Chapter - 8

Magnetism and Properties of Magnetic Substacnes

We have studied about magnets in earlier classes. The property of attracting iron, cobalt, nickel is called magntism and the material that shows this property is called magnet. In this chapter we will study about different physical quantities realted to magnetism. The earth also behave like a magnet, so we will study about elements of its magnetism. Every material show some magnetic property, so we will classify materials on this basis.

8.1 Natural Magnets

In anciant times in Greece, some deposits were found in island magnesia, which showed the property of attracting iron, cobatt and nickel. This material was named magnet after the place, and the property as magnetism. It was magnetite, an ore of iron (Fe_3O_4). Normally natural magnets are not used because of their irregular shape and weak strength.

8.2 Artifical Magnets

Artifical magnets are prepared either by rubbing a ferromagnetic material by a strong magnet, keeping in long contact with pole of a magnet or by keeping in magnetic field of a solenoid. They are of two types (i) permanent (ii) temporary.

(i) Permanent magnet - Their magnetism stay for a long time. They are prepared by hard steel, cobalt steel, tungustan or an alloy *ALNICO (Al Ni + Co)* or other alloys. Their magnetism can't be controlled.

(ii) Temporary Magnet - These magnets shows the property as long as magnetizing field exist. Their shape an strength can be manipulated. They normally are of soft iron, and used in motor, generator, electric bell and electromagnetic relay.

8.2.1 Properties of Bar Magnet

Normally magnets are used in the form of a bar. They have following basic properties -

(i) Attraction property - These magnets attract iron, nickel and cobalt like feromagnetic materials. The strength is maximum at ends (called Pole) and zero at mid point.

(ii) Directional Property - When suspended freely from centre of gravity, the bar magnet, in equilibrium it always stay in N-S direction. The end which stay in north direction is marked as north pole, the end which stay in south direction as south pole.

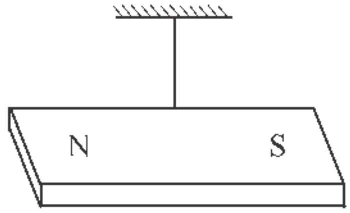

Fig 8.1 Directional property of a bar magnet

(iii) Existance as dispole - Magnets always exist as dipole. North pole and south pole are equal in magnetude (strength). Existance of monopole is not possible.

(iv) Attraction and repulsion - Same poles repell each other, while opposite poles attract.

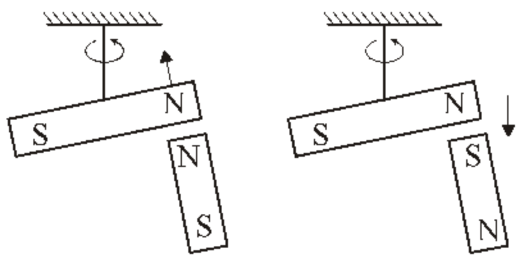

Fig 8.2 Attraction and repulsion light

(v) Equality of pole strength - The pole strength of both the poles are always same. As shown in the figure 8.3 (A) and (B). If devided transversaly, the two pieces behave like two separate magnets of same pole strength. And if devided longitudinally into two parts, their pole strength will be halved. Here m is taken as symbol of pole strength.

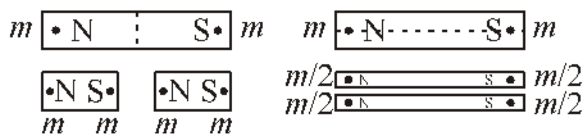

Fig 8.3 Division of pole strength of a magnet

(vi) Repulsion is a sure test to differentiate between a magnet and an iron bar- If you have two bars, one is certainly magnet, but the other you don't know. To test, bring one end of the second bar towards a magnet; if it gets attracted - other may be magnet or iron bar. If the second end is brought near the magnet -

(1) If it is attracted - the other bar is iron bar and

(2) If it gets repelled - the other bar is a magnet hence repulsion is sure test in this case.

(vii) Magnetic induction - When a magnetic material is kept near in contact with a bar magnet it acquires magnetic property. This phenomenon is called manetic induction. The other pole will be of opposite polarity.

(viii) Demagnetization - A magnet will loose its property by heating, beating by a hammer, kept under influence of AC current or by keeping dumped in earth for a long time.

(ix) Repulsion of some material - Some materials get repelled by a magnet these materials are called diamagnetic materials, water, gold and silver are some examples. This repulsion is extreamly weak and can only be observed by sensitive devices or arrangement.

8.2.2 Some Definations Realted to Magnet

(i) Magnetic Poles and Magnetic Axis - At the point, very near to the end of a bar magnet magnetism (field) is strongest. These points are called poles. All the field lines (lines of action of magnetic force) pass through these points.

The imaginary line passing through the poles and extending up to infinity is called axis of a bar magnet.

Fig 8.4 Magnetic axis and effective lenth

(ii) Effective length of a bar magnet - The distance between the two poles is called effecitve length of a bar magnet. It is aproximatly 5/6 of the physical length. (Since poles are situated slightly inside and not exactly at ends). It is a vector quantity $\vec{\ell}$ and its direction is from S pole to N pole.

(iii) Magnetic Meridian - The imaginary vertical plane passing through the axis of a bar magnet, when it is freely suspended and is in equilibrium is called magnetic meridian. Any other plane which is parallel to the aboce mentioned will also be magnetic meridian.

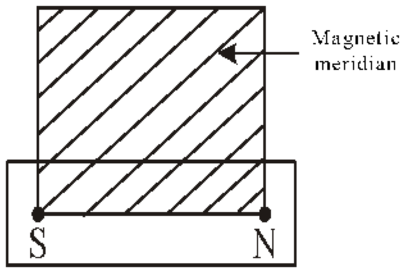

Fig 8.5 Magnetic meridian

(iv) Pole Strength - The attraction power of a magnet is expressed by a physical quantity called pole strength its symbol is m and unit $A\ m$.

(v) Coulomb's Law for the force between magnetic poles - Just as gravitational force between two masses and electrostic force between two electric charges, we have inverse square law for magnetism.

The Coulomb force is inversely proportional to the squared distance between the magnetic poles and directly proportional to the product of poles' strengths.

Let two poles of strength m_1 and m_2 are at a distance from each other in air/vacuum. (Situation is maginary since magnetic monopole does not exist). The attractive or repulsive force between them is

$$F \propto \frac{m_1 m_2}{r^2}$$

$$F = k\frac{m_1 m_2}{r^2}$$

$$F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2} \quad \text{. . . (8.1) is given by}$$

here $k = \frac{\mu_0}{4\pi} = 10^{-7}$ Web/Am is a constant

and μ_0 = magentic permiability of air/vaccum.

$$F = \frac{\mu_0}{4\pi} = 10^{-7}\ \text{N}$$

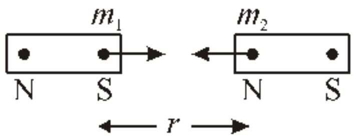

Fig 8.6 Force between magnetic poles

Definition of unit pole

If $m_1 = m_2 = 1$ A m , $r = 1$ m and

$F = \frac{\mu_0}{4\pi} = 10^{-7}$ N . Then using equation (8.1) we

get $m_1 = m_2 = 1$ A m (i.e unit pole)

If two equal poles separated by 1m in air/vacuum experience a force of 10^{-7} N, then both poles have unit pole strength.

8.3 Magnetic Field Lines (Magnetic Lines of Forces)

If a small magnetic compass needle is moved in a magnetic field, and path of one pole is traced using dots, joining these dots gives curves which are called magnic field lines. (Earliar it was defined as the locus of a free north pole in a magnetic field).

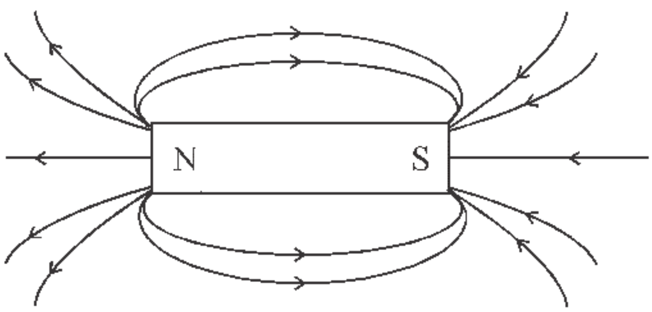

Fig 8.7 Magnetic field lines

Fig 8.7 show the magnetic field lines of a bar magnet. Place a paper or a glass sheet on a bar manget. Sprikle some iron fillings on the glass sheet. The pattern of the iron fillings will give you an idea of the field lines.

