36. Permanent Magnets

Short Answer

1. Question

Answer

No. A monopole (single pole) does not exist in magnetism. Magnetic poles always occur in pairs.

Magnetic fields of a magnet are formed as loops only and thus, it is necessary to have a beginning and an ending, externally. So, for a real magnet, the magnetic property will not exist without two poles. So, even if we break a magnet into pieces, each piece will form into individual magnets with two poles, North and South poles, each.

2. Question

Answer

No. In a magnet, even the concept of poles is relative. Poles are instantaneous and are defined as the points where the magnetic fields are assumed to originate and to end. For a real magnet, which is equivalent to a magnetic dipole, there should be a distance in between the two poles in order to create magnetic field.

The magnetic moments can be defined as the strength of a magnet, that enables the magnet to produce a magnetic field.

For a magnetic pole strength m, and distance in between the two poles as L, the magnetic moment M will be,

$$M = m \times L$$

Since the value of L is Zero in a dipole with nearby points, there won't be any magnetic moments, and hence there would not exist a magnetic dipole with a magnetic field.

3. Question

Answer

No. The material of the magnet is homogenous at every point, includin
and at the center and it is not the material property of magnet that cau
effect.

Iron, from which the needle is made, is ferromagnetic in nature. Hence its magnetic domains get aligned in a magnetic field. When the needle is placed near the poles of the magnet, the opposite magnetic polarity will be induced in the needle. So, whenever it comes to near a pole, it gets attracted. But, when the needle is near the middle portion of the magnet, the two poles will induce two different polarities in the needle. But, the magnetic domains set by one pole gets canceled by the other pole. As a result, the needle will not get attracted to either of the poles, when it is at the center.

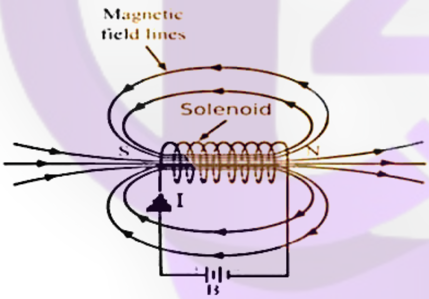
4. Question

Answer

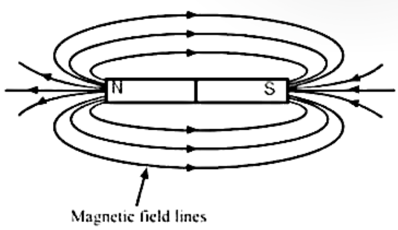
The magnetic field directions in both cases are the same. A current carrying solenoid is equivalent to a bar magnet.

In a magnet (or a combination of north pole and south pole), the magnetic poles would not change, if fixed once, and the direction of magnetic field is from South to North, internally.

In a current carrying solenoid, the magnetic field will be set up according to Ampere's law, and the direction is determined by Right-hand thumb rule, as shown in the figure.



Similarly the direction of magnetic field in a bar magnet is as shown in figure.



In the later case, in the bar magnet, it can be seen that the magnetic fie
South to North at the inside of magnet, while it is North to South at th

In the case of solenoid, the direction of magnetic field is determined by the direction of current. For the shown setup, with the direction of current as represented, the magnetic field inside the solenoid is from South to North. Even if we reverse the current, the direction of Magnetic field is unaltered but the imaginary South and North of the solenoid will interchange.

In both the cases, for bar magnet and for solenoid, the direction of magnetic field is from South to North in the inside and from North to South in the outside.

5. Question

Answer

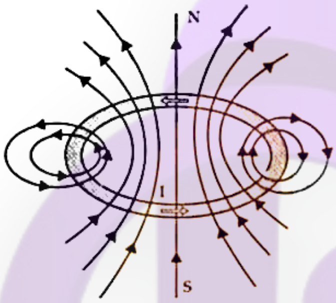


Fig 1

The sketch of magnetic field lines associated with a loop and a dipole are shown below in Fig.1 and Fig.2 respectively.

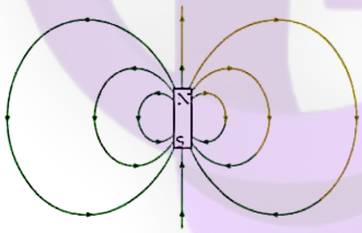


Fig.2

The magnetic field lines at the center of the loop, in Fig.1, is perpendicular to the loop, and the direction is determined by the direction of current.

But in the case of the magnetic dipole, in Fig.2, there is no magnetic field at the center of the dipole. Magnetic field lines start from the North pole and ends at the South pole, externally in the magnetic dipole, and hence they would not pass through center of the dipole.

