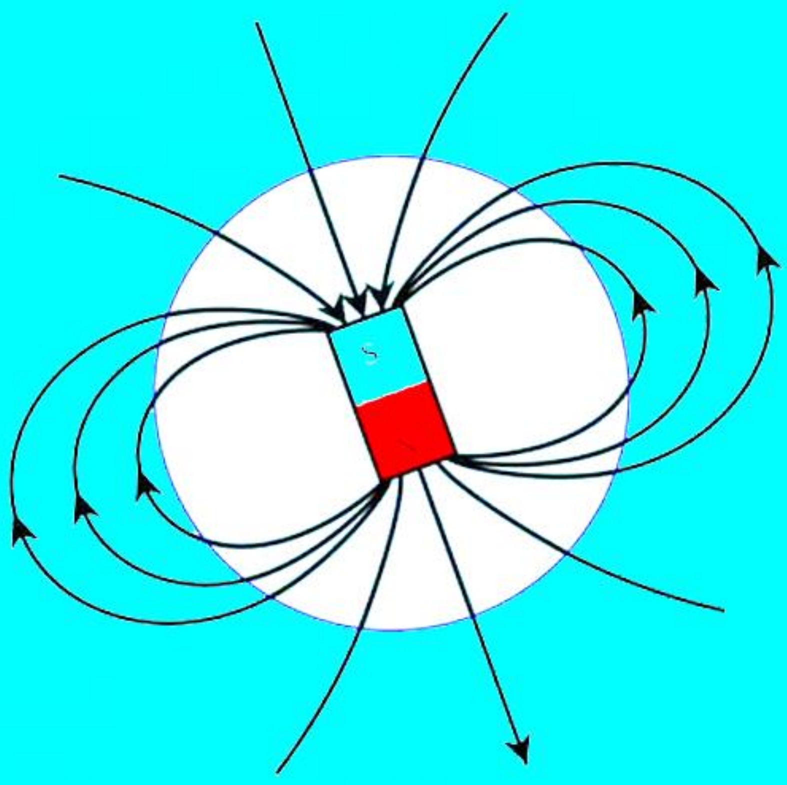
5.MAGNETISM AND MATTER



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MAGNETISM AND MATTER

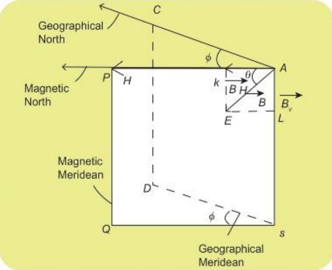
GEOMAGNETIC

Geographical Meridian
Planes passing through geographical north and south pole is called geographical meridian.

Magnetic Meridian
Planes passing through magnetic south and north pole is called magnetic meridian.

Angle of Declination ϕ
Angle between geographical & magnetic meridian.

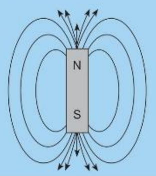
Earth also behaves as a magnet. Due to Earth's magnetic dipole, magnetic field is present everywhere around earth's surface.



Angle of dip (θ)
Angle between the direction of the earth's magnetic field and the horizontal in the magnetic meridian at that place.

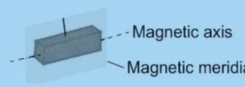
BAR MAGNET

- A bar magnet is a physical magnet in which two equal and opposite poles are separated by a small distance.
- The shortest distance between poles is known as effective length L_e.
- The effective length L_e is less than the geometric length $(L_e < L_g)$

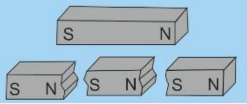


Important Points Related To Bar Magnet

Directive property of bar magnet:-
Bar magnetic is freely suspending in air align itself in N – S direction of Earth's magnetic fields.



Monopole Concept:-
Monopole does not exist. If we break a magnet into pieces each piece will have North & South pole of itself.



Pole Strength (M)

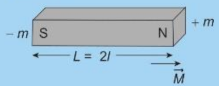
- Pole strength is a measure of the strength of mahnetic pole to attract magnetic material towards itself.
- It is a scalar quantity.
- SI unit is Am or N/T.

Properties of Bar Magnets

- A magnet attract magnetic substance such as nickel, cobalt, iron e.t.c
- North and south poles of magnet are little inward & from geometrical end.
- Poles exist always in pair and having equal strength i.e monopole do not exist.
- Like poles repel each other or unlike poles attract each other.

Magnetic Dipole Moment ($\vec{M}$)

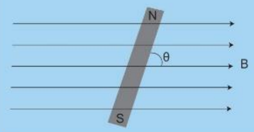
$\vec{M} = m(2\vec{l})$



M = magnetic pole strength
$\vec{l}$ = affective length
- It is a vector quantity
- SI unit is Am2 or N/T.

Bar Magnet Placed In An External Magnetic Field

- Torque ⟶ $\tau = |\vec{M} \times \vec{B}| = MB\sin\theta$
- Work ⟶ $W = MB(\cos\theta_1 - \cos\theta_2)$
- Potential ⟶ $U = -\vec{M}.\vec{B},\ = -MB_{\cos\theta}$



Magnetic Field at a Distance r from Bar Magnet for Different Position

Position	Magnetic field at this position	For Short magnet (l << r)
Axial line	$B_a = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2 - l^2)^2}$	$B_a = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$
Equatorial line	$B_e = \frac{\mu_0}{4\pi}\frac{M}{(r^2 + l^2)^{3/2}}$	$B_e = \frac{\mu_0}{4\pi}\frac{M}{r^3}$

MAGNETIC FLUX AND FLUX DENSITY

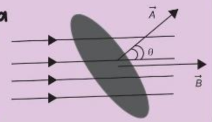
Gauss Law in Magnetism
The net magnetic flux associated with the closed surface is μ_0 times the net magnetic pole strength enclosed by the surface.

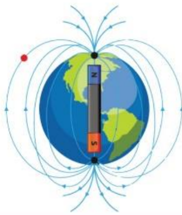
$\phi_B = \oint \vec{B}.d\vec{A}, = \mu_0 \times$ (net pole strength) = zero

The number of magnetic field lines passing through a surface is called magnetic flux.

$\phi_B = \vec{B}.d\vec{A}$

S.I unit of ϕ_B is weber (wb)





MAGNETIC FIELD STRENGTH

The magnetic field strength can be defined as the force experienced by a unit test north pole (m_0) placed in that field. $B = F/m_0 = \frac{\mu_0 m}{4\pi r^2}$

Properties of Magnetic Field Lines

- No two magnetic field lines can cut each other.
- Tangent at a point of magnetic field line give direction of field at that point.
- These form closed lines whose direction is from North to South always.

Magnetic Permeability	Intensity of Magnetizing Field $(\vec{H})$	Intensity of Magnetisation $(\vec{I})$	Magnetic Susceptibility (X_m)
(1) The extent to which magnetic Field lines can Penetrate the substance is known as Magnetic Permeability of that Substance. It is denoted by μ. (2) The Value of μ for free space or air is:- $4\pi \times 10^{-7}$ T.m / A	(1) The extent to which a magnetic field can magnetize a magnetic substance is called Intensity of Magnetizing Field $(\vec{H})$ (2) It is a Field Property (3) $\vec{H} = \vec{H} = \vec{B}/\mu$ (4) SI Unit is: A/m	(1) The Extent to which a magnetic substance is magnetized in a magnetic Field is Known as Intensity of magnetization $(\vec{I})$ (2) $\vec{I} = \frac{\vec{M}}{V}$ Where $\vec{M}$ = magnetic moment and V = Volume. (3) It is a material Property (4) SI Unit is A/m.	(1) The Ratio of intensity of magnetisation $(\vec{I})$ to magnetic Intensity $(\vec{H})$ applied to the substance is known as magnetic susceptibility of Substance. $X_m = \frac{\vec{I}}{\vec{H}}$ (2) Magnetic Susceptibility is a unitless and dimensionless quantity

Relation between magnetic permeability and suscaptibility

The sum of magnetic field in vacuum due to magnetizing force and magnetic field due to magnetization of material is known as total magnetic flux density.

$$B = B_0 + B_m = \mu_0 H + \mu_0 I = \mu_0 (H + I)$$

$$B = \mu_0 H\left(1 + \frac{I}{H}\right) = \mu_0 H(1 + \chi_m)$$

Also, $\mu_r = (1 + \chi_m) \quad [\because B/H = \mu_r]$

CURIE LAW

Curie law states that the magnetic sus castability of paramagnetic substance isinversely proportional to temperature of material.

$X \propto \frac{1}{T} \Rightarrow X = \frac{C}{T}$

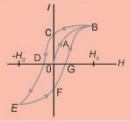
Curie Temperature
Temperature at which ferromagnetic material can be converted into paramagnetic material. denoted as T_c.

Curie – weiss law
The susceptibility of ferromagnetic material is inversely proportional to (T - TC) above curie temperature T_c.

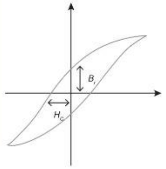
$X = \frac{C}{(T - T_c)}$

MAGNETIC HYSTERESIS

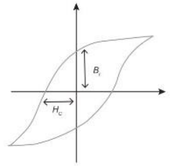
In ferromagnetic material when external magnetic field is removed some of domain remains aligned in direction of magnetic field.



Soft Magnetic Material



Hard Magnetic Material



MAGNETIC MATERIALS

On the basis of magnetic properties, materials can be classified into three categories.

PROPERTIES	DIAMAGNETIC MATERIAL	PARAMAGNETIC MATERIAL	FERRO MAGNETIC MATERIAL
Cause of magnetism	Motion of electrons in orbits	Electron spinning	Domain formation
Behavior when placed in uniform magnetic field.	Magnetization is poor and in opposite direction. $B_m < B_0$	Magnetization is poor and in same direction $B_m > B0$	Magnetization is strong and in same direction $B_m >> B_0$
Relative Permeability (μr)	$1 > \mu_r > 0$	$2 > \mu_r > 1$	$\mu_r >> 1$
Examples	Copper, silver, lead, water.	Sodium, potassium, manganese, aluminum.	Iron, cobalt, nickel, alnico.

Magnetism and Matter

The phenomenon of magnetism was known to Greeks as early as about 800 B.C. They discovered certain stones now known as magnetite (Fe_3O_4) which attracted pieces of iron. Magnetite was found near the city of magnesia and hence the name magnetite.

Bar magnet

A device that produces a magnetic field is generally called a magnet. The simplest way of obtaining magnetic fields is by using *bar magnets*. A bar magnet is a rod, generally of rectangular cross section and made of materials containing elements like iron, nickel, cobalt etc. and their alloys.

Properties of bar magnets

1. When a bar magnet is suspended freely near the surface of the earth, it tends to align always in the nearly North-South direction. One end of the bar magnet always pointing towards the geographic North is called the **North pole** of the magnet. The other end that always point towards the geographic South is called the **South pole** of the magnet.
2. Like poles repel and unlike poles attract each other.
3. The North and South poles of a bar magnet cannot be separated. *The magnetic monopoles do not exist*.
4. Bar magnets are made up of ferromagnetic materials, like iron, cobalt, nickel etc.

Characteristics of Magnetic Field lines

1. The tangent to the magnetic field line at a point gives the direction of the net magnetic field acting at that point.
2. *Magnetic field lines are always closed paths*, whatever may be the source of magnetic field. Hence, there is no beginning or end point for a magnetic field line. There are no sources or sinks for magnetic field lines in a magnetic field. That is, there is no isolated magnetic pole.
3. *The magnetic field lines can never intersect*.
4. The number of magnetic field lines across unit area in a region of space is a measure of the strength of the magnetic field in that region.

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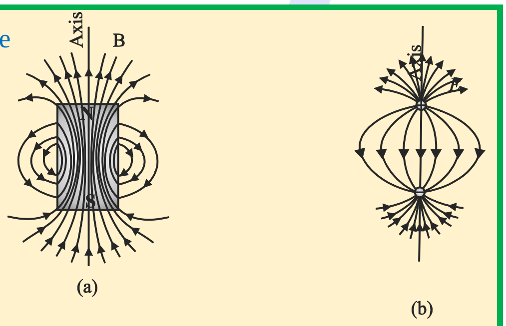
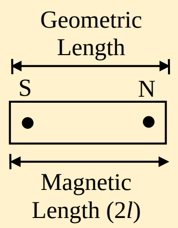
- The configuration of field lines of the magnetic field produced outside a bar magnet resemble that of the electric field lines around an electric dipole as shown in Fig. (a) and (b).



Field lines due to (a) a bar magnet (b) electric dipole

- Magnetic length ($2l$) = $\frac{7}{8}\times$ geometric length

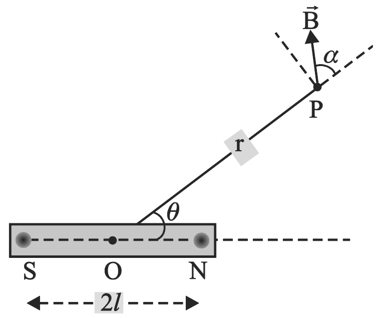


- There can be magnets without poles. A magnetized ring called toroid and a solenoid of infinite length has magnetic properties but has no poles.

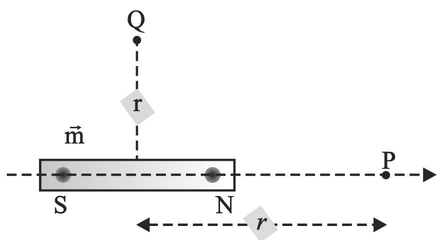
Magnetic field due to a bar magnet

- The magnetic field due to a small bar magnet at a point p, at a distance r from the centre of the magnet and at angle θ with the magnetic axis is $B=\frac{\mu_0}{4\pi}\times\frac{m}{r^3}\sqrt{3\cos^2\theta+1}$

The direction of field makes an angle 'α' with the line OP such that $\tan\alpha=\frac{1}{2}\tan\theta$.



Field at an arbitrary point due to a bar magnet



Field points on the axis and equatorial line for a short bar magnet

- For a point P on the axis of a short bar magnet the field is $B_d = \frac{\mu_0}{4\pi}\times\frac{m}{r^3}$
- For a point θ on the equatorial line of a short bar magnet the field is $B_e = \frac{\mu_0}{4\pi}\times\frac{2m}{r^3}$
- We see that, the field at a certain distance along *x* axis of a short bar magnet is twice that at the same distance along the equatorial line.

