Hwa Chong Institution (High School) Name : ______________________ (   )
PHYSICS Notes Class : __________

Magnetism Date : __________

Properties of Magnets

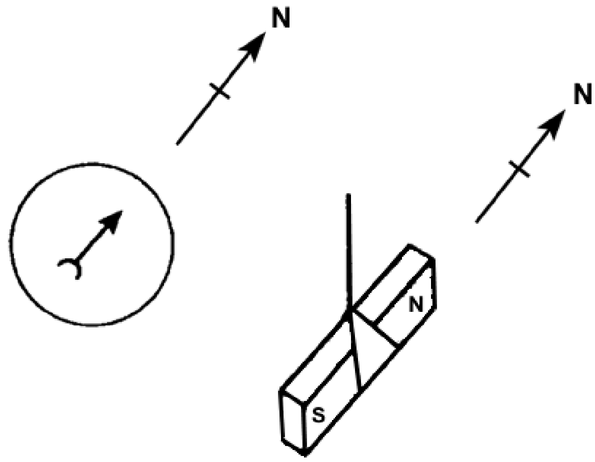
a) Magnetic poles

When a bar magnet is dipped into iron filings, it is noticed that the filings cling in tufts near the ends. Few filings are attracted to the middle of the bar. The places in a magnet where the resultant attractive force appears to be concentrated are called the poles.

b) North and South poles

When a magnet is freely suspended so that it can swing, it will finally come to rest in an approximate N-S direction. The pole which points towards the north (of the Earth) is called the north-seeking pole or simply the N-pole. The other pole is called the south-seeking or S-pole.

The poles are not quite at the ends of the magnet, but are placed symmetrically a short distance from the ends. The distance between the poles is about five-sixths of the length of the magnet. Thus the poles of a magnet which is 12 cm long are 1 cm from each end.

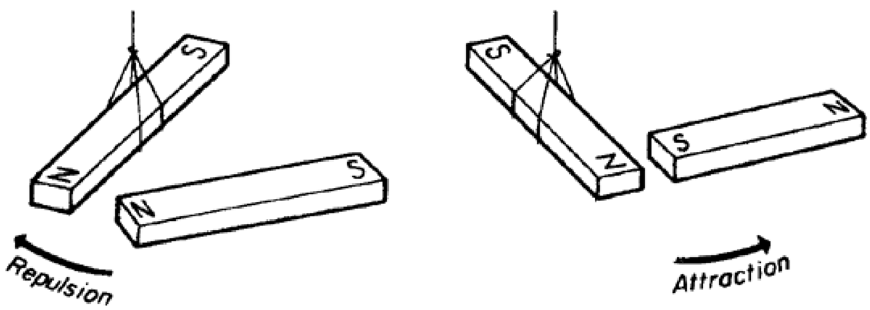


A magnet that is free to move always sets in the same direction.

c) Law of magnetic poles

If the N-pole of a magnet is brought near the N-pole of a suspended magnet, it is noticed that repulsion occurs. Similarly, repulsion is observed between two S-poles. On the other hand, a N-pole and a S-pole always attract one another as shown in the figure. These results may be summarised in the First Law of Magnetism:

Like poles repel, Unlike poles attract



Like poles repel Unlike poles attract

Magnetic and non-magnetic substances

Apart from iron, the other common elements which are attracted strongly by a magnet are cobalt and nickel. These are known as ferromagnetic substances. Substances such as copper, brass, wood and glass are not attracted by a magnet and are commonly described as non-magnetic. Nevertheless, experiments with very powerful magnets have shown that even the so-called non-magnetic substances have very feeble magnetic properties.

Test for polarity of a magnet

The polarity of any magnet may be tested by bringing both its poles, in turn, near to the known poles of a suspended magnet.
Repulsion will indicate similar polarity.
If attraction occurs, no firm conclusion can be drawn, since attraction would be obtained between either:

- two unlike poles, or
- a pole and a piece of unmagnetized material.

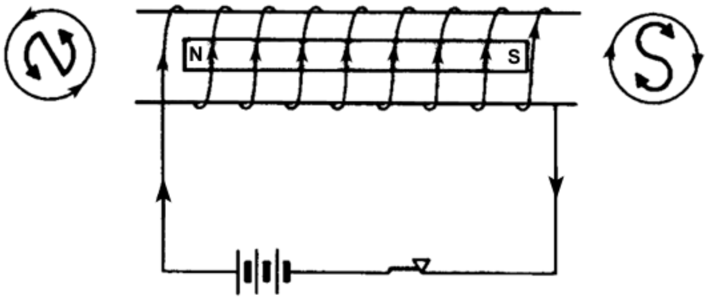
Repulsion is, therefore, the only sure test for polarity.

