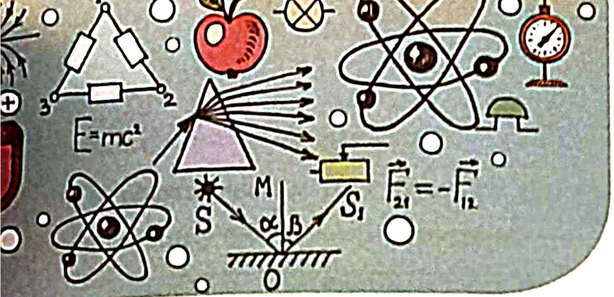


5

MAGNETISM AND MATTER

BASIC CONCEPTS

basic concepts

1. Magnets and Magnetism

A magnet is a material that has both directive and attractive properties.

- It attracts small piece of iron, nickel, cobalt etc. This property of attraction is called magnetism.

2. Basic Properties of Magnets

(*i*) When a magnet is brought near a heap of iron fillings, the ends of magnet show the maximum attraction, These ends where the magnetic attraction is maximum, are called poles of the magnet.

- Every magnet has two poles (North and South pole).

(*ii*) When a magnet is suspended or pivoted freely, it aligns itself in the geographical north-south direction. Hence it shows directive property.

(*iii*) Unlike poles attracts and like poles repel each other.

(*iv*) Magnetic poles always exist in pairs.

(*v*) A magnet induces magnetism in a magnetic substance placed near it. This phenomenon is called magnetic induction.

3. Magnetic Dipole

An arrangement of two equal and opposite poles of bar magnet separated by a small distance is called magnetic dipole.

4. Magnetic Dipole Moment

The magnetic dipole moment is defined as the product of its pole strength and small distance between two poles (*i.e.*, magnetic length)

Mathematically,

$$\vec{m} = q_m \times 2\vec{l}$$

where q_m is the pole strength and $2\vec{l}$ is the magnetic length of the dipole measured in the direction of S to N pole.

SI unit of magntic dipole moment is ampere metre^2 (Am^2).

- The pole strength q_m is also called magnetic charge. Thus we assign magnetic charge $+q_m$ to the north poles and $-q_m$ to the south pole.
- The direction of magnetic dipole moment $\vec{m}$ is from S-pole to N-pole.

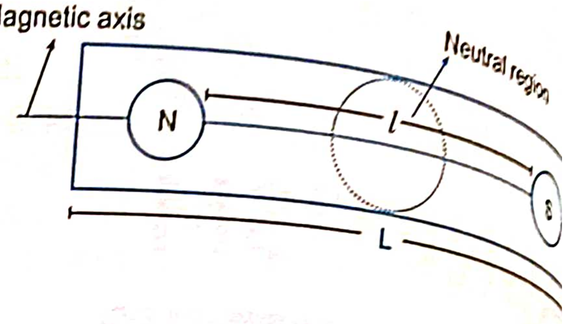
Note: When a magnet of pole strength q_m is cut into two equal parts:

(*a*) along its axis (longitudinally), the pole strength of each half becomes $q_m/2$.

(*b*) perpendicular to its axis (transversely), the pole strength of each half still remains q_m (same).

5. Magnetic length

The distance between the two poles of a magnet is called the magnetic length of the magnet.



- It is slightly less than the geometrical length of the magnet.

i.e., $$\frac{\text{Magnetic length }(l)}{\text{Geometrical length }(L)} = \frac{5}{6} = 0.84$$

6. Magnetic Field Lines

The continuous curve in a magnetic field such that the tangent at any point on it gives the dire of magnetic field at that point.

Properties of Magnetic Field Lines:

(i) Magnetic field lines in a magnetic field is a close and continuous curve such that the tang drawn at any point on it shows the direction of field intensity at that point.

(ii) Magnetic field lines begin normally from north-pole and enter normally on south-pole.

