CHAPTER : 5

MAGNETISM AND MATTER

STUDY NOTES

- **Magnets and magnetism:** A magnet is a piece of material that has both attractive and directive properties. It attracts small pieces of iron, nickel, cobalt, etc. This property of attraction is called magnetism.
- **Basic properties of magnets:** These are as follows:
  - (i) A magnet attracts small pieces of iron, nickel, cobalt, etc.
  - (ii) A freely suspended magnet aligns itself nearly in the geographic north-south direction.
  - (iii) Like poles repel and unlike poles attract.
  - (iv) Magnetic poles exist in pairs. Isolated magnetic poles do not exist. If we break a magnet into two pieces, we get two smaller dipole magnets.
- **Magnetic field:** The space around a magnet within which its influence can be experienced is called its magnetic field.
- **Uniform magnetic field:** A magnetic field in a region is said to be uniform if it has same magnitude and direction at all points of that region.
- **Magnetic poles:** These are the regions of apparently concentrated magnetic strength in a magnet where the magnetic attraction is maximum.
- **Magnetic axis:** The line passing through the poles of a magnet is called its magnetic axis.
- **Magnetic equator:** The line passing through the centre of the magnet and at right angles to the magnetic axis is called the magnetic equator of the magnet.
- **Magnetic length:** The distance between the two poles of a magnet is called its magnetic length. It is slightly less than the geometrical length of the magnet.
- **Coulomb's law of magnetic force:** This law states that the force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them. If q_{m_1} and q_{m_2} are the pole strengths of two magnetic poles separated by distance r, then the force of attraction or repulsion between them is

$$F = \frac{\mu_0}{4\pi} \cdot \frac{q_{m_1} q_{m_2}}{r^2}$$

- **Magnetic dipole:** Any arrangement of two equal and opposite magnetic poles separated by a small distance is called a magnetic dipole. A bar magnet and a current-carrying loop are magnetic dipoles.
- **Magnetic dipole moment:** It is equal to the product of the pole strength q_m and the magnetic length $(2l)$ of the magnet

$$m = q_m \times 2l$$

  The SI unit of magnetic dipole moment is Am^2 or JT^{-1}
- **Magnetic lines of force:** A magnetic line of force may be defined as the curve the tangent to which at any point gives the direction of the magnetic field at that point. It may also be defined as the path along which a unit north pole would tend to move if free to do so.

- **Properties of lines of force:**

  These are as follows:

  (i) Magnetic lines of force are closed curves which start from the N-pole and end at the S-pole in air and then return to the N-pole through the interior of the magnet.

  (ii) The lines of force never cross each other.

  (iii) They start from, and end on the surface of the magnet normally.

  (iv) The lines of force have a tendency to contract lengthwise and expand sidewise. This explains attraction between unlike poles and repulsion between like poles.

  (v) The relative closeness of the lines of force is a measure of the strength of the magnetic field which is maximum at the poles.

- **Magnetic field of a bar magnet at an axial point (end-on position).**

  (i) $B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2mr}{(r^2 - l^2)^2}$

  where r is the distance of the point from the centre of the magnet.

  (i) For a short magnet, $l << r$

  $$B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$$

  The magnetic field at any axial point of magnetic dipole is in the same direction as that of its magnetic dipole moment.

- **Magnetic field of a bar magnet at an equatorial point (Broadside-on position).**

  (i) $B_{equatorial} = \frac{\mu_0}{4\pi} \cdot \frac{2mr}{(r^2 - l^2)^2}$

  (ii) For short magnet, $l << r$, $B_{equatorial} = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$

  The magnetic field at any equatorial point of a magnetic dipole is in the direction opposite to that of its magnetic dipole moment.

- **Torque on a magnet in a magnetic field.**

  If a magnet of dipole moment is placed in a magnetic field B making an angle with it, then torque acting on the magnet is

  $$\tau = mB \sin\theta$$

  In vector notation, $\vec{\tau} = \vec{m} \times \vec{B}$

  The effect of the torque is to align the dipole to the field $\vec{B}$. If $\theta = 90°$, then $\tau = mB$

- **Potential energy of a magnetic dipole in a magnetic field:** When a magnetic dipole is rotated in a magnetic field against the torque from initial position θ_1 to final position θ_2, the work done or the potential energy stored is given by

  $W = U = -mB(\cos\theta_2 - \cos\theta_1)$

  P.E is zero when $\vec{m}$ perpendicular to $\vec{B}$.

  Hence, P.E of the dipole in any orientation θ is

  $$U = -mB\cos\theta = -\vec{m} \cdot \vec{B}$$

- **Special cases**

  (a) When $\theta = 0°$, $U = -mB$. Thus, the P.E. of a dipole is minimum when $\vec{m}$ is parallel to $\vec{B}$.
  This is the position of stable equilibrium.

  (b) When $\theta = 90°$, $U = 0$.

  (c) When $\theta = 180°$, $U = +mB$.

  Thus, the P.E. of the dipole is maximum when $\vec{m}$ is antiparallel to $\vec{B}$. This is the position of unstable equilibrium.

- **Current loop as a magnetic dipole:** A planar current loop of area A and carrying current I behaves as a magnetic dipole of dipole moment,

  $$m = IA$$

  In vector notation, $\vec{m} = I\vec{A}$

  The direction of $\vec{m}$ is given by right hand thumb rule. If we curl the fingers of the right hand along the direction of current in the loop, then the extended thumb gives the direction of the magnetic moment associated with the loop.

- **Magnetic dipole moment of a revolving electron:** The orbital magnetic moment of an electron revolving around a nucleus in nth orbit of radius r with speed v is given by

  $$\mu_l = \frac{evr}{2} = \frac{e}{2m_e} l = n\left(\frac{eh}{4\pi m_e}\right)$$

  where l is the magnitude of the angular momentum of the electron revolving around the nucleus.

