Very Short Answer Questions (PYQ)

Q. 1. Where on the earth's surface is the value of angle of dip maximum?

OR

Where on the surface of earth is the angle of dip 90°? [CBSE (AI) 2011]

Ans. Angle of dip (90°) is maximum at magnetic poles.

Q. 2. 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? [CBSE (F) 2012]

Ans. (i) 0° (ii) 90°

Q. 3. Where on the earth's surface is the value of vertical component of earth's magnetic field zero? [CBSE (F) 2011]

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

Q. 4. 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?
[CBSE Delhi 2012]

Ans. Zero

Q. 5. A small magnet is pivoted to move freely in the magnetic meridian. At what place on earth's surface will the magnet be vertical? [CBSE (F) 2012]

Ans. Magnet will be vertical at the either magnetic pole of earth.

Q. 6. 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. 7. 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. 8. 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 retentively and high coercively (e.g., steel).

Q. 9. Why is the core of an electromagnet made of ferromagnetic materials? [CBSE Delhi 2010]

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

Q. 10. The permeability of a magnetic material is 0.9983. Name the type of magnetic materials it represents. [CBSE Delhi 2011]

Ans. μ is <1 so magnetic material is diamagnetic.

Q. 11. 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. 12. 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. 13. 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? [CBSE Delhi 2017]

Ans. Here, $B_H = B$ and $\delta = 60°$

We know that

$$B_H = B_E \cos \delta$$

$$B = B_E \cos 60° \quad \Rightarrow B_E = 2B$$

At equator $\delta = 0°$

$\therefore \quad B_H = 2B \cos 0° = 2B$

Q. 14. What is the angle of dip at a place where the horizontal and vertical components of the Earth's magnetic field are equal? [CBSE (F) 2012]

Ans. We know

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

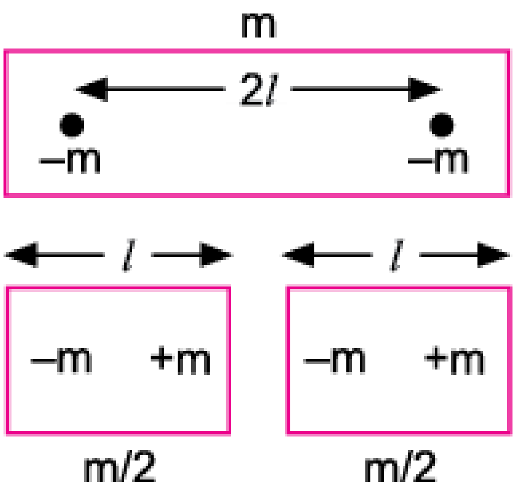
Given $B_V = B_H$ then $\tan \delta = 1$

Angle of dip, $\delta = 45°$

Very Short Answer Questions (OIQ)

Q. 1. How does the (i) pole strength and (ii) magnetic moment of each part of a bar magnet change if it is cut into two equal pieces transverse to length?

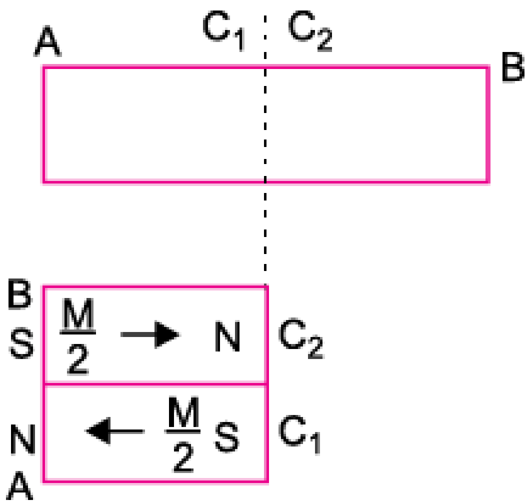
Ans. When a bar magnet of magnetic moment ($\vec{M} = m2\vec{l}$) is cut into two equal pieces transverse to its length,



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

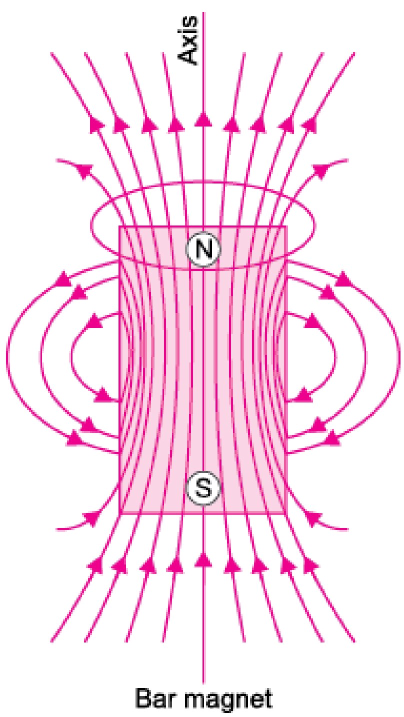
(ii) The magnetic moment is reduced to half (since $M \propto$ length and here length is halved).

Q. 2. 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).

Q. 3. A bar magnet has magnetic moment M. It is divided into n–equal parts. Will each part be a magnetic dipole? What will be the magnetic moment of each part?



Ans. Yes, each part will be a magnetic dipole. The dipole moment of each part will be equal to $\frac{m}{n}$.

Q. 4. Depict the field-line pattern due to a bar magnet.

Ans. The field lines are shown in the figure alongside. The magnetic field lines of magnet form continuous closed loops and are directed from N to S pole outside the magnet and S to N pole inside the magnet and forms closed loops.

Q. 5. What should be the orientation of a magnetic dipole in a uniform magnetic field so that its potential energy is maximum?

Ans. Potential energy of a magnetic dipole in a uniform magnetic field U= – MB cos q; clearly the potential energy is maximum when cos θ = – 1 or θ = π That is, potential energy is maximum when magnetic dipole with its magnetic moment $\underset{M}{\rightarrow}$ is oriented opposite to the direction of magnetic field (or angle between $\underset{M}{\rightarrow}$ and $\underset{B}{\rightarrow}$ is 180°).