(iii) Magnetic field lines tend to contract longitudinally. For this reason, two unlike poles attract e other.

(iv) Magnetic field lines tend to expand laterally. For this reason, two like poles repel each othe

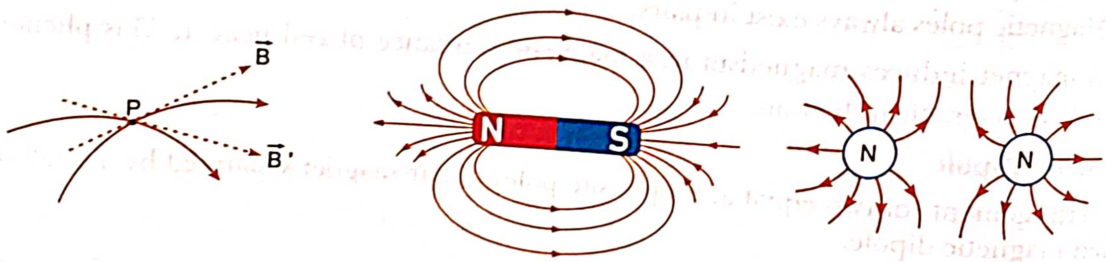
(v) Magnetic field lines within a magnet is directed from south-pole to north-pole. For this reas magnetic field lies within a magnet.

(vi) If magnetic field lines are parallel, then the magnetic field is uniform.

(vii) If magnetic field lines are not parallel, then the magnetic field is not uniform.

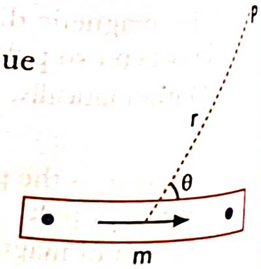
(viii) A stronger magnetic field is represented by more number of magnetic field lines.

(ix) Two magnetic field lines never intersect. If they intersect, then at the point of intersection there will be two tangents on the two magnetic field lines showing two values of magnetic field at a point which is impossible.



7. Magnetic Field Intensity due to a Magnetic Dipole (bar Magnet)

Magnetic field intensity at a general point having polar coordinates (r, θ) due to a short magnet is given by



$$B = \frac{\mu_0}{4\pi}\frac{M}{r^3}\sqrt{1 + 3\cos^2\theta}$$

where M is the magnetic moment of the bar magnet.

Special Cases

(i) At axial point $\theta = 0$,

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

(ii) At equatorial point $\theta = 90°$

$$B_{eql.} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$$

8. **Gauss's law in magnetism**

The net magnetic flux through any closed surface is zero. *i.e.,* $\oint \vec{B}.\vec{ds} = 0$

9. **Important Terms in Magnetism**

(i) **Magnetic permeability (μ):** It is the ability of a material to allow magnetic lines of force to pass through it and is equal to $\mu = \frac{B}{H}$, where B is the magnetic field strength and H is the magnetic field intensity.

The relative magnetic permeability $\mu_r = \frac{B}{B_0} = \frac{\mu}{\mu_0}$

where μ_0 is the permeability of free space and B_0 is the magnetic field strength in vacuum.

(ii) **Intensity of magnetisation ($\vec{M}$):** It is defined as the magnetic moment per unit volume of a magnetised material. Its unit is Am^{-1}.

i.e., $$\vec{M} = \frac{\vec{m}}{V}$$

(iii) **Magnetising field intensity (H):** It is the magnetic field used for magnetisation of a material. If I is the current in the solenoid, then magnetising field intensity $H = nI$, where n = number of turns per metre. Its unit is Am^{-1}.

(iv) **Magnetic susceptibility:** It is defined as the intensity of magnetisation per unit magnetising field, *i.e.,* $\chi_m = \frac{M}{H}$

It measures the ability of a substance to take up magnetisation when placed in a magnetic field.

