Chapter 2: Magnetic Properties of Matters

Short Answer Questions

1. **2075 GIE Q.No. 1e** **2074 Set A Q.No. 1d** **Why is soft iron preferred for making the core of a transformer?** [2]

The soft iron has narrow hysterisis loop and hence low coercivity and high remanence which means that it can be easily magnetized and demagnetized. That is why, soft iron is preferred to make core of transformer of high efficiency.

2. **2075 Set B Q.No. 1e** **What is the significance of the area of a hysteresis loop?** [2]

A broad hysteresis loop with high values of retentively and coercivity is characteristic of suitable material for a permanent magnet as a greater work must be done to change its magnetization i.e. more energy is required to damage its magnetic properties. For example, steel.

3. **2074 Supp Q.No. 1d** **Permanent magnets are made of steel. Why?** [2]

The shape and size of hysteresis loop is characteristic of each magnetic material. A broad hysteresis loop with high values of retentivity and coercive force is characteristic of suitable material for a permanent magnet as a greater work must be done to change its magnetization. This property is observed in steel and so, steel is used to make permanent magnets. However, a material having narrow hysteresis loop is suitable for transformer cores which undergoes many cycles of magnetization. Soft iron has smaller hysteresis loop, it has very low coercivity and high remanence which means that it can be easily magnetized and demagnetized. So, soft iron core is used in transformer core as the loss of energy is less and the efficiency of transformer is higher.

4. **2074 Set A Q.No. 1c** **What is angle of dip? How is it related with components of earth's magnetic field?** [2]

Angle of Dip: The angle made by a freely suspended magnet or magnetic needle with horizontal component of earth magnetic field at a place is called angle of dip. It is denoted as δ and given by

$$\tan\delta = \frac{V}{H};$$

where V and H are vertical and horizontal components of earth magnetic field respectively. If V = H, $\delta = 45^\circ$.

5. **2073 Supp Q.No. 1c** **2069 (Set A) Q.No. 1d** **Steel is used in making permanent magnets where as soft iron is preferred for making the core of transformer. Why?** [2]

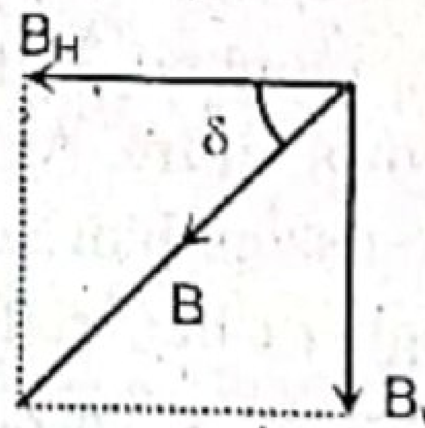
Please refer to 2074 Supp Q.No. 1d

6. **2073 Set D Q.No. 1a** **How do you expect about the directions of horizontal and vertical components of earth's magnetic intensity at pole and at equator? Give justification in terms of angle of dip.** [2]

The horizontal component (B_H) and vertical component (B_v) of earth magnetic field in terms of total earth magnetic filed (B) and dip angle δ are given as;

$B_H = B\cos\delta$ ... (i)

$B_v = B\sin\delta$ ....(ii)



At equator, $\delta = 0^\circ$, $B_H = B$; maximum value

$B_V = 0$; minimum or zero

At pole; $\delta = 90^\circ$, $B_H = 0$; minimum or zero

$B_V = B$; maximum value.

This shows that the horizontal component of earth magnetic field is maximum at equator and minimum at pole while vertical component is maximum at pole and minimum at equator.

7. **2072 Supp Q.No. 1d** **2071 Set D Q.No. 1 d** **Why should the permeability of a paramagnetic material be expected to decrease with increasing temperature?** [2]

The degree to which the magnetic lines of force can penetrate the magnetic substance placed inside to magnetizing field is called permeability of that substance. The permeability (μ) of the substance is given as $\mu = \frac{B}{H}$, where B is magnetic induction and H is magnetizing field. When the temperature of paramagnetic material increased, the alignment of molecular magnet disturbed and the value of magnetic induction B decreases as a result, μ also decrease.