To magnetize a steel bar

a) By an electrical method

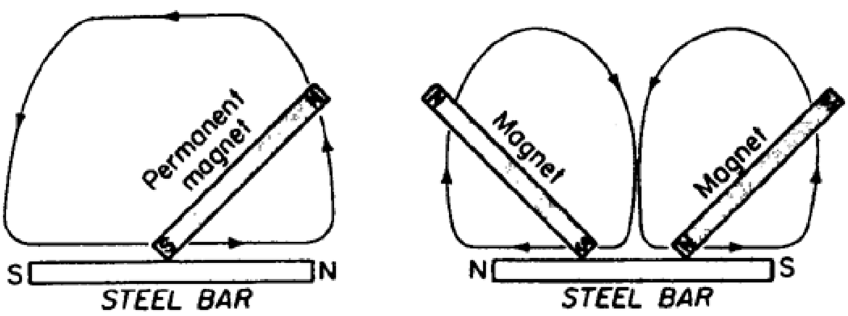
The best method of making magnets is to use the magnetic effect of an electric current. A cylindrical coil wound with 500 or more turns of insulated copper wire is connected in series with a 6 V or 12 V electric battery and switch (see diagram). A coil of this type is called a solenoid. A steel bar is placed inside the coil and the current switched on and off. On removing and testing the bar, it is found to be magnetized. It is unnecessary to leave the current on for any length of time, as the bar will not become magnetized any more strongly and the coil may be damaged through over-heating.

The polarity of the magnet depends on the direction of flow of the current. If, on looking at the end of the bar, the current is flowing in a clockwise direction, that end will be a S-pole; if anticlockwise, it will be a N-pole.



Magnetization by an electric method

b) By the stroking methods

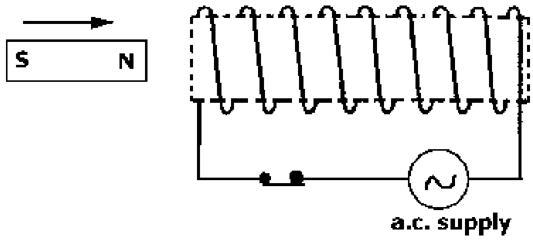


(a) Single touch (b) Divided touch

Older methods of making magnets

Demagnetization

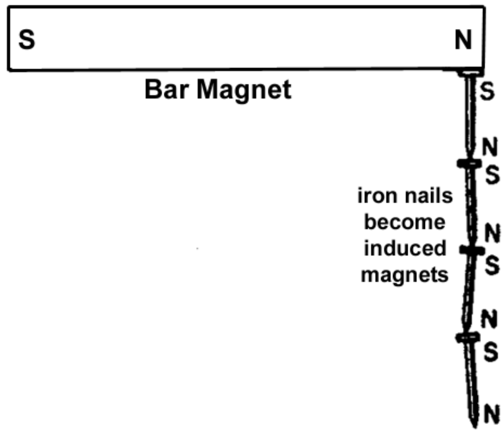
The best way of demagnetizing a magnet is to place it inside a solenoid through which an alternating current is flowing. The current may be obtained from a 12 V or 24 V mains transformer. While the current is still flowing, the magnet is withdrawn slowly to a distance of several metres from the solenoid in a West-East direction. The alternating current takes the magnet through a series of ever-diminishing magnetic cycles, fifty times a second, until it is completely demagnetized. The magnet is held in an E-W direction so that it will not be left with some residual magnetism owing to induction in the earth's magnetic field.



Another method of destroying magnetism is to heat the magnet to redness and then to allow it to cool while is is lying in an E-W direction. This is not recommended as a practical method, since heat treatment will spoil the steel.
Also, any vibration or rough treatment, such as dropping or hammering, particularly when the magnet is lying E-W, will cause weakening of the magnetism.

Induced magnetism

When a piece of unmagnetised steel is placed either near to or in contact with a pole of a magnet and then removed, it is found to be magnetized. This is called <u>induced magnetism</u>. Tests with a compass needle show that the induced pole nearest the magnet is of opposite sign to that of the inducing pole.

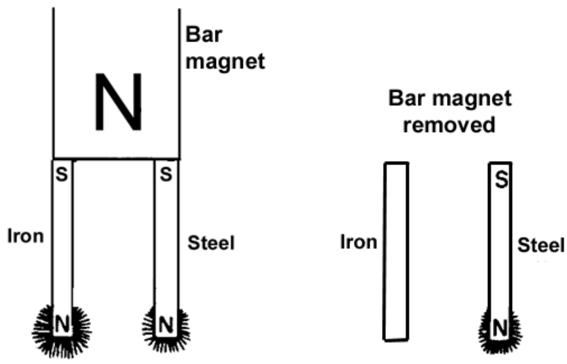


Induced magnetism can be used to form a "magnetic chain" as shown in the diagram. Each nail added to the chain magnetizes the next one by induction, and attraction occurs between their adjacent unlike poles.

Magnetic properties of Iron and Steel

The term "soft" as applied to iron means reasonably pure iron. It is otherwise known as wrought iron, and is soft in the sense that it bends easily and can be readily hammered into any required shape when red hot. Steel, which consists of iron combined with a small percentage of carbon, is a much harder and stronger material.