Properities of Field Lines

(i) They are imaginary and are in the form of closed loops.

(ii) Outside the magnet their direction is from N to S, while inside they are from S to N.

(iii) The tangent drawn at any point on the field line, gives the direction of magnetic field at that point.

(iv) They never intersect each other. If they do, two tangents can be drawn on the point of intersection which gives two directions of the field, which is not possible.

(v) The area where field lines are close, the field is strong and vice-versa. The field is strong near the poles.

(vi) The paralled field lines represent uniform magnetic field.

8.4 Neutral Point

The earth has its own magnetic field. So when we place a bar magnet on a paper placed on wooden table, there will be super position of two fields (i.e of earth and bar magnet). The pattern of field lines drawn, show some (one/two) points where the net magnetic field is zero. These points are called null points. At these points, the horizontal component of earth's magnetic field exactly cancells the magnet field of bar magnet i.e B - B_{11} = 0. The location of null points depends on the orientation of the bar magnet.

(i) When S pole of bar magnet is in Geographical North Direction - In this position/ orientation as shown in fig (8.8A). The field on equator (i.e ⊥ line to axis) is strong near the magnet because both fields are in the same direction. We get null points on axis as N_1 and N_2.

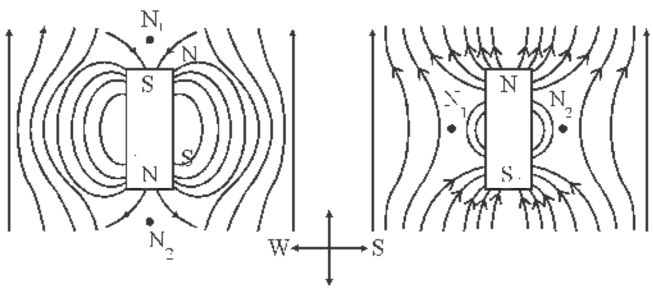

Fig 8.8 Neutral Point (A) When S pole of the magnet is towards geographical north. (B) When N pole of magnet is towards geographical north.

(ii) When North Pole of Bar Magnet is owards geographical North - In this case the null points N_1 and N_2 are obtained on equitorial line, as shown in fig 8.8 (B).

(iii) If the bar magnet is kept vertical and its north pole is downwards on the paper; the field lines will be as shown in fig 8.9. We get only one null point is in south direction. If south pole is kept downwards the position of null point is reversed, i.e. in north.

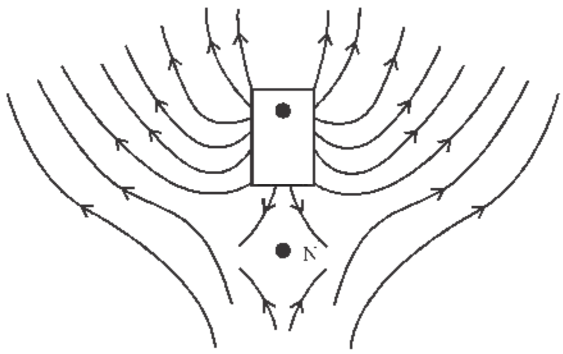

Fig 8.9 : Field lines when magnet is kept verticle

8.5 Magnetic Dipole and Magnetic Dipole Moment

8.5.1 Magnetic Dipole

In a bar magnet, both north pole and south pole exist. In a current carying solenoid, one end behaves like north pole and the other as south pole. In a current loop, one face behaves like north pole and other face as south pole. In nut shell magnetism exist as dipole and it is the elementary entity of magnetism. Mono pole is not possible. Even if we go on dividing a magnet into two, each piece has dipole.

8.5.2 Magentic Dipole Moment

It is the physical quantity which gives the strength of a magnet.

We have learnt that a coil having N turns, area A, current I, experiences a torque in external uniform magnetic field B;

$$\tau = NIAB\sin\theta \qquad \ldots (8.2)$$

Comparing it with the torque experienced by an electric dipole in external electrical field E,

$$\tau = pE\sin\theta \qquad \ldots (8.3)$$

We get an equivalent quantity to p as NIA, this quantity is similarly named as magnetic dipole moment M. Just as in electrostatics, we can write where m is pole strength and is a vector distance between two poles, which is from S to N.

In $\vec{M} = NI\vec{A}$ $\qquad \ldots (8.4)$

the direction of $\vec{A}$ is $\perp$ to the plane of current loop. The unit of $\vec{M}$ is A m^2.

It can be defined using realtion

$\tau = MB\sin\theta$ $\qquad \ldots$ (8.5) for a dipole. If B = 1, $\theta = 90°$, then $\tau = M$. Hence the magnetic moment is equal to the torque experienced by a dipole in unit magentic field, when it is placed perpnedicular to the field.

8.5.3 Magnetic Moment of a Bar Magnet

It is given by $M = m \times \ell$ $\qquad \ldots (8.6)$

where m = pole strength and ℓ is effective length of a bar magnet.

(A) If we bisect a bar magnet of dipole momnet M into two, perpendicular to its length. The dipole moment of each part is

$$M_1 = m \times \frac{\ell}{2} = \frac{m\ell}{2} = \frac{M}{2}$$

(B) If a bar magnet is dividend into two, by dividing along its length, again

$$M_2 = \frac{m}{2} \times \ell = \frac{m\ell}{2} = \frac{M}{2}$$

(C) If a bar magnet of length 2 ℓ and magnetic moment M is bent into a semi circle of radius r. Cirumferance of semi circle $\pi r = \ell$. Then $M_3 = m \times 2r$;

$$M_3 = m \times \frac{2\ell}{\pi} = \frac{2M}{\pi}$$

(D) If two bar imagnets are kept at an angle θ between their axis, the net magnetic moment will be vector sum of indivisul M.

$$M = \sqrt{M_1^2 + 2M_1M_2\cos\theta + M_2^2} \qquad \ldots (8.7)$$

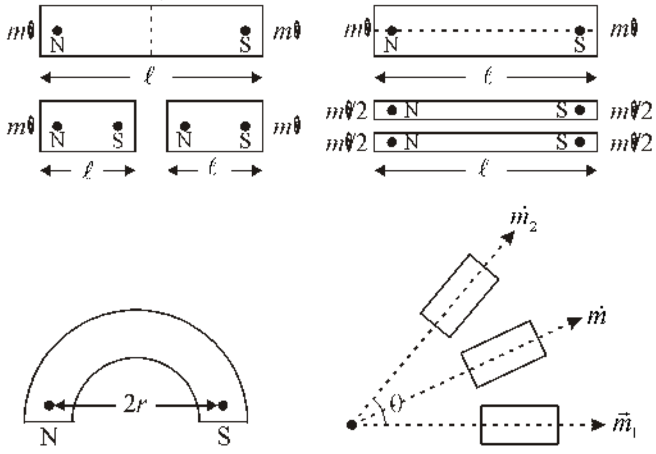

Fig 8.10 Magnetic moment of a bar magnet

8.5.2.2 Magentic Moment of a Revolving Electron

In an atom, electrons revolve round the nucleus, which is equivalent to current loop. Hence every orbit (having one electron) has a magnetic moment M = N I A. For an revolution (N=1), charge = e, and time t=T hence

$$I = \frac{e}{T} \text{ but } M = \frac{e}{T} \times \pi r^2 \text{ or } T = \frac{2\pi}{\omega}$$

where r = radius of orbit, v = linear velocity of electron and w = angular velocity.

$$\text{So } M = \frac{e}{2\pi/\omega} \times \pi r^2 = \frac{1}{2} e\omega r^2 \qquad ...(8.8)$$

$$\text{and } M = \frac{1}{2} evr \qquad ...(8.9)$$

since $v = r\omega$

Example 8.1 : Find the magnetic moment of a bar magnet with pole strength 40 Am and effective length 5 cm.

Solution : $M = m \times \ell$

$m = 40 \text{ Am}, \; l = 5\text{cm} = 0.05\text{m}$

$M = 0.05 \times 40 = 2 \text{ Am}^2$

Example 8.2 : A current carrying coil has magnetic moment 5 Am². If its radius is halved and the current is doubled, what will be new magnetic moment compared to previous one.

Solution : $M = NI\pi r^2$ The new magentic moment will be $M' = NI'\pi r'^2$

$$r' = \frac{r}{2} \quad I' = 2I$$

$$\frac{M'}{M} = \frac{N \times 2I \times (r/2)^2}{N \times I \times r^2} = \frac{1}{2};$$

deviding we get $M' = \dfrac{M}{2}$

Example 8.3 : Find the magentic moment of the elctron in first orbit of hydrogen atom.

