XXVIII. *On the power of masses of Iron to controul the Attractive Force of a Magnet.* By William Snow Harris, *Esq. F.R.S.*

Read June 16, 1831.

1. It may not be unfavourable to the further elucidation of the interesting subject of screens, treated of in my last paper, and which I had the honour of laying before the Royal Society, to give a short account of some subsequent experiments concerning the effects of masses of iron on a magnet, as they have more particularly arisen out of the investigation above alluded to.

2. The principal part of the apparatus which I employed in these experiments is represented in Plate XIV., fig. 1 & 2; it is extremely simple, and will be readily understood by the following description of it.

A light beam of dry clean-grained deal, of about fourteen inches in length, and somewhat less than a quarter of an inch square, is allowed to rest freely, by means of a delicate axis, on two horizontal bars of glass; the glass bars are secured on a convenient frame and stand, and the axis of the beam, as in many similar cases, is formed of a fine sewing-needle; it was passed in this case through the opposite angles, directly at the centre. From the extremity of one of the arms is suspended a small cylindrical piece of iron, about an inch and a half long and one fifth of an inch diameter, which is counterpoised by an equivalent weight, placed in a small pan suspended from the other; the method of suspension is by light hooks and rings, so as to obtain every possible degree of motion. The under part of the centre of the beam carries an index of about a foot in length, constructed of short pieces of straw, which, being tubular, are easily secured at their extremities one within the other; an index thus formed is very straight and true. By means of this index and a graduated arc the slightest motion of the beam is apparent.

3. The beam and index may be so managed, that for a short distance the deviations from the horizontal position, with equal and very small weights placed in the pan, will correspond to equal divisions on the arc, or very nearly so.

4. To regulate the distance between a magnet or other bodies, and the suspended iron, when placed immediately under the latter, either vertically or horizontally, I employed a simple screw and nut, attached to a brass frame similar to that shown in Fig. 2: thus any required altitude could be obtained, the distance between the magnet and the suspended iron being estimated by a graduated scale resting on the magnet.

5. Wherever magnetic attraction is exerted between two bodies, it seems to be accompanied by a sort of neutralization of the same force in respect of a third substance.

(*a*). Thus if the magnet A, Fig. 1, be attracting the suspended iron *b*, the vicinity of a mass of iron C will diminish the apparent force of A upon *b*: if, therefore, when the force of A upon *b* is exerted so as just to depress the beam, the force being measured by the inclination of the index (3), we place a mass of iron C close to A, the beam will immediately tend to recover its previous position.

(*b*). This power of the iron C to controul the attractive force of the magnet upon *b*, seems only to extend to a given point within the magnet, the distance between the magnet and iron remaining the same; for if the small iron *b* be suspended over a point at some distance from the extremity, as at *w*, then the action of C will not be felt at that point *w*, except by decreasing the distance between the iron and magnet, or otherwise by increasing the neutralizing power of the iron C.

6. That this depends on a sort of action which is not inappropriately termed a neutralization of force, in regard to the suspended iron *b*, is evident from the following experiments.

(*c*). The mass of iron C may be placed immediately below A, as in Fig. 3, the effect will be the most apparent when the thickness of A is not considerable; but if the magnet A be very thick, then the neutralizing effect of C is not so evident, on account of the intervening mass of which the magnet is composed, as also on account of the iron C being kept as it were at a greater distance from the immediate surface of attraction.

(*d*). Conversely, the mass of iron C may be placed above, immediately between *b* and A as in Fig. 4; but in this case we have to take into account the inductive effect on C, by which it becomes itself a temporary magnet, and consequently takes on an attractive power; the experiment should therefore be so managed as to have the distance between C and *b* such, that whilst by the intervention of C the action of A is neutralized, its induced magnetic state does not become sensible upon *b* at that distance; this will be always very evident when C is of some considerable thickness, and the previous distance of A and *b* taken just within the limit of the attraction.

7. In this case C is said to screen or stop out the attraction of A upon *b*, and this probably explains the way in which screens operate in impeding the magnetic influence. It seems therefore not unreasonable to infer, that substances, possessing the greatest inductive energy, are at the same time the most powerful neutralizers. Hence in employing various bodies as screens, those are the most efficient which are susceptible of the greatest transient magnetic state: thus zinc is more efficient than lead; copper more efficient than zinc; silver than copper, and iron the most efficient of any.

8. As the distance within the magnet, to which the neutralizing force can extend, must necessarily depend on the magnetic energy of the substance employed, it would be difficult with non-ferruginous bodies to controul any very sensible portion of the action of a magnet by placing them at its extremity, Fig. 1, or beneath it, Fig. 3, except in the latter case we suppose the magnet to be extremely thin; but by intervening a considerable mass, Fig. 4, immediately between the magnet and the substance acted on, we operate directly on the contiguous attracting surface of the bar, and thus the neutralizing effect at length becomes sensible.

9. The attractive force exerted between a magnet and a mass of iron is in the direct ratio of this neutralizing power of the iron; the distance between the magnet and the iron being the same.