- **Bohr magneton:** It is the magnetic dipole moment associated with an electron due to its orbital motion in the first orbit of hydrogen atom. It is the smallest value of μ_l.

  $$\mu_B = (\mu_l)_{min} = \frac{eh}{4\pi m_e} = 9.27 \times 10^{-24} Am^2$$

- **Gauss's law in magnetism:** This law states that the net magnetic flux through any closed surface is zero. Mathematically,

  $$\phi_B = \oint_s \vec{B} \cdot d\vec{S} = 0.$$

  This law indicates that monopoles does not exist.

- **Basic difference between electric and magnetic lines of force:** The magnetic lines of force are continuous and form closed loops. They do not start or end at a point. In contrast, the electric lines of force start from a positive charge and end on a negative charge or they fade out at infinity.

- **Earth's magnetic field:** When a magnet is suspended freely, it orients itself roughly in the geographical north-south direction. This suggests that the earth behaves as a huge magnet. Its field can be approximated to that of a magnetic dipole with dipole moment 80×10^{22} Am^2 with its axis aligned at a small angle with the rotation axis of the earth. The magnitude of the field on the earth's surface is typically about 10^{-4} T.

- **Magnetic meridian:** The vertical plane passing through the magnetic axis of a freely suspended small magnet is called magnetic meridian. The earth's magnetic field acts in the direction of the magnetic meridian.

- **Geographic meridian:** The vertical plane passing through the geographic north and south poles is called geographic meridian.

- **Elements of earth's magnetic field:** The earth's magnetic field at a place can be completely described by three parameters which are called elements of earth's magnetic field. These are declination, dip and horizontal component of earth's magnetic field.

- **Magnetic declination:** It is the angle between the geographic meridian and the magnetic meridian at the given place.

- **Angle of dip:** It is the angle made by the earth's total magnetic field with the horizontal direction.

- **Horizontal component of earth's magnetic field:** It is the component of the earth's total magnetic field B acting in the horizontal direction.

  $$B_H = B \cos \delta$$

  At the magnetic equator , $\delta = 0°$,

  $$B_H = B \cos 0° = B$$

  At the magnetic poles, $\delta = 90°$,

  $$B_H = B \cos 90° = 0$$

- Relations between the elements of earth's magnetic field,

$$B_H = B \cos \delta$$

And

$$B_V = B \sin \delta$$

$$\frac{B_V}{B_H} = \tan \delta$$

And

$$B = \sqrt{B_H^2 + B_V^2}$$

- **Neutral point:** It is the point where the magnetic field of a bar magnet is completely cancelled by the horizontal component of earth's magnetic field.
  (i) For a magnet placed with its N-pole pointing geographic north, the neutral points lie at the equatorial line. At each neutral point,

$$B_H = \frac{\mu_0}{4\pi} \cdot \frac{m}{\left(r^2 + l^2\right)^{3/2}}$$

$$\simeq \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3}$$

  (ii) For a magnet placed with its N-pole pointing geographic south, the neutral points lie at the axial line. At each neutral point,

$$B_H = \frac{\mu_0}{4\pi} \cdot \frac{2mr}{\left(r^2 - l^2\right)^{3/2}}$$

$$\simeq \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$$

- **Magnetizing field:** The magnetic field that exists in vacuum and induces magnetism is called magnetising field. The magnetising field set up in a solenoid carrying current I and placed in vacuum,

$$B_0 = \mu_0 nI$$

- **Magnetising field intensity or magnetic intensity:** It is the number of ampere-turns (nI) flowing round the unit length of the solenoid required to produce a given magnetising field.

  Thus,

$$H = nI$$

  Also,

$$B_0 = \mu_0 nI = \mu H$$

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

  SI unit of H is Am^{-1} and its dimensions are $[L^{-1}A]$.

- **Magnetisation or intensity of magnetisation:** It is the magnetic moment developed per unit volume of a material when placed in a magnetising field. It is a vector quantity.

$$M = \frac{m}{V}$$

- **Magnetic induction:** It is the total number of magnetic lines of force crossing per unit area through a magnetic material. Its Sl unit is tesla (T).
- **Magnetic permeability:** It is the ratio of the magnetic induction to the magnetising field intensity.

$$B_0 = \mu_0(H + M)$$

Its Sl unit is $Tm\,A^{-1}$ or $Wbm^{-1}\,A^{-1}$,

- **Relative permeability:** It is the ratio of the permeability of the material to the permeability of free space.

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

- **Magnetic susceptibility:** It is the ratio of the intensity of magnetisation (M) induced to the magnetising field intensity (H).

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

It can be shown that

$$\mu = \mu_0(1 + \chi_m)$$

$$\mu_r = 1 + \chi_m$$

- **Classification of magnetic materials:** Magnetic materials are broadly classified as diamagnetic, paramagnetic and ferromagnetic.
- **Diamagnetic substances:** These are the substances which when placed in a magnetising field get feebly magnetised in the opposite direction of the applied field. Such substances are feebly repelled by magnets and tend to move slowly from stronger to weaker parts of a magnetic field.
- **Paramagnetic substances:** These are the substances which when placed in a magnetising field get feebly magnetised in the direction of the magnetising field. Such substances are feebly attracted by magnets and tend to move slowly from weaker to stronger parts of a magnetic field.
- **Ferromagnetic substances:** These are the substances which when placed in a magnetising field get strongly magnetised in the direction of the magnetic field. Such substances tend to move quickly from weaker to stronger parts of a field.
- **Curie's law:** The magnetic susceptibility of a paramagnetic substance varies inversely with its absolute temperature.

$$\chi_m \propto \frac{1}{T}$$

$$\chi_m = \frac{C}{T}$$

Where C is curie constant.

