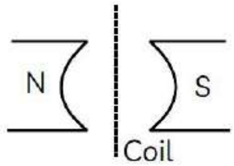
PRACTICE PAPER 05
CHAPTER 05 MAGNETISM AND MATTER

SUBJECT: PHYSICS **MAX. MARKS : 40**
CLASS : XII **DURATION : 1½ hrs**

General Instructions:
(i). **All** questions are compulsory.
(ii). This question paper contains 2**0** questions divided into five Sections A, B, C, D and E.
(iii). **Section A** comprises of **10 MCQs** of **1 mark** each. **Section B** comprises of 4 questions of **2 marks** each. **Section C** comprises of 3 questions of **3 marks** each. **Section D** comprises of 1 question of **5 marks** each and **Section E** comprises of 2 Case Study Based Questions of **4 marks** each.
(iv). There is no overall choice.
(v). Use of Calculators is not permitted

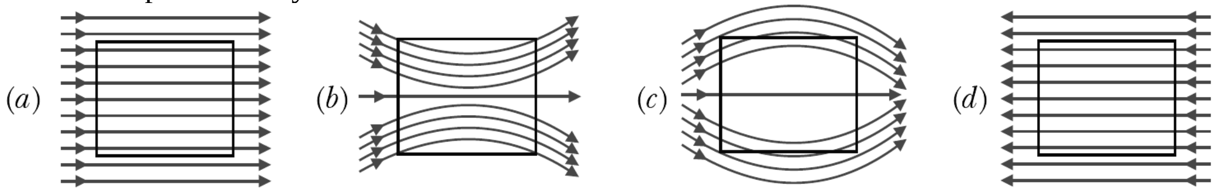
SECTION – A
Questions 1 to 10 carry 1 mark each.

1. The figure below shows the North and South poles of a permanent magnet in which n turn coil of area of cross – section A is resting, such that for a current I passed through the coil, the plane of the coil makes an angle θ with respect to the direction of magnetic field B. If the plane of the magnetic field B.
The torque on the coil will be.



(a) τ = nIAB cosθ
(b) τ = nIAB sinθ
(c) τ = nIAB
(d) None of the above, since the magnetic field is radial

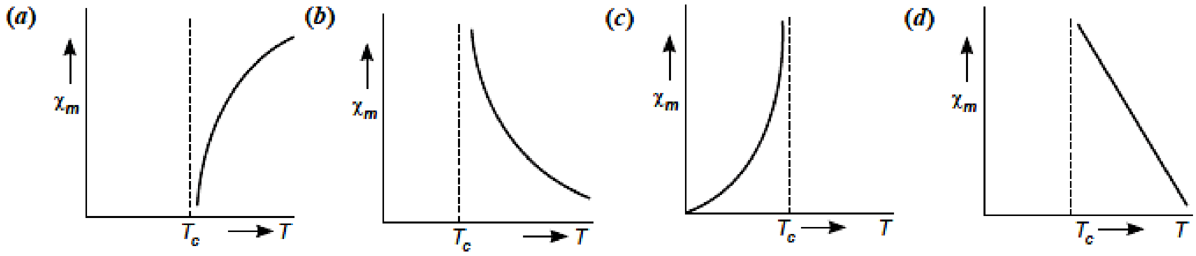
2. A uniform magnetic field exists in space in the plane of paper and is initially directed from left to right. When a bar of soft iron is placed in the field parallel to it, the lines of force passing through it will be represented by



3. A magnetic dipole moment of a bar magnet is a vector quantity directed:
(a) upward at perpendicular bisector to the line joining to north pole and south pole
(b) from North pole to South pole
(c) downward at perpendicular bisector to the line joining to north pole and south pole
(d) from South pole to North pole

4. A toroid of n turns, mean radius R and cross-sectional radius a carries current I. It is placed on a horizontal table taken as x-y plane. Its magnetic moment m
(a) is non-zero and points in the z-direction by symmetry.
(b) points along the axis of the tortoid (m = mφ).
(c) is zero, otherwise there would be a field falling at $\frac{1}{r^3}$ large distances outside the toroid.
(d) is pointing radially outwards.

5. The variation of magnetic susceptibility with the temperature of a ferromagnetic material can be plotted as



6. 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.
(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 does not diminishes.

7. A magnet of dipole moment M is aligned in equilibrium position in a magnetic field of intensity B. The work done to rotate it through an angle θ with the magnetic field is
(a) MB sin θ (b) MB cos θ (c) MB (1 – cos θ) (d) MB (1 – sin θ)

8. A magnetic needle suspended parallel to a magnetic field requires √3 J of work to turn it through 60°. The torque needed to maintain the needle in this position will be
(a) 2 √3 J (b) 3 J (c) √3 J (d) $\frac{3}{2}$ J

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** The poles of magnet cannot be separated by breaking into two pieces.
Reason (R): The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

10. **Assertion (A):** The ferromagnetic substances do not obey Curie's law.
Reason (R): At Curie point a ferromagnetic substance start behaving as a paramagnetic substance.

