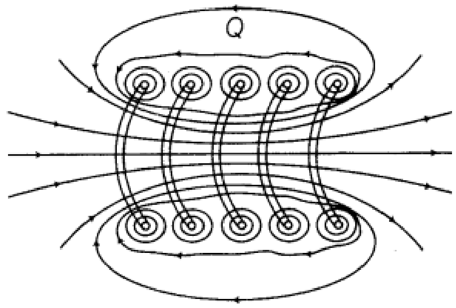
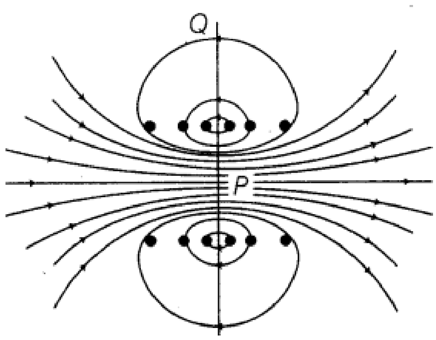
Chapter 5. Magnetism and Matter

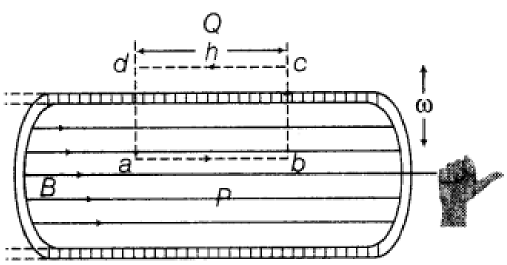
Magnetic Dipoleand Magnetic Field Lines

2 Marks Questions

1.Draw the magnetic field lines due to a current passing through a long solenoid. Use Ampere's circuital law, to obtain the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length. [Delhi 2014c]





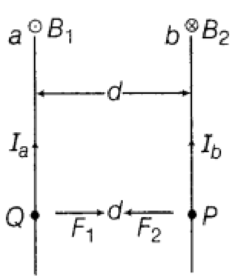


Applying Ampere's circuital law for the rectangular loop *abcd*,

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$$

$$Bh = \mu_0 I(nh)$$

$$B = \mu_0 nI \qquad \textbf{(1)}$$



Let a and b be two long straight parallel conductors. I_a and I_b are the current flowing through them and separated by a distance d. Magnetic field induction at a point P on a conductor b due to current I_a passing through a is

2.(i) Two long straight parallel conductors a and b carrying steady currents I_a and I_b respectively are separated by a distance d. Write the magnitude and direction, what is the nature and magnitude of the force between the two conductors?

(ii) Show with the help of a diagram, how the force between the two conductors would

change when the currents in them flow in the opposite directions. [Foreign 2014]

$$B_1 = \frac{\mu_0 2I_a}{4\pi d}$$

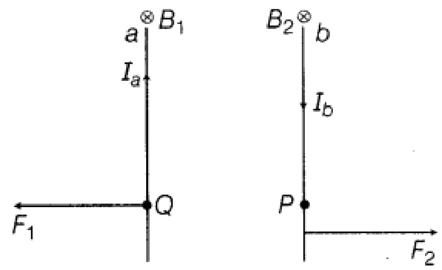
Now, unit length of b will experience a force as

$$F_2 = B_1 I_b \times 1 = B_1 I_b$$

$$\therefore \quad F_2 = \frac{\mu_0}{4\pi}\frac{2I_a I_b}{d}$$

Conductor a also experiences the same amount of force directed towards b. Hence, a and b attract each other. **(1)**

(*ii*)



Now, let the direction of current in conductor b be reversed. The magnetic field B_2 at point P due to current I_a flowing through a will be downwards. Similarly, the magnetic field B at point Q due to current I_b passing through b will also be downward as shown. The force on a will be, therefore towards the left. Also, the force on b will be towards the right. Hence, the two conductors will repel each other as shown.

3.A circular coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil. [All India 2012]

> The length of wire will be same in two cases as the same coil is unwound and rewound.

Length of the wire is same

$$\therefore \quad N_1 \times (2\pi R) = N_2 \times 2\pi\left(\frac{R}{2}\right)$$

[N_1 and N_2 = number of turns in two coils]

$$N_2 = 2N_1 \qquad \textbf{(1/2)}$$

Now, the ratio of magnetic moments is given by

$$\frac{M_1}{M_2} = \frac{N_1 I A_1}{N_2 I A_2} = \frac{N_1 \times \pi R_1^2}{N_2 \times \pi R_2^2} \qquad \textbf{(1/2)}$$

$$\frac{M_1}{M_2} = \left(\frac{N_1}{2N_1}\right) \times \left(\frac{R}{R/2}\right)^2 = \frac{1}{2} \times 4 = 2 \qquad \textbf{(1/2)}$$

$$M_1 : M_2 = 2:1 \qquad \textbf{(1/2)}$$

4.A circular coil of N turns and diameter d carries a current I. It is unwound and rewound to make another coil of diameter 2d, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil. [All India 2012]

The length of wire will be same in two cases as the same coil in unwound and rewound.

