CHAPTER VII.

MAGNETISM.

I.—GENERAL PROPERTIES OF MAGNETS.

Definition of Magnetism.

344. MAGNETISM, as a science, is that branch of Physics which treats of the properties of magnets, and of their action upon each other.

Magnets.

345. A MAGNET is a body which exercises a particular power of attraction upon iron and a few other metals.

Magnets are either *natural* or *artificial.*

Natural magnets are certain ores of iron, and are generally known under the name of loadstones.

The magnet is so called from the town of Magnesia, in Lydia, where it was first noticed by the Greeks. In its natural form it consists of a mixture of two oxides of iron, with a small proportion of quartz and alumina. It is now found in considerable quantities in Sweden and Norway, as well as in many other countries.

The magnet possesses the remarkable power, when freely suspended, of directing itself towards a particular point of the horizon, and it is to this property that its importance is

(**344.**) What is Magnetism as a science? What is a Magnet? How many kinds of magnets are there? What are natural magnets? *Whence the name? What is the constitution of a natural magnet?* What remarkable property does the magnet possess?

chiefly due. It may be suspended by a thread, or by balancing it on a pivot. In practice the latter method is the one most usually adopted.

Artificial magnets are bars of tempered steel, to which the property of the natural magnet has been imparted. The artificial magnet is far more valuable than the natural magnet, and is generally used in practice.

Steel is a mixture of iron with a small quantity of carbon, and when heated and then plunged into water, it becomes exceedingly hard, and capable of retaining the magnetism that may be imparted to it.

Artificial magnets for experiment are made of oblong bars, from twelve to fifteen inches in length, as represented in Figs. 245 and 246. They are sometimes made in the form of a horse-shoe, as shown in Fig. 247. Sometimes they are made in the form of a thin long needle, as shown in Fig. 239. This is the form in which they are constructed for pointing out the direction of the magnetic meridian, as in compasses. In this form they are also used in many magnetic experiments.

Magnets may be made of soft iron or untempered steel, but they do not retain their magnetism when the exciting cause is removed. Such magnets are called *temporary magnets.*

Distribution of Force in Magnets.

346. The force with which a magnet attracts iron, is not the same in all of its parts. The attraction is strongest at its extremities, from which it decreases towards its middle, where it is nothing.

This may be shown by plunging one end of a magnetized bar into iron filings; on withdrawing it, the filings will be seen adhering to it in long filaments, as shown in Fig. 237.

If the entire bar be rolled in the filings, it will be found that they adhere to both ends, but not to the middle.

What is an artificial magnet? What is steel? *Describe an artificial magnet. What are temporary magnets?* (**346.**) Where is the attraction strongest? *How shown?*

The two ends, where the attraction is strongest, are called *poles*, and the central part, where the attraction is nothing, is called the *equator*, or the *neutral line*.

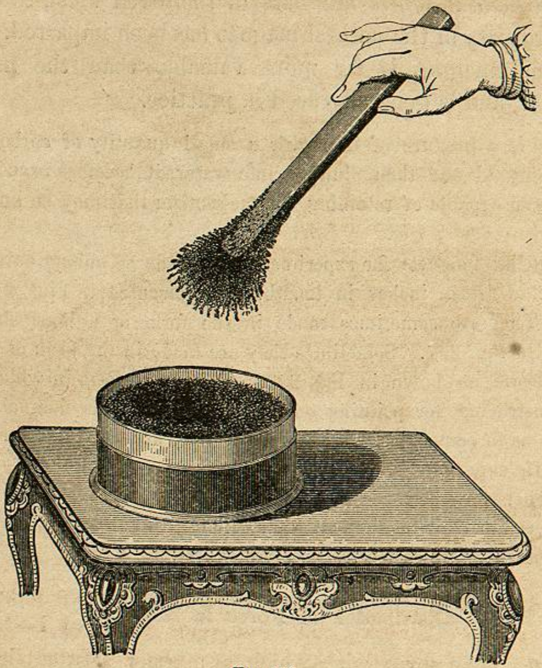

Fig. 237.

Every magnet has two poles and one neutral line, whether the magnet be natural or artificial. Sometimes. besides the two principal poles, there are other minor poles, called *secondary poles*. In artificial magnets these arise from inequality of temper in the steel bars, or from want of proper care in magnetizing them. We shall suppose each magnet to have but two poles.

The action of a magnet upon iron takes place through intermediate bodies. If a magnetized bar be covered with a sheet of paper, and

What are poles? Equator? *What are secondary poles? Their origin? How is it shown that magnetism is exerted through intermediate bodies?*

then fine iron filings be sifted uniformly over the paper, they will be seen arranging themselves in regular curves around each pole, as shown in Fig. 238. No action is observed about the neutral line, the filings falling there as on any other surface.

