Chapter 12: Magnetism

EXERCISES [PAGES 227 - 288]

Exercises | Q 1. (i) | Page 227

Choose the correct option.
Let r be the distance of a point on the axis of a bar magnet from its center. The magnetic field at r is always proportional to

$\frac{1}{r^2}$

$\frac{1}{r^3}$

$\frac{1}{r}$

not necessarily $\frac{1}{r^3}$ at all points

SOLUTION

Let r be the distance of a point on the axis of a bar magnet from its center. The magnetic field at r is always proportional to $1/r^3$

Exercises | Q 1. (ii) | Page 227
Choose the correct option.
Magnetic meridian is the plane

1. perpendicular to the magnetic axis of Earth
2. perpendicular to geographic axis of Earth
3. **passing through the magnetic axis of Earth**
4. passing through the geographic axis

SOLUTION

Magnetic meridian is the plane **passing through the magnetic axis of Earth**.

Exercises | Q 1. (iii) | Page 227
Choose the correct option.
The horizontal and vertical component of magnetic field of Earth are same at someplace on the surface of Earth. The magnetic dip angle at this place will be

1. 30°
2. **45°**
3. 0°
4. 90°

SOLUTION

45°

Explanation:

$$\frac{B_v}{B_H} = \tan\Phi$$

$\therefore \tan\Phi = 1 \Rightarrow \Phi = 45°$

Exercises | Q 1. (iv) | Page 228

Choose the correct option.

Inside a bar magnet, the magnetic field lines

1. are not present
2. are parallel to the cross-sectional area of the magnet
3. are in the direction from N pole to S pole
4. **are in the direction from S pole to N pole**

SOLUTION

Inside a bar magnet, the magnetic field lines **are in the direction from S pole to N pole**.

Exercises | Q 1. (v) | Page 228

Choose the correct option.

A place where the vertical components of Earth's magnetic field is zero has the angle of dip equal to

1. **0°**
2. 45°
3. 60°
4. 90°

SOLUTION

0°

Explanation:

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

As, $B_V = 0$, $\tan\Phi = 0 \Rightarrow \Phi = 0°$

Exercises | Q 1. (vi) | Page 228

Choose the correct option.

A place where the horizontal component of Earth's magnetic field is zero lies at

1. geographic equator
2. geomagnetic equator
3. one of the geographic poles
4. **one of the geomagnetic poles**

SOLUTION

A place where the horizontal component of Earth's magnetic field is zero lies at **one of the geomagnetic poles**.

Exercises | Q 1. (vii) | Page 228

Choose the correct option.

A magnetic needle kept nonparallel to the magnetic field in a nonuniform magnetic field experiences

1. a force but not a torque
2. a torque but not a force
3. **both a force and a torque**
4. neither force nor a torque

SOLUTION

Both a force and a torque

Exercises | Q 2. (i) | Page 228

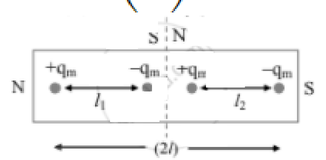
Answer the following question in brief.

What happens if a bar magnet is cut into two pieces transverse to its length/along its length?

SOLUTION

1. When a magnet is cut into two pieces, then each piece behaves like an independent magnet.
2. When a bar magnet is cut transverse to its length, the two pieces generated will behave as independent magnets of reduced magnetic length. However, the pole strength of all the four poles formed will be the same as that of the original bar magnet. Thus, the new dipole moment of the smaller magnets will be,

$$\overrightarrow{m_1} = q_m\left(\overrightarrow{l_1}\right), \overrightarrow{m_2} = q_m\left(\overrightarrow{l_2}\right)$$



3. When the bar magnet is cut along its length, the two pieces generated will behave like an independent magnet with reduced pole strength. However, the magnetic length of both the new magnets will be the same as that of the original bar magnet. Thus, the new dipole moment of the smaller magnets will be

$$\overrightarrow{m_1} = (q_m)_1\left(2\overrightarrow{l}\right), \overrightarrow{m_2} = (q_m)_2\left(2\overrightarrow{l}\right)$$

Exercises | Q 2. (ii) | Page 228

Answer the following question in brief.