8. 2072 Set C Q.No. 1c **What is retentivity and coercivity of a ferromagnetic material?** [2]

Retentivity: The induced magnetic field in the ferromagnetic material at which the magnetizing field is reduced to zero is called retentivity or remanance of ferromagnetic material. In the given figure of hysteresis loop, OR or OE at which external magnetic field or magnetising field is zero but induced magnetic field is not zero. So, OR or OE is the retentivity.

Coercivity: The coercivity is the reverse magnetic field to make the induced magnetic field zero of ferromagnets. In the given figure, OC = H_C is the coercive force or coercivity.

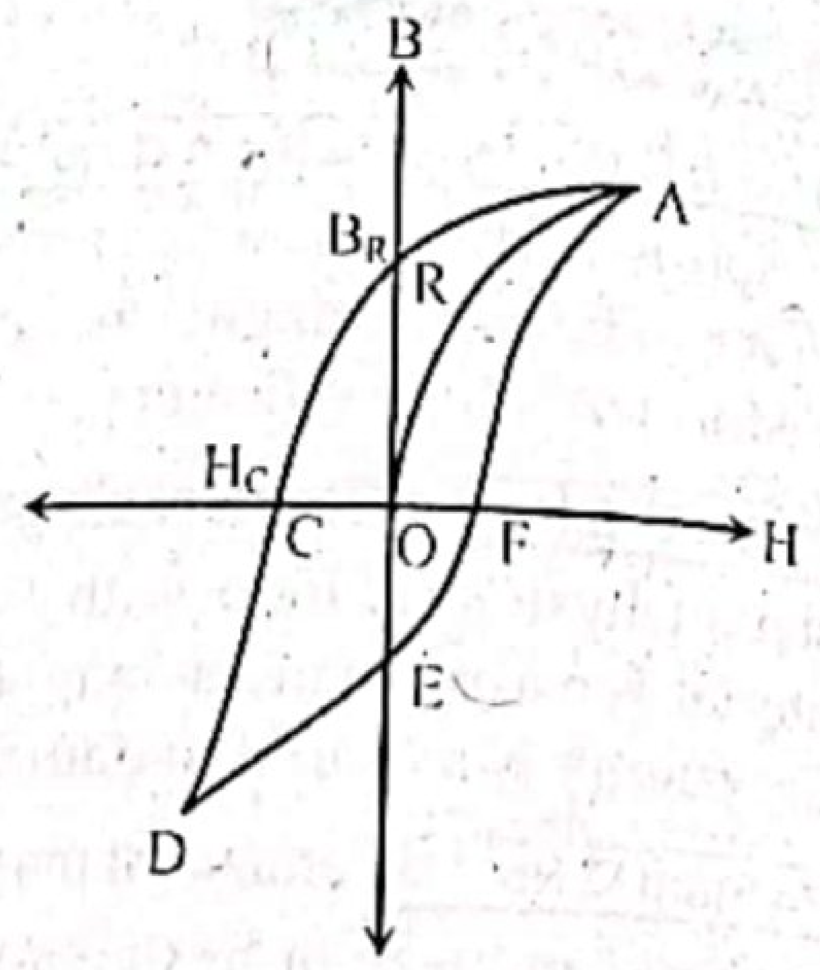


Fig: Hysteresis Loop

9. 2072 Set D Q.No. 1d **Define angle of dip. What will be its value at a place where the horizontal and vertical components of earth's magnetic field are equal?** [2]

Please refer to 2074 Set A Q.No. 1c

10. 2071 Supp Q.No. 1e **What is the role of hysteresis loop in choosing a material for making permanent magnets?** [2]

Please refer to 2075 Set B Q.No. 1e

11. 2070 Sup (Set A) Q.No. 1 d **Distinguish between dia and para magnetic substances on the basis of susceptibility.** [2]

The magnetic susceptibility of a magnetic material is defined as the ratio of the intensity of magnetization (I) to the strength of magnetizing field (H). It is denoted by χ and is given by $\chi = \frac{I}{H}$.

