MAGNETISM

1.COULOMB'S LAW

POINTS TO REMEMBER

1. Magnetism was first observed in the mineral called magnetite (Fe_3O_4). It is called load (showing the directions) stone.

2. **Properties of a magnet:**

   a) When a magnet is freely suspended or pivoted, it comes to rest showing north and south directions.
   b) Like poles repel and unlike poles attract each other (Dufay's law).
   c) A magnet attracts substances like iron, nickel, cobalt, steel etc.

3. **Pole strength (m) :**

   a. Pole strength is a scalar.
   b. S.I unit is ampere-metre.
   c. Dimensional formula of m = [IL]
   d. It (a) depends on nature of the material of the magnet (b) depends on level of magnetization (c) is directly proportional to area of cross-section.
   e. Isolated magnetic poles do not exist. They are imaginary.

4. **Magnetic moment :**

   a. It is the product of magnetic length and pole strength $M = 2l \times m$.
   b. Its S.I unit is ampere-metre^2 or Joule / Tesla or N–m^3/weber.
   c. Dimensional formula is $[I^1L^2]$.
   d. It is a vector with its direction from South Pole to North Pole along its axial line (SN).

5. . **Coulomb's inverse square law :**

   (i) The force of attraction between two point magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance them. $F \propto \frac{m_1m_2}{d^2}$

   Where m_1, m_2 are pole strength'd' is the distance between the magnetic poles.

   (ii) $F=\frac{\mu}{4\pi}.\frac{m_1m_2}{d^2}$

   Here $\mu = \mu_0\mu_r$ where $\mu_r =$ relative permeability and $\mu_0 =$ absolute permeability

   $\mu_0 = 4\pi\times10^{-7}\ Hm^{-1}$ (Henry / meter) and for air or vacuum $\mu_r = 1$.

   (iii) $F = \frac{\mu_0}{4\pi}\frac{m_1m_2}{d^2} = 10^{-7}\times\frac{m_1m_2}{d^2}$

   vi) If F is the force between two magnetic poles in the medium and F_0 is the force between the same poles when they are in air or vacuum, then the relative permeability is given by $\mu_r = \frac{F}{F_0}$

   vii) Force experienced by a magnetic pole 'm' when placed in a uniform field B is F = mB Newton.

6. **Unit Pole:** Unit pole is one which when placed at a distance of one meter apart from a similar pole in air or vacuum repels it with a force of 10^{-7} Newton.

7. **Magnetic lines of force:** A line of force in a magnetic field is the path or the curve along which a free unit north pole travels. The tangent to the magnetic field line at a point gives the direction of the field induction B at that point.

Very Short Answer Questions:

1. Define the magnetic moment of a bar magnet. What is its direction?

Ans : **Magnetic moment (M) :** It is defined as the torque acting on a bar magnet which when placed perpendicular to the direction of uniform magnetic field of unit induction.

It is also defined as the product length of a magnet and its pole strength. M = 2*l*m

It is a vector quantity. Its direction is for South Pole to North Pole along the axis of the magnet.

2. Distinguish between uniform and non-uniform magnetic fields. Give examples.

(June2010)

Ans : **Uniform magnetic field :** If the magnetic induction at every point in a field is same both in magnitude and in direction, the field is said to be uniform magnetic field.

Ex :- 1) The magnetic field between two pole pieces of an electromagnetic is uniform.

2) Horizontal component of earth's magnetic field at a given place is uniform.

Non –Uniform Magnetic field : If the magnetic induction varies from point to point in a field both in magnitude and in direction, then the field is said to be non – uniform.

Ex :- The magnetic field due to bar magnet is a non-uniform field.

3. What are the units of the following magnetic physical quantities?(i) Magnetic moment (ii) Magnetic permeability?

Ans: **M**agnetic moment: Am^2 and Magnetic permeability: $Hm^{-1}(or)NA^{-2}$.

4. Do you find two magnetic field lines intersecting? Why?

Ans: Two magnetic field lines will not intersect each other. If they intersect at the point of intersection, the magnetic field should have two different directions which is not possible

5. The force between two magnetic poles separated by a distance'd' in air is F. At what distance between them the force becomes doubled?

Ans: We have $F \alpha \frac{1}{d^2}$ But , $F_2 = 2F_1$

$$\therefore \frac{F_1}{F_2} = \frac{d_2^2}{d_1^2} \Rightarrow d_2^2 = \frac{d_1^2}{2} \qquad \Rightarrow d_2 = \sqrt{\frac{d_1^2}{2}} = \frac{d}{\sqrt{2}}$$

6. What is the magnetic moment of a semi circular magnet of radius ‘r’ and pole strength ‘m’?

Ans: Pole strength = m

Length of the magnet (SN) = 2r

$\therefore$ Magnetic moment (M) = Pole strength x length of the magnet = m x 2r = 2mr

7. The magnetic moment of a bar magnet is M. If it is cut into two pieces in the ratio 1:2 perpendicular to its length, what is the ratio of their magnetic moments?