- **Curie temperature:** The temperature above which a ferromagnetic substance becomes paramagnetic is called Curie temperature (T). The modified Curie law for ferromagnetic substances above the Curie temperature is

$$\chi_m = \frac{C'}{T - T_c} \qquad (T > T_C)$$

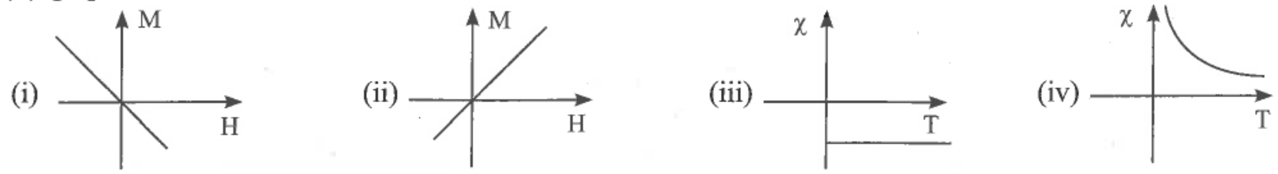
This relation is also called Curie-Weiss law.

- **Hysteresis:** The phenomenon of lagging of the magnetic induction behind the magnetising field in a ferromagnetic material is called hysteresis. The area of the hysteresis (B-H) loop gives the energy wasted in a sample when it is taken through a cycle of magnetisation.
- **Retentivity or remanence:** The magnetic induction left behind in the sample after the magnetising field has been removed is called retentivity.
- **Coercivity:** The value of the reverse magnetising field required to make the residual magnetism of a sample equal to zero is called coercivity.
- **Tangent law:** When a short magnet is suspended freely under the combined action of two uniform perpendicular magnetic fields B and B_H, the magnet comes to rest making an angle θ with the direction of B_H such that $B = B_H \tan\theta$.

QUESTION BANK

MULTIPLE CHOICE QUESTIONS

1. Following plots show magnetization (M) vs magnetizing field (H) and magnetic susceptibility (χ) vs temperature (T) graph :



Which of the following combination will be represented by a diamagnetic materials?

(a) (i), (iii) (b) (i), (iv) (c) (ii), (iv) (d) (ii), (iii)

2. A steel wire of length l has a magnetic moment M. It is bent in L shape. The new magnetic moment will be

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

3. The coercivity of a small magnet where the ferromagnet gets demagnetized is 3×10^3 Am^{-1}. The current required to be passed in a solenoid of length 10 cm, and number of turns 100, so that the magnet gets demagnetized when inside the solenoid is :

(a) 30 mA (b) 60 mA (c) 3 A (d) 6 A

4. A magnetic compass needle oscillates 30 times per minute at a place where the dip is 45°, and 40 times per minute where the dip is 30°. If B_1 and B_2 are respectively the total magnetic field due to the earth at the two places, then the ratio B_1/B_2 is best given by :

(a) 1.8 (b) 22 (c) 0.7 (d) 3.6

5. A paramagnetic material is kept in a magnetic field. The field is increased till the magnetization becomes constant. If the temperature is now decreased, the magnetization :

(a) will decrease (b) will increase
(c) remain constant (d) may increase or decrease

6. The permanent magnetic moment of the atoms of a material is not zero. The material :

(a) must be paramagnetic (b) must be diamagnetic
(c) must be ferromagnetic (d) may be paramagnetic

7. A solenoid of 500 turns/m is carrying a current of 3 A. Its core is made of iron which has a relative permeability of 5000. The magnetic field inside the core is :

(a) 0.94 T (b) 99.4 T (c) 994 T (d) 9.4 T

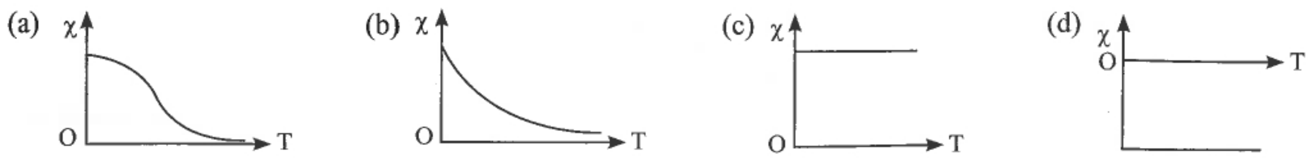
8. A iron rod having cross section 0.5 cm^2 is subjected to a magnetic field of 1500 Am^{-1}. If susceptibility of iron is 599, the magnetic field induced:

(a) 5.65×10^{-5}Wb (b) 5.65×10^{-7}Wb
(c) 56.5×10^{-5}Wb (d) 56.5×10^{-9}Wb

9. A specimen of iron is uniformly magnetized by a field of 500 Am^{-1}. If the magnetic induction in the specimen is 0.2Wbm^{-2}, susceptibility is :

(a) 317.5 (b) 418.5 (c) 217.5 (d) 175

10. The variation of magnetic susceptibility (χ) with absolute temperature T for a ferromagnetic material is given by the plot



11. A diamagnetic material in a magnetic field moves:
(a) perpendicular to the field.
(b) From weaker to the stronger parts of the field.
(c) From stronger to the weaker parts of the field.
(d) to none of the above directions.

12. When the distance between two magnetic poles is reduced to half, the force between the magnetic poles:
(a) increases by 2 times (b) decreases by 2 times (c) increases by 4 times (d) decreases by 4 times.

13. The magnetic properties of a magnet is lost at a temperature which is called:
(a) Curie point (b) melting point (c) boiling point (d) none of these

14. A bar magnet of magnetic moment M is cut in two parts of equal length. The magnetic moment of either part is:
(a) M (b) 2 M (c) M/2 (d) zero

15. A toroid of n turns, mean radius R and cross-sectional radius a carries current I. It is placed on a horizontal table taken as xy-plane. Its magnetic moment m
(a) is non-zero and points in the z-direction by symmetry
(b) points along the axis of the toroid
(c) is zero, otherwise there would be a field falling as $\frac{1}{r^3}$ at large distances outside the toroid
(d) is pointing radially outwards

16. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2 s. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be a
(a) 2 s (b) (2/3) s (c) $2\sqrt{3}$ s (d) $(2/\sqrt{3})$ s

17. A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60°. The torque needed to maintain the needle in this position will be
(a) $\sqrt{3}$ W (b) W (c) $(\sqrt{3}/2)$ W (d) 2 W

18. A thin rectangular magnet suspended freely has a period of oscillation equal to T. Now it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T′, the ratio T′/T is
(a) $\frac{1}{2\sqrt{2}}$ (b) $\frac{1}{2}$ (c) 2 (d) 1/4

19. A bar magnet is placed inside a non-uniform magnetic field. It experiences
(a) a force and a torque.
(b) a force but not a torque.
(c) a torque but not a force.
(d) neither a force nor a torque.