10. **Classification of Magnetic Materials**

Magnetic materials may be classified into three categories :

(i) **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. These substances have small negative values of susceptibility χ and positive low value of relative permeability μ_r, *i.e.,*

$$-1 \le \chi_m < 0 \quad \text{and} \quad 0 \le \mu_r < 1$$

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

(ii) **Paramagnetic substances:** These are the substances in which feeble magnetism is induced in the same direction as the applied magnetic field. These are feebly attracted by a strong magnet. These substances have small positive values of M and χ and relative permeability μ_r greater than 1, *i.e.,*

$$0 < \chi_m < \varepsilon, \quad 1 < \mu_r < 1 + \varepsilon$$

where ε is a small positive number. The examples of paramagnetic substances are platinum, aluminium, calcium, manganese, oxygen (at STP) and copper chloride.

(iii) **Ferromagnetic substances:** These are the substances in which a strong magnetism is produced in the same direction as the applied magnetic field. These are strongly attracted by a magnet. These substances are characterised by large positive values of M and χ and values of μ_r much greater than 1, *eg.* Iron, cobalt, nickel and alloy like alnico.

i.e., $\chi_m >> 1, \quad \mu_r >> 1$

Distinction between Dia–, Para– and Ferromagnetics

	Property	Diamagnetic	Paramagnetic	Ferromagnetic	Remark
(i)	Magnetic induction B	$B < B_0$	$B > B_0$	$B >> B_0$	B_0 is magnetic induction in free space
(ii)	Intensity of magnetisation $M = \frac{m}{V}$	small and negative	small and positive	very high and positive	m is magnetic moment

(iii)	Magnetic susceptibility $\chi = \frac{M}{H}$	small and negative	small and positive	very high and positive
(iv)	Relative permeability $\mu_r = \frac{\mu}{\mu_0}$	$\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$ (of the order the thousands)

11. Curie Law

It states that the magnetic susceptibility of paramagnetic substances is inversely proportio absolute temperature, *i.e.*,

$$\chi_m \propto \frac{1}{T} \Rightarrow \chi = \frac{C}{T} \text{ where } C \text{ is called Curie constant}$$

12. Curie Temperature

When temperature is increased continuously, the magnetic susceptibility of ferromag substances decrease and at a stage the substance changes to paramagnetic. The temperatu transition at which a ferromagnetic substance changes to paramagnetic is called Curie tempera It is denoted by TC. It is different for different materials. In paramagnetic phase the susceptil is given by

$$\chi_m = \frac{C}{T - T_C}$$

- Diamagnetism is universal properties of all substances but it is weak in para and ferromagn substances and hence difficult to detect.

13. Electromagnets and Permanent Magnets

Electromagnets are made of soft iron which is characterised by low retentivity, low coercivity a high permeability. The hysteresis curve must be narrow. The energy dissipated in magnetisati and demagnetisation is consequently small.

Permanent magnets are made of steel which is characterised by high retentivity, high permeabil and high coercivity.

They can retain their attractive property for a long period of time at room temperatures.

Selected NCERT Textbook Questions

Magnetism

Q. 1. A short bar magnet placed with its axis at 30° with a uniform external magnetic field o 0.25 T experiences a torque of magnitude equal to 4.5 × 10⁻² N–m. What is the magnitude o magnetic moment of the magnet?

Ans. Given, $B = 0.25$ T, $\tau = 4.5 \times 10^{-2}$ N-m, $\theta = 30°$

We have $\tau = mB \sin\theta$

$$\Rightarrow \text{Magnetic moment } m = \frac{\tau}{B\sin\theta} = \frac{4.5\times10^{-2}}{0.25\times\sin 30°} = \frac{4.5\times10^{-2}}{0.25\times0.5} = \mathbf{0.36\ A\text{–}m^2}$$

Q. 2. A short bar magnet of magnetic moment $m = 0.32$ JT⁻¹ is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field, which orientation would correspond to its (i) stable and (ii) unstable equilibrium? What is the potential energy of the magnet in each case?

