15.0 : Introduction

Q.1. What is magnetite?

Ans: i. Magnetite (Fe_3O_4) is an ore of iron which has a tendency to attract small pieces of iron.

ii. Such ore was first found in the district of Magnesia. Hence the ore was named as magnet.

iii. 'Lodestone' is an example of a natural magnetite (Fe_3O_4)' It contains about 72% cf iron. It is heavy and dark grey to black in colour.

Q.2. What is magnetism?

Ans: i. The attracting property of a magnet is called magnetism.

ii. Magnetism. has its origin in the circulating charges within the atoms of any substance.

iii. Magnetic monopoles do not exist.

Q.3. State the properties of a magnet.

Ans: Properties of a magnet:

i. When a magnet is suspended freely, it comes to rest in the north-south direction. This property is called directive property of magnet.

ii. When a magnet is dipped in Iron fillings, they cling to the magnet. This property is called attractive property of magnet.

iii. If a bar magnet is cut into pieces, each piece, however small it may be, is still a magnetic dipole.

Note:

The earth behaves as a magnet with the magnetic field pointing from geographic south to the north.

15.1 : Circular current loop as a magnetism dipole

Q.4. Show that current loop produces a magnetic field and behaves like a magnetic dipole.

Ans: i. The magnetic induction at a point at a distance 'x' from the centre of circular loop of a 'radius 'R' carrying a steady current 'I' is $B = \frac{\mu_0 IR^2}{2\left(x^2+R^2\right)^{\frac{3}{2}}}$ and its direction is along the axis, given by the right hand thumb rule.

ii. For x >> R , $B = \frac{\mu_0 IR^2}{2x^3}$

iii. Area of the loop, $A = \pi R^2$

$$\therefore \quad B = \frac{\mu_0 IA}{2\pi x^3} \qquad [\because R^2 = \frac{A}{\pi}]$$

$$B = \frac{\mu_0 M}{2\pi x^3} \qquad [\because M = IA]$$

$$B = \frac{\mu_0}{4\pi}\frac{2M}{x^3} \qquad .... (i)$$

iv. This expression is very similar to the expression obtained for electric field due to the electric dipole as

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{x^3} \qquad .... (ii)$$

where, x is the distance of the point from the centre of the dipole.

v. Comparing equations (i) and (ii), μ_0 is analogous to $\frac{1}{\varepsilon_0}$.

Magnetic dipole moment 'M' is analogous to electrostatic dipole moment 'p' and magnetic field is analogous to electrostatic field.

vi. A current loop produces a magnetic field and behaves like a magnetic dipole. It expenences a torque given by,

$$\vec{\tau} = \vec{M} \times \vec{B}$$

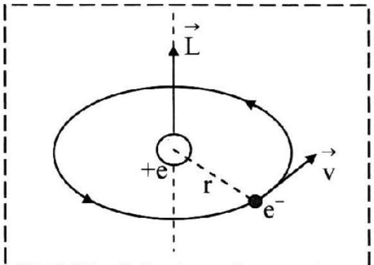
when placed in external magnetic field and also it generates its own magnetic field.

15.2 : Magnetic dipole moment of revolving electron

Q.5. Derive an expression for the magnetic dipole moment of a revolving electron.

Ans: Expression for magnetic dipole moment:

i. Consider an electron of mass me and charge e revolves in a circular orbit of radius r around the positive nucleus in anti clockwise direction, leading to a clockwise current.



U.C.M of electron in an atom

ii. The angular momentum of an electron due to its orbital motion is given by,
$L_0 = m_e vr$ .... (i)

iii. For the sense of orbital motion of electron shown in the figure, the angular momentum vector $\vec{L}$ acts along normal to the plane of the electron orbit and in upward direction.

iv. Suppose that the period of orbital motion of the electron is T. Then the electron crosses any point on its orbit after every T seconds or 1/T times in one second.

v. Magnitude of circulating current is given by,

$$I = e\left(\frac{1}{T}\right)$$

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

$$\therefore \quad I = e\left(\frac{1}{2\pi r / v}\right) = \frac{ev}{2\pi r}$$

vi. The magnetic dipole moment associated with circulating current is given by

$$M_0 = IA = \frac{ev}{2\pi r} \times \pi r^2$$

[$\because$ Area of current loop, A = πr^2]

$$\therefore \quad M_0 = \frac{evr}{2} \quad ...(ii)$$

vii. Multiplying and dividing the R.H.S of equation (ii) by m_e,

$$M_0 = \frac{e}{2m_e} \times m_e vr$$

$$\therefore \quad M_0 = \frac{eL_0}{2m_e} \quad .... (iii)$$

viii. In vector notation,

$$\vec{M}_0 = \left(\frac{e}{2m_e}\right)\vec{L}_0$$

The negative sign indicates that the orbital angular momentum of electron is opposite to the orbital magnetic moment.

Q.6. In a hydrogen atom, an electron of charge 'e' revolves in an orbit of radius 'r' with speed 'v'. Prove that the magnetic moment associate With the electron is given by $\frac{evr}{2}$.

OR

Show that the orbital magnetic dipole moment of a revolving electron is $\frac{eVr}{2}$.

OR

In a hydrogen atom, an electron carrying charge 'e' revolves in an orbit of radius 'r' with speed 'v'. Obtain an expression for the magnitude of magnetic moment of a revolving electron.

Ans: Expression for magnetic dipole moment:

i. Consider an electron of mass me and charge e revolves in a circular orbit of radius r around the positive nucleus in anti clockwise direction, leading to a clockwise current.

ii. The angular momentum of an electron due to its orbital motion is given by,
$L_0 = m_e vr$ .... (i)

iii. For the sense of orbital motion of electron shown in the figure, the angular momentum vector $\vec{L}$ acts along normal to the plane of the electron orbit and in upward direction.

iv. Suppose that the period of orbital motion of the electron is T. Then the electron crosses any point on its orbit after every T seconds or 1/T times in one second.

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

$$\therefore \quad I = e\left(\frac{1}{2\pi r / v}\right) = \frac{ev}{2\pi r}$$

vi. The magnetic dipole moment associated with circulating current is given by

$$M_0 = IA = \frac{ev}{2\pi r} \times \pi r^2$$

[$\because$ Area of current loop, A = πr^2]

$$\therefore \quad M_0 = \frac{evr}{2} \quad ...(ii)$$

vii. Multiplying and dividing the R.H.S of equation (ii) by m_e,

$$M_0 = \frac{e}{2m_e} \times m_e vr$$

$$\therefore \quad M_0 = \frac{eL_0}{2m_e} \quad .... (iii)$$

viii. In vector notation,

$$\vec{M}_0 = \left(\frac{e}{2m_e}\right)\vec{L}_0$$

The negative sign indicates that the orbital angular momentum of electron is opposite to the orbital magnetic moment.

Q.7. What is gyro magnetic ratio?

Ans: i. The ratio of magnetic dipole moment with angular momentum of revolving electron is called the. gyro magnetic ratio.

ii. Gyromagnetic ratio is given by,

$$\frac{M_0}{L_0} = \frac{e}{2m_e} = 8.8 \times 10^{10} \text{ C/kg} = \text{constant}$$

15.3 : Magnetization and magnetic intensity

Q.8. Define magnetization. State its unit and dimension. OR
Define magnetization. State its formula and S.I. unit. [Feb 13]

Ans: i. Definition:

The net magnetic dipole moment per unit volume, in the magnetic material is called as magnetization.

It is denoted by $\vec{M}_Z$.

If magnetic specimen of volume 'V' acquires net magnetic dipole moment 'M_{net}' due to the magnetising field, then

$$\vec{M}_Z = \frac{M_{net}}{V}$$

ii. Unit: Am^{-1}

iii. Dimensions: $[M^0L^{-1}T^0 I^1]$

Q.9. Define magnetic intensity. State its unit and dimension.

Ans: i. Definition:

The ratio of the strength of magnetising field to the permeability of.free space is called as magnetic intensity.