Q. 6. Define the term magnetic moment.

Ans. The magnetic moment of a magnet (or current loop) is defined as the maximum value of torque acting on a magnet when it is placed in a magnetic field of 1 T.

Q. 7. When is a magnet said to be in stable equilibrium in a magnetic field?

Ans. The magnet is said to be in stable equilibrium when the magnetic dipole moment of magnet is aligned along the direction of magnetic field.

Q. 8. The angles of dip at two places located on the earth are 0° and 90° respectively. Where are the places located?

Ans. The angle of dip is 0° at magnetic equator and it is 90° at magnetic poles. That is, the required places are located at magnetic equator and at either pole respectively.

Q. 9. In which direction would a compass needle align if taken to geographic (i) north pole and (ii) south pole?

Ans. The compass needle aligns along the horizontal component of earth's field (H). At poles H= 0, so compass needle will become free and may rest in any direction.

Q. 10. The magnetic field lines prefer to pass through iron than air. Explain why?

Ans. The magnetic field lines prefer to pass through iron than air because the permeability of iron is much larger than air.

Q. 11. Which has larger susceptibility: Iron or copper?

Ans. Iron is a ferromagnetic substance while and copper is diamagnetic, the susceptibility of iron is much larger.

Q. 12. State with reason, whether the following statement is true or false? "The product of magnetic susceptibility and absolute temperature χT is constant for a paramagnetic material".

Ans. Yes, According to Curie law, $\chi \propto \frac{1}{T} \cdot \chi T =$ constant is true for paramagnetic substances.

Q. 13. What are the factors which are considered for an electromagnet? Give an example.

Ans. For an electromagnet, the substance should have high retentivity but low coercivity. Soft iron is such a substance.

Q. 14. What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player or for building memory stores in a modern computer?

Ans. Ceramics are used for coating magnetic tapes in a cassette player or for building stores in a modern computer. Ceramics are specially treated barium-iron oxides and are also called ferrites.

Short Answer Questions – I (PYQ)

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. Two 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. 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 at to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place. [CBSE Delhi 2011]

Ans. Angle of dip, θ = 60°

H = 0.4 G = 0.4 × 10–4 T

If Be is earth's magnetic field, then

$$H = B_e \cos\theta. \Rightarrow \quad B_e = \frac{H}{\cos\ \theta} = \frac{0.4\times10^{-4}T}{\cos\ 60^{\circ}} = \frac{0.4\times10^{-4}T}{0.5} = 0.8\times10^{-4}\ T = 0.8\ G$$

Q. 4. 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. [CBSE Delhi 2013]

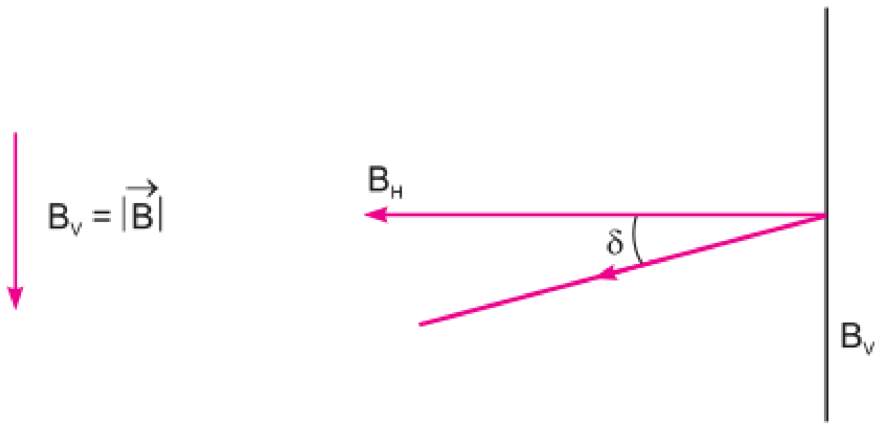
Ans. If compass needle orients itself with its axis vertical at a place, then

i. $B_H = 0$ because $B_V = |B|$

ii. $\tan \delta = \frac{B_V}{B_H} = \infty$

$\Rightarrow$ Angle of dip $\delta = 90^\circ$,

Concept: It is possible only on magnetic north or south poles.



Q. 5. A magnetised needle of magnetic moment 4.8×10^{-2} J T–1 is placed at 30° with the direction of uniform magnetic field of magnitude 3×10^{-2} T. Calculate the torque acting on the needle. [CBSE (F) 2012]

Ans. We have, $\tau = MB \sin \theta$

Where $\tau \rightarrow$ torque acting on magnetic needle

$M \rightarrow$ Magnetic moment

$B \rightarrow$ Magnetic field strength

Then $\tau = 4.8 \times 10^{-2} \times 3 \times 10^{-2} \sin 30^\circ$

$= 4.8 \times 10^{-2} \times 3 \times 10^{-2} \times \frac{1}{2}$

$= 7.2 \times 10^{-4}$ Nm

Q. 6. 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. [CBSE Delhi 2017]

Ans. Here, BH = B and $\delta = 60^\circ$

We know that

$B_H = B_E \cos \delta$

$B = B_E \cos 60^\circ \quad \Rightarrow \quad B_E = 2B$

At equator $\delta = 0°$

∴ $B_H = 2B \cos 0° = 2B$

Q. 7. 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

Short Answer Questions-I (OIQ)

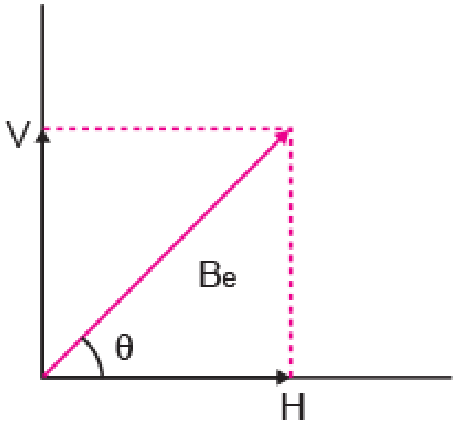
Q. 1. Define the term magnetic inclination. Deduce the relation connecting the horizontal component and inclination with the help of a diagram.

