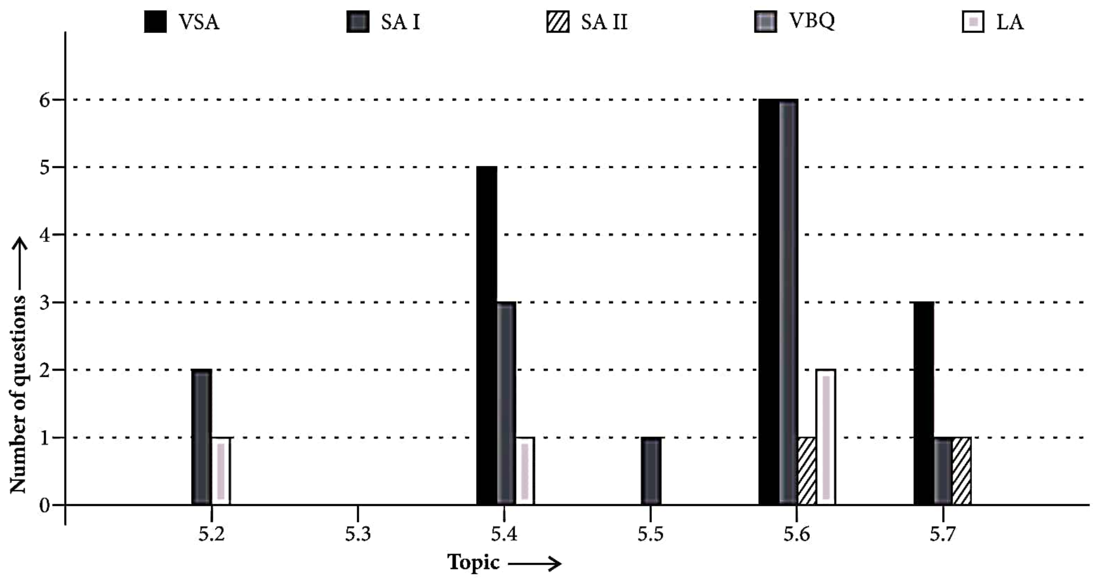
05 Magnetism and Matter

Topicwise Analysis of Last 10 Years' CBSE Board Questions



- Maximum weightage is of *Magnetic Properties of Materials.*
- Maximum VSA and SAI type questions were asked from *Magnetic Properties of Materials.*
- No VBQ type questions were asked till now.

QUICK RECAP

Natural magnet and artificial magnet

- **Natural magnet :** A natural magnet is an ore of iron (Fe_2O_4) which
  - attracts small pieces of iron, cobalt and nickel towards it
  - when suspended freely, comes to rest along north-south direction.
- **Artificial magnet :** Magnet which is prepared artifically is known as artifical magnets. e.g. a horseshoe magnet, a bar magnet, magnetic needle etc.

Properties of magnets

- **Attractive property :** When a magnet is dipped into iron filings, it is found that the concentration of iron filings, *i.e.*, attracting power of the magnet is maximum at two points near the ends and minimum at the centre. The places in a magnet where its attracting power is maximum are known as poles while the place of minimum attracting power is known as the neutral region.
- **Directive property :** When a magnet is suspended, its length becomes parallel to *N-S* direction. The pole at the end pointing north is known as north pole while the other pointing south is known as south pole.
- Magnetic poles always exist in pairs *i.e.*, an isolated magnetic pole does not exist.
- Like poles repel each other and unlike poles attract each other.

Magnetic Field : The space around a magnet within which its influence can be experienced is known as its magnetic field. The line joining the two poles of a magnet is known as magnetic axis.

Magnetic dipole : A magnetic dipole consists of two unlike poles of equal strength and separated by a small distance, *e.g.* a bar magnet, a compass needle etc. are magnetic dipoles.

- **Magnetic dipole moment :** It is defined as the product of strength of either pole (m) and the magnetic length ($2\vec{l}$) of the magnet. It is denoted by $\vec{M}$.