20. A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω. The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on
(a) ω and q (b) ω, q and m (c) q and m (d) ω and m

21. Two wires of same length are shaped into a square and a circle. If they carry same current, ratio of the magnetic moments is
(a) 2 : π (b) π : 2 (c) π : 4 (d) 4 : π

22. The magnetic moment (μ) of a revolving electron around the nucleus varies with principal quantum number n as
(a) $\mu \propto n^2$ (b) $\mu \propto \frac{1}{n}$ (c) $\mu \propto \frac{1}{n^2}$ (d) $\mu \propto n$

23. Lines of force, due to earth's horizontal magnetic field, are
(a) elliptical (b) curved lines (c) concentric circles (d) parallel and straight

24. Angle of dip is 90° at
(a) poles (b) equator (c) both (a) and (b) (d) none of the these.

25. What should be the current in a circular coil of radius 5 cm to produce $B_H = 5\times10^{-5}$T?
(a) 0.4 A (b) 4 A (c) 40 A (d) 1 A

26. Among the following properties describing diamagnetism, identify the property that is wrongly stated.

(a) diamagnetic materials do not have permanent magnetic moment

(b) diamagnetism is explained in terms of electromagnetic induction

(c) diamagnetic materials have a small positive susceptibility

(d) the magnetic moments of individual electron neutralize each other

27. According to Curie's law, the magnetic susceptibility of a substance as the absolute temperature T is proportional to

(a) T (b) T^2 (c) 1/T (d) $1/T^2$

28. If number of turns, area and current through a coil are given by n,A,I respectively then its magnetic moment is given by

(a) nIA (b) nIA^2 (c) n^2IA (d) $nI/\sqrt{A}$

29. A short magnet is placed with its axis at 30° with a uniform external magnetic field of 0.25 T experiences a torque of magnitude equal to 4.5×10^{-2}J, then the magnetic moment of the magnet is

(a) 0.36 JT (b) 0.36 JT^{-1} (c) 0.34 JT d. 0.34 JT^{-1}

30. Two similar magnetic poles having pole strength in the ratio 1:4 are placed 1 m apart. The point where a unit pole experiences no net force due to the two poles is :

(a) 0.334 m (b) 0.586m (c) 1.414 m (d) 0.414 cm

31. Two small magnets are placed horizontally, perpendicular to the magnetic meridian. Their north poles are at 30 cm east and 20 cm west from a compass needle. If the compass needle remains undeflected, then the ratio of the magnetic moments of the magnets is

(a) 8:27 (b) 2:3 (c) 2:9 (d) 8:81

32. Two particles, each of mass *m* and charge *q*, are attached to the two ends of a light rigid rod of length 2 *R*. The rod is rotated at constant angular speed about a perpendicular axis passing through its centre. The ratio of the magnitudes of the magnetic moment of the system and its angular momentum about the centre of the rod is

(a) $q/2m$ (b) q/m (c) $2q/m$ (d) $q/3m$

33. A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position will be

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

34. At a point A on the earth's surface the angle of dip δ = +25° and at a point B on the earth's surface the angle of dip δ = –25°, we can interpret that:

(a) A is located in the southern hemisphere and B is located in the northern hemisphere.

(b) A is located in the northern hemisphere and B is located in the southern hemisphere.

(c) A and B are both located in the southern hemisphere.

(d) A and B are both located in the northern hemisphere.

35. Magnetic moment of bar magnet is M. The work done in turning the magnet by 90° in direction of magnetic field B will be

(a) Zero (b) 2MB (c) 3MB (d) MB

36. In a permanent magnet at room temperature,

(a) magnetic moment of each molecule is zero

(b) the individual molecules have non-zero magnetic moment which are all perfectly aligned

(c) domains are partially aligned

(d) domains are all perfectly aligned

37. The magnetic field of the earth can be modelled by that of a point dipole placed at the centre of the earth. The dipole axis makes an angle of 11.3° with the axis of the earth. At Mumbai, declination is nearly zero. Then,

(a) the declination varies between 11.3° W to 11.3° E

(b) the least declination is 0°

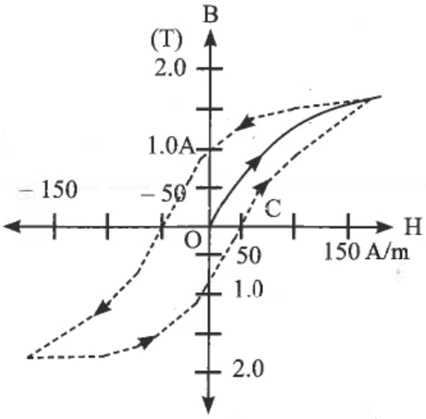
(c) the plane defined by dipole axis and the earth axis passes through Greenwich

(d) declination averaged over the earth must be always negative.