Ans. Given $m = 0.32$ JT^{-1}, $B = 0.15$ T

Potential energy of magnet in magnetic field

$$U = -mB \cos\theta$$

(*i*) In stable equilibrium the potential energy of magnet is the minimum; so

$$\cos\theta = 1 \quad \text{or} \quad \theta = 0°$$

Thus in stable equilibrium position, the bar magnet is so aligned that its magnetic moment is along the direction of magnetic field ($\theta = 0°$).

$$U_m = -mB = -0.32 \times 0.15 = \mathbf{-4.8 \times 10^{-2}\ J}$$

(*ii*) In unstable equilibrium, the potential energy of magnet is the maximum.

Thus in unstable equilibrium position, the bar magnetic is so aligned that its magnetic moment is opposite to the direction of the magnetic field, *i.e.*, $\cos\theta = -1$ or $\theta = 180°$.

In this orientation potential energy, $U_{max} = +mB = \mathbf{+4.8 \times 10^{-2}\ J}$.

Q. 3. (*a*) Closely wound solenoid of 800 turns and area of cross-section $2.5 \times 10^{-4}\ m^2$ carries a current of 3.0 A. Explain the sense in which solenoid acts like a bar magnet. What is the associated magnetic moment?

(*b*) If the solenoid is free to turn about the vertical direction in an external uniform horizontal magnetic field at 0.25 T, what is the magnitude of the torque on the solenoid when its axis makes an angle of 30° with the direction of the external field.

Ans. (*a*) If solenoid is suspended freely, it stays in N-S direction. The polarity of solenoid depends on the sense of flow of current. If to an observer looking towards an end of a solenoid, the current appears anticlockwise, the end of solenoid will be N-pole and other end will be S-pole.

Magnetic moment, $m = NIA = 800 \times 3.0 \times 2.5 \times 10^{-4} = \mathbf{0.60\ A\text{-}m^2}$

(*b*) Torque on solenoid $\tau = mB \sin\theta$

$$= 0.60 \times 0.25 \sin 30°$$

$$= 0.60 \times 0.25 \times 0.5 = \mathbf{7.5 \times 10^{-2}\ N\text{-}m}$$

Q. 4. A bar magnet of magnetic moment $1.5\ JT^{-1}$ lies aligned with the direction of a uniform magnetic field of 0.22 T.

(*a*) What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment

(*i*) normal to the field direction? and (*ii*) opposite to the field direction?

(*b*) What is the torque on the magnet in cases (*i*) and (*ii*)?

Ans. (*a*) Work done in aligning a magnet from orientation θ_1 to θ_2 is given by

$$W = U_2 - U_1 = -mB\cos\theta_2 - (-mB\cos\theta_1)$$

$$= -mB(\cos\theta_2 - \cos\theta_1) \qquad ...(i)$$

(*i*) Here $\theta_1 = 0°$, $\theta_2 = 90°$

$$\therefore \quad W = mB(\cos 0° - \cos 90°) = mB(1 - 0) = mB$$

$$= 1.5 \times 0.22 = \mathbf{0.33\ J}$$

(*ii*) Here $\theta_1 = 0°$, $\theta_2 = 180°$

$$\therefore \quad W = mB(\cos 0° - \cos 180°) = 2mB$$

$$= 2 \times 1.5 \times 0.22 = \mathbf{0.66\ J}$$

(*b*) Torque $\tau = mB\sin\theta$

In (*i*) $\theta = 90°$, $\tau = mB\sin 90° = mB = 1.5 \times 0.22 = \mathbf{0.33\ N\text{-}m}$

This torque tends to align the magnet along the direction of field direction.

In (*ii*) $\theta = 180°$, $\tau = mB\sin 180° = \mathbf{0}$

Q. 5. A closely wound solenoid of 2000 turns and area of cross-section $1.6 \times 10^{-4}\ m^2$, carrying a current of 4.0 A is suspended through its centre allowing it to turn in a horizontal plane.