Ans. Magnetic Inclination: It is the angle made by resultant magnetic field of earth with the horizontal. It is also called angle of dip.

Relation, suppose $\underset{Be}{\rightarrow}$ is earth's net magnetic field, θ is angle of dip. Resolving $\underset{Be}{\rightarrow}$ along horizontal and vertical directions; the horizontal component is H and vertical component is V. From fig. $\cos\theta = \frac{H}{B_e}$

∴ $H = B_e \cos\theta$

This is the required relation.



Q. 2. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?

Ans. Magnetic susceptibility: Refer to Basic Concepts Point 5 (iv).

Iron has positive susceptibility while **copper** has negative susceptibility.

Negative susceptibility of a substance signifies that the substance will be repelled by a strong magnet or opposite feeble magnetism induced in the substance. Such a substance is called diamagnetic.

Q. 3. Answer the following questions:

If χ-stands for the magnetic susceptibility of a given material, identity the class of materials for which (i) $-1 \geq \chi < 0$ (ii) $0 < \chi < \varepsilon$ 0 (ε is a small positive number).

(1) Write the range of relative magnetic permeability of these materials.

(2) Draw the pattern of the magnetic field lines when these materials are placed on an strong magnetic field.

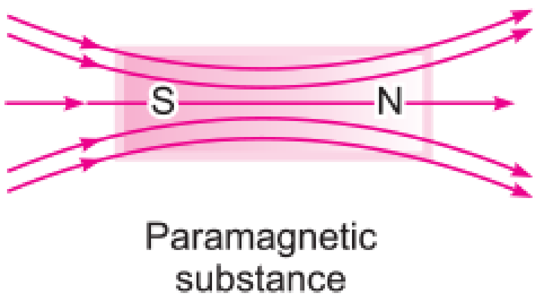
Ans. (1) Material is diamagnetic (ii) Material is paramagnetic.

$$\mu_r = 1 + \chi$$

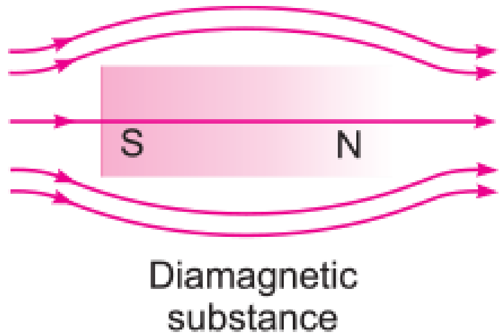
(i) Range of relative magnetic permeability for diamagnetic is $0 \leq \mu_r < 1$.

(ii) Range of relative magnetic permeability for paramagnetic is $1 < \mu_r < 1 + \varepsilon$.

(2)



(i)



(ii)

Q. 4. Write any three characteristics, a ferromagnetic substance should possess if it is to be used to make a permanent magnet. Give one example of such a material.

Ans. Characteristics for permanent magnet

(i) High permeability

(ii) High retentivity

(iii) High coercivity

Example: steel.

Q. 5. What is Curie law in magnetism?

Ans. Curie law. It states that the magnetic susceptibility of a paramagnetic material is inversely proportional to absolute temperature

$$\therefore \quad \chi \propto \frac{1}{T} = \frac{C}{T} \text{ where } C \text{ is Curie constant.}$$

Q. 6. When a compass needle be placed at magnetic north pole, how would it behave? If a dip needle be placed at the place, how would it behave?

Ans. Compass needle stays in horizontal north-south direction. At poles horizontal component H= 0; therefore there will be no effect of earth's field on magnetic north pole and it can stay in any direction; on the other hand a dip needle points along the resultant magnetic field and at poles the resultant field is vertical; hence the needle becomes vertical.

Q. 7. What is the value of magnetic field within a hollow sphere made of ferromagnetic substance? Hence explain magneto static shielding.

Ans. The magnetic field within, hollow sphere of ferromagnetic substance is zero. Magneto static shielding means to shield any specimen from magnetic effects by placing it within a hollow region of a ferromagnetic substance.

Q. 8. Horizontal component of earth's magnetic field at a place is $\sqrt{3}$ times its vertical component. What is the value of angle of dip at that place?

Ans.

$$\text{Given} \quad H = \sqrt{3}V \Rightarrow \tan\theta = \frac{V}{H} = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \quad \text{Angle of dip}, \ \theta = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30^{\circ}$$

Q. 9. From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, Para magnetism and ferromagnetism. [NCERT Exemplar]

Ans. Diamagnetism is due to orbital motion of electrons developing magnetic moments opposite to applied field and hence is not much affected by temperature.

Paramagnetic and ferromagnetism is due to alignments of atomic magnetic moments in the direction of the applied field. As temperature increases, this alignment is disturbed and hence susceptibilities of both decrease as temperature increases.