What is the unit of Magnetic Intensity?

SOLUTION

SI unit: weber/m^2 or Tesla.

Exercises | Q 2. (iii) | Page 228

Answer the following question in brief.

What could be the equation for Gauss' law of magnetism, if a monopole of pole strength p is enclosed by a surface?

SOLUTION

i. According to Gauss's law of electrostatics, the net electric flux through any Gaussian surface is proportional to the net charge enclosed in it. The equation is given as,

$$\Phi_E = \int \overrightarrow{E} . \overrightarrow{dS} = \frac{q}{\varepsilon_0}$$

ii. Similarly, if a monopole of a magnet of pole strength p exists, the Gauss' law of magnetism in S.I. units will be given as,

$$\Phi_B = \int \overrightarrow{B} . d\overrightarrow{S} = \mu_0 p$$

Exercises | Q 3. (i) | Page 228

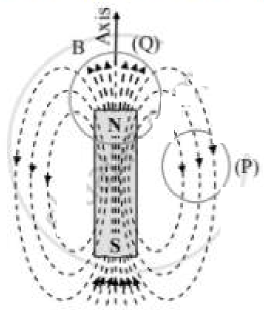
Answer the following question in detail.

Explain Gauss's law for magnetic fields.

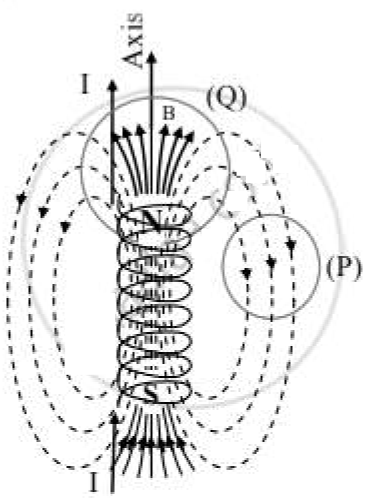
SOLUTION

i. Analogous to the Gauss' law for the electric field, the Gauss' law for magnetism states that the net magnetic flux (Φ_B) through a closed Gaussian surface is zero. $\Phi_B = \int \vec{B} . \vec{dS} = 0$

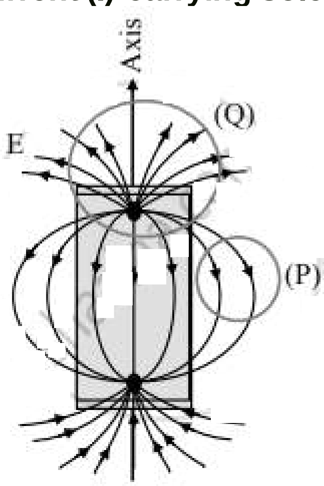
ii. Consider a bar magnet, a current-carrying solenoid, and an electric dipole. The magnetic field lines of these three areas shown in figures.



Bar magnet



Current (I) carrying solenoid



Electric dipole

i. The areas (P) and (Q) are the cross-sections of three-dimensional closed Gaussian surfaces. The Gaussian surface (P) does not include poles while the Gaussian surface (Q) includes the N-pole of a bar magnet, solenoid, and the positive charge in case of an electric dipole.

ii. The number of lines of force entering the surface (P) is equal to the number of lines of force leaving the surface. This can be observed in all three cases.

iii. However, the Gaussian surface (Q) of the bar magnet, enclose the north pole. As even a thin slice of a bar magnet will have both north and south poles associated with it, the number of lines of Force entering the surface (Q) is equal to the number of lines of force leaving the surface.

iv. For an electric dipole, the field lines begin from a positive charge and end on a negative charge. For a closed surface (Q), there is a net outward flux since it does include a net (positive) charge.

v. Thus, according to Gauss' law of electrostatics

vii. Thus, according to Gauss' law of electrostatics

$\Phi_E = \int \overrightarrow{E} . \overrightarrow{dS} = \frac{q}{\varepsilon_0}$, where q is the positive charge enclosed.

viii. The situation is entirely different from the magnetic lines of force. Gauss' law of magnetism can be written as $\Phi_B = \int \overrightarrow{B} . \overrightarrow{dS} = 0$.

From this, one can conclude that for electrostatics, an isolated electric charge exists but an isolated magnetic pole does not exist.