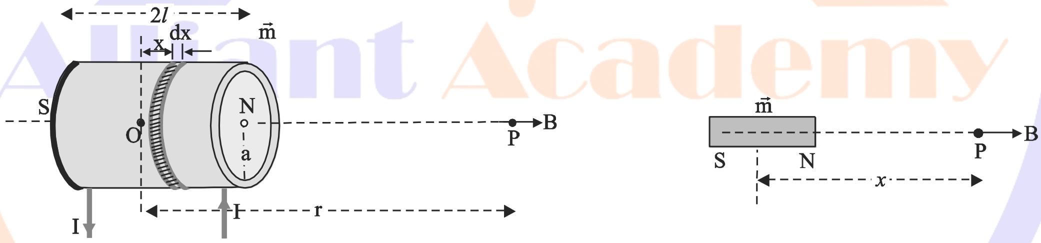
Magnetic field along the axis of a solenoid and of a bar magnet

Consider a solenoid of length $2l$, radius of cross section and 'a' having N turns. If n is the number of turns per unit length then, $N = n \times 2l$.

Consider a point P at a distance r from the center O of the solenoid.

The total magnetic field at point P due to the entire solenoid is

$$B_P = \frac{\mu_0 NIa^2}{2r^3} \qquad \text{(for } r >> l \text{ and } r >> a\text{)},$$



(a) (b)

Field along (a) the axis of a solenoid and (b) a bar magnet

If the radius 'a' of the solenoid is very small compared to r, we get, or $B_p = \frac{\mu_0}{4\pi}\times\frac{2NIA}{r^3}$

where $A = \pi a^2$ is area of cross section of the solenoid

$$B_P = \frac{\mu_0}{4\pi}\frac{2m}{r^3} \qquad \ldots(1)$$

where m = NIA is magnetic moment of the solenoid.

This equation is similar to the equation for the magnetic field due to a short bar magnet on the axial line

$$B_P = \frac{\mu_0}{4\pi}\frac{2m}{r^3} \qquad \ldots(2)$$

m represents the magnetic moment of the magnet, which is the product of its pole strength and magnetic length. The resemblance of Eqs., (1) and (2) reveal the equivalence of a solenoid and a bar magnet.

Magnetic Charge or Pole Strength

Magnetic moment $m = n(2l)IA = nIA\,(2l)$

i.e., $m = nIA\,(2l)$ ...(3)

The electric field on the axial line of a short dipole is also given by a similar equation.

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3} \qquad \ldots(4)$$

where p is the electric dipole moment given by

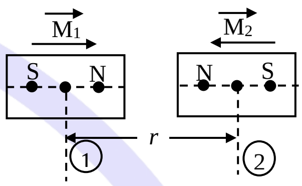
$p = q_m(2l)$ ...(5)

Comparing Eqs., (3) and (5) we observe that the quantity nIA can be regarded as the magnetic analogue of electric charge. It is sometimes called *magnetic charge* or *pole strength.*

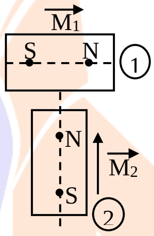
By convention, the positive pole of the magnet having a pole strength $+q_m$ (= nIA) is referred to as the N-pole and the negative pole of strength $-q_m$ is referred to as the S-pole.

Magnetic Force between short magnetic dipoles (Bar magnets) at distance 'r' a part

(i) If their magnetic moments are parallel to each other. Then, $F_m = \frac{\mu_0}{4\pi}\frac{6m_1m_2}{r^4}$



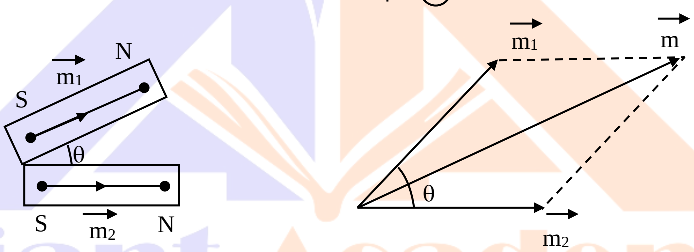
(ii) If their magnetic moments are ⊥ to each other.



Then, $F_m = \frac{\mu_0}{4\pi}\frac{3m_1m_2}{r^4}$

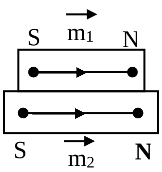
Magnetic moment of system:

(i)



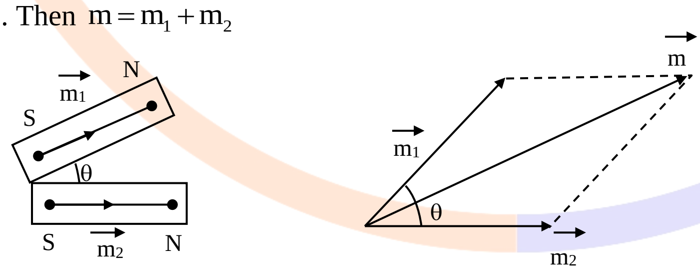
$\therefore |\vec{m}| = \sqrt{m_1^2 + m_2^2 + 2m_1m_2\cos\theta}$

Special case



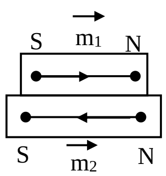
If $\theta = 0°$. Then $m = m_1 + m_2$

(ii)



$\therefore |\vec{m}| = \sqrt{m_1^2 + m_2^2 + 2m_1m_2\cos\theta}$

Special case



If one magnet is placed over the other with unlike poles touching $\theta = 0°$

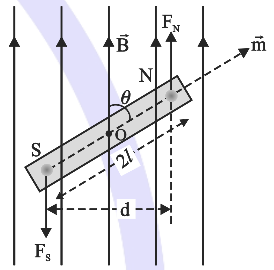
$\therefore\ m = m_1 - m_2$

(iii) If they are arranged to form a cross like T or L $(\theta = 90°)$

$\therefore\ m = \sqrt{m_1^2 + m_2^2}$

- If a bar magnet of magnetic moment m and pole strength (q) is cut into equal halves along axial line the magnetic moment of each part becomes $\frac{m}{2}$.
- If a bar magnet of magnetic moment m and pole strength q is cut in two equal halves along its equatorial line (a line passing through the midpoint of magnet and perpendicular to axial line).
- Then, magnetic moment becomes $\frac{m}{2}$.
- If a bar magnet of pole strength (q) and magnetic moment (m) is cut into n equal parts along axial line. The magnetic moment of each part is $\frac{m}{n}$.
- If a bar magnet of pole strength (q) and magnetic moment (m) is cut into n equal parts parallel to its length and then cut into n equal parts parallel to its breadth.
- $\therefore$ Magnetic moment of each part = $\frac{m}{n^2}$

Torque on a bar magnet in magnetic field



Consider a bar magnet of magnetic moment $\vec{m}$ held in a uniform magnetic field $\vec{B}$. In analogy with an electric dipole equal and opposite forces ($q_m B$) act on both North and South poles. This gives rise to a torque on the magnet. Figure shows the forces on the magnet.

Torque on the magnet = $\tau = F \times d = q_m B.2l \sin\theta = mB\sin\theta$

or $\vec{\tau} = \vec{m} \times \vec{B}$

The torque tends to rotate the bar magnet until its axis becomes parallel to the applied field.

If the magnetic dipole is placed in a non-uniform magnetic field, it experiences an unbalanced force and a torque.

Potential energy of a bar magnet in a magnetic field

Consider a bar magnet held in a magnetic field with its magnetic moment $\vec{m}$ making an angle θ with the field $\vec{B}$.

Potential energy of the magnetic dipole: The work done in rotating the dipole in the magnetic field is stored into it as magnetic potential energy given by

$U = -mB\cos\theta$ i.e., $U = -\vec{m} \cdot \vec{B}$

When the magnet is turned from an angle θ_1 to θ_2 change in potential energy is

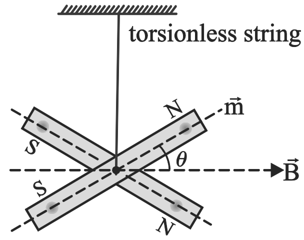
$\Delta U = mB[\cos\theta_1 - \cos\theta_2]$

- Choice of zero potential energy is a matter of convenience (ground level as zero potential energy in gravitation and infinity in electrostatic potential energy etc.).
- When the magnet is perpendicular to $\vec{B}$, θ = 0, then, U = – mB. The potential energy is minimum in this position and hence this is the most stable configuration. When the magnet is slightly displaced from this position, the torque acting on the magnet restores it to the minimum energy configuration.

  It is for this reason that a magnet suspended in a magnetic field aligns along the field.
- Let θ = 180°, then, U = + mB. The potential energy is maximum and hence this configuration is unstable.
- A magnet even slightly displaced from this position will turn by 180 degrees to take the most stable configuration which is also the minimum energy configuration.
- If a magnetic dipole from angular position θ_1 to θ_2, then work done is equal to potential energies in initial and final positions

  $W = U_2 - U_1 = -mB\cos\theta_2 - (-mB\cos\theta_1) = mB(\cos\theta_1 - \cos\theta_2)$

Oscillations of a bar magnet in a magnetic field



Consider a bar magnet of magnetic moment m suspended in a uniform horizontal magnetic field B. It comes to rest with its axis along the magnetic field. If the magnet is deflected through an angle θ, it experiences a torque $\tau = mB \sin\theta$. Then, if let free, the bar magnet rotates due to the restoring torque so as to align in direction of the field. If I is the moment of inertia and $\alpha = \frac{d^2\theta}{dt^2}$ is its angular acceleration then the product $I\alpha$ should be equal to the restoring torque on it.

i.e., $I\alpha = -mB \sin\theta$ or $\alpha = \frac{-mB}{I}\sin\theta$

For small angles, $\alpha = \frac{-mB}{I}\theta$ (since, $\sin\theta \approx \theta$, for small θ). ...(1)

$\alpha \propto -\theta$ ...(2)

This Eq., (2) always represents an angular simple harmonic motion with angular frequency ω, given by $\omega^2 = \frac{mB}{I}$

If T is the period of oscillation, then

$$\omega^2 = \frac{4\pi^2}{T^2} = \frac{mB}{I} \text{ or } T = 2\pi\sqrt{\frac{I}{mB}} \qquad \ldots(3)$$

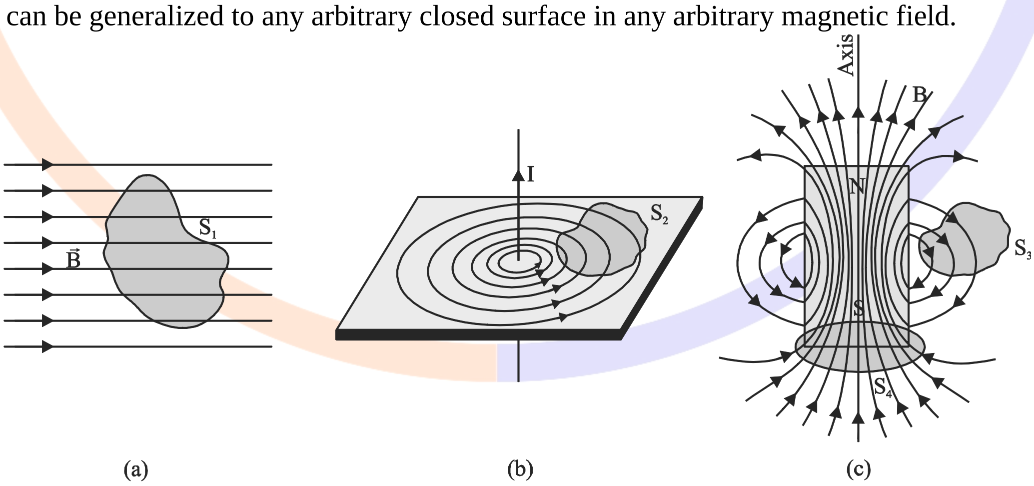
By measuring the period of oscillations of the magnet, the magnetic moment can be determined if B is known. Also, magnetic field B can be determined if m is known.

Gauss' law in magnetism

Statement: The net magnetic flux across a closed surface in a magnetic field is zero.

i.e., $\oint \vec{B}\cdot\vec{ds} = 0$

This result can be generalized to any arbitrary closed surface in any arbitrary magnetic field.



Gaussian surfaces in magnetic fields (a) in a uniform magnetic field,
(b) around a straight conductor and (c) due to a bar magnet / equivalent solenoid

The net magnetic moment of a material per unit volume is called magnetization. (It is sometimes called the intensity of magnetization).

Magnetization, $\vec{M} = \frac{\sum \vec{m}_i}{V} = \frac{\text{total magnetic moment}}{\text{volume}}$ ... (1)

$\vec{M}$ is a vector similar to the polarization vector $\vec{P}$ of a dielectric material. This magnetization produces an additional magnetic field in a material (similar to the electric fields produced by polarization of a dielectric).

Relation between magnetization and magnetic field in a material

Consider a long solenoid with n turns and carrying a current I. The magnetic field inside the solenoid is

$B_0 = \mu_0 nI$ … (2)

If this solenoid is filled with a material having a magnetization M, then the net magnetic field inside the solenoid is

$\vec{B} = \vec{B}_0 + \vec{B}_m$ … (3)

Here, $\vec{B}_m$ is the magnetic field produced by the magnetization $\vec{M}$ of the material. B_m increases with M. It can be shown that

$\vec{B}_m = \mu_0 \vec{M}$ … (4)

Hence, $\vec{B} = \vec{B}_0 + \mu_0 \vec{M}$ … (5)

Magnetizing field or Intensity of Magnetizing field (H)

The magnetization M in a small region inside the material arises due to

(i) the external influences (as the current in the solenoid) and

(ii) the field produced by the magnetic dipoles and magnetization in the surrounding medium.

Hence, to separate the contributions to the net field B from the two separate sources, a new vector called *magnetizing field* that represents the external factors (excluding the effect of magnetization of the medium) is introduced. It is denoted by H.

H is defined by the relation. $\vec{H} = \frac{\vec{B}}{\mu_0} - \vec{M}$

Magnetic Susceptibility

The relation between the magnetization M and the magnetizing field H can be written as

$\vec{M} = \chi \vec{H}$

where the constant of proportionality χ is a measure of the response of the medium to the external field H and is called susceptibility of the material.