  Magnetic dipole moment = strength of either pole × magnetic length

  $$\vec{M} = m(2\vec{l})$$

  - Magnetic dipole moment is a vector quantity and it is directed from south to north pole of the magnet.
  - The SI unit of magnetic dipole moment is A m^2.
  - If a magnet of moment M and pole strength m is cut into two equal parts along its length, then pole strength of each part is $m/2$ and the magnetic moment of each part is $M/2$.
  - If a magnet of magnetic moment M and pole strength m is cut into two equal halves along perpendicular to its length, the pole strength of each part is m and magnetic moment of each part is $M/2$.

Magnetic field at a point due to magnetic dipole

- The magnetic field due to a bar magnet at any point on the axial line (end on position) is

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

  where r = distance between the centre of the magnet and the given point on the axial line, $2l$ = magnetic length of the magnet and M = magnetic moment of the magnet.

  For short magnet $l^2 << r^2$

  $$B_{\text{axial}} = \frac{\mu_0 2M}{4\pi r^3}$$

  The direction of B_{axial} is along S-N.
- The magnetic field due to a bar magnet at any point on the equatorial line (broad-side on position) of the bar magnet is

  $$B_{\text{equatorial}} = \frac{\mu_0 M}{4\pi(r^2 + l^2)^{3/2}}$$

  For short magnet

  $$B_{\text{equatorial}} = \frac{\mu_0 M}{4\pi r^3}$$

  The direction of $B_{\text{equatorial}}$ is parallel to N-S.

Torque on a magnetic dipole placed in a uniform magnetic field : When a magnetic dipole of dipole moment $\vec{M}$ is placed in a uniform magnetic field $\vec{B}$, it will experience a torque and is given by

$$\vec{\tau} = \vec{M} \times \vec{B} \quad \text{or} \quad \tau = MB\sin\theta$$

where θ is the angle between $\vec{M}$ and $\vec{B}$.

- Torque acting on a dipole is maximum ($\tau_{max} = MB$) when dipole is perpendicular to the field and minimum ($\tau = 0$) when dipole is parallel or antiparallel to the field.
- When a dipole is placed in a uniform magnetic field, it will experience only torque and the net force on the dipole is zero while when it is placed in a non uniform magnetic field, it will experience both torque and net force.

Work done in rotating the magnetic dipole in a uniform magnetic field : Work done in rotating the magnetic dipole from θ_1 to θ_2 with respect to uniform magnetic field is

$$W = \int_{\theta_1}^{\theta_2} MB \sin\theta \, d\theta = -MB(\cos\theta_2 - \cos\theta_1)$$

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

- If the dipole is rotated from field direction *i.e.*, $\theta_1 = 0°$ to position θ *i.e.*, $\theta_2 = \theta$
$W = MB(1 - \cos\theta)$.

Potential energy of a magnetic dipole : Potential energy of a magnetic dipole in a uniform magnetic field is

$$U = -\vec{M}\cdot\vec{B} = -MB\cos\theta$$

- The potential energy of the dipole will be minimum (= – MB) when $\theta = 0°$, *i.e.*, the dipole is parallel to the field, and maximum (= MB) when $\theta = 180°$, *i.e.*, the dipole is antiparallel to the field.

Gauss's law for magnetism : Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero.

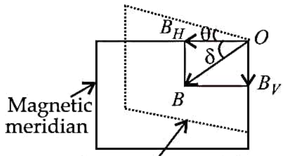
$$\phi = \sum_{\substack{\text{all area}\\ \text{elements}}} \vec{B}\cdot\Delta\vec{S} = 0$$

This law establishes that isolated magnetic poles do not exist.