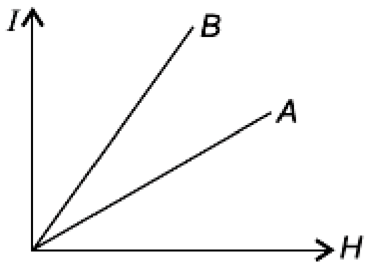
SECTION – B

Questions 11 to 14 carry 2 marks each.

11. 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?

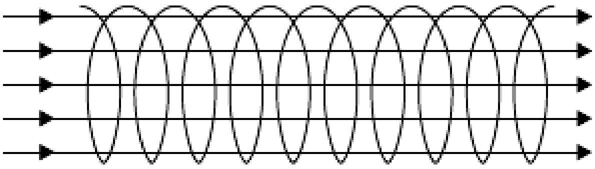
12. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?

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

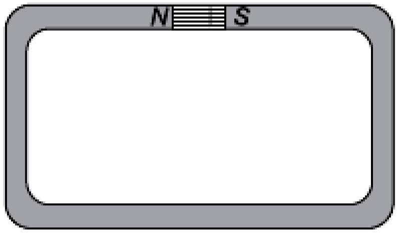


(a) Identify the materials *A* and *B*.
(b) Why does the material *B*, have a larger susceptibility than *A*, for a given field at constant temperature?

14. The diagrams given in the figure (a) and (b) show magnetic field lines (thick lines in the figure) wrongly. Point out what is wrong with them. Some of them may describe electrostatic field lines correctly. Point out which ones.



(*a*)

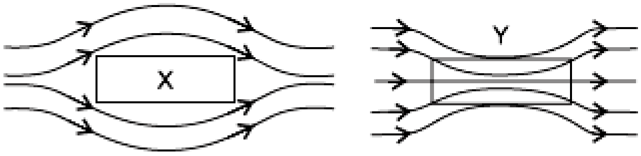


(*b*)

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. (i) A uniform magnetic field gets modified as shown below when two specimens X and Y are placed in it. Identify whether specimens X and Y are diamagnetic, paramagnetic or ferromagnetic.

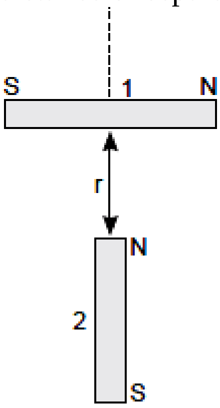


(ii) How is the magnetic permeability of specimen X different from that of specimen Y?

OR

Define the term magnetic permeability of a magnetic material. Write any two characteristics of a magnetic substance if it is to be used to make a permanent magnet. Give an example of such a material.

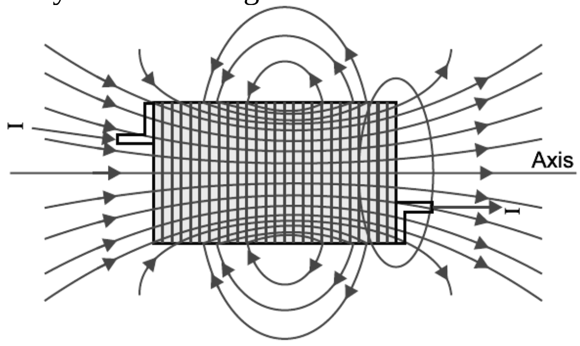
16. Two identical magnetic dipoles each of magnetic dipole moment 2 Am^2 are placed with their axes perpendicular to each other with a distance of separation being r = 2 m between them.



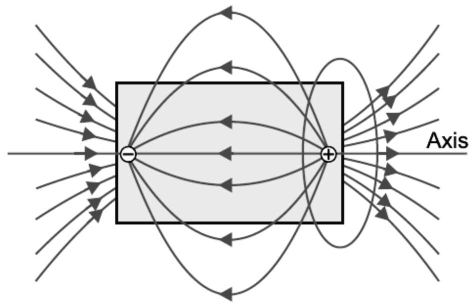
Find the magnetic field at the point that is midway along the distance of separation between the two dipoles.

OR

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?



Field lines of a current carrying solenoid



Field lines of an electric dipole

17. A short bar magnet of magnetic moment 0.9 J/T is placed with its axis at 30° to a uniform magnetic field. It experiences a torque of 0.063 J.
(i) Calculate the magnitude of the magnetic field.
(ii) In which orientation will the bar magnet be in stable equilibrium in the magnetic field?