The ratio of the magnetization induced in a material to the magnetizing field is called its magnetic susceptibility.

Magnetic Permeability

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

Let $(1 + \chi) = \mu_r$

where μ_r is called the relative permeability of the material.

$B = \mu_0\mu_r H$

But $\mu = \mu_0\mu_r$

where μ is called absolute permeability of the material. $\therefore B = \mu H$

☞

- In SI, unit of H and M is *ampere per meter*.
  However, in engineering practice H is expressed as ampere turns per meter, indicating the effect of number of turns in the solenoid used to produce H. Also turns refers to a number and hence does not change the dimensional expression.
- In SI, magnetic susceptibility χ is a dimensionless quantity.
- In the absence of a magnetic material inside a solenoid H = nI.

Magnetic properties of materials

Materials that can produce magnetic effects and also be influenced by magnetic fields are referred to as **magnetic materials**. They are broadly classified into three categories, namely

(i) *diamagnetic*,

(ii) *paramagnetic* and

(iii) *ferromagnetic* materials. This classification is based partly on the magnetic dipole moments of the atoms (or molecules) of the material and partly on the interactions between the atoms in the material.

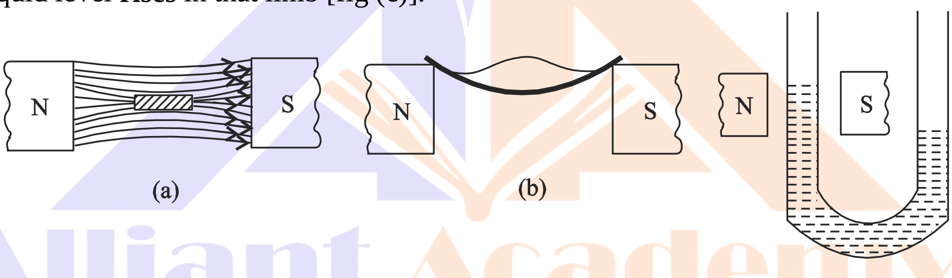
The characteristic features of each of these three different types are explained in the following sections.

Paramagnetic Materials

- *The phenomenon in which certain materials acquire a small magnetic moment in the direction of an applied magnetic field is called paramagnetism.*
- A paramagnetic material tends to get slightly attracted by a magnet and move from weaker to stronger regions of a non-uniform magnetic field.
- Some examples of paramagnetic materials are aluminium, platinum, chromium, manganese solutions of salts of nickel, oxygen etc.

Properties of paramagnetic materials

1. The relative permeability of a paramagnetic substance is greater than unity ($\mu_r > 1$).
2. Its susceptibility is a low positive value (10^{-4} to 10^{-6}).
3. When a paramagnetic solid in the form of a thin rod is freely suspended in a strong magnetic field the rod aligns with its **longer axis in the direction** [fig (a)].
4. When a paramagnetic liquid taken in a watch glass is placed between the pole pieces of two powerful magnets, there will be an **elevation** in the middle [fig (b)].
5. When one of the limbs of a U – tube containing a paramagnetic liquid is placed between the pole pieces of a powerful magnet, the liquid level **rises** in that limb [fig (c)].



Curie's law

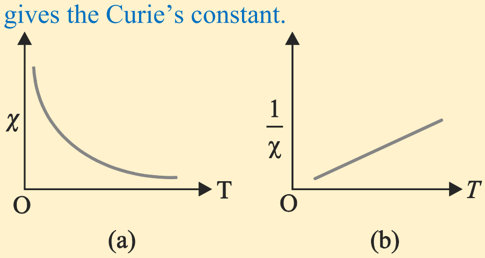
The magnetic susceptibility of a paramagnetic material is inversely proportional to its absolute temperature

$$\chi = \frac{C\mu_0}{T} \Rightarrow \chi \propto \frac{1}{T}$$

This is known as Curie's law. The constant of proportionality C is called the *Curie constant* for a given paramagnetic material.

☞

- As temperature decreases, degree of alignment of dipoles increases and hence the paramagnetic susceptibility increases. At very low temperatures, the paramagnetic moment reaches a certain saturation value.
- The variation of paramagnetic susceptibility χ with absolute temperature T (except at very low temperatures) is shown in the figure. The slope gives the Curie's constant.



Variation of paramagnetic susceptibility with increase in temperature

- The large paramagnetic susceptibility at low temperatures is used

(i) to produce and

(ii) to measure very small temperatures close to absolute zero using a technique called adiabatic demagnetization.

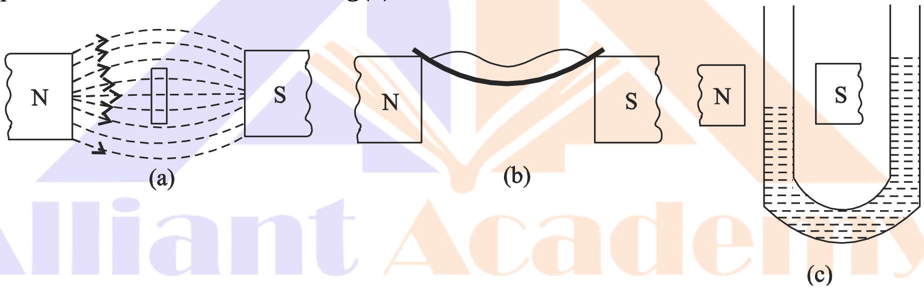
This is an important application of paramagnetism. Demagnetization of atomic magnetic dipoles can be used to produce temperatures as low as 0.001 K, where as demagnetization of nuclear magnetic moments may be used to achieve very low temperatures of the order of below 10^{-6} K.

Diamagnetism

- *The phenomenon in which a material acquires an induced small magnetic moment opposite to the applied magnetic field is called diamagnetism.*
- A diamagnetic material tends to get slightly repelled from a magnet and move from stronger to weaker regions in a non-uniform magnetic field.
- Some of the examples of diamagnetic substances are bismuth, antimony, zinc, silver, copper, gold, lead, mercury, water, alcohol, hydrogen etc. Majority of inorganic compounds and practically all organic compounds are diamagnetic.

Properties of Diamagnetism materials

1. The relative permeability of a diamagnetic substance is less than unity ($\mu_r < 1$).
2. Its susceptibility (χ) is a low negative value (10^{-5} or 10^{-6}) and is independent of temperature.
3. When a diamagnetic solid in the form of a thin rod is freely suspended in a strong magnetic field the rod **aligns with its length perpendicular to the field** [fig(a)].
4. When a diamagnetic liquid taken in a which glass is placed between the pole pieces of two powerful magnets, there will be a **depression** in the middle [fig(b)].
5. When one of the limbs of a U-tube containing a diamagnetic liquid is placed between the pole pieces of two powerful magnets, the liquid level **falls** in that limb [fig(c)].



Ferromagnetism

- **The phenomenon in which certain materials like iron acquire strong magnetic moments along an applied magnetic field and strongly attracted by magnets is called *ferromagnetism*.**
- A ferromagnetic material has a strong tendency to move from weaker to stronger regions of magnetic field.
- The word ferro- refers to iron. The materials that behave like iron in magnetic fields are called ferromagnetic materials. Some of the examples are Iron (Fe), Nickel (Ni), Cobalt (Co), Steel, Gadolinium and their alloys.
- The atoms or molecules of ferromagnetic materials possess permanent magnetic dipole moments similar to those of paramagnetic materials.

Properties of Ferromagnetic Materials

1. The relative permeability of a ferromagnetic substance is a very large positive value $(\mu_r \gg 1)$ Obviously the magnetic permeability is also very large.
2. Susceptibility is a very high positive value $(\chi \gg 1)$ of the order of 10^2 to 10^4.
3. Ferromagnetic substances exhibit the phenomenon of **magneto-striction** i.e. when a ferromagnetic bar is placed in a magnetic field its length changes in the direction of magnetisation.
4. Ferromagnetic substance exhibit a special property called **hysteresis**.
5. Susceptibility varies inversely as the temperature $\left(\chi \propto \frac{1}{T}\right)$, Curie law). The susceptibility decreases steadily with the rise of temperature, till a critical temperature called the curie temperature (T_C) is reached. At the curie temperature ferromagnetism disappears and the substance becomes para-magnetic. *The susceptibility of a ferromagnetic substance above its curie temperature is inversely proportional to the excess of temperature* $(T - T_C)$ *above the curie temperature*.

i.e., $\chi \propto \frac{1}{(T - T_C)} \Rightarrow \chi = \frac{C}{(T - T_C)}$ (When $T > T_C$)

This is called **Curie – Weiss law.**

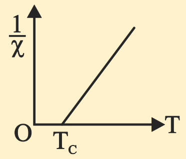
where C is material specific Curie constant.

The above equation is called the Curie – Weiss law. This is valid at temperatures above T_C.

We have a phase transition from ferromagnetic to paramagnetic state at the Curie temperature.

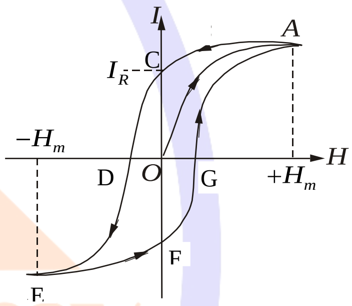
Below Curie temperature, the relation between susceptibility and temperature is not well defined.

- Above T_C, only spontaneous alignment of dipoles is lost but the magnetic dipole moments of the atoms are not destroyed. Thus the material behaves as a paramagnetic.
- The variation of susceptibility of a ferromagnetic material with increase in temperature is shown in the figure.
- The curie temperature for iron is 1043 K and for cobalt 1423 K.



Hysteresis

- When a ferromagnetic specimen is taken through a cycle of magnetisation, the lagging behind of intensity of magnetisation (M) with the magnetising field (H) is called hysteresis.
- When a ferromagnetic material is being taken through a cycle of magnetisation the intensity of magnetisation remaining in the specimen even when the magnetising field is made zero is called residual intensity of magnetisation.
- When a ferromagnetic material is being taken through a cycle of magnetisation, the reverse magnetising field required to reduce residual magnetisation to zero (i.e., to completely demagnetise the specimen) is called coercive field.



Hysteresis loop

Retentivity: The ability of a ferromagnetic material to retain magnetisation even after magnetising field is removed is called retentivity.

Coercivity: The property of a ferromagnetic material that determines the coercive field required to demagnetise it is called coercivity.

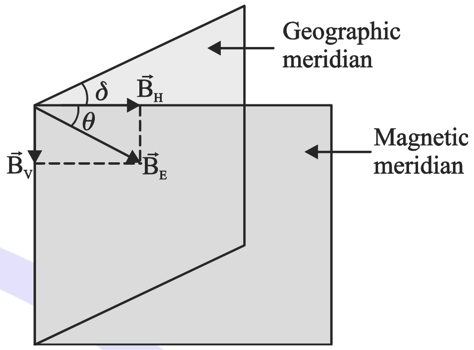
Significance of hysteresis curve

1. The area of the hysteresis loop (M-H curve) of a ferromagnetic specimen is a measure of loss of energy in the form of heat, during one cycle of magnetisation per unit volume of the material. The work done in orienting the atomic magnetic dipoles using the magnetising field, is not completely recovered during a cycle of magnetisation. The energy lost is called hysteresis loss and it appears as heat. (If B vs H is plotted, area of hysteresis is loop is equal to hysteresis loss per unit volume per cycle, Jm^{-3}).
2. The study of hysteresis is loop helps in identifying suitable materials for permanent magnets, transformer cores, electromagnets etc. For example, a material with high retentivity and high coercivity is used to construct permanent magnets. Example: Alnico, Ticonal.

- A material with low hysteresis loss is preferred for transformer core. Example: Permalloy.
- A material with low retentivity, low coercivity and small hystersis loss is used to construct electromagnets. Example: Soft iron.

Earth's magnetic field

Earth has a magnetic field around it. Generally, the magnetic axis of the earth does not coincide with the geographic axis. A vertical plane passing through the given place and the magnetic north and south poles of the earth is called the **magnetic meridian.** Similarly, the vertical plane passing through the given place and the geographic north and south poles of the earth is called the **geographic meridian**.



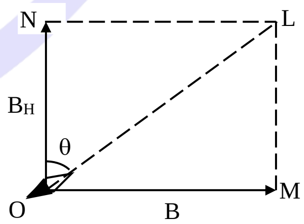
The direction and magnitude of the earth's magnetic field generally vary from place to place on the surface of the earth. The earth's magnetic field **at a place** can be understood in terms of the following experimentally measurable quantities, called **earth's magnetic elements at the place.** They are declination (δ), dip (inclination, θ), and horizontal component of earth's magnetic field (B_H).

- $B_H = B_E \cos\theta$
- $B_V = B_E \sin\theta$
- $B_E = \sqrt{B_H^2 + B_V^2}$
- $\tan\theta = \frac{B_V}{B_H}$

☞
- A magnetic needle free to rotate in a vertical plane in the magnetic meridian comes to rest along B_E.
- A magnetic needle (compass needle) free to rotate in a horizontal plane comes to rest along B_H.
- A magnetic needle free to rotate in a vertical plane perpendicular to magnetic meridian comes to rest along B_V.
- Magnetic maps: World maps showing the lines passing through places having the same value of a particular magnetic element.
  - ➢ Isogonals : Lines passing through places of equal declination.
  - ➢ Agonals : Lines passing through places of zero declination.
  - ➢ Isoclinals : Lines passing through places of equal inclination (dip).
  - ➢ Isodynamic lines : Lines passing through places of equal B_H.

Tangent law in magnetism

A magnetic needle free to rotate is placed in a combined magnetic field containing two, uniform magnetic fields acting perpendicular to each other, then the magnetic needle comes to rest in the resultant direction making an angle θ with B_H, which is given by $B = B_H \tan\theta$. This is called *tangent rule* or *tangent law, in magnetism*.



