Magnetism and Magnet

The property of any object by virtue of which it can attract a piece of iron, cobalt etc. is known as magnetism.

Important terms connected with magnetism

1. **Magnetic field:** The space around a magnet within which its influence can be experience is known as magnetic field.
2. **Uniform magnetic field:** A magnetic field in a region is said to be uniform if it has same magnitude and direction at all points of that region.
3. **Magnetic poles:** These are the regions of apparently concentrated magnetic strength in a magnet where the magnetic attraction is maximum.
4. **Magnetic equator:** The line passing through the centre of the magnet and at right angles to the magnetic axis.
5. **Magnetic length:** The distance between the two poles of a magnet is known as magnetic length of the magnet. It is slightly less than the geometrical length.
6. **Magnetic axis:** The line passing through the poles of a magnet.

Natural Magnet

It is an ore of iron (Fe_2O_3) which attracts small pieces of iron, nickel and cobalt towards it.

Permanent Magnet

It is branch of physics in which we study about the properties of bar magnets mainly.

Any bar magnet has two poles one is called North Pole and another is called South Pole. North Pole is taken as positively magnetic charge and South Pole is taken as negatively magnetic charge.

The strength of either pole is measured by comparing the strength of current carrying element (idl). It is called pole strength of magnet of either pole. It is denoted by 'm'. Its unit is Ampere metre.

Magnetic Moment

Magnetic moment is defined as the product of pole strength of either pole and magnetic length of bar magnet.

M = m (2l)

(i) Magnetic pole is a vector quantity.
(ii) It is always directed from South Pole to North Pole.
(iii) It S.I. unit = Am^2
(iv) Its Dimensional equation = IL^2

Coulomb's law in magnetism

Two poles of same nature repel each other and two poles of opposite in nature attract each other. The force attraction (or repulsion) between two poles is directly proportional to the product of pole strength of each pole and inversely proportional to square of the distance between them.

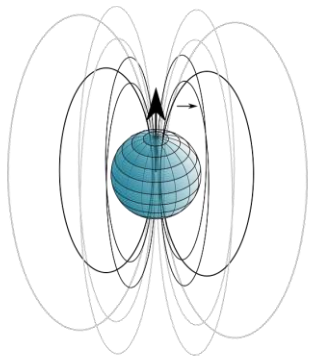
Magnetic field intensity

Magnetic field per unit North Pole or pole strength is defined as magnetic field intensity.

It is a vector quantity. It is always directed along the direction of force on test North Pole.

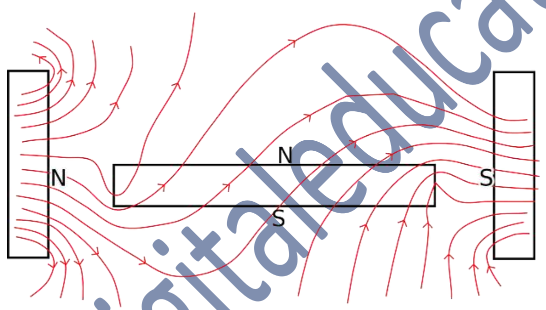
Magnetic field lines

Michael Faraday introduced the concept of the magnetic lines of force to represent a magnetic field visually. Magnetic lines of force don't really exist.



Magnetic lines of force originate from North Pole (N-Pole) and terminate on South Pole (S-pole). The tangent at any point on the lines of force indicates the direction of magnetic field at that point inside the bar magnet.

(i) Magnetic lines of force are closed curve which start in air from the N-pole and end at the S-pole and then return to the N-pole through the interior of the magnet.



(ii) The lines of force never cross each other. If they do so, that would mean there are two directions of the magnetic field at the point of intersection, which is impossible.

Magnetic potential

Magnetic potential is required work done to bring a unit North Pole from infinity to a given point. It is a scalar quantity.

Pole Strength

It can be defined as the strength of magnetic pole to attract magnetic material towards itself. It is scalar quantity and its SI unit is ampere-metre (A-m).

Magnetic Dipole

Magnetic dipole is an arrangement of two unlike magnetic poles of equal pole strength separated by a very small distance is called a magnetic dipole.

Magnetic Dipole Moment

The dipole moment of a magnet of a magnetic dipole defined as the product of its pole strength and magnetic length.

(i) It is vector quantity.
(ii) It is directed from S-pole to N-pole.
(iii) SI unit of magnetic dipole moment is Ampere metre^2 or joule per Tesla.

$$\mathbf{m = q_m \times 2l}$$

Where, $q_m$is the pole strength

And 2l is the magnetic length of the dipole from S-pole to N-pole.

Terrestrial Magnetism

Earth is neutral source of magnetic field. We have magnetic field present everywhere near the earth's surface.

