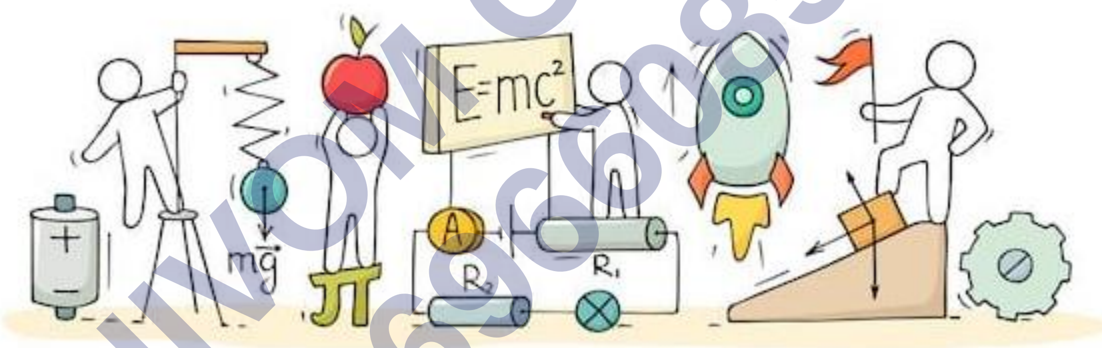
# PHYSICS

## CHAPTER 5: MAGNETISM AND MATTER

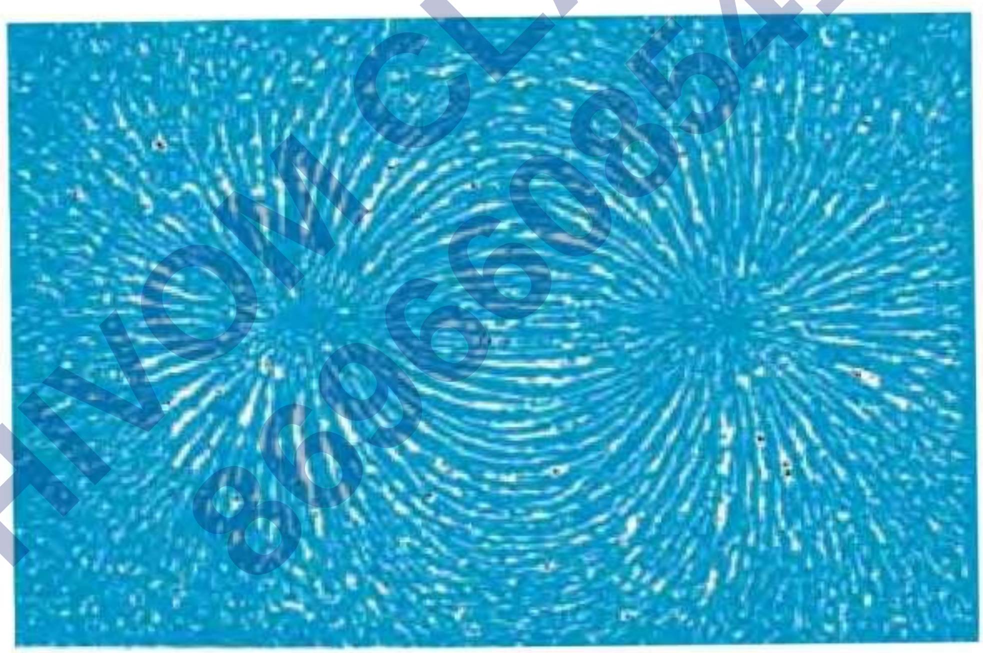


# MAGNETISM AND MATTER

## Bar Magnet:

When iron filings are sprinkled on a sheet of glass placed over a short bar magnet, a particular pattern is formed and following conclusions are drawn

- The bar magnet has poles similar to the positive and negative charge of an electric dipole.
- One pole is designated as north pole and other as south pole.
- When suspended freely, these poles point approximately towards the geographic north and south poles.
- Like poles repel each other and unlike poles attract each other.
- The poles of a magnet can never be separated.