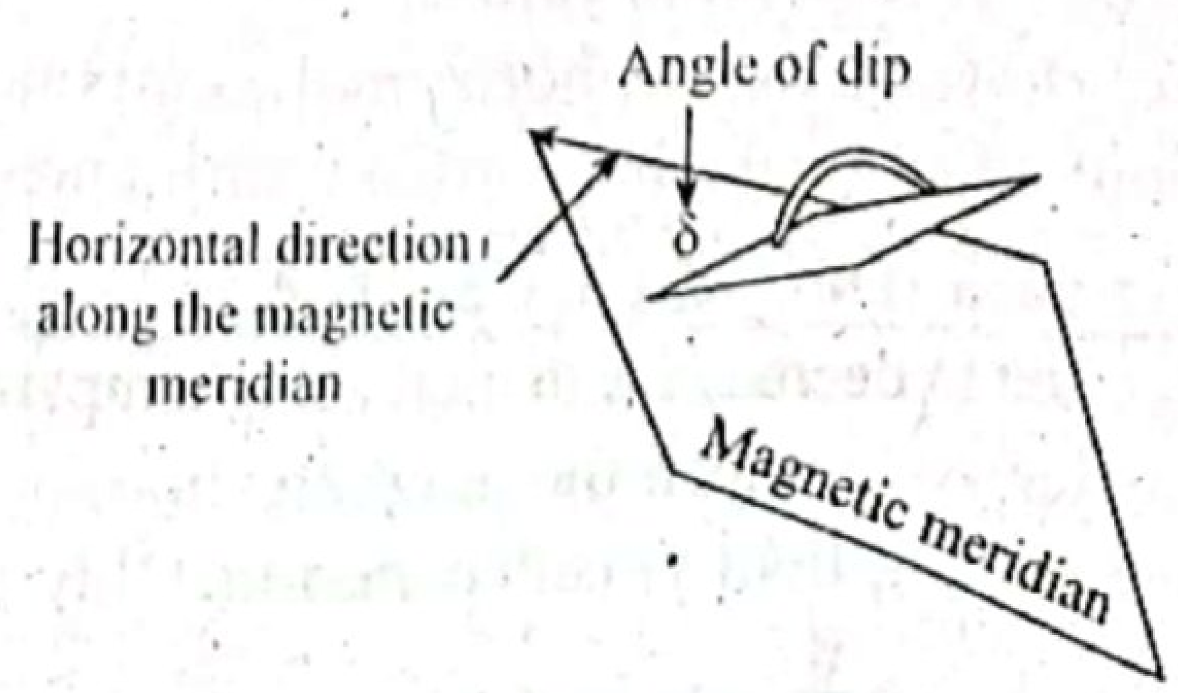
The magnetic susceptibility of a diamagnetic substance is small and negative, paramagnetic material is small and positive while that of ferromagnetic material is very high and positive.

2. 2070 Set D Q.No. 1 c **The magnetic susceptibility of a paramagnetic material is quite strongly temperature dependent, but that of diamagnetic material is nearly independent of temperature. Why?** [2]

The magnetic susceptibility of magnetic material depends upon the magnetic moments. The paramagnetic materials have permanent magnetic moment whereas the diamagnetic materials have zero magnetic moment. In paramagnets, the alignment of magnetic moment gets disturbed due to increase in temperature. As result, the paramagnet loses its magnetic properties. Due to this reason, the magnetic susceptibility of a paramagnetic material is quite strongly temperature dependent, but that of diamagnetic material is nearly independent of temperature.

2069 Supp Set B Q.No. 1 e **Define an angle of dip. What will be its value at the pole of the earth?** [2]

The angle made by a freely suspended magnet or nagnetic needle with horizontal component of earth nagnetic field at a place is called angle of dip. The esultant magnetic field is along the inclined irection of the magnet so the angle of dip is the igle between the resultant field and the horizontal. is denoted by δ. At equator, the value of angle of › is zero and the angle of dip at poles is 90°. Thus, lue of angle of dip increases from equator (where value is zero) to poles.



14. 2068 Old Q.No. 8 a XI What are the characteristics of a fero-magnetic substance? [2]

Ferromagnetic substances: The substances which are strongly attracted towards the magnet are called ferromagnetic substances. For e.g. iron, cobalt, gadolinium, and their alloys such as gadolinium are ferromagnetic substances.