SECTION – D

Questions 18 carry 5 marks.

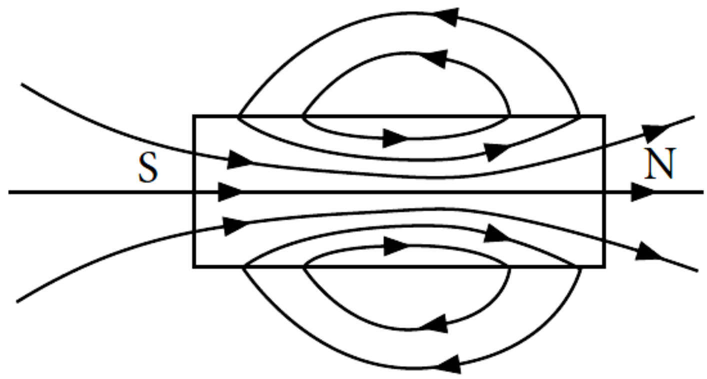
18. Derive an expression for magnetic field intensity due to a magnetic dipole at a point on its axial line.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. Gauss's Law for Magnetism

By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as $\oint \vec{B}.\vec{ds} = \mu_0 m_{inside}$ where $\oint \vec{B}.\vec{ds}$ is the magnetic flux and m_{inside} is the net pole strength inside the closed surface. We do not have an isolated magnetic pole in nature. At least none has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



(i) Consider the two idealised systems
(I) a parallel plate capacitor with large plates and small separation and
(II) a long solenoid of length L >> R, radius of cross-section.

In (I) $\vec{E}$ is ideally treated as a constant between plates and zero outside. In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below
(a) case (I) contradicts Gauss's law for electrostatic fields.
(b) case (II) contradicts Gauss's law for magnetic fields.
(c) case (I) agrees with $\oint \vec{E}.\vec{dl} = 0$.
(d) case (II) contradicts $\oint \vec{H}.\vec{dl} = I_{en}$.

(ii) The net magnetic flux through any closed surface, kept in a magnetic field is
(a) zero (b) $\mu_0/4\pi$ (c) $4\pi\mu_0$ (d) $4\mu_0/\pi$

(iii) A closed surface S encloses a magnetic dipole of magnetic moment 2ml. The magnetic flux emerging from the surface is
(a) $\mu_0 m$ (b) zero (c) $2\mu_0 m$ (d) $2m/\mu_0$

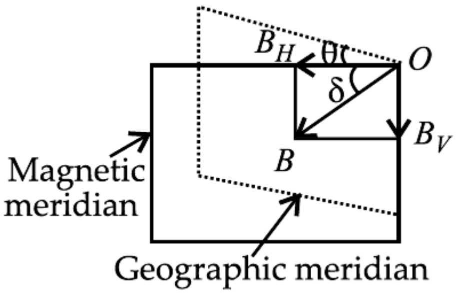
(iv) Which of the following is not a consequence of Gauss's law?
(a) The magnetic poles always exist as unlike pairs of equal strength.
(b) If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface.
(c) There are abundant sources or sinks of the magnetic field inside a closed surface.
(d) Isolated magnetic poles do not exist.

OR

(v) The surface integral of a magnetic field over a surface
(a) is proportional to mass enclosed (b) is proportional to charge enclosed
(c) is zero (d) equal to its magnetic flux through that surface.

20. Elements of the Earth's Magnetic Field

The earth's magnetic field at a point on its surface is usually characterised by three quantities: (a) declination (b) inclination or dip and (c) horizontal component of the field. These are known as the elements of the earth's magnetic field. At a place, angle between geographic meridian and magnetic meridian is defined as magnetic declination, whereas angle made by the earth's magnetic field with the horizontal in magnetic meridian is known as magnetic dip.



(i) In a certain place, the horizontal component of magnetic field is $1/\sqrt{3}$ times the vertical component. The angle of dip at this place is
(a) zero (b) $\pi/3$ (c) $\pi/2$ (d) $\pi/6$

(ii) The angle between the true geographic north and the north shown by a compass needle is called as
(a) inclination (b) magnetic declination (c) angle of meridian (d) magnetic pole.

(iii) The angles of dip at the poles and the equator respectively are
(a) 30°, 60° (b) 0°, 90° (c) 45°, 90° (d) 90°, 0°

(iv) A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It

(a) will become rigid showing no movement
(b) will stay in any position
(c) will stay in north-south direction only
(d) will stay in east-west direction only.

OR

(v) Select the correct statement from the following.
(a) The magnetic dip is zero at the centre of the earth.
(b) Magnetic dip decreases as we move away from the equator towards the magnetic pole.
(c) Magnetic dip increases as we move away from the equator towards the magnetic pole.
(d) Magnetic dip does not vary from place to place.