Illustrations

1. An iron wire of length l is magnetized to have a magnetic moment m. If it is bent into a semicircle of radius r, its magnetic moment is

(A) m (B) $\frac{2m}{\pi}$ (C) $\frac{m}{\pi}$ (D) $m\frac{l}{r}$

Ans (B)

The magnetic moment of straight wire, m = (q_m) (l)

The magnetic moment of the semicircular wire, m′ = (q_m) (2r)

$$\therefore \frac{m'}{m} = \frac{2r}{l} = \frac{2r}{\pi r} = \frac{2}{\pi} \therefore m' = \frac{2m}{\pi}$$

2. A solenoid 10 cm long is wound with 1000 turns of wire. The current that is needed to produce 6.28×10^{-4} T at the centre of the solenoid is

(A) 30 mA (B) 40 mA (C) 50 mA (D) 60 mA

Ans (C)

$$B = \mu_0 n i = \mu_0 \left(\frac{N}{L}\right) i$$

$$\Rightarrow 6.28 \times 10^{-4} = 4\pi(10^{-7})\left(\frac{1000}{10 \times 10^{-2}}\right)$$

$$\Rightarrow i = 50\,mA$$

3. A magnet is suspended horizontally in the earth's magnetic field. When slightly displaced, it oscillates in the horizontal plane with a period T. If a piece of wood having the same moment of inertia as the magnet is attached to the magnet, the new period of oscillation is

(A) $\frac{T}{\sqrt{2}}$ (B) $\frac{T}{2}$ (C) $\sqrt{2}T$ (D) 2T

Ans (C)

$$T = 2\pi\sqrt{\frac{I}{mB_H}};\ T' = 2\pi\sqrt{\frac{2I}{mB_H}} = \sqrt{2}T$$

4. The work done in rotating a magnet of magnetic moment m by an angle 90° from the magnetic meridian is n times the corresponding work done to rotate it through an angle of 60°. The value of n is

(A) ½ (B) 2 (C) ¼ (D) 1.

Ans (B)

Work done in rotating a manget from an angle θ_1 to an angle θ_2 is given by $W = mB(\cos\theta_1 - \cos\theta_2)$

In the first case, $W = mB(\cos 0° - \cos 90°) = MB$

In the second case, $W' = mB(\cos 0° - \cos 60°) = \frac{MB}{2}$

$\therefore$ W = 2W′ $\therefore$ n = 2

5. A magnet is suspended in such a way that it oscillates in the horizontal plane. It makes 20 oscillations per minute at a place where the angle of dip is 30° and 15 oscillations per minute at a place where the angle of dip is 60°. The ratio of earth's total magnetic field sat the two places is

(A) $3\sqrt{3}:8$ (B) $16:9\sqrt{3}$ (C) 4 : 9 (D) $2\sqrt{3}:9$

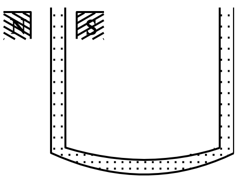
Ans (B)

$$T = 2\pi\sqrt{\frac{I}{mB_H}} = 2\pi\sqrt{\frac{I}{mB\cos\theta}}$$

$$\therefore \frac{T_1}{T_2} = \sqrt{\frac{B_2\cos\theta_2}{B_1\cos\theta_1}} \Rightarrow \frac{B_1}{B_2} = \frac{T_2^2}{T_1^2}\left(\frac{\cos\theta_2}{\cos\theta_1}\right)$$

$$\therefore \frac{B_1}{B_2} = \left(\frac{4}{3}\right)^2 \frac{\cos 60}{\cos 30} = \frac{16}{9}\cdot\frac{1/2}{\sqrt{3}/2} = \frac{16}{9\sqrt{3}}$$

6. A diamagnetic liquid is taken in a U-tube. A strong magnetic field is applied across the liquid in any one limb of the U-tube. The level of the liquid in that limb.



(A) raises relative to the liquid level in the other limb.

(B) falls relative to the liquid level in the other limb

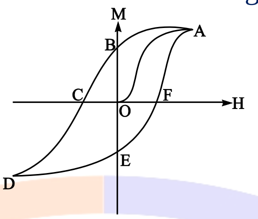
(C) remains same

(D) oscillates up and down

Ans (B)

For a diamagnetic material, the relative permeability, $\mu_r < 1$. Hence, the diamagnetic materials tend to move away from the magnetic field, thereby reducing the number of magnetic field lines through them. Hence the liquid level falls.

7. The I – H curve for a ferromagnetic material is as shown in the figure. In this figure



(A) OC is a measure of the retentivity.

(B) OB is a measure of coercivity.

(C) Area enclosed by the curve ABCDEA represents the energy lost during one cycle of magnetisation.

(D) Area enclosed by the curve ABCDEA represents the work done in orientating the molecular dipoles along the direction of the external field.

Ans (C)

Each of the following questions consists of a Statement−I and a Statement−II. Examine both of them and select one of the options using the following codes:

(A) Statement-I and Statement-II are true and Statement-II is the correct explanation of Statement-I.

(B) Statement-I and Statement-II are true, but Statement-II is not the correct explanation of Statement -I

(C) Statement-I is true, but Statement -II is false

(D) Statement-I is false, but Statement -II is true

8. **Statement I:** Magnetic field lines always form closed loops.

Statement II: According to Gauss' law in magnetism $\oint_S \vec{B}\cdot\vec{dS}=0$

9. **Statement I:** The magnetic field produced by a solenoid is uniform at the centre of the solenoid along its axis.

Statement II: The magnetic field at the edge of a solenoid is half the field at its centre.

10. **Statement I:** When a magnet is cut into two equal parts with half the original breadth, its pole strength remains same but its and magnetic moment is halved.

Statement II: When a bar magnet is cut into two equal parts with half the original length its pole strength remains same but the magnetic moment is halved.

11. **Statement I:** The horizontal component of the earth's magnetic field is maximum at the equator and minimum at the poles.

Statement II: The vertical component of the earth's magnetic field is maximum at the equator and minimum at the poles

12. **Statement I:** The magnetic elements of earth's magnetic field vary from place to place and also from time to time.

Statement II: The magnetic elements of earth's magnetic field vary only from place to place but not from time to time.

13. **Statement I:** A super conductor is repelled by a magnet.

Statement II: A superconductor is a perfect diamagnet.

14. **Statement I:** All magnetic materials exhibit hysteresis

Statement II: Only ferromagnetic materials exhibit hysteresis.

15. **Statement I:** Iron is attracted by a magnet but stainless steel is not attracted by a magnet.

Statement II: Stainless steel is an alloy of iron, chromium, manganese, etc whose curie temperature is below room temperature.

NCERT LINE BY LINE QUESTIONS

1. The net magnetic flux through any closed surface is [NCERT Pg. 182]
(1) Always positive (2) Always negative
(3) May be positive or negative (4) Always zero

2. The vertical plane which passes through the imaginary line joining the magnetic north & the south poles is known as [NCERT Pg. 186)
(1) Geographical meridian (2) Magnetic meridian
(3) Magnetic declination (4) Magnetic dip

3. Which of the following quantities include in the element of earth's magnetic field? [NCERT Pg. 187]
(1) The declination (2) Angle of dip
(3) Horizontal component of earths magnetic field
(4) All of the above

4. The magnetic needle shown in the figure has magnetic moment $6.7 \times 10^{-2}\,A\,m^2$ and moment of inertia $7.5 \times 10^{-6}\,kg\,m^2$. It performs 10 complete oscillations in 6-70 s. The magnitude of magnetic field is [NCERT Pg. 178]
(1) 0.02 T (2) 0.01 T (3) 0.03 T (4) 0.05 T

5. A short bar magnet placed with its axis at 53° with an external field of 600 G experiences a torque of 0.024 N m. Magnetic moment of the magnet is [NCERT Pg. 179]
(1) $0.4Am^2$ (2) $0.8Am^2$ (3) $0.6Am^2$ (4) $0.5Am^2$

6. A magnetic needle is placed in an external magnetic field at an angle Owith the field. Needle is in most stable position if the value of is [NCERT Pg 178]
(1) 180° (2) 90° (3) 0° (4) 60°

7. In the magnetic meridian of a certain place, the horizontal component of earth's magnetic field is 0.48 G and the dip angle is 53°. Magnetic field of the earth at this location is [NCERT Pg. 188]
(1) 0.3G (2) 0.8 G (3) 0.64 G (4) 0.96 G

8. Which of the following is a correct relation? [NCERT Pg. 190]
(1) $\mu_r = \chi\mu$ (2) $\mu_r = 1 + \chi$ (3) $\mu_r = 1 - \chi$ (4) $\mu_r = \frac{1}{\chi}$

9. A solenoid has a core of a magnetic material with relative permeability 500. Number of turns in the solenoid are 1000 per metre and carry a currents of 5 A. Magnetic intensity H will be. [NCERT Pg. 191]
(1) 5×10^3 A/m (2) 2.5×10^6 A/m
(3) 10^5 A/m (4) 250 A/m

10. Which of the following is not a diamagnetic material? [NCERT Pg. 192]
(1) Bismuth (2) Copper (3) Nitrogen (STP) (4) Sodium

11. According to Curie's law for paramagnetic material [NCERT Pg. 193]
(1) $\mu_0 = \frac{C\chi}{T}$ (2) $\chi = C\mu_0 T$ (3) $\chi = \frac{C\mu_0}{T}$ (4) $\mu_0\chi = CT$

12. The temperature of transition from ferromagnetic to paramagnetic is called the [NCERT Pg. 194]
(1) Transition temperature (2) Inversion temperature

(3) Curie temperature (4) Neutral temperature

13. Suitable materials for permanent magnets, should have [NCERT Pg. 196]
(1) High retentivity and low coercivity
(2) Low retentivity and high coercivity
(3) High retentivity and high coercivity
(4) Low retentivity and low coercivity

14. Curie temperature for cobalt is NCERT Pg. 194]
(1) 1394 °C (2) 1394 K (3) 1043 °C (4) 1043 K

15. At a certain place a freely suspended magnetic needle makes 20 oscillations per minute. At another place where the magnetic field is 4 times, time period of same needle will be [NCERT Pg. 178]
(1) 10 s (2) 1 s (3) 1.5 s (4) 3 s

16. Correct dimensional formula for the permeability of free space is [NCERT Pg. 198]
(1) $[MLT^{-2}A^{-2}]$ (2) $[ML^{-1}T^{-2}A^{3}]$ (3) $[M^{-1}L^{2}T^{-2}A]$ (4) $[ML^{3}T^{-3}A^{2}]$

17. Which of the following relation is correct? (symbols have their usual meaning) [NCERT Pg. 190]
(1) $B=\mu_0(1+\chi)H$ (2) $B=\mu_0\mu_r H$ (3) $B=\mu_0(H-M)$ (4) Both (1) and (2)

18. The phenomenon of perfect diamagnetism in superconductors is called [NCERT Pg. 192]
(1) Dynamo effect (2) Meissner effect
(3) Stark effect (4) Zeeman effect

19. A closely wound solenoid of 3000 turns and area of cross- section 1.610^{-4} m², carrying a current of 5.0 A, is suspended through its centre. Magnetic moment associated with the sclenoid is [NCERT Pg. 201]
(1) 12.8 Am^2 (2) 5.6 A m^2
(3) 4.8Am^2 (4) 2.4 Am^2

20. Electromagnets are used in [NCERT Pg. 196)
(1) Electric bells (2) Cranes to lift machinery
(3) Loudspeaker (4) All of the above

NCERT BASED PRACTICE QUESTIONS

1. Unit of magnetic flux density is :-
(1) Tesla (2) Wb/m²
(3) NA^{-1} m^{-1} (4) All of the above

2. If a magnet of pole strength m is cut into four parts such that length and width of each part is half that of initial one, then pole strength of each part :-
(1) m/4 (2) m (3) m/8 (4) m/2

3. Magnetic field at a distance d from a short bar magnet in tan A and tan B position are in ratio:-
(1) 2 : 1 (exact) (2) 2 : 1 (approx)
(3) 1 : 2 (exact) (4) 1 : 2 (approx)

4. A magnet of magnetic moment M is situated having its axis along magnetic field B, the work done in rotating the magnet by 180° will be:-
(1) –MB (2) +MB (3) zero (4) +2MB

5. Material suitable for making electromagnet should have :-
(1) High retentivity and High coercivity
(2) Low retentivity and Low coercivity

(3) High retentivity and Low coercivity
(4) Low retentivity and High coercivity

6. A dip circle is at right angle to magnetic meridian, then apparent dip :-
(1) 0^o (2) 30^o (3) 60^o (4) 90^o

7. A line passing through places having zero dip angle is called :-
(1) Isoclinic lines (2) Aclinic lines
(3) Isogonic lines (4) Agonic lines

8. Universal property of all substance is :-
(1) Diamagnetism (2) Paramagnetism
(3) Ferromagnetism (4) All of above

9. Unit of magnetic susceptibility is :-
(1) Henry (2) Wb/m (3) Amp/m (4) None of these

10. Magnetic field is measured by :-
(1) Pyrometer (2) Hydrometer
(3) Thermometer (4) Fluxmeter

11. The magnetic moment produced in a substance of 1 gm is 6×10^{-7} A×m². If its density is 5gm/cm³, then the intensity of magnetisation in A/m will be:-
(1) 8.3×10^6 (2) 3.0 (3) 1.2×10^{-7} (4) 3×10^{-6}

12. Relative permeability of iron is 5500, then its magnetic susceptibility is :-
(1) 5500 (2) 5501 (3) 5499 (4) zero

13. Superconducting material is :-
(1) Diamagnetic (2)Perfect diamagnetic
(3) Paramagnetic (4) Ferromagnetic

14. If current is doubled, the deflection is also doubled in :-
(1) Tangent galvanometer (2) Moving coil galvanometer
(3) both (1) and (2) (4) None of above

15. For paramagnetic materials :-
(1) c is positive at all temperature (2) c is negative at all temperature
(3) c may be positive or negative (4) c does not depend on temperature

16. Magnetic field lines represent the direction :-
(1) Along which a small magnetised needle aligns
(2) Along which moving charge particle experiences a force
(3) Both (1) and (2)
(4) None of (1) and (2)

17. Which effect is responsible for earth magnetic field :-
(1) Dynamo effect (2) Photo electric effect
(3) Compton effect (4) Solar effect

18. When a dip magnetic needle is suspended in the earth's magnetic field :-
(1) In northern hemisphere, the north pole of dip tilts downwards. At southern hemisphere south pole of dip tilts downwards
(2) In northern hemisphere, the south pole of dip tilts downwards. At southern hemisphere north pole of dip tilts downwards
(3) In both (northern and southern hemisphere), north pole of dip tilts downwards.
(4) In both northern, hemisphere and southern hemisphere, south-pole of dip tilts downwards

