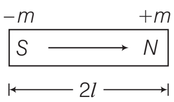
C H A P T E R

5

Magnetism and Matter

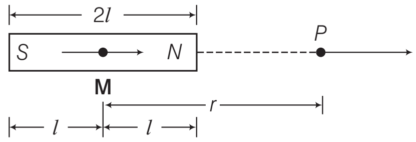
A Quick Recapitulation of the Chapter

1. Magnetic materials tend to point in the North-South direction. Like magnetic poles repel and unlike poles attract each other.
2. Cutting a bar magnet creates two smaller magnets. Therefore, magnetic poles cannot be separated *i.e.,* magnetic monopole does not exist.
3. **Magnetic field lines** are imaginary lines which give pictorial representation for the magnetic field inside and around a magnet.
   Their properties are given below
   (i) These lines form continuous closed loops.
   (ii) The tangent to the field line gives direction of the field at that point.
   (iii) Greater the density of the lines, stronger will be the magnetic field.
   (iv) These lines do not intersect one another.
4. Current bearing loop of wire behaves like a magnetic dipole whose **dipole moment** is given by
$$M = IA$$
   The direction of dipole moment can be obtained by right hand thumb rule. Its SI unit is A-m^2.
5. **Bar Magnet as an Equivalent Solenoid** The expression for magnetic field at distance r from centre is given by
$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{2\mathbf{M}}{r^3}$$
   This expression is equivalent to magnetic field of bar magnet.
6. The magnetic dipole moment of a magnetic dipole is given by



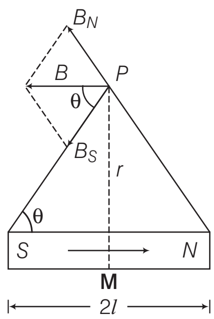
$$\mathbf{M} = m \times 2\mathbf{l}$$

   where, m is pole strength and $2\mathbf{l}$ is dipole length directed from S to N. The SI unit of magnetic dipole moment is A-m^2 or JT^{-1}. It is a vector quantity and its direction is from South pole to North pole.
7. **Magnetic Field due to a Bar Magnet**
   (i) The magnetic field in free space at a distance r from the given bar magnet along its axial line is given by
$$B = \frac{\mu_0}{4\pi} \cdot \frac{2Mr}{(r^2 - l^2)^2}$$



   When $r >> l$, the above relation is simplified as
$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{2\,\mathbf{M}}{r^3} \qquad (\because\ r >> l)$$
   The direction of magnetic field is along the **direction** of magnetic dipole **moment (M)**.

   (ii) Along the equatorial line of a magnetic dipole, the magnetic field **B** in free space is given by
$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{M}{(r^2 + l^2)^{3/2}}$$
$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{\mathbf{M}}{r^3} \qquad (\because\ r >> l)$$



   The direction of magnetic field is parallel to the magnetic dipole and opposite to the direction of dipole moment.

8. **Torque** on a bar magnet in a uniform magnetic field is

$$\tau = MB \sin\theta = \mathbf{M} \times \mathbf{B}$$

where, θ is the angle between $\mathbf{M}$ and $\mathbf{B}$. Its SI unit is joule per tesla (JT^{-1}).

9. **Oscillation of a Freely Suspended Magnet**

The oscillations of a freely suspended magnet (magnetic dipole) in a uniform magnetic field are SHM.

The time period of oscillation,

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

where, I = moment of inertia of the magnet,
M = magnetic moment and
B = magnetic field intensity.

10. **Potential energy** of a magnetic dipole in a magnetic field is given by

$$U = -MB\cos\theta = -\mathbf{M}\cdot\mathbf{B}$$

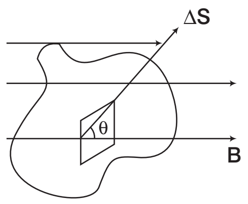
where, θ is the angle between $\mathbf{M}$ and $\mathbf{B}$.