Length of wire of coil 1 = Length of wire of coil 2

$$N_1 \times \pi d_1 = N_2 \times \pi d_2$$

$$N_1 \times \pi d = N_2 \times \pi \times 2d$$

$$N_2 = \frac{N_1}{2} \qquad \text{where } N_1 = N$$

$\Rightarrow$ $N_2 : N_1 = 1:2$

$\Rightarrow$ $N_1 : N_2 = 2:1$ **(1/2)**

Magnetic moment, $M = NIA$ **(1/2)**

$$\therefore \quad \frac{M_1}{M_2} = \frac{N_1 I A_1}{N_2 I A_2} = \frac{N_1 \pi d^2}{N_2 \pi (2d)^2}$$

$$\frac{M_1}{M_2} = \left(\frac{N_1}{N_2}\right) \times \frac{1}{4} = 2 \times \frac{1}{4} = \frac{1}{2}$$ **(1/2)**

$$\frac{M_1}{M_2} = \frac{1}{2}$$

$\Rightarrow$ $M_1 : M_2 = 1:2$ **(1/2)**

5.Explain the following:

- Why do magnetic lines of force form continuous closed loops?
- Why are the field lines repelled (expelled) when a diamagnetic material is placed in an external uniform magnetic field? [Foreign 2011]

(*i*) Magnetic lines of force come out from North pole and enter into the South pole outside the magnet and travels from South pole to North pole inside the magnet. So, magnetic lines of force form closed loop. **(1)**

(*ii*) The diamagnetic material gets slightly magnetised in a direction opposite to external field, therefore lines of force are repelled by diamagnetic material. **(1)**

NOTE When South pole of the magnet is viewed with the frame of reference inside the magnet would appear as North pole and similarly, North pole as South pole. Therefore, magnetic lines of force traversed from South pole to North pole inside the magnet.

6.A small compass needle of magnetic moment M and moment of inertia I is free to oscillate in a magnetic field It is slightly disturbed from its equilibrium position and then released. Show that it executes simple harmonic motion. Hence, write the expression for its time period. [HOTS, Delhi 2011C]

As the needle is displaced from the equilibrium position, the torque will try to bring it back in equilibrium position hence, acceleration will be related with negative of angular displacement.

When compass needle of magnetic moment M and moment of inertia I is slightly disturbed by an angle θ from the mean position of equilibrium. Then, restoring torque begin to act

the needle which try to bring the needle back to its mean position which is given by

$$\tau = -MB\sin\theta$$

Since, θ is small

So, $\sin\theta \approx \theta$

$\therefore$ $\tau = -MB\theta$

But $\tau = I\alpha$

where, α = angular acceleration

M = magnetic moment of dipole

$\Rightarrow$ $I\alpha = -MB\theta$

$$\alpha = -\left(\frac{MB}{I}\right)\theta$$

$\therefore$ $\alpha \propto -\theta$ **(1)**

$\Rightarrow$ Angular acceleration $\propto$ − angular displacement

$\Rightarrow$ Therefore, needle executed SHM.

Hence, the time period,

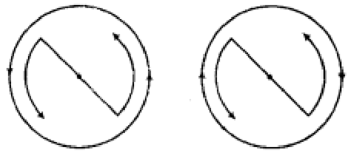
$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{MB}{I}}}$$

or $$T = 2\pi\sqrt{\frac{I}{MB}}$$ **(1)**

This is the required expression.

7.How does a circular loop carrying current behaves as a magnet? [Delhi 2011]

Ans.The current round in the face of the coil is in anti-clockwise direction, then this behaves like a North pole, whereas when it viewed from other sc le, then current round in it is in clockwise direction necessarily forming South pole of magnet.

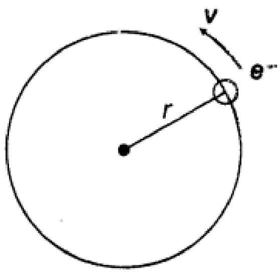


Hence, current loop have both magnetic poles and therefore, behaves like a magnetic dipole

8.Deduce the expression for the magnetic dipole moment of an electron orbiting around the central nucleus. [All India 2010, Foreign 2009]

As we know that a moving charge always produces an electric current, so there will be electric current due to revolving electron, this is the current which produces magnetic field.