Elements of the earth's magnetic field

- **Magnetic declination :** The vertical plane passing through the geographical north pole and south pole at given place is known as the geographical meridian of that place. And a vertical plane passing through the axis of a freely suspended or pivoted magnet is known as magnetic meridian. Magnetic declination at a place is defined as the angle between the geographic meridian and magnetic meridian.
- **Magnetic dip or inclination :** Magnetic dip at a place is defined as the angle made by the earth's magnetic field with the horizontal in the magnetic meridian. It is denoted by δ.
- **Horizontal component :** It is the component of earth's magnetic field along the horizontal direction in the magnetic meridian. It is denoted by B_H.
  - If B is intensity of earth's total magnetic field, then the horizontal component of earth's magnetic field is given by
  $B_H = B\cos\delta$
  - The Earth always has a horizontal component except at the poles.
- The vertical component of earth's magnetic field, $B_V = B\sin\delta$

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



  - The Earth always has a vertical component except at equator.
  - In a vertical plane at an angle θ to magnetic meridian
  $B'_H = B_H\cos\theta$ and $B'_V = B_V$

$$\therefore \quad \tan\delta' = \frac{B'_V}{B'_H} = \frac{B_V}{B_H\cos\theta} = \frac{\tan\delta}{\cos\theta}$$

$$\tan\delta' = \frac{\tan\delta}{\cos\theta}$$

- If at a given place δ_1 and δ_2 are angles of dip in two arbitrary vertical planes which are perpendicular to each other, the true angle of dip δ is given by
$\cot^2\delta = \cot^2\delta_1 + \cot^2\delta_2$
- Angle of dip δ at a place is related to its magnetic latitude λ through the relation
$\tan\delta = 2\tan\lambda$

Magnetic intensity : When a magnetic material is placed in a magnetic field, it becomes magnetised. The capability of the magnetic field to magnetise a material is expressed by means of a magnetic vector $\vec{H}$, called the magnetic intensity of the field. The relation between magnetic induction B and magnetising field H is

$$B = \mu H$$

where μ is the permeability of medium.

- It is a vector quantity and its SI unit is A m^{-1}.

Intensity of magnetisation : It is defined as the magnetic moment per unit volume.

$$I = \frac{\text{Magnetic moment}}{\text{Volume}} = \frac{M}{V}$$

If A = uniform area of cross-section of the magnetised specimen (a rectangular bar)

$2l$ = magnetic length of the specimen

m = strength of each pole of the specimen, then

$$I = \frac{m \times 2l}{A \times 2l} = \frac{m}{A}$$

- The intensity of magnetisation is a vector quantity and its SI unit is Am^{-1}. Its dimensional formula is $[M^0L^{-1}T^0A]$.

Magnetic susceptibility : It is defined as the ratio of the intensity of magnetisation (I) to the magnetising field (H).

$$\chi_m = \frac{I}{H}$$

- It is a scalar quantity with no units and dimensions. Physically, it represents the ease with which a magnetic material can be magnetised, *i.e.*, large value of χ_m implies that the material is more susceptible to the field and hence can be easily magnetised.

Magnetic permeability : It is defined as the ratio of magnetic induction (B) to the magnetising field (H).

$$\mu = \frac{B}{H}$$

- It is a scalar quantity having unit H m^{-1} and dimensional formula $[MLT^{-2}A^{-2}]$.
- It measures the degree to which a magnetic material can be penetrated by the magnetising field.
- **Relative permeability :** It is defined as ratio of permeability of a medium to that of free space

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

  - It has no units and dimensions.
- **Relationship between relative magnetic permeability and susceptibility**
  - $\mu_r = 1 + \chi_m$

Classification of magnetic materials :

- On the basis of magnetic properties, different materials have been classified into three categories :
- **Diamagnetic substances :** Diamagnetic substances are those in which the individual atoms/molecules/ions do not posses any net magnetic moment of their own.
- **Paramagnetic substances :** Paramagnetic substances are those in which each individual atom/molecule/ion has a net non zero magnetic moment of its own. The magnetic susceptibility of paramagnetic substance depends on the temperature and it varies with temperature according to the given equation, $\chi_m = \frac{C}{T}$