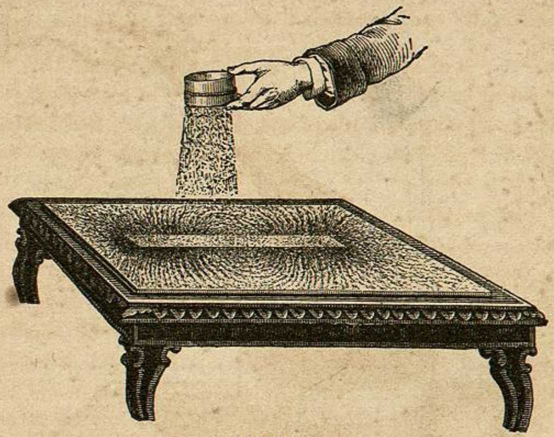

Fig. 238.

Hypothesis of two Magnetic Fluids.

347. If we compare the action of the two poles upon soft iron, we observe the same phenomena at both. It is not so, however, when we compare the action of two magnets upon each other. If to the same pole of a magnetic needle, *ab*, balanced on a pivot (Fig. 239), we present in succession the two poles of a magnetized bar, held in the hand, we observe the curious phenomena, that if the pole, *a*, of the needle is attracted by the pole, *B*, of the bar, the pole, *b*, will be repelled by it; if the pole, *a*, is repelled, the pole, *b*, will be attracted.

To explain these phenomena, it has been supposed that there are two *magnetic fluids*, that is to say, two kinds of

(**347.**) What is the action of one magnet upon another? What is the theory of two fluids?

subtile matter surrounding the molecules of the magnet, each fluid repelling its own kind, and attracting the other kind.

According to this hypothesis, a body is magnetized when these fluids are separated and driven to its opposite extremities. The difference of the two poles arises from the nature

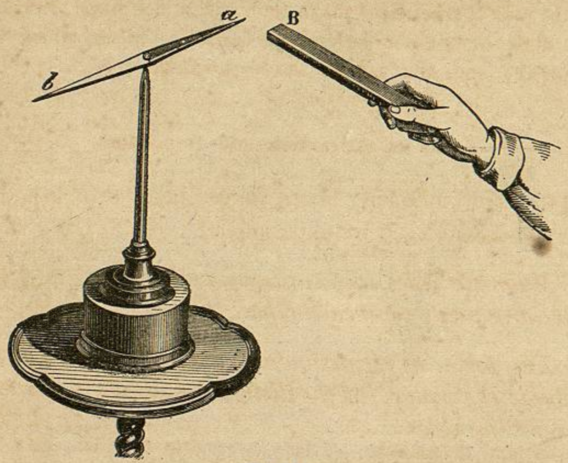

Fig. 239.

of the fluids which predominate in them; the poles which contain the same kind of fluid, *repel*, those which contain opposite kinds, *attract each other*. The attraction and repulsion are mutual.

Another theory supposes but one kind of magnetic fluid, and explains the phenomena by supposing this to exist in excess at one pole, and in defect at the opposite pole. Either theory explains the phenomena, but that of two fluids is the most easily applied, and for that reason, *solely*, it is adopted.

The earth, as we shall see hereafter, resembles a huge magnet, acting upon magnetic needles in the same way that magnetized bars

When is a body magnetized according to this theory? *What other theory is there? Describe the magnetic action of the earth.*

do. Its magnetic poles are near the geographic poles of the earth, and the neutral line coincides very nearly with the equator. Consequently the fluid which is supposed to predominate near the north pole of the earth is called the *boreal fluid*, and that which is supposed to predominate near the south pole of the earth is called the *austral fluid*.

Because dissimilar poles attract and similar ones repel, it follows that the pole of a balanced magnetic needle which turns towards the north must contain the *austral fluid*, whilst the one which turns towards the south must contain the *boreal fluid*.

Laws of Attraction and Repulsion.

348. The following laws have been established by theory and confirmed by experiment:

1. *Magnetic poles of contrary names attract, and those of the same name repel each other.*

2. *The forces of attraction and repulsion both vary inversely as the square of the distance between the attracting and repelling poles.*

Magnetic and Magnetized Bodies.

349. A MAGNETIC BODY is one which contains the two magnetic fluids, but in a state of equilibrium, that is, balancing each other; thus, iron, steel, nickel, and cobalt, are such bodies.

MAGNETIZED BODIES also contain the two fluids, but the difference between them and magnetic bodies is, that in the former the two fluids are separated, each producing an opposite effect, whilst in the latter the fluids are combined and produce no effect. In a word, magnetic bodies are

What is the boreal fluid? The austral fluid? Which turns towards the north? Why? (**348.**) What is the first law of magnetic attraction and repulsion? The second law? (**349.**) What is a Magnetic Body? Examples. What are Magnetized Bodies?

capable of being magnetized, but are not yet magnets; they present neither poles nor neutral line.

When a magnetic substance is brought into contact with one of the poles of the magnet, as the *boreal* pole, for example, the latter, acting by its attraction upon the *austral* fluid, and by its repulsion upon the *boreal* fluid, separates them, giving rise to poles, producing a real magnet.