6. Question

Answer

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Yes, The question statement contradicts our earlier knowledge. But this confusion can be rectified by understanding the above equation.

In the equation, $\vec{F} = m\vec{B}$, m represents the 'Magnetic charge', $\vec{F}$ represents the Magnetic force and $\vec{B}$ represents the magnetic field.

A magnetic charge can be understood by doing the analogy with an electric charge.

A magnetic field, exert a force on the magnetic charge, which is parallel to the Magnetic field itself and is proportional to the magnitude of magnetic charge and Magnetic field, analogous to electric field exerting force on an electric charge.

But, from Lorentz law, we know that Magnetic force is perpendicular to magnetic field.

$\vec{F} = qv \times \vec{B}$

Where q represents an electric charge, v represents the velocity of movement. By this relation, the magnetic force is perpendicular to the magnetic field.

In this law, a moving electric charge is used to define the magnetic force, which is not used in the former equation. So the above cases cannot be compared directly.

The non-existence of a monopole in magnetism makes the former equation obsolete and hence Lorentz equation is widely used for practical cases.

Hence, even though the two concepts seem to contradict while comparing the orientations of magnetic field and magnetic force, they are not effectively the same equations.

7. Question

Answer

Yes. It does contradicts our earlier knowledge that magnetic forces cannot do any work and hence cannot increase kinetic energy of a system.

But, our earlier knowledge about the above situation comes from the Lorentz equation, which is $\vec{F} = qv \times \vec{B}$, we understood that the a "Uniform magnetic field" can not do any work on the charge,q.

But this equation would not apply when the magnetic field is non-unif given case, when two opposite poles are placed proximal, each of the n experiences a non-uniform magnetic field and there will be instantane moment and that will produce the movement.

To summarize, both the poles are in the influence of an external force, which is the cause for the kinetic energy dissipated, and it is not the internal magnetic force.

8. Question

Answer

No, a magnetic scalar potential is not possible in this case.

The magnetic scalar potential, analogous to electric scalar potential, is calculated between two different point. But Ampere's law is used for a closed, plane curve only.

For a straight long wire, the magnetic field is distributed surrounding the wire. In that case, if we calculate the magnetic potential by the given expression, over a closed curve, the beginning and the end points will coincide and the potential becomes zero.

Hence, In the given case, even though the RHS gives a non-zero value, it is not possible to have magnetic scalar potential.

9. Question

Answer

Yes, The magnetic field of the earth is vertical at poles. So, a freely suspended magnet will try to align with earth's magnetic field. Hence the magnet will stay in a vertical position, with its south pole pointing towards Earth's south pole, which is magnetic north.

As angle of dip is the inclination between the horizontal and the magnetic field lines of earth, poles will have an angle of dip of value 90°

10. Question

Answer

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Dip is the angle made by the magnetic field lines of earth with the hori

a) Yes, As the magnetic field lines at the equator of earth is horizontal, the dip is 0°

b) Yes, As the magnetic field lines at poles of earth is vertical, the dip is 90°

The angle of Dip can vary from 0° to 90°

11. Question

Answer

Yes. The procedure will work if it is taken to Nepal as well.

The tangent Galvanometer is used to find out current or earth's magnetic field. It works on the equation,

$$B = B_H tan\theta \ (eqn. 1)$$

Where B is a known magnetic field produced, B_H is the horizontal component of geomagnetic field, and θ is the angle shown in the galvanometer dial.

As the magnetic field, B is produced by the current passing through a loop according to Ampere's law, is,

$$B = \frac{\mu_0 ni}{2r}$$

Where n is the number of loops, i is the current and r is the radius of the loop.

Substituting this in eqn.1, we can rearrange it to find tan θ as,

$$\tan\theta = \frac{\mu_0 ni}{2r \times B_H}$$

Also,

$$i = k \times tan\theta$$

Where k is the reduction factor and is a constant. So, by correcting the data for k and the value of tanθ, the measurements can be accurately conducted.

So, despite the place, we can calculate the current depending on the tanθ value. So, any error caused can be rectified by the angle corrections and there is no need to bring the instrument back to the factory.

Objective I

1. Question

Answer

Any point on the axis of a bar magnet (or a magnetic dipole) is called as a point at “End-on position”. In the given case, when the loop is replaced by a dipole, and hence the point on the axis of the loop will come at an axial position of dipole as well. So, the point can be considered at ‘end-on position’.

2. Question

Answer

Any point on the equatorial line of a bar magnet (or a magnetic dipole) is called as a point at “Broadside-on position”. So, when the current carrying circular loop is replaced with a magnetic dipole, the point on the loop comes at the equatorial position, Thus the point is said to be located at broadside-on position.