19. The positions on earth where angle of declination is greater, at :-
(1) Higher latitudes
(2) Near the equator
(3) Lower latitudes
(4) Same at all position of the earth

20. The position on the earth where angle of declination is smaller, at :-
(1) Higher latitudes
(2) Near the equator
(3) Away from equator
(4) Same at all positions of earth

21. In Delhi and Mumbai magnetic needle shows the true north quite accurately because :-
(1) In Delhi and Mumbai angle of dip is small
(2) In Delhi and Mumbai angle of dip is large
(3) In Delhi and Mumbai angle of declination is small
(4) In Delhi and Mumbai angle of declination is large

22. When a superconductor is placed near a bar magnet then :-
(1) It repels the magnet
(2) It attracts the magnet
(3) Neither repels nor attracted
(4) Some time repels and some time attracts

23. Dia-magnetic property of material can be explained by :-
(1) Lenz's law
(2) Faraday law
(3) Ampere's law
(4) Gauss's law

24. A ferromagnetic material is placed in an external magnetic field. The magnetic domains:
(1) increase in size
(2) decrease in size
(3) may increase or decrease in size
(4) have no relation with the field

25. If magnetic monopoles existed, how would the Gauss's law of magnetism be modified ? (Here q_m is the monopole magnetic charge enclosed by surface S)
(1) $\oint \vec{B}.d\vec{S} = \frac{q_m}{\mu_0}$
(2) $\oint \vec{B}.d\vec{S} = q_m$
(3) $\oint \vec{B}.d\vec{S} = \mu_0 q_m$
(4) $\oint \vec{B}.d\vec{S} = \mu_0 q_m^2$

26. Which of the following statements are correct?
(A) Magnetic field lines can be entirely confined (within the core) of a toroid
(B) Magnetic field lines can be entirely confined within the core of a solenoid
(C) a bar magnet exert a torque on itself due to its own field.
(D) a system can have magnetic moment even though its net charge is zero.
(1) A, B, D
(2) only A, D
(3) A, C
(4) A, B, C, D

27. Which planets have maximum & minimum magnetic fields respectively :-
(1) Jupiter & Venus
(2) Mercury & Mars
(3) Jupiter & Mars
(4) Venus & Mercury

28. A solenoid has core of material with relative permeability 400. The winding of the solenoid are insulated from the core and carry a current of 2A. It has 1000 turns/meter. Then magnetising current will be :-
(1) 798 A
(2) 1000 A
(3) 500 A
(4) 1494 A

29. The earth's magnetic field at the equator is approximately 0.4 G. Then the earth's dipole moment will be :-
(1) 1.05×10^{23} A-m^2
(2) 5.05×10^{23} A-m^2
(3) 9.5×10^{23} A-m^2
(4) 1.05×10^{21} A-m^2

30. If external magnetic intensity on a paramagnetic material is made 4 times and the absolute temperature is made 3 times then how many times will be the self magnetisation ?

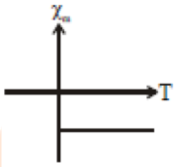
(1) 4 times (2) $\frac{1}{3}$ times (3) $\frac{4}{3}$ times (4) $\frac{3}{4}$ times

31. The angle of declination is :-

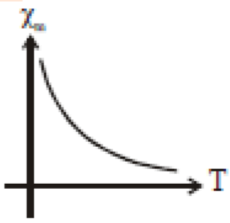
(1) The angle of earth magnetic field with horizontal
(2) The angle of earth magnetic field with vertical
(3) The angle between the geographic axis and magnetic axis of the earth
(4) The angle between the geographic meridian and the magnetic meridian

32. Match the column I, in which magnetic susceptibility (χ_m) and temperature (T) curve is given, to the suitable magnetic material of the column-II choose the correct option from the codes given below:

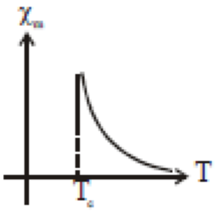
Column - I **Column - II**

(A) 

(p) Ferromagnetic material

(B) 

(q) diamagnetic material

(C) 

(r) Paramagnetic material

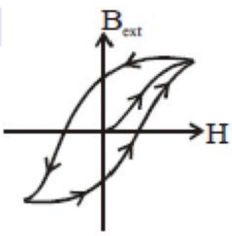
Code

	A B C	**A B C**	**A B C**	**A B C**
	(1) p q r	(2) r q p	(3) q p r	(4) q r p

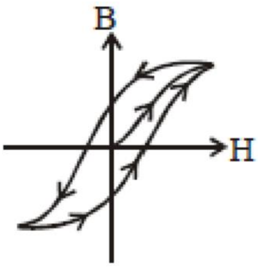
33. For the given uses select the correct magnetic material :-

Column-I **Column-II**

(p) Electro magnet

(A) 

(q) Transformer

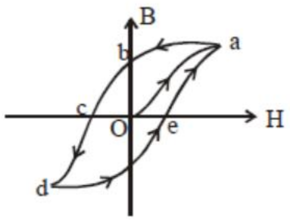
(B) 

(r) Permanent magnet used in generator

Codes :

p q r	**p q r**	**p q r**	**p q r**
(1) A B B	(2) B B A	(3) B A B	(4) A A D

34. Figure shows the magnetic hysteresis loop that is the B-H curve for ferromagnetic materials. Select the correct statement :-



(1) The value of B at H = 0 is called coercivity
(2) An electromagnet has low remanence and low coercivity
(3) The value of H at C is called remanence.
(4) A permanent magnet has low remanence and low coercivity

35. When will the field lines be completely expelled (χ = magnetic susceptibility)

(1) $\chi = -1$ and $\mu_r = 0$ (2) $-1 \le \chi$ and $\mu_r >> 0$

(3) $\chi \le 1$ and $\mu_r << 1$ (4) $\chi \le 1$ and $\mu_r << 0$

36. Select the incorrect statement :-

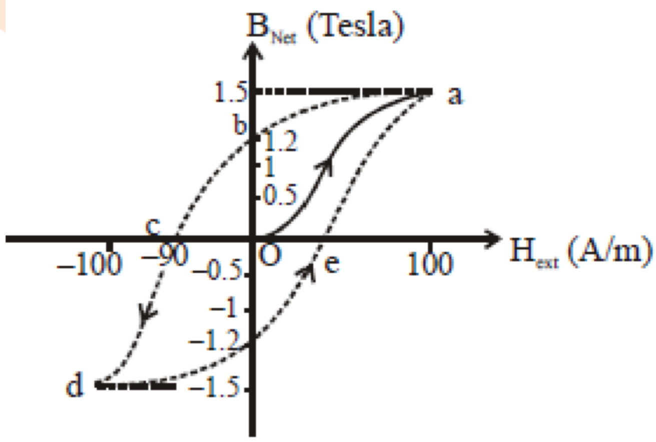
(1) When a bar magnet of dipole moment $\vec{M}$ is placed in a uniform magnetic field $\vec{B}$ the torque on it is $\vec{M} \times \vec{B}$

(2) Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero

(3) For diamagnetic materials magnetic susceptibility $\chi = +10^{-5}$ whereas paramagnetic materials $\chi = -10^{-5}$

(4) Magnetisation of a paramagnetic material is inversely proportional to the absolute temperature T.

37. The hysteresis curve for a material is shown in figure. Then for the material retentivity coercivity and saturation magnetic field will be respectively:-



(1) 90 A/m, 1.2 T, 1.5 T
(2) 1.5T, 90 A/m, 1.2 T
(3) 1.2T, 90 A/m, 1.5 T
(4) 90 A/m, 1.5 T, 1.2 T

38. The magnetic material having very large positive magnetic susceptibility is :-

(1) Ferromagnetic
(2) Diamagnetic
(3) Paramagnetic
(4) Both Ferromagnetic and Paramagnetic have large positive magnetic susceptibility

39. A long solenoid has 1000 turns per meter and carries a current of 1A. It has a soft iron core of μ_r = 1000. The core is heated beyond the critical temperature, Tc.

(1) The H field in the solenoid is decreases drastically but the 'B' field is (nearly) unchanged
(2) The H and B fields in the solenoid are nearly unchanged.
(3) The magnetisation in the core reverse direction
(4) The magnetisation in the core diminishes by a factor of about 108

40. The line on the earth's surface joing the points where the field is horizontal is called :-

(1) magnetic meridian
(2) magnetic axis
(3) magnetic line
(4) magnetic equator

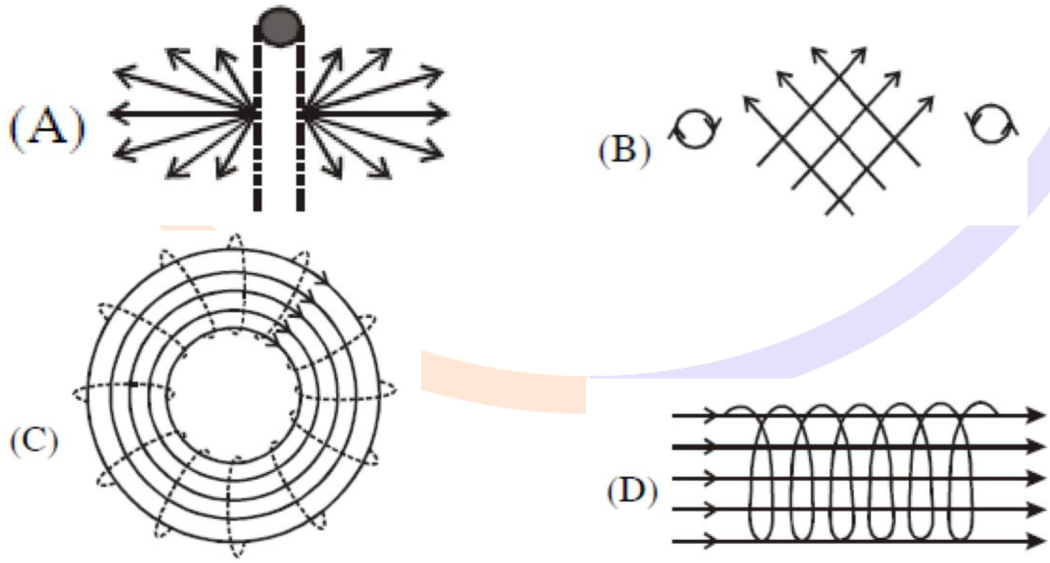
41. The magnetic field is now thought to arise due to electrical currents produced by convective motion of metallic fluid. (consisting mostly of molten iron and nickel) in the outer core of the earth. This is known as the

(1) dynamo effect
(2) tidal effect
(3) both (1) and (2)
(4) None of these

42. Nickel shows ferromagnetic property at room temperature. If the temperature is increased beyond Curie temperature, then it will show :-

(1) paramagnetism
(2) ferromagnetism
(3) no magnetic property
(4) diamagnetism

43. Many of the diagrams given in figure, show magnetic field lines (thick lines in the figure). Point out which one is/are correct :-



(1) both A and D
(2) both B and D
(3) both C and D
(4) only C

44. New Zealand is situated in southern hemisphere and Russia is situated in Northern hemisphere. The angle of dip at New Zealand and Russia are and respectively, then

(1) $\delta_1 = +(\text{up}), \delta_2 = +(\text{up})$
(2) $\delta_1 = -(\text{down}), \delta_2 = +(\text{up})$
(3) $\delta_1 = -(\text{up}), \delta_2 = +(\text{down})$
(4) $\delta_1 = -(\text{down}), \delta_2 = -(\text{down})$

TOPIC WISE PRACTICE QUESTIONS

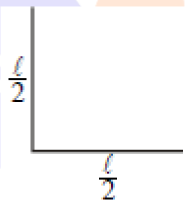
Topic 1: Magnetism, Gauss's Law, Magnetic Moment and Properties of Magnet

1. If a bar magnet of pole strength m and magnetic moment M is cut perpendicular to its axis in two equal halves then its new pole strength m¢ and magnetic moment M' are respectively

(a) $m' = m$ and $M' = M$ (b) $m' = m$ and $M' = \frac{M}{2}$

(c) $m' = \frac{m}{2}$ and $M' = 2M$ (d) $m' = 2m$ and $M' = \frac{M}{2}$

2. A steel wire of length ℓ has a magnetic moment M. It is bent in L-shape (Figure). The new magnetic moment is



(a) M (b) $\frac{M}{\sqrt{2}}$ (c) $\frac{M}{2}$ (d) 2M

3. The major contribution of magnetism in substances is due to
(a) orbital motion of electrons
(b) spin motion of electrons
(c) equally due to orbital and spin motions of electrons
(d) hidden magnets

4. Magnetic dipole moment is a vector quantity directed from
(a) south pole to north pole (b) north pole to south pole
(c) east to west (d) west to east

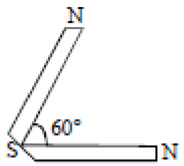
5. The magnetic potential at a point distant 10 cm, from the middle point of a magnetic dipole on a line inclined at an angle of 60° with the axis is 3 CGS emu. Then, the magnetic dipole moment of the magnet is:
(a) 300 ab – amp × cm^2 (b) 600 ab – amp × cm^2
(c) 30 ab – amp × cm^2 (d) 60 ab – amp × cm^2

6. If the distance between two magnetic poles is doubled and their pole strength is doubled, then force between them will be
(a) remain unchanged (b) become twice (c) become 8 times (d) become 4 time

7. Magnetic lines of force due to a bar magnet do not intersect because
(a) a point always has a single net magnetic field
(b) the lines have similar charges and so repel each other
(c) the lines always diverge from a single force
(d) None of these

8. A short bar magnet, placed with its axis at 30° with an external magnetic field of 0.16 T, experiences a torque of magnitude 0.032 J. The magnetic moment of the bar magnet is (in units of J/T)
(a) 4 (b) 0.2 (c) 0.5 (d) 0.4

9. The net magnetic moment of two identical magnets each of magnetic moment M_0, inclined at 60° with each other is



(a) M_0 (b) $\sqrt{2}\, M_0$ (c) $\sqrt{3}\, M_0$ (d) $2M_0$

10. A bar magnet having centre O has a length of 4 cm. Point P_1 is in the broad side-on and P_2 is in the end side-on position with $OP_1 = OP_2 = 10$ metres. The ratio of magnetic intensities H at P_1 and P_2 is