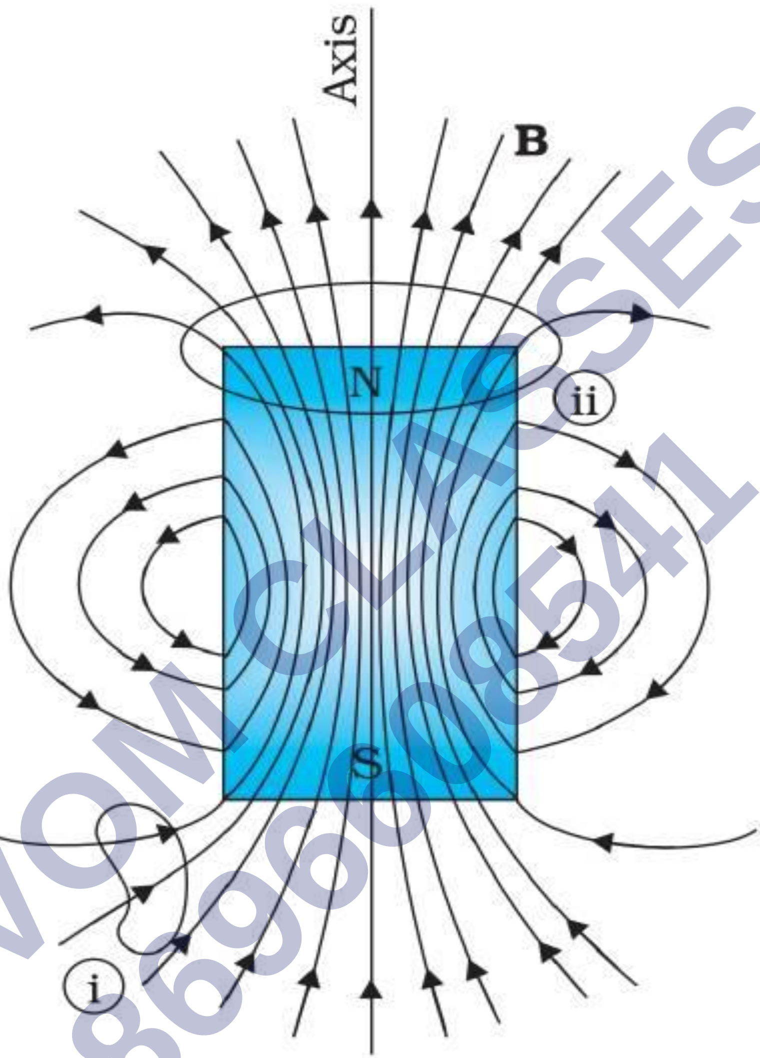


## Magnetic Field Lines:

- Magnetic field line is an imaginary curve, the tangent to which at any point gives direction of magnetic field B at that point.
- The magnetic field lines of a magnet form close-continuous loop.
- Outside the body of magnet, the direction of magnetic field lines are from north pole to south pole.
- No two magnetic field lines can intersect each other. This is because at the point

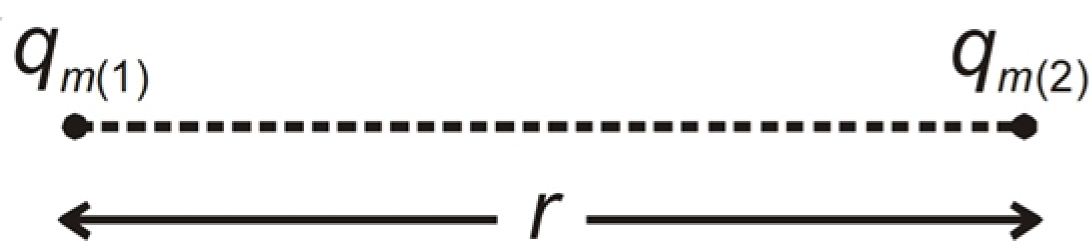
of intersection, we can draw two tangents. This would mean two directions of magnetic field at the same point, which is not possible.

- Larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.






## Coulomb's Law of Magnetism:




Let pole strength of a monopole be $q_m$, then magnetic force between two isolated poles kept at separation r is.

$$F \propto \frac{q_m(1) \times q_m(2)}{r^2}$$

$$F = \frac{\mu_0}{4\pi}\frac{q_m(1) \times q_m(2)}{r^2}$$

This force will be attractive if one pole is North and other is South and force will be repulsive if both poles are of same type (i.e., North-North or South-South).

## Magnetic Field due to a Monopole:

Magnetic field due to monopole at a point is equal to magnetic force experienced by a unit pole strength if kept at that point.

$$B = \frac{\mu_0}{4\pi}\frac{m}{r^2}$$

It is away from pole if it is N-pole and it is towards pole if it is S-pole.

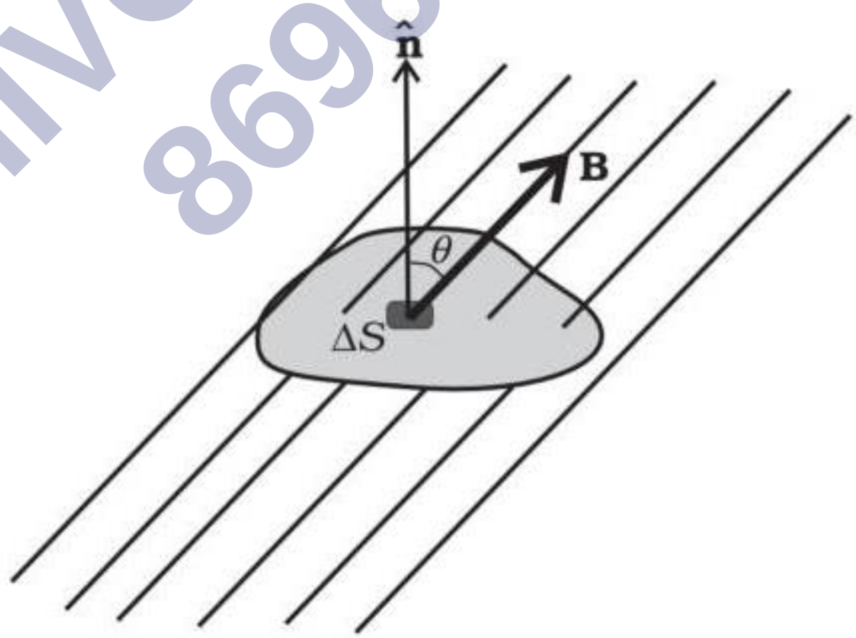
## Magnetic Dipole Moment of a Bar Magnet:

It is equal to the product of any one pole strength and separation between two poles.

$$M = m \times 2l$$

It is directed from South-pole to north-pole.