11. **Work done** in rotating the dipole in a uniform magnetic field from θ_1 to θ_2 is given by

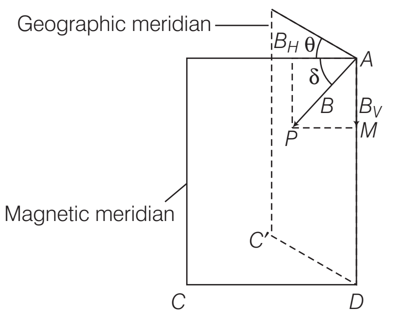
$$W = MB(\cos\theta_1 - \cos\theta_2)$$

12. **Magnetism and Gauss' Law** The net magnetic flux (ϕ_B) through any closed surface is always zero.

$$\phi_B = \Sigma\,\mathbf{B}\cdot\Delta\mathbf{S} = 0$$



13. **Earth's Magnetism** Magnetic declination at a place is the angle between the geographic meridian and magnetic meridian. It is denoted by θ.



Magnetic inclination dip (δ) is the angle made by the direction of the intensity of the total earth's magnetic field with the horizontal direction. If B is intensity of the earth's total magnetic field and B_V is the vertical component of the earth's magnetic field, then

$$B_H = B\cos\delta, \quad B_V = B\sin\delta$$

so that $B = \sqrt{B_H^2 + B_V^2}$ and $\tan\delta = \dfrac{B_V}{B_H}$

14. **Intensity of magnetisation** of a substance is defined as the magnetic moment induced in the substance per unit volume when placed in the magnetising field.

Thus, $I = \dfrac{M}{V} = \dfrac{m}{A}$

It is a vector quantity and its SI unit is Am^{-1}.

15. **Magnetic intensity** is a measure of the capability of external magnetising field to magnetise the given substance and is mathematically defined as,

$$H = \frac{B_0}{\mu_0} \quad \text{or} \quad H = \frac{B}{\mu}$$

Magnetic intensity H is a vector quantity and its SI unit is Am^{-1}.

16. **Magnetic permeability** is the ability of a material to permit the passage of magnetic lines of force through it $\mu = \dfrac{B}{H}$

17. **Magnetic susceptibility** of a substance is the ratio of intensity of magnetisation I induced in the substance to the magnetic intensity H. Thus, $\chi_m = \dfrac{I}{H}$. It is a scalar term and has no units or dimensions.

(i) $B = \mu_0(H + I)$

(ii) $\mu_r = 1 + \chi_m$

18. Magnetic materials are broadly classified as diamagnetic, paramagnetic and ferromagnetic. For diamagnetic materials χ is negative and small and for paramagnetic materials it is positive and small.

19. Ferromagnetic materials have large χ and are characterised by non-linear relation between $\mathbf{B}$ and $\mathbf{H}$. They show the property of hysteresis.

20. The magnetic susceptibility of a ferromagnetic materials varies as

$$\chi_m \propto \frac{1}{(T - T_c)} \quad \text{or} \quad \chi_m = \frac{C}{(T - T_c)}$$

where, C is a constant. It is known as **Curie-Weiss** law and T_c is curie temperature.

Objective Questions Based on NCERT Text

Topic 1
Magnet and Magnetisation

1. The tip of a suspended magnet which points to the geographic North is called
(a) South-pole (b) North-pole
(c) East-pole (d) West-pole

2. The pattern of iron fillings suggests that the
(a) magnet has only one pole
(b) magnet has two poles
(c) magnet is a magnetic dipole
(d) Both (b) and (c)

3. The pattern of iron filling permit us
(a) to plot the North-South poles
(b) to plot the geographic North-South poles
(c) to plot the magnetic field lines
(d) to plot the electric dipole

4. Magnetic field lines show the direction (at every point) along which a small magnetised needle aligns. Do the magnetic field lines also represent the lines of force on a moving charge at every point?
(a) No
(b) Yes
(c) Neither (a) nor (b)
(d) Given information is not sufficient

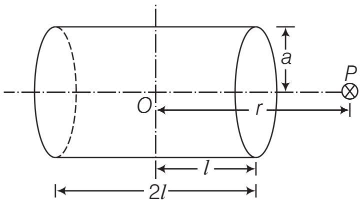
5. The resemblance of magnetic field lines for a bar magnet and a solenoid suggest that
(a) a bar magnet may be thought of as a large number of circulating currents in analogy with a solenoid
(b) cutting a bar magnet in half is like cutting a solenoid
(c) Both (a) and (b)
(d) Neither (a) nor (b)

6. Cutting a bar magnet in half is like cutting a solenoid, such that we get two smaller solenoids with
(a) weaker magnetic properties
(b) strong magnetic properties
(c) constant magnetic properties
(d) Both (a) and (b)

