3	104.0	130.0	74.6	Sun obscured by light haze.
	4 07	90+84.5	5 33.4	21.0	93.5	122.0	74.0	Sun obscured by hazy cloud.
	5 43	90+84.5	5 34.4	22.5	79.5	80.5	72.2	Sun obscured by cloud.
	5 54	90+84.5	5 34.6	22.0	79.0	80.3	72.2	Sun obscured by cloud.

From these observations it appears, that the diminution in the terminal arc in all cases corresponded to the intensity with which the sun shone on the needle; that this arc was in all cases increased by a screen being interposed, whether the screen entirely excluded the direct rays, as when the wooden screen was interposed, or only partially, as in the cases of the sun being obscured by haze or cloud, or the needle being covered with blue glass, which

appeared to act simply as a screen; and that the diminution in the terminal arc did not correspond to the heat imparted to the needle or the medium in which it vibrated, excepting so far as this in some cases might correspond with the intensity of the sun's rays.

In the following observations I varied some of the circumstances: the day was most favourable for them, the sky continuing cloudless throughout, and the heat of the sun great, in the middle of the day intense.

Circumstances under which the Needle vibrated.	Time of commencing the Observation.	Extent of the first arc of Vibration.	Time of making 100 Vibrations.	Terminal Arc.	Thermometer. Within the Compass-box.	Thermometer. Exposed to the Sun.	Thermometer. In Shade.	Remarks.
	July 30th. h m	°	m s	°	°	°	°	
Screened from the Sun.	10 27	90+86.5	5 41.0	19.5	77.5	132.8	64.8	The sky cloudless throughout the day, and the heat of the sun very great, in the middle of the day intense.
	10 36	90+86.5	5 41.0	20.5	77.5	139.5	68.2	
	10 45	90+86.3	5 42.2	20.5	78.4	143.5	69.0	
Exposed to the Sun.	10 56	90+86.5	5 40.4	12.8	97.7	146.0	70.0	The full effect does not appear to have been produced immediately.
	11 20	90+86.5	5 40.2	8.3	130.5	145.3	71.8	
	11 30	90+86.5	5 40.5	8.0	136.5	146.0	72.0	
Screened from the Sun.	11 44	90+86	5 41.6	17.5	124.5	147.0	72.3	The full effect does not appear to have been produced immediately.
	11 56	90+86	5 42.6	21.0	101.0	149.0	73.3	
	0 06	90+86	5 42.6	21.5	96.0	152.0	74.0	
Exposed to the Sun, but two semicircles of red glass over the Compass-box.	0 23	90+87	5 41.7	12.5	114.0	150.4	74.2	
	0 33	90+86	5 41.7	13.0	120.3	151.8	74.6	
	0 44	90+85.8	5 42.2	13.0	124.4	150.8	75.0	
The Sun's rays concentrated by the lens nearly over the space in which the Needle vibrates. — Two semicircles of red glass over the Needle.	1 11	90+85	5 42.4	13.0	129.0	150.7	75.4	
	1 26	90+85.5	5 42.7	12.8	132.9	149.0	76.0	
The semicircles of red glass removed.	1 36	90+85.5	5 42.6	7.3	141.0	149.5	76.0	N. end of the needle vibrates, on the west side, in the violet rays from the lens.
	1 48	90+85	5 41.9	5.8	156.0	150.2	77.0	The violet rays further from the N. end of the needle.
	1 59	90+85.3	5 41.4	6.8	156.0	150.4	77.2	The violet rays again nearer to the N. end of the needle.
Two semicircles of blue glass over the Needle.	2 13	90+85.3	5 41.8	13.5	137.8	151.0	78.0	
	2 26	90+85.5	5 43.0	17.5	124.0	149.9	78.0	
A semicircle of blue glass over S. side of Compass-box.	2 37	90+86	5 42.8	14.5	†119.5	148.0	78.2	† The rays on the bulb of the thermometer transmitted through the blue glass.
	2 48	90+86	5 42.6	15.0	†116.5	145.5	78.2	
A semicircle of blue glass over E. side of Compass-box.	3 04	90+85.5	5 41.4	11.0	‡126.5	140.0	78.4	‡ The rays again striking immediately on the bulb.
	3 15	90+84.5	5 41.4	13.3	‡125.5	137.0	78.4	
Blue glass removed: Needle exposed to concentrated rays.	3 33	90+86	5 42.6	5.5	165.5	135.0	78.4	Rays of greatest intensity on S. side of compass-box.
	3 43	90+85	5 43.4	3.8	167.0	130.5	78.2	Rays of greatest intensity on centre of needle.
Lens removed: needle exposed to the Sun.	3 53	90+84.8	5 41.8	7.0	158.0	129.0	78.2	
	4 04	90+85.8	5 42.6	8.8	139.5	123.0	78.4	
Screened from the Sun.	4 14	90+85	5 42.8	17.5	123.5	120.0	78.0	The full effect does not appear to have been produced immediately.
	5 55	90+86	5 44.2	21.5	82.0	*79.5	74.0	
	6 05	90+85.8	5 43.8	21.5	81.0	*78.3	73.2	* This thermometer had now become shaded by a wall.
	6 14	90+86	5 43.8	21.8	80.0	*76.4	73.0	