(a) $H_1 : H_2 = 16 : 100$ (b) $H_1 : H_2 = 1 : 2$ (c) $H_1 : H_2 = 2 : 1$ (d) $H_1 : H_2 = 100 : 16$

11. A bar magnet of magnetic moment M and length L is cut into two equal parts each of length L/3. The magnetic moment of each part will be

(a) M (b) M/4 (c) $\sqrt{2}$ M (d) M/3

12. Two identical magnetic dipoles of magnetic moments 1.0 A-m^2 each, placed at a separation of 2 m with their axis perpendicular to each other. The resultant magnetic field at point midway between the dipole is

(a) 5×10^{-7} T (b) $\sqrt{5} \times 10^{-7}$ T (c) 10^{-7} T (d) 2×10^{-7} T

13. The force between two short bar magnets with magnetic moments M_1 and M_2 whose centres are r metres apart is 8 N when their axes are in same line. If the separation is increased to 2r, the force between them is reduced to

(a) 4 N (b) 2 N (c) 1 N (d) 0.5 N

14. A bar magnet having a magnetic moment of 2×10^4 JT^{-1} is free to rotate in a horizontal plane. A horizontal magnetic field $B = 6 \times 10^{-4}$ T exists in the space. The work done in taking the magnet slowly from a direction parallel to the field to a direction 60° from the field is

(a) 12 J (b) 6 J (c) 2 J (d) 0.6 J

15. A bar magnet is cut into two equal halves by a plane parallel to the magnetic axis. Of the following physical quantities the one which remains unchanged is

(a) pole strength (b) magnetic moment

(c) intensity of magnetisatio (d) moment of inertia

16. A thin bar magnet of length 2 ℓ and breadth 2 b pole strength m and magnetic moment M is divided into four equal parts with length and breadth of each part being half of original magnet. Then the pole strength of each part is

(a) m (b) m/2 (c) 2 m (d) m/4

17. Two points A and B are situated at a distance x and 2x respectively from the nearer pole of a magnet 2 cm long. The ratio of magnetic field at A and B is

(a) 4 : 1 exactly (b) 4 : 1 approximately

(c) 8 : 1 approximately (d) 1 : 1 approximately

18. A bar magnet has a length 8 cm. The magnetic field at a point at a distance 3 cm from the centre in the broad side-on position is found to be $4{\times}10^{-6}T$. The pole strength of the magnet is

(a) 6×10^{-5} Am (b) 5×10^{-5} Am (c) 2×10^{-4} Am (d) 3×10^{-4} Am

19. The magnetic moment of a magnet is 0.1 amp × m^2. It is suspended in a magnetic field of intensity 3×10^{-4} weber/m^2. The couple acting upon it when deflected by 30° from the magnetic field is

(a) 1×10^{-5} N m (b) 1.5×10^{-5} N m (c) 2×10^{-5} N m (d) 2.5×10^{-5} N m

20. A steel wire of length ℓ has a magnetic moment M. It is then bent into a semi-circular arc. The new magnetic moment is

(a) $\frac{M}{\pi}$ (b) $\frac{2M}{\pi}$ (c) $\frac{3M}{\pi}$ (d) $\frac{4M}{\pi}$

21. Let r be the distance of a point on the axis of a bar magnet from its centre. The magnetic field at such a point is proportional to

(a) $\frac{1}{r}$ (b) (c) $\frac{1}{r^2}$ (d) None of these

22. The magnetic dipole moment of a coil is 5.4×10^{-6} joule/ tesla and it is lined up with an external magnetic field whose strength is 0.80 T. Then the work done in rotating the coil (for q = 180º) is

(a) 4.32 μJ (b) 2.16 μJ (c) 8.6 μJ (d) None of these

Topic 2: Earth's Magnetism

23. A bar magnet is oscillating in the earth's magnetic field with a period T. What happens to its period of motion, if its mass is quadrupled?

(a) Motion remains simple harmonic with new period = T/2

(b) Motion remains simple harmonic with new period = 2 T

(c) Motion remains simple harmonic with new period = 4T

(d) Motion remains simple harmonic and the period stays nearly constant

24. At the magnetic north pole of the earth, the value of the horizontal component of earth's magnetic field and angle of dip are respectively

(a) zero, maximum (b) maximum, minimum

(c) maximum, maximum (d) minimum, minimum

25. The horizontal component of the earth's magnetic field is 3.6×10^{-5} tesla where the dip angle is 60°. The magnitude of the earth's magnetic field is

(a) 2.8×10^{-4} tesla (b) 2.1×10^{-4} tesla (c) 7.2×10^{-5} tesla (d) 3.6×10^{-5} tesla

26. Work done in turning a magnet of magnetic moment M by an angle 90º from the magnetic meridian is n times the corresponding work done to turn through an angle of 60º, where n is

(a) 1/2 (b) 2 (c) 1/4 (d) 1

27. A short magnet of length 4 cm is kept at a distance of 20 cm to the east of a compass box such that is axis is perpendicular to the magnetic meridian. If the deflection produced is 45°, find the pole strength (H = 30 Am^{-1})

(a) 17.7 Am (b) 44.2 Am (c) 27.7 Am (d) 37.7 Am

28. A current carrying coil is placed with its axis perpendicular to *N-S* direction. Let horizontal component of earth's magnetic field be H_0 and magnetic field inside the loop be H. If a magnet is suspended inside the loop, it makes angle q with H. Then θ =

(a) $\tan^{-1}\left(\frac{H_0}{H}\right)$ (b) $\tan^{-1}\left(\frac{H}{H_0}\right)$ (c) $\operatorname{cosec}^{-1}\left(\frac{H}{H_0}\right)$ (d) $\cot^{-1}\left(\frac{H_0}{H}\right)$

29. A compass needle whose magnetic moment is 60 Am^2, is directed towards geographical north at any place experiencing moment of force of 1.2×10^{-3} Nm. At that place the horizontal component of earth field is 40 micro W/m^2. What is the value of dip angle at that place?

(a) 30° (b) 60° (c) 45° (d) 15°

30. At a certain place, horizontal component is $\sqrt{3}$ times the vertical component. The angle of dip at this place is

(a) 0 (b) $\pi/3$ (c) $\pi/6$ (d) $\pi/8$

31. At a certain place, the angle of dip is 30º and the horizontal component of earth's magnetic field is 0.50 oerested. The earth's total magnetic field (in oerested) is

(a) $\sqrt{3}$ (b) 1 (c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{2}$

32. Which of the following is responsible for the earth's magnetic field?

(a) Convective currents in earth's core. (b) Diversive current in earth's core.

(c) Rotational motion of earth. (d) Translational motion of earth.

33. Horizontal component of earth's field at a height of 1 m from the surface of earth is H. Its value at a height of 10 m from surface of earth is
(a) H/10 (b) H/9 (c) H/100 (d) H

34. The earth's magnetic field lines resemble that of a dipole at the centre of the earth. If the magnetic moment of this dipole is close to 8×10^{22} Am^2, the value of earth's magnetic field near the equator is close to (radius of the earth = 6.4×10^6 m)
(a) 0.6 Gauss (b) 1.2 Gauss (c) 1.8 Gauss (d) 0.32 Gauss

35. A short bar magnet with its north pole facing north forms a neutral point at P in the horizontal plane. If the magnet is rotated by 90° in the horizontal plane, the net magnetic induction at P is (Horizontal component of earth's magnetic field = B_H)
(a) 0 (b) 2 B_H (c) $\frac{\sqrt{5}}{2} B_H$ (d) $\sqrt{5}\, B_H$

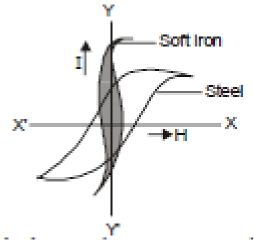
Topic 3: Magnetic Materials and It's Properties

36. The materials suitable for making electromagnets should have
(a) high retentivity and low coercivity (b) low retentivity and low coercivity
(c) high retentivity and high coercivity (d) low retentivity and high coercivity

37. The meniscus of a liquid contained in one of the limbs of a narrow U-tube is held in an electromagnet with the meniscus in line with the field. The liquid is seen to rise. This indicates that the liquid is
(a) ferromagnetic (b) paramagnetic (c) diamagnetic (d) non-magnetic

38. If a diamagnetic solution is poured into a U-tube and one arm of this U-tube is placed between the poles of a strong magnet, with the meniscus in line with the field, then the level of solution will
(a) rise (b) fall (c) oscillate slowly (d) remain as such

39. The mass of a specimen of a ferromagnetic material is 0.6 kg. and its density is 7.8×10^3 kg/m^3. If the area of hysteresis loop of alternating magnetising field of frequency 50Hz is 0.722 MKS units then the hysteresis loss per second will be



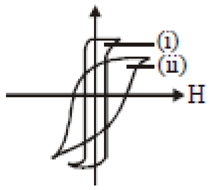
(a) 277.7×10^{-5} joule (b) 277.7×10^{-6} joule
(c) 277.7×10^{-4} joule (d) 27.77×10^{-4} joule

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

41. If μ_0 is absolute permeability of vacuum and μ_r is relative magnetic permeability of another medium, then permeability m of the medium is
(a) $\mu_0\mu_r$ (b) μ_0 / μ_r (c) μ_r / μ_0 (d) $1/\mu_0\mu_r$

42. The ferromagnetic core of electromagnets should have
(a) a broad hysteresis loop
(b) high permeability and high retentivity
(c) low permeability and low retentivity
(d) high permeability and low retentivity

43. The B – H curve (i) and (ii) shown in fig associated with

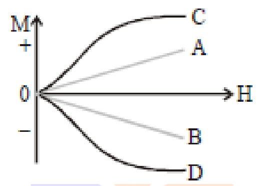


(a) (i) diamagnetic and
(ii) paramagnetic substance
(b) (i) paramagnetic and
(ii) ferromagnetic substance
(c) (i) soft iron and (ii) steel
(d) (i) steel and (ii) soft iron

44. The relative permeability of iron is 6000. Its magnetic susceptibility is
(a) 5999 (b) 6001 (c) 6000×10^{-7} (d) 6000×10^{7}

45. Demagnetisation of magnets can be done by
(a) rough handling (b) heating
(c) magnetising in the opposite direction (d) All the above

46. The most appropriate magnetization M versus magnetising field H curve for a paramagnetic substance is



(a) A (b) B (c) C (d) D

47. When a piece of a ferromagnetic substance is put in a uniform magnetic field, the flux density inside it is four times the flux density away from the piece. The magnetic permeability of the material is
(a) 1 (b) 2 (c) 3 (d) 4

48. The permanent magnet is made from which one of the following substances?
(a) Diamagnetic (b) Paramagnetic (c) Ferromagnetic (d) Electromagnetic

49. Which of the following is not correct about relative magnetic permeability (μ_r)?
(a) It is a dimensionless pure ratio. (b) For vacuum medium its value is one.
(c) For ferromagnetic materials $\mu_r >> 1$ (d) For paramagnetic materials $\mu_r > 1$.

50. Nickel shows ferromagnetic property at room temperature. If the temperature is increased beyond Curie temperature, then it will show
(a) anti ferromagnetism (b) no magnetic property
(c) diamagnetism (d) paramagnetism

51. The narrowest hysteresis loop is for
(a) cobalt steel (b) alnico (c) stainless steel (d) perm alloy

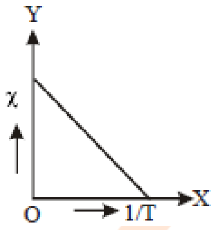
52. A paramagnetic substance is placed in a weak magnetic field and its absolute temperature T is increased. As a result, its magnetisation
(a) increases in proportion to T (b) decreases in proportion to1/T
(c) increases in proportion to T^2 (d) decreases in proportion to $1/T^2$

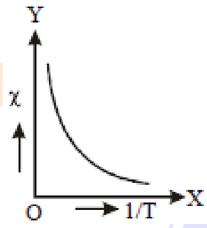
53. When a ferromagnetic material is heated to temperature above its Curie temperature, the material
(a) is permanently magnetized (b) remains ferromagnetic
(c) behaves like a diamagnetic material (d) behaves like a paramagnetic material

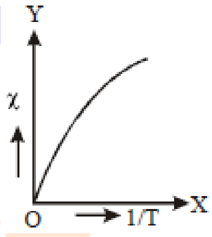
54. The moment of a magnet (15 cm × 2 cm × 1 cm) is 1.2 A-m^2. What is its intensity of magnetisation?
(a) 4×10^4 A m^{-1} (b) 2×10^4 A m^{-1} (c) 10^4 A m^{-1} (d) None of these

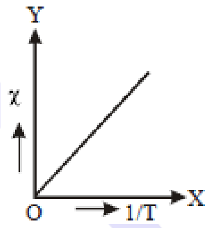
55. Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet when brought close to them will
(a) attract N_1 and N_2 strongly but repel N_3
(b) attract N_1 strongly, N_2 weakly and repel N_3 weakly
(c) attract N_1 strongly, but repel N_2 and N_3 weakly
(d) attract all three of them

56. The graph between c and 1/T for paramagnetic material will be represented by

(a) 

(b) 

(c) 

(d) 

57. Relative permittivity and permeability of a material ε_r and μ_r, respectively. Which of the following values of these quantities are allowed for a diamagnetic material?
(a) $\varepsilon_r = 0.5,\ \mu_r = 1.5$ (b) $\varepsilon_r = 1.5,\ \mu_r = 0.5$ (c) $\varepsilon_r = 0.5,\ \mu_r = 0.5$ (d) $\varepsilon_r = 1.5,\ \mu_r = 1.5$

Topic 4: Magnetic Equipment's

58. Two magnets of magnetic moments M and 2M are placed in a vibration magnetometer, with the identical poles in the same direction. The time period of vibration is T_1. If the magnets are placed with opposite poles together and vibrate with time period T_2, then
(a) T_2 is infinite (b) $T_2 = T_1$ (c) $T_2 > T_1$ (d) $T_2 < T_1$

59. If the period of oscillation of freely suspended bar magnet in earth's horizontal field H is 4 sec. When another magnet is brought near it, the period of oscillation is reduced to 2s. The magnetic field of second bar magnet is
(a) 4 H (b) 3 H (c) 2 H (d) $\sqrt{3}$ H

