true meridian of the same place is called the *declination of the needle.* In short, the declination of the needle is its variation from true north and south. This is different at different places on the earth, and even at the same place at different times.

When the north end of the needle points to the east of true north, the declination is said to be *to the east;* when to the west of true north the declination is said to be *to the west.*

There is a line running from near Cleveland, Ohio, to Charleston, S. C., along which the needle points to the true north; this is called a line of *no declination.*

The line of no declination is travelling slowly to the westward at a rate which would carry it around the globe in about 1000 years. For all points of the United States east of the line of no declination, the declination of the needle is to the west; for all points to the west of it, the declination is to the east; that is, the north end of the needle in all cases is inclined towards the line of *no declination.*

For all points in the United States to the east of the line of no declination, the declination is slowly increasing, whilst for all points to the west of it, the declination is slowly decreasing.

Besides this slow change in declination, the needle undergoes slight changes, some of which are pretty regular and others very irregular. In our latitude the north end of the needle moves towards the west during the early part of every day, through an angle of 10 or 15 minutes, and moves back again during the latter part of the day. This is called the *diurnal variation.* In the southern hemisphere this motion is reversed. There is also a small change of similar character which takes place every year, called the *annual* variation.

When is it to the east? To the west? What is the line of no declination? *How does this line move? At what rate? Where is the declination to the west? To the east? How does the declination vary in the United States?* What is the diurnal variation? The annual variation?

Irregular changes are called *perturbations.* They usually take place during thunder storms, during the appearance of the aurora borealis, and in general, when there is any sudden change in the electrical condition of the atmosphere.

The Compass.

353. The property possessed by magnets of arranging themselves in the magnetic meridian has been utilized in the construction of Compasses.

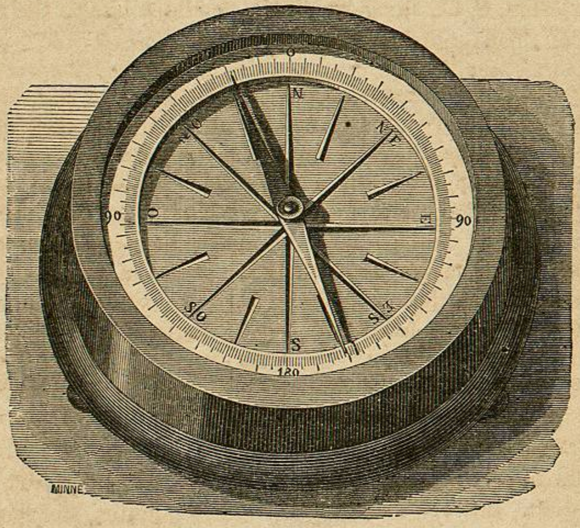

Fig. 243.

Fig. 243 represents a compass. It consists of a compass-box, having a pivot at its centre, on which is poised a delicate magnetic needle. Around the rim of the box is a graduated circle, whose diameter is somewhat less than the length of the needle, and of which the pin is the centre. The pin is of hard steel, carefully pointed; a piece of hard stone is let

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What are perturbations? Illustrate. (**353.**) What is a Compass? Describe it.

into the needle, in which is a conical hole to rest upon the pivot, to diminish the friction between the needle and its support. In addition to the graduation on the circle, the bottom of the box is divided into sixteen equal parts, indicating the *points of the compass.*

This instrument under various forms is used for a great variety of purposes. It is used in navigation, in surveying, and is of importance to the traveller and explorer, to say nothing of its use in mining.

The magnetic declination at any place may easily be found when the true meridian is known. Let the compass be so placed that the line, *NS*, coincides with the true meridian, then when the needle comes to rest, the reading under the head of the needle will be the declination required. In the figure, if we suppose *NS* to be in the true meridian, the declination is 19° west.

The Dipping Needle.

354. When a steel needle, mounted as shown in Fig. 242, is carefully balanced before being magnetized, it is found, after being magnetized, to incline downwards or to *dip.* This dip is towards the north in our latitude, that is, the north end of the needle dips or inclines. The defect of dipping in the compass is remedied by making the other end of the needle a little heavier, by adding a movable weight, as a piece of wire wound round the needle, and capable of sliding along it.