Properties of Ferromagnetic substances:

The properties of ferromagnetic substances are similar to that of paramagnetic substances but are exhibited in a large scale.

i. These substances are strongly attracted by a magnet. This is due to the reason that when a ferromagnetic material is placed inside a magnetic field, it gets magnetized strongly in the direction of the magnetic field.

ii. In a non uniform magnetic field, ferromagnetic substance moves from weaker part of the magnetic field to stronger part.

iii. When a rod of a ferromagnetic substance is freely suspended in a uniform magnetic field, it rotates and aligns itself parallel to the applied field.

iv. The relative permeability of the ferromagnetic substance is much greater than 1.

v. The intensity of magnetization of ferromagnetic substance has positive value much greater than 1.

vi. The susceptibility of a ferromagnetic substance has a large positive value because $\chi = I/H$ and I has large positive value.

vii. The susceptibility of the ferromagnetic substance decreases with a rise of temperature. For i.e., the ferromagnetism decreases. At a critical temperature called Curie point, all the ferromagnetic substances become paramagnetic.

15. 2068 Q.No. 1 c **A permanent magnet can be used to pick up a string of nails, tacks or paper clips, even though these are not magnets by themselves. How can this be?** [2]

When a magnet is taken near a string of nails, tacks or paper clips, they get magnetized due to the magnetizing field of permanent magnet. The magnetic field produced in opposite direction in the magnetic material. Hence, the magnetic material like string of nail, paper clip are attracted by a permanent magnet, even through these are note magnets themselves.

16. 2068 Can. Q.No. 1e 2063 Q.No. 8 a **Above curie temperature a ferromagnetic material becomes paramagnetic. Why?** [2]

According to the Curie's law, the magnetic susceptibility (χ) of paramagnetic material is inversely proportional to its absolute temperature (T) i.e., $\chi \propto \frac{1}{T}$. The susceptibility of ferromagnetic material decreases with the rise of temperature in a complicated manner. A ferromagnetic material starts behaving as a paramagnetic material at a certain temperature which is called Curie temperature. Due to increase in temperature, the alignment of molecular magnet in the magnetic domain distributed and they lose their magnetic properties. Above curie temperature, the alignment of domain is completely random and the ferromagnetic substance becomes paramagnet.

17. 2067 Sup Q.No. 1e **Permanent magnets are made of steel while the core of transformer is made of soft iron. Why?** [2]

Please refer to 2074 Supp Q.No. 1d

18. 2067 Q.No. 1c **Why does a magnet lose its magnetism when heated to high temperature?** [2]

When a magnet is heated, due to thermal energy, the tiny molecular magnet gains kinetic energy and orients itself in any direction. As temperature increases up to the melting point of the material of the magnet, the orientation is completely random and it completely loses its magnetic properties and hence not retains its magnetism.

19. 2066 Old Q.No. 8 a **The angle of dip in Britain is greater than that in Kathmandu. Why?** [2]

The angle made by a freely suspended magnet or magnetic needle with horizontal component of earth magnetic field at a place is called angle of dip. It is denoted by δ. At equator, the value of angle of dip is zero and the angle of dip at poles is 90°. Thus, value of angle of dip increases from equator (where it's value is zero) to poles. Kathmandu lies near to equator than the Britain, so the angle of dip in Britain is greater than that in Kathmandu.

20. 2064 Q.No. 8 a **Why does a bar magnet not retain its magnetism when it is melted?** [2]

Please refer to 2067 Q.No. 1c

21. 2059 Q.No. 8 c **How does dip vary from place to place on earth's surface?** [2]

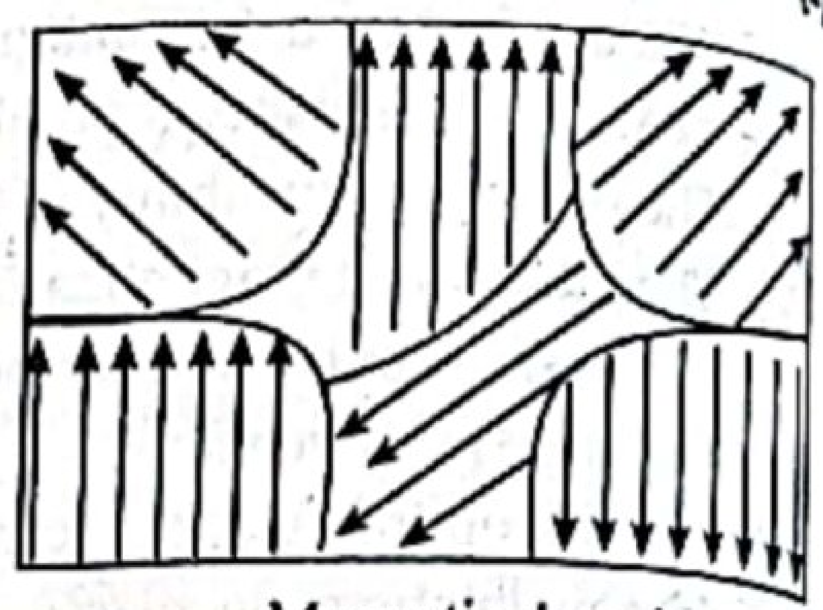
Please refer to 2069 Supp Set B Q.No. 1 e