60. A bar magnet of moment of inertia 9×10^{-5} kg m^2 placed in a vibration magnetometer and oscillating in a uniform magnetic field $16\pi^2 \times 10^{-5}$T makes 20 oscillations in 15 s. The magnetic moment of the bar magnet is
(a) 3 Am^2 (b) 2 Am^2 (c) 5 Am^2 (d) 4 Am^2

61. To measure the magnetic moment of a bar magnet, one may use
(a) a deflection galvanometer if the earth's horizontal field is known
(b) an oscillation magnetometer if the earth's horizontal field is known
(c) both deflection and oscillation magnetometer if the earth's horizontal field is not known.
(d) all of the above

62. A thin rectangular magnet suspended freely has a period of oscillation of 4 s. If it is broken into two halves (each having half the original length) and one of the pieces is suspended similarly. The period of its oscillation will be
(a) 4 s (b) 2 s (c) 0.5 s (d) 0.25 s

63. A compass needle placed at a distance r from a short magnet in Tan A position shows a deflection of 60°. If the distance is increased to r $(3)^{1/3}$, then deflection of compass needle is
(a) 30^0 (b) 50^0 (c) 60^0 (d) 80^0

64. Two tangent galvanometers having coils of the same radius are connected in series. A current flowing in them produces deflections of 60° and 45° respectively. The ratio of the number of turns in the coils is
(a) 4/3 (b) $\frac{\sqrt{3}+1}{1}$ (c) $\frac{\sqrt{3}+1}{\sqrt{3}-1}$ (d) $\frac{\sqrt{3}}{1}$

65. In a vibration magnetometer, the time period of a bar magnet oscillating in horizontal component of earth's magnetic field is 2 sec. When a magnet is brought near and parallel to it, the time period reduces to 1 sec. The ratio H/F of the horizontal component H and the field F due to magnet will be

(a) 3 (b) 1/3 (c) $\sqrt{3}$ (d) $1/\sqrt{3}$

66. If the current is doubled, the deflection is also doubled in

(a) a tangent galvanometer (b) a moving-coil galvanometer
(c) both (d) None of these

67. Two tangent galvanometers A and B have coils of radii 8 cm and 16 cm respectively and resistance $8\,\Omega$ each. They are connected in parallel with a cell of emf 4 V and negligible internal resistance. The deflections produced in the tangent galvanometers A and B are 30° and 60° respectively. If A has 2 truns, then B must have

(a) 18 turns (b) 12 turns (c) 6 turns (d) 2 turns

68. The magnetic needle of a tangent galvanometer is deflected at an angle 30° due to a magnet. The horizontal component of earth's magnetic field $0.34 \times 10^{-4}\ T$ is along the plane of the coil. The magnetic intensity is

(a) $1.96 \times 10^{-4} T$ (b) $1.96 \times 10^{-5} T$ (c) $1.96 \times 10^{4} T$ (d) $1.96 \times 10^{5} T$

69. In end on and broadside on position of a deflection magnetometer, if θ_1 and θ_2 are the deflections produced by short magnets at equal distances, then $\tan\theta_1 / \tan\theta_2$ is

(a) 2 : 1 (b) 1 : 2 (c) 1 : 1 (d) None of these

70. The period of oscillation of a magnet in a vibration magnetometer is 2 sec. The period of oscillation of a magnet whose magnetic moment is four times that of the first magnet is

(a) 1 sec (b) 5 sec (c) 8 sec (d) 0.5 sec

NEET PREVIOUS YEARS QUESTIONS

1. A thin diamagnetic rod is placed vertically between the poles of an electromagnet. When the current in the electromagnet is switched on, then the diamagnetic rod is pushed up, out of the horizontal magnetic field. Hence the rod gains gravitational potential energy. The work required to do this comes from **[2018]**

(a) the current source (b) the magnetic field
(c) the induced electric field due to the changing magnetic field
(d) the lattice structure of the material of the rod

2. A magnetic needle of magnetic moment 6.7×10^{-2} Am^2 and moment of inertia 7.5×10^{-6} kg m^2 is performing simple harmonic oscillations in a magnetic field of 0.01 T. Time taken for 10 complete oscillations is : **[2017]**

(a) 6.98 s (b) 8.76 s (c) 6.65 s (d) 8. 89 s

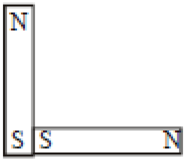
3. If θ_1 and θ_2 be the apparent angles of dip observed in two vertical planes at right angles to each other, then the true angle of dip q is given by : **[2017]**

(a) $\tan^2\theta = \tan^2\theta_1 + \tan^2\theta_2$ (b) $\cot^2\theta = \cot^2\theta_1 - \cot^2\theta_2$
(c) $\tan^2\theta = \tan^2\theta_1 - \tan^2\theta_2$ (d) $\cot^2\theta = \cot^2\theta_1 + \cot^2\theta_2$

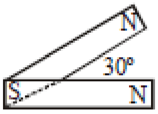
4. The magnetic susceptibility is negative for : **[2016]**

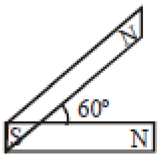
(a) diamagnetic material only
(b) paramagnetic material only
(c) ferromagnetic material only
(d) paramagnetic and ferromagnetic materials

5. Following figures show the arrangement of bar magnets in different configurations. Each magnet has magnetic dipole moment $\vec{m}$. Which configuration has highest net magnetic dipole moment? **[2014]**

A. 

B. 

C. 

D. 

(a) A (b) B (c) C (d) D

6. The relations amongst the three elements earth's magnetic field, namely horizontal component H, vertical component V and dip δ are, (B_E = total magnetic field) **[NEET – 2019 (ODISSA)]**

(1) $V = B_E \tan \delta$, $H = B_E$
(2) $V = B_E \sin \delta$, $H = B_E \cos \delta$
(3) $V = B_E \cos \delta$, $H = B_E \sin d$
(4) $V = B_E$, $H = B_E \tan \delta$

7. A wire of length L metre carrying a current of I ampere is bent in the form of a circle. Its magnetic moment is, **[NEET – 2020 (Covid-19)]**

(1) $I L^2/4$ A m^2 (2) $I \pi L^2/4$ A m^2 (3) $2 I L^2/\pi$ A m^2 (4) $I L^2/4\pi$ A m^2

8. An iron rod of susceptibility 599 is subjected to a magnetizing field of 1200 A m^{-1}. The permeability of the material of the rod is **[NEET – 2021]**

$\left(\mu_0 = 4\pi \times 10^{-7} Tm\ A^{-1}\right)$

1) $2.4\pi \times 10^{-7} T\ m\ A^{-1}$
2) $2.4\pi \times 10^{-4} T\ m\ A^{-1}$
3) $8.0\pi \times 10^{-5} T\ m\ A^{-1}$
4) $2.4\pi \times 10^{-5} T\ m\ A^{-1}$

9. A big circular coil of 1000 turns and average radius 10 m is rotating about its horizontal diameter at 2 rad s^{-1} If the vertical component of earth's magnetic field at that place is $2 \times 10^{-5} T$ and electrical resistance of the coil is $12.56\,\Omega$ then the maximum induced current in the coil will be : **[NEET – 2022]**

1) 0.25A 2) 1.5A 3) 1A 4) 2A

NCERT LINE BY LINE QUESTIONS – ANSWERS

1) 4	2) 2	3) 4	4) 2	5) 4	6) 3	7) 2	8) 2	9) 1	10) 4
11) 3	12) 3	13) 3	14) 2	15) 3	16) 1	17) 4	18) 2	19) 4	20) 4

NCERT BASED PRACTICE QUESTIONS-ANSWERS

1) 4	2) 4	3) 2	4) 4	5) 2	6) 4	7) 2	8) 1	9) 4	10) 4
11) 2	12) 3	13) 2	14) 2	15) 1	16) 1	17) 1	18) 1	19) 1	20) 2
21) 3	22) 1	23) 1	24) 3	25) 3	26) 2	27) 1	28) 1	29) 1	30) 3
31) 4	32) 4	33) 2	34) 2	35) 1	36) 3	37) 3	38) 1	39) 4	40) 4
41) 1	42) 1	43) 4	44) 3						

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	2	2)	2	3)	2	4)	1	5)	2	6)	1	7)	1	8)	4	9)	3	10)	2
11)	4	12)	2	13)	4	14)	2	15)	3	16)	2	17)	3	18)	1	19)	2	20)	2
21)	4	22)	3	23)	2	24)	1	25)	3	26)	2	27)	4	28)	1	29)	1	30)	3
31)	3	32)	1	33)	4	34)	1	35)	4	36)	2	37)	2	38)	2	39)	1	40)	2
41)	1	42)	4	43)	3	44)	1	45)	4	46)	1	47)	4	48)	3	49)	4	50)	4
51)	4	52)	2	53)	4	54)	1	55)	2	56)	4	57)	2	58)	3	59)	1	60)	4
61)	4	62)	2	63)	1	64)	4	65)	2	66)	2	67)	2	68)	2	69)	1	70)	1

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	1	2)	3	3)	4	4)	1	5)	3	6)	2	7)	4	8)	2	9)	3

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(b)** When a bar magnet cut perpendicular to its axis into two equal parts then m¢ = m and length $\ell^{|} = \frac{\ell}{2}$

2. **(b)** Magnetic moment, $M = m\ell$, where m is the pole strength.

   Therefore distance between poles $= \sqrt{(\ell/2)^2 + (\ell/2)^2} = \frac{\ell}{\sqrt{2}}$

   So, $M^{|} = \frac{m\ell}{\sqrt{2}} = \frac{M}{\sqrt{2}}$

3. (b) Spin of the electrons contributes to magnetism, whereas orbital motion of electrons contributes to diamagnetism only in external magnetic field

4. **(a)** Magnetic dipole moment is directed from south pole to north pole of magnetic dipole.

5. **(b)** $V = \frac{\mu_0}{4\pi}\frac{M\cos\theta}{r^2}$

   $V = \frac{m\cos\theta}{r^2}$ in C.G.S system; $M = \frac{Vr^2}{\cos\theta} = \frac{3\times100}{\cos 60} = 600\,\text{ab Acm}^2$

6. **(a)** remain unchanged

7. (a) Magnetic lines of force due to a bar magnet do not intersect because a point always has a single net magnetic field.

8. **(d)** Torque, $\tau = MB\sin\theta$

   $\Rightarrow M = \frac{\tau}{B\sin\theta} = \frac{0.032}{0.16\times\sin 30^0} = \frac{0.032\times2}{0.16\times1} = 0.4J/T$

9. **(c)** $M_{net} = \sqrt{M_0^2 + M_0^2 + 2M_0^2\cos 60^0}$

$= \sqrt{3M_0^2} = \sqrt{3}M_0$

10. **(b)** Magnetic intensity on end side -on position is twice than broad side on position.

11. **(d)** As magnetic moment = pole strength x length and length is halved without affecting pole strength, therefore, magnetic moment becomes half.

12. **(b)** As the axes are perpendicular, mid-point lies on axial line of one magnet and on equatorial line of other magnet.

$\therefore B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = \frac{10^{-7}\times 2\times 1}{1^3} = 2\times 10^{-7}$ and $B_2 = \frac{\mu_0}{4\pi}\frac{M}{d^3} = 10^{-7}$

$\therefore$ Resultant field $= \sqrt{B_1^2 + B_2^2} = \sqrt{5}\times 10^{-7}\,T$

13. **(d)** As $F \propto \frac{1}{r^4}$ and r becomes twice, therefore, F becomes

$\frac{1}{2^4} = \frac{1}{16}$ times $\quad \therefore \frac{1}{16}\times 8 = 0.5N$

14. **(b)** Work done

$= MB\,(\cos\theta_1 - \cos\theta_2) = MB\,(\cos 0° - \cos 60°)$

$= MB\left(1 - \frac{1}{2}\right) = \frac{2\times 10^4 \times 6\times 10^4}{2} = 6J$

15. **(c)** For each half M = m × 2 ℓ becomes half and volume
V = a × 2 ℓ also becomes half therefore, I = M/V, remains constant.

16. **(b)** As breadth of each part is half the original breadth, therefore, pole strength becomes half (i.e. m/2).

17. **(c)** Taking distances from the centre of the magnet,

$\frac{B_1}{B_2} = \left(\frac{x_2}{x_1}\right)^3 = \left(\frac{2x+1}{x+1}\right)^3 = 8:1$ approximately.

18. **(a)** Magnetic field due to a bar magnet in the broad-side on position is given by
After substituting the values and simplifying we get

$B = \frac{\mu_0}{4\pi} = \frac{M}{\left[r^2 + \frac{\ell^2}{4}\right]^{3/2}}$; $M = m\ell$

19. **(b)** $\tau = MB\sin\theta = 0.1\times 3\times 10^{-4}\sin 30^0$ or $\tau = 1.5\times 10^{-5}\,N-m$

20. (b) When wire is bent in the form of semi-circular arc then, $l=\pi r$
∴ The radius of semi-circular arc, $r=l/\pi$

Distance between two end points of semi-circular wire $=2r = \frac{2l}{\pi}$
∴ Magnetic moment of semi-circular wire

$= m\times 2r = m\times\frac{2l}{\pi} = \frac{2}{\pi}ml$

But ml is the magnetic moment of straight wire
i.e., ml=M

∴ New magnetic moment $= \frac{2}{\pi}M$

21. **(d)** $B = \left(\frac{\mu_0}{4\pi}\right)\frac{2M}{d^3}$

The formula is valid for $d \gg l$ where l is the length of the magnet and d is the distance from the center of the magnet.

If the above condition is not satisfied, B will not be proportional to any of, $\frac{1}{d^3}$ or $\frac{1}{d^2}$ or $\frac{1}{d}$

22. **(c)** The potential energy of a magnetic dipole m placed in an external magnetic dipole is $U = -\vec{m}.\vec{B}$.

Therefore, work done in rotating the dipole is-

$W = \Delta U = 2mB = 2\times 5.4\times 10^{-6}\times 0.8$

$= 8.6 \times 10^{-6}$ Joule.

23. **(b)** Motion remains simple harmonic with new period = 2 T

24. **(a)** At magnetic north pole of earth, H = 0 and $\delta = 90^o$, maximum.