(*e*). Let a magnet A, Fig. 5, of about ten inches in length, and three eighths of an inch square, be placed at some convenient distance, immediately under the suspended iron *b*, and the observed force carefully counterpoised by small weights placed in the opposite pan at *p*, so as to bring the index of the beam, Fig. 1, to zero of the graduated arc; then the neutralizing power of a few small pieces of very soft iron, *w*, *x*, *y*, *z*, about the same diameter as the magnet, and varying from a quarter of an inch to two inches in length, may be easily estimated on the graduated arc, Fig. 1, by bringing each piece successively in contact, or very nearly so, with the extremity of the magnet *a* (3). Let these small iron cylinders be now substituted in succession for the suspended iron *b*; and being first nicely counterpoised, let the attractive forces be determined at a constant distance from the magnet A by means of the graduated scale *s*; then these respective forces will be found to be very nearly in the same ratio as the previous powers of neutralization: in a great variety of cases they were found to be exactly in the same ratio.

(*f*). Where the neutralizing power is equal, there the attractive force is also equal; thus the neutralizing power, with a given magnet, not being greater in a cylindrical mass of iron of two inches in length than in one of an inch and half in length, no difference was subsequently found in the respective forces of attraction.

10. The foregoing illustrations seem to throw some light on the manner in which magnetic action may be supposed to pervade bodies.

(*g*). Having assigned any given distance, A *b*, Fig. 6, through which we know the influence of a magnet A can extend as estimated by some sensible measure *b*, then in interposing a third substance C in the space A *b*, the latter may receive a temporary magnetic state in two ways, either by the immediate action of the magnet A upon every particle of C, or otherwise by the propagation of magnetism from particle to particle, or by both: now these operations seem to be in some inverse ratio of each other; thus when the induced magnetic energy in C is considerable, the influence of the magnet A is more or less arrested by the laminæ first acted on, which operate as screens on the succeeding ones; so that the magnetic development after a certain distance proceeds entirely by propagation from one particle to another, until it is finally as it were expended; and a body *b* which was before attracted at the distance A *b* will at the same distance now remain at rest *c*. Such is the case in interposing a screen of iron between a revolving magnet and a metallic disc; but if the body C be low in the scale of magnetic energy, then the induced magnetic state is so weak that little or no screening influence is exerted between its particles, and the body *b* may be attracted as before: hence each particle of C will owe its magnetic development to the direct operation of the exciting magnet; and it is only by the successive action of a great number of particles that we at length neutralize or cut off the magnetic force by means of such a substance employed as a screen: it therefore follows in this instance, that whilst an inconsiderable portion of the magnetic action is neutralized, a considerable mass of the screen is pervaded; at the same time a very thin stratum only of the magnet is penetrated *b* (8).

11. The diminished influence of a magnet on a metallic disc, observed to ensue on intersecting the surface of the disc by radiating grooves varying in depth *, may possibly depend on the above-mentioned circumstance (10); for in this case we actually take away a portion of the substance in which the magnetic development takes place, and thus diminish the force. I wish, however, to be understood as speaking with some degree of reserve on this point, although the conclusion is by no means unwarranted, as in the following experiment.

(*h*). The number of vibrations of a delicately suspended bar in a given arc taken in vacuo, in two similar rings of copper of equal weights and quality as nearly as may be, did not materially differ, although one of the rings was made up of separate concentric laminæ, the other being a perfectly solid mass; whereas the removal of a very thin lamina externally from the former caused a very decided change in the number of the vibrations of the bar †.

12. The preceding inquiries appear calculated to modify in some measure our views concerning the operation of a magnet, which by experiment (*e*) is rather the patient than the agent in the production of the observed effects: it cannot therefore be considered as a purely active force, much less can it be viewed as a substance, from which emanations of an unknown subtile fluid are constantly proceeding; for it may be shown, Exp. (*c*), that a magnetic lamina of steel, supposed without sensible thickness, cannot act at the same time on two masses of iron, in every respect alike, when placed between them, and at an equal distance from each; as in this case we should have an annihilation of power as regards the magnet: hence each mass of iron, if at the same time drawn by some other force, and free to move, would drop away from the magnetized steel in opposite directions. If therefore the attractive energy of a magnet be supposed to arise out of any subtle principle emanating from it,