22. 2058 Q.No. 8 c **Define angle of dip and angle of declination at a place.** [2]

The angle made by a freely suspended magnet or magnetic needle with horizontal component of earth magnetic field at a place is called angle of dip. The value of this angle varies from zero at the equator to 90° at the geomagnetic pole. The angle of declination is the angle between the magnetic meridian and the geographic meridian.

23. 2057 Q.No. 8 b **What are magnetic domains?** [2]

The atoms of a ferromagnetic material possess non-zero magnetic moment. According to atomic view of magnetism, an atom acts as a small magnet due to the orbital and spinning motion of its electrons. In small regions, there are large numbers of atoms. These small regions in which all-atomic magnets align along same direction and have very strong magnetism inside the ferromagnetic material are called magnetic domains. There are very large numbers of domains, which align along various directions. Hence, net magnetic moment is zero but inside the domains there exist strong magnets.



Magnetic domain

24. 2057 Q.No. 8 c **What is angle of dip? How does it vary from the equator to the poles?** [2]

Please refer to 2069 Supp Set B Q.No. 1 e

Long Answer Questions

25. 2076 Set C Q.No. 5c **Define angle of dip. If δ is the true dip at a place, δ_1 and δ_2 are the apparent dips observed in two vertical planes at right angles to each other at that place, then prove the relation, $\cot^2\delta = \cot^2\delta_1 + \cot^2\delta_2$.** [4]

Angle of Dip: The angle made by a freely suspended magnet or magnetic needle with horizontal component of earth magnetic field at a place is called angle of dip. It is denoted as δ and given by

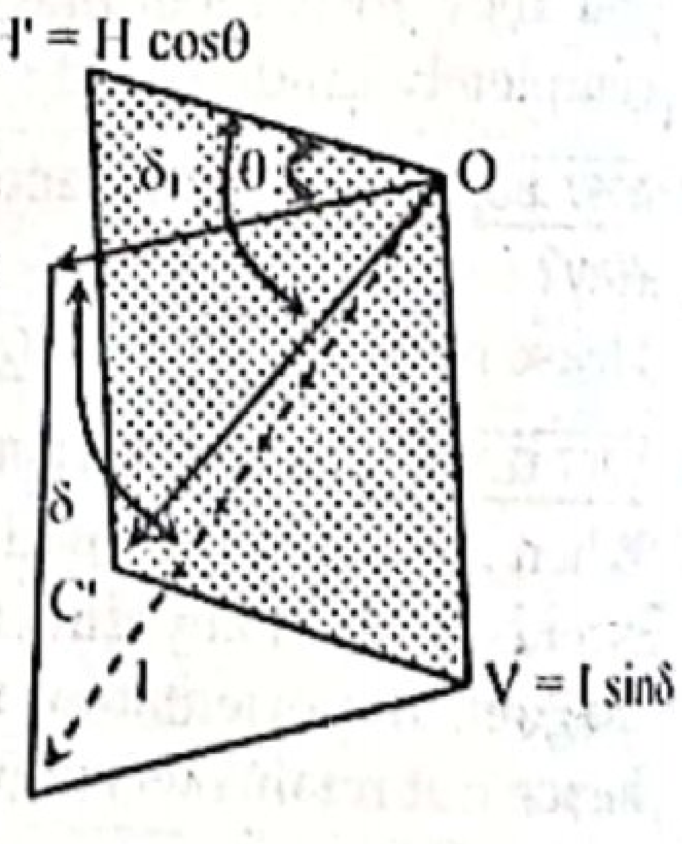
$$\tan\delta = \frac{V}{H};$$

where V and H are vertical and horizontal components of earth magnetic field respectively.

The angle of dip measured by keeping the dip circle in magnetic meridian is called true angle of dip.

The angle of dip at a place measured without bringing the dip circle in the magnetic meridian is called apparent dip.