The strength of magnetic field at a point can be given in terms of vector quantity called as magnetic intensity (H).

Magnetic intensity is a quantity used in describing magnetic phenomenon in terms of their magnetic field.

$$H = \frac{B_0}{\mu_0} \text{ or } B_0 = \mu_0 H$$

ii. Unit: SI unit of magnetic intensity is Am^{-1}.

iii. Dimensions: $[M^0L^{-1}T^0I^1]$

Q.10. What is –
i. Magnetization and
ii. Magnetic intensity? [Oct 13]

Ans: i. Magnetization

Definition:

The net magnetic dipole moment per unit volume, in the magnetic material is called as magnetization.

It is denoted by $\vec{M}_Z$.

If magnetic specimen of volume 'V' acquires net magnetic dipole moment 'M_{net}' due to the magnetising field, then

$$\vec{M}_Z = \frac{M_{net}}{V}$$

Unit: Am^{-1}

Dimensions: $[M^0L^{-1}T^0 I^1]$

ii. Magnetic intensity :

Definition:

The ratio of the strength of magnetising field to the permeability of.free space is called as magnetic intensity.

The strength of magnetic field at a point can be given in terms of vector quantity called as magnetic intensity (H).

Magnetic intensity is a quantity used in describing magnetic phenomenon in terms of their magnetic field.

$$H = \frac{B_0}{\mu_0} \text{ or } B_0 = \mu_0 H$$

Unit: SI unit of magnetic intensity is Am^{-1}.
Dimensions: $[M^0L^{-1}T^0I^1]$

Q.11. State Curie's law.

Ans: Curie's law:

Magnetization of a paramagnetic sample is directly proportional to the external magnetic field and inversely proportional to the absolute temperature.

Mathematically,

$$M_Z \propto B_{ext} \text{ and } M_Z \propto \frac{1}{T}$$

$$\therefore \quad M_Z \propto \frac{B_{ext}}{T}$$

$$\therefore \quad M_Z = C \times \frac{B_{ext}}{T}$$

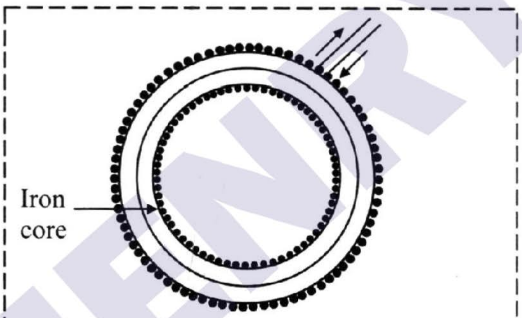
where, C is called Curie constant.

Above equation represents Curie's law for magnetization.

Q.12. Discuss magnetization of a ferromagnetic material with the help of Rowland ring.

Ans: Magnetization of a ferromagnetic material by Rowland ring:

i. The magnetization of a ferromagnetic material such as iron can be studied using Rowland ring. Rowland ring is similar in shape of the toroid as shown in the figure.



Toroid with an iron core (Rowland ring)

ii. The material is formed into a thin toroidal core of circular cross section. A toroidal coil having On' turns per unit length is wrapped around the core and carries current 'I'.

iii. The coil is long solenoid bent into a circle. If iron core was not present, the magnitude of the magnetic field inside the coil would be, $B_0 = \mu_0 nI$, where μ_0 is the permeability of vacuum.

iv. If iron core was present, the magnetic field $\vec{B}$ inside the coil is greater than $\vec{B}_0$.

We can write magnitude of this field as

$B = B_0 + B_M$ .... (i)

Where, B_M is the magnetic field contributed by the iron core.

v. Additional field B_M is directly proportional to the magnetization M_Z of the iron.

$\therefore$ $B_M = \mu_0 M_Z$ .... (ii)

vi. Also, $B_0 = \mu_0 H$ .... (iii)

where H= nI

From equations (i), (ii) and (iii), we have,

$B = \mu_0(H + M_Z)$

Q.13. Define the followingterms.

i. Magnetic susceptibility

ii. Magnetic permeability

iii. Relative permeability

Ans: i. Magnetic susceptibility (X):

The ratio of magnitude of intensity of magnetization to that of magnetic intensity is called as magnetic susceptibility.

It is given by $\chi = \frac{\vec{M}_Z}{\vec{H}}$.

ii. Magnetic permeability (μ):

The ratio of the magnitude of total field inside the material to that of intensity of magnetising field is called magnetic permeability.

i.e $\mu = \frac{B}{H}$

It measures the degree to which a magnetic material can be penetrated by the magnetising field.

Unit : Hm^{-1}

Dimensions: $[M^1L^1T^{-2}I^{-2}]$

iii. Relative permeability (μ_r):

The ratio of magnetic permeability of the material (μ) and magnetic permeability of free space (μ_0) is called relative permeability.

$$\mu_r = \frac{B}{B_0}$$

$$\mu_r = \frac{\mu H}{\mu_0 H} = \frac{\mu}{\mu_0}$$

It has no units and dimensions.

Q.14. Establish the relation between permeability and susceptibility of a substance.

Ans: Relation between permeability and susceptibility:

i. When magnetic material is placed in a magnetising field for its magnetization, the field inside the magnetic material is the resultant of the magnetising field B_0 and the induced field B_M.

$\therefore$ $B = B_0 + B_M$

ii. Since, $B_0 = \mu_0 H$ and $B_M = \mu_0 M_Z$

$$\therefore \quad B = \mu_0(H + M_Z) = \mu_0 H\left(1+\frac{M_Z}{H}\right)$$

$$\therefore \quad \frac{B}{H} = \mu_0\left(1+\frac{M_Z}{H}\right)$$

iii. $$\frac{B}{H} = \mu_0(1+\chi) \qquad \left[\because \frac{M_Z}{H} = \chi\right]$$

Also $\frac{B}{H} = \mu$

$$\therefore \quad \mu = \mu_0(1+\chi)$$

$$\therefore \quad \frac{\mu}{\mu_0} = 1+\chi$$

$$\therefore \quad \mu_r = 1+\chi \qquad \left[\because \frac{\mu}{\mu_0} = \mu_r\right]$$

15.4: Diamagnetism, paramagnetism and ferromagnetism on the basis of domain theory

Q.15. Explain origin of magnetism on the basis of circulating charges.

Ans: i. Magnetism has its ongm in the circulating charges in an atom.

ii. Circulating electron is equivalent to a current loop and has a magnetic dipole moment.

iii. An atom of any substance consists of a small massive positively charged nucleus surrounded by negatively charged electrons revolving in circular orbit round the nucleus.

iv. The magnetic moment is associated with motion of electron in its orbit and is termed as orbital magnetic moment.

v. An electron also has an intrinsic angular momentum called spin. The magnetic moment associated with the spin of electron is termed as spin magnetic moment.

vi. The resulting magnetic moment of the electron is thus equal to the vector sum of the magnetic dipole moments associated with its orbital motion and spin motion.

Note:
On microscopic level, spin magnetic moment is thought to be responsible for magnetism in iron and other materials.

Q.16. Discuss the classification of materials based on their behaviour in magnetic field.