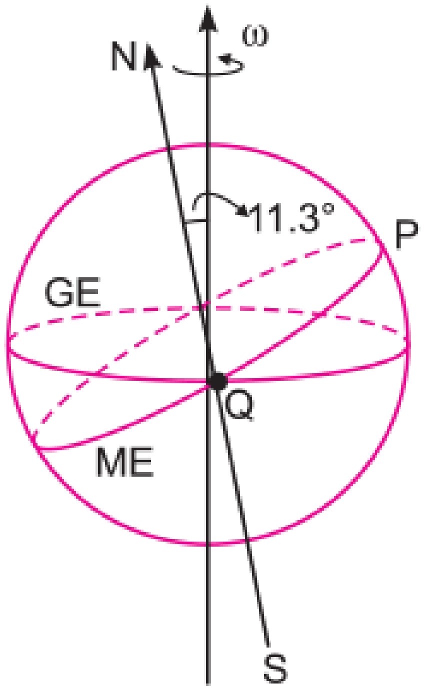
Q. 10.Consider the plane S formed by the dipole axis and the axis of earth. Let P be point on the magnetic equator and in S. Let Q be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angles at P and Q.
[NCERT Exemplar]

Ans. In following figure:

(i) P is in S (needle will point both north) Declination = 0P is also on magnetic equator.∴ Dip = 0

(ii) Q is on magnetic equator.∴ Dip = 0

But declination = 11.3.

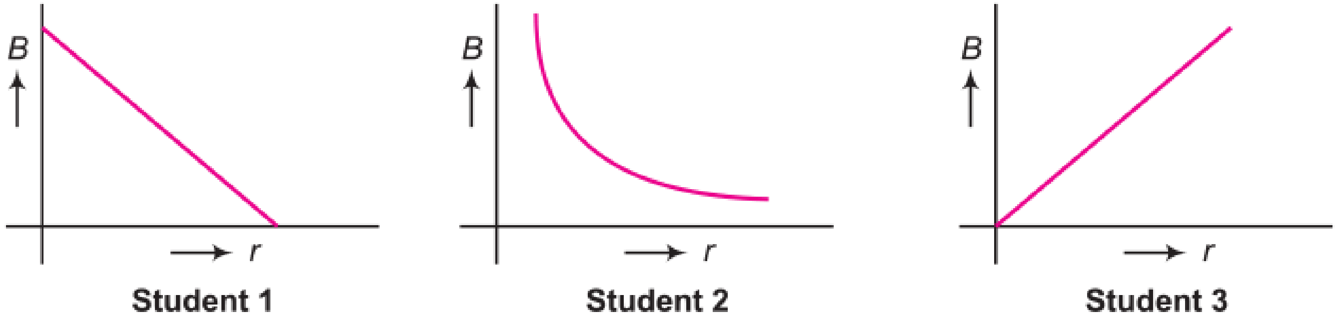


Q. 11. What is the basic difference between the atom and molecule of a diamagnetic and a paramagnetic material? Why are elements with even atomic number more likely to be diamagnetic?

Ans. Atoms/molecules of a diamagnetic substance contain even number of electrons and these electrons from 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.

Q. 12. Three students represent the variation of magnetic field B with distance r for a straight infinity long current carrying conductor as



Which of the three students has drawn the graph correctly and why?

Ans. For a straight infinitely long current carrying conductor, the magnetic field is given by the relation

$$\overrightarrow{B} = \frac{\mu_0 I}{2\pi r}$$

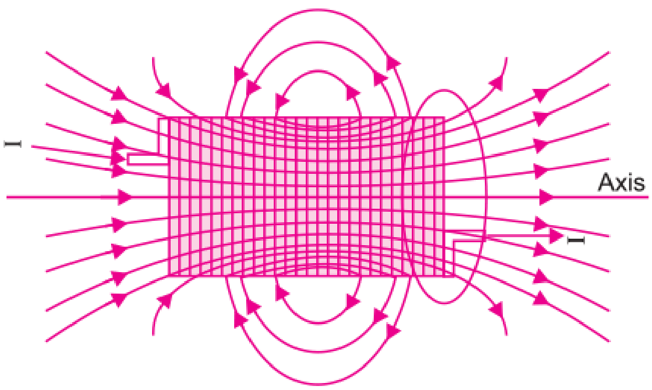
Thus, $B \propto \frac{1}{r}$ and the graph between B and r will be a rectangular hyperbola. Thus, student 2 has drawn the graph correctly.

Short Answer Questions –II (PYQ)

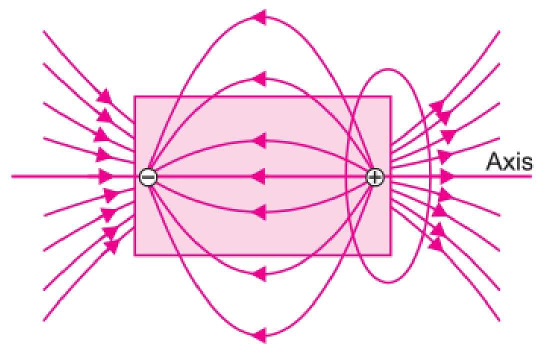
Q. 1. Depict the field-line pattern due to a current carrying solenoid of finite length.

(i) In what way do these lines differ from those due to an electric dipole?

(ii) Why can't two magnetic field lines intersect each other? [CBSE (F) 2009]



Field fines of a current carrying solenoid



Field fines of an electric dipole

Ans. Two magnetic field lines cannot intersect because at the point of intersection, these will be two directions of magnetic field which is impossible.

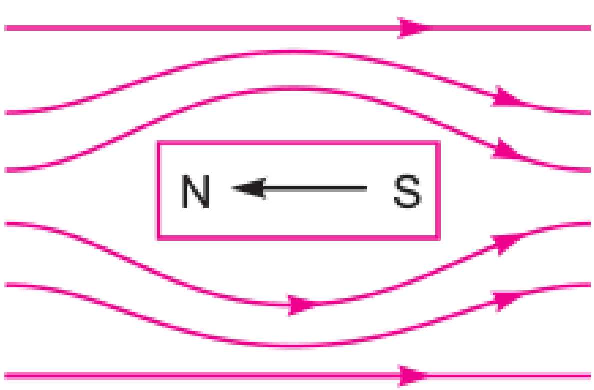
Q. 2. Explain the following:

(i) Why do magnetic field lines form continuous closed loops?

(ii) Why are the field lines repelled (expelled) when a diamagnetic material is placed in an external uniform magnetic field? [CBSE (F) 2011]

Ans. (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.