The magnitude and direction of this field can be obtained approximately by assuming that the earth has a magnetic dipole movement about 8 x 10^{22n} J/T located at its centre.

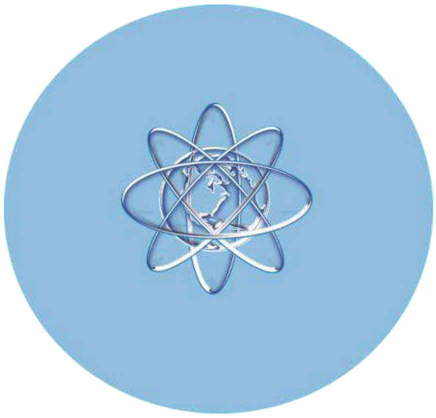
The axis of this dipole makes an angle of about 11.5 degree with the Earth's axis of rotation.

This field arises due to rotational motion of earth. When a bar magnet is freely suspended near the earth surface, it stay in equilibrium along Geo-magnetic axis (North-South direction), its North Pole is directed due north and South pole is directed due south.

We conclude that magnetic lines of force originate from Geo-magnetic South Pole and terminate on Geo-magnetic North Pole. At either pole magnetic lines of force are vertical.

Earth's Magnetism

Earth behaves like a huge magnet. The value of magnetic field on the surface of earth is a few of tenths of a gauss. Earth's magnetic strength varies from place to place on the earth's surface.



Experimental evidences in support of Earth's Magnetism

1. A freely suspended magnetic needle comes to rest roughly in N-S direction.
2. An iron bar buried in the earth becomes weak magnet after some time.
3. Existence of neutral points near a bar magnet indicates the presence of earth's magnetic field.

Important term of earth's magnetism

1. **Geographical axis:** The straight line passing through the geographical north and south poles of the earth is known as geographical axis. It is axis of rotation of the earth.

2. **Magnetic axis:** The straight line passing through the magnetic north and south poles of the earth.

3. **Magnetic equator:** It is the great circle on the earth perpendicular to the magnetic axis.

4. **Magnetic Meridian:** A vertical plane passing through the magnetic axis is known as magnetic meridian.

5. **Geographical Meridian:** A vertical line passing through the geographical axis is known as geographic meridian.

Elements of earth's magnetic field

1. **Magnetic Declination:**

A plane passing through geographical poles and with the given points on the earth surface is called geographical meridian. A plane passing through geo-magnetic poles and with the point is called magnetic meridian. The angle between the geographical-meridian and magnetic meridian is called magnetic declination.

2. **Magnetic Inclination or Angle of Dip**

The angle between earth's magnetic field and the horizontal direction in the magnetic meridian is called the magnetic inclination or angle of dip at that point.

3. **Horizontal component of earth's magnetic field**

It is component of earth magnetic field along horizontal direction in magnetic meridian. Horizontal component of earth's magnetic field is always directed from South to North. It is denoted by B_H.

Neutral point

The point where net magnetic field along horizontal direction is zero is known as neutral point. To get neutral point of external magnetic field should be directed from North to South and its magnetic magnitude should be equal.

Magnetic properties of matter

1. **Intensity of Magnetization**

Magnetic moment per unit volume is defined as intensity of magnetization.

(i) It is vector quantity.
(ii) It is always directed along the direction of magnetic moment.
(iii) Pole strength per unit area is also defined s intensity of magnetization.
(iv) Its SI unit = A/m
(v) Its Dimensional formula = $L^{-1}A$

2. **Magnetic Intensity**

In vacuum, magnetic intensity is defined as magnetic field divided μ_o.

$H = B/\mu_o$

For magnetic medium magnetic intensity is written as,

$H = B/\mu_o - I$

Where, I be the intensity of magnetization

3. Magnetic Susceptibility

For diamagnetic and paramagnetic substances, intensity of magnetization is directly proportional to magnetic intensity.

$I = X H$

Where, x is a constant which is called susceptibility.

$X = I/H$

X is positive (+ve) for paramagnetic and negative (-ve) for diamagnetic.

4. Magnetic field

When a magnetic material is placed in a magnetic field, magnetism is induced in it.

The magnetic field that exists in vacuum and induces magnetism is known as magnetizing field.

5. Magnetic induction

The magnetic induction may be defined as the number of magnetic lines of force crossing per unit area normally through a material.

6. Magnetic field intensity

The ability of magnetizing field to magnetise a material medium is expressed by a vector H.

7. Magnetic permeability

The magnetic permeability of a material may be defined as the ratio of its magnetic induction B to the magnetic intensity H.

8. **Relative permeability**

Relative permeability is defined as the ratio of the permeability of the medium to the permeability of free space.