Ans: All the substances possess magnetic properties. On the basis of their magnetic behaviour, Faraday divided the magnetic materials into three classes:

i. Diamagnetic materials:

a. These substances, when placed in magnetic field are feebly magnetised in a direction opposite to that of the magnetising field.

b. When a diamagnetic substance is placed inside an external magnetic field, the magnetic field inside the diamagnetic is found to be slightly less than the external magnetic field .

c. It is observed that when a diamagnetic sample is placed inside a non-uniform magnetic field, it tends to move from stronger part to the weaker part of the magnetic field.

d. It may be pointed out that the diamagnetic effects are too feeble to be detected, unless the applied magnetic field is strong.

e. The behaviour of a diamagnetic substance is independent of temperature. Further, a diamagnetic substance .has the nature similar to that of a dielectric having non-polar atoms.

ii. Paramagnetic materials:

a. These substances, when placed in a magnetic field are feebly magnetised in the direction of the magnetising field.

b. When a paramagnetic substance is placed inside an external magnetic field, the magnetic field inside the paramagnetic is found to be slightly greater than the external magnetic field.

c. A paramagnetic substance tends to move from weaker part of the magnetic field to stronger part, when placed in a non-uniform magnetic field.

d. The behaviour of a paramagnetic is temperature dependent also, the paramagnetic effects are perceptible only with a strong magnetic field. The nature of a paramagnetic is similar to that of a dielectric having polar atoms.

iii. Ferromagnetic materials:

a. These substances, when placed in a magnetic field are strongly magnetised, in the direction of the magnetising field.

b. When a ferromagnetic substance is placed inside a magnetic field, the field inside the feomagnetic substance gets greatly enhanced.

c. As a result, when a ferromagnetic is placed in a non-uniform magnetic field, it quickly moves from weaker part to stronger part of the magnetic field.

d. Thus, the ferromagnetic effects are perceptible even in the presence of a weak magnetic field.

e. The ferromagnetic behaviour of a substance becomes temperature dependent above certain temperature, which is characteristic of that substance.

Q.17.Explain origin of diamagnetism on the basis of its atomic structure.

OR

What are diamagnetic substances? Explain why diamagnetic substances are repelled by the applied field when suspended freely in magnetic field.

Ans: Diamagnetic substances:

i. Substances which are weakly repelled by a magnet are called diamagnetic substances.

ii. In diamagnetic substance, magnetic dipole moment of all the electrons in an atom cancel each other. Thus resulting magnetic moment of the atom is zero. ego air bismuth, copper, gold, water, alcohol, hydrogen, zinc, diamond, salt, nitrogen, magnesium, silver, mercury etc.

iii. When diamagnetic materials are kept in an external magnetic field then those electrons whose orbital magnetic moments are in the same direction as that of the external magnetic field slow down and those electrons whose orbital magnetic moments are in the opposite direction to that of the external magnetic field speeds up.

iv. Thus, a magnetic moment is developed in the direction opposite to that of applied external magnetic field. As a result, the diamagnetic substance is repelled by the applied field and sets itself at right angles to the direction of the field when suspended freely in magnetic field.

v. The superconductors are perfect example of diamagnetism. The phenomenon of perfect diamagnetism in superconductors is called Meissner effect.

Note:

i. Diamagnetism is universal which is present in all materials, but it is weak and hard to detect if the substance is paramagnetic or ferromagnetic.

ii. Metals when cooled to very low temperature exhibit perfect conductivity are termed as superconductors. A superconductor repels a magnet and in turn is repelled by the magnet. Hence superconductors are the most exotic diamagnetic materials.

Q.18. State the main properties of diamagnetic substances.

Ans: Properties of diamagnetic substances:

i. If a thin rod of a diamagnetic material is suspended freely in an external uniform magnetic field, it comes to rest with its length perpendicular to the direction of the field.

ii. These materials when placed in an external nonuniform magnetic field, tend to move from the stronger part of the field to the weaker part of the field.

iii. In the absence of external magnetic field, the net magnetic moment of diamagnetic substances is zero.

iv. Diamagnetic substances loose their magnetism on removal of external magnetic field.

v. If a watchglass contaming a small quantity of a diamagnetic liquid is placed on two dissimilar magnetic poles, the liquid shows a depression in the middle.

vi. If a magnetic field is applied to diamagnetic liquid in one arm of U-tube, the liquid level in that arm is lowered.

vii. If a diamagnetic gas is introduced between the pole-pieces of a magnet, it spreads at right angles to the magnetic field.

Q.19. Why are diamagnetic substance feebly repelled by a magnet?

Ans: i. When a diamagnetic substance is placed near a magnet, its atoms acquire a small magnetic dipole moment in the direction opposite to that of the external magnetic field.

ii. As a result, the diamagnetic substance moves from stronger part to weaker part of the magnetic field.

iii. Hence, diamagnetic substances are feebly repelled by a magnet.

Q.20. Explain, why a diamagnetic liquid contained in a watch glass when placed between two closely spaced pole pieces of a magnet, suffers a depression in the middle but it shows a. rise when pole pieces are moved apart.

Ans: i. When the pole-pieces of the magnet are close to each other, the magnetic field in the middle is stronger than that near the poles of the magnet. Since a diamagnetic substance moves from stronger part of the magnetic field to the weaker part. Hence in the watch glass liquid depresses in the middle as shown in figure (a).

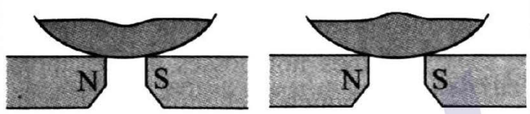


Figure (a) Figure (b)

ii. When the pole-pieces are moved apart, the magnetic field becomes weaker in the middle. As a result, the diamagnetic liquid kept in watch glass shows a rise in the middle as shown in figure (b).

Q.21. What are paramagnetic substances? Give examples of paramagnetic substances.

Ans: Paramagnetic substances:

i. Substances which are weakly attracted by a magnet are called paramagnetic substances.

ii. In paramagnetic substances, the magnetic dipole moments of all the electrons do not cancel out, resulting in some dipole moment for an atom so that each atom of paramagnetic substance is equivalent to tiny magnetic dipole, called atomic magnets.

iii. In the absence of external magnetic field, the dipole moments of the atoms are randomly oriented and hence the net dipole moment of the substance is zero.

eg. Aluminium, tungsten, niobium, calcium, lithium, platinum, oxygen, chromium, sodium, manganese, copper chloride etc.

Q.22. Explain origin of paramagnetism on the basis of its atomic structure.

Ans: Origin of paramagnetism:

For the atom of a paramagnetic substance, the orbital motion and spin motion of the electrons is such that, the resultant magnetic dipole moment of the atom is non-zero. Each atom behaves as a tiny dipole called as atomic dipole. The phenomenon can be explained in following ways.

i. Absence of external magnetic field:

A specimen of a paramagnet is kept at a place where there are no external magnetic field. Due to thermalvibration, atomic dipoles have random orientation and the specimen as a whole does not posses a net dipole moment. Though each atom is a tiny magnet, the specimen as a whole does not behave as a magnet. Thus the specimen is in unmagnetized state as shown in figure (a).

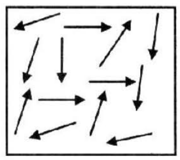


Figure (a): Absence of external field

ii. Effect of weak external field:

The specimen placed in a weak external magnetic field $\vec{B}$ is as shown in , figure (b). Partial alignment of the atomic dipoles takes place.

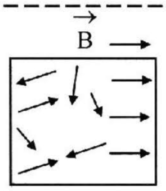


Figure (b): Weak external magnetic field

A complete alignment is prevented due to thermal vibration. The specimen has acquired a net dipole moment $\vec{M}$.

iii. Effect of strong external field:

The specimen placed in a strong external magnetic field $\vec{B}$ is as shown in figure (c). Inspite of thermal vibrations, a complete alignment of atomic dipoles along the external field takes place. The specimen is said to be saturated and possesses maximum net magnetic dipole moment $\vec{M}$.

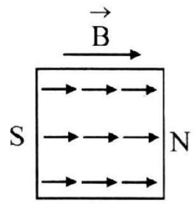


Figure (c): Strong external magnetic field

The net magnetic dipole moment is parallel to $\vec{B}$. Hence the specimen shows a tendency to move from weaker field to stronger field.

The alignment of atomic dipoles is temporary. When the external magnetic field is switched off, immediately the alignment is disturbed by thermal vibration and specimen gets demagnetized. Hence, permanent magnets cannot be made out of paramagnetic substances. The tendency of alignment is greater in stronger magnetic field at low temperature.

Q.23. Why paramagnetic materials are not used for making permanent magnet?