Q. 3. Answer the following questions.

(i) Mention two properties of soft iron due to which it is preferred for making an electromagnet.

(ii) State Gauss's law in magnetism. How is it different from Gauss's law in electrostatics and why? [CBSE South 2016]

Ans. (i) Low coercivity and high permeability

(ii) Gauss's Law in magnetism: The net magnetic flux through any closed surface is zero.

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

Gauss's Law in electrostatics: The net electric flux through any closed surface is $\frac{1}{\varepsilon 0}$ times the net charge.

$$\oint E.\text{ds} = \frac{q}{\varepsilon_0}$$

The difference between the Gauss's law of magnetism and that for electrostatic is a reflection of the fact that magnetic monopole do not exist i.e. magnetic poles always exist in pairs.

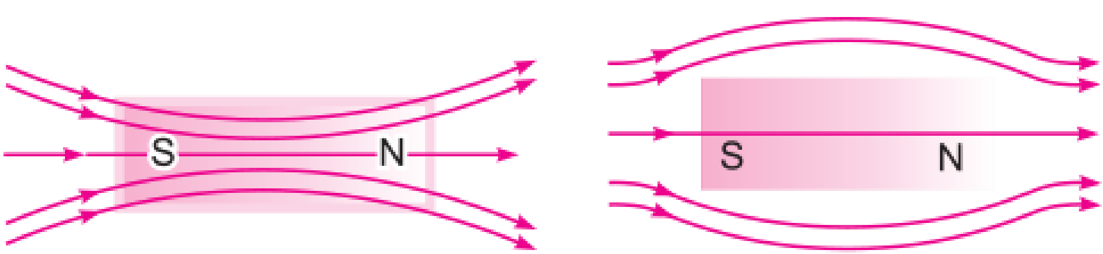
Q. 4. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature? [CBSE (AI) 2014]

OR

Draw the magnetic field lines distinguishing between diamagnetic and paramagnetic materials.

Give a simple explanation to account for the difference in the magnetic behaviour of these materials. [CBSE Bhubaneshwar 2015, Central 2016]

Ans.



Paramagnetic substance

Diamagnetic substance

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 ($-1 \le x < 0$).

Q. 5. Answer the following questions.

(i) What happens when a diamagnetic substance is placed in a varying magnetic field?

(ii) Name the properties of a magnetic material that make it suitable for making (a) a permanent magnet and (b) a core of an electromagnet. [CBSE (F) 2009]

Ans. (i) A diamagnetic substance is attracted towards a region of weaker magnetic field.

(ii) (a) Permanent magnets are made of steel which is characterised by **high retentivity** and **high coercivity.**

(b) Electro magnets are made of soft iron which is characterised by **high retentivity** and **low coercivity.**

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]

Ans. As we know that

Isolated positive or negative charge exists freely. So, Gauss's law states that

$$\oint \vec{E} \cdot d\vec{S} = \frac{1}{\varepsilon_0}[q]$$

Isolated magnetic poles do not exist. So, Gauss's law states that

$$\oint \vec{B} \cdot \vec{dS} = 0$$

Magnetic field intensity at the equator is

$$B = \frac{\mu_0}{4\pi} \cdot \frac{m}{R^3} = 10^{-7} \frac{m}{R^3}$$

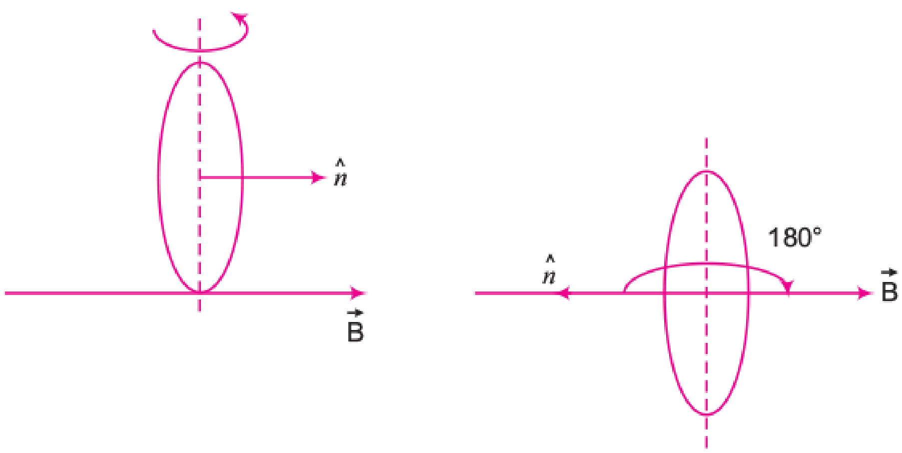
$$\therefore \quad m = 10^{7} \, . \, B \left|R\right|^{3}$$

$$= 10^{7} \times 0.4 \times 10^{-4} \times \left(6400 \times 10^{3}\right)^{3}$$

$$= 1.1 \times 10^{23} \text{ Am}^{2}$$

Q. 7. A circular coil of radius 10 cm, 500 turns and resistance 200 W is placed with its plane perpendicular to the horizontal component of the Earth's magnetic field. It is rotated about its vertical diameter through 180° in 0.25 s. Estimate the magnitudes of the emf and current induced in the coil. (Horizontal component of the Earth's magnetic field at the place is 3.0 × 10^{-5} T) [CBSE (F) 2015]

Ans.



Initial magnetic flux, φ_i = NBA

= 500 × 3 × 10^{-5} × π (0.1)2

= 15 π × 10^{-5} Wb

On turning by 180°

Final flux, φ_f = – NBA = – 15 π × 10^{-5} Wb

Magnitude of induced emf, $e = -\frac{d\varphi}{dt}$

$$= \frac{2 \times 15\pi \times 10^{-5}}{0.25} = 120\pi \times 10^{-5} \text{ volt}$$

$$= 376.8 \times 10^{-5} = 0.038 \text{ volt}$$

Induced current, $I = \frac{\varepsilon}{R} = \frac{0.038}{200} = 19_{10^{-5}}$

Short Answer Questions –II (OIQ)

Q. 1. What are permanent magnets? What is an efficient way of preparing a permanent magnet? Write two characteristic properties of materials which are required to select them for making permanent magnets.

