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 magnetic 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)*

SA II (3 marks)

3. Write the four important properties of the magnetic field lines due to a bar magnet. (2/3, *Delhi 2019*)

4. A bar magnet of magnetic moment 6 J T^{-1} is aligned at 60° with a uniform external magnetic field of 0.44 T. Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii). *(2018)*

LA (5 marks)

5. 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*)

5.3 Magnetism and Gauss's Law

SA II (3 marks)

6. State Gauss's law for magnetism. Explain its significance. (1/3, *Delhi 2019*)

5.4 The Earth's Magnetism

VSA (1 mark)

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

8. Where on the surface of Earth is the vertical component of Earth's magnetic field zero? *(Delhi 2013C)*

9. 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)*

10. 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)*

11. Where on the surface of Earth is the angle of dip 90°? *(AI 2011)*

12. 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)

13. 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)*

14. (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)*

15. 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)

16. 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 II (3 marks)

17. An iron ring of relative permeability μ_r has windings of insulated copper wire of n turns per metre. When the current in the windings is I, find the expression for the magnetic field in the ring. *(2/3, 2018)*

5.6 Magnetic Properties of Materials

VSA (1 mark)

18. 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)*

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

20. 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)*

21. 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)*

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

SA I (2 marks)

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

24. 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)*

25. (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)*

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

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

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

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

SA II (3 marks)

28. Write three points of differences between para-, dia- and ferro- magnetic materials giving one example for each. *(Delhi 2019)*

29. The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field. *(1/3, 2018)*

30. 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)

31. 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)*

5.7 Permanent Magnets and Electromagnets

VSA (1 mark)

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

33. (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)*

SA I (2 marks)

34. Write two properties of a material suitable for making (a) a permanent magnet, and (b) an electromagnet. *(AI 2017)*

35. (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)*

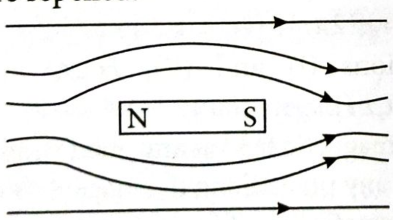
SA II (3 marks)

36. 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 θ ≈ θ, 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. Properties of magnets

(i) Attractive property : When a magnet is dipped into iron filings, it is found that the concentration of iron filings is maximum at the ends. It means 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.

(ii) 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.

(iii) Magnetic poles always exist in pairs *i.e.*, an isolated magnetic pole does not exist.

(iv) Like poles repel each other and unlike poles attract each other.

4. Here, $m = 6\ J\ T^{-1}$, $\theta_1 = 60°$, $B = 0.44$ T

(a) Work done in turning the magnet,

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

(i) $\theta_1 = 60°$, $\theta_2 = 90°$

$\therefore \quad W = -6 \times 0.44(\cos 90° - \cos 60°)$

$$= -6 \times 0.44\left(0 - \frac{1}{2}\right) = 1.32 \text{ J}$$

(ii) $\theta_1 = 60°$, $\theta_2 = 180°$

$\therefore \quad W = -6 \times 0.44(\cos 180° - \cos 60°)$

$$= -6 \times 0.44\left(-1 - \frac{1}{2}\right) = 3.96 \text{ J}$$

(b) $\tau = mB \sin\theta = mB \sin 180° = 0$

5. *Refer to answer 2.*

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

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

Physical significance : This law establishes that isolated magnetic poles do not exist.

7. Given: $B_H = B$, $\delta = 60°$; $B_H = B_T \cos\delta$

$B = \frac{B_T}{2} \Rightarrow B_T = 2B$

At equator $\delta = 0$

$\therefore \quad B_{Heq} = B_T \cos\delta \Rightarrow B_{Heq} = 2B$

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

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

10. (i) 0, (ii) 90°

11. At North and South poles.

12. Given, $B_V = B_H = 1$

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

$\delta = 45°$.

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

$H = B_E \cos\delta$

Given, $H = 0.4$ G and $\theta = 60°$

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

14. (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.

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

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

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

$\delta = 60°$

$\therefore$ The angle of dip is 60°.

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

16. (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, $\delta = 90°$.