PRACTICE PAPER 05
CHAPTER 05 MAGNETISM AND MATTER
(ANSWERS)

SUBJECT: PHYSICS | **MAX. MARKS : 40**
CLASS : XII | **DURATION : 1½ hrs**

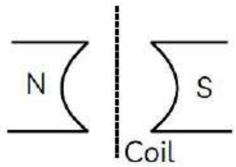
General Instructions:

(i). **All** questions are compulsory.
(ii). This question paper contains 20 questions divided into five Sections A, B, C, D and E.
(iii). **Section A** comprises of **10 MCQs** of **1 mark** each. **Section B** comprises of 4 questions of **2 marks** each. **Section C** comprises of 3 questions of **3 marks** each. **Section D** comprises of 1 question of **5 marks** each and **Section E** comprises of 2 Case Study Based Questions of **4 marks** each.
(iv). There is no overall choice.
(v). Use of Calculators is not permitted

SECTION – A

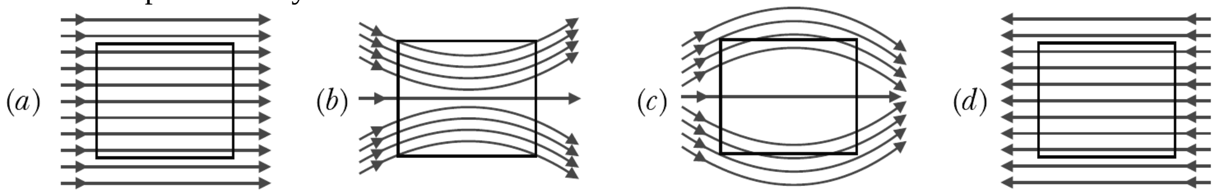
Questions 1 to 10 carry 1 mark each.

1. The figure below shows the North and South poles of a permanent magnet in which n turn coil of area of cross – section A is resting, such that for a current I passed through the coil, the plane of the coil makes an angle θ with respect to the direction of magnetic field B. If the plane of the magnetic field B.



The torque on the coil will be.
(a) $\tau = nIAB \cos\theta$
(b) $\tau = nIAB \sin\theta$
(c) $\tau = nIAB$
(d) None of the above, since the magnetic field is radial
Ans. (a) $\tau = nIAB \cos\theta$
Plane of coil makes an angle q with the magnetic field.
i.e., The magnetic dipole moment of the coil will make an angle (90° – θ) with the direction of magnetic field.
$\tau = MB \sin(90 - \theta)$
$\Rightarrow \tau = nIAB\cos\theta$ [As $M = nIA$]

2. 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



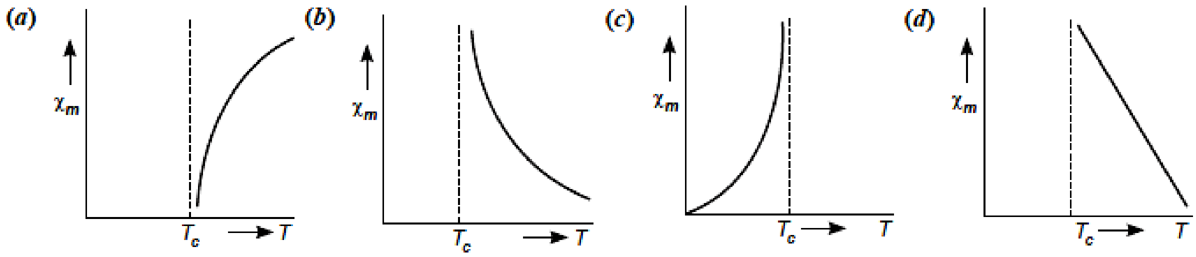
Ans. (b)
Permeability of soft iron is maximum, so maximum lines of force tries to pass through the soft iron.

3. A magnetic dipole moment of a bar magnet is a vector quantity directed:
(a) upward at perpendicular bisector to the line joining to north pole and south pole
(b) from North pole to South pole

(c) downward at perpendicular bisector to the line joining to north pole and south pole
(d) from South pole to North pole
Ans. (d) from South pole to North pole
The magnetic dipole moment is a vector quantity with direction perpendicular to the current loop in the right-hand-rule direction. From south pole to north pole of a bar magnet. The direction of magnetic dipole moment is from south pole to north pole of a bar magnet.