Ans. Permanent Magnets: The magnets prepared from ferromagnetic materials which retain their magnetic properties for a long time are called permanent magnets.

An efficient way to make a permanent magnet is to place a ferromagnetic rod in a solenoid and pass a current. The magnetic field of the solenoid magnetises the rod.

The materials used for permanent magnet must have the following characteristic properties:

(i) High retentivity so that the magnet may cause strong magnetic field.

(ii) High coercivity so that the magnetisation is not wiped out by strong external fields, mechanical ill-treatment and temperature changes. The loss due to hysteresis is immaterial because the magnet in this case is never put to cyclic changes.

Q. 2. Distinguish between diamagnetic and ferromagnetic materials in respect of their (i) intensity of magnetisation (ii) behaviour in non-uniform magnetic field and (iii) susceptibility.

Ans.

S. No.	S. No.	S. No.	Ferromagnetic
(i)	Intensity of magnetisation	Negative and very small	Positive and very large

(i)	Behaviour in non-uniform magnetic field	Attracted towards a region of weaker magnetic field	Attracted towards a region of stronger magnetic field.
(iii)	Susceptibility	Negative and small 0<χ<∈∈ small quantity.	Positive and large χ of the order of hundreds & thousands.

Q. 3. The horizontal component of earth's magnetic field at a given place is 0.4 × 10^{-4} Wb/m^2 and angle of dip is 30°. Calculate the value of (i) Vertical component (ii) Total intensity of earth's magnetic field.

Ans.

i. Given $H = 0.4 \times 10^{-4}$ Wb /m^2, θ = 30°

$$\tan\theta = \frac{V}{H} \Rightarrow \text{vertical component } V = H \tan\theta = 0.4 \times 10^{-4} \times \tan 30^\circ$$

$$= \frac{0.4\times10^{-4}}{\sqrt{3}} = 0.23 \times 10^{-4}\,\mathrm{Wb}/m^2$$

ii. Total intensity of earth's magnetic field

$$B_e = \sqrt{H^2 + V^2} = \sqrt{(0.4\times10^{-4})^2 + \left(\frac{0.4\times10^{-4}}{\sqrt{3}}\right)^2} = 0.46 \times 10^{-4}\,\mathrm{Wb}/m^2$$

Q. 4. The magnetic properties of the different materials A, B and C are shown in the following table:

Material	Permeability	Susceptibility	Temperature dependence of susceptibility
A	Low positive	Small but negative	Independent of temperature
B	High	Very high 1	Susceptibility decreases with temperature
C	Greater than 1	Small but positive	Decreases with temperature

Which of the above three materials should be used for making an electromagnet and why?

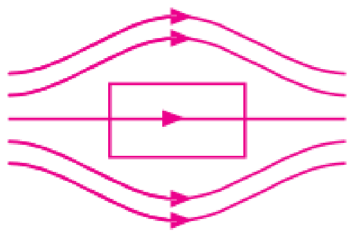
Ans. The material to be used for making an electromagnet should have high permerability and low retentivity. Moreover, less energy should be utilised for magnetisation of the material.

Thus, material B should be used for making the core of an electromagnet.

Q. 5. Draw diagrams to depict the behaviour of magnetic field lines near a 'bar' of:

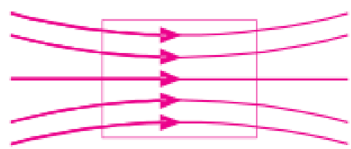
(i) Copper (ii) Aluminium (iii) Mercury, cooled to a very low temperature (4.2K

Ans. (i) Copper is diamagnetic.



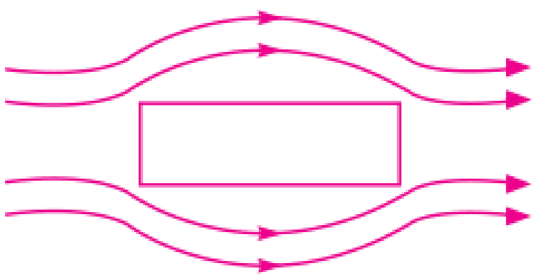
Magnetic field lines near copper bar

(ii) Aluminium is paramagnetic.



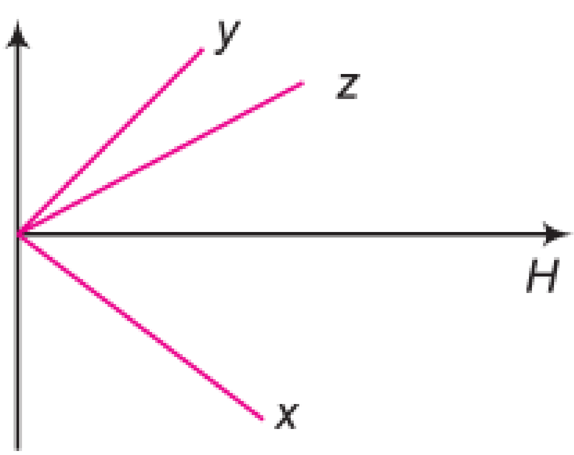
Magnetic field lines near aluminium bar

(iii) Mercury cooled to low temperature (4.2 K) is a super conductor. It behaves as a perfect diamagnetic, so no lines of force passes through it.



Mercury cooled to 4.2 K behaves as a diamagnet

Q. 6. The variation of intensity of magnetisation I and the applied magnetic field intensity H for three magnetic materials X, Y and Z are as shown in the given graphs.