$\left(r = 0.53 \text{ Å}, \; v = 2.2 \times 10^6 \text{ ms}^{-1}\right)$.

Solution : $M = \frac{1}{2} evr$

$r = 0.53 \text{ Å}$

$r = 0.53 \times 10^{-10} \text{ m}$

$v = 2.2 \times 10^6 \text{ m s}^{-1}$

$$M = \frac{1}{2} \times 1.6 \times 10^{-19} \times 2.2 \times 10^6 \times 0.53 \times 10^{-10}$$

$M = 0.93 \times 10^{-23} \text{ Am}^2$

Note : It is called Bohr Mahneton and is a fundamental constant in physics.

8.6 Intensity of Magnetic Field

Earlier it was defined as $\vec{B}$ (force on unit N pole). In analogy to (force per unit positive charge).

But now we define it using the realtion $\tau = \vec{M} \times \vec{B}$ (since M is the most basic quantity in magnetism and magnetic momopole does not exist.

B is equal to the torque experienced by a magnet of unit magnetic moment placed perpendicular to it.

Its SI unit is N / Am, or Tesla.

8.6.1 Magentic Field at an Axial Point of a Bar Magnet

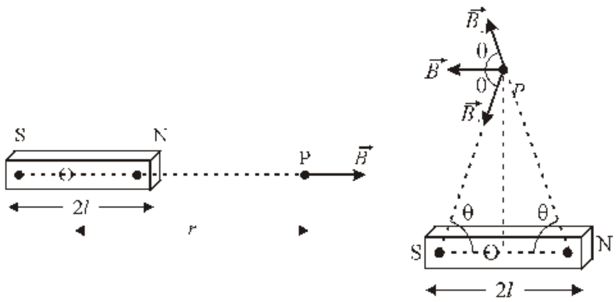

Fig 8.11 : Intensity at an equatorial point

As shown in fig 8.11, pole strength of a bar magnet is m, its effective length is $2l$. The magnet field at an axial point at a distance r from the center O, of the bar magnet is $\vec{B} = \vec{B}_1 + \vec{B}_2$, where $\vec{B}_1$ and $\vec{B}_2$ are the field due to north and south pole at p. Using Coulomb's law, and definition of B we get ; hence

$$B_1 = \frac{\mu_0}{4\pi} \frac{m}{(r-l)^2}$$

and $B_2 = \frac{\mu_0}{4\pi}\frac{(m)}{(r+l)^2}$ . . . (8.9b)

By convention, taking pole strength of north pole is (+m) and for that of south pole as (-m).

We get $B = \frac{\mu_0}{4\pi}\frac{m}{(r-l)^2} + \frac{\mu_0(-m)}{4\pi(r+l)^2}$

$$= \frac{\mu_0 m}{4\pi}\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right]$$

$$= \frac{\mu_0 m}{4\pi} \times \frac{m4rl}{(r^2-l^2)^2}$$

$$B = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2-l^2)^2}\ [\because\ M = m\times 2l] \ . . . (8.10)$$

For Special Condition of $l << r$ (for a very small magnet) we modify equ. 8.10 by taking common from denomenator-

$$B = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2-l^2)^2}$$

here l^2/r^2 is a negligible quanitity

hence $B = \frac{\mu_0}{4\pi} \times \frac{2M}{r^3}$ . . . (8.11)

8.6.2 Magnetic Field due to Bar Magnet at its Equitorial Point

As clear from fig 8.11, the magentic field at P, due to north pole is $B_1 = \frac{\mu_0}{4\pi} \times \frac{m}{(r^2+l^2)}$ along line NP and away from N. Similarly field due to south pole is

$B_2 = \frac{\mu_0}{4\pi} \times \frac{m}{(r^2+l^2)}$ (a long Ps, towards S).

Resolving $\vec{B}_1$ and $\vec{B}_2$ into components along axis and equator. We see that the sine components get cancelled being equal and opposite; and only cosine components contribute to $\vec{B}$ at equator. We get

$\vec{B} = \vec{B}_1 + \vec{B}_2$ (only cosine components of $\vec{B}_1$ & $\vec{B}_2$)

$\therefore \quad B = B_1\cos\theta + B_2\cos\theta$

$B = 2B_1\cos\theta \qquad [\because B_1 = B_2]$

$\therefore \quad B = \frac{\mu_0 \times 2m}{4\pi(r^2+l^2)} \times \cos\theta$

(but $\cos\theta = \frac{\ell}{(r^2+l^2)^{1/2}}$)

$\therefore \quad B = \frac{\mu_0}{4\pi}\frac{2ml}{(r^2+l^2)^{3/2}}$ . . . (8.12a)

Again for special condition for a small ba magnet $l << r$, l^2/r^2 being negligible, we get

$B = \frac{\mu_0}{4\pi}\frac{M}{r^3}\ [\because\ M = m\times 2l]$ . . . (8.12b)

The direction of $\vec{B}$ here is opposite to that of $\vec{M}$.

We appreciate the similarity to that of the electric field due an electric dipole at axis and equator

$\vec{E} = \frac{1}{4\pi\in_0}\frac{2\vec{p}}{r^3}$ . . . (8.13a)

$\vec{E} = \frac{1}{4\pi\in_0}\frac{\vec{p}}{r^3}$ . . . (8.13b)

here M is replaced by P and μ_0 by $\frac{1}{\in_0}$.

8.7 The Torque on a Bar Magnet in Uniform External Magnet Field

As in fig 8.12 a bar magnet of pole strength m and effective length 2 ℓ is placed in external uniform magnetic field $\vec{B}$, such that it is parallel to $\vec{B}$. The net force on the magnet is F = $F_N + F_S$ = mB + (-mB) = 0. Also the torque is zero.

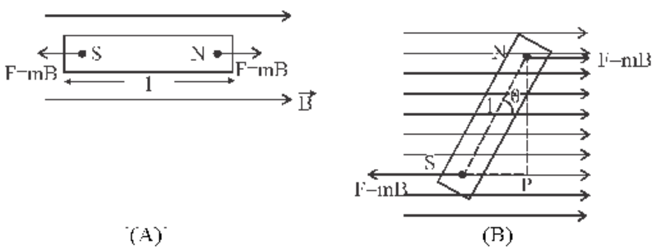

Fig 8.12 (A) and (B) Force on poles of a bar magnet in external magentic field

If the bar magnet is slightly rotated by an angle θ from equilibrium (θ is angle between $\vec{B}$ and 2ℓ), The net force on the magnet is again zero; but the magnet experiences a torque which is $\tau = mBxNP$(distance between forces).

$$\tau = mB \times NP$$

$$\tau = mB \times \ell \sin\theta$$

$$\tau = (m \times \ell)B \sin\theta$$

$$\tau = MB \sin\theta \qquad \text{. . . (8.14a)}$$

$$(M = m \times \ell)$$

$$\vec{\tau} = \vec{M} \times \vec{B} \qquad \text{. . . (8.14b)}$$

Special Conditions

(i) When $(\theta = 0)$ magnet being parallel to B

$$\tau = MB \sin 0 = 0$$

(ii) When magnet is perpendicular to $\vec{B}$, then $(\theta = 90^\circ)$ and $\tau_{max} = MB \sin 90 = MB$. The torque will be maximum.

The potential energy of a bar magnet (manetic dipole) in external magnetic field.

Um = work done in rotating the magnet by angle θ.

$U_m = \int \tau(\theta) d\theta$ here shows that τ is a function of θ.

$$U_m = \int \tau(\theta) d\theta$$

$$= \int MB \sin\theta \, d\theta = -MB \cos\theta$$

$$U_M = -\vec{M}.\vec{B} \qquad \text{. . . (8.15)}$$

for position $\theta = 0^\circ$; $(U_M)_{Min} = -MB$ (most stable condition for (ii) $\theta = \pi$, $(U_M)_{Max} = MB$)

(most unstable)

If we rotate the magnet by an angle to θ. then the definit integral will give you -

$$W = \int_0^\theta MB \sin\theta \, d\theta$$

$$W = MB[-\cos\theta]_0^\theta$$

$$= MB(\cos 0 - \cos\theta)$$

$$W = MB(1 - \cos\theta) \qquad \text{. . . (8.16)}$$

Example 8.4 : Find the torque on a bar magnet of pole strength 25 Am and effective length 10 cm, which is at an angle $\theta = 30^\circ$ from B_H(earth magentic field) ($B_H = 0.4 \times 10^{-4}$T).