7. The magnetic dipole moment m of a current loop is given by
(a) AI (b) NAI (c) $2NAI$ (d) $\frac{NAI}{2}$

8. The magnitude of the magnetic moment of the solenoid is
(a) $m = n\,(2l), I\,(\pi a^2)$ (b) $m = n\,(4l), I\,(\pi a^2)$
(c) $m = n\,(2l), 2I\,(\pi a^2)$ (d) $m = n\,(2l^2), I\,(\pi a^2)$

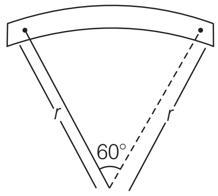
9. In the given figure, the axial magnetic field at a point P, at a distance r from the centre O of a solenoid is (Consider m as the magnitude of the magnetic moment of the solenoid).



(a) $B = \frac{2\mu_0}{3\pi}\frac{2m}{r^3}$ (b) $B = \frac{4}{3}\frac{\mu_0}{\pi}\frac{2m}{r^3}$
(c) $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$ (d) $B = \frac{\mu_0}{2\pi}\frac{2m}{r^3}$

10. Two magnets have the same length and the same pole strength. But one of the magnets has a small hole at its centre. Then,
(a) both have equal magnetic moment
(b) one with hole has small magnetic moment
(c) one with hole has large magnetic moment
(d) one with hole loses magnetism through the hole

11. A bar magnet of length l and magnetic dipole moment M is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be **[NEET 2013]**



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

12. A large magnet is broken into two pieces so that their lengths are in the ratio 2 : 1. The pole strengths of the two pieces will have ratio
(a) 2 : 1 (b) 1 : 2 (c) 4 : 1 (d) 1 : 1

13. If the bar magnet of magnetic moment 40 Am^2 is replaced by a solenoid of cross-sectional area $2 \times 10^{-4}\,m^2$ and 1000 turns but of the same magnetic moment, the current flowing through the solenoid is
(a) − 2 A (b) 2 A (c) 20 A (d) 1 A

14. The length of a magnetised steel wire is l and the magnetic moment is m. It is bent into the shape of L with two sides equal. The magnetic moment now will be

(a) $m/2$ (b) $2m$
(c) $\sqrt{2}\,m$ (d) $m/\sqrt{2}$

15. A straight wire carrying current I is turned into a circular loop. If the magnitude of magnetic moment associated with it in MKS unit is m, then length of the wire will be

(a) $\frac{4\pi}{m}$ (b) $\frac{m\pi}{4I}$
(c) $\sqrt{\frac{4\pi m}{I}}$ (d) $\sqrt{\frac{4\pi I}{m}}$

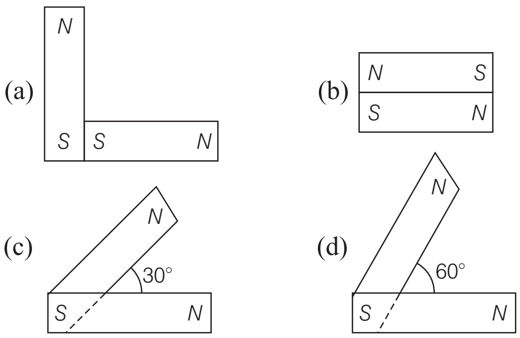
16. A magnet with moment P_m is given. If it is bent into a semi-circular form, its new magnetic moment will be

(a) $\frac{P_m}{\pi}$ (b) $\frac{P_m}{2}$
(c) P_m (d) $\frac{2P_m}{\pi}$

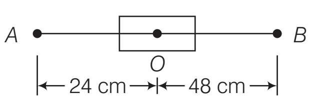
17. The areas of cross-section of three magnets of same lengths are $A, 2A$ and $6A$, respectively. The ratio of their magnetic moments will be

(a) 6 : 2 : 1 (b) 1 : 2 : 6
(c) 2 : 6 : 1 (d) 1 : 1 : 1

18. Following figures show the arrangement of bar magnets in different configurations. Each magnet has magnetic dipole moment m. Which configuration has highest net magnetic dipole moment? **[CBSE AIPMT 2014]**

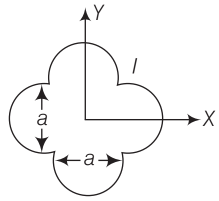


19. A bar magnet of length 3 cm has points A and B along axis at a distance of 24 cm and 48 cm on the opposite ends. Ratio of magnetic fields at these points will be