Although it appears from these observations, as from the preceding ones, that the diminution of the terminal arc did not in all cases correspond to the temperature of the needle or of the medium, yet it depended essentially on the intensity of the rays in the space in which the needle vibrated; the terminal arc being 3°.8 when the rays were most concentrated, and 5°.5, 5°.8, 6°.8, 7°, 8°, and 8°.8 as their intensity was diminished. The results obtained with the coloured glasses appear to indicate that the red rays had a greater effect in diminishing the terminal arc than the blue; for although the blue on the glass was very transparent, and the red far from being so, yet when the needle was screened by the blue glass, the terminal arc was 17°.5, and when screened by the red 13°, the thermometer within the compass-box indicating nearly the same temperature in the two cases. The effect which I observed on throwing the violet rays, as separated by the lens, further from the end of the needle and then bringing them nearer, although not very decided, favours the same conclusion. No further effect than that of partially screening, appears to have been produced by making one end of the needle vibrate in the blue rays while the other vibrated in the direct light of the sun.

If we may conclude from these observations, that the red rays are those which cause the diminution in the terminal arc, we might infer that the heat imparted to the needle or to the air was the cause of this diminution; but the experiments themselves show that this was not the case. However, to remove all doubt on this part of the subject, I determined to observe the terminal arcs with the different needles when their temperature and that of the medium in which they vibrated varied, and all other circumstances remained precisely the same.

For the purpose of making these observations, I placed a graduated circle of paper in a shallow vessel of earthenware, 7.5 inches in diameter, and 1.2 inch deep, having a rim projecting 1.2 inch all round. This rim rested on the rim of another vessel of earthenware 9.4 inches in diameter, and 3.6 inches deep, and which contained hot or cold water, according to circumstances, so as to surround the upper vessel to its rim. The glass cover of the compass, having in its centre the glass tube carrying the wire of suspension, was placed over the upper vessel, which thus supplied the place of a compass-box. The needles were successively suspended within this vessel by the same wires and in the same stirrups as before; the magnetized needle by the very fine brass wire; the glass, the copper, and the unmagnetized steel needle by the much thicker

wire, which caused them to vibrate in nearly the same time as the magnetized needle. So that, as before, the needles and suspending wires were the only substances of metal used in the apparatus. The upper vessel contained the small spirit thermometer which had before been placed in the compass-box. The ivory scale rested upon pieces of cork, which prevented the contact of the bulb or scale with the bottom or sides of the vessel; so that this thermometer indicated pretty accurately the temperature of the air within the vessel in which the needle vibrated; and likewise nearly that of the needle itself, by allowing some time to elapse, after making a considerable change in the temperature, previously to commencing the observations.