Solution : $\tau = MB_H \sin\theta$

$$m = 25\,\text{Am},\ \ell = 0.1\text{m}, \theta = 30^\circ$$

$$\tau = m\ell B_H \sin\theta$$

$$= 25 \times 0.1 \times 0.4 \times 10^{-4} \times 0.5$$

$$= 0.5 \times 10^{-4}\ \text{N m}$$

Example 8.5 : A magnet of magnetic moment 5 Am^2 is placed in magnetic filled 0.2 T. Find the work done in rotating it, from parallel to antiparallel position. Also find the potential energy at the two positions.

Solution : The work done in rotating the magnet is

$$W = MB(\cos\theta_1 - \cos\theta_2)$$

$$W = 5 \times 0.2(\cos 0 - \cos 180)$$

$$= 1.0\,(1 + 1) = 2\ \text{J}$$

Similarly the energy in position 1 i.e. θ=0

$$U_1 = -MB\cos\theta_1 = -MB\cos 0 = -MB$$

$$= -5 \times 0.2 = -1\,\text{J}$$

$$U_2 = -MB\cos 180 = MB = 5 \times 0.2 = 1\,\text{J}$$

8.8 Earth's Magnetism

The earth behave like a bar magnet, it has its own magnetic field. It is called geomagnetism. The following facts confirm it -

(i) A bar magnet freely suspended from its C G always stay is NS direction in equilibrium.

(ii) An iron piece kept buried in earth for a long time aquires magnetism.

(iii) We get null points while ploting field lines of a bar magnet.

The magnetic field on the surfaces varies from place to place and is of the order 10^{-5}T.

8.8.1 Cause of Earth's Magnetism

The origion of geomagnetism is not well understood. There are certain explanations, the simplest one of existance of a giant magnet at the center of earth was rejected due to hot conditions inside earth where such magnet can't exist. The other one is "dynemo effect", given by Elsister is most accepted. According to it certain metals like iron and nickel exist in the outer core of earth in molten and ionic form. They rotate with earth and causes convention current which in turn produces magentic field.

Magnetic field lines of earth are maped, and their simplest version resembles to the field lines of an imaginary bar magnet placed inside the earth such that its axis makes an angle 11.30^0 to earth's axis and its north pole is towards south pole and south pole towards north pole of the earth. The location of these pole on earth surface are at lattitude $79.74°N$ and longitude $71.8°W$ a place in north canada. And $79.74°S$ and $108.22°E$ which is in Antartictica.

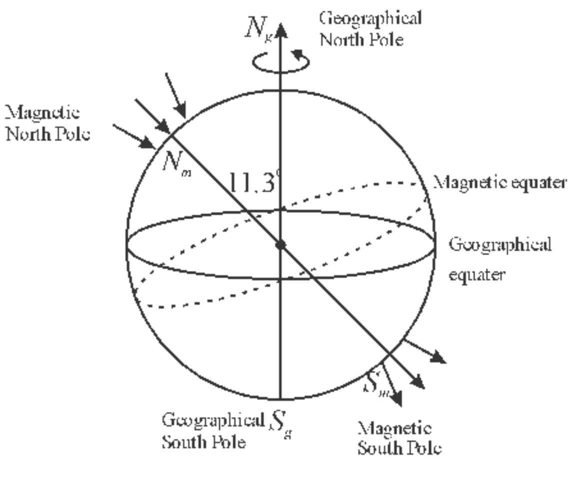

Fig 8.13 : Geomgnetism

8.8.2 Elements of Earth's Magnetism

To know about earth's magnetic field at certain place, need to know about three physical quantites about it. These are called elements of earth's magnetism. They are -

(1) Angle of declination (or simply declination).

(2) Dip angle.

(3) Intensity of earth's magnetism (or simpley horizontal component of it). First two gives the direction of earth's magnetic field in horizontal and vertical plane respectively, and third gives its magnitude (or magnitude in hortizontal direction).

(1) Angle of declination

Magentic meridian is a vertical plane passing through the axis of a freely suspended bar magnet from its CG and is in equilibrium.

Geographical meridian is a vertical plane passing through the axis of rotation of earth. It also contain longitude circle.

The angle of declination is the acute angle between magnetic meridian and geographical meridian. It is different at different places of earth. A Delhi it is $0^0.41$ E and at Mumbai it is $0^0 58'$ W. These small values shows that at these places, the direction shown by a compass needle is true north south.

(ii) Dip angle or angle of dip

If we take a compass needle, which is free to rotate about a horizontal axis, in vertical plane, then in equilibrium, the angle between its axis with horizontal is called angle of dip. It gives the direction of earth's magnetic field in verticle plane. Again the dip angle vaies from place to place on surface of the earth. It is O^0 at equator and 90^0 at poles.

(iii) Horizontal component of earth's magnetic field

At a place other then equator or pole the direction of magnetic field make certain angle with horizontal. We can resolve this magnetic field B, into two components, as B_V and B_H i.e. vertical component and horizontal component

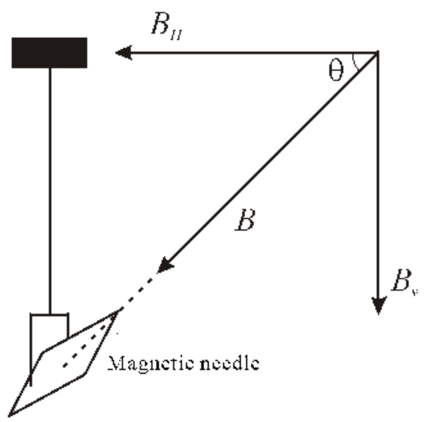

Fig 8.16 Components of earth's magnetic field

$$B_V = B\sin\theta \quad ...(8.17)$$

$$B_H = B\cos\theta \quad ...(8.18)$$

Such that $\vec{B} = \vec{B}_H + \vec{B}_v$

$$B = \sqrt{B_H^2 + B_v^2 + 2B_H B_v \cos 90^0}$$

$$B = \sqrt{B_H^2 + B_v^2}$$

$$\tan\theta = \frac{B_v}{B_H}$$

$$B_v = B_H \tan\theta \quad ...(8.19)$$

Example 8.6 : At certian point on earth surface dip angle is 60^0 and horizontal component of earth's magnetic field is 0.25 G. Find vertical component of earth's magentic field at this place. Also find the resultant magnetic field at that point.

Solution : $B_v = B_H \tan\theta$

$$B_v = 0.25\tan 60^0$$

$$= 0.25\times\sqrt{3} = 0.25\times 1.732 = 0.433\text{G}$$

$$B_H = B\cos\theta$$

$$B = \frac{B_H}{\cos\theta} = \frac{0.25}{\cos 60} = \frac{0.25}{0.5}$$

$$B = 0.50\,\text{G}$$

8.9 Magnetism and Gauss's Law

According Gauss's law in electrostatics i.e for a closed surface integral of electric filed is proportional to the algebric sum of charges enclosed by the surface.

If a surface encloses electric dipole . The incoming electric flux is equal to outgoing electric flux. Exaclty in the same wayfor magnetic field $\phi_B = \oint_S \vec{B}\cdot d\vec{S}$ because magnet always exist as dipole. The incoming magnetic flux through a closed surface is exactly equal to the outgoing flux, and net flux = 0. Hence Gausses law for magnetism is

$$\phi_B = \oint_S \vec{B}\cdot d\vec{S} = 0 \quad ...(8.20)$$

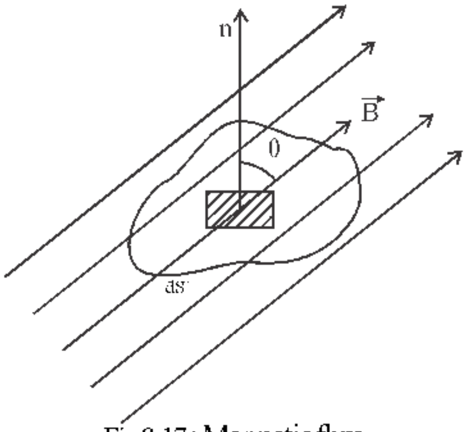

Fig 8.17 : Magnetic flux

8.10 Behaviour of Substances/Materials in External Magnetic Field

Farady found that all materials are effected by magnetic field or react to external magnetic field. However they interact with the field differently.