Let OVCH represents the magnetic meridian & the shaded area OH'C'V represent a plane which is not in magnetic meridian, obtained after rotation of the OVCH plane through an angle θ along the vertical axis OV, the resulted intensity I acts along the OC and makes an angle δ with the horizontal line OH. This angle δ is the true dip at the plane.



In figure, OH represents the horizontal component and OV represents the vertical component of I, so that, $H = OH = I\cos\delta$ and $V = OV = I\sin\delta$.

After rotation of the plane to the position OVC'H', the angle made by the resultant intensity OC' with the horizontal line OH' is δ_1. This angle δ_1 is called apparent dip at that plane. For the new plane, OH' represents the horizontal component and OV represents the vertical component of I, so that, $OH' = H\cos\theta$ and $OV = I\sin\delta$. Now, from right angled $\Delta OC'H'$,

$$\tan\delta_1 = \frac{C'H'}{OH'} = OV/OH' = I\sin\delta / H\cos\theta$$

But we have, $H = I\cos\delta$

So, $\tan\delta_1 = I\sin\delta / I\cos\delta\cos\theta = \tan\delta/\cos\theta$

or, $1/\tan^2\delta_1 = \cos^2\theta/\tan^2\delta$ .... (i)

Let the plane OVC'H' is rotated through an angle 90° from its position.

Suppose, at that place, angle of apparent dip is δ_2, so that

$\tan\delta_2 = \tan\delta/\cos(90+\theta) = \tan\delta/-\sin\theta$

or, $1/\tan^2\delta_2 = \sin^2\theta/\tan^2\delta$ ... (ii)

Now adding (i) and (ii) we get,

$1/\tan^2\delta_1 + 1/\tan^2\delta_2 = \cos^2\theta/\tan^2\delta + \sin^2\theta/\tan^2\delta$

or, $1/\tan^2\delta_1 + 1/\tan^2\delta_2 = (\cos^2\theta + \sin^2\theta)/\tan^2\delta = 1/\tan^2\delta$

$\therefore \cot^2\delta_1 + \cot^2\delta_2 = \cot^2\delta$ **Proved**

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5. 2074 Set B Q.No. 5c **Define permeability and susceptibility of magnetic materials. Derive a relation between them.** **[4]**

» **Permeability (μ):** The degree to which the magnetic lines of force can penetrate in a substance placed in magnetising field is called the permeability of the substance. It is a property of magnetic substance. It is also defined as the ratio of the magnetic induction to the strength of magnetizing field. It is denoted by μ. By definition, $\mu = B/H$, where B is value of magnetic induction and H is the value of magnetizing field and value of μ in free space is $\mu_0 = 4\pi\times10^{-7}\ \mathrm{WbA^{-1}m^{-1}}$

Relative Permeability (μ_r): It is defined as the ratio of the permeability of a medium to that in vacuum. So, by definition, $\mu_r = \mu/\mu_0$. Since, it is a pure ratio, it has no unit.

Magnetic Susceptibility(χ): The magnetism induced in a material when it is placed in a magnetic field depends upon the magnetising field and nature of the material. Thus, when two identical pieces of the same volume and size of different materials are placed in the magnetising field H, they would be magnetized to different extents.

This property of the magnetic substance also defined as the ratio of the intensity of magnetisation to the strength of the magnetising field. It is denoted by χ.

By definition, $\chi = I/H$

Relation between μ_r and χ

When a magnetic material is magnetized in a magnetising field vacuum, the magnetic induction developed in the material is due to the magnetizing field H and induced magnetism in the material i.e., the intensity of magnetization. Hence, the total magnetic induction is the sum of these two quantities and we have,

$B = B_1$ (magnetic field inside material) + B_2 (Magnetic field due to material)

or, $B = \mu_0 H + \mu_0 I$

or, $\mu H = \mu_0 H + \mu_0 I$

or, $\dfrac{\mu}{\mu_0} = 1 + \dfrac{I}{H}$

or, $\mu_r = 1 + \chi$

This is the required relationship between the relative permeability and magnetic susceptibility.

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7. 2073 Set C Q.No. 5b **Relate magnetic permeability and susceptibility features of a magnetic material. Can hysteresis curve be drawn in the case of diamagnetic material? Explain on the basis of above features.** **[4]**

» **First Part:** Please refer to 2074 Set B Q.No. 5c

Second Part

No, hysteresis curve cannot be drawn in the case of diamagnetic material because hysteresis is the phenomena of ferromagnetic material which is easily magnetized and demagnetized by external magnetic field. The causes are:

i. The permeability (μ) of diamagnet is less than 1.
ii. The intensity of magnetization has a small negative value.
iii. Susceptibility has value less then one.
iv. They are feebly repelled by magnets.