In making the observations, the under vessel was first filled with cold water, and the apparatus so adjusted that the needle pointed to zero on the graduated circle when the wire was devoid of torsion. The needle was then made to vibrate until the arc on the western side of zero was as near to 90° as I could obtain*; the time of its next passing zero was noted, and also the arc of vibration on the other side. At the hundredth vibration, the time and the arc beyond zero were noted, as before. The state of the thermometer in the upper vessel was taken at the commencement and likewise at the conclusion of the observation, the mean being considered as the temperature of the needle and of the air in which it vibrated. After thus making three observations, the upper vessel containing the needle was removed, the cold water contained in the lower one poured out, that vessel heated and filled with boiling water, and the upper vessel replaced and adjusted as before. Cloths steeped in boiling water were placed over the glass cover, for the double purpose of more rapidly heating the air in the vessel in which the needle vibrated, and of preventing the deposition of dew on the under surface by condensation. When the temperature of the air within the upper vessel had nearly attained its maximum, observations on the vibrations of the needle were made as before. The lower vessel was again filled with cold water, and the observations repeated. The following table contains two sets of observations with the magnetized steel needle: in the first set, the plane of the needle having been somewhat inclined laterally

* The magnetized needle was made to vibrate by means of a weak magnet held on the outside of the box, and the other needles by turning the index to which the upper part of the suspending wire was attached, and again bringing that index to zero. As I could have no perforation either in the side of the vessel containing the needle, or in the glass cover, I was obliged to adopt this method.

to the horizon, it was rendered horizontal previous to making the second, which is the reason that the terminal arcs in the first are rather less than the corresponding arcs in the second.

	Extent of 1st Vibration.	Time of making 100 Vibrations.	100th or Terminal Arc.	Inclosed Thermometer.	Terminal Excess.	Difference of Temperature.
		m s	°	°		
Magnetized Needle. Weight = 197 grains.	90 +88	5 55.0	28.5	62.0		
	90 +88	5 55.4	28.75	62.5		
	90 +88	5 55.1	28.5	63.0		
Means.....	90 +88	5 55.2	28.6	62.5		
	90 +89	6 01.8	34.5	137.5		
	89 +87.5	6 02.2	34.0	139.0		
	90 +89	6 00.8	33.75	137.5		
Means at High Temperature	89.7 +88.3	6 01.6	34.1	138.0	5.05	75.1
	90.5 +88	5 54.8	29.5	64.25		
	90.5 +88	5 54.7	29.5	62.5		
Means.....	90.5 +88	5 54.75	29.5	63.37		
Means at Low Temperature	90.25+88	5 55.0	29.05	62.9		
Magnetized Needle. Weight = 197 grains.	90 +89	5 55.2	33.0	50.0		
	89.5 +89	5 55.2	32.0	50.0		
	91 +90	5 55.7	32.0	50.0		
Means.....	90.2 +89.3	5 55.4	32.3	50.0		
	90 +90	6 01.8	36.5	124.5		
	90 +90.5	6 02.2	37.0	128.5		
	90 +89	6 01.5	36.5	126.0		
Means at High Temperature	90 +89.8	6 01.8	36.7	126.3	4.1	75.2
	91 +90.5	5 56.4	33.0	53.5		
	89.5 +89	5 55.8	32.75	52.0		
Means.....	90.25+89.75	5 56.1	32.9	52.75		
Means at Low Temperature	90.2 +89.5	5 55.7	32.6	51.1		

Since, as might have been anticipated, it appears here that the effect upon the terminal arc, produced by an increase of temperature, is decidedly the reverse of that caused by the direct influence of the sun's rays, it follows that the latter effect does not arise from an increase in the temperature of the needle or of the medium in which it is vibrated. That there might be no doubt on the

subject, I repeated the observations with the magnetized needle, and made corresponding observations with the other three, the two steel needles having been previously rendered, as before, of the same weight as the others. In these observations, contained in the following table, the extent of the arc at the hundredth vibration was observed on both sides of zero, except with the copper needle.