4. A toroid of n turns, mean radius R and cross-sectional radius a carries current I. It is placed on a horizontal table taken as x-y plane. Its magnetic moment m
(a) is non-zero and points in the z-direction by symmetry.
(b) points along the axis of the tortoid ($m = m\varphi$).
(c) is zero, otherwise there would be a field falling at $\frac{1}{r^3}$ large distances outside the toroid.
(d) is pointing radially outwards.
Ans. (c) is zero, otherwise there would be a field falling at $\frac{1}{r^3}$ large distances outside the toroid.
For any point inside the empty space surrounded by toroid and outside the toroid, the magnetic field B is zero because the net current enclosed in these spaces is zero.

5. The variation of magnetic susceptibility with the temperature of a ferromagnetic material can be plotted as



Ans. (b)
Since susceptibility (χ_m) of ferromagnetic material decreases with increase in temperature and above curie temperature T_c, it becomes paramagnetic.

6. 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.
(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 does not diminishes.
Ans. (a) The H field in the solenoid is (nearly) unchanged but the B field decreases drastically.
At normal temperature, a solenoid behaves as a ferromagnetic substance and at the temperature beyond the Curie temperature, it behaves as a paramagnetic substance.

7. A magnet of dipole moment M is aligned in equilibrium position in a magnetic field of intensity B. The work done to rotate it through an angle θ with the magnetic field is
(a) MB sin θ (b) MB cos θ (c) MB (1 – cos θ) (d) MB (1 – sin θ)
Ans. (c) MB (1 – cos θ)
At equilibrium position $\theta = 0$,

$$\text{Work done, } W = \int_0^{\theta} MB \sin\theta \, d\theta = MB(1 - \sin\theta)$$

8. A magnetic needle suspended parallel to a magnetic field requires √3 J of work to turn it through 60°. The torque needed to maintain the needle in this position will be

(a) $2\sqrt{3}$ J (b) 3 J (c) $\sqrt{3}$ J (d) $\frac{3}{2}$ J

Ans. (b) 3 J

Since, $W = -MB(\cos\theta_2 - \cos\theta_1) = -MB(\cos 60° - \cos 0°) = \frac{MB}{2} \Rightarrow MB = 2W$

Torque on the needle, $\tau = MB\sin\theta = MB\sin 60° = \frac{MB\sqrt{3}}{2} = \frac{2W\sqrt{3}}{2} = W\sqrt{3} = \sqrt{3}\,.\,\sqrt{3} = 3J$

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** The poles of magnet cannot be separated by breaking into two pieces.
Reason (R): The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.
Ans. (b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
As we know every atom of a magnet acts as a dipole, so poles cannot be separated. When magnet is broken into two equal pieces, magnetic moment of each part wiil be half of the original magnet.

10. Assertion (A): The ferromagnetic substances do not obey Curie's law.
Reason (R): At Curie point a ferromagnetic substance start behaving as a paramagnetic substance.
Ans. (b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
The susceptibility of ferromagnetic substance decreases with the rise of temperature in a complicated manner. After Curie point the susceptibility ferromagnetic substance varies inversely with its absolute temperature.

SECTION – B

Questions 11 to 14 carry 2 marks each.

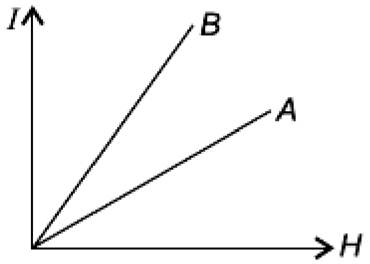
11. Explain the following:
(i) Why do magnetic lines of force form continuous closed loops?
(ii) Why are the field lines repelled (expelled) when a diamagnetic material is placed in an external uniform magnetic field?
Ans. (i) Magnetic lines of force form continuous closed loops because a magnet is always 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.

12. 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 is the ratio of the intensity of magnetisation (I) produced in the material to the intensity of magnetising field (H).

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

Positive susceptibility: paramagnetic material e.g. Al, Ca.
Negative susceptibility: diamagnetic material e.g. Bi, Cu.
The negative susceptibility signifies that the material is diamagnetic in nature.

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

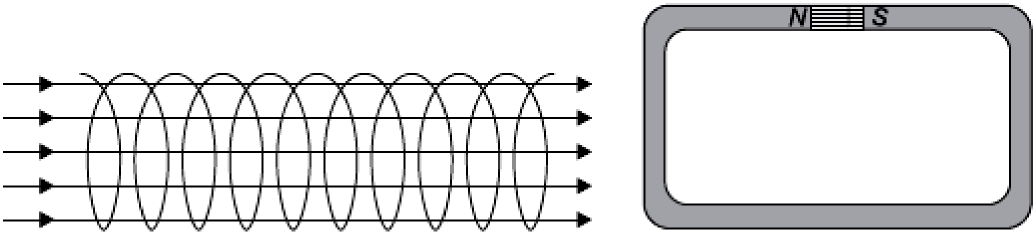


(a) Identify the materials *A* and *B*.
(b) Why does the material *B*, have a larger susceptibility than *A*, for a given field at constant temperature?