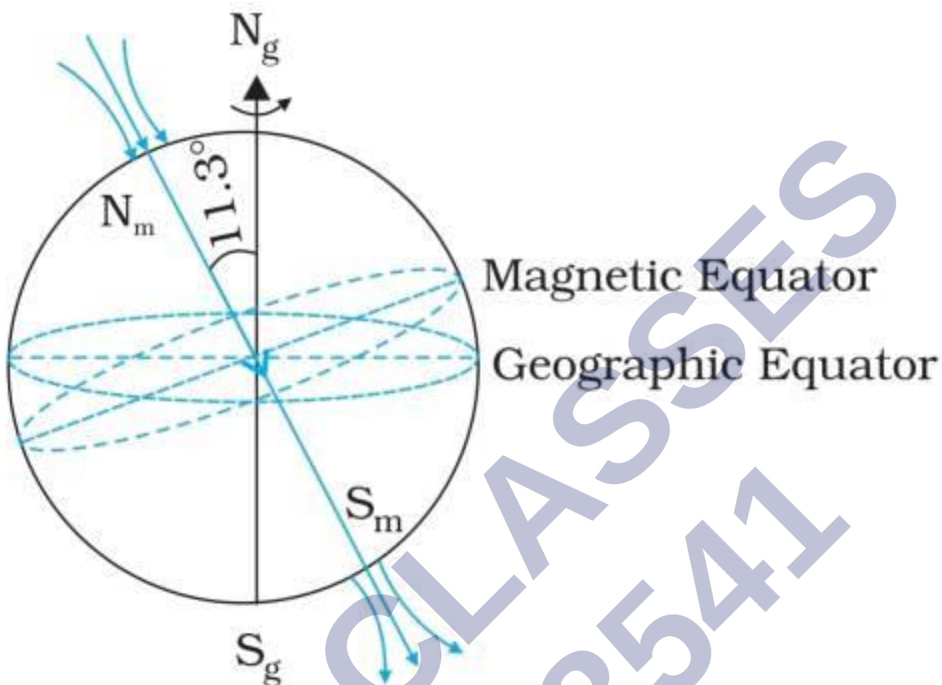
## Gauss's Law in Magnetism:




This law states that "the surface integral of a magnetic field over a closed surface is zero i.e., the net magnetic flux through any closed surface is always zero".

$$\oint \vec{B}.\vec{ds} = 0$$

## Earth's Magnetism:






1. The earth's magnetism was assumed to arise from a very large bar magnet placed deep inside earth along its rotational axis but main argument against theory is that the interior of earth is too hot to maintain any magnetism.
2. The pattern of earth's magnetic field varies with position as well as time. This is most affected by solar wind.
3. The magnetic field lines of earth appear same as a magnetic dipole located at the center of the earth.
4. The pole near the geographic north pole is called the north magnetic pole and the pole near the geographic south pole is called the south magnetic pole.
5. **Geographic meridian:** It is a vertical plane passing through the geographic north-south direction. It contains the longitude circle and axis of rotation of the earth.
6. **Magnetic meridian:** It is a vertical plane passing through N-S line of freely suspended magnet.

## Magnetic Declination:

It is angle between the true geographic north-south direction and the north south line shown by a compass needle at a place. Its value is more at higher latitude and smaller near equator. The declination in India is small.

## Magnetic Inclination or Dip:

It is angle between axis of needle, (in magnetic meridian) which is free to move about a horizontal axis and horizontal. Thus, dip is an angle that total magnetic field of earth Be makes with the surface of the earth. Angle of dip is maximum δ = 90º at poles. It is zero at magnetic equator.

## Classification of Magnetic Materials:

**Magnetic materials are broadly classified as:**

**Diamagnetic:** Diamagnetism is a fundamental property of all matter, although it is usually very weak. It is due to the non-cooperative behavior of orbiting electrons when exposed to an applied magnetic field.

**Paramagnetic:** This class of materials, some of the atoms or ions in the material have a net magnetic moment due to unpaired electrons in partially filled orbitals.

**Ferromagnetic:** When you think of magnetic materials, you probably think of iron, nickel, or magnetite. Unlike paramagnetic materials, the atomic moments in these materials exhibit very strong interactions.

## Curie's Law:

Magnetic susceptibility of paramagnetic substance is inversely proportional to absolute temperature T.

$$x_m \propto \frac{1}{T}$$

$$x_m = \frac{C}{T}$$

The constant C is called Curie's constant.

## Curie-Weiss law:

At temperature above the Curie temperature, a ferromagnetic substance becomes an ordinary paramagnetic substance whose magnetic susceptibility obeys the Curie-Weiss law according to which

$$x_m = \frac{C}{T - T_c}$$

## Hard and Soft Magnets:

**Hard Magnets:**

The ferromagnetic material which retains magnetization for a long period of time are called hard magnetic material or hard ferromagnets. Some hard magnetic materials are Alnico (an alloy of iron, aluminium, nickel, cobalt and copper) and naturally occurring lodestone.

**Soft Magnets:**

The ferromagnetic material which retains magnetization as long as the external field persists are called soft magnetic materials or soft ferromagnets. Soft ferromagnets is soft iron. Such material is used for making electromagnets.

## Permanent Magnets and Electromagnets:

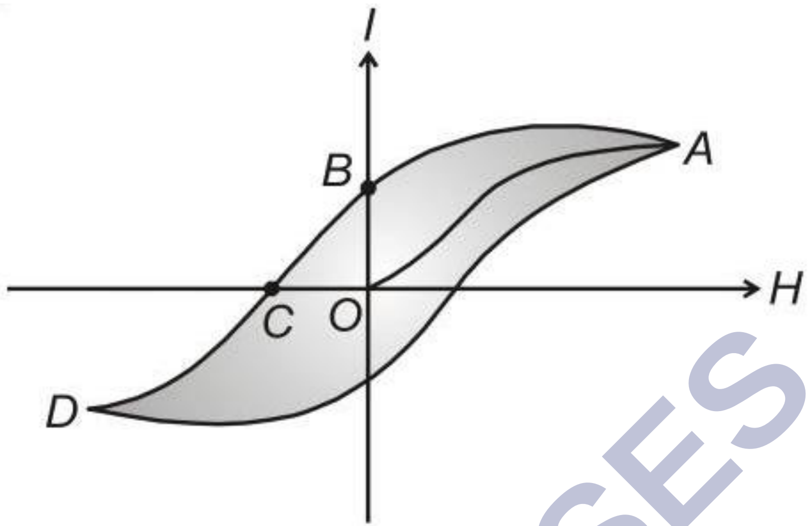
**Permanent Magnets:** The substances which at room temperature retain their magnetization for long period of time are called Permanent magnets. Permanent magnets should have.