Needle vibrated.	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Thermometer.	Terminal Excess.	Difference of Temperature.
	° °	m s	° °	°		
Magnetized Steel Needle. Weight = 252¼ grains.	90 +88.5	5 58.8	33 +33.5	51.5		
	90 +88	5 58.5	33.5+33.5	51.0		
	90 +88.5	5 58.2	33.5+33.5	51.5		
Means.....	90 +88.3	5 58.5	33.3+33.5	51.3		
	90 +88	6 13.2	40 +40	140.5		
	90 +88	6 11.8	39 +38.5	135.5		
	90 +88	6 11.8	41 +39.8	134.0		
Means at High Temperature.	90 +88	6 12.3	40 +39.4	136.7	5.8	85.2
	90.5+88.5	6 06.5	34 +34	51.75		
	90.5+88.5	6 05.0	35 +34	51.75		
	90.5+88	6 05.2	35 +34	51.75		
Means.....	90.5+88.3	6 05.6	34.7+34	51.75		
Means at Low Temperature.	90.3+88.3	6 02.05	34 +33.8	51.5		
Unmagnetized Steel Needle. Weight = 252¼ grains.	90 +87	5 52.8	21 +22	49.0		
	90 +88	5 52.6	21 +23	49.5		
	90 +87	5 52.6	21 +23	50.0		
Means.....	90 +87.3	5 52.7	21 +22.7	49.5		
	89 +87	5 51.4	26 +26.5	143.5		
	90 +88	5 50.8	25.5+26.5	139.0		
	90 +87.5	5 50.5	26 +26.5	130.5		
Means at High Temperature.	89.7+87.8	5 50.9	25.8+26.5	137.7	4.4	88.6
	90.5+88	5 50.0	22 +22	48.0		
	90 +87.5	5 49.9	21.5+22	48.5		
	90 +87	5 49.8	21.5+21.5	49.5		
Means.....	90.2+87.5	5 49.9	21.7+21.8	48.7		
Means at Low Temperature.	90.1+87.4	5 51.3	21.3+22.2	49.1		

Needle vibrated.	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Thermometer.	Terminal Excess.	Difference of Temperature.
	° °	m s	° °	°		
Copper Needle.	90 +89	5 51.1	28	57.0		
Weight = 252¼ grains.	89.5+88	5 51.2	28	57.0		
	90 +88.5	5 51.2	28	57.0		
Means.....	89.8+88.5	5 51.2	28	57.0		
	91 +89	5 49.9	32	136.5		
	89.5+89	5 49.8	32.3	138.0		
	90 +88.5	5 49.6	32	135.0		
Means at High Temperature.	90.2+88.8	5 49.8	32.1	136.5	4.0	79.75
	90 +89.5	5 51.2	28	57.5		
	90 +88	5 51.0	28.5	56.0		
	90 +88	5 51.2	28.5	56.0		
Means.....	90 +88.5	5 51.1	28.3	56.5		
Means at Low Temperature.	89.9+88.5	5 51.15	28.1	56.75		
Glass Needle.	90.5+90	5 56.0	27	51.0		
Weight = 252¼ grains.	90 +88	5 56.2	26.5	51.0		
	90 +88.5	5 56.2	26.5	52.0		
Means.....	90.2+88.8	5 56.1	26.7	51.3		
	90 +88	5 56.6	32.5+31.5	142.0		
	90 +88.3	5 56.4	31 +32	139.0		
	90 +88	5 56.4	32 +31.5	135.5		
Means at High Temperature.	90 +88.1	5 56.5	31.8+31.7	138.8	5.4	86.6
	90 +88	5 56.4	26 +25.5	57.0		
	90.5+88.5	5 56.0	26 +26	51.5		
	91 +90	5 56.2	26.5+26	50.75		
Means.....	90.5+88.8	5 56.2	26.2+25.8	53.1		
Means at Low Temperature.	90.3+88.8	5 56.2	26.3	52.2		