To invesitigate the behaviour of different materials following experimental set up is suggested -

A current carrying sole noid produces magnetic field, strong inside and weak near its ends. A test tube with sample to be tested is attached to a very sensitive spring balance near the end, as shown in fig 8.18.

When a current is set in the sole noid -

(i) Some materials like, iron, nickel and cobalt are strongly pulled inside the sole noid, these materials move from weak field to strong field.

(ii) Some other materials like aluminium, $CuCl_2$ etc are weakly attracted inside, i.e. with very weak force.

(iii) Majority of the materials like Z_n, B_i, gold etc are weakly repelled out in above experiment i.e they go from strong magnetic field to weak magnetic field.

There are many more types of materials, which you will know in chemistry or in higher classes. Here we restrict ourself to only three types mentioned above.

(i) The first type strongly attacted by mangetic field are called Ferromagnetic materials.

(ii) The second type which are very weakly attracted by magnetic field are called paramagnetic materials.

(iii) The third type which is very weakly repelled by magnetic field is called dimagnetic, material.

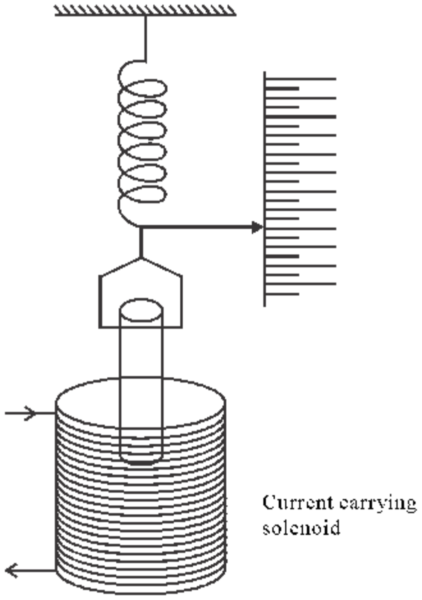

Fig 8.18 Behaviour of materials in a solenoid

8.11 Important Physical Quantities Related to Magnetism

8.11.1 Intensity of magnetisation I

We know that the circulating electron has a magnetic moment; when material is not magnetized, the magnetic dipole sum up to zero. When an external magnetic field is applied the magnetic moments are alligned in a particular direction, and the material gets a net non-zero dipole moment. The net dipole moment per unit volume is defined as magnetization or intensity of magnetisation. Its symbol is I, and its unit is Am^{-1}. It is a vector quantity. Its dimensional formula is $[M^0L^{-1}T^0A^1]$.

8.11.2 Magnetizing Field H

The magnetic field produced only by electric current (without any contribution of medium) in sole noid,

it is nI or $\vec{H} = \dfrac{\vec{B}_0}{\mu_0}$. It is also called magnetic intensity. It is the external field that induce magentic property in material. Its unit is also Am^{-1}.

8.11.3 Magnetic Susceptibility

When a material is placed in external magnetizing field H, the material get magnetized. For small magnetizing field, the I aquired by the material is proportional to H. i.e $I \propto H$ or $I = \chi_m H$ here χ_m is a constant for a perticular material called the magnetic susceptibility of that material. It is defined as, if H = 1, then $\chi_m = I$ in words we say the magnetization I aquired by the material in unit magnetizing field is equal to its magnetic susceptibility.

8.11.4 Magnetic permeability μ

It is a measure of ability of the medium to allow magnetic field to set in the medium. μ_0 is magnetic permeability of vacuum/air. μ is magnetic permiability of medium. And $\mu_r = \dfrac{\mu}{\mu_0}$ is relative magnetic permiability of the medium.

8.12 Relation between different Magnetic Quantities

Imagine a core of a material is placed in-side the sole noid. The net magnetic field produced by the system is

$$B = B_0 + B_1 \qquad \text{. . . (8.25)}$$

B_0 is contribution of current B_m is contribution of material of core.

here $B_1 \propto I$

$$\Rightarrow \quad B_1 = \mu_0 I$$

again $B = \mu_0 H + \mu_0 I$

Substituting in equation 8.25

$$B = \mu_0 (H + I) \qquad \text{. . . (8.26)}$$

$$B = \mu_0 (H + \chi_m H) \qquad [\because I = \chi_m H]$$

$$\frac{B}{H} = \mu_0 (1 + \chi_m)$$

$$\mu = \mu_0 (1 + \chi_m) \qquad \because \frac{\mu}{\mu_0} = \mu_r$$

$$\mu_r = (1 + \chi_m) \qquad \text{. . . (8.27)}$$

Or
$$\frac{B}{\mu_0} - I = H \qquad \text{. . . (8.28)}$$

Example 8.7 : The paramagentic material cromium has magnetic susceptibility as 2.7×10^{-4}. Find its magnetic permeability and relative magnetic permeability.

Solution : $\mu = \mu_0 (1 + \chi_m)$

$$\chi_m = 2.7\times10^{-4}$$

$$\mu = 4\pi\times10^{7}(1+2.7\times10^{4})$$

$$\mu = 12.56 \times 1.00027 \times 10^{7}$$

$$\mu = 12.5634 \times 10^{7}\,\mathrm{H/m}$$

Relative permeability

$$\mu_r = 1+\chi_m$$

$$= 1 + 2.7 \times 10^{4} = 1.00027$$

Example 8.8 : Paramagnetic material Aluminium has magnetic susceptibility 2.3×10^{5}. It is placed in a manetizing field $4\times10^5\,\mathrm{Am}^{1}$. Find the magentization of the material.

Solution : $I = \chi_m H$

$\chi_m = 2.3\times10^{5}$ and $H = 4 \times 10^5\,\mathrm{A/m}$

$I = 2.3 \times 10^{5} \times 4 \times 10^5 = 9.2\,\mathrm{A/m}$

Example 8.9 : An iron wire of length $l = 1m$ and cross section $1\,\mathrm{mm}^2$ is placed inside a sole noid, which produced a magnetizing field $4\times10^3\,\mathrm{A/m}$. Find the magnetic moment of the wire.$(16\pi\times10^{-5}\,\mathrm{H/m})$

Solution : $\chi_m = \dfrac{I}{H} = \dfrac{M}{H\,V}$

$$M = \chi_m HV$$

$$\ell = 1\,\mathrm{m},$$

$$A = 1\,\mathrm{mm}^2 = 10^{6}\,\mathrm{m}$$

$$H = 4\times10^3\,\mathrm{A/m},\quad \mu = 16\pi\times10^{-5}\,H/m$$

$$V = A\ell = 10^{-6}\times1 = 10^{-6}\,\mathrm{m}^3$$

$$\chi_m = \frac{\mu}{\mu_0} - 1 = \frac{16\pi\times10^{-5}}{4\pi\times10^{-7}} - 1 = 400 - 1 = 399$$

$$M = \chi_m HV$$

$$= 399 \times 4 \times 10^3 \times 10^{-6} = 1.596\,\mathrm{A\,m}^2$$

Example 8.10 : A rod of cross section $0.40\,\mathrm{cm}^2$ is placed in magnetizing field $4000\,\mathrm{Am}^{1}$. If the magnetic flux passing the rod is $5\times10^{5}\,\mathrm{Wb}$, then find magnetic induction, magnetic susceptibility and magnetization of the material of rod.

Solution : $B = \dfrac{\phi_B}{A}$

given $\phi_B = 5\times10^{-5}\,\mathrm{Wb}$,

$$A = 4\times10^{-5}\,\mathrm{m}^2,\ H = 4000\,\mathrm{A/m}$$

$$B = \frac{5\times10^{-5}}{4\times10^{-5}} = 1.25\,\mathrm{Wb/m}^2$$

Magnetic permeability

$$\mu = \frac{B}{H} = \frac{1.25}{4000} = 0.3125\times10^{3}$$

$$= 3.125 \times 10^{-4}\,\mathrm{H/m}$$

Magnetic susceptibility

$$\chi_m = \mu_r - 1 = \frac{\mu}{\mu_0} - 1 = \frac{3.125\times10^{-4}}{4\times3.14\times10^{-7}} - 1$$

$$\chi_m\ 1 = 248.8 - 1 = 247.8$$

$I = \chi_m H = 247.8\times4000 = 9.90\times10^5\,\mathrm{A/m}$ given

Example 8.11 : An iron rod of dimensions $5\,\mathrm{cm}\times1\,\mathrm{cm}\times0.5\,\mathrm{cm}$ is placed the in magnetizing field $10^{4}\,\mathrm{A/m}$. If a magnetic momen of $10\,\mathrm{A/m}^2$ is induced in it. Find magnetic induction.