Let an electron revolves around the nucleus on a circular path of radius r with a uniform linear speed v.



Time period of electron is given by

$$T = \frac{2\pi r}{v}$$

∴ Electric current produced due to the orbital motion of electron is given by

$$I = \frac{-e}{T}$$

$$I = \frac{-e}{\left(\frac{2\pi r}{v}\right)}$$

$$I = -\frac{ev}{2\pi r} \quad \ldots(i)$$

(1)

Magnetic dipole moment is given by

$$M = IA = \left(\frac{-ev}{2\pi r}\right)\pi r^2$$

$$M = -\frac{evr}{2}$$

$$\Rightarrow \quad M = -\frac{e}{2m}(mvr)$$

where, m = mass of electron.

$$\Rightarrow \quad M = -\frac{e}{2m}L$$

where, $L = mvr$ and known as angular momentum,

$$M = -\frac{e}{2m}L$$

The direction of magnetic dipole moment is perpendicular to the plane of paper and directed inward. **(1)**

1 Mark Questions

1. Relative permeability of a material $\mu_r = 0.5$. Identify the nature of the magnetic material and write its relation of magnetic susceptibility. **[Delhi 2014]**

Ans. The nature of magnetic material is diamagnetic.

$$\mu_r = 1 + \chi_m$$

2.What are permanent magnets? Give one example. [Delhi 2013]

Ans. Permanent magnets are those magnets which have high retentivity and coercivity The magnetisation of permanent magnet is not easily destroyed even if it is handled roughly or exposed in stray reverse magnetic field, e.g. steel.

3.Where on the surface of the earth's vertical component of earth's magnetic field zero?
[Delhi 2013C, All india 2011]
3.Where on the surface of the earth's vertical component of earth's magnetic field zero?

Ans. At equator, vertical component will be zero.

4.The horizontal component of the earth's magnetic field at a place is B and angle of dip is 60°. What is the value of vertical component of the earth's magnetic field at equator? [Delhi 2012]

Ans.

The horizontal and vertical components of the earth's magnetic field are perpendicular to each other.

Horizontal component of earth's magnetic field,

$$H = B_e \cos 60° = B \quad \text{(given)}$$

$$\Rightarrow \quad B_e \times \frac{1}{2} = B$$

or $$B_e = 2B$$

Vertical component of earth's magnetic field,

$$V = B_e \sin 60°$$

$$\Rightarrow \quad V = 2B \times \frac{\sqrt{3}}{2}$$

$$\Rightarrow \quad V = \sqrt{3}B$$

5.What is the angle of dip at a place where the horizontal and vertical components of the earth's magnetic field are equal? [Foreign 2012]

Ans.

The angle of dip is given by

$$\delta = \tan^{-1}\left(\frac{B_V}{B_H}\right)$$

B_V = vertical component of the earth's magnetic field.

B_H = horizontal component of the earth's magnetic field.

So, as $B_V = B_H$

Then, $\delta = \tan^{-1}(1) = 45°$

∴ The angle of dip will be $\delta = 45°$. **(1)**

6.A magnetic needle free to rotate m a vertical plane orients itself vertically at a certain place on the earth What are the values of

- **horizontal component df the earth's magnetic field and**
- **angle of dip at this place? [Foreign 2012]**

Ans. (i) The coil is free to move in vertical plane, it means that there is no componerr A the earth's magnetic field in horizontal direction, so the horizontal component of the earth's magnetic field is 0.

(ii) The angle of dip is 90°.

7.Where on the surface of earth is the angle of dip 90°? [All India 2011]

Ans. At poles, the angle of dip is 90°.

8.The permeability of a magnetic material is 0.9983. Name the type of magnetic material, it represents. [Delhi 2011]

Ans.

The magnetic material is diamagnetic substance for which $\mu_r < 1$. **(1)**

9.The susceptibility of a magnetic material is 1.9 x 10^{-5}. Name the of magnetic material, it represents. [Delhi 2011]

Ans. The small and positive susceptibility of 1.9 x 10^{-5} represents paramagnetic substance.

10. The susceptibility of a magnetic material is -4.2×10^{-6}. Name the type of magnetic material, it represents. **[Delhi 2011]**

Ans. Negative susceptibility diamagnetic substance.

11. If the horizontal and vertical components of the earth's magnetic field are equal at a certain place, what would be the angle of dip at that place? **[All India 2011C]**

Ans.