The effects here are not very different with the four needles. The glass needle and the two steel needles presenting broader surfaces on their sides to the air's resistance than the copper needle, it was to be expected that the terminal excess with these should be greater than with that needle; and I am not aware of any circumstance, except the shorter time during which the vibrations continued, that should have rendered it less with the unmagnetized

steel needle than with the other two. The principal fact, however, which I looked to ascertaining by these experiments was, whether the terminal excess was of the same character here when the temperature was increased, as that arising from vibrating the needle successively in the shade and exposed to the sun, when an increase of temperature likewise took place; and on this point they were quite conclusive, showing clearly, that if the terminal excess is considered plus in the latter case, it will be minus in the former. It is evident then from all these results, that if the rays of the sun had simply, uniformly increased the temperature of the medium in which the needle vibrated, and of the needle itself, the effect would have been in all cases to increase the length of the terminal arc, instead of diminishing it, as was invariably the case when exposure to the rays of the sun caused an increase of temperature. There can therefore be no doubt that the influence of the sun was not confined to uniformly heating the medium and the needle, but that, in all cases, other effects than would arise from this were produced, and that the influence upon the magnetized needle was very different from that upon either of the others.

I next proposed to determine the effects that would be produced on the arcs of vibration by the heat of a fire. For this purpose I placed the apparatus before a strong fire, at the distance of about two feet from the front, and six inches below the bottom of the iron grate containing it, and vibrated the magnetized needle, and likewise the glass needle, when successively screened from, and exposed to its direct influence. The observations, which are contained in the subjoined Table, show that the effect produced by exposure to the fire, though small, was to bring the needle sooner to rest, or that it was of the same character as that produced by exposure to the sun. I am not disposed to lay any stress upon the circumstance that the terminal excess was almost precisely the same in the two cases, but to attribute it to the small errors in the observations having accidentally so compensated each other as to produce this very close agreement. Indeed, if I could have detected such minute differences, the terminal excess ought to have been rather greater with the magnetized than with the glass needle, since the intensity of the fire's heat appeared to be greater with the former than with the latter. We may, however, infer from these experiments, that if the intensity of the fire's heat had been precisely the same with the two needles, no sensible difference would have been observed in the effects produced on them. The observations were

made in this order: The first three observations with the apparatus screened from the fire by a thick board; then immediately the four with the screen removed; after which it was replaced, and the other observations made.

Needle vibrated.	Needle vibrated screened from the Fire.				Needle vibrated exposed to the Fire.					
	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Therm.	Extent of 1st Vibration.	Time of making 100 Vibrations.	Extent of 100th Vibration or Terminal Arc.	Inclosed Therm.	Terminal excess.	Difference of Temp.
		m s								
Magnetized Needle.	90°+89°	5 48.2	35° +34°.5	51°.0						
Weight = 252½ grains.	90+88.5	5 48.4	34.5+34.3	51.5						
	90+89	5 48.4	34.5+34.3	52.0	90°+89°	5 48.8	34°.3+34°	56°.5		
	90+89	5 49.2	34.5+34	84.0	90+89	5 49.8	33.5+34	76.0		
	90+88.5	5 48.8	34.5+34.2	76.5	90+88.5	5 50.4	33.5+34.2	83.0		
	90+89.5	5 48.7	35 +34.5	67.0	90+89	5 50.6	33.8+34	90.0		
Means...	90+88.9	5 48.6	34.7+34.3	63.7	90+88.9	5 49.9	33.8+34	76.4	0°.57	12°.8
Glass Needle.	90+84	5 56.8	25 +25.5	58.0						
Weight = 252¼ grains.	90+85	5 57.2	25.2+25.8	58.25	90+84.5	5 58.0	24 +25.5	62.5		
	90+84	5 57.3	25 +25.5	58.75	90+85	5 58.4	24 +25.3	70.0		
	90+84	5 57.8	25 +25.3	74.5	90+85	5 58.6	24.2+25.3	75.0		
	90+84	5 57.5	25 +25.3	71.5	90+85	5 58.6	24.2+25	77.0		
	90+84.2	5 57.3	25 +25.5	64.25	90+84.9	5 58.4	24.1+25.3	71.1	0.56	6.9