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

20. A loop carrying current I lies in the XY-plane as shown in figure. The unit vector $\hat{\mathbf{k}}$ is coming out of the plane of the paper. The magnetic moment of the current loop is **[IIT JEE 2013]**



(a) $a^2 I\hat{\mathbf{k}}$ (b) $\left(\frac{\pi}{2}+1\right)a^2 I\hat{\mathbf{k}}$
(c) $-\left(\frac{\pi}{2}+1\right)a^2 I\hat{\mathbf{k}}$ (d) $(2\pi+1)a^2 I\hat{\mathbf{k}}$

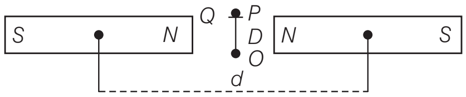
21. The equatorial field (B_E) of a bar magnet at a distance r, for $r >> l$, where l is the size of the magnet is that

(a) $\frac{\mu_0 m}{4\pi r^3}$ (b) $-\frac{\mu_0 m}{4\pi r^3}$ (c) $\frac{\mu_0 m}{4\pi l^3}$ (d) $-\frac{\mu_0 m}{4\pi l^3}$

22. The axial field (B_A) of a bar magnet for $r >> l$ is

(a) $-\frac{\mu_0}{4\pi}\frac{2m}{r^3}$ (b) $\frac{\mu_0}{4\pi}\frac{2m}{r^3}$
(c) $\frac{\mu_0}{4\pi}\frac{2m}{l^3}$ (d) $-\frac{\mu_0}{4\pi}\cdot\frac{2m}{l^3}$

23. Two identical bar magnets are fixed with their centres at a distance d apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance D from the centre O as shown in the figure. The force on the charge Q is



(a) zero
(b) directed along OP
(c) directed along PO
(d) directed perpendicular to the plane of paper

24. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 5.0 cm at a distance of 50 cm from its mid-point ? The magnetic moment of the bar magnet is $0.40\ \text{Am}^2$.

(a) 3.2×10^{-6} T, 6.4×10^{-7} T
(b) 4.2×10^{5} T, 6×10^{-7} T
(c) 5×10^{-6} T, 3.2×10^{-7} T
(d) 3.2×10^{-7} T, 6.4×10^{-7} T

25. The intensity of magnetic field at a point X on the axis of a small magnet is equal to the field intensity at another point Y on equatorial axis. The ratio of distance of X and Y from the centre of the magnet will be

(a) $(2)^{-3}$ (b) $(2)^{-1/3}$ (c) 2^3 (d) $2^{1/3}$

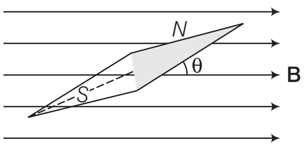
Topic 2
The Dipole in a Uniform Magnetic Field

26. A short bar magnet placed with its axis at 30° with an external field of 800 G experiences a torque of 0.016 Nm. The magnetic moment of the magnet is
(a) 4 Am^2
(b) 0.5 Am^2
(c) 2 Am^2
(d) 0.40 Am^2

27. A short bar magnet 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} Nm. The magnitude of magnetic moment of the magnet is
(a) 0.38 JT^{-1} (b) 0.96 JT^{-1}
(c) 0.48 JT^{-1} (d) 0.36 JT^{-1}

28. A copper rod is suspended in a non-homogenous magnetic field region. The rod when in equilibrium will align itself
(a) in the region where magnetic field is stranger
(b) in the region where magnetic field is weaker and parallel to the direction of magnetic field there
(c) in the direction in which it was originally suspended
(d) in the region where magnetic field is weaker and perpendicular to the direction of magnetic field there

29. In the given figure, the magnetic needle has magnetic moment $6.7 \times 10^{-2}\ Am^2$ and moment of inertia $I = 7.5 \times 10^{-6}$ kg-m^2. It performs 10 complete oscillations in 6.70 s. The magnitude of the magnetic field is



(a) 1.00 T (b) 0.67 T
(c) 0.01 T (d) 1.50 T

30. In the Q. 26, the work done in moving it from its most stable to most unstable position is that
(a) 0.064 J (b) 0.024 J
(c) 0.01 J (d) 3.2 J