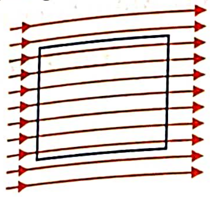
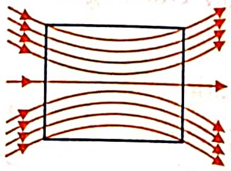
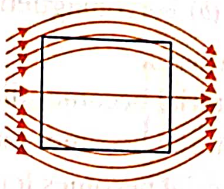
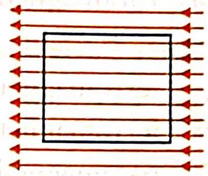
(*a*) What is the magnetic moment associated with the solenoid?

(*b*) What are the force and torque on the solenoid if a uniform magnetic field of 7.5×10^{-2} T is set up at an angle of 30° with the axis of the solenoid?

3. A magnetic needle is kept in a non-uniform magnetic field. It experiences
(a) a force and a torque
(b) a force but not a torque
(c) a torque but not a force
(d) neither a force nor a torque

4. A bar magnet of magnetic moment $\vec{m}$ is placed in a uniform magnetic field of induction $\vec{B}$. The torque exerted on it is
(a) $\vec{m} \cdot \vec{B}$
(b) $-\vec{m} \cdot \vec{B}$
(c) $\vec{m} \times \vec{B}$
(d) $-\vec{m} \times \vec{B}$

5. A uniform magnetic field exists in space in the plane of paper and is initially directed from left to right. When a bar of soft iron is placed in the field parallel to it, the lines of force passing through it will be represented by

(a) 
(b) 
(c) 
(d) 

6. Points A and B are situated perpendicular to the axis of a 2 cm long bar magnet at large distances x and $3x$ from its centre on opposite sides. The ratio of the magnetic fields at A and B will be approximately equal to
(a) 1: 9
(b) 2: 9
(c) 27: 1
(d) 9: 1

7. A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field of 0.6 T at a temperature of 4 K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16 K, the magnetisation will be [*NCERT Exemplar*]
(a) $\frac{32}{3} Am^{-1}$
(b) $\frac{2}{3} Am^{-1}$
(c) 6 Am^{-1}
(d) 2.4 Am^{-1}

8. Two bar magnets of same geometry with magnetic moments M and $2M$ are first placed in such a way that their similar poles are on the same side, then its period of oscillation is T_1. Now the polarity of one of the magnets is reversed, then the time period of oscillations is T_2 then,
(a) $T_1 < T_2$
(b) $T_1 > T_2$
(c) $T_1 = T_2$
(d) $T_2 = \infty$

9. A long solenoid has 1000 turns per metre and carries a current of 1 A. It has a soft iron core of $\mu_r = 1000$. The core is heated beyond the Curie temperature, T_c, then [*NCERT Exemplar*]
(a) the H field in the solenoid is (nearly) unchanged but the B field decreases drastically.
(b) the H and B fields in the solenoid are nearly unchanged.
(c) the magnetisation in the core reverses direction.
(d) the magnetisation in the core diminishes by a factor of about 10^8.

10. A bar magnet AB with magnetic moment M is cut into two equal parts perpendicular to its axis. One part is kept over the other so that end B is exactly over A. What will be the magnetic moment of the combination so formed?
(a) $\frac{M}{4}$
(b) $\frac{3M}{4}$
(c) M
(d) Zero

11. A magnet of magnetic moment m is cut into two equal parts. The two parts are placed perpendicular to each other so that their north poles touch each other. The resultant magnetic moment is:
(a) $\sqrt{2}\, m$
(b) $\frac{m}{\sqrt{2}}$
(c) $\sqrt{3}\, m$
(d) $\frac{m}{\sqrt{3}}$