- High retentivity
- High coercivity.

As the material in this case is never put to cyclic changes of magnetization, hence hysteresis is immaterial. From the viewpoint of these facts, steel is more suitable for the construction of permanent magnets than soft iron. The fact that the retentivity of iron is little greater than that of steel is outweighed by the much smaller value of its coercivity.

**Electromagnets:** An electromagnet is a temporary strong magnet and is just a solenoid with its winding on a soft iron core which has high permeability and low retentivity.

## Hysteresis:




- When intensity of magnetization (I) of ferromagnetic substances is plotted against magnetic intensity for a complete cycle of magnetization and demagnetization the resulting loop is called hysteresis loop.
- When intensity of magnetizing field (H) is increased, the intensity of magnetization increases, because more and more domains are aligned in the direction of applied field.
- When all domains are aligned, material is magnetically saturated. Beyond this if intensity of magnetizing field (H) is increased, intensity of magnetization (I) does not increase.
- The value of intensity of magnetization (I) left in the material at H = 0, is called retentivity or remanence.
- Now if magnetizing field is applied in reverse direction and its intensity H is increased, material starts de-magnetizing. The value of magnetizing field needed to reduce magnetization to zero is called coercivity (OC).
- As reverse magnetizing field is increased further, the material again becomes saturated. Now, if the magnetizing field is reduced after attaining the reverse saturation, the cycle repeats itself.
- The area enclosed by the loop represents loss of energy during a cycle of magnetization and demagnetization.

## Relation Between Horizontal and Vertical Component:

Squaring and adding equation (1) and (2), we get

$$B_H^2 + B_V^2 = B_e^2\left(\cos^2\delta + \sin^2\delta\right)$$

$$B_e = \sqrt{B_H^2 + B_V^2}$$

Dividing equation (2) by (1)

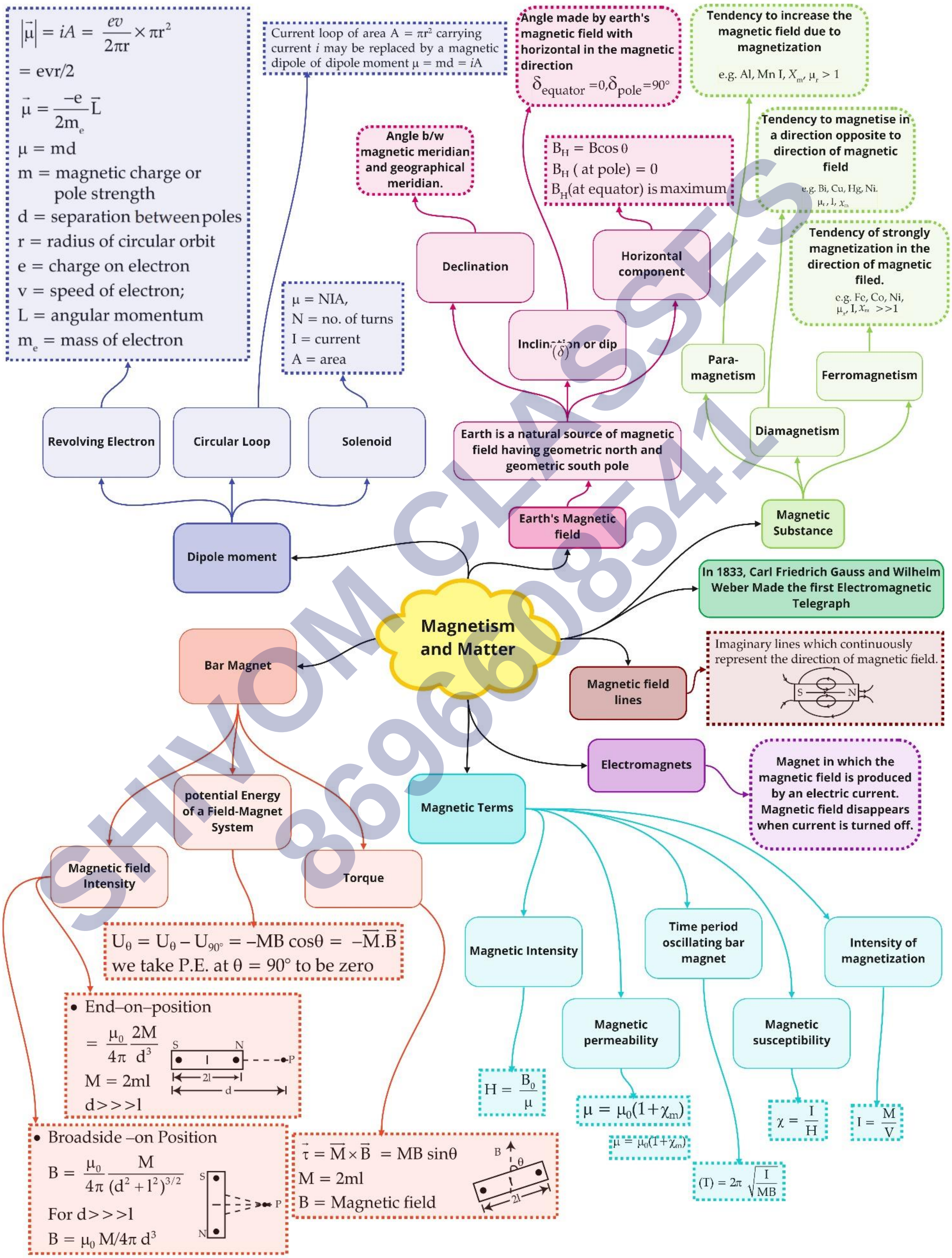
$$\frac{B_V}{B_H} = \tan\delta$$

## Relative Permeability ($\mu_r$):

It is the ratio of permeability of a medium to that of permeability of free space.