Solution : $B = \mu_0\left(\dfrac{M}{V} + H\right)$

$M = 10\,\mathrm{Am}^2$,

$V = 5 \times 1 \times 0.5 \times 10^{6} = 2.5 \times 10^{6}\,\mathrm{m}^3$

$\mathrm{H} = 10^4\,\mathrm{A/m}$

$$B = 4\pi\times10^{-7}\left(\frac{10}{2.5\times10^{6}} + 10^4\right)$$

$$= 12.56\times10^{-7}(4\times10^6 + 10^4) = 5.036\,\mathrm{Wb/m}^2$$

8.13 Classification of magnetic materials

According to the behaviour of materials in external magnetic field, the materials are of mainly three types - (i) Diamagnetic (ii) Paramagnetic (iii) Ferromagnetic

8.13.1 Diamagnetic Substances

If placed in non uniform exrternal magnetic field, the materials moves from strong field to weak field, or they outstead by the field. Actually they aquire a small, net non-zero magnetization opposite to the applied field. These materials are called diamagnetic and the property, diamagnetism. examples- Cu, Zn, Sb, Bi, Hg, H_2, N_2, Au, Ag, air water diamond etc.

Explanation of Diamagnetism

Such materials have pairedelectron in their atoms, which revole in opposite direction. In the absence external magnetic field, the magnetic moment of those electron get cancalled being equal and opposite. In the presence of external magnetic field, the magnetic force on moving electron is opposite in both pairing electrons, on one electron, it is towards the nucleus, increasing its velocity, hence increasing magnetic moment; $m = 1/2evr$. One other it is away from nucleus, thus decreasing v and magnetic moment.

The magnetic moment in the direction of applied field get decreased, and that which is opposite, get increased. Hence the net magnetization induced in the material is opposite to the appilied field.

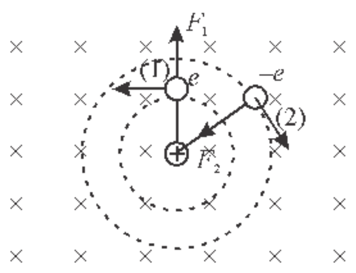

Fig 8.19 Explaination of diamagnetism

Diamagnetism is present in all substances in some it is not observed due to other dominet properties present. Super conductors are ideal diamagnetic substances. For them $\chi_m = -1$; $\mu_0 = 0$ this effect is called Meisner effect. Magnetic field lines of external field are completly expelled by them. Aliquid diamagnetic substance placed in watch glass over magentic poles, behaves as shown in the figure 8.20.

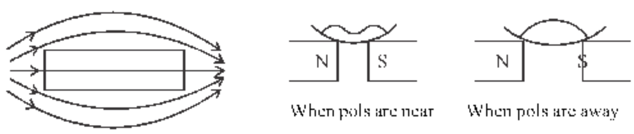

Fig 8.20 : Behaviour of diamagnetic materials

8.13.2 Paramagnetic Substances

These substances, when placed in external magnetic field move slightly from weak field to strong field or they are slightly, attracted by manetic field. We say that they aquire small net magnetic moment in the direction of applied field. These substances are called paramagnetic substances. Example - Na, Ca, Al, $CuCl_2$ etc.

Explanation of Paramagnetism-

This type of materials have unpaired electron in their atom. So every atom is a magnetic moment. The net magnetic moment, in the absence of external field is zero because of random orientations due to thermal agitation.

When external field is applied, the torque acting on them; align some of these atomic magnetic dipoles in the direction of applied field. All magnetic dipoles do not get aligned due to thermal effect. Hence the material gets some net non-zero magnetic moment in the direction of applied field.

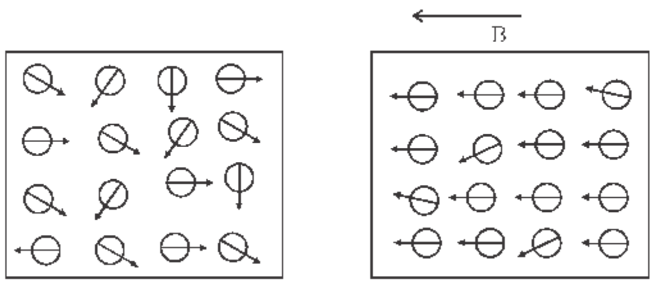

Fig 8.21 : Explanation of paramagnetism

Such materials allow. Some of the field lines of external field to pass through them. IF placed in watch glass over the poles of a magnet, shows the behaviour as shown in fig 8.22.

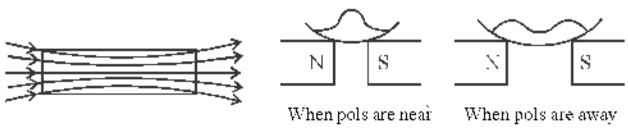

Fig 8.22 : Behaviour of paramagnetic materials

Temparature Dependance

Practically the magnetic intensity of a paramagnetic substance is proportional to the imposed magnetic field and inversly proportional to the absolute temparature

$$I \propto \frac{B_0}{T}$$

or $$I = C\frac{B_0}{T} \qquad \ldots (8.29)$$

here C = Curie Constant

But $B_0 = \mu_0 H$

$$I = C\frac{\mu_0 H}{T}$$

or $$\frac{I}{H} = C\frac{\mu_0}{T}$$

which gives $$\chi_m = \frac{C\mu_0}{T} \quad \ldots (8.30)$$

called curie law.

8.13.3 Ferromagnetic Substances

When placed in non uniform magnetic field, these materials rapildy move towards strong field ot they are strongly attracted by a magnetic field. Also they get magnetized in the direction of applied magnetic field.

Example - Fe, C_O, Ni, Fe_2O_3, gadolinium and magnetite (Fe_3O_4).

Explanation of Ferromagnetism

As in paramagnetism, the ferromagetic materials also have permanet dipole moment (of a group of atoms, oriented in same direction). The difference is of intensity. The orientation of these groups of atom is random; which make for whole sample.

Due to complex interaction between the atoms, one dipole, compels the other, to orient in the same direction. In this process, small colony of dipoles having same orientation is formed. This colony is called "domian". Whole sample is devided into domains having different orientations, making for whole sample. Size of one domian is of the order of few mm and it contain atom of the order of 10^{11}.

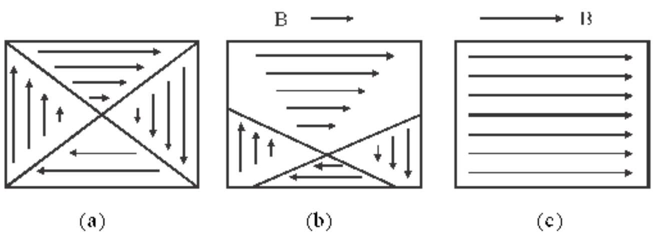

Fig 8.23 : Ferromagnetic materials

When a sample of ferromagnetic material is kept in an external magnetic field; if the applied field is weak, then the area or size of the domain having same orientation as that of applied field, increases and vice-versa. If the exrternal magnetic field is removed; the phenomenon is reversed due to thermal effect. Hence the process in reversible.

If the applied magnetic field is strong. The whole domain rotates in the direction of applied field. The first to rotate is that which makes minimum angle with applied field. If kept in the field for a long time, the whole sample becomes one domain.

If the external field is removed, the sample does not returns to original state, but some residual magnetism remains.

8.14 Curie Law and Curie Temparature

Pierre Curie studied the effect of temparature on magnetic materials and found that the magnetic susceptibility of diamagnetic materials does not depend on temparature, whereas the magnetic susceptibility of paramatic substance/material in inversly proportional to its absoulte temprature i.e

$$\chi_m \propto \frac{1}{T} \text{ Or } \chi_m = \frac{C}{T}$$

where C = Curie temparature

T = Absolute Temparature of the material

Temparature dependance of a ferromatic material obeys Curie - Weiss law. According to this law the magnetic susceptibility of a ferromagnetic material is given

by $$\chi_m = \frac{C}{T - Tc} \quad \ldots (8.31)$$

where C = Curie constant; T is the temparature of the material and T_C is curie temparature for that material. Below T_C the material behave like a ferromagnetic material and above T_C the material behave like a paramagnetic material. Above T_C all materials are paramagnetic. T_C is different for different materials. The curie temparature for some materials are given as -

Materials	Curie temprature
Iron	$T_C = 1043$ K
Cobalt	$T_C = 1394$ K
Nickle	$T_C = 631$ K
Gadolanium	$T_C = 317$ K

Example 8.12 : The curie temparature for some material is 300 K. If its magnetic susceptibility at 420 K is 0.4, then find curie constant.