Ans. (a) As $\chi_m = \frac{I}{H}$

The slope of the line gives the magnetic susceptibilities.
For the magnetic material *B*, it is giving higher positive (+ve) value. So, the material is ferromagnetic.
For the magnetic material *A*, the slope is positive (+ve) and lesser than that for *B*. So, the material is paramagnetic.
(b) The larger susceptibility is due to a characteristic, i.e. 'domain structure'. The more number of magnetic moments get aligned in the direction of magnetising field in comparison to that for the paramagnetic materials for the same value of magnetising field.

14. The diagrams given in the figure (a) and (b) show magnetic field lines (thick lines in the figure) wrongly. Point out what is wrong with them. Some of them may describe electrostatic field lines correctly. Point out which ones.



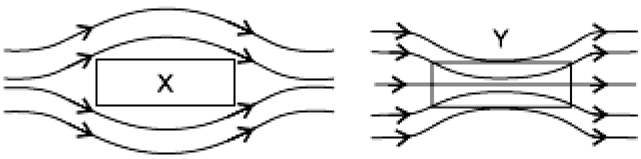
(a) (b)

Ans. (a) Wrong. The lines should curve out at both ends, and meet eventually to form closed loops otherwise, it will violate the Ampere's circuital law.
(b) Wrong. Magnetic field lines between two pole pieces cannot be precisely straight at the ends. Some fringing of lines is inevitable. Otherwise, Ampere's law is violated. This is also true for electric field lines.

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. (i) A uniform magnetic field gets modified as shown below when two specimens X and Y are placed in it. Identify whether specimens X and Y are diamagnetic, paramagnetic or ferromagnetic.



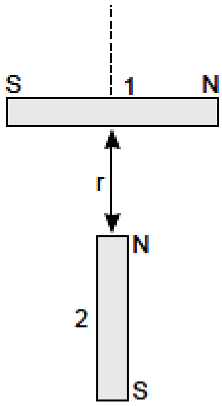
(ii) How is the magnetic permeability of specimen X different from that of specimen Y?

Ans. (i) X→ Expulsion of field. So, it is diamagnetic.
Y→ Field is pulled in. So, it is ferromagnetic.
(ii) The magnetic permeability of X is less than 1 and that of Y is very much greater than 1.

OR

Define the term magnetic permeability of a magnetic material. Write any two characteristics of a magnetic substance if it is to be used to make a permanent magnet. Give an example of such a material.
Ans. Magnetic permeability: It is a measure of the extent to which magnetic field influence can pass through a material.
The following are the characteristics:
(i) Material should have high retentivity.
(ii) Material should have high coercivity.
(iii) Material should have high permeability. (any two)
A suitable material for permanent magnet is alnico steel.

16. Two identical magnetic dipoles each of magnetic dipole moment 2 Am^2 are placed with their axes perpendicular to each other with a distance of separation being r = 2 m between them.



Find the magnetic field at the point that is midway along the distance of separation between the two dipoles.

Ans. Magnetic field due to magnetic dipole 1 at point O (midway along r) (along the equatorial line)

$$B_1 = \frac{\mu_0}{4\pi}\frac{2m}{(r/2)^2}$$

Magnetic field due to magnetic dipole 2 at point O (midway along r) (along the axial line)

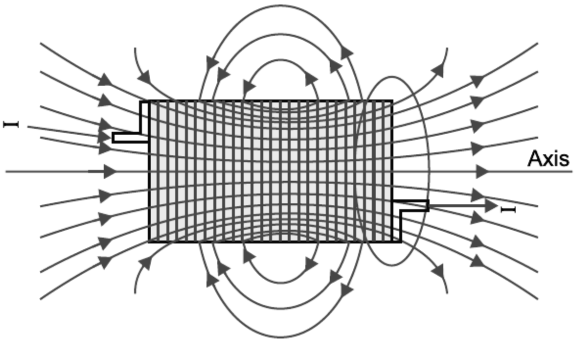
$$B_2 = \frac{\mu_0}{4\pi}\frac{m}{(r/2)^2}$$

Net magnetic field at the point: (B_1 and B_2 are perpendicular to each other)

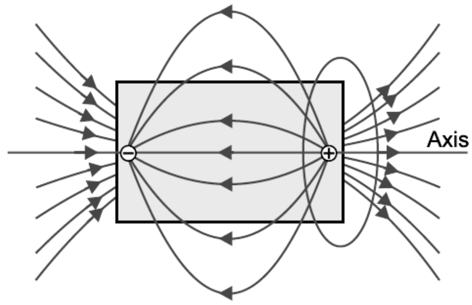
$$B = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0}{4\pi} m\sqrt{5} = 2\sqrt{5}\times 10^{-7} T$$

OR

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?