A strip of soft iron and a strip of steel of the same dimensions, both initially unmagnetized, are placed side by side in contact with a pole of a magnet as shown. Both strips become magnetized by induction, and on dipping their free ends into iron filings it is noticed that slightly more cling to the iron than to the steel. From this we conclude that the induced magnetism in the iron is slightly greater than that in the steel when both are subjected to the same magnetizing force.



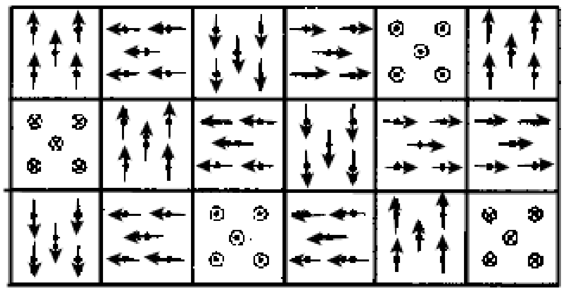
Difference between iron and steel

If both strips are held firmly in the fingers while the magnet is removed, it is noticed that practically all the filings fall from the iron, while few, if any, fall from the steel. The magnetic chain experiment illustrated previously may also be used to show the difference between iron and steel. If the topmost nail is held between finger and thumb while the magnet is removed, the chain immediately collapses, showing that the induced magnetism in the iron is only temporary. When, however, the experiment is carried out using steel pen nibs or short pieces of clockspring, the chain remains intact, showing that the magnetism induced in the steel is permanent.

Ferromagnetism. The domain theory of magnetism

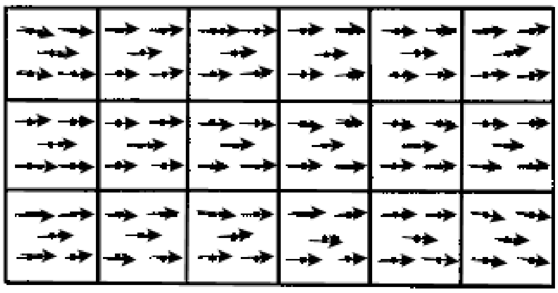
In some materials, of which iron, steel and certain alloys are outstanding examples, the atomic magnets or dipoles do not act independently. Instead small groups of dipoles interact with one another so that their magnetic axes spontaneously line up together in a certain preferred direction. Groups such as these are described as magnetic domain. In the "unmagnetized" state, the resultant magnetic axes of the domains point in all directions at random and so the bar as a whole shows no polarity.

This condition is illustrated below in which, for simplicity, the domains are drawn as uniform cubes. In actual fact, however, the domains are not at all cubical in shape but can vary in size and their edges will lie in different directions from grain to grain throughout the whole material. The atomic magnets or dipoles have been represented by a dot and arrow, and the arrow head signifies the N-pole.



(a) Magnetic material in demagnetized condition

Atomic magnets in alignment inside domains but domain magnetic axes in random directions



(b) Magnetized state

Atomic magnets (not domains) turn to bring domain magnetic axes in direction of magnetizing field

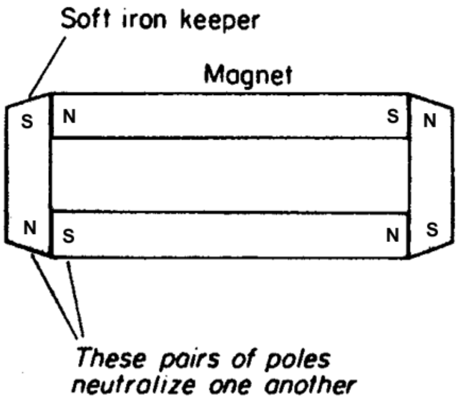
If the bar is placed in a gradually increasing magnetic field (e.g. inside a solenoid with steadily increasing current, then in some of the domains all the atomic dipoles may turn out of their preferred directions so that their axes all come into a new direction more closely related to that of the magnetizing field.

Eventually, if the magnetizing field is strong enough, the resultant magnetic axes of all the domains will be brought into the best possible alignment with the field and the material is said to be magnetically saturated, as shown above. We now have free atomic poles at the ends of the bar which will give rise to the poles of the magnet. Finally, when the magnetizing field is removed, the mutual repulsion between the free atomic poles at the ends of the bar will cause the domain axes to fan out slightly. This explains why the poles of a bar magnet are never situated exactly at its ends.

Further work: read up on paramagnetism, and diamagnetism

Keepers

A bar magnet tends to become weaker with age, owing to self-demagnetization. This is caused by the poles at the ends of the magnet which tend to reverse the direction of the atomic dipoles inside it. In order to prevent this, bar magnets are stored in pairs, with their opposite poles adjacent and with small pieces of soft iron, called keepers, placed across their ends, as shown.



These keepers become strong induced magnets, and the opposite induced poles at their ends neutralize the poles of the bar magnets. In other words, the magnetic dipoles in the domains of both magnets and keepers form closed loops with no free poles. Consequently the demagnetizing effect disappears.

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