38. Magnets lose their properties significantly if

(a) Left in the open
(b) Touched with iron
(c) Dropped from a height repeatedly.
(d) None of these

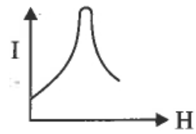
39. The figure gives experimentally measured B vs. H variation in a ferromagnetic material. The retentivity, coercivity and saturation, respectively, of the material are:



(a) 1.5 T, 50A/m and 1.0T
(b) 150 A/m, 1.0T and 1.5T
(c) 1.5 T, 50A/m and 1.0T
(d) 1.0T, 50A/m and 1.5T

40. The correct I-H curve for a paramagnetic material is represented by, figure

(a) closed loop
(b) straight line
(c)



(d) none of these

41. A magnet oscillating in a horizontal plane has a time period of 2 second at a place where the angle of dip is 30° and 3 seconds at another place where the angle of dip is 60°. The ratio of resultant magnetic fields at the two places is

(a) $\frac{4\sqrt{3}}{7}$
(b) $\frac{4}{9\sqrt{3}}$
(c) $\frac{9}{4\sqrt{3}}$
(d) $\frac{9}{\sqrt{3}}$

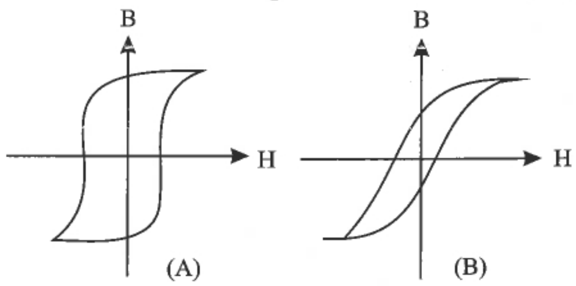
42. Three identical bar magnets, each of pole strength 10 A–m and length 10 cm are placed in a uniform field of induction 0.05 Wb/m^2. If the three magnets are fastened end to end along the same axis with opposite poles touching each other, resulting magnetic moment in Am^2 is:

(a) 3
(b) 9
(c) 6
(d) 8

43. A closed surface S encloses a magnet of magnetic moment 2 ml. The magnetic flux emerging from the surface is:

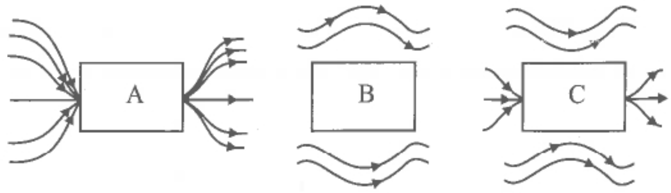
(a) $\mu_0 m$
(b) zero
(c) $2\mu_0 m$
(d) $2m/\mu_0$

44. Hysteresis loops for two magnetic materials A and B are given below. These materials are used to make magnets for electric generators, transformer core and electromagnet core. Then it is proper to use:



(a) A for electric generators and transformers
(b) A for electromagnets and B for electric generators
(c) A for transformer and B for electric generators
(d) B for electromagnets and transformers

45. Three identical bars A, B and C are made of different magnetic materials. When kept in a uniform magnetic field, the field lines around them look as given in the figure. Make the correspondence of these bars with their material being diamagnetic (D), ferromagnetic (F) and paramagnetic (P).

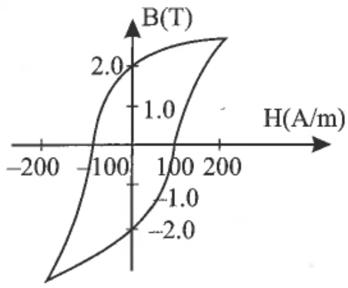


(a) A ↔ F, B ↔ D, C ↔ P
(b) A ↔ D, B↔P, C ↔ F
(c) A↔ F, B ↔ P, C ↔ D
(d) A ↔ P, B ↔ F, C↔ D

46. 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) attracts all three of them.
(b) attract N_1 and N_2 strongly but repel N_3
(c) attract N_1 strongly, N_2 weakly and repel N_3 weakly.
(d) attract N_1 strongly, but repel N_2 and N_3 weakly

47. The B-H curve for a ferromagnet is shown in the figure. The ferromagnet is placed inside a long solenoid with 1000 turns/cm. The current that should be passed in the solenoid to demagnetise the ferromagnet completely is:



(a) 2 mA (b) 1 mA (c) 3 mA (d) none of these

48. For soft iron, in comparison with steel:

(a) hysteresis loss is more
(b) hysteresis loss is same
(c) hysteresis loss is less
(d) hysteresis loss is negligible

49. The area enclosed by a hysteresis loop is a measure of

(a) retentivity (b) susceptibility (c) permeability (d) energy loss per cycle

50. A compass needle of magnetic moment 60 Am^2 is pointing geographical north at a certain place. It experiences a torque of 1.2×10^{-3} N-m. The horizontal component of earth's magnetic field at that place is or lift 40 $\mu Wb/m^2$. What is the angle of declination at that place?

(a) 30° (b) 60° (c) 45° (d) zero

51. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.16 T experiences a torque of magnitude 0.032 J. The magnetic moment of the bar magnet will be

(a) 0.23 J/T (b) 0.40 J/T (c) 0.80 J/T (d) zero

52. If the angles of dip at two places are 30° and 45° respectively, then the ratio of horizontal components of earth's magnetic field at the two places will be

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

53. The earth's magnetic field at a certain place has a horizontal component 0.3 G and the total strength 0.5 G. The angle of dip is

(a) $\sin^{-1}\left(\frac{3}{4}\right)$ (b) $\tan^{-1}\left(\frac{4}{3}\right)$ (c) $\tan^{-1}\left(\frac{3}{4}\right)$ (d) $\sin^{-1}\left(\frac{3}{5}\right)$

54. 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
(a) The lattice structure of the material of the rod
(b) The current source
(c) The induced electric field due to the changing magnetic field
(d) The magnetic field

55. **Statement I:** The ferromagnetic property depends on temperature. At high temperature, ferromagnet becomes paramagnet.