∵ Horizontal component,

$$H = B\cos\theta$$
$$= 0.4\cos 60°$$
$$= 0.4 \times \frac{1}{2}$$
$$\Rightarrow \quad = 0.2\ G$$
$$H = 0.2 \times 10^{-4}\ T \quad [\because \cos 60° = 1/2]$$

The wheel is rotating in a plane normal to the horizontal component, so it will cut the horizontal component only, vertical component of earth will contribute nothing in emf. **(1)**

Thus, the emf induced is given as

$$E = \frac{1}{2}Hl^2\omega,$$

where, $\omega = \frac{2\pi N}{t}$ and

l = length of the spoke

$= 50\ cm = 0.5\ m$

$$\therefore \quad E = \frac{1}{2}\times 0.2\times 10^{-4}\times(0.5)^2\times\frac{2\times 3.14\times 120}{60}$$

$$E = 3.14\times 10^{-5}\ V$$ **(1)**

12. What is the Characteristic property of a diamagnetic material? [Foreign 2010]

Ans. Diamagnetic material acquires magnetisation in the opposite direction of the magnetic field when they are placed in an external magnetic field

13. Define the term magnetic declination. [All India 2009c]

Ans. Magnetic declination The angle between geographical meridian and magnetic meridian at any place of the earth is known as magnetic declination (a) at that place of the earth.

2 Marks Questions

14.Show diagrammatically the behaviour of magnetic field lines in the presence of

- **paramagnetic and**
- **diamagnetic substances. How does one explain this distinguishing feature? [All ihdia 2014]**

Ans. Magnetic permeability of paramagnetic is more than air, so it allows more lines to pass through it while permeability of diamagnetic is less than air, so it does not allow lines to pass through it.

For figure, refer ans. 34.

This difference can be explained as diamagnetic substances repel or expel the magnetic field lines while paramagnetic substance attract the magnetic field lines

15.Out of the two magnetic materials, A has relative permeability slightly greater than unity while B has less than unity. Identify the nature of the materials A and B. Will their susceptibilities be positive r negative? [Delhi 2014]

Ans.

The nature of the material A is paramagnetic and its susceptibility χ_m is positive.

The nature of the material B is diamagnetic and its susceptibility χ_m is negative. **(2)**

16. Give two points to distinguish between a paramagnetic and diamagnetic substance.

Ans.

	Paramagnetic substance	Diamagnetic substance
1.	A paramagnetic substance is feebly attracted by magnet.	A diamagnetic substance is feebly repelled by a magnet.
2.	For a paramagnetic subst -e, the intensity of magnetisation has a small positive value.	For a diamagnetic substance, the intensity of magnetism has a small negative value.

17. (i) How is an electromagnet different from a permanent magnet?

(ii) Write two properties of a material which makes it suitable for making electromagnet. [All India 2014C]

Ans. An electromagnet consists of a core made of a ferromagnetic material placed inside a solenoid. It behaves like a strong magnet when current flows through the solenoid and effectively loses its magnetism when the current is switched off.

(i) A permanent magnet is also made up of a ferromagnetic material but it retains its magnetism at room temperature for a long time after being magnetised one.

(ii) Properties of material are as below:

- High permeability
- Low retentivity
- Low coercivity

18. The relative magnetic permeability of a magnetic material is 800. Identify the nature of magnetic material and state its two properties. [Delhi 2012]

Ans. Ferromagnetic substance as these substances have very high magnetic permeability.

Properties (i) High retentivity

(ii) High susceptibility

19.(i) How does a diamagnetic material behave when it is cooled to very low temperature?

(ii) Why does a paramagnetic sample display greater magnetisation when cooled? Explain. [Delhi 2012]

Ans. (i) As, the resistance (electrical of metal decreases with decrease in temperature.

But for diamagnetic substances, the variation of susceptibility is very small, i.e. diamagnetic materials are unaffected by the change in temperature (except bismuth). (1)

(ii) Paramagnetic materials when cooled due to thermal agitation tendency alignment of magnetic dipoles decreases. Hence, they shows greater magnetisation.

20.A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its North tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place. [Delhi 2011]

Ans.

Angle of dip, $\delta = 60° = \frac{\pi}{3}$

Horizontal component of the earth's magnetic field, $H = 0.4$ G

Earth magnetic field $(B_e) = ?$

$\because$ Horizontal component of the earth's magnetic field, $H = B_e \cos\delta$ **(1)**

$$\Rightarrow B_e = \frac{H}{\cos\delta} = \frac{0.4\text{ G}}{\cos 60°} = \frac{0.4\text{ G}}{\left(\frac{1}{2}\right)} = 0.8\text{ G}$$

$\therefore$ $B_e = 0.8$ G **(1)**

21.Distinguish between diamagnetic and ferromagnetic materials in terms of

- **susceptibility and**
- **their behaviour in a non-uniform magnetic field. [All India 2011]**

Ans.