25. **(c)** Horizontal component of earth's field, $H = B\cos\theta$, since, $\theta = 60°$

26. **(b)** $W_1 = -MB(\cos 90^o - \cos 0^o) = MB$

$W_2 = -MB(\cos 60^o - \cos 0^o)$

$= -MB\left(\frac{1}{2}-1\right) = \frac{1}{2}MB = \frac{1}{2}W_1$

As $W_1 = nW_2$; $\therefore n = 2$

27. **(d)** $B_0 = \mu_0 \times H$; $\frac{\mu_0}{4\pi}\frac{2M}{d^3} = \mu_0 \times 30$; $\frac{1}{4\pi}\times\frac{2\times 4\times 10^{-2}\times m}{(20\times 10^{-2})^3} = 30$

$\therefore m = 37.7\,A\,m$

28. **(a)** $\tan\theta = \frac{H_0}{H}$ $\theta = \tan^{-1}\left(\frac{H_0}{H}\right)$

29. (a) In stable equilibrium, a compass needle points along the magnetic north and experiences no torque. When it is turned through declination α, it points along geographic north and experiences torque,

$T = mB\sin\alpha$

$\therefore \sin\alpha = \frac{T}{mB} = \frac{1.2\times 10^{-3}}{60\times 40\times 10^{-6}} = \frac{1}{2}$ or $\alpha = 30^0$

30. **(c)** $\tan\delta = \frac{V}{H} = \frac{V}{\sqrt{3}V} = \frac{1}{\sqrt{3}}$

$\therefore \delta = 30^0 = \pi/6$ radian

31. **(c)** $B = \frac{H}{\cos\theta} = \frac{0.50}{\cos 30^0} = \frac{0.50\times 2}{\sqrt{3}} = 1/\sqrt{3}$

32. **(a)** The earth's core is hot and molten. Hence, convective current in earth's core is responsible for it's magnetic field.

33. (d) The value of Horizontal component of earth magnetic field H is fairly uniform over small distances.

34. **(a)** Given $M = 8\times 10^{22}\,Am^2$

$d = R_e = 6.4\times 10^6\,m$

Earth's magnetic field, $B = \frac{\mu_0}{4\pi}.\frac{2M}{d^3} = \frac{4\pi\times 10^{-7}}{4\pi}\times\frac{2\times 8\times 10^{22}}{(6.4\times 10^6)^3} \simeq 0.6$ Gauss

35. (d) When the north pole of short bar magnet is facing North pole of the earth, at the neutral point P, which is on equatorial line.

$B_H = \frac{\mu_0 M}{4\pi d^3} = B_1$ ....(1)

When the magnet is rotated by 90o, the magnetic induction at P which is on axial line,

$B_H = \frac{\mu_0 2M}{4\pi d^3} = B_2$ ....(2)

Therefore, net magnetic induction at P is

$B_{net} = \sqrt{(B_1^2 + B_1^2)}$

$B_{net} = \sqrt{(1^2 + 2^2)}B_H = \sqrt{5}B_H$

36. **(b)** Electro magnet should be amenable to magnetisation and demagnetization

$\therefore$ retentivity should be low and coercivity should be low.

37. **(b)** Paramagnetic liquid tends to flow from region of weaker magnetic fields to stronger magnetic fields.
38. **(b)** A diamagnetic liquid moves from stronger parts of magnetic field to weaker parts.
39. **(a)** $W_H = VAft = \frac{m}{d}Aft$

or $W_H = \frac{0.6}{7.8\times10^3}\times0.722\times50 = 277.7\times10^{-5}$ Joule

40. **(b)** Diamagnetic substances are repelled by the poles of a bar magnet.
41. **(a)** $\mu = \mu_r\mu_0$, as $\mu_r = \mu/\mu_0$
42. **(d)** The ferromagnetic core of electromagnets should have high permeability and low retentivity
43. **(c)** The loop (i) is for soft iron and the loop (ii) is for steel.
44. **(a)** Relative permeability of iron, $\mu_r = 6000$

Magnetic susceptibility $\chi_m = \mu_r - 1 = 5999$.

45. (d) Demagnetization processes include heating past the Curie point, applying a strong magnetic field, applying alternating current, or hammering the metal. Demagnetization occurs naturally over time. The speed of the process depends on the material, the temperature, and other factors.
46. **(a)** For paramagnetic substance magnetization M is proportional to magnetising field H, and M is positive.
47. **(d)** The magnetic permeability of the material

$\mu = \frac{B}{H} = \frac{4H}{H} = 4$

48. (c) The permanent magnet is made from ferromagnetic substances.
49. **(d)** Relative magnetic permeability

$\mu_r = \frac{\text{magnetic permeability of material}(\mu)}{\text{permeability of free space}(\mu_0)}$

It is a dimensionless pure ratio and for paramagnetic materials $\mu_r > 1$

50. **(d)** Beyond Curie temperature, ferromagnetic substances behaves like a paramagnetic substance.
51. **(d)** The narrowest hysteresis loop is for perm alloy
52. **(b)** Magnetisation $(\vec{I})$ is given by

$\vec{I} = \lambda\vec{H}$ where λ = susceptibility

$\vec{H}$ = magnetic intensity

For a paramagnetic substance,

$\lambda \propto \frac{1}{T} \qquad \therefore I \propto \frac{1}{T}$

53. (d) When a ferromagnetic material in heated above its curie temperature then it behaves like paramagnetic material.
54. **(a)** Intensity of magnetisation

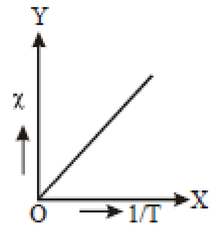
$I_m = \frac{M}{V} = \frac{1.2}{(15\times2\times1)10^{-6}} = 4\times10^4\,Am^{-1}$

55. **(b)** Ferromagnetic substance has magnetic domains whereas paramagnetic substances have magnetic dipoles which get attracted to a magnetic field. Diamagnetic substances do not have magnetic dipole but in the presence of external magnetic field due to their orbital motion these substance are repelled.

$\frac{\chi_{m_1}}{\chi_{m_2}} = \frac{T_2}{T_1} = \frac{273+333}{273+30} = \frac{606}{303} = 2$

$\therefore \chi_{m_2} = \chi_{m_1}/2 = 0.5\chi_{m_1} = 0.5\chi\left(\because \chi_{m_1} = \chi\right)$

56. **(d)** According to Curie's law $\lambda \propto 1/T$. So, the graph between λ and 1/T will be represented by fig



57. **(b)** For diarnagnetic material, $0<\mu_r<1$ and for any material, $\varepsilon_r>1$.

58. **(c)** $T_1 = 2\pi\sqrt{\frac{I_1+I_2}{(M+2M)H}} = 2\pi\sqrt{\frac{I}{3MH}}$; $T_2 = 2\pi\sqrt{\frac{I_1+I_2}{(2M-M)H}} = 2\pi\sqrt{\frac{I}{MH}}$

Obviously, $T_2 > T_1$

59. **(a)** The time period of oscillation of a freely suspended magnet is given by

$T = 2\pi\sqrt{\frac{I}{MH}}$ Thus, $\frac{T}{T^{|}} = \frac{2\pi\sqrt{\frac{I}{MH}}}{2\pi\sqrt{\frac{I}{MH^{|}}}}$

Given $T = 4\sec$, $T^{|} = 2\sec$, So, $\frac{4}{2} = \sqrt{\frac{H^{|}}{H}} \Rightarrow \sqrt{\frac{H^{|}}{H}} = 2 \Rightarrow H^{|} = 4H$

60. (d) Time period is given by

$T = 2\pi\sqrt{\frac{I}{MB}}$; $T^2 = 4\pi^2 \times \frac{I}{MB}$

$M = 4\pi^2 \times \frac{I}{T^2 B}$

Time period $T = \frac{15}{20} = 0.75\,s$

$\therefore M = 4\pi^2 \times \frac{9\times10^{-5}}{16\pi^2\times10^{-5}\times(0.75)^2}$

$M = \frac{9}{4\times0.5625} \Rightarrow M = \frac{9}{2.25} = 4A-m^2$

61. (d) To measure the magnetic moment of a bar magnet,
a deflection galvanometer is used if the earth's horizontal field is known.
An oscillation magnetometer can be used if the earth's horizontal field is known.
Both deflection and oscillation magnetometer can be used if the earth's horizontal field is not known since there are two variables.

62. **(b)** $T = 2\pi\sqrt{\frac{I}{MB}}$ $I = \frac{m}{2}\left(\frac{\ell}{2}\right)^2 \Rightarrow I^{|} = \frac{I}{8}$

$M^{|} = \frac{M}{2}$ So, $T^{|} = 2\pi\sqrt{\frac{I}{4\pi B}} \Rightarrow T^{|} = \frac{T}{2} = 2\sec$

63. **(a)** $\frac{\tan\theta_2}{\tan\theta_1} = \frac{d_1^3}{d_2^3} = \frac{r^3}{\left[r(3)^{1/3}\right]^3} = \frac{1}{3}$

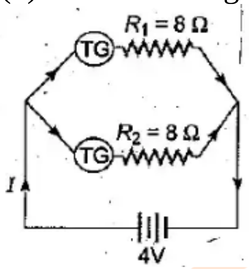
$\tan\theta_2 = \frac{1}{3}\tan\theta_1 = \frac{\tan 60}{3} = \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}}$ **;** $\therefore \theta_2 = 30^0$

64. **(d)** In series, same current flows through two tangent galvanometers

65. **(b)** $T \propto \frac{1}{\sqrt{H}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{H_2}{H_1}} \Rightarrow \frac{2}{1} = \sqrt{\frac{H+F}{H}} \quad \Rightarrow F = 3H \text{ or } \frac{H}{F} = \frac{1}{3}$

66. (b) In MCG, deflection is proportional to torque on the coil and torque is proportional to current. Hence, when current is doubled, deflection is doubled.

67. (b) Current in tangent galvanometer



$I = \frac{2rH}{\mu_0 N}\tan\theta$ ---------(i)

Here, R_1 and R_2 are in parallel

$\therefore \frac{1}{R_{net}} = \frac{1}{R_1} + \frac{1}{R_2}$

$R_{net} = \frac{R_2 + R_1}{R_1 R_2} = \frac{8+8}{8\times 8}$; $R_{net} = 4\Omega$

Hence, $I = \frac{V}{R} = \frac{4}{4} = 1A$

From Eq. (i), we get $\frac{r\tan\theta}{N} = \frac{\mu_0 I}{2H}$

Since same current flows through both galvanometers, thus we get

$\therefore \frac{r_A \tan\theta_A}{N_A} = \frac{r_B \tan\theta_B}{N_B} \Rightarrow \frac{8\times 1}{\sqrt{3}\times 2} = \frac{16\times\sqrt{3}}{N_B}$

$\therefore N_B = 12$ turns.

68. **(b)** We know that

$\frac{B}{B_H} = \tan\theta \text{ or } B = B_H \tan\theta = 0.34\times 10^{-4}\tan 30^0 = 1.96\times 10^{-5}T$

69. **(a)** $\frac{\tan\theta_1}{\tan\theta_2} = \frac{2}{1}$

70. **(a)** $T = 2\pi\sqrt{\left(\frac{I}{MB_H}\right)}$

$T^{|} = 2\pi\sqrt{\left(\frac{I}{4MB_H}\right)} = \frac{1}{2}\left[2\pi\sqrt{\frac{I}{(MB_H)}}\right] = \frac{1}{2}\times 2 = 1\text{second.}$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(a)** Rod gains gravitational potential energy which comes from energy of current source.

2. **(c)** Given : Magnetic moment, $M = 6.7 \times 10^{-2}\ Am^2$

Magnetic field, B = 0.01 T

Moment of inertia, $I = 7.5 \times 10^{-6}$ Kgm^2

Using, $T = 2\pi\sqrt{\frac{I}{MB}} = \frac{2\pi}{10}\times 1.06s$

Time taken for 10 complete oscillations

$t = 10T = 2\pi \times 1.06 = 6.6568 \approx 6.65$ s

3. **(d)** If θ_1 and θ_2 are apparent angles of dip

Let α be the angle which one of the plane make with the magnetic meridian.

$$\tan\theta_1 = \frac{V}{H\cos\alpha} \Rightarrow \text{i.e., } \cos\alpha = \frac{V}{H\tan\theta_1} \text{ ---------(i)}$$

$$\tan\theta_2 = \frac{V}{H\sin\alpha} \Rightarrow \text{i.e., } \sin\alpha = \frac{V}{H\tan\theta_2} \text{ ---------(ii)}$$

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

$$\cos^2\alpha + \sin^2\alpha = \left(\frac{V}{H}\right)^2\left(\frac{1}{\tan^2\theta_1} + \frac{1}{\tan^2\theta_2}\right)$$

$$\text{i.e., } 1 = \frac{V^2}{H^2}\left[\cot^2\theta_1 + \cot^2\theta_2\right] \text{ or } \frac{H^2}{V^2} = \cot^2\theta_1 + \cot^2\theta_2$$

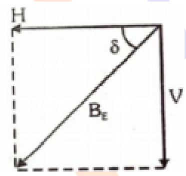
i.e., $\cot^2\theta = \cot^2\theta_1 + \cot^2\theta_2$

4. **(a)** Magnetic susceptibility χ for dia-magnetic materials only is negative and low $|\chi| = -1$; for paramagnetic substances low but positive $|\chi| = 1$ and for ferromagnetic substances positive and high $|\chi| = 10^2$.

5. **(c)** Net magnetic dipole moment $= 2M\cos\frac{\theta}{2}$

As value of $\cos\frac{\theta}{2}$ is maximum in case (c) hence net magnetic dipole moment is maximum for option (c).

6. **(b)** $V = B_E \sin\delta$ **;** $H = B_E\cos\delta$



7. $M = I(\pi r^2)$ where, $r = \frac{l}{2\pi}$

$$\Rightarrow M = I(\pi)\left(\frac{L}{2\pi}\right)^2 = \frac{IL^2}{4\pi}$$

8. Relative permeability $\mu_r = 1 + x_m = 599 + 1 = 600$

$$\mu = \mu_0\mu_r = 4\pi \times 10^{-7} \times 600 = 2.4\pi \times 10^{-4} \frac{Tm}{A}$$

9. $e_{max} = NABW = N\pi r^2 BW = 1000 \times \pi r^2 \times 2 \times 10^{-5} \times 2$

$$i_{max} = \frac{e_{max}}{R} = \frac{1000 \times \pi(10)^2 \times 2 \times 10^{-5} \times 2}{12.56} = 1A$$