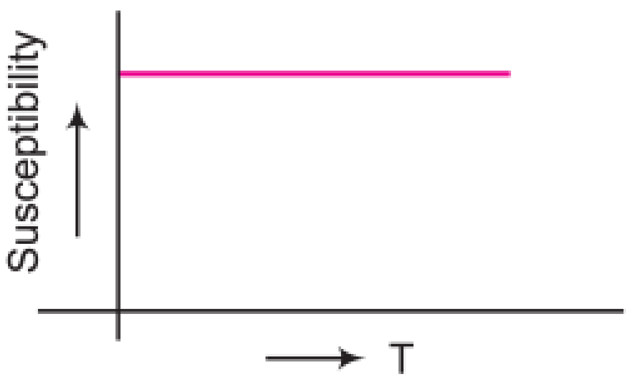
(i) Identify the materials X, Y and Z.

(ii) Show graphically the variation of susceptibility with temperature for X.

(iii) Put of Y and Z, which of the material will you prefer for making transformer cores and why?

Ans. (i) X — diamagnetic, Z — paramagnetic, Y — ferromagnetic

(ii) For X



(iii) Y will be preferred to be used in the transformer core because it has high permeability and low hysteresis loss.

Long Answer Questions

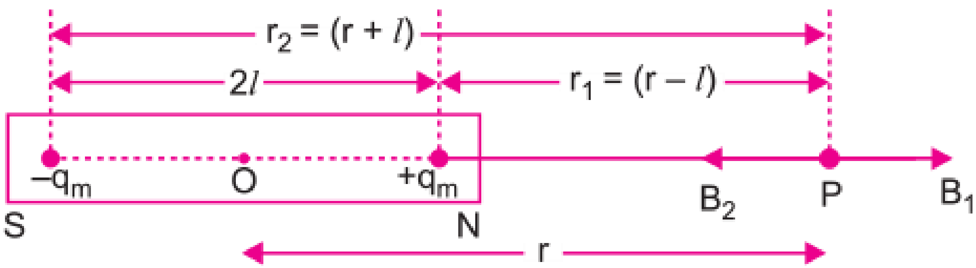
Q. 1. Derive an expression for magnetic field intensity due to a magnetic dipole at a point on its axial line. [5 marks]

Ans. Consider a magnetic dipole (or a bar magnet) SN of length 2l having South Pole at S and North Pole at N. The strength of south and north poles are – q_m and + q_m respectively.

Magnetic moment of magnetic dipole m = q_m 2l, its direction is from S to N.

Consider a point P on the axis of magnetic dipole at a distance r from mid-point O of dipole.

The distance of point P from N-pole,



r_1 = (r – l)

The distance of point P from S-pole, r_2 = (r + l)

Let B_1 and B_2 be the magnetic field intensities at point P due to north and south poles respectively. The directions of magnetic field due to North Pole is away from N-pole and due to South Pole is towards the S-pole. Therefore,

$$B_1 = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2} \text{ from } N \text{ to } P \text{ and } B_2 = \frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2} \text{ from } P \text{ to } S$$

Clearly, the directions of magnetic field strengths $\underset{B\,1}{\longrightarrow}$ and $\underset{B\,2}{\longrightarrow}$ are along the same line but opposite to each other and B_1>B_2.

Therefore, the resultant magnetic field intensity due to bar magnet has magnitude equal to the difference of B_1 and B_2 and direction from N to P.

$$i.e., \quad B = B_1 - B_2 = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2} - \frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}$$

$$= \frac{\mu_0}{4\pi} q_m \left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right] = \frac{\mu_0}{4\pi} q_m \left[\frac{(r+l)^2 - (r-l)^2}{(r^2 - l^2)^2}\right]$$

$$= \frac{\mu_0}{4\pi} q_m \left[\frac{4\,\mathrm{rl}}{(r^2 - l^2)^2}\right] = \frac{\mu_0}{4\pi}\frac{2(q_m 2l)r}{(r^2 - l^2)^2}$$

But $q_m\, 2l = m$ (magnetic dipole moment)

$$\therefore \; B = \frac{\mu_0}{4\pi}\frac{2m.r}{(r^2 - l^2)^2} \qquad \ldots(1)$$

If the bar magnet is very short and point P is far away from the magnet, the r >> l, therefore, equation (1) takes the form

$$B = \frac{\mu_0}{4\pi}\frac{2\,\mathrm{mr}}{r^4}$$

$$\text{or} \qquad \boxed{B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}} \qquad \ldots(2)$$

This is expression for magnetic field intensity at axial position due to a short bar magnet.

Q. 2. Derive an expression for magnetic field intensity due to a magnetic dipole at a point lies on its equatorial line.

Ans. Consider a point P on equatorial position (or broad side on position) of short bar magnet of length 2l, having north pole (N) and south pole (S) of strength $+q_m$ and $-q_m$ respectively. The distance of point P from the mid-point (O) of magnet is r. Let B_1 and B_2 be the magnetic field intensities due to north and south poles respectively. NP = SP $=\sqrt{r^2 + l^2}$.

$$\overrightarrow{B}_1 = \frac{\mu_0}{4\pi}\frac{q_m}{r^2+l^2} \text{along } N \text{ to } P$$

$$\overrightarrow{B}_2 = \frac{\mu_0}{4\pi}\frac{q_m}{r^2+l^2} \quad \text{along } P \text{ to } S$$

Clearly, magnitudes of and are equal

$$i.e., |\overrightarrow{B}_1| = \overrightarrow{B}_2| \qquad \text{or} \qquad B_1 = B_2$$

To find the resultant of $\underset{B1}{\rightarrow}$ and $\underset{B2}{\rightarrow}$ we resolve them along and perpendicular to magnetic axis SN. Components $\underset{B1}{\rightarrow}$ of along and perpendicular to magnetic axis are $B_1 \cos \theta$ and $B_2 \sin \theta$ respectively.