Statement II: At high temperature, the domain wall area of a ferromagnetic substance increases. In the light of the above statements, choose the most appropriate answer from the options given below:
(a) Statement I is false but Statement II is true
(b) Statement I is true but Statement II is false
(c) Both Statement I and Statement II are false
(d) Both Statement I and Statement II are true

56. The plane of a dip circle is set in the geographic meridian and the apparent dip is δ_1. It is then set in a vertical plane perpendicular to the geographic meridian. The apparent dip angle is δ_2. The declination θ at the plane is
(a) $\theta = \tan^{-1}(\tan \delta_1 \tan \delta_2)$
(b) $\theta = \tan^{-1}(\tan \delta_1 + \tan \delta_2)$
(c) $\theta = \tan^{-1}(\tan \delta_1 / \tan \delta_2)$
(d) $\theta = \tan^{-1}(\tan \delta_1 - \tan \delta_2)$

57. A magnet is suspended in such a way that it oscillates in the horizontal plane. It makes 20 oscillations per minute at a plane where dip angle is 30° and 15 oscillations per minute at a place where dip angle is 60°. The ratio of earth's magnetic fields at two places is
(a) $3\sqrt{3}:8$
(b) $16:9\sqrt{3}$
(c) 4:9
(d) $2\sqrt{2}:3$

58. There are four light-weight-rod samples A, B, C and D separately suspended by threads. A bar magnet is slowly brought near each sample and the following observations are noted.
(i) A is feebly repelled
(ii) B is feebly attracted
(iii) C is strongly attracted
(iv) D remains unaffected

Which one of the following is true?
(a) C is of a diamagnetic material
(b) D is of a ferromagnetic material
(c) A is of a non-magnetic material
(d) B is of a paramagnetic material

59. The work done in turning a magnet of magnetic moment M by an angle of 90° from the meridian is n times the corresponding work done to turn it through an angle of 60°
(a) $n = ½$
(b) $n = 2$
(c) $n = ¼$
(d) $n = 1$

60. Torques τ_1 and τ_2 are required for magnetic needle to remain perpendicular to the magnetic fields B_1 and B_2 at two different places. The ratio B_1/B_2 is
(a) τ_2/τ_1
(b) τ_1/τ_2
(c) $\frac{\tau_1 + \tau_2}{\tau_1 - \tau_2}$
(d) $\frac{\tau_1 - \tau_2}{\tau_1 + \tau_2}$

61. The magnetic susceptibility of a paramagnetic substance at –73°C is 0.0060, then its value at –173°C will be
(a) 0.0030
(b) 0.0120
(c) 0.0180
(d) 0.0045

62. The magnetic moment produced in a substance of 1 g is 6×10^{-7} Am^2. If its density is $5 g/cm^3$, then the intensity of magnetisation in A/m will be
(a) 8.3×10^6
(b) 3
(c) 1.2×10^{-7}
(d) 3×10^{-6}

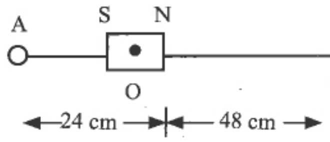
63. Ferromagnetic materials used in transformer must have
(a) low permeability and high hysteresis loss
(b) high permeability and low hysteresis loss
(c) high permeability and high hysteresis loss
(d) low permeability and low hysteresis loss

64. A superconducting material is
(a) ferromagnetic
(b) ferroelectric
(c) diamagnetic
(d) paramagnetic

65. A certain amount of current when flowing in a properly set tangent galvanometer, produces a deflection of 45°. If the current be reduced by a factor of $\sqrt{3}$, the deflection would

(a) decrease by 30° (b) decrease by 15° (c) increase by 15° (d) None of these

66. A bar magnet of length 3 cm has points A and B along its axis at distances of 24 cm and 48 cm on the opposite sides. Ratio of magnetic fields at these points will be



(a) 8 (b) $\frac{1}{2\sqrt{2}}$ (c) 3 (d) 4

67. 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 is 0.34×10^{-4} T along the plane of the coil. The magnetic intensity is

(a) 1.96×10^{-4} T (b) 1.96×10^{4} T (c) 1.96×10^{-5} T (d) 1.96×10^{5} T

68. Two bar magnets having same geometry with magnetic moments M and 2M are placed in such a way that their similar poles are on the same side, then its time period of oscillation is T_1. Now, if the polarity of one of the magnets is reversed, then time period of oscillation is T_2, then

(a) $T_1 < T_2$ (b) $T_1 > T_2$ (c) $T_1 = T_2$ (d) $T_1 = 0, T_2 = \infty$

69. A paramagnetic liquid is filled in a glass U-tube of which one limb is placed between the pole pieces of an electromagnet. When the field is switched on the liquid in the limb which is in the field will

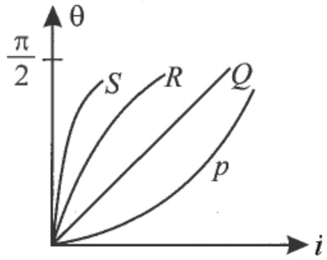
(a) rise (b) fall

(c) remain stationary (d) first rise and then fall

70. The magnetic field on the axis of a short bar magnet at a distance of 10 cm is 0.2 oersted. What will be the field at a point, distant 5 cm on the line perpendicular to the axis and passing through the magnet?

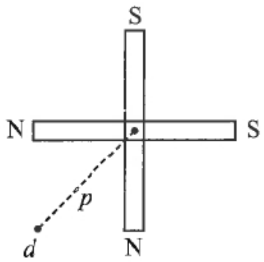
(a) 0.025 oersted (b) 0.2 oersted (c) 0.8 oersted (d) 0.4 oersted

71. Which of the four graphs may best represent the current deflection relation in a tangent galvanometer?



(a) S (b) P (c) R (d) Q

72. Two short magnets of equal dipole moments M are fastened perpendicularly at their centres (figure). The magnitude of the magnetic field at a distance d from the centre on the bisector of the right angle is



(a) $\frac{\mu_0}{4\pi}\frac{M}{d^3}$ (b) $\frac{\mu_0}{4\pi}\frac{\sqrt{2}\,M}{d^3}$ (c) $\frac{\mu_0}{4\pi}\frac{2\sqrt{2}\,M}{d^3}$ (d) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$