3. Question

Answer

When we replace a current carrying circular loop with an equivalent r dipole, the quantity that is not altered is 'Magnetic moment'.

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We know that, for a circular loop of area A and current I, the magnetic moment is,

$$M = IA$$

So, when we replace it with a a dipole of pole strength m and in-between distance d, the magnetic dipole should be same as the first case, hence

$$M = IA = md$$

So, the product of pole strength, m and distance d should be fixed, even though they are not fixed individually.

4. Question

Answer

For a bar magnet with length 2l, and magnetic moment M, the magnetic field on any point in the axis at a distance r from the centre can be expressed as,

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

Hence, we can understand that, magnetic field is inversely proportional to $(r^2-l^2)^2$, that is,

$$B \propto \frac{1}{(r^2 - l^2)^2}$$

Hence option D is the correct option.

5. Question

Answer

For a bar magnet with length 2l, and magnetic moment M, the magnetic field on any point in the axis at a distance r from the center can be expressed as,

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

But, in the case of dipole, the length in-between the poles are very small. So, r>>> l . Hence the above expression will become,

$$B = \frac{\mu_0 Mr}{2\pi(r^2)^2}$$

Or,

$$B = \frac{\mu_0 M}{2\pi r^3}$$

Hence, we can see that, in the case of dipole, the magnetic field in inversely proportional to the third power of r, that is

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

Thus, option C is the correct option.

6. Question

Answer

We know that the resultant magnetic field on a point P due to a dipole can be expressed as,

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

Where, M is the magnetic moment, r is the perpendicular distance of the point P from the centre of the dipole. Θ is the angle made by the line connecting the centre and the point P with that of axis of the dipole.

In the given question, as the point is on the angular bisector of the right angle, Θ is 45° . Hence the above expression becomes,

$$B_{1,2} = \frac{\mu_0 M}{4\pi r^3}\sqrt{1 + 3cos^2 45}$$

Or,

$$B_{1,2} = \frac{\mu_0 2M}{4\pi r^3}$$

Here the point P will affected by both the crossed dipoles, hence the total magnetic field will be,

$$B_{Resultant} = \sqrt{{B_1}^2 + {B_2}^2}$$

Or,

$$B_{Resultant} = \sqrt{\left(\frac{\mu_0 2M}{4\pi r^3}\right)^2 + \left(\frac{\mu_0 2M}{4\pi r^3}\right)^2}$$

Or,

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

Thus, option C is the correct option.

7. Question

Answer

Magnetic meridian at a place can be defined as a vertical plane passing through the axis of a freely suspended magnet. It is neither a plane nor a point.

8. Question

Answer

The magnetic field of the earth is vertical at poles. So, a freely suspended magnet, or a compass needle will align vertically at poles. But, the compass needle, in the given situation is restricted from any vertical movements. But, the horizontal motion is unprecedented and can be oriented to any direction. Hence, the needle will take any position depending on any external horizontal forces or other conditions.

9. Question

Answer

The earth's magnetic field at the geomagnetic equator is horizontal. Hence, the needle of a dip circle will aligned according to the earth's magnetic field, if suspended freely. But, in this case, movement in the horizontal direction is restricted but is free to move in vertical direction. Since there is no magnetic field in the vertical direction at the geomagnetic equator, the needle is restricted to move only in the vertical plane perpendicular to the magnetic meridian. Hence, the needle will assume any direction once it is released.

10. Question

Answer

We know that for a tangent galvanometer,

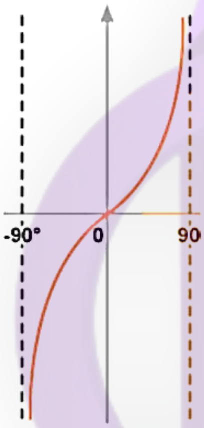
$$i = k tan\theta$$

Or,

$$i \propto tan\theta$$

Where θ represents the deflection, i represents the current and k is the reduction constant.

From the above relation, we can see that the current is proportional to the tangent of the deflection angle. Hence the graph showing their relation should be equivalent to tan θ graph, which is,



So, from the given curves, one that is similar to the above graph is curve(C).

11. Question

Answer

We know that for a tangent galvanometer, the relation connecting curr
deflection, θ is,

$$i = ktan\theta$$

Or,

$$\theta = tan^{-1}(i/k)$$

Where k is the reduction constant and is fixed for a galvanometer.

So, we can see that deflection depends only on i and k. Hence, the deflection won't change when the number of turns is changed.