If a magnetized bar be presented to a magnetic body, as an iron ring, it converts it into a magnet in the manner just described. If a second ring be presented to the first, it is in like manner converted into a magnet, and so on for a third, fourth, &c. The magnets thus formed adhere to each other, as shown in Fig. 240. If the bar be removed, the rings cease to be magnets, the chain falls to pieces, and the rings separate. This mode of exciting magnetic phenomena is called magnetizing by *induction.* According to the theory of two fluids, it is in consequence of this action that a magnet is capable of attracting magnetic bodies. It first acts by induction to convert them into magnets, and then it attracts them according to the laws laid down in the last article.

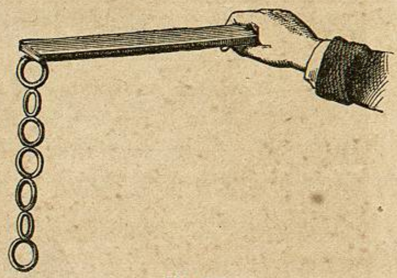

Fig. 240.

Fig. 241 represents a common child's toy. A small swan made of glass has a piece of iron in its head, and on presenting to it a magnet, the swan approaches it, swimming along the surface of the water upon which it is placed. The magnet may be concealed in a piece of bread, in which case the swan seems desirous of feeding upon the bread.

How are magnets produced? Illustrate. What is magnetic induction? Explain it on the two fluid theory. *Explain the magnetic swan.*

Fig. 241.

The Coercive Force.

350. The force required to separate the two fluids in a magnetic body is called the Coercive Force.

The fluids are not separable with equal ease in all bodies. In some, as, for example, in soft iron, they yield easily and separate at once; in others, as in hardened steel, for example, the fluids yield with difficulty, and a powerful magnet is required to effect the separation, and it is only effected after a greater or shorter length of time. The harder and better tempered the steel, the more difficult it becomes to separate the two fluids.

(**350.**) What is the Coercive Force? How is it in different bodies?

In soft iron the coercive force required to separate the fluids is very small, in hardened steel it is very great. Soft iron brought in contact with a bar magnet becomes a magnet instantly, and on being removed returns to its neutral condition, ceasing to be a magnet. With hardened steel the reverse is the case; it takes considerable force and some time to render it a magnet, and on being removed from the bar it continues to be a magnet. The force which resisted the separation of the fluids in the first instance, now acts to prevent their reunion, so that the steel magnet retains its magnetism for a long time.

II.—TERRESTRIAL MAGNETISM.—COMPASSES.

Directive Force of Magnets.

351. When a permanent magnet is balanced so that it can turn freely in a horizontal direction, it assumes, after a few oscillations, a determinate direction, which is very nearly north and south.

Fig. 242 shows the manner of balancing a needle, and indicates the north and south direction which it assumes. In this figure, as in all others illustrating the subject of magnetism, the pole which contains the *austral* fluid is designated by the letter *A*, whilst that which contains the *boreal* fluid is designated by the letter *B*.

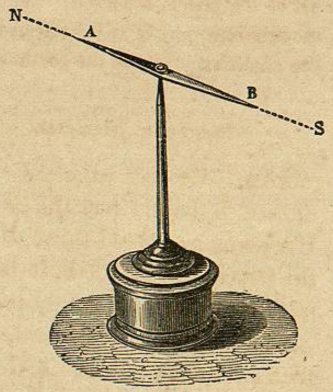

Fig. 242.

It will be noticed that it is the austral pole which turns towards the north, and the

Illustrate. (**351.**) What direction does a free magnet take? How is a needle balanced? In what other way may it be balanced?

boreal pole which turns towards the south, the reason of which will be seen hereafter.

If, instead of mounting the needle on a pivot, it be attached to a piece of cork and placed in a vessel of water, so that the needle may float in a horizontal position, it will turn itself slowly around and come to rest in the same general direction as though it were balanced on a pivot. In this experiment it will be found that the needle once in the meridian, does not advance either towards the north or south. Hence we infer that the force exerted upon the needle is simply a *directive* one.

The force which causes a movable magnet to direct itself north and south is called the *directive force.*

Since the phenomena described takes place at all points of the earth's surface, the earth has been regarded as an immense magnet, having its boreal and austral poles near the north and south poles of the earth, and a neutral line near the equator. This immense magnet acting upon the smaller magnets described, would produce all of the effects observed. When we come to explain the action of electric currents, it will be seen that there is another explanation of the *directive* power of the earth.

Magnetic Meridian.—Declination.—Variations.

352. When a balanced magnetic needle comes to a state of rest, it points out the line of magnetic north and south. If a plane be passed through the needle in this position and the centre of the earth, it is called the plane of the *magnetic meridian*, or simply the magnetic meridian.

This does not, in general, coincide with the plane of the true meridian, which is determined by a plane passing through the place and the axis of the earth. The angle which the magnetic meridian at any place makes with the

How is it shown that the magnetic force is simply directive? What is the directive force? *Why has the earth been regarded as a magnet? Where are its poles?* (**352.**) What is the magnetic meridian? What is the declination of the needle?