To show the dip and to measure it, the needle is mounted in the way indicated in Fig. 244. The needle is suspended on a horizontal axis, so that it can move up and down freely, and the amount of the dip is indicated by a graduated circle or quadrant. The dip indicated in the figure is 54°, which is the angle made by the needle with

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What is its use? How is the magnetic declination found at any place? (**354.**) What is a dipping needle? How is the compass needle prevented from dipping? How is the dip shown and measured?

the horizon. At any place the dip will be the greatest possible when the needle vibrates in the plane of the magnetic meridian.

The dip varies in passing from place to place, increasing as we approach the magnetic poles of the earth, where the dip is 90°; that is, the needle is perpendicular to the horizon.

The dip is subject to irregularities corresponding to those of the declination. The amount of the dip is an important element in forming a correct notion of the laws of terrestrial magnetism, and for this reason many observations have been made and are still making, to determine it at different places, and at different times at the same place.

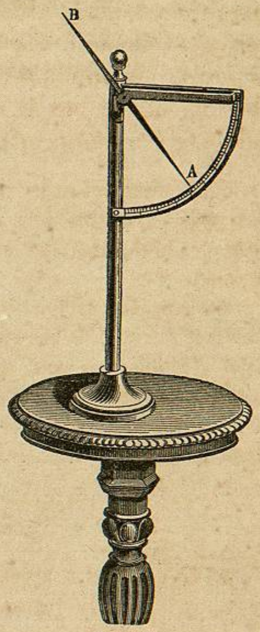

Fig. 224.

III.—METHODS OF IMPARTING MAGNETISM.

Magnetizing by Terrestrial Induction.

355. To MAGNETIZE a body is to impart to it the properties of a magnet; that is, to impart to it the property of attracting magnetic bodies.

The only substances that can be permanently magnetized, are steel and the compound oxide of iron, which constitutes the loadstone. A body capable of being magnetized may be converted into a magnet by the inductive influence of

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How does the dip vary? Is it subject to irregularities? (**355.**) What is meant by magnetizing a body? What substances can be permanently magnetized?

the earth, or more rapidly by being rubbed by another magnet, or finally, by the action of electricity, in which case the operation is instantaneous.

The magnetic ores of iron may exist as magnets in the natural state, or they may possess no trace of magnetic action. But they are highly susceptible to magnetic influence, and once magnetized, they retain their magnetic action by virtue of their strong coercive force.

Natural magnets owe their magnetism to the slow action of the earth, which separates the two fluids in them. The magnetic action of the earth is so great as to be used successfully in forming artificial magnets.

To use this principle, we place a thin bar of iron in the magnetic meridian and incline it to the horizon by an angle equal to the dip. In this position the earth acts upon it by induction, driving the austral fluid to the lower end (in our latitude), and the boreal fluid to the upper end.

The magnetism thus induced is only temporary, for if the bar be moved from its position, the two fluids return to a state of equilibrium. If, however, when the bar is in position, it be struck smartly by a hammer, or if it be violently twisted, sufficient coercive force may be developed to retain the induced magnetism for a time.

Magnetizing by Friction.

356. Bars of steel, and needles for compasses, are usually magnetized by rubbing them with other magnets. The three methods are called the methods by *single touch*, by *separate touch*, and by *double touch*.

To magnetize a steel bar by *single touch*, we hold the

Are the magnetic ores of iron always magnets? To what is the natural magnetization of these ores due? How are bars magnetized by this principle? (**356.**) How may bars of steel be magnetized? Explain the method of single touch.

body to be magnetized in one hand, and with the other we pass over it a powerful bar magnet, as shown in Fig. 245. After several repetitions of this process, the steel is found to possess all the properties of a magnet. These properties are the more durable in proportion to the hardness of the steel.