  This is known as Curie law. The constant C is known as Curie's constant.
- **Ferromagnetic substances :** Ferromagnetic substances are those in which each individual atom/molecule/ion has a non zero magnetic moment, as in a paramagnetic substance. At high temperature, ferromagnetic becomes paramagnet. The temperature of transition from ferromagnetic to paramagnetic is known as Curie temperature (T_C). The susceptibility above the Curie temperature *i.e.*, in the paramagnetic phase is given by

$$\chi_m = \frac{C}{T - T_C} \qquad (T > T_C)$$

This is known as Curie Weiss law.

- **Type of ferromagnetic materials :** Ferromagnetic materials are divided into two types :

  Soft magnetic materials : These have low retentivity, low coercivity and small hysteresis loss. These are used for making electromagnets, cores of transformers, motors and generators. Soft iron, mu-metal and stalloy are examples of these materials.

  Hard magnetic materials : These have high retentivity, high coercivity and large hysteresis loss. These are used in making permanent magnets of various kinds of electric meters and loudspeakers. Steel, alnico, alcomax and ticonal are examples of these materials.

The comparison between dia, para and ferromagnetic substances are as shown in the table.

S.No.	Diamagnetic	Paramagnetic	Ferromagnetic
1.	Substances are feebly repelled by the magnet.	Substances are feebly attracted by the magnet.	Substances are strongly attracted by the magnet.
2.	Susceptibility χ_m is small, negative and temperature independent.	χ_m is small, positive and varies inversely with temperature, *i.e.*, $\chi_m \propto (1/T)$.	χ_m is very large, positive and temperature dependent.
3.	Relative permeability μ_r is slightly lesser than unity, *i.e.*, $\mu < \mu_0$	μ_r is slightly greater than unity, *i.e.*, $\mu > \mu_0$.	μ_r is much greater than unity, *i.e.*, $\mu >> \mu_0$.
4.	Atoms do not have any permanent dipole moment.	Atoms have permanent dipole moments which are randomly oriented.	Atoms have permanent dipole moments which are organised in domains.
5.	Bi, Cu, Ag, Hg, Pb, water, hydrogen, He, Ne, etc. are diamagnetic.	Na, K, Mg, Mn, Al, Cr, Sn and liquid oxygen are paramagnetic.	Fe, Co, Ni and their alloys are ferromagnetic.

Hysteresis : Hysteresis is the phenomenon of lagging of magnetic induction (*B*) or intensity of magnetisation (*I*) behind the magnetising field (*H*), when a specimen is taken through a cycle of magnetisation. From the hysteresis loop of material, we can study about retentivity, coercivity etc. of the material. The study of these characteristics enables us to select suitable materials for different purposes.

Permanent magnets and electromagnets :

- Substances which at room temperature retain their ferromagnetic property for a long period of time are known as permanent magnets.
- When a ferromagnetic rod is placed in a solenoid and current is passed through it then the magnetic field of the solenoid magnetises the rod. This produces an electromagnet.

Previous Years' CBSE Board Questions

5.2 The Bar Magnet

SA I (2 marks)

1. Explain the following :
   (i) Why do magnetic lines of force form continuous closed loops?
   (ii) Why are the field lines repelled (expelled) when a diamagnetic material is placed in an external uniform magnetic field? *(Foreign 2011)*
2. A small compass needle of magnetic moment 'M' and moment of inertia 'I' is free to oscillate in a magentic field 'B'. It is slightly disturbed from its equilibrium position and then released. Show that it executes simple harmonic motion. Hence, write the expression for its time period. *(Delhi 2011C)*

LA (5 marks)

3. (a) A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period. *(3/5, Delhi 2013)*

5.4 The Earth's Magnetism

VSA (1 mark)