$$\mu_r = \frac{\mu}{\mu_0}$$

**Class : 12th Physics**
**Chapter- 5 : Magnetism and Matter**



# Important Questions

## Multiple Choice questions-

1. The earth behaves as a magnet with magnetic field pointing approximately from the geographic

(a) North to South

(b) South to North

(c) East to West

(d) West to East

2. The strength of the earth's magnetic field is

(a) constant everywhere.

(b) zero everywhere.

(c) having very high value.

(d) vary from place to place on the earth's surface.

3. Which of the following is responsible for the earth's magnetic field?

(a) Convective currents in earth's core

(b) Diversive current in earth's core.

(c) Rotational motion of earth.

(d) Translational motion of earth.

4. Which of the following independent quantities is not used to specify the earth's magnetic field?

(a) Magnetic declination (θ).

(b) Magnetic dip (δ).

(c) Horizontal component of earth's field (BH).

(d) Vertical component of earth's field (BV).

5. Let the magnetic field on earth be modelled by that of a point magnetic dipole at the centre of earth. The angle of dip at a point on the geographical equator is

(a) always zero

(b) positive, negative or zero

(c) unbounded

(d) always negative

6. The angle of dip at a certain place where the horizontal and vertical components

of the earth's magnetic field are equal is

(a) 30°

(b) 75°

(c) 60°

(d) 45°

7. The vertical component of earth's magnetic field. at a place is √3 times the horizontal component

the value of angle of dip at this place is

(a) 30°

(b) 45°

(c) 60°

(d) 90°

8. At a given place on earth's surface the horizontal component of earth's magnetic field is 2 × 103-5 T and resultant magnetic field is 4 × 103-5 T. The angle of dip at this place is

(a) 30°

(b) 60°

(c) 90°

(d) 45°

9. Which of the following property shows the property of ferromagnetic substances?

(a) The ferromagnetic property depends on tem-perature. '

(b) The ferromagnetic property does not depend on temperature.

(c) At high enough temperature ferromagnet becomes a diamagnet.

(d) At low temperature ferromagnet becomes a paramagnet.

10. The primary origin of magnetism lies in

(a) atomic current and intrinsic spin of electrons.

(b) polar and non-polar nature of molecules.

(c) pauli exclusion principle.

(d) electronegative nature of materials.

9. The magnetic moment of a current I carrying circular coil of radius r and number of turns N varies as

(a) $\frac{1}{r_2}$

(b) $\frac{1}{r}$

(c) r

(d) $r^2$

10. A short bar magnet has a magnetic moment of 0. 65 J $T^{-1}$, then the magnitude and direction of the magnetic field produced by the magnet at a distance 8 cm from the center of magnet on the axis is

(a) $2.5 \times 10^{-4}$ T, along NS direction

(b) $2.5 \times 10^{-4}$ T along SN direction

(c) $4.5 \times 10^{-4}$ T, along NS direction

(d) $4.5 \times 10^{-4}$ T, along SN direction

## Very Short:

1. A small magnetic needle pivoted at the center is free to rotate In a magnetic meridian. At what place will the needle be vertical?

2. What is the angle of dip at a place where the horizontal and vertical components of the earth's magnetic field are equal?

3. How does the intensity of a paramagnetic sample vary with temperature?

4. What should be the orientation of a magnetic dipole in a uniform magnetic field so that its potential energy is maximum?

5. What is the value of angle of dip at a place on the surface of the earth where the ratio of the vertical component to the horizontal component of the earth's magnetic field is $\frac{1}{\sqrt{3}}$?

6. Where on the surface of the earth is the angle of dip 90°? (CBSE Al 2011)

7. Where on the surface of the earth is the angle dip zero? (CBSE Al 2011)

8. What are permanent magnets? Give one example. (CBSE Delhi 2013)

9. At a place, the horizontal component of the earth's magnetic field is B, and the angle of dip is 60°. What is the value of the horizontal component of the earth's magnetic field at the equator? (CBSE Delhi 2017)

10. Is the steady electric current the only source of the magnetic field? Justify your answer. (CBSE Delhi 2013C)

## Short Questions:

1.

(a) Define the term magnetic susceptibility and write its relation in terms of relative magnetic permeability.

(b) Two magnetic materials A and B have relative magnetic permeabilities of 0. 96 and 500. Identify the magnetic materials A and B. (CBSE Al, Delhi 2018C)

2. A magnetic needle free to rotate in a vertical position orient itself with its axis vertical at a certain place on the earth. What are the values of?

(a) the angle of dip and

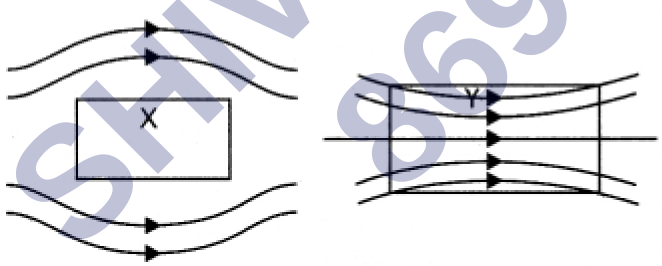
(b) the horizontal component of the earth's magnetic field at this place? Where will this place be on the earth?