Components of $\underset{B2}{\rightarrow}$ along and perpendicular to magnetic axis are B2 cos θ and B2 sin θ respectively. Clearly, components of and perpendicular to axis SN. B1 sin θ and B2 sin θ are equal in magnitude and opposite in direction and hence, cancel each other; while the components of $\underset{B1}{\rightarrow}$ and $\underset{B2}{\rightarrow}$ along the axis are in the same direction and hence, add up to give to resultant magnetic field parallel to the direction $\underset{NS}{\rightarrow}$.

∴ Resultant magnetic field intensity at P.

$B = B_1 \cos \theta + B_2 \cos \theta$

$$\text{But } B_1 = B_2 = \frac{\mu_0}{4\pi}\frac{q_m}{r^2+l^2}$$

$$\text{and } \cos \theta = \frac{\text{ON}}{\text{PN}} = \frac{1}{\sqrt{r^2+l^2}} = \frac{l}{(r^2+l^2)^{1/2}}$$

$$\therefore \quad B = 2B_1 \cos\theta = 2 \times \frac{\mu_0}{4\pi}\frac{q_m}{(r^2+l^2)} \times \frac{l}{(r^2+l^2)^{1/2}} = \frac{\mu_0}{4\pi}\frac{2q_m l}{(r^2+l^2)^{3/2}}$$

But $q_m.2l = m$, magnetic moment of magnet

$$\therefore \qquad B = \frac{\mu_0}{4\pi}\frac{m}{(r^2+l^2)^{3/2}} \qquad \ldots(3)$$

If the magnet is very short and point P is far away, we have l<<r; so l2 may be neglected as compared to r^2 and so equation (3) takes the form

$$B = \frac{\mu_0}{4\pi}\frac{m}{r^3} \qquad \ldots(4)$$

This is expression for magnetic field intensity at equatorial position of the magnet.

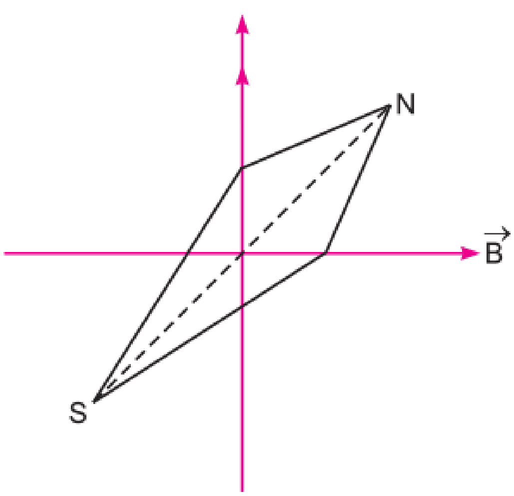
It is clear from equations (2) and (4) that the magnetic field strength due to a short magnetic dipole is inversely proportional to the cube of its distance from the centre of the dipole and the magnetic field intensity at axial position is twice that at equatorial position for the same distance.

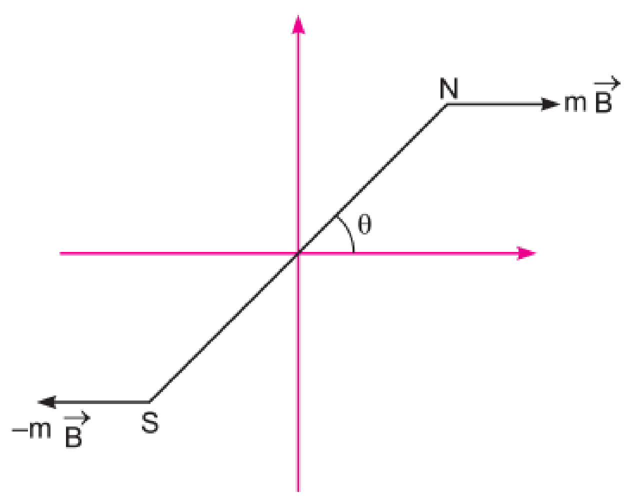
Q. 3. Answer the following the questions.

(i) 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.

(ii) 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.

Ans. (i) If magnetic compass of dipole moment $\vec{m}$ is placed at angle θ in uniform magnetic field, and released it experiences a restoring torque.





$\vec{\tau} = -$ magnetic force × perpendicular distance

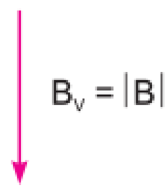
$= -|mB| \,.\, (2a \sin \theta)$, $\vec{\tau} = -\vec{m} \times \vec{B}$

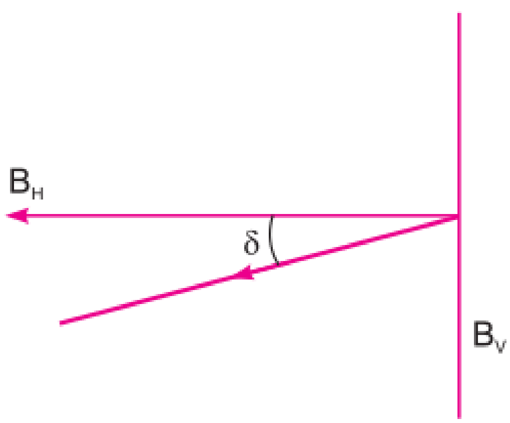
$|\tau| = -m\,|B|.\sin\theta$, where m = pole strength

In equilibrium, the equation of motion,

$$\Rightarrow I\frac{d^2\theta}{dt^2} = -|m||B|\theta \text{ (For small angle sin)}$$

$$\Rightarrow \frac{d^2\theta}{dt^2} = -\frac{|m||B|}{I}\theta \Rightarrow \frac{d^2\theta}{dt^2} = -\left(\frac{mB}{I}\right)\theta$$





Since $\frac{d^2\theta}{dt^2} \propto \theta$

It represents the simple harmonic motion with angular frequency

$$\omega^2 = \frac{|m|B|}{I} \Rightarrow T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{mB}}$$