Ans: i. When a paramagnetic substance is kept in an external magnetic field, the tiny atomic magnets tend to align parallel to the applied field and show temporary magnetization.

ii. As soon as the external field is removed, the atomic magnets again get randomly oriented and the substance looses its magnetism.

iii. Since paramagnetic materials loose their magnetism on removal of external field, they cannot be used to make permanent magnets.

Q.24. State the main properties of paramagnetic substances.

Ans: Properties of paramagnetic substances:

i. If a thin rod of a paramagnetic material is freely suspended in a uniform magnetic field, it - comes to rest with its length parallel to the direction of the field.

ii. These materials when placed in an external non-uniform magnetic field, tend to move from the weaker part to the stronger part of the field.

iii. In the absence of external magnetic field, the dipole moments of the atoms are randomly oriented and hence the net dipole moment ofthe substance is zero.

iv. When paramagnetic substance is kept in an 'external magnetic field, the tiny atomic magnets tend to align parallel to the applied field and show magnetic effects. As soon as the external field 'is removed, the atomic magnets again get randomly oriented and the substance looses its magnetism.

v. If a watchglass containing a small quantity of a paramagnetic liquid is placed on two dissimilar magnetic poles, the liquid shows an elevation in the middle.

vi. If a magnetic field is applied to paramagnetic liquid in one arm of utube the liquid level rises in that arm.

vii. If a paramagnetic gas is introduced between the pole pieces of a magnet, it spreads in the direction of the field.

viii. The. susceptibility of paramagnetic substance is small but positive. It depends on the temperature of the substance. The susceptibility is inversely proportional to absolute temperature $\left(\chi \propto \frac{1}{T}\right)$.

Note:

1. The magnetic moment of each atom of a paramagnetic substance is slightly greater than zero.
2. The permeability of paramagnetic substance is slightly greater than one.

Q.25. What are ferromagnetic substances? Give examples.

Ans: Substances which are strongly attracted by a magnet are calledferromagnetic substances.

Examples: Iron, nickel, cobalt, gadolinium, dysprosium and their alloys.

Q.26. State the properties of ferromagnetic substances.

Ans: Properties of ferromagnetic substances:

i. These materials when placed in an external uniform magnetic field, get strongly magnetised in the direction of the external magnetic field.

ii. These materials when placed in an external non uniform magnetic field, tend to move from the weaker part to the stronger part of the field.

iii. All the atoms of the ferromagnetic materials have a resultant magnetic moment even in the absence of external magnetic field.

iv. When a thin rod of a ferromagnetic substance is kept between two conical pole pieces of an electromagnet, it comes to rest with its axis parallel to the magnetic induction between the two poles.

v. Ferromagnets remain magnetized even after the removal of the magnetizing field.

vi. The susceptibility is positive and very high.

Q.27. Why ferromagnetic substances are used to make permanent magnet?

Ans: i. The atoms of ferromagnetic substances acquire a high degree of magnetic alignment, even when they are placed in a weak external magnetic field.

ii. They retain some magnetism even after the removal of the external field. Therefore, permanent magnets are made up of ferromagnetic substances.

Q.28. Write a note on domain theory.

Ans: Domain theory:

i. Ferromagnetism can be explained on the basis of domain theory proposed by Weiss.

ii. A ferromagnetic material contains a large number of small regions or domains.

iii. Even in the absence of magnetic field millions of atomic magnets form a group.

iv. The region in which all magnetic moments are aligned in the same direction are known as domains.

v. Magnetic dipole moments of all the atoms in one domain are aligned in the same direction. Each domain thus behaves as a resultant magnetic dipole moment.

vi. The domains have irregular shape and large magnetic dipole moment.

vii. Due to strong exchange coupling between neighbouring atoms in domain, all the dipoles have magnetic dipole moments in the same direction.

Q.29. Explain ferromagnetism on the basis of domain theory.

[Mar 99, Oct 08, Oct 11, Feb 13 old course]

Ans: Ferromagnetism on the basis of domain theory:

i. Absence of external magnetic field:

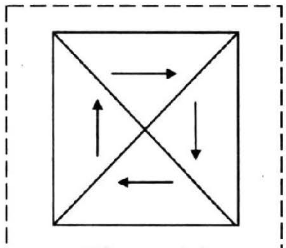


Figure (a)
Unmagnetised state

In the absence of any external magnetic field, the different domains are oriented at random -so that the magnetic fields of the domains cancel each other and does not show any magnetic (effect) properties, as shown in figure (a).

ii. Effect of weak magnetic field:

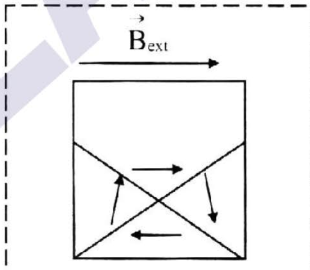


Figure (b)
Weak magnetic field

When the external applied magnetic field is weak, the individual atomic magnets tend to align their dipole moments parallel to the direction of the field, as shown in figure (b). The domain wall shifts in the direction of applied field. With the removal of the external magnetic field, the boundaries return to their original positions and the material loses its magnetism.

iii. Effect of strong magnetic field:

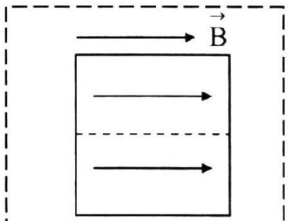


Figure (c)
Strong magnetic field

When the external applied magnetic field is strong as shown in figure (c), the dipole moments of non-aligned domains abruptly rotate in the direction of the applied field. Removal of external field does not set the domain boundaries back to their original position, and the material gets the magnetic property permanently.

Q.30. Why ferromagnetic substances cannot be magnetised beyond a certain limit?

Ans: i. Ferromagnetic substances contain large number of domains.

ii. If the ferromagnetic substance is placed in external strong magnetic field, then all the domains rotate in the direction of the field. So, substance is completely magnetised.

iii. If the strength of the external magnetic field is increased further, the magnetization of the substance cannot be increased because there are no domains left for alignment. Thus, there is a limit beyond which a ferromagnetic substance cannot be magnetised.

Note:

Degree of magnetization of ferromagnetic substance depends on temperature of the' substance.

Q.31. Answer the following questions:

i. Why does a paramagnetic sample display greater magnetisation (for the same magnetising field) when cooled?

ii. Why is diamagnetism, in contrast, almost independent of temperature?

iii. If a toroid uses bismuth for its core, will the field in the core be (slightly) greater or (slightly) less than when the core is empty?

iv. Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?

v. Magnetic field lines are always nearly normal to the surface of a ferromagnet at every point (This fact is analogous to the static electric field lines being normal to the surfaces of a conductor at every point). Why?

vi. Would the maximum possible magnetisation of a paramagnetic sample be of the same order of magnitude as the magnetisation of a ferromagnet? (NCERT)

Ans: i. This is because at lower temperatures, the tendency to disturb the alignment of dipoles (due to magnetising field) decreases due to reduced random thermal motion.

ii. In a diamagnetic sample, each molecule is not a magnetic dipole. Hence, random thermal motion of molecules does not affect the magnetism of the specimen. Thus, diamagnetism is independent of temperature.

iii. Bismuth being diamagnetic, the field in its core will be slightly less than when the core is empty.

iv. No. Permeability of a ferromagnetic material depends on magnetic field. As can be seen from the hysteresis curve, μ is greater for lower fields.

v. Magnetic field lines are always nearly normal to the surface of a ferromagnet at every point. The proof of the same is based on the boundary conditions of magnetic fields (B and H) at the interface, of two media. The magnetic permeability of a ferromagnetic material $\mu >> 1$. Hence the field lines meet this medium normally.

vi. Yes. Maximum possible magnetisation of a paramagnetic sample will be of the same order of magnitude as the magnetisation of a ferromagnet. But the saturation requires very high magnetising fields which are hard to achieve.

Q.32. Distinguish between diamagnetic substance and paramagnetic substance.