4. Where on the surface of Earth is the vertical component of Earth's magnetic field zero? *(Delhi 2013C)*
5. The horizontal component of the earth's magnetic field at a place is B and angle of dip is 60°. What is the value of vertical component of earth's magnetic field at equator? *(Delhi 2012)*
6. A magnetic needle, free to rotate in a vertical plane, orients itself vertically at a certain place on the Earth. What are the values of (i) horizontal component of Earth's magnetic field and (ii) angle of dip at this place? *(Foreign 2012)*
7. Where on the surface of Earth is the angle of dip 90°? *(AI 2011)*
8. If the horizontal and vertical components of the Earth's magnetic field are equal at a certain place, what would be the angle of dip at that place? *(AI 2011C)*

SA I (2 marks)

9. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north 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. *(Delhi 2011)*
10. (i) Name the three elements of the Earth's magnetic field.
    (ii) Where on the surface of the Earth is the vertical component of the Earth's magnetic field zero? *(Foreign 2011)*
11. The horizontal component, of the earth's magnetic field, at a place is $\frac{1}{\sqrt{3}}$ times its vertical component there. Find the value of the angle of dip at that place. What is the ratio of the horizontal component to the total magnetic field of the earth at that place? *(AI 2010C)*

LA (5 marks)

12. A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place. *(2/5, Delhi 2013)*

5.5 Magnetisation and Magnetic Intensity

SA I (2 marks)

13. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify? *(Delhi 2008)*

5.6 Magnetic Properties of Materials

VSA (1 mark)

14. The permeability of a magnetic material is 0.9983. Name the type of magnetic materials it represents. *(Delhi 2008)*

15. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field? *(AI 2016)*

16. Depict the behaviour of magnetic field lines in the presence of a diamagnetic material. *(Foreign 2016)*

17. Relative permeability of a material $\mu_r = 0.5$. Identify the nature of the magnetic material and write its relation to magnetic susceptibility. *(Delhi 2014C)*

18. Draw magnetic field lines when a (i) diamagnetic, (ii) paramagnetic substance is placed in an external magnetic field. Which magnetic property distinguishes this behaviour of the field lines due to the two substances? *(Delhi 2010)*

19. What is the characteristic property of a diamagnetic material? *(Foreign 2010)*

SA I (2 marks)

20. If χ stands for the magnetic susceptibility of a given material, identify the class of material for which

(i) $-1 \le \chi < 0$

(ii) $0 < \chi < \varepsilon$ (ε stands for a small positive number) *(AI 2011)*

21. Give two points to distinguish between a paramagnetic and a diamagnetic substance. *(Foreign 2014)*

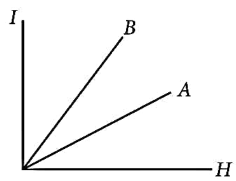
22. Depict the behaviour of magnetic field lines with (i) a diamagnetic material and (ii) a paramagnetic material placed in an external magnetic field. Mention briefly the properties of these materials which explain this distinguishing behaviour. *(AI 2013C)*

23. (a) How does a diamagnetic material behave when it is cooled to very low temperatures?

(b) Why does a paramagnetic sample display greater magnetisation when cooled? Explain. *(Delhi 2012C)*

24. State two characteristic properties distinguishing the behaviour of paramagnetic and diamagnetic materials. *(AI 2012C)*

25. The following figure shows the variation of intensity of magnetisation versus the applied magnetic field intensity, H, for two magnetic materials A and B:



(a) Identify the materials A and B.

(b) Why does the material B, have a larger susceptibility than A, for a given field at constant temperature? *(AI 2008)*

SA II (3 marks)

26. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature. *(AI 2014)*

LA (5 marks)

27. Distinguish between diamagnetic and ferromagnetic materials in terms of (i) susceptibility and (ii) their behaviour in a non-uniform magnetic field. *(2/5, AI 2011C)*

28. Distinguish few magnetic properties of dia-, para- and ferro-magnetic substances in terms of (i) susceptibility, (ii) magnetic permeability and (iii) coercivity. Give one example of each of these materials.