12. The meniscus of a liquid contained in one of the limbs of a narrow U-tube is placed between the pole-pieces of an electromagnet with the meniscus in a line with the field. When the electromagnet is switched on, the liquid is seen to rise in the limb. This indicates that the liquid is
(a) ferromagnetic
(b) paramagnetic
(c) diamagnetic
(d) non-magnetic

(a) directed along $\overrightarrow{OP}$

(b) directed along $\overrightarrow{PO}$

(c) directed perpendicular to the plane of the paper

(d) zero

24. A stationary magnet does not interact with

(a) magnet (b) stationary charge

(c) iron rod (d) moving charge

Answers

1. (c)	2. (c)	3. (a)	4. (c)	5. (b)	6. (c)
7. (b)	8. (a)	9. (a), (d)	10. (a)	11. (b)	12. (b)
13. (b)	14. (c)	15. (c)	16. (b)	17. (b)	18. (b)
19. (a), (b)	20. (d)	21. (c)	22. (d)	23. (d)	24. (b)

Very Short Answer Questions

Each of the following questions are of 1 mark.

Q. 1. Which of the following substances are diamagnetic?

Bi, Al, Na, Cu, Ca and Ni *[CBSE Delhi 2013]*

Ans. Diamagnetic substances are (i) Bi (ii) Cu.

Q. 2. What are permanent magnets? Give one example. *[CBSE Delhi 2013]*

Ans. Substances that retain their attractive property for a long period of time at room temperature are called permanent magnets.

Examples: Those pieces which are made up of steel, alnico, cobalt and ticonal.

Q. 3. Mention two characteristics of a material that can be used for making permanent magnets. *[CBSE Delhi 2010]*

Ans. For making permanent magnet, the material must have high **retentivity** and high **coercivity** (e.g., steel).

Q. 4. Why is the core of an electromagnet made of ferromagnetic materials? *[CBSE Delhi 2010]*

Ans. Ferromagnetic material has a high permeability. So on passing current through windings it gains sufficient magnetism immediately.

Q. 5. The permeability of a magnetic material is 0.9983. Name the type of magnetic materials it represents. *[CBSE Delhi 2011]*

Ans. μ is <1 and >0, so magnetic material is diamagnetic.

Q. 6. The susceptibility of a magnetic materials is -4.2×10^{-6}. Name the type of magnetic materials it represents. *[CBSE Delhi 2011]*

Ans. Susceptibility of material is negative, so given material is diamagnetic.

Q. 7. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field? *[CBSE Central 2016]*

Ans. A diamagnetic specimen would move towards the weaker region of the field while a paramagnetic specimen would move towards the stronger region.

Q. 8. The magnetic susceptibility of magnesium at 300 K is 1.2×10^5. At what temperature will its magnetic susceptibility become 1.44×10^5? *[CBSE 2019 (55/2/1)]*

Ans. The susceptibility of a paramagnetic substance is inversely proportional to the absolute temperature.

According to Curie's law,

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

$$\chi = \frac{C}{T} \quad \text{(where C is curie constant)}$$

Here $\chi_1 = 1.2 \times 10^5, T_1 = 300\text{ K}$

$\chi_2 = 1.44 \times 10^5, T_2 = ?$

$$\chi_1 = \frac{C}{T_1} \Rightarrow C = \chi_1 T_1$$

$$\chi_2 = \frac{C}{T_2}$$

$$T_2 = \frac{C}{\chi_2} = \frac{\chi_1 T_1}{\chi_2} = \frac{1.2 \times 10^5}{1.44 \times 10^5} \times 300 = \mathbf{250\ K}$$

Q. 9. The magnetic susceptibility χ of a given material is – 0.5. Identify the magnetic mat
[CBSE 2019 (55

Ans. The susceptibility of material is – 0.5, which is negative. Hence, material is diamagnetic subst

Q. 10. Write one important property of a paramagnetic material. **[CBSE 2019 (55**

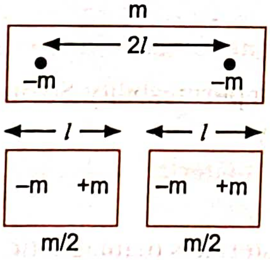
Ans. It moves from weaker magnetic field towards stronger magnetic field.

