MAGNETISM AND MATTER

20 EARTH'S MAGNETISM

A freely suspended magnet always aligns itself along north-south direction. If this magnet is turned away from this position and left, it oscillates for some time and finally aligns along, its initial north south direction.

It suggests as if there is a giant magnet inside the earth with its magnetic south pole near the geographic north pole of earth and the magnetic north pole near the geographic north pole.

20.1 DEFINITIONS OF IMPORTANT TERMS

(i) Geographic axis

The axis of rotation of earth is called its geographic axis and the points where it cuts the earth's surface are called its geographic pole (north and south).

(ii) Geographic Meridian

An imaginary vertical plane passing though the geographic axis of earth is called its geographic meridian.

(iii) Geographic equator

The great circle on earth's surface whose plane is perpendicular to the geographic axis is called geographic equator of earth.

(iv) Magnetic axis

The axis of the giant fictitious magnet inside the earth is called earth's magnetic axis and the points where the magnetic axis cuts the earth's surface are called the magnetic north (MN) and magnetic south (MS) pole of earth.

(v) Magnetic meridian

An imaginary vertical plane passing through the magnetic axis of the earth is called magnetic meridian.

(vi) Magnetic equator

The great circle on earth's surface whose plane is perpendicular to earth's magnetic axis is called magnetic equator.

20.2 ELEMENTS OF EARTH'S MAGNETISM

The physical quantities which enables us to completely describe the magnitude and direction of earth's magnetic field at a place are called the elements of earth's magnetism. These are

(i) Magnetic declination or declination (θ)

(ii) Magnetic inclination or dip or angle of dip (δ) and

(iii) Horizontal component of earth's magnetic field.

(i) Magnetic Declination (θ)

Magnetic Declination at a place may be defined as the angle between its magnetic meridian and the earth geographic meridian at the place.

It is due to the fact that the magnetic axis of the earth does not coincide with its geographic axis.

(ii) Magnetic Inclination or Angle of Dip (δ)

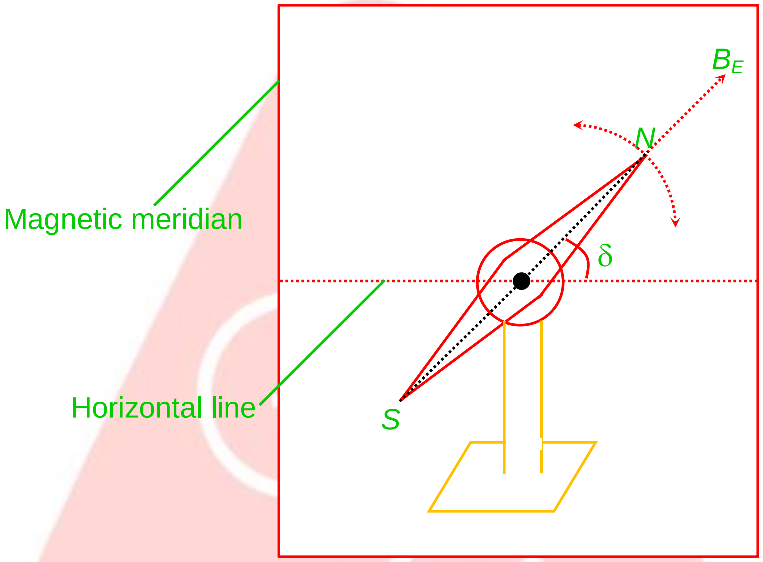
Angle of dip at a place is defined as the angle between the direction of intensity of earth's magnetic field (B_E) and the horizontal direction in magnetic meridian at that place.

Consider a light magnetic needle free to rotate about a horizontal axis passing through its centre. Let the magnet be free to rotate in a vertical plane in the magnetic meridian.

The magnet, therefore, aligns itself along the direction of earth's magnetic field (B_E). The angle (δ) which the magnet makes with the horizontal is the angle of dip at that place.

The instrument consisting of a light magnetic needle mounted on a horizontal axis on a stand and free to turn in a vertical plane can be used to measure the angle of dip. It is therefore, called Dip circle.

Note: The value of dip is 90^0 at pole and zero at the equator.



(iii) Horizontal component of earth's magnetic field

It is defined as the component of earth's magnetic field (B_E) along the horizontal direction in magnetic meridian. It may be represented by B_H or H.

Let B_E is the earth's magnetic field and δ is the angle of dip at that place.

$\therefore$ Horizontal component of earth's magnetic field

$$B_H = B_E \cos\delta$$

and vertical component, $B_v = B_E \sin\delta$

$$\therefore \quad B_H^2 + B_V^2 = B_E^2 \quad \text{and} \quad \tan\delta = \frac{B_V}{B_H}$$

The value of B_H can be determined by using vibration magnetometer.