28. 2072 Set E Q.No. 5c **What do you mean by true dip and apparent dip? Show that $Cos^2\delta = Cot^2\delta_1 + Co$ where symbols have usual meanings.**

Please refer to 2076 Set C Q.No. 5c

29. 2070 Supp. (Set B) Q.No. 5 d **Prove that $\cot^2\delta = \cot^2\delta_1 + \cot^2\delta_2$, where symbols have usual meanings.**

Please refer to 2076 Set C Q.No. 5c

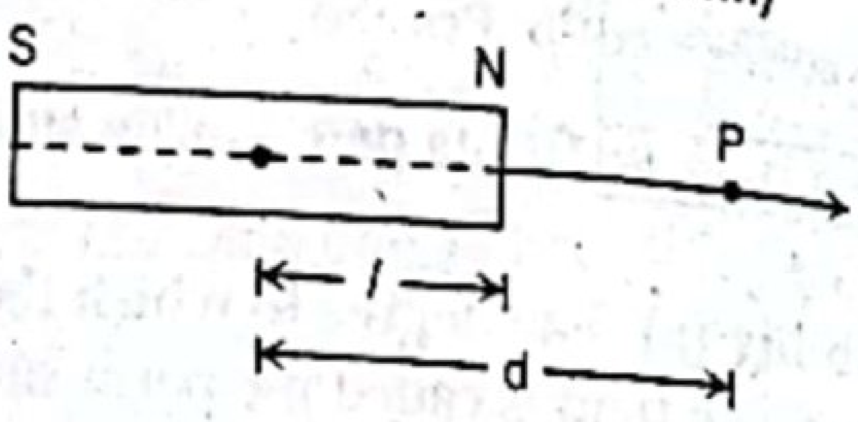
30. 2070 Set C Q.No. 5 b **Define magnetic susceptibility and relative permeability and establish a relation betw them.**

Please refer to 2074 Set B Q.No. 5c

Numerical Problems

31. 2075 Set A Q.No. 9c **A bar magnet, 10 cm in length, has pole strength of 10 AM. Determine the magnetic fi at a point on its axis at a distance of 15 cm from the center of the magnet. ($\mu_0 = 4\pi \times 10^{-7}$ H/m)**

Solution



Given,

Length of bar magnet ($2l$) = 10cm

or, l = 5 cm = 0.05 m

Pole strength (m) = 10Am

Magnetic moment (M) = $m.2l = 10 \times 0.1 = 1$ Am^2

Distance (d) = 15 cm = 0.15 m

Magnetic permeability (μ_0) = $4\pi \times 10^{-7}$ H/m

Magnetic field (B) = ?

We have,

$$B = \frac{\mu_0}{4\pi} \times \frac{2Md}{(d^2 - l^2)^2}$$

$$= \frac{4 \times \pi \times 10^{-7}}{4\pi} \times \frac{2 \times 3 \times 0.15}{(0.15^2 - 0.05^2)^2}$$

$$= \frac{3 \times 10^{-8}}{4 \times 10^{-4}}$$

$$= 7.5 \times 10^{-5}\ T$$

32. 2062 Q.No. 9 b **The needle of a dip circle shows an apparent dip of 45° in a particular position and 53° when the circle is rotated through 90°. Find the true dip.**

Solution

Given,

Apparent dip at one place (δ_1) = 45°

Apparent dip at another place right angle to the first place (δ_2) = 53°

True value of dip (δ) = ?

If δ be the true value of dip, then, $\cot^2\delta = \cot^2\delta_1 + \cot^2\delta_2$

$$\frac{1}{\tan^2\delta} = \frac{1}{\tan^2\delta_1} + \frac{1}{\tan^2\delta_2} \Rightarrow \frac{1}{\tan^2\delta} = \frac{1}{\tan^2 45°} + \frac{1}{\tan^2 53°}$$

$$\frac{1}{\tan^2\delta} = 1 + 0.57 \Rightarrow \delta = 38.7°$$

Hence, the required true angle of dip is 38.7°.

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