(*i*) **Susceptibility for diamagnetic material** It is independent of magnetic field and temperature (except for bismuth at low temperature). **(1)**

Susceptibility for ferromagnetic material The susceptibility of ferromagnetic metarials decreases steadily with increase in temperature. At the Curie temperature, the ferromagnetic materials become paramagnetic. **(1)**

(*ii*) **Behaviour in non-uniform magnetic field** Diamagnets are feebly repelled, whereas ferromagnets are strongly attracted by non-uniform field, i.e. diamagnets move in the direction of decreasing field, whereas ferromagnet feels force in the direction of increasing field intensity.

22.(i) Write two characteristics of a material used for making permanent magnets?

(ii) Why is core of an electromagnet made of ferromagnetic materials? [Delhi 2010]

Ans.

(i) Two characteristics of material used for making permanent magnets are

(a) high coercivity.

(b) high retentivity and high hysterisis loss.

(ii) Core of an electromagnet made of ferromagnetic material because of its

(a) low coercvity

(b) low hysterisis loss

23.The horizontal component of the earth's magnetic field at a place is V3 times its vertical component there. Find the value of the angle of dip at that place. What is the ratio of the horizontal component to the total magnetic field of the earth at that place? [All India 2010c]

Ans.

? As vertical and horizontal components of magnetic fields are perpendicular to each other, when their magnitudes are equal, resultant will divide their angle equally.

According to the question,

$$H = \sqrt{3}\,V$$

where, H and V are the horizontal and vertical components of the earth's magnetic field.

If angle of dip at that place is δ, then

$$\tan\delta = \frac{V}{H} = \frac{V}{\sqrt{3}\,V} \qquad [\because H = \sqrt{3}\,V]$$

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

$$\Rightarrow \qquad \delta = \frac{\pi}{6} \qquad \textbf{(1)}$$

$\because$ Horizontal component of the earth's magnetic field, $H = B_e \cos\delta$

where, B_e = Earth's magnetic field

$$\frac{H}{B_e} = \cos\delta$$

$$= \cos\frac{\pi}{6} = \frac{\sqrt{3}}{2}$$

$$H : B_e = \sqrt{3} : 2$$

24.The horizontal component of the earth's magnetic field at a place equals to its vertical component there. Find the value of the angle of dip at that place. What is the ratio of the horizontal component to the total magnetic field of the earth at that place? [HOTS, All India 2010C]

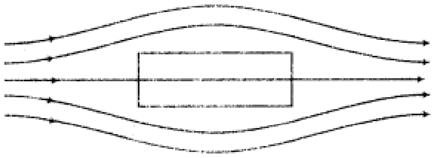
Ans.

Refer to ans. 23. (Ans $1:\sqrt{2}$).

25. Draw magnetic field lines when a (*i*) diamagnetic, (*ii*) paramagnetic substance is placed in an external magnetic field. Which magnetic property distinguishes this behaviour of the field lines due to the two substances? **[Delhi 2010]**

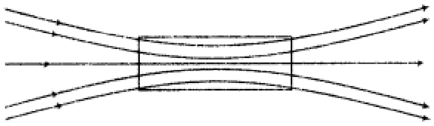
Ans.

(*i*) Behaviour of magnetic field lines when diamagnetic substance is placed in an external field.



(1)

(*ii*) Behaviour of magnetic field lines when paramagnetic substance is placed in a external field.



(1)

Magnetic susceptibility distinguishes the behaviour of the field lines due to diamagnetic and paramagnetic substance. **(1)**

26. State briefly an efficient way of making a permanent magnet. Write two properties to select suitable materials for making permanent magnets. **[Delhi 2009C]**

Ans.

Permanent magnet can be made by putting a steel rod inside the solenoid and a strong current is allowed to pass through solenoid. The strong magnetic field inside the solenoid magnetise the rod. **(1)**

For properties to select suitable materials for making parmanent magnets

Refer to ans. 22 (i). **(1)**

27. Out of the following, identify the materials which can be classified as
(*i*) paramagnetic (*ii*) diamagnetic

(*a*) Aluminium (*b*) Bismuth
(*c*) Copper (*d*) Sodium

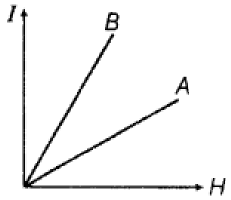
Write one property to distinguish between paramagnetic and diamagnetic materials. **[Delhi 2009C]**

Ans.