Solution : manetic susceplibility $\chi = \dfrac{C}{T - T_C}$

$\chi = 0.4, \ T_C = 300\,K$ तथा $T = 420$ K

$C = \chi(T - T_C)$

$= 0.4\ (420 - 300) = 0.4 \times 120 = 48$ K

8.15 Magnetic Hysteresis Curve (B - H Curve)

When a ferromagnetic material is placed in magnetic field H (magnetizing field), magnetization of material takes place which produces magnetic field B. The curve showing of B and H is known as Hysteresis curve or B-H curve.

To find B-H curve of a ferromagnetic material we take its demagnetized from in the shape of a rod. We place this rod in a current carrying sole noid. The current in the sole noid produces $H\ (H = ni)$. This H magnetises the material which in turn produces B. We can change H by changing current, and we have a device to measure B.

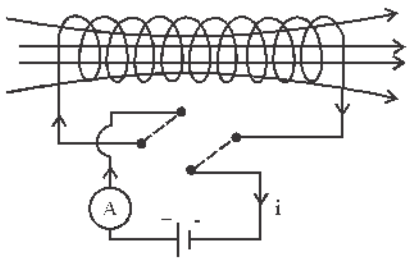

Fig 8.24 : Magnetic material inside a solenoid

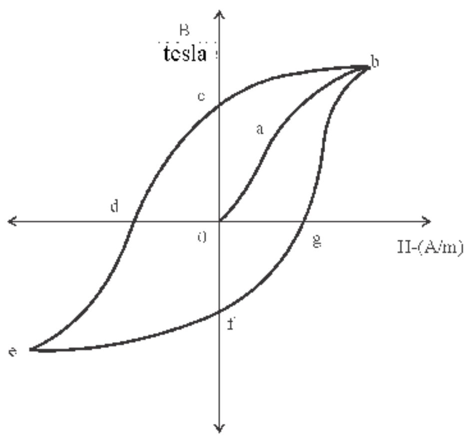

Fig 8.25 : Hystersiss loop

We start our experiment with $i = o, H = 0$, B will be zero i.e the origin O. Increasing H, B will increase but the relation is not lenear, it goes as per curve O ab in the diagram. After the point b, increasing H does increase B (the material is saturated and all the domains are aligned in one direction). The value of H after which B does not increases, but become constant, is called magnetic saturation.

Now if we reduce H to zero, the curve does not retrace the path b a o; but it goes from b to c. At point c, H = 0 but B ≠ 0 i.e some magnetization remains in the material. This remainent magnetism is called sesidual magnetism. The value of B at H = 0 is called retentivity or remanence, B_R. The domains are not completely randomised although external field H = 0.

Now if we reverse the direction of current in the sole noid, and increase it slowly, B decreases as curve cd and B becomes zero at certain value of H, which is called coercivity of the material. If we go on increasing H beyond d, the material is magnetized in opposite direction and get saturated at e (i.e all the domains are alligned in opposite direction). If we reduce H to zero again B will bot be zero but have a value of the remamant value in opposite direction. This is show as *of* in the curve. Again if we increase *i* in the original direction, the curve goes as *fgb*, and completes a cycle. Again the value of H, Og is coercivity of the material. We can know about the behaviour of material and its magnetic properties from its B-H loop *bcdefgb*. Fig 8.26 shows B-H curves of soft-iron and steel.

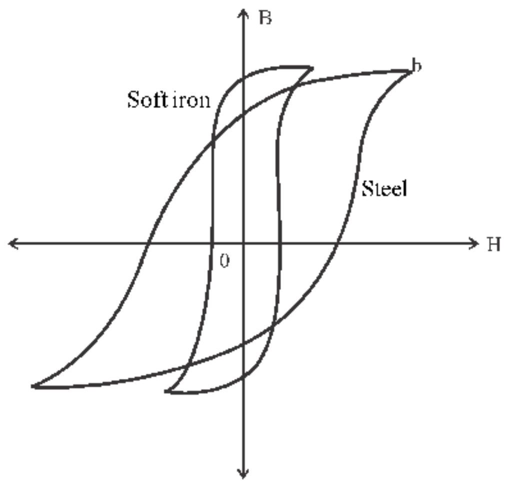

Fig 8.26 : Hystersiss loop for soft iron & steel

From this diagram it is evident that -

(1) For any value of H, the value of B for soft iron is more than that for steel, hence magnetic permeability μ, of soft iron is more than that of steel.

(2) Retentivity of soft iron is more than of steel.

(3) Steel has more coercivity than soft iron.

(4) For any value of H, the value of magnetization I is more for soft iron than steel; i.e. $\chi_m = I / H$ is more for iron which shows that the value of magnetic suceplibility of soft iron is more than that of steel.

(5) The area of B-H loop for soft iron is less than that for steel which shows that hysteresis loss is less in soft iron compared to steel. The area of B-H loop represents the enrgy loss per cycle per unit volume.

(6) B always lags behind H, this property is called hysteresis.

To select a material for core of electromagnet soft iron is suitable for its high permitivity μ, less coercivity and less hysteresis loss.

8.15.1 Hysteresis Loss

Energy is given to the material during magnezation. But during demagnezation the material does not release the whole energy it recieved. Some energy get lost (work done in rotating the domains). This loss of energy per cycle is called Hysteresis loss. This energy is converted to heat energy.

Area of B-H loop represents energy loss per cycle per unit volume. Hence the loss of energy per second is $Q = VAn;$ V = Volume of sample; A = Area of B-H loop and n is the frequency (number of cycles/s).

Electromagnet consists of insulated copper wire wound over a soft iron core. It is used in telephone electric bell, electric motor, dynamo, telegraphy and separation of magnetic materials from a mixture. It is also used in medical sciences.

For a permament magnet the material choosed, should have high retaintivity and high coercivity. It should also have high curie temparature and high saturation magnetism, so that it does not get demagnetized due to temparature, stray magnetic field and mechanical impulses. Hysteresis is meaningless for permanent magnet. For permanent magnet the suitable materials are steel and alnico (Al + Ni + Co). In these materials, the domains once get orienated remains as such and the external demagnetizing effects are minimum. Permanent magnets are used in galvanometers, ammeter, volmeter and loudspeaker.

The material for a transformer core, should also have the properties that are required for electromagnet i.e high μ, high χ_m, high retaintivity. An extra quality of low hysteresis is required. For transformer core the suitable materials are, superalloy, transformer steel (soft iron 4% silicon) and μ-metal (Cu+Fe+Ni+Mn).

Important Points

1. Magnets show directional and attractive properties. Both the poles can not be separated.
2. Magnetic field lines are imaginary close loops. The tangent drawn at any point gives the direction of magnetic field at that point.
3. Super position of magnetic fields of two magnets gives two points, where mahnetic field is zero, these points are called null points.
4. The magnetic moment of following dipoles is as given -

   (i) For bar magnet M = pole strenth x effective length

   (ii) For a revolving electron

   $M = 1/2evr = 1/2e\omega r^2$
5. When a magnet of manetic moment M is placed in niform magnetic field B (i) net force on it is zero.

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

   (iii) Potential energy $U = -\vec{M} \cdot \vec{B}$

(iv) work done in rotating the magnet is

$W = MB(1-\cos\theta)$

6. Magnetic axis does not coincide with axis of rotation of earth, but it makes an able 11.3^0.
7. The quantities that give complete infromation about earth's magnetic field are called elements of earth's magnetism, they are (i) angle of declination (ii) dip angle (iii) Horizontal component of earth;s magnetic field.
8. The Gauss's law for magnetism is

$$\phi_B = \oint_S \vec{B}.d\vec{s} = 0$$

9. If a material is kept in magnetic field B_0 then magnetizing field or magnetic intensity $\vec{H} = \vec{B}_0 / \mu_0$.

Magnetic intensity $I = M/V$ i.e magnetic moment per unit volume.