Q. 11. Do the diamagnetic substances have resultant magnetic moment in an atom in the absenc external magnetic field? **[CBSE 2019 (55**

Ans. No, diamagnetic substances have no resultant magnetic moment in the absence of exte magnetic field.

Q. 12. How does the (*i*) pole strength and (*ii*) magnetic moment of each part of a bar magnet chang it is cut into two equal pieces transverse to length?

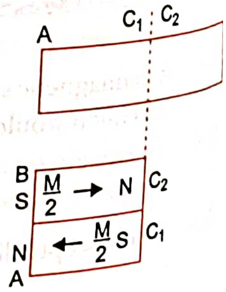
Ans. When a bar magnet of magnetic moment ($\vec{M} = m2\vec{l}$) is cut into two equal pieces transverse to length,



(*i*) the pole strength remains unchanged (since pole strength depends on number of atoms cross-sectional area).

(*ii*) the magnetic moment is reduced to half (since $M \propto$ length and here length is halved).

Q. 13. A hypothetical bar magnet (*AB*) is cut into two equal parts. One part is now kept over the other, so that the pole C_2 is above C_1. If M is the magnetic moment of the original magnet, what would be the magnetic moment of the combination, so formed?



Ans. The magnetic moment of each half bar magnet is $\frac{M}{2}$ but oppositely directed, so net magnetic moment of combination $= \frac{M}{2} - \frac{M}{2} = 0$ (zero).

Short Answer Questions–I

Each of the following questions are of 2 marks.

Q. 1. The susceptibility of a magnetic material is 2.6×10^{-5}. Identify the type of magnetic material and state its two properties. **[CBSE Delhi 2012]**

Ans. The material having positive and small susceptibility is paramagnetic material.

Properties

(*i*) They have tendency to move from a region of weak magnetic field to strong magnetic field, *i.e.*, they get weakly attracted to a magnet.

(*ii*) When a paramagnetic material is placed in an external field the field lines get concentrated inside the material, and the field inside is enhanced.

Q. 2. The susceptibility of a magnetic material is -2.6×10^{-5}. Identify the type of magnetic material and state its two properties. **[CBSE Delhi 2012]**

Ans. The magnetic material having negative susceptibility is diamagnetic in nature.

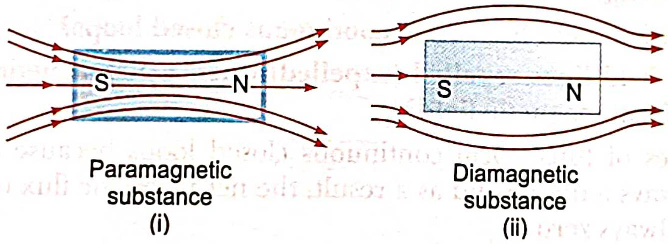
Properties:

(*i*) This material has + ve but low relative permeability.

(*ii*) They have the tendency to move from stronger to weaker part of the external magnetic field.

Q. 3. Two identical bars, one of paramagnetic material and other of diamagnetic material are kept in a uniform external magnetic field parallel to it. Draw diagrammatically the modifications in the magnetic field pattern in each case. **[CBSE 2020 (55/3/1)]**

Ans.



- A paramagnetic material tends to move from weaker field to stronger field regions of the magnetic field. So, the number of lines of magnetic field increases when passing through it.
- A diamagnetic material tends to move from stronger field to weaker field region of the magnetic field. So, the number of lines of magnetic field passing through it decreases.

