MAGNETISM.*

MAGNETISM and electricity are very closely allied, each being more easily converted into the other than into any other form of energy. In fact, as will be seen later, the presence of an electric current implies magnetism, or, as it is termed, a magnetic field around the conductor through which it is passing; while any change of the magnetism of any body or system, —or, as it is technically expressed, any change in the strength of the magnetic field, —immediately gives rise to electric currents.

Like electricity also, we know very little of its nature, though rather more than we do of the sister science. We know, for instance, that an iron bar when magnetized is longer than when not magnetized; and from various researches, principally by Professor David Hughes, we gather that the act of magnetization consists in an attempt by the molecules of the body to turn on their axis, and to place themselves in line with the direction of the magnetizing forces. All bodies conduct magnetism, some with greater facility than others, but of all bodies, iron and its compounds, steel and cast iron, alone exhibit appreciably the magnetic properties, which are:

1. The property of pointing, when freely suspended, to those spots on the earth's surface known as its magnetic North and South Poles, one end, or one pole, as it is termed, turning always towards the magnetic North Pole, and the opposite one to the magnetic South Pole.

2. The property of repelling the pole that, if both were freely suspended beyond the influence of magnets other than the earth, —would point in the same direction, and of attracting the opposite pole. Thus, two north-seeking ends of a magnet; or, as they are called, two north poles repel each other, and two south poles repel each other; while a north and south pole attract each other.

3. The property possessed by a magnetized body of inducing magnetism in other bodies not in contact with it, and in such a manner as to cause motion between the two, if either is free to move, or if the inducing force is sufficiently powerful to overcome the mechanical resistance to motion.

As with electricity also, we have a magnetic circuit, which consists of a closed ring of attractions, and whose resistance to magnetization varies with the substance and with the dimensions of the magnetic conductor. Thus, a long, thin bar offers a greater resistance to magnetization than a short, thick one; and, stated shortly, the magnetic resistance offered by any body varies directly at its length in the direction of the magnetic circuit, and inversely at its cross section.

Steel offers a greater resistance to magnetization than pure wrought iron, as also does cast iron; and all three have the property of retaining their magnetism to a certain degree, when once they have been magnetized. As might be expected, upon the theory that the operation of magnetizing consists in a twisting of the molecules, those bodies, as steel and cast iron, which offer most resistance to the inducing force, as it is termed, retain more of their magnetism, and far longer than wrought iron. With very pure iron, such as Swedish, Farnley, or Lowmoor, it is very difficult to find any traces of magnetism when no inducing force is present, while either will give a very high return for a given magnetizing power that is applied. With steel or cast iron, on the contrary, it is by no means easy to induce them to accept of magnetization, but when once it has been accomplished, they retain a very large percentage for some considerable time.

These properties are of very great importance in the construction of electric and electro-magnetic apparatus. Thus, the needles of compasses and miners' dials are always made of steel, their property of pointing north and south being all the service that is required of them. In any apparatus where a selective action is required (or where an attractive power is required in a light, portable form, as in the magneto-telephone receiver), a piece of magnetized steel, or a steel magnet, as it is called, is used.

Where it is required to control the magnetic effect for producing motion, pure wrought iron is generally used, for the double reason, that a smaller weight will answer than with cast iron for the same work, and that it responds more readily to the magnetizing influence—usually an electric current—taking up and losing its magnetism readily at the will of the operator.

In dynamo electric machines,—where parts of the apparatus are required to retain their magnetism in the same sense, that is, with the same polarity, as it is termed, as long as the apparatus is working—those parts may be constructed from wrought iron or cast iron, according to the fancy of the designer; but he will have to provide a heavier weight of the latter, to do the same work.

Those parts containing iron which are in motion and continually changing the direction of their magnetization, as the iron core of the armature, are always made from the purest wrought iron obtainable.

It has been stated that there is a magnetic circuit of attractions, or a continuous path for the magnetism, just as there is a continuous path for an electric current; but with this difference, that magnetism always passes, no matter how great the resistance, and the effect of the magnetic resistance is simply one of degree.

Air, for instance, has an enormously greater resistance than iron, some 1400 times, according to a recent investigator, Mr Kapp, to whom dynamo manufacturers are very much indebted for his able researches, and above all for his exposition of the law of magnetic resistance. Yet, if no other path be open, the magnetic influence will pass through air, imperceptibly, of course, until some body, such as a piece of iron, able to denote its presence, is placed within its influence.

Perhaps the method adopted for explaining the working of the *electric circuit may be of service here. Imagine a ring of iron* or steel, not covered. Iron or steel, because, as has already been explained, these substances conduct magnetism better than any others, so far as we know at present; uncovered, because we know of no substance that will act as an insulator for magnetism in the same sense that india-rubber or gutta-percha does for an electric current. The bodies which offer the highest resistance do conduct magnetism, even under moderate exciting power, to a very appreciable degree.

If we apply to any part of our ring an exciting power, such as an electric current passing in a wire wrapped round the iron, moderate in proportion to its resistance—that is, which will develop a moderate degree of magnetization in opposition to the resistance of the ring—we shall find scarcely any traces of magnetism anywhere outside the ring, though we can show, by suitable apparatus, as will be seen when we come to deal with transformers, that the magnetism is there, and is a perfectly measurable quantity. It has only passed by way of the ring, just as the electric current passes by way of a wire, because, *with the force available, that is for practical purposes the only* path open to it. Now let us cut out say one-sixteenth of the ring; and we shall find that we have created a totally different set of conditions, giving rise to totally different phenomena.

First, then, the piece we have cut out—if free to move, and placed at such a distance that the magnetic power is sufficient to overcome the friction, mechanical inertia, etc., present—will move back exactly into its old place, or as nearly as it can, when the exciting power is applied.

We shall find also that, if our ring is made of steel, it has retained a certain power of attracting the piece that we have cut out after the exciting power has been removed. If our ring is made of wrought iron, it will pull the piece up sharply when the exciting power is applied; while, when the current is broken, it can easily be removed, and may even fall off itself if it is heavy in proportion to the attracting power. If we pursue the matter a little further, we shall discover another and very important phenomenon. It has just been remarked that, in the case of wrought iron, the piece of the ring we had cut out might detach itself under certain conditions. Let us find the conditions under which it will not detach itself. Let the piece we have cut out of the iron ring be replaced by a piece fitting very exactly, the four surfaces being planed true to each other. Now, we shall find that we have a slightly increased holding power when the ring is excited; and further, that after the exciting *power has been removed, it will still require the expenditure of* a certain amount of energy to pull it away. The reason is, that while the magnetic circuit is complete, a certain amount of magnetism remains in the iron even after the exciting power has been removed. Forcibly pulling away the armature, or keeper—as the piece of iron employed to close the magnetic circuit is usually called—dissipates this residual magnetism; and so, if we replace the keeper ever so truly and carefully in

* Walker's "Electricity."