12. Question

Answer

We know that for a moving-coil galvanometer, the relation between current, i and deflection, θ can be expressed as,

$$i = \frac{k}{nAB}\theta$$

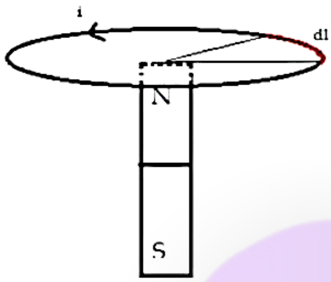
Where k is the torsional constant, A is the area of the coil, n is the number of turns and B is the strength of Magnetic field.

From the above expression, we can see that the current is directly proportional to the deflection. And hence, if the current is doubled, the deflection will also get doubled.

13. Question

Answer

When a bar magnet's north pole is placed at the centre of a current carrying loop, the magnetic field will get distributed in such a way that the magnetic field will lie in the plane of the loop. So, the magnetic force will be perpendicular to the plane of the loop.



Now, let's take a current element idl, and the magnetic field associated with it is B. Then the magnetic force on the element is,

$$dF = B \times idl$$

On integration throughout the loop of radius a,

$$F = \int_0^{2\pi a} Bidl$$

Or,

$$F = 2\pi aiB$$

Hence the force acting on the wire is 2πaiB, which is directed in the perpendicular direction of the plane of the loop.

Objective II

1. Question

Answer

Magnetic Fields are produced by electric charges. Hence A is true. And magnetic poles are a theoretical concept thus B is true. A clockwise current gives a south pole and so C is incorrect. A bar magnet is equivalent to a solenoid so D is wrong.

2. Question

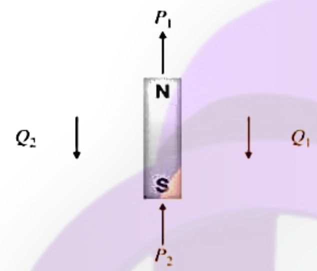
Answer

Clockwise current is equivalent to a south pole. hence, the SN line should be perpendicular to the plane of the loop with South above the loop and north below it. Thus options B and D are correct.

3. Question

Answer

The following diagram explains the configuration.



4. Question

Answer

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Again from the above diagram, it is evident that the field are opposite at P_1 and Q_1 and P_2 and Q_2

5. Question

Answer

A deflection or oscillation galvanometer can be used to know the magnetic moment of a bar magnet. For a deflection magnetometer, the formula to calculate moment is

$$\frac{M}{B_H} = \frac{4\pi(d^2 - l^2)}{\mu_0 2d}$$

And for a vibrational magnetometer is

$$MB_H = 4\pi^2 \frac{I}{T^2}$$

Where, M is the magnetic moment, B_H is the horizontal magnetic field, T is the time period.

Combining both equations, we can get rid of B_H. Hence, B, C and D are true.

Exercises

1. Question

Answer

Given: - M = 10Am

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r = 5cm =0.05m =5×10^{-2}m

we now that, μ_0 = 1.257 x 10 $^{-6}$ henry per meter

π = 3.142

We need to find the magnetic field due to magnetic charge B is given by

$$B = \frac{\mu_0}{4\pi} \times \frac{M}{r}$$

$$B = \frac{1.257 \times 10^{-6}}{4 \times 3.142} \times \frac{10}{(5 \times 10^{-2})^2}$$

$$B = 1 \times 10^{-7} \times \frac{10}{2.5 \times 10^{-3}}$$

$$B = 1 \times 10^{-7} \times 4000$$

$$B = 4 \times 10^{-4}\ T$$

2. Question

Answer

Given: - pole strength, M_1=M_2 = 10Am

r_2 = 2 cm =0.02m = 2×10^{-2}m

We need to find the force exerted by one magnet of the other F is given by

$$F = \frac{\mu_0}{4\pi} \times \frac{M_1 M_2}{r_2}$$

$$F = \frac{1.257 \times 10^{-6}}{4 \times 3.142} \times \frac{10^2}{(2 \times 10^{-2})^2}$$

$$F = 1 \times 10^{-7} \times \frac{100}{4 \times 10^{-4}}$$

$$F = 1 \times 10^{-7} \times 250000$$

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

3. Question

Answer

Given, $B = 0.20 \times 10^{-3}\ T$

r = 50cm = 50×10^{-2}

we need to find the change in the magnetic scalar ΔV is given by

$$B = -\frac{dv}{dl}$$

$$dv = -Bdl$$

on integration on both side we get

$$\int dv = -\int_{r_1}^{r_2} Bdl$$

$$\Delta V = B \times \Delta r$$

$$\Delta V = -0.20 \times 10^{-3} \times 50 \times 10^{-2}$$

$$\Delta V = -0.1 \times 10^{-3}$$

4. Question

Answer

Given, change in potential, $dv = 0.1 \times 10^{-4} T - m$

perpendicular distance, $dx = 10 \sin 30^{\circ} = 10 \times \frac{1}{2} = 5cm = 5 \times 10^{-2} m$