Ans:

No.	Diamagnetic substance	Paramagnetic substance
i.	In an external magnetic field, a substance gets weakly magnetised in the direction opposite to that of the field.	In an external magnetic field, a paramagnetic substance gets weakly magnetised in the same direction as that of the field.
ii.	When placed in a non-uniform magnetic field, it tends to move from the stronger to the	When placed in a non-uniform magnetic field, it tends to move from the weaker to the

	weaker part of the field.	stronger part of the field.
iii.	It is weakly repelled by a magnet.	It is weakly attracted by a magnet.
iv.	Magnetic moment of every atom of a diamagnetic substance is zero.	Every atom of a paramagnetic substance is a magnetic dipole having a certain resultant magnetic moment.
v.	When a rod of diamagnetic substance is suspended in a uniform magnetic field, it comes to rest with its length perpendicular to the direction of the field.	When a rod of paramagnetic substance is suspended in a uniform magnetic field, it comes to rest with its length parallel to the direction of the field.
vi.	There is no effect of temperature on diamagnetic substance.	There is effect of temperature on paramagnetic substance.

Q.33. Distinguish between paramagnetic substance and ferromagnetic substance.

Ans:

No.	Paramagnetic substance	Ferromagnetic substance
i.	It is weakly attracted by a magnet.	It is strongly attracted by a magnet.
ii.	When kept in a non-uniform magnetic field, it shows moderate tendency to move from weaker to the stronger part of the field.	When kept in a non-uniform magnetic field, it shows strong tendency to move from weaker to the stronger part of the field.
iii.	When kept in an external magnetic field it becomes weakly magnetised, and the direction of magnetic moment acquired will be same as that of the field.	When kept in an external magnetic field it becomes strongly magnetised, and the direction of magnetic moment acquired will be same as that of the field.
iv.	When the external magnetic field is removed, the paramagnetic substance loses its magnetism.	When the external magnetic field is removed, the ferromagnetic substance retains magnetism permanently.
v.	They cannot be converted into ferromagnetic substances.	When heated above curie temperature, they become paramagnetic substances.
vi.	Every atom has some magnetic dipole moment but resultant dipole moment is zero.	The resultant magnetic dipole moment is greater.
vii.	They can be temporarily magnetised in external magnetic field.	They can be permanently magnetised.

Q.34. Distinguish between diamagnetic and ferromagnetic substances.

Ans:

No.	Diamagnetic Substance	Ferromagnetic Substance
i.	They are weakly repelled by magnet.	They are strongly attracted by magnet.
ii.	If a thin rod of diamagnetic substance is freely suspended in uniform magnetic field, it comes to rest slowly with its length perpendicular to the direction of magnetic field.	If a thin rod of ferromagnetic substance is freely suspended in a uniform magnetic field, it comes quickly to rest with its length parallel to the direction of the field.
iii.	When placed in non uniform magnetic field, they show a moderate tendency to move from the stronger to the weaker part of the field.	When placed in non uniform magnetic field, they show a strong tendency to move from the weaker to the stronger part of the field.

iv.	In the absence of external magnetic field, the resultant magnetic moment of each atom is zero.	The resultant magnetic moment of each atom of a ferromagnetic substance is much greater than zero.
v.	There is no effect of temperature on diamagnetic substance.	There is effect of temperature on ferromagnetic substance.
vi.	They cannot be permanently magnetised.	They can be permanently magnetised.

Q.35. Answer the following questions:

i. The hysteresis loop of a soft iron piece has a much smaller area than that of a carbon steel piece. If the material is to go through repeated cycles of magnetisation, which piece will dissipate greater heat energy?

ii. A system displaying a hysteresis loop such as a ferromagnet is a device for strong memory. Explain the meaning of this statement.

iii. What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player or for building memory stores in a modern computer?

iv. A certain region of space is to be shielded from magnetic fields. Suggest a method.

(NCERT)

Ans: i. The energy dissipated per cycle by any magnetic substance is directly proportional to the area of the hysteresis loop. Hence, carbon steel piece will dissipate greater heat energy.

ii. Mangnetisation of a ferromagnet depends on the magnetising field as well as the history of magnetisation. Thus, value of magnetisation of a specimen is an indicator of the cycles of magnetisation it has undergone. The system displaying such a hysteresis loop can thus act as a device for storing memory.

iii. The ceramic meterials (specially treated barium, iron oxides also called ferrites) are used for coating magnetic tapes as memory tapes in a cassette player or for building memory stores in modem computers.

iv. A space can be shielded from magnetic field by surrounding the space with a substance like soft Iron nng. As magnetic field lines will be drawn into the ring, the enclosed region will become free of magnetic field.

15.5 : Curie temperature

Q.36. What is Curie temperature? What happens above the Curie temperature?

Ans: i. The temperature at which the domain structure is destroyed and a ferromagnetic substance looses its magnetism is called Curie temperature.

ii. Above the Curie temperature, a ferromagnetic substance is converted into paramagnetic substance. The Curie temperature is different for different substances.

No.	Substances	Curie temperature in K
i.	Cobalt (Co)	1394
ii.	Iron (Fe)	1043
iii.	Nickel (Ni)	631
iv.	Gadolinium (Gd)	317

Q.37. What is the effect of heat on a ferromagnetic substance? [Mar 99]

Ans: i. With increase .in the temperature, the thermal vibrations of the atoms in the given ferromagnetic substance is increased and as a result, the inter atomic coupling becomes weak.

ii. At a higher temperature, the exchange coupling between the atomic magnets in each domain breaks completely and all the atomic dipoles get randomly oriented, destroying the domain structure.

iii. Hence above the Curie temperature ferromagnetic substance is converted into a paramagnetic substance.

Summary :

1. A circular current loop produces magnetic field in the same manner as a magnetic dipole.
2. If a material is placed in an external magnetic field B_0, the magnetic intensity is given by,

$$H = \frac{B_0}{\mu_0}$$

3. The three quantities, susceptibility χ, the relative magnetic permeability 'μ_r' and the magnetic permeability 'μ' are related as follows:
$\mu = \mu_0 \mu_r$
$\mu_r = 1 + \chi$
4. Depending upon the nature and behaviour of atomic magnets in external field, substances have been classified into three groups as diamagnetic, paramagnetic and ferromagnetic. Ferromagnetic properties are due to partially filled sub-shells.
6. The resultant magnetic dipole moment of each atom of a diamagnetic substance is zero; that of paramagnetic material atom is small and that of ferromagnetic material atom is very large.
7. Domain is a region in which the dipole moments of all atoms are similarly directed.
8. Normally, domains are randomly oriented showing no resultant magnetization.
9. When ferromagnetic substance is subjected to strong external magnetic field, then it gets magnetised in the direction of magnetic field
10. Curie tcmperature is different for different materials.
11. Above Curie tcmperature, ferromagnetic materials are converted into paramagnetic materials.

Formulae :

1. **Magnetic moment of current loop or a solenoid:**
   i. $M = IA$ (for single turn)
   ii. $M = nIA$ (for n turns)
2. **Magnetic induction due to current loop:**

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

3. **Torque:** $\tau = MB \sin \theta$
4. **For a revolving electron:**
   i. Magnetic moment,

$$M_0 = \frac{evr}{2} = \frac{eL_0}{2m_e}$$

   where L_0 = angular momentum

   ii. $$I = \frac{e}{T} = ef = \frac{e}{2\pi r / v} = \frac{ev}{2\pi r}$$

5. **Magnetic intensity :** $H = \dfrac{B_0}{\mu_0}$
6. **Magnetization:**
   i. $$M_Z = \frac{M_{net}}{V}$$
   ii. $$M_Z = \frac{CB_{ext}}{T}$$
   where, C = Curie constant
7. **Magnetic field due to iron core in toroid:**
   $B_M =; \mu_0 (H + M_Z) = B_0 + B_M = \mu_0 \mu_r H = \mu H$
   where, $B_0 = \mu_0 H$ and $B_M = \mu_0 M_Z$
8. **Magnetic susceptibility :** $\chi_m = \dfrac{M_Z}{H} = \dfrac{B - B_0}{B_0}$
9. **Magnetic permeaebility :** $\mu = \dfrac{B}{H}$
10. **Relation between permeability and susceptibility :** $\mu = \mu_0(1 + \chi_m)$
11. **Relative permeability:**

$$\mu_r = \frac{\mu}{\mu_0} = 1 + \chi_m$$

Solved Problcms

Example 1

A circular coil of 300 turns and diameter 14 cm carries a current of 15 A. What is the magnitude of magnetic moment associated with the coil?