Draw the field lines due to an external magnetic field near a (i) diamagnetic, (ii) paramagnetic substance. *(AI 2007)*

5.7 Permanent Magnets and Electromagnets

VSA (1 mark)

29. What are permanent magnets? Give one example. *(Delhi 2013)*

30. (i) Write two characteristics of a material used for making permanent magnets.

(ii) Why is core of an electromagnet made of ferromagnetic materials? *(Delhi 2010)*

31. Why should the material used for making permanent magnets have high coercivity? *(Delhi 2007)*

SA I (2 marks)

32. (a) How is an electromagnet different from a permanent magnet?

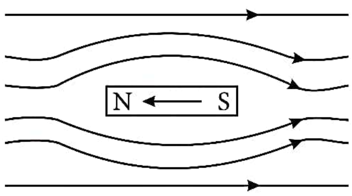
(b) Write two properties of a material which make it suitable for making electromagnets. *(AI 2014C)*

SA II (3 marks)

33. What is the difference between an electromagnet and a permanent magnet? How is an electromagnet designed? State any two factors on which the strength of an electromagnet depends. *(Delhi 2010C)*

Detailed Solutions

1. (i) Magnetic lines of force form continuous closed loops because a magnet is always a dipole and as a result, the net magnetic flux of a magnet is always zero.
(ii) When a diamagnetic substance is placed in an external magnetic field, a feeble magnetism is induced in opposite direction. So, magnetic lines of force are repelled.



2. If a small bar magnet placed in uniform magnetic field $\vec{B}$ in equilibrium, is rotated through a small angle θ, then it experiences a restoring torque, which tends to align it in the direction of magnetic field, given by $\tau_R = -MB\sin\theta$

$$|\tau_R| = I\frac{d^2\theta}{dt^2} = MB\sin\theta \text{ or } \frac{d^2\theta}{dt^2} = \frac{MB}{I}\sin\theta$$

For small angle θ, $\sin\theta \approx \theta$, so this represents SHM. So small bar magnet executes SHM in uniform magnetic field of time period

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{MB}{I}}} \quad \left[\because \omega^2 = \frac{MB}{I}\right]$$

or $$T = 2\pi\sqrt{\frac{I}{MB}}$$

where I is moment of inertia of bar magnet.

3. (a) *Refer to answer 2.*

4. Vertical component of earth's magnetic field is zero at magnetic equator.

5. At equator the value of vertical component of earth's magnetic field is zero.

6. (i) 0, (ii) 90°

7. At North and South poles.

8. Given, $B_V = B_H = 1$

$$\tan\delta = \frac{B_V}{B_H} \Rightarrow \tan\delta = 1$$

$\delta = 45°$.

9. The horizontal component of earth's magnetic field is

$$H = B_E\cos\delta$$

Given, $H = 0.4$ G and $\theta = 60°$

$$\therefore B_E = \frac{0.4}{\cos 60°} = 0.8 \text{ G} \quad \left(\because \cos 60° = \frac{1}{2}\right)$$

10. (i) Elements of earth's magnetic field :
(a) Angle of declination (θ)
(b) Angle of dip (δ)
(c) Horizontal component of earth's magnetic field (B_H)
(ii) At equator.

11. Let the horizontal component of the earth's magnetic field be H_E and vertical component be Z_E

$$\therefore H_E = \frac{1}{\sqrt{3}} Z_E \quad \text{...(given)}$$

$$\therefore \tan\delta = \frac{Z_E}{H_E} = \frac{Z_E}{\frac{1}{\sqrt{3}}Z_E} = \sqrt{3} = \tan 60°$$

$\delta = 60°$

∴ The angle of dip is 60°.
Ratio of the horizontal component to the magnetic field is $\frac{H_E}{B_E} = \cos\delta = \cos 60° = \frac{1}{2} = 1:2$

12. (i) As, horizontal component of earth's magnetic field, $B_H = B\cos\delta$
Putting $\delta = 90°$, $B_H = 0$
(ii) For a compass needle aligned vertically at a certain place, angle of dip, $\delta = 90°$.