we now that relation between the potential and the field is given by

$$B = -\frac{dv}{dx}$$

$$B = -\frac{0.1 \times 10^{-4}}{5 \times 10^{-2}} = -2 \times 10^{-4} T$$

$$B = -2 \times 10^{-4} T$$

Since B is perpendicular to equipotential surface were it is angle is 12(
x-axis

5. Question

Answer

Given, $B = 2 \times 10^{-4} T$

$d = 10cm = 10 \times 10^{-2} m$

(a) End-on-position is: -

$$B = \frac{\mu_0}{4\pi} \times \frac{2M}{d^3}$$

$$2 \times 10^{-4} = \frac{10^{-7} \times 2M}{(10 \times 10^{-2})^3}$$

M = 1A-m

(b) Broadside-on-position: -

$$B = \frac{\mu_0}{4\pi} \times \frac{M}{d^3}$$

$$2 \times 10^{-4} = \frac{10^{-7} \times M}{(10 \times 10^{-2})^3}$$

M = 2A-m

6. Question

Answer

$\theta = \tan^{-1} \sqrt{2} \tan \theta = \sqrt{2}$

$Tan^2 \theta = 2$

we can written as, $Tan\theta \times Tan\theta = 2$

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$$Tan\theta = \frac{2}{Tan\theta} = 2Cot\theta$$

$$Cot\theta = \frac{Tan\theta}{2} ------(1)$$

we know that, $\tan\alpha = \frac{Tan\theta}{2} ----------(2)$

Now from equation (1) and (2) we get

Tanα =Cotθ

⇒ Tanα = Tan(90-θ)

α = 90-θ

θ + α =90° hence we proved that the magnetic field at a point due to a magnetic dipole is perpendicular to the magnetic axis

7. Question

Answer

Given, $B = 4 \times 10^{-6}\, T$

$2l = 8\ cm$

$l = 4\ cm$

$d = 3cm = 3 \times 10^{-2}$

we need to find the value of the pole strength of the magnetthe magnetic field due to the dipole on the equatorial point B is given by $B = \frac{\mu_0}{4\pi} \times \frac{M \times 2l}{(d^{2+}l^2)^{\frac{3}{2}}}$

$$4 \times 10^{-6} = 10^{-7} \times \frac{M \times (2 \times 4 \times 10^{-2})}{[(9 \times 10^{-4}) + (16 \times 10^{-4})]^{\frac{3}{2}}}$$

$$M = \frac{(4 \times 10^{-6} \times 2.5 \times 10^{-3})}{(10^{-7} \times 8 \times 10^{-2})}$$

$$M = 6.25 \times 10^{-2} Am$$

8. Question

Answer

Given, $B = 18\mu T$

M=1.44Am^2

We know for a magnetic dipole with its pole pointing to the north, neutral point always lies in the broadside-on position.

let d be the perpendicular distance of the neutral point from midpoint of the magnet

the magnetic field due to the dipole at the broadside-on position(B) is given by

$$B = \frac{\mu_0 M}{4\pi d^3}$$

$$18 \times 10^{-6} = \frac{10^{-7} \times 1.44}{d^3}$$

$$d^3 = \frac{10^{-7} \times 1.44}{18 \times 10^{-6}}$$

$$d = \sqrt[3]{8 \times 10^{-3}}$$

$$d = 0.2m = 20cm$$

9. Question

Answer

Given :- $M = 0.72Am^2$

$B = 18\mu T$

When the magnet is such that the its north pole faces the geographic south of earth, the natural point lies along the axial line of the magnet

$$B = \frac{\mu_0 \times 2M}{4\pi d^3}$$

$$18 \times 10^{-6} = \frac{10^{-7} \times 0.72}{d^3}$$

$$d^3 = \frac{10^{-7} \times 2 \times 0.72}{18 \times 10^{-6}}$$

$d = \sqrt[3]{8 \times 10^{-3}}$

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$d = 0.2m = 20cm$

10. Question

Answer

Given, $M = 0.72\sqrt{2}Am$

$B_H = 18\mu T = 18 \times 10^{-6}T$

$\vec{B} = \frac{\mu_0}{4\pi} \times \frac{M}{d^3}$

$\therefore B_H = \vec{B}$ at point d

$\Rightarrow 18 \times 10^{-6} = \frac{10^{-7} \times 0.72 \times \sqrt{2}}{d^3}$

$d^3 = \frac{10^{-7} \times 0.72 \times 1.414}{18 \times 10^{-6}}$

$d = 0.2m = 20cm$

11. Question

Answer

Given, $M = 8 \times 10^{22}Am^2$

R =6400KM

$\underset{B}{\rightarrow} = \frac{\mu_0}{4\pi} \times \frac{2M}{d^3}$

$\vec{B} = \frac{10^{-7} \times 2 \times 8 \times 10^{22}}{(64)^3 \times 10^{15}}$

$\vec{B} = 6 \times 10^{-5}$ T

12. Question

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Answer

Given, magnetic field at the magnetic equator, $\overrightarrow{B_1} = 3.4 \times 10^{-5} T$

let M be the magnetic moment of earth's magnetic dipole and R be the distance of the observation point from the centre of earth magnetic dipole.