Field lines of a current carrying solenoid



Field lines of an electric dipole

Ans. (i) Difference: Field lines of a solenoid form continuous current loops, while in the case of an electric dipole the field lines begin from a positive charge and end on a negative charge or scape to infinity.
(ii) Two magnetic field lines cannot intersect because at the point of intersection, there will be two directions of magnetic field which is impossible.

17. A short bar magnet of magnetic moment 0.9 J/T is placed with its axis at 30° to a uniform magnetic field. It experiences a torque of 0.063 J.
(i) Calculate the magnitude of the magnetic field.
(ii) In which orientation will the bar magnet be in stable equilibrium in the magnetic field?
Ans. (i) We know that $\tau = MB\sin\theta$
Magnitude of the magnetic field is calculated as

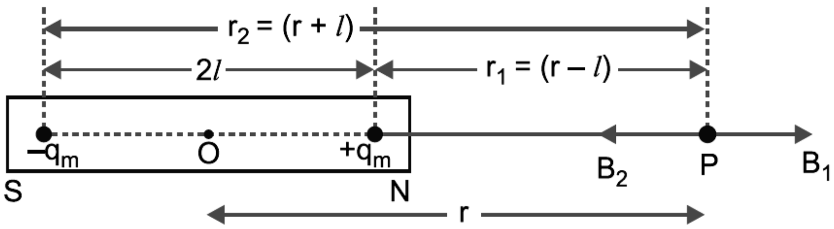
$$B = \frac{\tau}{M\sin\theta} = \frac{0.063}{0.9\times\sin 30^0} = \frac{0.063}{0.9\times 0.5} = 0.14T$$

(ii) When the magnetic moment vector and the magnetic field vectors are in the same direction, i.e. $\theta = 0°$
It's so because this configuration corresponds to a minimum energy.
$U = -MB$

SECTION – D

Questions 18 carry 5 marks.

18. Derive an expression for magnetic field intensity due to a magnetic dipole at a point on its axial line.
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,

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

Clearly, the directions of magnetic field strengths B1 and B2 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. $B = B_1 - B_2 = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2} - \frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}$

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

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

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

$$\therefore\ B = \frac{\mu_0}{4\pi}\frac{2mr}{(r^2-l^2)^2}$$

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

$$B = \frac{\mu_0}{4\pi}\frac{2mr}{(r^2)^2} = \frac{\mu_0}{4\pi}\frac{2mr}{r^4} \Rightarrow \boxed{B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}}$$

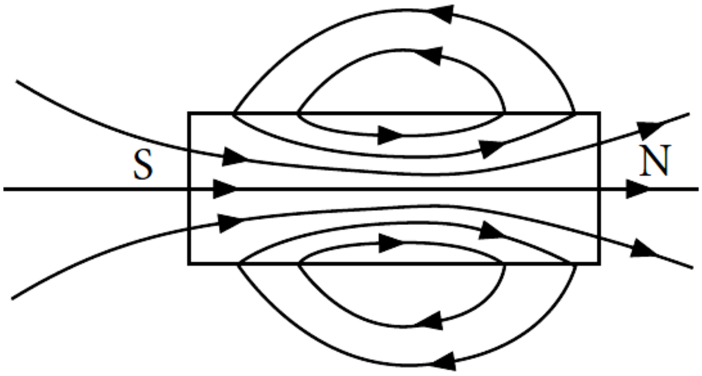
This is the expression for magnetic field intensity at axial position due to a short bar magnet.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. Gauss's Law for Magnetism

By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as $\oint \vec{B}.\vec{ds} = \mu_0\, m_{inside}$ where $\oint \vec{B}.\vec{ds}$ is the magnetic flux and m_{inside} is the net pole strength inside the closed surface. We do not have an isolated magnetic pole in nature. At least none has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



(i) Consider the two idealised systems
(I) a parallel plate capacitor with large plates and small separation and
(II) a long solenoid of length L >> R, radius of cross-section.

In (I) $\vec{E}$ is ideally treated as a constant between plates and zero outside. In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below

(a) case (I) contradicts Gauss's law for electrostatic fields.
(b) case (II) contradicts Gauss's law for magnetic fields.
(c) case (I) agrees with $\oint \vec{E}.\vec{dl} = 0$.
(d) case (II) contradicts $\oint \vec{H}.\vec{dl} = I_{en}$.