(*i*) **Permagnetic substance** Aluminium, sodium **(1)**

(*ii*) **Diamagnetic substance** Bismuth, copper, the susceptibility of the diamagnetic materials is small and negative, i.e. $-1 < \chi_m < 0$, whereas for paramagnetic substance the susceptibility is small and positive, i.e. $0 < \chi_m < a$, where a is a small number. **(1)**

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



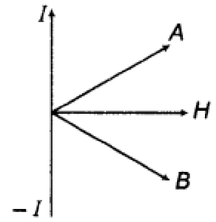
(*i*) Identify the materials *A* and *B*.
(*ii*) Why does the material *B* have a larger susceptibility than *A* for a given field at constant temperature? **[HOTS, All India 2008]**

Ans.

The slope of *I*-*H* curve gives the magnetic susceptibility, $\chi_m = \frac{Z}{H}$.

Material *A* Paramagnetic substance (χ_m is small but positive) **(1/2)**
Material *B* Ferromagnetic substance (χ_m is large and positive). **(1/2)**
The susceptibility of material *B* is larger than that of *A* in a given magnetic field because ferromagnetic material gets strongly magnetised and hence, produces larger intensity of magnetisation in comparison to paramagnetic substance, therefore it is strongly magnetised. **(1)**

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



(*i*) Identify the materials A and B.

(*ii*) Draw the variation of susceptibility χ_m with temperature for B.

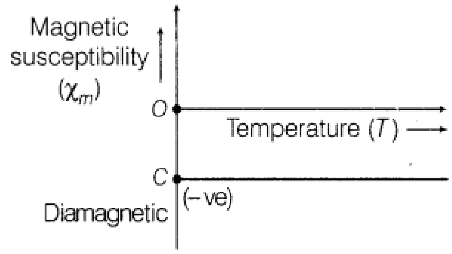
[All India 2008]

Ans.

Material *A* Paramagnetic substance (χ_m is small and positive)

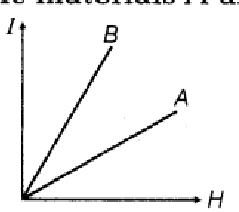
Material *B* Diamagnetic substance (χ_m is small but negative)

The susceptibility of a diamagnetic substance is independent of temperature and magnetising field.



This is the graph for variation of χ_m with temperature (T) of diamagnetic substance for material B. **(1)**

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



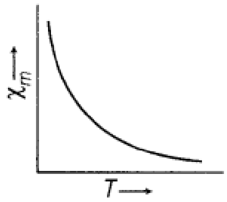
(*i*) Identify the materials A and B.

(*ii*) For the material A, plot the variation of intensity of magnetisation. **[All India 2008]**

Ans.

(i) Refer to ans. 28. **(1)**

(ii) The magnetic susceptibility (χ_m) of paramagnetic substance (i.e. material A) varies inversely with the absolute temperature.



31.Define magnetic susceptibility Of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify? [Delhi 2008]

Ans.

Magnetic susceptibility The magnetic susceptibility (χ_m) of a magnetic material is equal to the ratio of intensity of magnetisation and magnetising field, i.e.

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

where, I = intensity of magnetisation

H = magnetising field **(1)**

It has no unit. **(1/2)**

Positive magnetic susceptibility possesses by paramagnetic substance, e.g. aluminium, sodium.

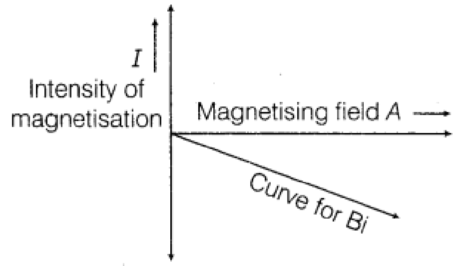
Negative magnetic susceptibility possesses by diamagnetic substance, e.g. bismuth, copper.

Negative susceptibility shows that substance gets magnetised in a direction opposite to the direction of magnetising field. **(1/2)**

32.Draw a plot showing the variation of intensity of magnetisation with the applied magnetic field intensity for bismuth. Under what condition cfbes a diamagnetic material exhibit perfect conductivity and perfect diamagnetism? [Foreign 2008]

Ans.

Bismuth, diamagnetic material get feebly intensity of magnetisation with the applied magnetic field intensity in a direction opposite to it. **(1/2)**



(1/2)

The diamagnetic material exhibits perfect conductivity (superconductivity) and perfect diamagnetism when metal is cooled below the critical temperature of the material (Meissner effect). **(1)**

3 Marks Questions

33.A wheel with 8 metallic spokes each 50 cm long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the each's magnetic field. The earth's magnetic field at the place is 0.4 G and the angle of dip is 60°. Calcu] ate the emf induced between the 3txle and the rim of wheel. How will the value of emf be affected if the number of spokes were increased? [All India 2013]

Ans.