Solution:

Given : $n = 300$, $d = 14$ cm,
$r = 7$ cm $= 7 \times 10^{-2}$ m,
$I = 15$ A

To find : Magnetic moment of the coil (M)

Formula : $M = nIA$

Calculation : From formula,

$M = nI \pi r^2$
$= 300 \times 15 \times \pi \times (7 \times 10^{-2})^2$

$\therefore$ $M = \mathbf{69.24\ Am^2}$

Ans: The magnetic moment of the coil is **69.24 Am²**.

Example 2

A circular coil of 250 turns and diameter 18 cm carries a current of 12 A. What is the magnitude of magnetic moment associated with the coil?

[Feb 13]

Solution:

Given : $n = 250$, $d = 18$ cm,
$r = 9$ cm $= 9 \times 10^{-2}$ m,
$I = 12$ A

To find : Magnetic moment of the coil (M)

Formula : $M = nIA$

Calculation : From formula,

$$M = nI\pi r^2$$
$$= 250 \times 12 \times 3.14 \times (9 \times 10^{-2})^2$$
$$\therefore \quad M = \mathbf{76.3\ Am^2}$$

Ans: The magnetic moment of the coil is **76.3 Am²**.

Example 3

An electron in an atom revolves around the nucleus in an orbit of radius 0.53 Å. Calculate the equivalent magnetic moment if the frequency of revolution of electron is 6.8 × 10⁹ MHz.

(NCERT)

Solution:

Given : $r = 0.53$ Å $= 0.53 \times 10^{-10}$ m,
$f = 6.8 \times 10^9$ MHz
$= 6.8 \times 10^{15}$ Hz

To find : Magnetic moment (M)

Formula : $M = IA$

Calculation : Since, $I = \frac{e}{T} = ef$

From formula,

$$M = IA = ef \times \pi r^2 = \pi efr^2$$
$$= \pi \times 1.6 \times 10^{-19} \times 6.8 \times 10^{15} \times (0.53 \times 10^{-10})^2$$
$$M = \mathbf{9.6 \times 10^{-24}\ Am^2}$$

Ans: The equivalent magnetic moment is **9.6 × 10⁻²⁴ Am²**.

Example 4

An electron in an atom revolves around the nucleus in an orbit of radius 0.5 Å. Calculate the equivalent magnetic moment if the frequency of revolution of electron is 10¹⁰ MHz.

Solution:

Given : $r = 0.5$ Å $= 0.5 \times 10^{-10}$ m,
$f = 10^{10}$ MHz $= 10^{10} \times 10^6$
$= 10^{16}$ Hz

To find : Magnetic moment (M)

Formula : $M = IA$

Calculation : Since, $I = \frac{1}{T}e = fe$

From formula,

$$M = feA = fe\pi r^2$$
$$= 10^{16} \times 1.6 \times 10^{-19} \times \pi \times (0.5 \times 10^{-10})^2$$
$$= 1.6 \times \pi \times 0.25 \times 10^{-23}$$
$$M = 1.256 \times 10^{-23}\ Am^2$$

Ans: The equivalent magnetic moment is **1.256 × 10⁻²³ Am²**.

Example 5

Find the percent increase in the magnetic field B when the space within a current carrying toroid is filled with aluminium. The susceptibility of aluminium is 2.1 × 10⁻⁵.

Solution:

The magnetic field inside the toroid in the absence of aluminium $= B_0 = \mu_0 H$

When filled with aluminium, $B = \mu_0 (1 + \chi) H$

The increase in the field $= B - B_0 = \mu_0 \chi H$

The percent increase in the magnetic field

$$= \frac{B - B_0}{B_0} \times 100 = \frac{\mu_0 \chi H \times 100}{\mu_0 H} = \chi \times 100$$
$$= 2.1 \times 10^{-5} \times 100$$

Ans: The percent Increase in magnetic field is **2.1 × 10⁻³**.

Example 6

The magnetic moment of a magnet of dimensions 5 cm × 2.5 cm × 1.25 cm is 3 Am². Calculate the intensity of magnetization. **[Oct 14]**

Solution:

Given : $l = 5$ cm $= 5 \times 10^{-2}$ m,
$b = 2.5$ cm $= 2.5 \times 10^{-2}$ m,
$h = 1.25$ cm $= 1.25 \times 10^{-2}$ m,
$M_{net} = 3\ Am^2$

To find : Intensity of magnetization (M_Z)

Formula : $M_Z = \frac{M_{net}}{V}$

Calculation : Using formula,

$$M_Z = \frac{M_{net}}{l \times b \times h}$$

...[$\because V = l \times b \times h$]

$= 0.192 \times 10^6$

$= \mathbf{1.92 \times 10^5\ A/m}$

Ans: The intensity of magnetization is **1.92×10^5 A/m**.

Example 7

A bar magnet made of steel has magnetic moment of 2.5 Am² and a mass of 6.6 × 10⁻³ kg. If the density of steel is 7.9 × 10³. kg/m³, find the intensity of magnetiz ation of the magnet.

Solution:

Given: $M_{net} = 2.5\ Am^2$, $m = 6.6 \times 10^{-3}$ kg, $\rho = 7.9 \times 10^3\ kg/m^3$

To find: Intensity of magnetisation (M_Z)

Formula: $M_Z = \frac{M_{net}}{V}$

Calculation: Since $\rho = \frac{m}{V}$

$\therefore\ V = \frac{m}{\rho} = \frac{6.6 \times 10^{-3}}{7.9 \times 10^3}$

$= 8.354 \times 10^{-7}$

From formula,

$M_Z = \frac{2.5}{8.354 \times 10^{-7}}$

$\therefore\ M_Z = \mathbf{3 \times 10^6\ A/m}$

Ans: The intensity of magnet isation is **3×10^6 A/m**.

Example 8

The maximum value of permeability of (77% Ni, 16% Fe, 5% Cu, 2% Cr) 0.126 T mA⁻¹. Find the maximum permeability and susceptibility.

Solution:

Given: $\mu = 0.126\ T\ mA^{-1}$

To find: Relative permeability (μ_r), Susceptibility (χ)

Formulae: i. $\mu_r = \frac{\mu}{\mu_0}$

ii. $\mu_r = 1 + \chi$

Calculation: From formula (i),

$= \frac{0.126}{4\pi \times 10^{-7}} = 1.0 \times 10^5$

From formula (ii),

$\chi = \mu_r - 1$

$\chi = 1.0 \times 10^5 - 1$

$\chi = \mathbf{99.99 \times 10^3}$

Ans: i. The relative permeability is **1.0×10^5**.

ii. The susceptibility is **99.99×10^3**.

Example 9

An iron rod is subjected to a magnetising field of 1200 Am⁻¹. The susceptibility of iron is 599. Find the permeability and the magnetic field produced.

Solution:

Given: $H = 1200\ Am^{-1}$, $\chi = 599$

To find: Permeability (μ), Magnetic field (B)

Formula: i. $\mu = \mu_0(1 + \chi)$

ii. $\mu = \frac{B}{H}$

Calculation: From formula (i),

$\mu = 4\pi \times 10^{-7} \times (1 + 599)$

$\therefore\ \mu = \mathbf{7.536 \times 10^{-4}\ T\ mA^{-1}}$

From formula (ii),

$B = \mu H = 7.536 \times 10^{-4} \times 1200$

$\therefore\ B = \mathbf{0.904\ T}$

Ans: i. The permeability is **7.536×10^{-4} T mA⁻¹**.

ii. The magnetic field produced is **0.904 T**.