21 CLASSIFICATION OF MAGNETIC MATERIALS

As motioned earlier, all substances, depending upon their behaviour in external magnetic field, can be dividing into following three categories.

(i) Diamagnetic substances
(ii) Paramagnetic substances and
(iii) Ferro magnetic substances

Let us, now understand these substances one by one.

(i) Diamagnetic Substances

The substances which are feebly repelled by a magnet and hence tend to move from stronger the weaker parts of the magnetic field are called diamagnetic substances. For example –zinc, copper, gold, water, etc.

(ii) Paramagnetic substances

The substances which get feebly attracted by a magnet are called paramagnetic substances. Such substances when placed in an external magnetising field, get feebly magnetised along the direction of the field.

For example: Aluminium, platinum, chromium, manganese, copper sulphate and solutions of iron and nickel etc.

(iii) Ferromagnetic substance

The substances which are strongly attracted by a magnet and hence tend to move from weaker to stronger parts of a magnetic field are called Ferromagnetic substances.

Thus, ferromagnetic substances behave like paramagnetic substances but the effect is much more intense.

For example: Iron nickel, cobalt, gadolinium etc.

SELECTION OF MAGNETIC MATERIAL

The hysteresis curves provide us the necessary information for selecting a particular material for a special particle use in various devices. For example

(i) Electromagnets (Temporary Magnets)

The material of the core of an electromagnet should have the following prosperities.

(a) Low retentivity. Because of this, the material will get almost completely demagnetised after the removal of the magnetising field.

(b) High permeability. Because of this, it will have value of magnetic saturation and hence the electromagnet will be very strong.

(c) Low coercivity: Due to this, the core gets easily demagnetised.

Hence soft iron is suitable for making electromagnetics.

(ii) Permanent Magnets

The material used for making permanent magnets should have the following prosperities.

(a) It should have high retentivity so that it remains strongly magnetised after the removal of the magnetising field.

(b) It should soft iron is suitable for making electromagnets.

MIND MAP

MAGNETICS

1. Biot-Savart law

It gives the magnetic induction due to an infinitesimal current element

$$dB = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3}$$

2. Field due to straight current carrying wire

(a) When the wire is of finite length

$$B = \frac{\mu_0}{4\pi}\frac{I}{d}[\sin\alpha + \sin\beta]$$

(b) When the wires of infinite length

$$B = \frac{\mu_0}{4\pi}\frac{2I}{d}$$

3. Field due to circular current carrying wire

(a) At an axial point

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{(R^2+x^2)^{3/2}}$$

(b) At the centre

$$B = \frac{\mu_0}{2}\frac{I}{R}$$

4. Field due to current carrying arc

(a) At the centre making an angle ϕ

$$B = \frac{\mu_0}{4\pi}\frac{I\phi}{R} = \frac{\mu_0}{4\pi}\frac{Il}{R^2}$$

(b) At the centre of semi circular wire

$$B = \frac{\mu_0}{4}\frac{I}{R}$$

5. Field due to solenoid

(a) At a point on the axis of solenoid of finite length

$$B = \frac{\mu_0}{2}nI(\sin\alpha + \sin\beta)$$

(b) At a point inside the solenoid of infinite length $B = \mu_0 nI$

6. (i) Force on a moving charge

(a) When it is moving in a magnetic field

$$\vec{F} = q(\vec{v}\times\vec{B})$$

(b) When it is moving in a combined electric and magnetic field

$$\vec{F} = q\vec{E} + q(\vec{v}\times\vec{B})$$

(ii) Force on a current carrying straight wire when it is in a uniform magnetic field

$$F = I(\vec{l}\times\vec{B})$$

7. Motion of charged particle in a uniform magnetic field.

(a) When it enters at right angle to the field, Path will be circular and

$$r = \frac{mv}{qB}, \quad T = \frac{2\pi m}{qB}$$

(b) When it enters at some angle θ with the field, Path will be helical

$$r = \frac{mv\sin\theta}{qB}, \quad T = \frac{2\pi m}{qB}$$

$$\text{Pitch} = \frac{2\pi m}{qB}v\cos\theta$$

8. When a current carrying loop is in a uniform field

(i) Force = 0

(ii) Magnetic moment $\vec{M} = I\vec{A}$

(ii) Torque, $(\vec{\tau}) = \vec{M}\times\vec{B}$

(iii) Work done = $MB(1-\cos\theta)$

9. Force between two long straight parallel wire per unit length carrying current I_1 and I_2

$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$$