$\because$ Horizontal component,

$$H = B\cos\theta$$
$$= 0.4\cos 60^\circ$$
$$= 0.4 \times \frac{1}{2}$$
$$\Rightarrow \quad = 0.2\ \text{G}$$
$$H = 0.2 \times 10^{-4}\ \text{T} \quad [\because \cos 60^\circ = 1/2]$$

The wheel is rotating in a plane normal to the horizontal component, so it will cut the horizontal component only, vertical component of earth will contribute nothing in emf. **(1)**

Thus, the emf induced is given as

$$E = \frac{1}{2}Hl^2\omega,$$

where, $\omega = \frac{2\pi N}{t}$ and

l = length of the spoke

= 50 cm = 0.5 m

$$\therefore \quad E = \frac{1}{2}\times 0.2\times 10^{-4}\times(0.5)^2\times\frac{2\times 3.14\times 120}{60}$$

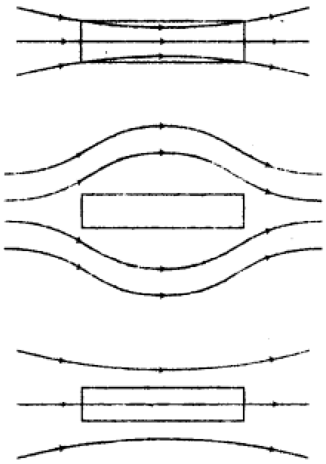
$$E = 3.14\times 10^{-5}\ \text{V}$$ **(1)**

The value of emf induced is independent of the number of spokes as the emf's across the spokes are in parallel. So, the emf will be unaffected with the increase in spokes. **(1)**

34. Three identical specimens of a magnetic materials nickel, antimony and aluminium are kept in a non-uniform magnetic field. Draw the modification in the field lines in each case. Justify your answer. **[Delhi 2011]**

Ans.

The modifications are shown in the figure.



It happens because

(*i*) nickel is a ferromagnetic substance.

(*ii*) antimony is a diamagnetic substance.

(*iii*) aluminium is a paramagnetic substance.

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

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

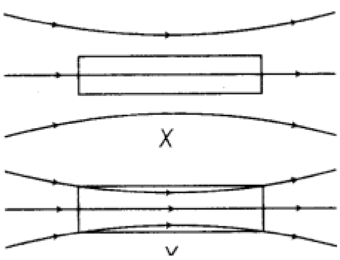
Ans.

(*i*) When diamagnetic substance is placed in a varying magnetic field, it tends to move from stronger magnetic field to weaker magnetic field. **(1)**

(*ii*) Refer to ans. 25. **(2)**

36.(i) How does angle of dip change as line goes from magnetic pole to magnetic equator of the earth?

(ii) A uniform magnetic field gets modified as shown in the figure below, when two specimens X and Y are placed in it. Identify whether specimens X and Y are diamagnetic, paramagnetic or ferromagnetic. [Foreign 2009]

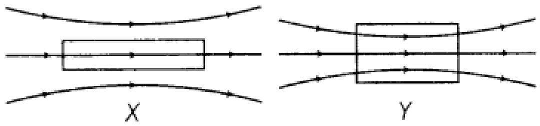


Ans.

(i) The angle of dip decreases from 90° to 0°. **(1)**

(ii) For paramagnetic materials, no magnetic lines of force enter in it. So, specimen *X* is paramagnetic. For ferromagnetic materials, all magnetic lines of force prefer to go through it. So, specimen *Y* is ferromagnetic. **(2)**

37.When two materials are placed in an external magnetic field, the behaviour of magnetic field lines is as shown in the figure. Identify the magnetic nature of each of these two materials. [Delhi 2009c]



Ans.

(i) Material *X* is paramagnetic substance. When a specimen of a paramagnetic substance is placed in a magnetising field, the lines of force prefer to pass through the specimen rather than through air. Thus, magnetic induction inside the sample is more than the magnetic intensity. **(1½)**

(ii) Material *Y* is ferromagnetic substance. These are the substances in which a strong magnetism is produced in the same direction as the applied magnetic field, these are strongly attracted by a magnet. **(1½)**

38.Name the three elements required to specify the earth's magnetic field at a given place. Draw a labelled diagram to define these elements. Explain briefly how these elements are determining to find out the magnetic field at a given place on the surface of the earth. [Delhi 2008]

Ans.

