

On Atmospheric Magnetism. By PROFESSOR FARADAY.

From the Proceedings of the Royal Institute of Great Britain, April 11, 1851.

On a former evening (January 24), it was shown that oxygen gas was magnetic, being attracted towards the poles of a magnet; and that like other magnetic bodies, it lost and gained in power as its temperature was raised and lowered, and that the change occurred within the range of natural temperatures. These properties it carries into the atmosphere; and the object, this evening, was to show how far they might be applied to explain certain of the observed variations of the terrestrial magnetic force.

If a source of magnetic power be considered (as a magnet) it presents us with a system having polarity; and if the parts which are called the poles be taken as representing the most concentrated condition of the polarity, then the contrary polarities, manifest externally in relation to the magnet, are perfectly definite, being exactly equal to each other. If the magnet be irregular in the disposition of its force, still the same definite character of the sum of the contrary polarities holds good.

External to the magnet those concentrations which are named poles may be considered as connected by what are called magnetic curves, or lines of magnetic force, existing in the space around. These phrases have a high meaning, and represent the ideality of magnetism. They imply not merely the directions of force, which are made manifest when a little magnet, or a crystal, or other subject of magnetic action, is placed amongst them, but those lines of power which connect and sustain the polarities, and exist as much when there is no magnetic needle or crystal there as when there is; having an independent existence analogous to (though very different in nature from) a ray of light or heat, which, though it be present in a given space, and even occupies time in its transmission, is absolutely insensible to us by any means whilst it remains a ray, and is only made known through its effects when it ceases to exist. The form of a line of magnetic force may vary exceedingly from a straight line to every degree of curvature, and may even have double and complicated curvatures impressed upon it. Its direction is determined by its polarity, the two changing together. Its powers are such, that a magnetic needle placed in it finds its place of rest parallel to it; a crystal of calcareous spar turns until its optic axis is transverse to it; and a wire which is unaffected when moved in or along it, has an electric current evolved the instant that it passes across it: by these and by other means the presence of the magnetic line of force and its direction are rendered manifest.

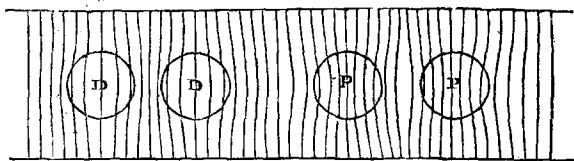
The earth is a great magnet: its power, according to Gauss, being equal to that which would be conferred if every cubic yard of it contained six one-pound magnets; the sum of the force therefore is equal to 8,464,000,000,000,000,000,000 such magnets. The disposition of this magnetic force is not regular, nor are there any points on the surface which can be properly called poles: still the regions of polarity are in high north and south latitudes; and these are connected by lines of magnetic force (being the lines of direction) which, generally speaking, rise out of the earth in one (magnetic) hemisphere, and passing in varied directions over the equatorial regions into the other hemisphere, there

enter into the earth to complete the known circuit of power. A free needle shows the presence and direction of these lines. In London they issue from the earth at an angle of about 69° with the horizon (being the dip or inclination); and the plane in which they rise forms an angle of 23° W. nearly with true north, giving what is called west declination. Where the dip is small, as at the magnetic equator, these lines scarcely rise out of the earth, and pass but a little way above the surface; but where it is large, as in northern or southern latitudes, they rise up at a greater angle, and pass into the distant realms of space, from whence they return again to the earth in the opposite magnetic hemisphere; thus investing the globe with a system of forces like that about an ordinary magnet, which wherever it passes through the atmosphere, is subject to the changing action of its magnetic oxygen. There is every reason to believe that these lines are *held* in the earth, out of which they arise and by which they are produced, just as the lines which originate in a magnet are held by it, though not in the same degree; and that any disturbance from above affecting them, will cause a greater change in their place and direction, in the atmosphere and space above, than in the earth beneath.

The system of lines of magnetic force around a magnet or the earth is related by a lateral tension of the whole, analogous in some degree to the lateral tension of lines of static electrical force; both the one and the other being easily made manifest by experiment. The disturbance of the tension in one part is accompanied instantly by a disturbance of the tension in every other part; for as the sum of the external powers of a system, unaltered at its origin, is definite and cannot be changed; so any alteration, either of intensity or direction amongst the lines of force at one place, must be accompanied by a corresponding change at every other. So if a mass of soft iron on the east side of a magnet causes a concentration of the lines of force from the magnet on that side, a corresponding expansion or opening out of the lines on the west side must be, and is at the same time produced; or if the sun, on rising in the east, renders all the oxygen of the air on that side of the globe less magnetic, and less able therefore to favor the transition of the lines of terrestrial force there, a greater number of them will be determined through the western region; and even though the lines of force may be doubted by some as having a separate existence, such as that above assumed, still no error as to the effects on magnetic needles would in that case be introduced, for they by experiment would be and are the same.