73. The tangents deflection produced in tan A and tan B positions by a short magnet at equal distances are in the ratio

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

74. Permeability is defined as the ratio between

(a) magnetic induction and susceptibility
(b) magnetic induction and magnetising field
(c) magnetising field and magnetic induction
(d) magnetising field and susceptibility

75. A bar magnet is oscillating in the earth's magnetic field with time period T. If its mass is increased four times then its time period will be

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

76. At a neutral point

(a) field of magnet is zero
(b) field of earth is zero
(c) field of magnet is perpendicular to field of earth
(d) None of these

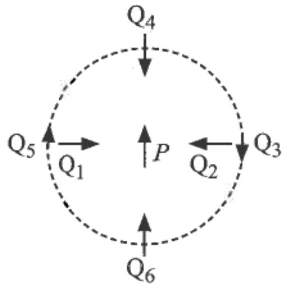
77. Two tangent galvanometers having coils of same radius are connected in series. A current flowing in them produces deflections of 60° and 45° respectively. The ratio of number of turns in the coils is

(a) $\frac{\sqrt{3}}{1}$ (b) $\frac{(\sqrt{3}+1)}{(\sqrt{3}-1)}$ (c) $\frac{(\sqrt{3}+1)}{1}$ (d) $\frac{4}{3}$

78. The gyromagnetic ratio of an electron of charge e for and mass m is equal to

(a) $e^2/2m$ (b) $e/2m^2$ (c) e/4m (d) e/2m

79. The figure below shows the various positions P (labelled by subscipts) of small magnetized needles P and Q. The arrows show the direction of their magnetic moment. Which configuration corresponds to the lowest potential energy among all the configurations shown?



(a) PQ_3 (b) PQ_5
(c) PQ_4 (d) PQ_6

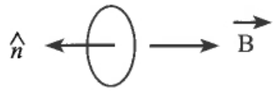
80. The magnetic force required to demagnetize the material is

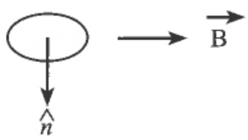
(a) retentivity (b) coercivity (c) energy loss (d) hysteresis.

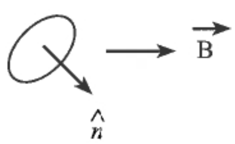
81. If the current is doubled, the deflection is also doubled in

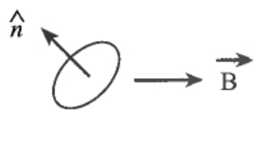
(a) a tangent galvanometer
(b) a moving coil galvanometer
(c) both (a) and (b)
(d) none of these

82. A current carrying loop is placed in a uniform magnetic field in four different orientations, I, II, III and IV. Arrange them in the decreasing order of potential energy.

(i) 

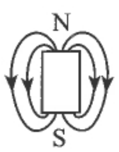
(ii) 

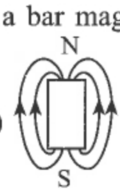
(iii) 

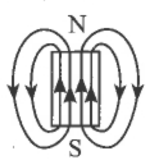
(iv) 

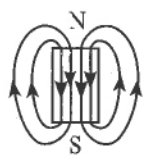
(a) I > III >II>IV (b) I>II>III > IV (c) I > IV > II > III (d) III > IV > I > II

83. The magnetic field lines due to a bar magnet are correctly shown as

(a) 

(b) 

(c) 

(d) 

84. A tape-recorder records sound in the form of

(a) electrical energy
(b) magnetic field on the tape
(c) magnetic energy
(d) variable resistance on the tape.

85. Which of the following is true regarding diamagnetic substances (symbols have their usual meaning)?
(a) $\mu_r > 1, \chi_m > 1$
(b) $\mu_r > 1, \chi_m < 1$
(c) $\mu_r < 1, \chi_m < 0$
(d) $\mu_r < 1, \chi_m > 0$

86. The direction of null points is on the equatorial line of a bar magnet, when the north pole of the magnet is pointing
(a) west
(b) east
(c) south
(d) north.

87. Which of the following relation is correct in magnetism?
(a) $I^2 = V^2 + H^2$
(b) $V = I^2 + H^2$
(c) $I = V + H$
(d) $V^2 = 1 + H$

88. A magnet with moment P_m, is given. If it is bent into a semicircular form, its new magnetic moment will be
(a) P_m/π
(b) $P_m/2$
(c) P_m
(d) $2P_m/\pi$

89. A bar magnet of dipole moment m is initially perpendicular to a magnetic field of intensity B. The angle by which the magnet should be rotated so that the torque acting on it is half the maximum torque is
(a) 30°
(b) 45°
(c) 60°
(d) 90°

90. The magnetic field intensity due to a bar magnet is 100 Am^{-1}. The magnetic induction field strength to it is :
(a) $\frac{4\pi}{10^7}$ T
(b) $\frac{4\pi}{10^5}$ T
(c) $\frac{10^3}{4\pi}$ T
(d) $\frac{10^5}{4\pi}$ T

91. A bar magnet of magnetic moment M is cut into two parts of equal length. The magnetic moment and pole strength of either part is:
(a) M/2, m/2
(b) M,m/2
(c) M/2, m
(d) M,m

92. If the distance between two similar magnetic poles held one cm apart be doubled, then the force of interaction between them will be:
(a) doubled
(b) halved
(c) unchanged
(d) one quarter of original value

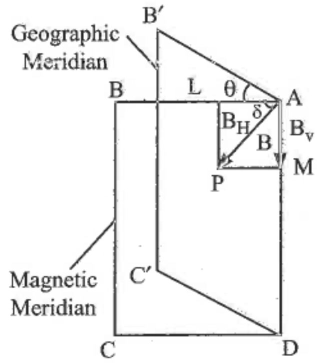
93. The magnetic moment of atomic neon is equal to :
(a) 0
(b) (1/2) μ_B
(c) μ_B
(d) (3/2) μ_B

where, μ_B is the Bohr's magneton.