17. When current I is passed through the wire having n turns per unit length and of mean radius r, then magnetic field lines set up inside the ring in the form of concentric circles. Let one such loop be of radius r, then line integral of magnetic field over that closed loop is

$$\oint \vec{H} \cdot d\vec{l} = \oint H dl \cos 0° = H \oint dl = H \cdot 2\pi r \quad \text{...(i)}$$

But by Ampere's circuital law,

$\oint \vec{H} \cdot d\vec{l}$ = total current threading the toroid

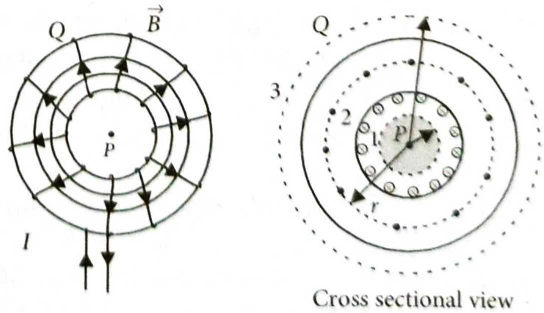
= total number of turns in toroid $\times I$

$= n(2\pi r)I$ ...(ii)

By equations (i) and (ii), $H.2\pi r = n\ 2\pi r I$

or $B = \mu_0 \mu_r n I$.

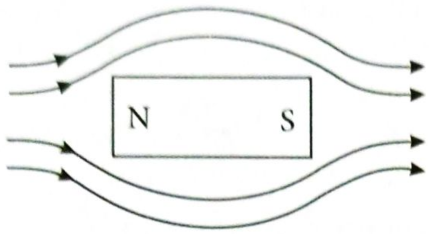
This gives magnetic field at any point inside the ring, directed at any point along the tangent to concentric circular magnetic line of force at that point inside the toroid.



Cross sectional view

18. 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.

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



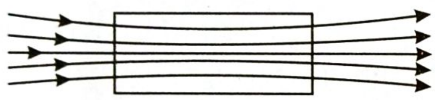
20. The relative permeability is an intrinsic property of a magnetic material. A related quantity is the magnetic susceptibility, denoted by χ_m.

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

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

21. (i) *Refer to answer 19.*

(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.

22. 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 magnetism $\vec{M}$ and susceptibility χ and positive low value of relative permeability μ_r, *i.e.*,

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

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

23.

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.

24. *Refer to answer 21.*

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.

25. (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.

26. *Refer to answer 23.*

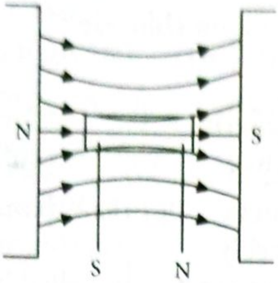
27. (i) For $-1 \le \chi < 0$, material is diamagnetic.

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

28.

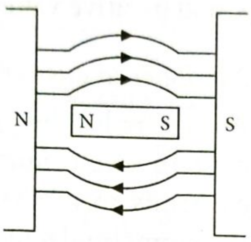
S.No.	Paramagnetic	Diamagnetic	Ferromagnetic
1.	Substances are feebly attracted by the magnet. Na, K, Mg, Mn, Al, Cr, Sn and liquid oxygen are paramagnetic.	Substances are feebly repelled by the magnet. Bi, Cu, Ag, Hg, Pb, water, hydrogen, He, Ne, etc. are diamagnetic.	Substances are strongly attracted by the magnet. Fe, Co, Ni and their alloys are ferromagnetic.
2.	χ_m is small, positive and varies inversely with temperature, *i.e.*, $\chi_m \propto (1/T)$.	Susceptibility χ_m is small, negative and temperature independent.	χ_m is very large, positive and temperature dependent.
3.	μ_r is slightly greater than unity, *i.e.*, $\mu > \mu_0$.	Relative permeability μ_r is slightly lesser than unity, *i.e.*, $\mu < \mu_0$	μ_r is much greater than unity, *i.e.*, $\mu >> \mu_0$.

29. As $\chi = 0.9853$, so material is paramagnetic. The behaviour of magnetic field lines in the presence of a paramagnetic substance is shown :



30. *Refer to answer 29.*

(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.

31. (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.

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

33. (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.

34. (a) For permanent magnet

1. Material should have high retentivity and high coercivity.
2. Material should have high permeability.

(b) For electromagnet

1. Material should have low retentivity.
2. Material should have high permeability.

35. (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.

36. 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.