3. Out of the two magnetic materials 'A' has relative permeability slightly greater than unity while 'B' has less than unity. Identify the nature of the material's 'A' and 'B'. Will their susceptibilities be positive or negative? (CBSE Delhi 2014)

4. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its northern tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place. (CBSE Delhi 2011)

5. The susceptibility of a magnetic material is -0.085. Identify the type of magnetic material. A specimen of this material is kept in a non-uniform magnetic field. Draw the modified field pattern.

6. A uniform magnetic field gets modified as shown below when two specimens X and Y are placed in it.




(a) Identify the two specimens X and Y.

(b) State the reason for the behavior of the field lines in X and Y.

7. Three identical specimens of magnetic materials nickel, antimony, and aluminum are kept in a non-uniform magnetic field. Draw the modification in the field lines in each case. Justify your answer.

8. Define neutral point. Draw lines of force when two identical magnets are placed at a finite distance apart with their N-poles facing each other. Locate the neutral points.

## Long Questions:

1. Write the expression for the magnetic dipole moment for a closed current loop. Give its SI unit. Derive an expression for the torque experienced by a magnetic dipole in a uniform magnetic field.

2.

(a) State Gauss's law for magnetism. Explain Its significance.

(b) Write the four Important properties of the magnetic field lines due to a bar magnet. (CBSE Delhi 2019).

## Assertion and Reason Questions-

**1.** Two statements are given-one labelled Assertion(A) and the other labelled Reason (R). Select the correct answer to these questions from the codes(a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is NOT the correct explanation of A.

c) A is true but R is false.

d) A is false and R is also false.

**Assertion (A):** There is only one neutral points on a horizontal board when a magnet is held vertically on the board.

**Reason (R):** At the neutral point the net magnetic field due to the magnetic and magnetic field of the earth is zero.

**2.** Two statements are given-one labelled Assertion(A) and the other labelled Reason (R). Select the correct answer to these questions from the codes(a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is NOT the correct explanation of A.

c) A is true but R is false.

d) A is false and R is also false.

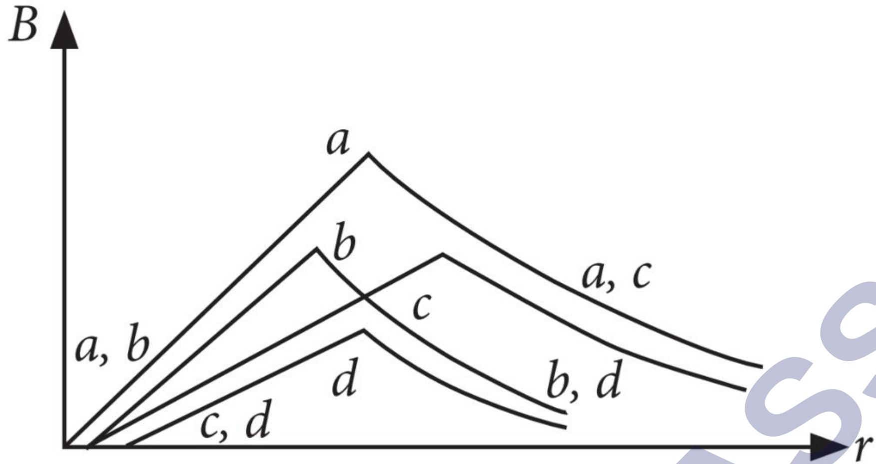
**Assertion (A):** The true geographic north direction is found by using a compass needle.

**Reason (R):** The magnetic meridian of the earth is along the axis of rotation of the earth.

## Case Study Questions-

**1.** The field of a hollow wire with constant current is homageneous.

Curves in the graph shown give, as functions of radius distance r, the magnitude B of the magnetic field inside and outside four long wires a, b, c and d, carrying currents that are uniformly distributed across the cross sections of the wires. Overlapping portions of the plots are indicated by double labels.




(i) Which wire has the greatest magnitude of the magnetic field on the surface?

a) a

b) b

c) c

d) d

(ii) The current density in a wire a is:

a) Greater than in wire c.

b) Less than in wire c.

c) Equal to that in wire c.

d) Not comparable to that of in wire c due to lack of information.

(iii) Which wire has the greatest radius?

a) a

b) b

c) c

d) d

(iv) A direct current I flows along the length of an infinitely long straight thin walled pipe, then the magnetic field is:

a) Uniform throughout the pipe but not zero.

b) Zero only along the axis of the pipe.

c) Zero at any point inside the pipe.

d) Maximum at the centre and minimum at the edges.

(v) In a coaxial, straight cable, the central conductor and the outer conductor carry equal currents in opposite direction. The magnetic field is zero.

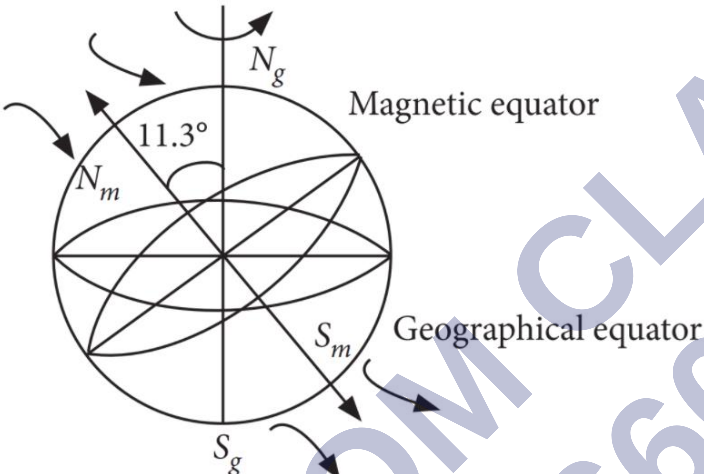
a) Outside the cable.

b) Inside the inner conductor.

c) Inside the outer conductor.

d) In between the two conductor.