As the point on the magnetic equator is on the equatorial position of earth magnet, the magnetic field at the equatorial point(B)is given by,

$$\vec{B}_1 = \frac{\mu_0}{4\pi} \times \frac{2M}{R^3}$$

$$3.4 \times 10^{-5} = \frac{10^{-7} \times M}{R^3}$$

$$M = 3.4 \times 10^2 R^3 ------------(1)$$

$\overrightarrow{B_2}$ at the pole $\Rightarrow \overrightarrow{B_2} = \frac{\mu_0}{4\pi} \times \frac{2M}{d^3}$

$$\overrightarrow{B_2} = 10^{-7} \times \frac{2 \times 3.4 \times 10^2 R^3}{R^3}$$

$$\overrightarrow{B_2} = 6.8 \times 10^{-5} T$$

13. Question

Answer

Given, B_H = 26μT =26 × 10^{-6} T

δ = 60°

(a) for horizontal component

we know that

$$\overrightarrow{B_H} = B \times \cos\delta$$

$$\Rightarrow 26 \times 10^{-6} = B \times Cos60$$

$$B = \frac{26 \times 10^{-6}}{0.5}$$

$$\vec{B} = 52 \times 10^{-6} T$$

$\vec{B} = 52\mu T$

(b) for vertical component

$\vec{B}_v = B \times \sin\delta$

$\vec{B}_v = 52 \times 10^{-6} \times \sin 60$

$\vec{B}_v = 44.98 \times 10^{-6}$

$\vec{B}_v = 45\mu T$

14. Question

Answer

Given, the angle made by the magnetic meridian with the plane of rotation of the needle $\theta = 60°$

angle made by the needle with the horizontal

$\delta = \tan^{-1}\left(\frac{2}{\sqrt{3}}\right)$

$\tan\delta = \tan^{-1}(\cos\theta)$

$\tan\delta = \frac{2}{\sqrt{3}}\cos 60$

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

$\tan\delta = \frac{1}{\sqrt{3}}$

$\delta = \tan^{-1} 0.5773$

$\delta = 30°$

15. Question

Answer

If $\delta_1$and$\delta_2$be the apparent dips shown by the dip circle in the 2 perpendicular positions

$\delta_1 = 45°$ and $\delta_2 = 53°$

To find δ

the true dip (δ) is given by

$$cot^2\delta = cot^2\delta_1 + cot^2\delta_2$$

$$cot^2\delta = cot^2 45 + cot^2 53$$

$$cot^2\delta = 1.56$$

$$\delta = cot^{-1}(1.56)$$

$$\delta = 38.6° \cong 39°$$

16. Question

Answer

Given,

horizontal components of earth's magnetic field,

$B_H = 3.6 \times 10^{-5}$ T

deflection shown by the tangent galvanometer, θ = 45°

radius of coil, r = 10cm =0.1m

current through the galvanometer, I =10mA =10 x 10^{-3}A =10^{-3}A

number of turn's in the coil, n =?

$$B_H \tan\theta = \frac{\mu_0 nI}{2r}$$

$$n = \frac{B_H tan\theta 2r}{\mu_0 I}$$

$$n = \frac{3.6 \times 10^{-5} \times \tan 45 \times 2 \times 0.1}{4\pi \times 10^{-7} \times 10^{-2}}$$

$$n = 0.5723 \times 10^3$$

n =573

17. Question

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Answer

Given,

number of turns in the coil n=50

area of the cross section of the coil, A = 4 cm^2

magnetic field strength due to the presence of the pole B =0.5 T

current flow through the coil I =20mA = $20X10^{-3}$

ζ=?