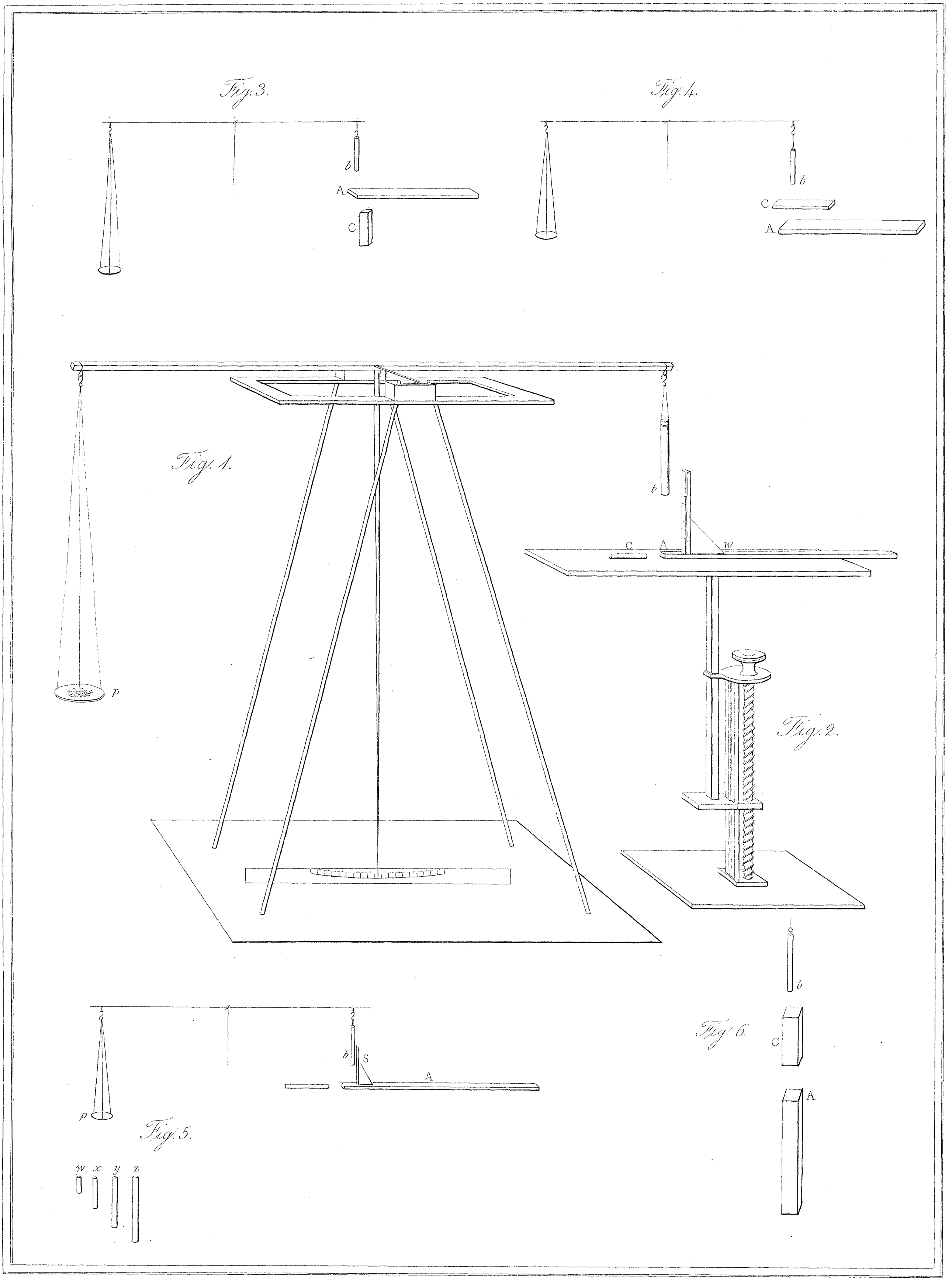
* Philosophical Transactions for 1825, p. 481.

† These vibrations were determined in the way described in the Royal Society's Transactions for 1831, Part I., p. 76.

such emanations cannot pass off in opposite directions at the same instant: now there is no sufficient reason why they should pass rather in one direction than another, and it therefore remains that an hypothesis which supposes them to pass in either, is quite unwarranted. The arrangement assumed by fine particles of iron, sifted on paper immediately over a magnet, arises out of the circumstance that the bar has generally a very sensible thickness; whilst the small particles of iron cannot operate beyond a certain distance *a, b, c,* and this equally applies to other cases in which the opposite sides of a magnet appear to attract at the same time. Moreover, the superficial boundaries of a magnet may be considered as so many distinct magnetic laminæ of uncertain thickness, as is evident from the circumstance, that the magnetic centre and poles of one surface of a bar very frequently fall in a different way from those of another surface according to the trifling variations in the progress of magnetizing; and sometimes all the surfaces differ in this respect in the same bar, that is to say, the centre and poles do not correspond to the same relative points on any two sides.

13. The wonderful phænomenon of magnetic attraction then is evidently the result of an impression first made on the magnet *e*, since with different masses of iron the attractive force at the same distance is unequal *e*: hence a magnet must be considered as a body in a peculiar state or condition, by which it may be caused to exhibit given powers or capabilities in consequence of external excitation.

15. It is always difficult in inquiries of this nature to employ terms which shall seem altogether without objection. I trust therefore that those resorted to in the course of this paper, will be taken only in the arbitrary sense in which they have been used, and not as having any necessary connection with a particular set of opinions: thus the expressions neutralizing force, magnetic development, magnetic excitation, and so on, must be taken merely as arbitrary terms, employed of necessity to facilitate the progress of inquiry, and to render its description as intelligible as possible, according to the general and unembarrassed acceptation of such terms.



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