Exercises | Q 3. (ii) | Page 228

Answer the following question in detail.

How does the magnetic declination vary with latitude? Where is it minimum?

SOLUTION

Magnetic declination varies with location and over time. As one moves away from the true north the declination changes depending on the latitude as well as the longitude of the place. By convention, declination is positive when the magnetic north is east of true north, and negative when it is to the west. The decline is small in India. It is 0° 58′ west at Mumbai and 0° 41′ east at Delhi.

Exercises | Q 3. (iii) | Page 228

Answer the following question in detail.

Define the Angle of Dip.

SOLUTION

Angle made by the direction of the resultant magnetic field with the horizontal at a place is inclination or angle of dip (Φ) at the place.

Exercises | Q 3. (iv) | Page 228

Answer the following question in detail.

What happens to the angle of dip as we move towards magnetic pole from magnetic equator?

SOLUTION

At the magnetic pole value of $\Phi = 90°$ and it goes on decreasing when we move towards equator such that at equator value of $\Phi = 0°$.

Exercises | Q 4. (i) | Page 228

Solve the following problem.

A magnetic pole of a bar magnet with a pole strength of 100 A m is 20 cm away from the centre of a bar magnet. The bar magnet has a pole strength of 200 A m and has a length of 5 cm. If the magnetic pole is on the axis of the bar magnet, find the force on the magnetic pole.

SOLUTION

Given that, $(q_m)_1 = 200$ Am and

$(2l) = 5 \text{ cm} = 5 \times 10^{-2}$ m

$\therefore m = 200 \times 5 \times 10^{-2} = 10 \text{ Am}^2$

For a bar magnet, magnetic dipole moment is,

$m = q_m (2l)$

For a point on the axis of a bar magnet at distance, r = 20 cm = 0.2 m,

$$B_a = \frac{\mu_0}{4\pi} \times \frac{2m}{r^3}$$

$$= 10^{-7} \times \frac{2 \times 10}{(0.2)^3}$$

$= 0.25 \times 10^{-3}$

$= 2.5 \times 10^{-4} \text{ Wb/m}^2$

The force acting on the pole will be given by,

$F = q_m B_a = 100 \times 2.5 \times 10^{-4}$

$= 2.5 \times 10^{-2}$ N

The force acting on the magnetic pole due to the bar magnet is **2.5×10^{-2} N**.

Exercises | Q 4. (ii) | Page 288

Solve the following problem.

A magnet makes an angle of 45° with the horizontal in a plane making an angle of 30° with the magnetic meridian. Find the true value of the dip angle at the place.

SOLUTION

Let the true value of dip be Φ. When the magnet is kept 45° aligned with declination 30°, the horizontal component of Earth's magnetic field.

$B'_H = B_H \cos 30°$ Whereas, the vertical component remains unchanged.

∴ For an apparent dip of 45°,

$$\tan 45° = \frac{B'_V}{B'_H} = \frac{B_V}{B_H \cos 30^\circ} = \frac{B_V}{B_H} \times \frac{1}{\cos 30^\circ}$$

But, real value of dip is,

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

$$\therefore \tan 45° = \frac{\tan \Phi}{\cos 30^\circ}$$

$$\therefore \tan \Phi = \tan 45° \times \cos 30°$$

$$= 1 \times \frac{\sqrt{3}}{2}$$

$$\therefore \Phi = \tan^{-1}(0.866)$$

The true value of angle of dip is **$\tan^{-1}$ (0.866)**.

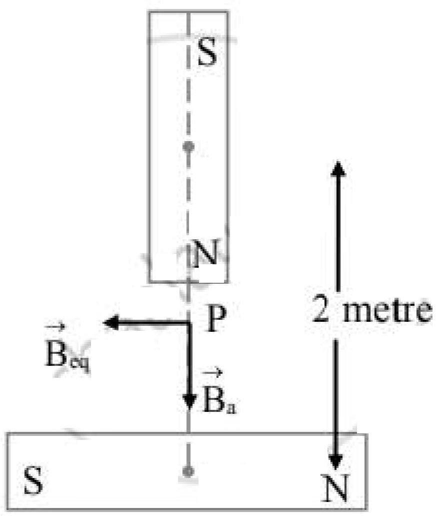
Exercises | Q 4. (iii) | Page 228

Solve the following problem.