94. Due to earth's magnetic field, the charged particles :
(a) require greater K.E. to reach equator than pole
(b) require less K.E. to reach equator than pole
(c) can never reach poles
(d) can never reach the equator.

INPUT TEXT BASED MCQ'S

1. *The magnetic field lines of the earth resemble that of a hypothetical magnetic dipole located at the centre of the earth. The axis of the dipole does not coincide with the axis of rotation of the earth but is presently tilted by approximately 11.3° with respect to the later. If the magnetic needle is perfectly balanced about a horizontal axis so that it can swing in a plane of the magnetic meridian, the needle would make an angle with the horizontal. This is known as the angle of dip (also known as inclination).*



(i) At the poles, the dip needle will

(a) stay horizontal
(b) stay vertical
(c) stays at 45° angle with the horizontal
(d) does not remain steady in any fixed position

(ii) In a certain place, the horizontal component of magnetic field is $\frac{1}{\sqrt{3}}$ times the vertical component. The angle dip at this place is

(a) 0 (b) 60° (c) 90° (d) 30°

(iii) What is the angle of dip at the equator?

(a) 0° (b) 45° (c) 60° (d) 90°

(iv) Which of the following independent quantities is not used to specify the earth's magnetic field?

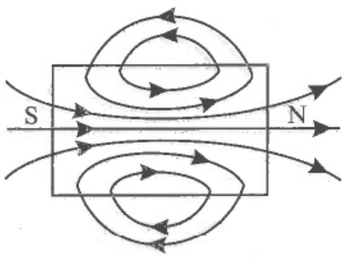
(a) Magnetic declination (θ)
(b) Angle of dip (δ)
(c) Horizontal component of earth's magnetic field (B_H)
(d) Vertical component of earth's magnetic field (B_V)

(v) A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It

(a) will become rigid showing no movement
(b) will stay in any position
(c) will stay in north-south direction only
(d) will stay in east-west direction only

2. *In electrostatics we have studied the Gauss's law that is the number of lines leaving the surface is equal to the number of lines entering it. By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as* $\oint \vec{B}\, d\vec{S} = \mu_0 m_{inside}$ *where* $\oint \vec{B}\, \vec{dS}$ *is the magnetic flux and* m_{inside} *is the net pole strength inside the closed surface.*

We do not have an isolated magnetic pole in nature. At least none has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



(i) Consider the two idealised systems

(i) a parallel plate capacitor with large plates and small separation and
(ii) a long solenoid of length $l >> R$, radius of corss-section

In (i) $\vec{E}$ is ideally treated as a constant between plates and zero outside. In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as

(a) case (i) contradicts Gauss's law for electrostatic fields.
(b) case (ii) contradicts Gauss's law for magnetic fields.
(c) case (i) agress with $\phi \vec{E} \cdot \vec{dl} = 0$
(d) case (ii) contradicts $\phi \vec{H} \cdot \vec{dl} = 1_{cm}$.

(ii) The net magnetic flux through any closed surface, kept in a magnetic field is

(a) zero (b) $\frac{\mu_0}{4\pi}$ (c) $4\pi\mu_0$ (d) $\frac{4\mu_0}{\pi}$

(iii) A closed surface S encloses a magnetic dipole of magnetic moment $2ml$. The magnetic flux emerging from the surface is

(a) $\mu_0 m$ (b) zero (c) $2\mu_0 m$ (d) $\frac{2m}{\mu_0}$

(iv) Which of the following is not a consequence of Gauss's law?

(a) The magnetic poles always exist as unlike pairs of equal strength.

(b) If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface.

(c) There are abundant sources or sinks of the magnetic field inside a closed surface.

(d) Isolated magnetic poles do not exist.

(v) The surface integral of a magnetic field over a surface

(a) is proportional to mass enclosed

(b) is proportional to charge enclosed

(c) is zero

(d) equal to its magnetic flux through that surface

ANSWERS

1. (a)	**2.** (b)	**3.** (c)	**4.** (c)	**5.** (b)	**6.** (c)	**7.** (d)	**8.** (a)	**9.** (a)	**10.** (a)
11. (c)	**12.** (c)	**13.** (a)	**14.** (c)	**15.** (c)	**16.** (b)	**17.** (a)	**18.** (b)	**19.** (a)	**20.** (c)
21. (c)	**22.** (d)	**23.** (b)	**24.** (a)	**25.** (b)	**26.** (c)	**27.** (c)	**28.** (a)	**29.** (b)	**30.** (a)
31. (a)	**32.** (a)	**33.** (b)	**34.** (b)	**35.** (d)	**36.** (d)	**37.** (d)	**38.** (c)	**39.** (d)	**40.** (b)
41. (c)	**42.** (a)	**43.** (b)	**44.** (b)	**45.** (a)	**46.** (b)	**47.** (b)	**48.** (c)	**49.** (d)	**50.** (a)
51. (b)	**52.** (a)	**53.** (b)	**54.** (b)	**55.** (b)	**56.** (c)	**57.** (b)	**58.** (d)	**59.** (b)	**60.** (b)
61. (b)	**62.** (b)	**63.** (b)	**64.** (c)	**65.** (b)	**66.** (a)	**67.** (c)	**68.** (a)	**69.** (a)	**70.** (c)
71. (c)	**72.** (b)	**73.** (c)	**74.** (b)	**75.** (b)	**76.** (d)	**77.** (a)	**78.** (d)	**79.** (d)	**80.** (b)
81. (b)	**82.** (c)	**83.** (c)	**84.** (b)	**85.** (c)	**86.** (d)	**87.** (a)	**88.** (d)	**89.** (c)	**90.** (b)
91. (c)	**92.** (d)	**93.** (a)	**94.** (a)						

Input Text Based MCQ's

1. (i) (b), (ii) (b), (iii) (a), (iv) (d), (v) (a) **2.** (i) (b), (ii) (a), (iii) (b), (iv) (c), (v) (d)