10. Magnetic susceptibility $\chi_m = \dfrac{M}{H}$.
11. Relation between χ_m, and μ_0 is given as

$$\mu = \mu_0(1+\chi_m)$$

$$\mu = \mu_0\mu_r \quad \mu_r = 1+\chi_m$$

12. Magnetic materials are classified as diamagnetic paramagnetic and ferromagnetic according to their reaction to B.
13. Diamanetism is due to orbital motion of electrons, paramagnetism is due to orbital and spin motion of electron, ferromagnetism is due to domain property.
14. The hysteresis loop or B-H loop is used to study magnetic properties of of materials, and in selecting suitable materials for electric devices.
15. Diamagnetism does not depend on temparature for paramagnetic material $\chi_m \propto 1/T$ curie law. For

ferromagnetism $\chi_m \propto \dfrac{1}{T-T_C}$ (curie-wiess law).

where T_C = Curie temparature

Questions for Practice

Multiple Choice Questions -

1. If two magnetic poles of unit pole strength are at 1m distance in vacuum. The force between them will be -

(a) $4\pi \times 10^{7}$ N (b) 4π N

(c) 10^{-7} N (d) $\dfrac{4\pi}{10^{-7}} N$

2. For super conductors, magnetic susceptibility is -

(a) + 1 (b) - 1

(c) Zero (d) Infinite

3. Magnetic susceptibility of free space is -

(a) +1 (b) - 1

(c) Zero (d) Infinite

4. The magnetic susceptibility is negative and very smallfor -

(a) Feromagnetic materials

(b) Paramagnetic materials

(c) Diamagnetic materials

(d) All of these

5. The relative permeability of a meterial is 1.0001 the material will be -

(a) Feromagnetic (b) Paramagnetic

(c) Diamagnetic (d) Non of above

6. The unit of magnetic moment is -

(a) Wb (b) Wb / m^2

(c) A / m (d) Am^2

7. Wb x A/m is equal to -

(a) J (b) N

(c) H (d) W

8. Magnetic field does not interact with -

(a) Another magnetic field

(b) Accelarated magnet

(c) A stationary chagre

(d) Moving electric charge

9. The cause of diamagnetism is -

(a) Orbital motion of electron

(b) Spin motion of electron

(c) Paired electron

(d) Non of the above

10. Magnetic moment of diamagnetic substances -

(a) Infinite (b) Zero

(c) 100 Am^2 (d) Non of the above

11. Relative permeability of ferromagnetisc substances is -

(a) > 1 (b) > > 1

(c) = 1 (d) = 0

12. The vertical component of earth's magnetic field is zero etc.

(a) Magnetic pole (b) Geographical pole

(c) Magnetic meridian (d) Non of the above

13. The area of hysteresis loop of a substance represents -

(a) Energy loss per cycle to magnetise the material

(b) Energy loss per unit volume per cycle in magnetizing the material

(c) Energy loss per unit volume in magnetizing

(d) Energy loss in magnetizing the material

14. Steel is used to prepare permanent magnet -

(a) Less energy loss

(b) Density of steel is more

(c) The residual magnetism is more

(d) Magnetism is not destroyed by ordinary external magnetic field

15. At curie temperature, a ferromagnetic substance becomes -

(a) Non-magnetic (b) Dia magnetic

(c) Paramagnetic (d) More ferromagnetic

Very Short Answer Type Questions -

1. A magnetic needle is free to rotate in vertical plane about horizontal axis. What direction it will indicate at magnetic poles?

2. Name the type of magnetic material which does not depend on temparature?

3. How the value of dip angle changes in going from equator to poles?

4. A magnetic material has magnetic susceptibility as -0.085. What type of materal it is?

5. What is retentivity or remanence?

6. Name two paramagnetic substances.

7. What is magnetic meridian?

8. Where on earth's surface the dip angle is zero and 90^0?

9. Write realtion between magnetic parmeability and magnetic susceptibility for a medium.

10. Write unit of pole strength.

11. What will be the value of dipangle, where the ratio of vertical and horizontal component of earth's magnetic field is $\frac{1}{\sqrt{3}}$.

12. What is magnetic Hysteresis?

13. What will be the ratio of magnetic fields at the points on axis and equator, equidistant from center of bar magnet?
14. What will be value of dip angle at a place where vertical and horizontal components of earth's magnetic field are equal?
15. What will be the change in magnetic moment of a bar magnetic if we bisected it along its length?

Short Answer Type Questions -

1. Find the expression for potential energy of a bar magnet placed in uniform magnetic field B, such that the angle between its dipole moment and B is .
2. How you will identify rods of paramagentic and diamagnetic substance?
3. Why we get two null points for a bar magnet? Can we get only one null point? How?
4. Why soft iron is used for electro magnets.
5. A bar magnet of magnetic moment $\vec{M}$ is placed parallel to uniform magnetic field $\vec{B}$. What will be the work done in rotating it by 90^0?
6. Difine angle of declination and dip angle.
7. Write down curie-wies law and write the value of curie temparature for iron.
8. Write four properties of magnetic field lines.
9. What is the behaviour of diamagnetic, paramagnetic and ferromagnetic substances in non-uniform magnetic field?
10. What is Gauss's law for magnetism? What does it indicates?
11. Why magnetic field lines are closed loops?
12. Compare magnetic fields of a bar magnet and a current carrying sole noid.
13. What is cause of earth's magnetism?
14. What are uses of hysteresis curve?
15. Find the expression for torque on a bar magnet placed at angle with uniform magnetic field. When it will be maximum?

Essay Type Questions -

1. What are elements of earth's magnetism? Define them and show with a labled diagram.
2. What is meant by hysteresis loop? Draw it and define its main physical quantities (specilities).
3. Explain diamagnetism, discuss its properties. Write five difference between paramagnetic and diamagnetic substances.
4. What is curie temparature? Explain how the magnetic susceptibility of paramagnetic, diamagnetic and ferromagnetic substances depend on temparature? Also write law regarding it.
5. Write specilities of the materials used for (i) Electri magnet (ii) Permanent magnet. Also write their uses.

Anwers (Mutliple Choice Questions)

1. (A) 2. (B) 3. (C) 4. (C) 5. (B) 6. (D) 7. (B) 8. (C) 9. (A) 10. (B) 11. (B) 12. (D) 13. (B) 14. (D) 15. (C)

Numerial Questions -

1. A bar magnet of magnetic moment 20 A m^2 is suspended in uniform magnetic field of 0.86T. Find the torque in rotating it by 60^0.

   ($86\sqrt{3}$ N×m)

2. The horizontal component of earth's magnetic field at certain place is $B_H = 0.5\times10^{-4}\, Wb/m^2$ and dip angle is 45^0. Find vertical component of earths magnetic field.

   ($5\times10^{-5}\, Wb/m^2$)

3. An iron rod of cross section 1 cm^2 is placed in magnetic field of 200 orested. It proudces a magnetic field of 3000 G. Find magnetic permeability and magnetic suceptibility of the material.

   (15 and 14)

4. For a sample of iron the following relation holds -

   $$\mu = \left[\frac{0.4}{H} + 12\times10^{-4}\right] \text{H/m}$$

   Find the value of H which produce a magnetic field of 1 T.

   (500 H/m)

5. A magnetic field of 2×10^3 A/m. produces a field

8π T in a sample of iron rod. Find relative magnetic permeability of the sample.

(10^4)

6. A sample of volume 30 cm^3 is placed in magnetic field of 5 orested. The magnetic moment induced is $6A/m^2$. Find magnetic induction.

(0.2517 T)

7. A sample of ferromagnetic material of mass 0.6 Kg and density 7.8 x 10^3 kg/m^3 is placed in a alternating magnetic field of frequency 50Hz. If the area of hysteresis loop is $0.722m^2$. Find hysteresis loss per second.

(2.777 x 10^{-4}J)

8. The curie temparature of ferromagnetic material is 300 K. If the magnetic suceptibility at 450 K is 0.6. Find curie constant for it.

(90 K)

9. Magnetic susceptibility for a paramagnetuic material is 0.60 at 120 K. Find its magnetic susceptibility at 27^0 C.

(0.24)

10. An iron rod of cross section 4 cm^2 is placed parallel to a magnetic field of 10^3 A/m. If the magnetic flux passing through it is 4×10^{-4}Web. Find magnetic permeability, relative magnetic permeability and magnetic susceptibility of iron.

(10^{-3} Web / A × m, 796, 795)

11. A circular coil of 100 turns and radius 0.05 m, has a current 0.1 A. Find the work done in rotating it by 180^0 in a field of 1.5 T.

(0.236 J)

12. A coil in the form of unilateral tringle of side l is suspended in magnetic $\vec{B}$ which is perpendicular to plane of coil. If the current in the coil is I and it experience a torque τ; find the expression for length of one side of the tringle.

$$\left[\left(2\frac{\tau}{\sqrt{3}BI}\right)^{1/2}\right]$$