From all the experiments which I have described, there can, I think, be no doubt that the rays of the sun have a peculiar influence on a magnetized needle, which causes, when such a needle is exposed to them, a greater diminution in its arcs of vibration than in those of any other needle under like circumstances; and that this effect is independent of the heat imparted to the needle or to the medium in which it vibrates. That part of the effect which is produced on all needles may perhaps be caused in this manner: as the air directly below the needle is in the shade, and therefore colder than that above it, a current of air will pass the edges of the needle, which may considerably increase the resistance and consequently diminish the terminal arc; and this may possibly account for the full effect not taking place immediately, since these currents would not be excited in full force immediately on exposing the needle to the sun, nor on screening it would they immediately subside*. Had this, however, been the

* If this is the cause of the terminal excess with the non-magnetic needles, this excess would nearly vanish if a wire frame of the same form as the needles were successively vibrated in the shade and exposed to the influence of the sun, since in this case there would be little shadow below the needle. This experiment I proposed making, but have not yet had an opportunity.

only cause of the terminal excess with the magnetized needle as well as with the others, this excess would have been nearly the same for all, or it would only have differed according to the thickness of the needle. The terminal excess ought in this case to have been nearly the same for the glass, the unmagnetized steel and the magnetized steel needles, and less for the copper than for either of these. This accords, in some measure, with the experimental results which I obtained with the copper needle, the glass needle, and the unmagnetized steel needle; but as the effect on the last was only about four-sevenths of that on the magnetized steel needle, we must, for part of the effect upon this needle, look to causes distinct from that which produced the effect on the others.

It is extremely difficult to point out any principle to which this effect upon the magnetized needle can be referred. Are we to infer from these experiments that light and magnetism have relative density, although the density of either is evanescent with regard to that of the rarest gas; and that therefore light may offer a sensible resistance to magnetic particles in their passage through it, and consequently also to the bodies with which they are united? That light is of such extreme tenuity as to offer no resistance to the passage of the rarest gas,—of which, however, we have no proof,—cannot be adduced as an argument against such an inference. Or, is it possible that the effect may be produced in a manner similar to that on needles vibrating within metallic rings? If this be the case, we must suppose that the rays become magnetic by induction, in their passage by the needle, and that their maximum of magnetism not being developed until after they have passed it, the most magnetic rays will always be in the rear of the needle, and by their attraction impede its progress. If the effect is produced in this manner, we might expect, when a strong magnet is brought near to a ray of light transmitted through a small opening into a dark room, that the ray would be inflected. I have not had an opportunity of making this experiment in a conclusive manner, but in the trials which I have made I have observed no such effect.

In the conclusion of my former paper I stated, that as magnetic influence in the compound solar rays was indicated by the effects which I had described, this would tend to remove the doubts which had been entertained respecting the results obtained by Morichini, by means of the violet rays; and Mrs. Somerville's paper, read almost immediately after mine, describing the effects

which that lady had observed to be produced under different circumstances by the more refrangible rays, appeared completely to verify MORICHINI's results, and to corroborate my opinion. Although the experiments of Mrs. SOMERVILLE have, on repetition, in many instances failed, we cannot, seeing the precautions that were taken, suppose that the effects described were due to other causes than the influence of the rays, but must rather infer that we are not aware of all the circumstances which may interfere with the success of the experiment. It cannot, however, be denied that the subject is at present involved in much mystery; and it is therefore very desirable that the circumstances on which the success of Mrs. SOMERVILLE's experiment depends should be clearly ascertained, and that the effects which I have invariably found to be produced by the compound rays should be traced to some known principle of action. I had proposed to myself to make several series of observations with the view of obtaining comparative results with different azimuths of the sun, at different seasons of the year, and likewise with the horizontal needle and the dipping needle vibrated both in the meridian and at right angles to it; and also to determine, with some degree of precision, the effects produced by the several separated rays under different circumstances. But in the experiments which I have already made, I have met with so many and such vexatious interruptions, arising principally from the uncertainty of our climate, and partly from my not always being able to avail myself of a favourable state of the weather, that seeing no prospect of succeeding in experiments requiring continued clear weather and uninterrupted leisure, I must leave them to be made by those who may be placed under more favourable circumstances, and be content to prosecute the inquiry by making such experiments as intervals of leisure, which I may have during fine weather, will allow.

Royal Military Academy,
2nd June, 1828.

S. H. CHRISTIE.