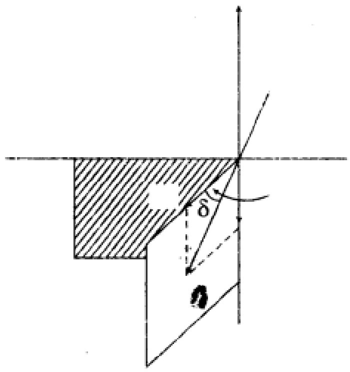
There are three elements determining earth's magnetic field at any point of the earth.

(*i*) Magnetic declination.

(*ii*) Magnetic dip.

(*iii*) Horizontal component of earth's magnetic field. **(1)**

Angle between geographical meridian and the magnetic meridian at any point is known as the magnetic declination at that point. Magnetic dip is the angle between the direction of earth's magnetic field and the horizontal direction along the magnetic meridian.



(2)

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If χ_m stands for the magnetic susceptibility of a given material, identify the class of materials for which .

(*i*) $-1 \leq \chi_m < 0$

(*ii*) $0 < \chi_m < \varepsilon$ (ε stands for a small positive number)

- Write the range of relative magnetic permeability of the materials .
- Draw the pattern of magnetic field lines when the materials are placed in external magnetic field. [Delhi 2008]

Ans.

(i) $-1 \le \chi_m < 0$

$\Rightarrow$ Diamagnetic material

(ii) $0 < \chi_m < \varepsilon$

(ε stand for small positive number)

$\Rightarrow$ Paramagnetic substance, **(1)**

(a) Relative permeability of diamagnetic material

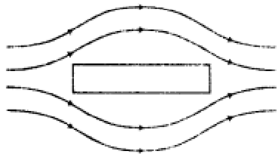
$$\mu = \frac{B}{H}, \quad \text{where, } 0 < \mu < 1$$

For paramagnetic substance,

$$\mu > 1$$

But, μ is not very large. **(1)**

(b)



40.Name and define the elements of the earth's magnetic field other than the horizontal component of the earth's magnetic field. Why do we say that at the place like Delhi and Mumbai, a magnetic needle shows the true North direction quite accurately as compared to other places in India? [All India 20011c]

Ans.

The two elements of earth's magnetism other than horizontal components of magnetic field are

(a) **Magnetic declination** (α) The angle between the magnetic meridian and geographical meridian is known as the angle of declination at a given place of earth. **(1)**

(b) **Angle of dip** (δ) The angle made by resultant of the earth's magnetic field (B_e) with the horizontal in magnetic meridian is known as angle of dip at the given place of earth.

The angle of dip is 90° at poles and 0° at the equator.

The declination in India is small, it being 0°41′ NE at delhi and 0.58° NW at Mumbai. Thus, at both of these places a magnetic needle shows the true north quite accurately. **(1)**

5 Marks Questions

41. (i) A small compass needle of magnetic moment M is free to turn about an axis perpendicular to the direction of uniform magnetic field B. The moment of inertia of the needle about the axis is I. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence, deduce , the expression for its time period, (ii) A compass needle free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (a) horizontal component of the earth's magnetic field and (b) angle of dip at the place. [Delhi 2013]

Ans.

> The torque always tries to bring back the needle in equilibrium position *i.e.* parallel to the existing field.

(*i*) The torque on the needle is $\tau = M \times B$

In magnitude, $\tau = MB \sin\theta$

Here, τ is restoring torque and θ is the angle between M and B.

Therefore, in equilibrium,

Restoring force = Deflecting torque

$$I\frac{d^2\theta}{dt^2} = -MB\sin\theta$$ **(1)**

Negative sign with $MB\sin\theta$ implies that restoring torque is in opposition to deflecting torque. For small values of θ in radians, we approximate $\sin\theta = \theta$ and get

$$I\frac{d^2\theta}{dt^2} = -MB\theta$$

or $$\frac{d^2\theta}{dt^2} = -\frac{MB}{I}\theta$$

or $$\frac{d^2\theta}{dt^2} = -\omega^2\theta$$ **(1)**

This equation represents a simple harmonic motion.

where, $$\omega = \sqrt{\frac{mB}{I}}$$

Time period, $$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{MB}}$$ **(1)**

(*ii*) (*a*) As, horizontal component of earth's magnetic field, $B_H = B\cos\delta$

Putting $\delta = 90°$ (as compass needle orients itself vertically)

$\therefore \quad B_H = 0$

(*b*) For a compass needle align vertical at a certain place, angle of dip, $\delta = 90°$.

(2)