Example 10

The susceptibility of annealed iron at saturation is 5500. Find the permeability of annealed iron at saturation.

Solution:

Given: $\chi = 5500$

To find: Permeability (μ)

Formula: $\mu = \mu_0(1 + \chi)$

Calculation: From formula,

$\mu = 4\pi \times 10^{-7}(1 + 5500)$

$\mu = \mathbf{6.9 \times 10^{-3}\ Hm^{-1}}$

Ans: The permeability of annealed Iron at saturation is **6.9×10^{-3} Hm⁻¹**.

Example 11

The magnetic susceptibility of annealed iron at saturation is 4224. Find the permeability of annealed iron at saturation. ($\mu_0 = 4\pi \times 10^{-7}$ SI unit).

Solution:

Given: $\chi = 4224$

To find: Permeability (μ)

Formula: $\mu = \mu_0(1 + \chi)$

Calculation: From formula,

$\mu = 4\pi \times 10^{-7}(1 + 4224)$

$= 5.31 \times 10^{-3}$ T m/A

Ans: The permeability of annealed iron at saturation is **5.31 × 10⁻³ T m/A.**

Example 12

The maximum value of permeability of (77% Ni, 16% Fe, 5% Cu, 2% Cr) 0.126 T mA⁻¹. Find the maximum permeability and susceptibility.

Solution:

Given : $\mu = 0.126 \text{ T mA}^{-1}$

To find : Relative permeability (μ_r), Susceptibility (χ)

Formulae : i. $\mu_r = \dfrac{\mu}{\mu_0}$

ii. $\mu_r = 1 + \chi$

Calculation : From formula (i),

$$= \frac{0.126}{4\pi\times10^{-7}} = 1.0 \times 10^5$$

From formula (ii),

$\chi = \mu_r - 1$

$\chi = 1.0 \times 10^5 - 1$

$\chi = \mathbf{99.99 \times 10^3}$

Ans: i. The relative permeability is $\mathbf{1.0 \times 10^5}$.

ii. The susceptibility is $\mathbf{99.99 \times 10^3}$.

Example 13

An iron rod is subjected to a magnetising field of 1200 Am⁻¹. The susceptibility of iron is 599. Find the permeability and the magnetic field produced.

Solution:

Given : $H = 1200 \text{ Am}^{-1}$, $\chi = 599$

To find : Permeability (μ), Magnetic field (B)

Formula : i. $\mu = \mu_0(1 + \chi)$

ii. $\mu = \dfrac{B}{H}$

Calculation : From formula (i),

$\mu = 4\pi \times 10^{-7} \times (1 + 599)$

$\therefore$ $\mu = \mathbf{7.536 \times 10^{-4} \text{ T mA}^{-1}}$

From formula (ii),

$B = \mu H = 7.536 \times 10^{-4} \times 1200$

$\therefore$ B = **0.904 T**

Ans: i. The permeability is $\mathbf{7.536 \times 10^{-4} \text{ T mA}^{-1}}$.

ii. The magnetic field produced is **0.904 T**.

Example 14

A Rowland ring of mean radius 15 cm has 3500 turns of wire wound on a ferromangnetic core of relative permeability 800. What is the magnetic field B in the core for a magnetising current of 1.2 A? (NCERT)

Solution:

Given : $r = 15 \text{ cm} = 15 \times 10^{-2}$ m, $N = 3500$, $\mu_r = 800$, $I = 1.2$ A

To find : Magnetic field (B)

Formulae : i. $n = \dfrac{N}{2\pi r}$

ii. $B = \mu_0 \mu_r n I$

Calculation : Using formula (i),

$$N = \frac{3500}{2\pi\times15\times10^{-2}}$$

Using formula (ii),

$$B = 4\pi \times 10^{-7} \times 800 \times \frac{3500\times1.2}{2\pi\times15\times10^{-2}}$$

= **4.48 T**

Ans: The magnetic field in the core of Rowland ring is **4.48 T**.

Example 15

The susceptibility of magnesium at 300 K is 1.2 × 10⁻⁵. At what tcmperature will the susceptibility increase to 1.8 × 10⁻⁵ ?

Solution:

Given : $\chi_1 = 1.2 \times 10^{-5}$, $T_1 = 300$ K,

$\chi_2 = 1.8 \times 10^{-5}$

To find : Required tcmperature (T_2)

Formula : χT = constant

Calculation : From formula,

$\chi_1 T_1 = \chi_2 T_2$

$$\therefore \quad T_2 = \frac{\chi_1 T_1}{\chi_2} = \frac{1.2\times10^{-5}\times300}{1.8\times10^{-5}}$$

$\therefore$ T_2 = **200 K**

Ans: The required tcmperature is **200 K.**

Example 16

The susceptibility of magnesium at 300 K is 2.4 × 10⁻⁵. At what tcmperature will the susceptibility increase to 3.6 × 10⁻⁵?

[Mar 14]

Solution:

Given : $\chi_1 = 2.4 \times 10^{-5}$, $T_1 = 300$ K,

$\chi_2 = 3.6 \times 10^{-5}$

To find : Required temperature (T_2)

Formula : χT = constant

Calculation : From formula we get,

$$\chi_1 T_1 = \chi_2 T_2$$

$$\therefore \quad T_2 = \frac{\chi_1 T_1}{\chi_2}$$

$$= \frac{2.4\times10^{-5}\times300}{3.6\times10^{-5}}$$

$$= \frac{2\times300}{3}$$

$$\therefore \quad T_2 = \mathbf{200\ K}$$

Ans: The tcmperature at which the susceptibility will increase is **200 K**.

Example 17

A sample of paramagnetic salt contains 2×10^{24} atomic dipoles, each of moment 1.5×10^{-23} JT^{-1}. The sample is placed under a homogeneous magnetic field of 0.64 T and cooled to a tcmperature of 4.2 K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment of the sample for a magnetic field of 0.98 T and a tcmperature of 2.8 K?

(Assume Curie's law) (NCERT)

Solution:

Number of dipoles, $n = 2 \times 10^{24}$

Magnetic moment of each dipole,

$M' = 1.5 \times 10^{-23}$ JT^{-1}

Total dipole moment of sample = n × M'

$= 2 \times 10^{24} \times 1.5 \times 10^{-23} = 30$ JT^{-1}

As saturation achieved is 15%, therefore, effective dipole moment

$$M_1 = \frac{15}{100} \times 30 = 4.5\ JT^{-1}.$$

$B_1 = 0.64T$, $T_1 = 4.2$ K

Now, $B_2 = 0.98$ T, $T_2 = 2.8$ K

According to Curie law,

$$\chi_m = \frac{C}{T} = \frac{M_Z}{H} \text{ or } M_Z = \frac{CH}{T}$$

As, $M_Z \propto M$ and $H \propto B$,

$$\therefore \quad M \propto \frac{CB}{T}$$

$$\therefore \quad \frac{M_2}{M_1} = \frac{B_2}{B_1} = \frac{T_1}{T_2} \text{ or}$$

$$M_2 = \frac{B_2 T_1 M_1}{T_2 B_1}$$

$$= \frac{0.98\times4.2\times4.5}{2.8\times0.64}$$

$$M_2 = \mathbf{10.34\ JT^{-1}}$$

Ans: The total dipole moment of the sample is **10.34 JT^{-1}**

EXERCISE :

Section A: Practice Problems

1. In a hydrogen atom, an electron revolves with a frequency of 6.8×10^9 megahertz in an orbit of diameter 1.06 Å. Calculate the equivalent magnetic moment.
2. The moment of magnet (15 cm × 2 cm × 1 cm) is 1.2 Am^2. What is its intensity of magnetization?
3. In hydrogen atom, the electron is making 6.6×10^{15} rev/sec around the nucleus in an orbit of radius 0.528 Å. Find the magnetic moment (Am^2).
4. The magnetic field B and the magnetic intensity H in a material are found to be 0.3 T and 400 A/m respectively. Calculate the relative permeability' llr' and the susceptibility 'χ' of the material.
5. A current of 3 A flows through a plane circular coil of radius 4 em and having 20 number of turns. Find dipole moment of the coil.