$\zeta = nI(\underset{A}{\rightarrow} \times \underset{B}{\rightarrow})$

$\zeta = nI(AB\sin 90°)$

$\zeta = 50 \times 20 \times 10^{-3} \times 4 \times 10^{-4} \times 0.5$

$\zeta = 2 \times 10^{-4} N - m$

18. Question

Answer

Given,

separation between the magnet and the needle, d = 10cm =0.1m

deflection in the magnetometer in the given position when placed in the magnetic field of a short magnet, θ = 37°

$\frac{M}{B_H} = ?$

let M be the magnetic moment of the magnet and B_H be earth's horizontal magnetic field.

according to magnetometer theory

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times \frac{(d^2 - l^2)^2}{2d} \times \tan\theta$$

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times \frac{d^4}{2d} \times \tan\theta$$

CLASS24

$$\frac{M}{B_H} = \frac{4 \times 3.142}{4 \times 3.142 \times 10^{-7}} \times \frac{(0.1)^4}{(2 \times 0.1)} \times \tan 37°$$

$$\frac{M}{B_H} = 0.5 \times 0.75 \times 1 \times 10^4$$

$$\frac{M}{B_H} = 3.75 \times 10^3 A\, {m^2}/{T}$$

19. Question

Answer

Given,

separation between the magnet and the needle d = 10cm =0.1 m

deflection in the magnetometer in the given position when placed in the magnetic field of a short magnet, θ = 37°

let M be the magnetic moment of the magnet and B_H be earth's horizontal magnetic field.

according to magnetometer theory

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times \frac{(d^2 - l^2)^2}{2d} \times \tan\theta$$

for short magnet → d ⋙⋙ l

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times \frac{d^4}{2d} \times \tan\theta$$

$$\frac{M}{B_H} = \frac{4 \times 3.142}{4 \times 3.142 \times 10^{-7}} \times \frac{(0.1)^4}{(2 \times 0.1)} \times \tan 37°$$

$$\frac{M}{B_H} = 0.5 \times 0.75 \times 1 \times 10^4$$

deflection in the magnetometer θ =37°

From the magnetometer theory in Tan-B position, we have

$\frac{M}{B_H} = 3.75 \times 10^3 A\, {m^2}/{T}$ ----------------------(1)

$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times (d^2 + l^2)^{\frac{3}{2}} \times \tan\theta$ l≪≪≪d

CLASS24

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times d^3 \times (tan\theta)$$

$$3.75 \times 10^3 = \frac{4 \times 3.142}{4 \times 3.142 \times 10^{-7}} \times d^3 \times \tan 37$$

$$d^3 = \frac{3.75 \times 10^3 \times 10^{-7}}{0.75}$$

$$d = \sqrt[3]{5 \times 10^{-4}}$$

d = 0.079370m =7.9370cm

20. Question

Answer

given, $\frac{M}{B_H} = 40A\, {m^2}/{T}$

d =?

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times \frac{(d^2 - l^2)^2}{2d} \times \tan\theta$$

d ≫≫≫l

$$\frac{M}{B_H} = \frac{4\pi}{\mu_0} \times \frac{d^3}{2}$$

$$40 = \frac{4 \times 3.142}{4 \times 3.142 \times 10^{-7}} \times \frac{d^3}{2}$$

$$d^3 = 40 \times 10^{-7} \times 2$$

$$d = \sqrt[3]{8 \times 10^{-6}}$$

d = 0.02 m =2cm

21. Question

Answer

Given, $T = \frac{\pi}{10} sec$

the earth's horizontal magnetic field, $B_H = 30\mu T = 30 \times 10^{-6}$

The moment of inertia of the magnet about the axis of rotation

$I = 1.2 \times 10^{-4}\, {kg}/{m^2}$

the time period of a magnetometer is given by,

$$T = 2\pi\sqrt{\frac{I}{MB_H}}$$

$$\frac{\pi}{10} = 2\pi\sqrt{\frac{1.2 \times 10^{-4}}{M \times 30 \times 10^{-6}}}$$

$$\left(\frac{1}{20}\right)^2 = \frac{1.2 \times 10^{-4}}{M \times 30 \times 10^{-6}}$$

$$M = \frac{1.2 \times 10^{-4} \times 400}{30 \times 10^{-6}}$$

M = $1600 Am^2$

22. Question

Answer

given,

Number of oscillations per second made by the combination of bar magnets with like poles, $f_1 = 10s^{-1}$

Number of oscillations per second made by the combination of bar magnets with unlike poles, $f_2 = 2s^{-1}$

The frequency of oscillations in the magnetometer (v)ν is given by

$$T = 2\pi\sqrt{\frac{I}{MB_H}}$$

$$\Rightarrow f = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}}\text{------------------------}(1)$$

(1) When like poles are tied together, the effective magnetic moment is M= M_1 - M_2

(2) When unlike poles are tied together, the effective magnetic moment is M= M_1 + M_2