**2.** The magnetic field lines of the earth resemble that of a hypothetical magnetic dipole located at the centre of the earth. The axis of the dipole is presently tilted by approximately 11.3° with respect to the axis of rotation of the earth.




The pole near the geographic North pole of the earth is called the North magnetic pole and the pole near the geographic South pole is called South magnetic pole.

(i) Magnetization of a sample is:

a) $10^5$T

b) $10^{-6}$T

c) $10^{-5}$T

d) $10^8$T

(ii) A bar magnet is placed North-South with its North-pole due North. The points of zero magnetic field will be in which direction from centre of magnet?

a) North-South

b) East- West

c) North-East and South-West

d) None of these.

(iii) The value of angle of dip is zero at the magnetic equator because on it:

a) V and Hare equal.

b) The values of V and H zero.

c) The value of V is zero.

d) The value of His zero.

(iv) The angle of dip at a certain place, where the horizontal and vertical components of the earth's magnetic field are equal, is:

a) 30º

b) 90º

c) 60º

d) 45º

(v) At a place, angle of dip is 300. If horizontal component of earth's magnetic field is H, then the total intensity of magnetic field will be.

a. $\frac{H}{2}$

b. $\frac{2H}{\sqrt{3}}$

c. $H\sqrt{\frac{3}{2}}$

d. $2H$

## ✓ Answer Key:

## Multiple Choice Answers-

1. Answer: b
2. Answer: d
3. Answer: a
4. Answer: d
5. Answer: b
6. Answer: d
7. Answer: c
8. Answer: b
9. Answer: a
10. Answer: a

## Very Short Answers:

1. Answer: At the potes
2. Answer: 450
3. Answer: it decreases with the increase in temperature.
4. Answer: It should be anti-parallel to the applied magnetic field.
5. Answer:

   Using the expression $\tan \delta = \frac{B_V}{B_H} = \frac{1}{\sqrt{3}}$

   Therefore, δ = 30°
6. Answer: Poles.
7. Answer: Magnetic equator
8. Answer: It is an arrangement that has a permanent dipole moment, e.g. bar magnet.
9. Answer: Zero.
10. Answer: No, the magnetic field is also produced by alternating current.

## Short Questions Answers:

1. Answer:

   (a) It refers to the ease with which a substance can be magnetized. It is defined as the ratio of the intensity of magnetization to the magnetizing field. The required relation is $\mu_r = 1 + \chi_m$

   (b)

   A: Paramagnetic,

   B: Ferromagnetic
2. Answer: The angle of dip is 90° and the horizontal component of the earth's magnetic field is zero. This place is the magnetic pole of the earth.
3. Answer:
   - 'A' is paramagnetic and 'B' is diamagnetic.
   - 'A' will have positive susceptibility while
   - 'B' will have negative susceptibility.
4. Answer:

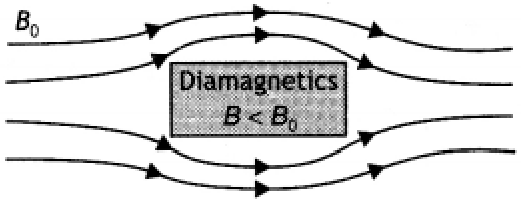
   Given δ = 30°, BH = 0.4 G, B = ?

   Using the expression

BH = Bcos δ we have

$$B = \frac{B_H}{\cos\delta} = \frac{0.4}{\cos 30^\circ} = \frac{0.4}{\sqrt{3}/2} = \frac{0.8}{\sqrt{3}}\ G$$

5. Answer: The material is a diamagnetic material as diamagnetic materials have negative susceptibility. The modified field pattern is as shown below.

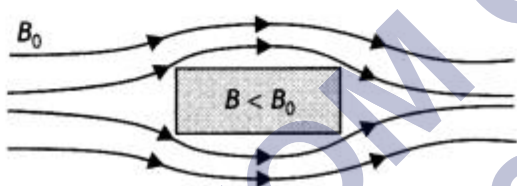



6. Answer:

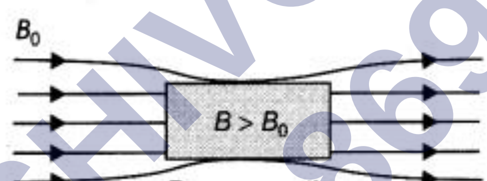
(a) X is a diamagnetic substance and Y is a paramagnetic substance.

(b) This is because the permeability of a diamagnetic substance is less than one and that of a paramagnetic substance is greater than one.

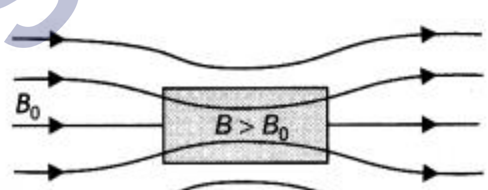
7. Answer: Nickel is ferromagnetic, antimony is diamagnetic, and aluminium is paramagnetic. Therefore, they will show the behaviour as shown in the following figures.



Diamagnetics

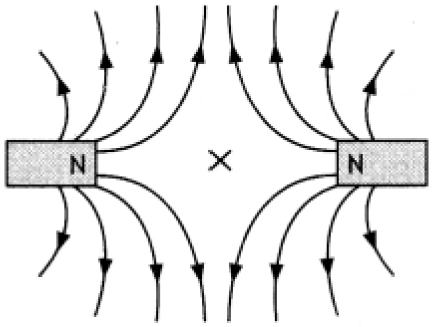


Paramagnetics



Ferromagnetic

8. Answer: It is a point near a magnet where the magnetic field of the earth is completely balanced by the magnetic field of the magnet. The figure is as shown below.