Section B: Theoretical Board Questions

1. What is Curie temperature and what happens above Curie temperature? **[Mar 97]**
2. Explain ferromagnetism on the basis of domain theory. **[Mar 99]**
3. Explain ferromagnetism on the basis of domain theory.' State any two points of difference between ferromagnetic and paramagnetic substances. **[Oct 2000]**
4. Explain ferromagnetism on the basis of domain theory. What is Curie temperature? **[Oct 06]**

Multipal Choice Questions

1. The root cause of magnetic properties in substance is
a) orbital motion of electron.
b) spin motion of proton.
c) orbital and spin motion of electron.
d) orbital and spin motion of proton.

2. Above Curie temperature, the ferromagnetic materials get converted into material.
a) diamagnetic
b) non-magnetic
c) paramagnetic
d) ferrimagnetic

3. The null points are on the equatorial line of a bar magnet when the north pole of the magnet is pointing _____
a) north b) south
c) east d) west

4. An example of diamagnetic substance is
a) Iron b) Copper
c) Aluminium d) Nickel

5. A magnetising field of 2×10^3 ampere/m produces a magnetic flux density of 8n tesla in an iron rod. The relative permeability of the rod will be
a) 10^2 b) $10°$
c) 10^4 d) 10^1

6. Diamagnetism is _____
a) an orientation effect
b) a distortion effect
c) both orientation and distortion effects
d) mutual induction-effect

7. If a diamagnetic material is placed in a magnetic field, the flux density inside the material compared to that outside will be
a) slightly less
b) slightly more
c) very much more
d) same

8. A copper rod is suspended in a nonhomogeneous magnetic field region. The rod when in equilibrium will align itself
a) in the direction in which it was originally suspended.
b) in the region where the magnetic field is strongest.
c) in the region where the magnetic field is weakest and perpendicular to the direction of the magnetic field.
d) in the region where the magnetic field is weakest and parallel to the direction of the magnetic field there.

9. Which of the following substance has negative and very large value of permeability?
a) Ferromagnetic
b) Paramagnetic
c) Diamagnetic
d) None of these

10. Paramagnetism is _____
a) an orientation effect
b) distortion effect
c) both orientation and distortion effects
d) neither orientation effect nor distortion effect

11. A magnetic material of volume 30 cm^3 is placed In a magnetic field of intensity 5 oersted. The magnetic moment produced due to it is 6 Am^2. The value of magnetic induction will be
a) 0.2517 tesla
b) 0.025 tesla
c) 0.0025 tesla
d) 25 tesla

12. Property possessed only by ferromagnetic substance is _____
a) attracting magnetic substance
b) hysteresis
c) susceptibility independent of temperature
d) directional property

13. The SI unit of magnetic flux is
a) weber b) maxwell
c) tesla d) gauss

14. S.I. unit of magnetic dipole moment is
a) A/m^3 b) Am^{-2}
c) Am^2 d) $A - m$

15. To protect the machine of a watch from external magnetic field, its box should be made of _____
a) paramagnetic material
b) diamagnetic material
c) ferromagnetic material
d) non-magnetic material

16. Which of the following materials is repelled by an external magnetic field?
a) iron b) cobalt
c) steel d) copper

17. A non-magnetic material when brought near a powerful magnet, it gets repelled. The material is ______
a) paramagnetic
b) ferromagnetic
c) non-magnetic
d) diamagnetic

18. Which of the following groups are diamagnetic?
a) Hydrogen, oxygen, argon
b) Oxygen, copper, silver
c) Hydrogen, argon, copper
d) Argon, copper, silver

19. The correct relation between B, Hand Mz is
a) $B = \mu_0 (M_Z + H)$
b) $B = \mu_0 M_Z - H$
c) $B = \frac{\mu_0 M_Z}{H}$
d) $B = \mu_0 M_Z \times \mu_0 H$

20. Iron shows its ferromagnetic property at
a) temperatures below 770°C
b) temperatures above 770 °C
c) all temperatures
d) normal temperature

21. If a diamagnetic substance is brought near north or south pole of a bar magnet, it is
a) attracted by the pole.
b) repelled by the poles.
c) repelled by north pole and attracted by the south pole.
d) attracted by the north pole and repelled by the south pole.

22. In a ferromagnetic material, the volume of each domain and number of atoms in it are respectively.
a) 10^{-10} m^3 and 10^{20}
b) 10^{20} m^3 and 10^{40}
c) 10^{-3} m^3 and 10^{-20}
d) 10^{-20} m^3 and 10^3

23. Which of the following is a paramagnetic group?
a) Manganese, aluminum, oxygen
b) Water, oxygen, aluminium
c) Copper, manganese, aluminium
d) Aluminium, copper, water

24. Which of the following is a paramagnetic substance?
a) Air b) Water
c) Oxygen d) Copper

25. The magnetic moment is not represented by
a) accelerated charge.
b) stationary charge.
c) retarded charge.
d) charge moving with constant velocity.

26. If a magnetic material moves from a stronger to weaker parts of a magnetic field, then it is known as ______
a) diamagnetic
b) paramagnetic
c) ferromagnetic
d) anti- ferromagnetic

27. The cause of ferromagnetism is _____
a) orbital motion of electrons
b) spin motion of electrons
c) permanent dipole moment
d) neither spin motion nor orbital motion.

28. When a small magnet is aligned' with a nonuniform magnetic field, it will
a) remain at rest.
b) rotate but will not move.
c) move from high field region to low field region.
d) move from low field region to high field region.

29. In paramagnetic substances, the atom has
a) no magnetic moment
b) torque
c) magnetic moment
d) domain

30. Some atoms have permanent magnetic dipole moments and others do not. The correct reason for the same is
a) If magnetic moments are paired, the dipole moment becomes zero.
b) It depends on the number of inner electrons.
c) It depends on the nuclear properties of the atom.
d) When magnetic moments are not paired, the dipole moment becomes zero.

31. If the relative permeability of iron is 2000, its absolute permeability in SI unit is
a) $8\pi \times 10^{-4}$ T m/A
b) $80\pi \times 10^{-4}$ T m/A
c) $\frac{800}{\pi}$ T m/A
d) $\frac{5\times10^9}{\pi}$ T m/A

32. A circular loop is carrying current and is said to be equivalent to a magnetic dipole. Then, a point on the axis of the loop lies in its

a) end-on position.

b) broad side-on position.

c) both end-on and broad side-on positions.

d) none of the above.

33. Which of the following is incorrect relation?

a) $\chi = \frac{M_Z}{H}$

b) $B = \mu_0 (1 + \chi)H$

c) $\mu_0 = \mu (1 + \chi)$

d) $\mu_r = 1 + \chi$

34. Which of following is not a unit of the intensity of magnetization?

a) Am^{-1}

b) $J\ T^{-1}\ m^{-3}$

c) $N\ T^{-1}\ m^{-2}$

d) $A\ T^{-1}\ m^{-2}$

Answer Keys

1. c)	2. c)	3. a)	4. b)	5. c)	6. b)	7. a)	8. d)	9. d)	10. a)
11. a)	12. b)	13. a)	14. c)	15. c)	16. d)	17. d)	18. d)	19. a)	20. a)
21. b)	22. a)	23. a)	24. c)	25. b)	26. a)	27. c)	28. d)	29. c)	30. a)
31. a)	32. a)	33. c)	34. d)						

Answers :

Section A

1. $9.6 \times 10^{-24}\ Am^2$

2. $4 \times 10^4\ Am^{-1}$

3. $9.24 \times 10^{-24}\ Am^2$

4. 597, 596

5. $0.3\ Am^2$