13. Magnetic susceptibility : Magnetic susceptibility of a material is defined as the ratio of the intensity of magnetisation (I) induced in the material to the magnetisation force (H) applied on it.
Magnetic susceptibility is represented by

$$\chi_m = \frac{I}{H}$$

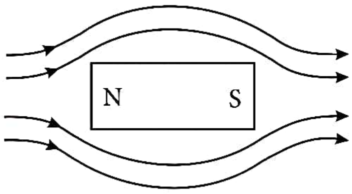
Diamagnetic substances like copper, lead etc. have negative susceptibility.
Paramagnetic substances like aluminium, calcium etc. have positive susceptibility.

Negative susceptibility shows that substance gets magnetised in a direction opposite to the direction of magentising field.

14. Since the value 0.9983 lies between 0 and 1, hence the material is diamagnetic.

15. A diamagnetic specimen would tend to move towards the region of weaker magnetic field while a paramagnetic specimen would tend to move towards the region of stronger magnetic field.

16. Behaviour of magnetic field lines when a diamagnetic substance is placed in an external field.



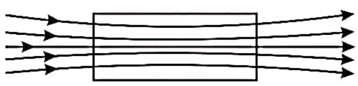
17. The relative permeability is an intrinsic property of a magnetic material. A related quantity is the magnetic susceptibility, denoted by χ_m.

$\mu_r = 1 + \chi_m$ $[\because \mu_r = 0.5]$

Here, $\mu_r < 1$ (χ_m negative), so the material is termed diamagnetic.

18. (i) *Refer to answer 16.*

(ii) Behaviour of magnetic field lines when a paramagnetic substance is placed in an external field.



Magnetic susceptibility distinguishes this behaviour of the field lines due to diamagnetic and paramagnetic substances.

19. Diamagnetic substances : These are the substances in which feeble magnetism is produced in a direction opposite to the applied magnetic field. These substances are repelled by a strong magnet. substances are repelled by a strong magnet. These substances have small negative values of magnetism $\vec{M}$ and susceptibility χ and positive low value of relative permeability μ_r, *i.e.*,

$-1 \leq \chi \leq 0, 0 < \mu_r < 1$

The examples of diamagnetic substances are bismuth, antimony, copper, lead, water, nitrogen (at STP) and sodium chloride.

20. (i) For $-1 \leq \chi < 0$, material is diamagnetic.

(ii) For $0 < \chi < \varepsilon$, material is paramagentic.

21.

Paramagnetic substance	Diamagnetic substance
1. A paramagnetic substance is feebly attracted by a magnet.	**1.** A diamagnetic substance is feebly repelled by a magnet.
2. For a paramagnetic substance, the intensity of magnetisation has a small positive value.	**2.** For a diamagnetic substance, the intensity of magnetisation has a small negative value.

22. *Refer to answer 18.*

Atoms/molecules of a diamagnetic substance contain even number of electrons and these electrons form the pair of opposite spin; while the atoms/molecules of a paramagnetic substance have excess of electrons spinning in the same direction.

23. (a) When a diamagnetic material cooled to very low temperatures, it is unaffected because it is independent of temperature.

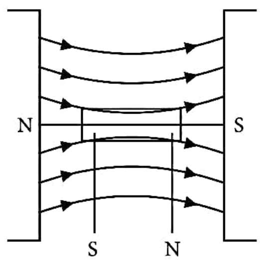
(b) When cooled, the tendency of the thermal agitation to disrupt the alignment of magnetic dipoles decreases in case of paramagnetic materials. Hence, they display greater magnetisations.