Q. 4. Write two properties of a material suitable for making (*a*) a permanent magnet, and (*b*) an electromagnet. **[CBSE (AI) 2017]**

Ans. (*a*) Two properties of material used for making permanent magnets are

(*i*) High coercivity (*ii*) High retentivity

(*iii*) High permeability

(*b*) Two properties of material used for making electromagnets are

(*i*) High permeability (*ii*) Low coercivity

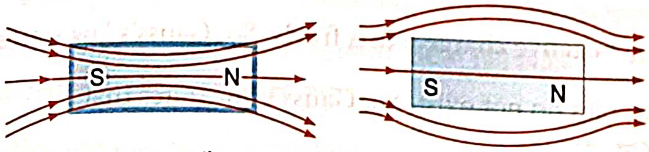
(*iii*) Low retentivity

Q. 5. What is the basic difference between the atom and molecule of a diamagnetic and a paramagnetic material? Why are elements with even atomic number more likely to be diamagnetic?

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

The elements with even atomic number Z has even number of electrons in its atoms/molecules, so they are more likely to form electrons pairs of opposite spin and hence more likely to be diamagnetic.

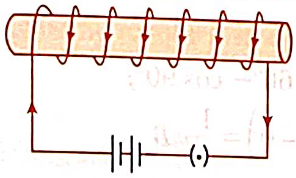
Ans.



Paramagnetic substance (i)   Diamagnetic substance (ii)

- A paramagnetic material tends to move from weaker field to stronger field regions of the magnetic field. So, the number of lines of magnetic field increases when passing through it. Magnetic dipole moments are induced in the direction of magnetic field. Paramagnetic materials has a small positive susceptibility.
- A diamagnetic material tends to move from stronger field to weaker field region of the magnetic field. So, the number of lines of magnetic field passing through it decreases. Magnetic dipole moments are induced in the opposite direction of the applied magnetic field. Diamagnetic materials has a negative susceptibility in the range $(-1 \leq \chi < 0)$.

Q. 5. Draw the magnetic field lines for a current carrying solenoid when a rod made of (*a*) copper, (*b*) aluminium and (*c*) iron are inserted within the solenoid as shown.



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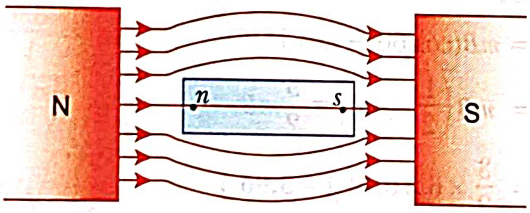
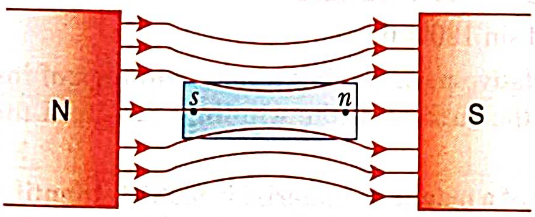
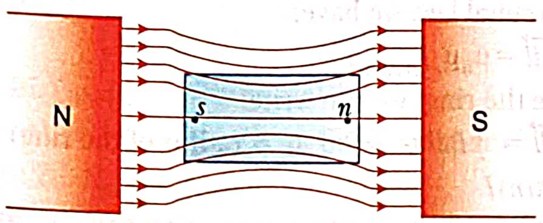
Ans. (*a*) When a bar of diamagnetic material (copper) is placed in an external magnetic field, the field lines are repelled or expelled and the field inside the material is reduced.



(*b*) When a bar of paramagnetic material (Aluminium) is placed in an external field, the field lines gets concentrated inside the material and the field inside is enhanced.



(*c*) When a ferromagnetic material (Iron) is placed in an internal magnetic field, the field lines are highly concentrated inside the material.



Q. 6. In what way is Gauss's law in magnetism different from that used in electrostatics? Explain briefly.

The Earth's magnetic field at the equator is approximately 0.4 G. Estimate the Earth's magnetic dipole moment. Given: Radius of the Earth = 6400 km. **[*CBSE Patna 2015*]**