(ii) The net magnetic flux through any closed surface, kept in a magnetic field is
(a) zero (b) $\mu_0/4\pi$ (c) $4\pi\mu_0$ (d) $4\mu_0/\pi$

(iii) A closed surface S encloses a magnetic dipole of magnetic moment 2ml. The magnetic flux emerging from the surface is
(a) $\mu_0 m$ (b) zero (c) $2\mu_0 m$ (d) $2m/\mu_0$

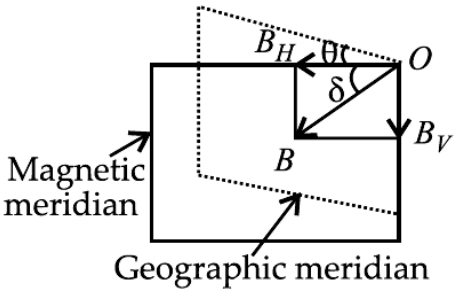
(iv) Which of the following is not a consequence of Gauss's law?
(a) The magnetic poles always exist as unlike pairs of equal strength.
(b) If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface.
(c) There are abundant sources or sinks of the magnetic field inside a closed surface.
(d) Isolated magnetic poles do not exist.

OR

(v) The surface integral of a magnetic field over a surface
(a) is proportional to mass enclosed (b) is proportional to charge enclosed
(c) is zero (d) equal to its magnetic flux through that surface.
Ans. (i) (b) case (II) contradicts Gauss's law for magnetic fields.
According to Gauss's law in magnetism $\oint \vec{B}.\vec{ds} = 0$, which implies that number of magnetic field lines entering the Gaussian surface is equal to the number of magnetic field lines leaving it. Therefore, case (ii) is not possible.
(ii) (a) zero
The net magnetic flux through a closed surface will be zero, i.e. $\oint \vec{B}.\vec{ds} = 0$, because there are no magnetic monopoles.
(iii) (b) zero
(iv) (c) There are abundant sources or sinks of the magnetic field inside a closed surface.
Gauss's law indicates that there are no sources or sinks of the magnetic field inside a closed surface. In other words, there are no free magnetic charges.
(v) (d) equal to its magnetic flux through that surface.
The surface integral of a magnetic field over a surface gives magnetic flux through that surface.

20. Elements of the Earth's Magnetic Field

The earth's magnetic field at a point on its surface is usually characterised by three quantities: (a) declination (b) inclination or dip and (c) horizontal component of the field. These are known as the elements of the earth's magnetic field. At a place, angle between geographic meridian and magnetic meridian is defined as magnetic declination, whereas angle made by the earth's magnetic field with the horizontal in magnetic meridian is known as magnetic dip.



(i) In a certain place, the horizontal component of magnetic field is $1/\sqrt{3}$ times the vertical component. The angle of dip at this place is
(a) zero (b) $\pi/3$ (c) $\pi/2$ (d) $\pi/6$

(ii) The angle between the true geographic north and the north shown by a compass needle is called as
(a) inclination (b) magnetic declination (c) angle of meridian (d) magnetic pole.

(iii) The angles of dip at the poles and the equator respectively are
(a) 30°, 60° (b) 0°, 90° (c) 45°, 90° (d) 90°, 0°

(iv) A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It
(a) will become rigid showing no movement
(b) will stay in any position
(c) will stay in north-south direction only
(d) will stay in east-west direction only.

OR

(v) Select the correct statement from the following.
(a) The magnetic dip is zero at the centre of the earth.
(b) Magnetic dip decreases as we move away from the equator towards the magnetic pole.
(c) Magnetic dip increases as we move away from the equator towards the magnetic pole.
(d) Magnetic dip does not vary from place to place.

Ans. (i) (b) $\pi/3$

$$\tan\theta = \frac{B_V}{B_H} \text{ and } B_H = \frac{B_V}{\sqrt{3}}$$

$$\therefore \tan\theta = \sqrt{3} = \tan\frac{\pi}{3} \Rightarrow \theta = \frac{\pi}{3}$$

(ii) (b) magnetic declination
The angle between the true geographic north and the north shown by a compass needle is called as magnetic declination or simply declination.
(iii) (d) 90°, 0°
Since angle of dip at a place is defined as the angle δ, which is the direction of total intensity of earth's magnetic field B makes with a horizontal line in magnetic meridian,
At poles $B = B_V$ and $B_V = B \sin\delta$
$\therefore \sin\delta = 1 \Rightarrow \delta = 90°$
At equator $B = B_H$ and $B_H = B\cos\delta$
$\therefore \cos\delta = 1 \Rightarrow \delta = 0°$.
(iv) (a) will become rigid showing no movement
A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It will stay in any position as the horizontal component of earth's magnetic field becomes zero at the geomagnetic pole.
(v) (c) Magnetic dip increases as we move away from the equator towards the magnetic pole.
At equator, $\delta = 0°$
At poles, $\delta = 90°$
$\therefore$ δ increases as we move from equator towards poles.