As the frequency of oscillations is directly proportional to the magnetic moment,

$$\Rightarrow \frac{f_1}{f_2} = \sqrt{\frac{M_1 - M_2}{M_1 + M_2}}$$

$$\left(\frac{10}{2}\right)^2 = \frac{M_1 - M_2}{M_1 + M_2}$$

$$\frac{M_1 - M_2}{M_1 + M_2} = \frac{25}{1}$$

$$\frac{M_1 - M_2 + M_1 + M_2}{M_1 + M_2 - M_1 - M_2} = \frac{25 + 1}{25 - 1}$$

$$\frac{M_1}{M_2} = -\frac{26}{24} = -\frac{13}{12}$$

$$\frac{M_1}{M_2} = -\frac{13}{12}$$

23. Question

Answer

Given, Time period of oscillation, T_1 = 0.10 sec

Horizontal component of Earth's magnetic field,

$B_H = 24\mu T = 24 \times 10^{-6} T$

Downward current in the vertical wire, I =18A

Distance of wire from the magnet, d = 20cm =0.2m

When a current-carrying wire is placed near the magnet, the effective magnetic field gets changed. Now the net magnetic field can be obtained by subtracting the magnetic field due to the wire from Earth's magnetic field.

$\vec{B} = \vec{B}_H - \overrightarrow{B_{Wire}}$

$\Rightarrow \vec{B} = \vec{B}_H - \frac{\mu_0 I}{2\pi r}$

$$\vec{B} = 24 \times 10^{-6} - \frac{4\pi \times 10^{-7} \times 18}{2\pi \times 0.2}$$

$$\vec{B} = 24 \times 10^{-6} - \frac{2 \times 10^{-7} \times 18}{0.2}$$

$$\vec{B} = 14 \times 10^{-6} T$$

Time period of the coil (T) is given by

$$T = 2\pi\sqrt{\frac{I}{MB_H}}$$

Let T_1 and T_2 be the time periods of the coil in the absence of the wire and in the presence the wire respectively. As time period is inversely proportional to magnetic field,

$$\frac{T_1}{T_2} = \sqrt{\frac{B}{B_H}}$$

$$\Rightarrow \frac{0.1}{T_2} = \sqrt{\frac{14 \times 10^{-6}}{24 \times 10^{-6}}}$$

$$T_2 = \sqrt{\frac{0.01 \times 14}{24}}$$

T_2 = 0.076sec

24. Question

Answer

Given,

$T_1 = \frac{1}{40}\ min$ Here I' = 2I

T_2 = ?

$$T = 2\pi\sqrt{\frac{I}{MB_H}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{I}{I'}}$$

$$\Rightarrow \frac{1}{40T_2} = \sqrt{\frac{1}{2}}$$

$$\Rightarrow \frac{1}{1600T_2} = \frac{1}{2}$$

$$T_2 = \frac{1}{800}$$

$$T_2 = 0.03536\ min$$

for 1 oscillation time taken = 0.03536 min

for 40 oscillation time taken = 40x0.03536 =1.414 =2min

25. Question

Answer

Given, v_1 =40oscillation/min

$$B_H = 25\mu T$$

M of second magnet =1.6Am^2

(a) for north pole facing north

$$\gamma_1 = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}}, \gamma_2 = \frac{1}{2\pi}\sqrt{\frac{M(B_H - B)}{I}}$$

$$B = \frac{\mu_0}{4\pi} \times \frac{M}{d^3}$$

$$B = \frac{10^{-7} \times 1.6}{8 \times 10^{-3}} = 20\mu T$$

$$\frac{\gamma_1}{\gamma_2} = \sqrt{\frac{B_H}{(B_H - B)}}$$

$$\Rightarrow \frac{40}{\gamma_2} = \sqrt{\frac{25}{(25-20)}}$$

$$\frac{40}{\gamma_2} = \sqrt{\frac{25}{5}}$$

$$\gamma_2 = \frac{40}{\frac{5}{\sqrt{5}}} = 17.88$$

$\gamma_2 = 17.88 = 18$ oscillation/min

(b) for north pole facing south

$$\gamma_1 = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}}, \gamma_2 = \frac{1}{2\pi}\sqrt{\frac{M(B_H - B)}{I}}$$

$$B = \frac{\mu_0}{4\pi} \times \frac{M}{d^3}$$

$$B = \frac{10^{-7} \times 1.6}{8 \times 10^{-3}} = 20\mu T$$

$$\frac{\gamma_1}{\gamma_2} = \sqrt{\frac{B_H}{(B_H + B)}}$$

$$\Rightarrow \frac{40}{\gamma_2} = \sqrt{\frac{25}{(25+20)}}$$

$$\frac{40}{\gamma_2} = \sqrt{\frac{25}{45}}$$

$$\gamma_2 = \frac{40}{\frac{5}{\sqrt{45}}} = 53.6656$$

$\gamma_2 = 53.6656 = 54$ oscillation/min