The cross indicates the neutral point.

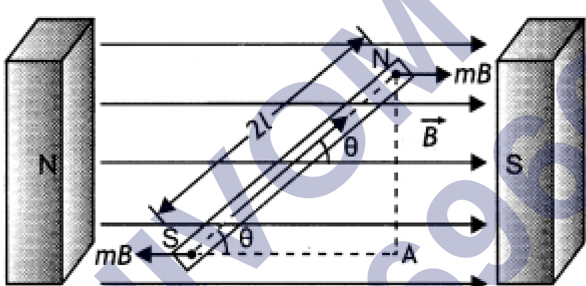
## Long Questions Answers:

1. Answer:

The required expression is m = nIA.

It is measured in A $m^2$.

Consider a uniform magnetic field of strength B. Let a magnetic dipole be suspended in it such that its axis makes an angle 6 with the field as shown in the figure below. If 'm' is the strength of each pole, the two poles experience two equal and opposite force 'B' each. These forces constitute a couple that tends to rotate the dipole. Suppose the couple exerts a torque of magnitude τ.




Then

τ = either force × arm of the couple

= mB × AN = mB × 2 L sin θ

or

Since m × 2L is the magnetic dipole moment of the magnet.

Therefore τ = MB sin θ in vector form

we have $\vec{\tau} = \vec{M} \times \vec{B}$

2. Answer:

(a) Gauss's Law for magnetism states that "The total flux of the magnetic field, through any closed surface, is always

zero, i.e. $\oint \vec{B}.\overrightarrow{dL} = 0$

This law implies that magnetic monopoles do not exist" or magnetic field lines form closed loops.

(b) Four properties of magnetic field lines are as follows:

- Magnetic field lines always form continuous closed loops.
- The tangent to the magnetic field line at a given point represents the direction of the net magnetic field at that point.
- The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field.
- Magnetic field lines do not intersect.

## Assertion and Reason Answers-

**1.** (b) Both A and Rare true but R is NOT the correct explanation of A.

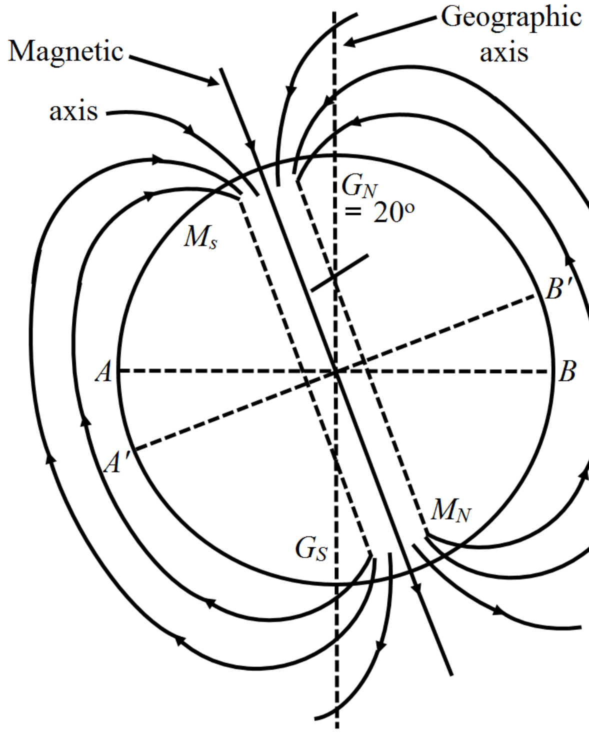
**Explanation:**

There will be only one neutral point on the horizontal board. This is because field of earth magnetic field is from south to north; and the field of pole on the board is radially outwards. At any point towards south of magnetic pole, field of earth and field of pole will cancel out to give a neutral point.

**2.** (d) A is false and R is also false.

**Explanation:**

From the compass we are able to know the poles. The north of compass points towards the magnetic south pole.




If we know the magnetic declination at that particular place (which is angle between geographic meridian and magnetic meridian) we can easily find out the true geographic north-south direction. Imaginary lines drawn along the earth's surface in the direction of the horizontal component of the magnetic field of the earth at all points passing through the north and south magnetic poles. This is similar to the longitudes of the earth, which pass through the geographic north and south poles.

## Case Study Answers-

**1. Answer :**

(i) (a) a

**Explanation:**

It can be seen that slop of curve for wire a is greater th an wire c.

(ii) (b) Less than in wire c.

**Explanation:**

Inside the wire

$$B(r) = \frac{\mu_0}{2\pi}\frac{I}{R^2}r \Rightarrow \frac{dB}{dr} = \frac{\mu_0}{dr} = \frac{I}{R^2}r$$

$$\text{i.e. slope} \propto \frac{I}{\pi R^2} \propto \text{Current density}$$

(iii) (c) c

**Explanation:**

Wire c has the greatest radius.

(iv) (c) Zero at any point inside the pipe.

(v) (a) Outside the cable.

**2. Answer :**

(i) (c) $10^{-5}$T

(ii) (b) East- West

(iii) (c) The value of V is zero.

**Explanation:**

At equator vertical component of magnetic fields is zero.

(iv) (d) 45º

**Explanation:**

Given, $\mathrm{V} = \mathrm{H}$

$\therefore \tan \delta = \frac{\mathrm{V}}{\mathrm{H}} = 1$ or $\delta = 45^{\circ}$

(v) (b) $\frac{2\mathrm{H}}{\sqrt{3}}$

**Explanation:**

Given: Biot-Savart law can be expressed alternatively as Ampere circuital law.