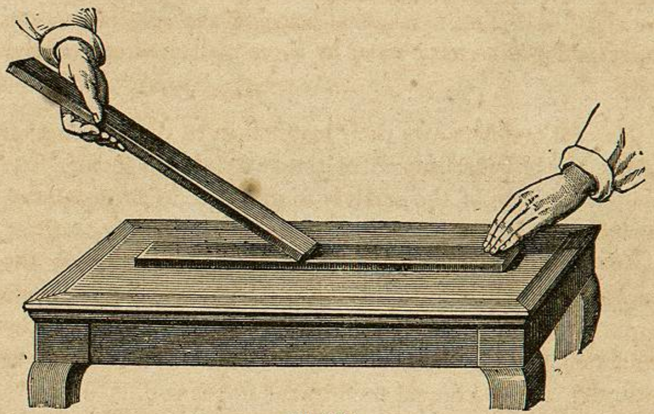

Fig. 245.

To magnetize a steel bar by *separate touch*, we rub it in one direction with one pole of a magnetized bar, and in the opposite direction with the opposite pole.

To magnetize a body by *double touch*, we make use of two magnetized bars, which are placed with their opposite poles in contact with the bar at its middle point, being only separated by a small interval, as shown in Fig. 246; the combined bars are then moved alternately in opposite directions to the two ends of the bar, and the operation is repeated several times. Care must be taken to apply the same number of touches to each end of the bar.

Of separate touch. Of double touch.

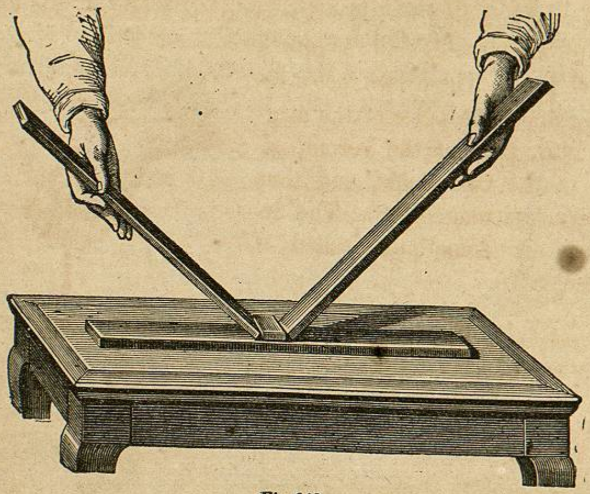

Fig. 246.

The method of magnetizing by electricity will be treated of under the head of electrical currents.

Bundles of Magnets.—Armatures.

357. A Bundle of Magnets consists of a group of magnetized bars united, so that their poles of the same name may be coincident.

Sometimes these bundles are composed of straight bars, like that shown in Fig. 245, and sometimes they are curved in the shape of a horse-shoe, as shown in Fig. 247.

Magnets, if abandoned to themselves, would lose in a short time much of their power; hence it is, that *armatures* are employed.

An Armature is a piece of soft iron, placed in contact with the poles of a magnet. Thus, *ab*, in Fig. 247, is an *armature.*

(357.) What is a Bundle of Magnets? What is an Armature?

The poles, acting by induction upon the armature, convert *a* into an austral, and *b* into a boreal pole. These two poles reacting upon the poles of the magnet, *AB*, prevent the recomposition of the two fluids, and thus preserve its magnetism. The armature is sometimes called *a keeper.*

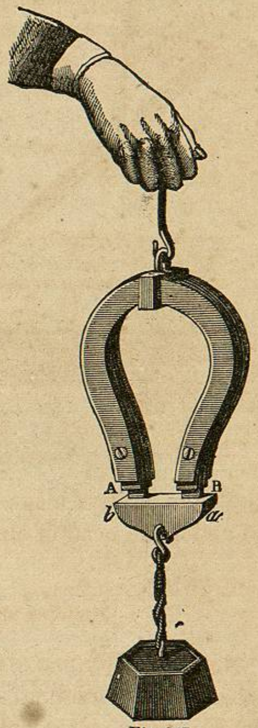

Fig. 247.

If weights be attached to the keeper till it separates from the magnet, we can, from the number of pounds applied, judge of the power of the magnet.

For many kinds of magnetic experiment the horse-shoe form is preferable. It is also the form best adapted to the application of an armature or keeper.

The most powerful horse-shoe magnets are formed by means of electrical currents. Magnets of this kind have been constructed by Prof. Henry, of the Smithsonian Institution, capable of sustaining a weight of more than a ton and a quarter.

A keeper? *How can we judge of the power of a magnet? What are the advantages of the horse-shoe magnet?*