24. *Refer to answer 21.*

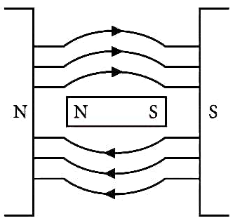
25. (a) Material *A* is diamagnetic. Material *B* is paramagnetic.

(b) Since paramagnetic substance have a tendency to pull in magnetic field lines when placed in a magnetic field, and *B* is a paramagnetic material.

26. (i) The behaviour of magnetic field lines in the presence of a paramagnetic substance is shown:



(ii) The behaviour of magnetic field lines in the presence of a diamagnetic substance is shown :



This distinguishing feature is because of the difference in their relative permeabilities. The relative permeability of the diamagnetic substance is negative; so, the magnetic lines of force do not prefer passing through the substance. The relative permeability of a paramagnetic substance is greater than 1; so, the magnetic lines of force prefer passing through the substance.

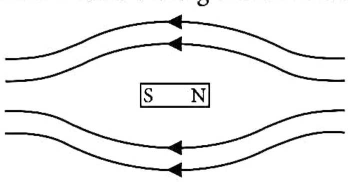
27. (i) Susceptibility for diamagnetic material : It is independent of magnetic field and temperature (except for bismuth at low temperature).
Susceptibility for ferromagnetic material : The susceptibility of ferromagnetic materials decreases steadily with increase in temperature. At the Curie temperature, the ferromagnetic materials become paramagnetic.

(ii) Behaviour in non-uniform magnetic field – Diamagnets are feebly repelled, whereas ferromagnets are strongly attracted by non-uniform field, *i.e.*, diamagnets move in the direction of decreasing field, whereas ferromagnets feel force in the direction of increasing field intensity

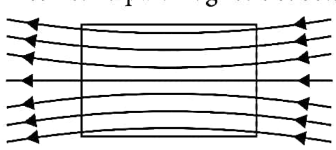
28.

Material	Susceptibility	Magnetic permeability	Coercivity	Example
Diamagnetic	$-1 \le \chi < 0$	$0 \le \mu_r < 1$	High	Gold
Paramagnetic	$0 < \chi < \varepsilon$	$1 < \mu_r < 1 + \varepsilon$	Low	Platinum
Ferromagnetic	$\chi >> 1$	$\mu_r >> 1$	Very low	Cobalt

(i) Field lines near a diamagnetic substance



(ii) Field lines near a paramagnetic substances



29. Permanent magnets are those magnets made of ferromagnetic materials with high retentivity and high coercivity. For example, steel.
Permanent magnets are those magnets made of ferromagnetic materials with high retentivity and high coercivity. For example, steel.

30. (i) The material chosen to make permanent magnets should have

(a) High retentivity so that it produces a strong magnetic field.

(b) High permeability so that the magnet can be magnitised easily.

(ii) The core of electromagnets are made of ferromagnetic materials, which have high permeability and low retentivity. Soft iron is a suitable material for this purpose.

31. The material used for making permanent magnet should have high coercivity so that the magnetisation is not erased by stray magnetic field, temperature fluctuations or minor mechanical damage.

32. (a) An electromagnet is different from a permanent magnet because electromagnets are made of soft iron which is characterised by high retentivity and low coercivity however, permanent magnets are made of steel which is characterised by high retentivity and high coercivity.
(b) Two properties : Soft iron has high retentivity and low coercivity. Electromagnets have these characteristics, so soft iron is preferred for making electromagnets.

33. A permanent magnet is an object made from a material that is magnetized and creates its own persistent magnetic field. An everyday example is a refrigerator magnet used to hold-notes on a refrigerator door.
An electromagnet is a type of magnet whose magnetic field is produced by the flow of electric current. The magnetic field disappears when the current ceases.
Design of electromagnet : An electromagnet is made from a coil of wire wrapped on a soft iron core which acts as a magnet when an electric current passes through it, but stops being a magnet when the current stops.

Following factors affect the strength of electromagnet :

(i) The number of windings in the electromagnet.

(ii) The amount of current supplied.