Ans: In this case, pole strength remains same for both the pieces. Hence $M_1 : M_2 = 1:2$

SOLVED PROBLEMS

1. The distance between a north pole of strength $6\times10^{-3}\ Am$ and a south pole of strength $8\times10^{-3}\ Am$ is 10 cm. The poles are separated in air. Find the force between them.

Sol: The force between two magnetic poles is, $F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{d^2}$

$$\therefore F = 10^{-7} \times \frac{6\times10^{-3}\times8\times10^{-3}}{(0.1)^2} = 48\times10^{-11}\,N$$

2. A N-pole of a very long magnetic needle is placed at a distance of 20cm from a point ‘P’. If the pole strength of the magnetic needle is 40 Am, what is the magnetic induction at the point P?

Sol: $\therefore$ The magnetic induction due to the N-pole at P is,

$$B = \frac{\mu_0}{4\pi}\frac{m}{r^2} = \frac{4\pi\times10^{-7}}{4\pi}\times\frac{40}{(20\times10^{-2})^2} = 10^{-4}\,T$$

Unsolved Problem

1. Two magnetic poles of strengths 40 Am and 10Am are separated by a distance of 20 cm. in air. Find the force between them .If the distance is reduced to 10 cm, find the force between them.(March2011)

Sol: Case (1): m = 40 Am, m_2 = 10Am, d=20 cm

$$F = \frac{\mu_0}{4\pi}.\frac{m_1 m_2}{d^2} \Rightarrow F = 10^{-7}\times\frac{40\times10}{(20\times10^{-2})^2} = 10^{-3}\,N$$

Case (2) : $F_1 = 10^{-3}\,N$, $d_1 = 20cm$, $d_2 = 10cm$, $F_2 = ?$

$$\frac{F_1}{F_2}=\frac{d_2^2}{d_1^2}\Rightarrow\frac{10^{-3}}{F_2}=\frac{(10\times10^{-2})^2}{(20\times10^{-2})^2}$$

$$\therefore F_2=4\times10^{-3}\,N$$

2. Two magnetic poles one of which is three times stronger than the other, exert on each other a force equal to $3\times10^{-3}N$ when separated by a distance of 10 cm. Find the strength of each pole.

Ans: If $m_1=m$, then $m_2=3m$ m d = 10 cm, $F=3\times10^{-3}N$

$$F=\frac{\mu_0}{4\pi}\times\frac{m_1m_2}{d^2}\Rightarrow 3\times10^{-3}=10^{-7}\times\frac{3m^2}{10^{-2}}\Rightarrow m=10Am$$

$$\therefore m_1=m=10Am \ \ and \ \ m_2=3m=3\times10=30Am$$

3. A bar magnet of magnetic moment M is bent into a semicircle. What is its new magnetic moment?

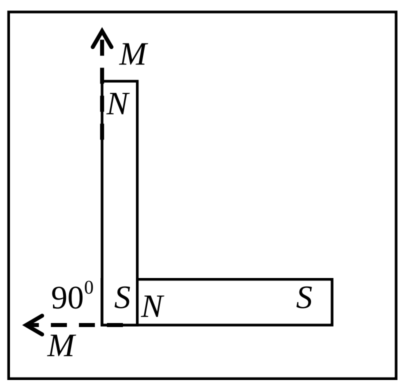
Ans: When a magnet is bent into a semi circular arc its distance between the poles is reduced.

$\therefore$ New magnetic moment $M_1=2rm$

But $r=\dfrac{2l}{\pi}$

$$\therefore M_1=2\times\frac{2lm}{\pi}=\frac{2M}{\pi}$$

4. Two identical magnets are placed perpendicular to each other with their unlike poles in contact. If each magnet has a magnetic moment M, what is the magnetic moment the combination?



Ans: $M_1=M$ and $M_2=M$

Angle between their axes $\theta=90^0$

$$\therefore M'=\sqrt{M_1^2+M_2^2-2M_1M_2\,Cos\,\theta}$$
$$\Rightarrow M'=\sqrt{M^2+M^2}$$

$$\therefore M'=M\sqrt{2}$$

<u>ASSESS YOURSELF:</u>

1. Can the force on unit N-pole between two isolated like pole be zero at any point?

Ans: Yes, at the midpoint of the line joining the two poles the force on unit N-pole becomes zero.

2. Can the force on unit N-pole between two isolated unlike poles be zero at any point?

Ans: No. At every point on the line joining them between the poles the forces due to both the poles will be in the same direction.

2. **What do you infer from the magnetic field lines around a bar magnet which are closed loops?**

Ans: Isolated poles do not exist.

3. **What happens if a bar magnet is cut into two equal pieces a) along its length b) perpendicular to its length ?**

Ans: a) The pole strength gets halved and hence the magnetic moment of each piece becomes half of the original moment.

b) The magnetic length gets halved and hence the magnetic moment of each piece becomes half of the original moment.

5. What is the magnetic induction at the mid-point of the straight line joining the two poles of a horse shoe magnet separated by a distance 'd'? (The pole strength of each pole is 'm')

Ans: Magnetic induction $B = \frac{\mu_0}{4\pi}\frac{8m}{d^2}$, towards the S-pole and away from N-pole.