31. A short bar magnet of magnetic moment $m = 0.32\ JT^{-1}$ is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field the potential energy which would correspond to its unstable equilibrium?
(a) 4.8×10^{-2} J (b) -4.8×10^{-2} J
(c) 7.5×10^{-2} J (d) 3.6×10^{5} J

32. A rectangular coil of length 0.12 m and width 0.1 m having 50 turns of wire is suspended vertically in a uniform magnetic field of strength 0.2 Wbm^{-2}. The coil carries a current of 2 A. If the plane of the coil is inclined at an angle of 30° with the direction of the field, the torque required to keep the coil in stable equilibrium will be **[CBSE AIPMT 2015]**
(a) 0.15 Nm (b) 0.20 Nm
(c) 0.24 Nm (d) 0.12 Nm

33. A magnet of dipole moment m is aligned in equilibrium position in a magnetic field of intensity B. The work done to rotate it through an angle θ in the magnetic field is
(a) $mB \sin\theta$ (b) $mB \cos\theta$
(c) $mB(1-\cos\theta)$ (d) $mB(1-\sin\theta)$

34. Rate of change of torque τ with deflection θ is maximum for a magnet suspended freely in a uniform magnetic field of induction B, when
(a) $\theta = 0°$ (b) $\theta = 45°$ (c) $\theta = 60°$ (d) $\theta = 90°$

35. Potential energy of a bar magnet of magnetic moment m placed in a magnetic field of induction B such that, it makes an angle θ with the direction of B is
(a) $mB\cos\theta$ (b) $-mB\cos\theta$
(c) $mB(1-\cos\theta)$ (d) $mB(1+\cos\theta)$

36. A thin bar magnet is placed in a uniform magnetic field and is aligned with the field. The needle is now rotated by an angle of 45° and the work done is W. The torque on the magnetic needle at this position is
(a) zero (b) $\frac{W}{\sqrt{2}-1}$
(c) $\frac{W}{\sqrt{2}}$ (d) $\sqrt{2}W$

37. Work done in rotating a bar magnet from 0 to angle 120° is
(a) $\frac{1}{2}MB$ (b) $\frac{3}{2}MB$
(c) MB (d) $\frac{2}{3}MB$

38. A magnetic needle suspended parallel to a magnetic field requires 10 J of work to turn it through 30°. The torque needed to maintain the needle in this position will be
(a) $10\sqrt{3}$ N-m (b) $\sqrt{3}$ N-m
(c) $\frac{10}{2-\sqrt{3}}$ N-m (d) $\frac{2-\sqrt{3}}{10}$ N-m

39. 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

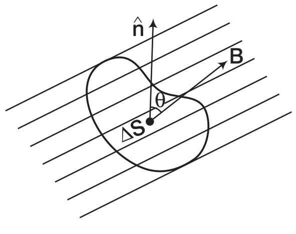
(a) 0.6 J (b) 12 J
(c) 6 J (d) 2 J

40. 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°. The value of n is given by

(a) 2
(b) 1
(c) 0.5
(d) 0.25

Topic 3
Magnetism and Gauss's Law

41. Consider a small vector area element ΔS of a closed surface S as shown in figure. The magnetic flux through ΔS defined as $\Delta\phi_B$ is



(a) $\mathbf{B} \cdot \Delta\mathbf{S}$ (b) $2\mathbf{B} \cdot \Delta\mathbf{S}$ (c) $\mathbf{B} \cdot 2\Delta\mathbf{S}$ (d) $\mathbf{B} \times \Delta\mathbf{S}$

42. In the above question, divide S into many small area elements and the individual flux through each is calculated. Then, net flux ϕ_B is

(a) $\sum_{\text{all}} \mathbf{B} \cdot \Delta\mathbf{S}$ (b) $2\sum_{\text{all}} \mathbf{B} \cdot \Delta\mathbf{S}$
(c) 0 (d) Both (a) and (c)