Two small and similar bar magnets have a magnetic dipole moment of 1.0 Am^2 each. They are kept in a plane in such a way that their axes are perpendicular to each other. A line drawn through the axis of one magnet passes through the center of other magnet. If the distance between their centers is 2 m, find the magnitude of the magnetic field at the midpoint of the line joining their centers.

SOLUTION

Let P be the midpoint of the line joining the centres of two bar magnets. As shown in figure, P is at the axis of one bar magnet and at the equator of another bar magnet. Thus, the magnetic field on the axis of the first bar magnet at distance of 1 m from the centre will be,



$$B_a = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

$$= 10^{-7} \times \frac{2 \times 1.0}{(1)^3}$$

$$= 2 \times 10^{-7}\ Wb/m^2$$

Magnetic field on the equator of second bar magnet will be,

$$B_{eq} = \frac{\mu_0}{4\pi}\frac{m}{r^3}$$

$$= 10^{-7} \times \frac{1.0}{(1)^3}$$

$$= 1 \times 10^{-7}\ Wb/m^2$$

The net magnetic field at P,

$$B_{net} = \sqrt{B_a^2 + B_{eq}^2}$$

$$= \sqrt{(2 \times 10^{-7})^2 + (1 \times 10^{-7})^2}$$

$$= \sqrt{(10^{-7})^2 \times (4 + 1)}$$

$$= \sqrt{5} \times 10^{-7} \text{ Wb/m}^2$$

Magnitude of net magnetic field at midpoint of line will be $\sqrt{5} \times 10^{-7}$ **Wb/m²**.

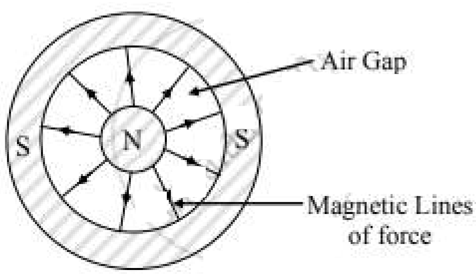
Exercises | Q 4. (iv) | Page 228

Answer the following question in detail.

A circular magnet is made with its north pole at the centre, separated from the surrounding circular south pole by an air gap. Draw the magnetic field lines in the gap.

SOLUTION

For a circular magnet:



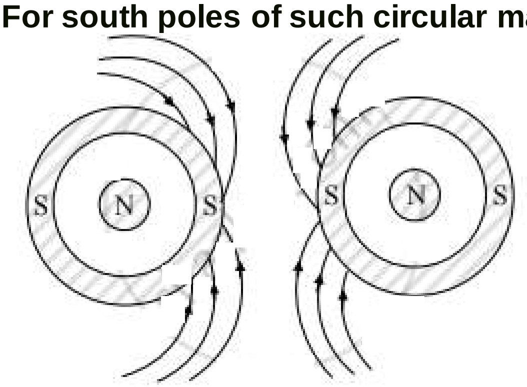
Exercises | Q 4. (iv) | Page 228

Answer the following question in detail.

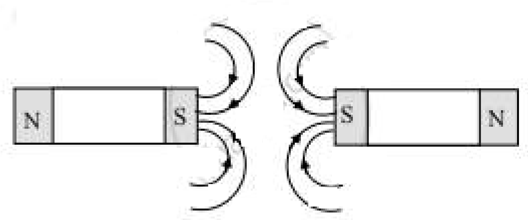
Draw a diagram to illustrate the magnetic lines of force between the south poles of two such magnets.

SOLUTION

- **For south poles of such circular magnets facing each other:**



- **For south poles of bar magnets facing each other:**



Exercises | Q 4. (v) | Page 228

Answer the following question in detail.
Two bar magnets are placed on a horizontal surface. Draw magnetic lines around them. Mark the position of any neutral points (points where there is no resultant magnetic field) on your diagram.

SOLUTION

The magnetic lines of force between two magnets will depend on their relative positions. Considering the magnets to be placed one beside the other as shown in the figure, the magnetic lines of force will be as shown.