Curie's laws

For paramagnetic substance, magnetic susceptibility is inversely proportional to absolute temperature.

X is proportional to 1/T

X = C/T

Where, 'C' is a constant, it is called Curie's constant.

When temperature of ferromagnetic substance is increased, it becomes paramagnetic at a certain temperature. Curie temperature of iron is 1043k.

Classification of Magnetic Materials

1. Diamagnetic substances
2. Paramagnetic substances
3. Ferromagnetic substances

Diamagnetic Substances

Those substances which when placed in magnetic field it gets magnetized opposite to the direction of magnetizing field (external field). Thus, net field inside the materials is smaller than external field; such a substance is called diamagnetic substances.

(i) When it is placed in non-uniform magnetic field, it has tendency to move from stronger to weaker part of magnetic field.
(ii) It is independent of temperature.
(iii) Its susceptibility is negative.
(iv) Example: copper, zinc, silver, gold, lead, glass, marble, water, helium, argon, etc.

Paramagnetic substances

When such a substance is placed in magnetic field, it gets magnetized along the direction of magnetizing field. Thus net field inside the material becomes greater than magnetizing field. Such a substance is called paramagnetic substance.

(i) When it is placed in non-uniform magnetic field, it tends to move from weaker to stronger part of magnetic field.
(ii) It depends on temperature.
(iii) Its susceptibility has small positive value.
(iv) Example: aluminium, sodium, antimony, copper chloride, manganese, chromium, liquid oxygen etc.

Ferromagnetic Substances

When a substance is placed in magnetic field, it is strongly magnetized along the direction of magnetizing field. Thus net magnetic field inside the material becomes much greater than magnetizing field. Such a material is ferromagnetic material and permanent magnets are made from them.

(i) When it is placed in non uniform magnetic field. It has strong tendency to move from weaker part to stronger part of magnetic field.
(ii) It depends on temperature. At a particular temperature, ferromagnetic substance is converted into paramagnetic. This temperature is called Curie temperature.
(iii) Example: Iron, Nickel, Cobalt etc.

Hysteresis loop

When a demagnetized material (soft iron) is placed in B-field, material gets magnetized along the direction of external field (magnetizing field).

When external field is increased, intensity of magnetisation increase to maximum value, it is represented by Curve 'OA'

When external field is decreased to zero, intensity of magnetization is not zero. It is represented by the curve 'AC'.

The intensity of magnetization (OC) in absence of external field is called retensivity of material or residual magnetism.

When external field is increased along opposite direction, material gets demagnetized at a certain value of external field, the required external field (OD) in opposite direction to demagnetise the material is called backward coercive force.

If external field is further increased, intensity of magnetization increases to the maximum value in opposite direction. The same process is repeated by reversing the direction of external field. We get a loop ACDEFGA as shown in figure this loop is called Hysteresis loop.

Larger the area of loop, larger will be the heat produced.

OD = Backward Coercive force

OG = Forward Coercive force.

Selection of magnetic materials

1. **Permanent magnets**

The material used for making permanent magnets must have the following properties:

(i) High retentivity so that it produces a strong magnetic field.
(ii) High permeability
(iii) High coercivity so that its magnetization is not destroyed by stray magnetic fields, temperature variations or minor mechanical damage.

2. **Electromagnets**

The material used for making cores of electromagnets must have the following properties:

(i) High initial permeability
(ii) Low retentivity

3. **Transfer of cores**

The materials used for making cores of electromagnets must have following properties:

(i) High initial permeability
(ii) Low retentivity
(iii) Low hysteresis loop

Electromagnets

Take a soft iron rod and wind a large number of turns of insulated copper wires over it. When we pass the current through the solenoid, a magnetic field is setup in the space within the solenoid. The high permeability of soft iron increases the field 1000 times. The end of the solenoid at which the current in the solenoid seems to flow anticlockwise acts as North Pole and other one as South Pole. When the current in the solenoid is switch off, the soft iron rod loses its magnetism almost completely due to its low retentivity.

Uses of Electromagnets

(i) It is used in electric bells, loudspeakers and telephone diaphragms.
(ii) Large electromagnets are used in cranes to lift heavy machinery, and bulk quantities of iron and steel.
(iii) In hospital, electromagnets are used to remove iron or steel bullets from the human body.

Frequently Asked Question (FAQ)

1. **What is coercivity?**

Answer: The value of the reverse magnetising field that should be applied to a given sample in order to reduce its intensity of magnetisation or magnetic induction to zero is known as coercivity.

2. **What is retentivity or residue magnetism?**

Answer: The value of the intensity of magnetisation of material, when the magnetising field is reduced to zero is known as retentivity or residue magnetism of the material.