The power of a magnetic body as iron or oxygen to favor the transmission of lines of force through it more than other bodies not magnetic, may be expressed by the term conduction. Different bodies, as iron, nickel, oxygen, conduct in various degrees, and not only that, but the same body as iron or oxygen conducts in different degrees at different temperatures. When space traversed by uniform lines of magnetic force is occupied by a uniform body as air, the disposition of the lines is not altered; but if a better conducting substance than the air is introduced, so as to occupy part of the space, the lines are concentrated in it, and drawn from other parts as shown by P P in the figure, or if a worse conducting substance is introduced, the lines are opened out as at D D.

In both cases the lines of force are inflected, and a small magnetic needle standing in them at the inflected part, would have its direction changed accordingly. Experimental illustrations of these changes in direction are given in Mr. Faraday's paper in the Philosophical Transactions for 1851, Part I. Par. 2843, &c.



Now this by the hypothesis is assumed to take place in the atmosphere. Supposing it all at mean temperature, the lines of force would have the direction determined by the arrangement of the power within the earth. Then the sun's presence in the east would make all the atmosphere in that region a worse conductor, and cause it to assume the character of D; and as the sun came up to and passed over the meridian and away to the west, the atmosphere under his influence would bring up changes in direction like those shown in either D or P; it would therefore manifestly set a needle in a given latitude in opposite directions as it passed by; and as evidently set two needles in north and south latitudes in opposite directions at the same moment of time. As the night came on, and a temperature lower than the mean came up from the east and passed over, the lines of force would be inflected as in P or P, and a reverse variation of the needle to that which occurred before, would now take place.

That natural effects of variation must be produced consequent upon the magnetic nature of oxygen and its daily variations of temperature, is manifest; but whether they cause the observed variations, or are competent to do so, is a question that can only be decided after very careful inquiry. Observations are now made on the surface of the earth with extreme care in many places, and these are collated, and the average or mean result, as to direction and intensity of the earth's force, ascertained for every hour and season; and also many remarkable, anomalous, and extra results evolved. A theory of the causes of any or all of these variations may be examined first by the *direction* which the varying needle does or ought to assume, and then by the *amount* of the variation. The hypothesis now brought forward has been compared with the mean daily variation for all the months in the year at north and south stations, as Toronto and Hobarton, and at many others near to and far from the equator, and agrees in direction with the results observed far beyond what the author anticipated. Thus the paths described by the upper ends of free needles in the north and south hemispheres should be closed curves, with the motion in opposite and certain directions, and so they are:—the curves described by needles in north or south latitudes should be larger in summer and smaller in winter, and so they are:—a night or cold action should grow up in the winter months, and such is the case:—the northern hemisphere ought to have a certain predominance over the southern, because of its superior temperature, and that is so:—the disposition of land and water ought to have an influence, and there

is one in the right direction:—so that in the first statement and examination of the hypothesis, it appears to be remarkably supported by the facts. All these coincidences are particularly examined into and stated in the Philosophical Transactions already referred to. The next step will be to ascertain what is the amount of change in the conducting power of the air for given changes of temperature, and then to apply that in the endeavor to ascertain whether the amount of change to be expected is (as well as the direction) accordant with that which really occurs.

For the Journal of the Franklin Institute.

A Series of Lectures on the Telegraph, delivered before the Franklin Institute.

Session, 1850-51. By DR. L. TURNBULL.

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Gauss and Weber Electro-Magnetic Needle Telegraph.

Counsellor Gauss, and Professor Weber, two of the most illustrious philosophers of Germany, to whom the science of magnetism is deeply indebted, entered nobly into the list in establishing, by means of electricity, telegraphic communication between the Astronomical Observatory, Physical Cabinet, and Magnetic Observatory, at Gottingen, the first notice of which is found in *Göt. Gel. Anz.*, 1834, 1273, and in 1836, *Schumacher Jahrbach*, p. 38-39. It consisted of a double line of wire carried over the houses and steeples at Gottingen. It was constructed chiefly for the purpose of being able to make investigations respecting the laws of the force of galvanic currents on a large scale, under different circumstances. The circuit employed in 1833 was about nine thousand feet; and in 1834 or 1835, at least fifteen thousand, but part of this wire was reeled. The form of wire employed was mostly copper, of the size known in commerce as No. 3, of which a length of one metre weighs eight grammes; the wire of the multiplier in the Magnetic Observatory was of silvered copper, No. 14, of 2.6 metres to the gramme. They first employed galvanic electricity by employing small sized plates, and found that the action was much increased by adding to their number. They repeated and perfected their first form of telegraph, by applying the phenomenon of magnetic induction, discovered by Prof. Faraday. The divers movements or the slow oscillations of magnetic bars, caused by the passage of the currents, and observed by the aid of a glass, furnished to Gauss and Weber all the signals which they wished in corresponding, but the number of signals which could be transmitted was few, and the time occupied by each considerable.

The main apparatus was a magneto-electric machine, and to this, Counsellor Gauss adapted a peculiar arrangement, by which the direction of the current can be reversed by a single pressure of the finger.

Professor Weber had a delicate apparatus for setting off an alarm of a clock, placed at the side of the magnet in the physical cabinet, by means of the current conducted from the observatory.

The telegraphing apparatus consisted of the following parts:

1. The apparatus for generating the galvanic current.
2. The apparatus for observing the given signal.