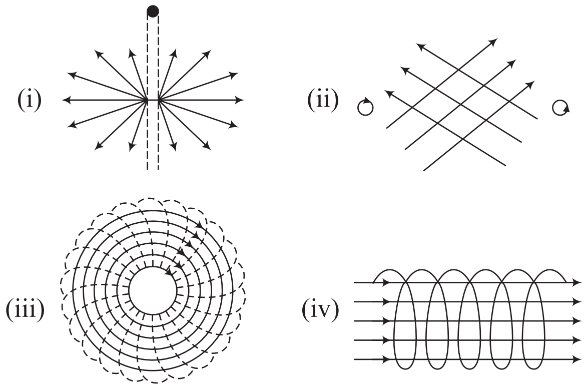
43. In the Gauss's law of electrostatics, the flux through a closed surface is given by

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{2q}{\varepsilon_0}$ (c) $\frac{q}{2\varepsilon_0}$ (d) $\frac{q}{4\varepsilon_0}$

44. Gauss's law for magnetism is

(a) the net magnetic flux through any closed surface is $B \cdot \Delta S$
(b) the net magnetic flux through any closed surface is $E \cdot \Delta S$
(c) the net magnetic flux through any closed surface is 0
(d) Both (a) and (c)

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



(a) Both (i) and (iv) (b) Both (ii) and (iv)
(c) Both (iii) and (iv) (d) Only (iii)

Topic 4
The Earth's Magnetism

46. The strength of the earth's magnetic field varies from place to place on the earth's surface, its value being of the order of

(a) 10^5 T (b) 10^{-6} T (c) 10^{-5} T (d) 10^8 T

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

(a) dynamo effect (b) tidal effect
(c) Both (a) and (b) (d) Neither (a) nor (b)

48. The pole near the geographic North-pole of the earth is called the ……… magnetic pole and the pole near the geographic South-pole is called the ……… magnetic pole.

(a) South-North (b) South-East
(c) North-East (d) North-South

49. The vertical plane containing the longitude circle and the axis of rotation of the earth is called the

(a) geographic meridian (b) magnetic meridian
(c) magnetic declination (d) magnetic inclination

50. One can define ……… of a place as the vertical plane which passes through the imaginary line joining the magnetic North and the South-poles.
(a) geographic meridian (b) magnetic meridian
(c) magnetic declination (d) magnetic inclination

51. Dip is the angle that the total ……… of the of earth makes with the surface of the earth.
(a) magnetic field B_E (b) magnetic inclination
(c) magnetic declination (d) magnetic meridian

52. To describe the magnetic field of the earth at a point on its surface, we need to specify three quantities, *viz* . the declination D, the angle of dip or the inclination and the horizontal component of the earth's field H_E. These are known as the element of the
(a) earth's gravitational field
(b) earth's magnetic field
(c) earth's friction
(d) Both (a) and (b)

53. If a 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
(a) angle of dip (b) angle of inclination
(c) angle of declination (d) Both (a) and (b)

54. The earth's magnetic field at the equator is approximately 0.4 G, the earth's dipole moment is
(a) 1×10^{23} Am^2 (b) 1.05×10^{23} Am^2
(c) 8×10^{22} Am^2 (d) 4×10^2 Am^2

55. In the magnetic meridian of a certain place, the horizontal component of the earth's magnetic field is 0.26 G and the dip angle is 60°. The magnetic field of the earth at this location is
(a) 5.2 G (b) 5.00 G (c) 0.52 G (d) 0.5 G

56. A magnetic dipole is placed in two perpendicular magnetic fields **B** and **H** and is in equilibrium taking angle θ with **B**. Then,
(a) $B = H$ (b) $B \cos\theta = H \sin\theta$
(c) $B \sin\theta = H \cos\theta$ (d) $B = H \tan\theta$

57. If a magnet is suspended at an angle of 30° to the magnetic meridian, the dip needle makes an angle of 45° with the horizontal. The real dip is
(a) $\tan^{-1}(\sqrt{3/2})$ (b) $\tan^{-1}(\sqrt{3})$
(c) $\tan^{-1}(\sqrt{3}/2)$ (d) $\tan^{-1}(2/\sqrt{3})$

58. The time of vibration of a magnetic needle vibrating in the vertical plane is 3 s. When magnetic needle is made to vibrate in the horizontal plane, the time of vibration is $3\sqrt{2}$. Then the angle of dip is
(a) 30° (b) 45° (c) 60° (d) 90°

59. The value of angle of dip is zero at the magnetic equator because on it
(a) V and H are equal
(b) the values of V and H are zero
(c) the value of V is zero
(d) the value of H is zero

60. A bar magnet 30 cm long is placed in the magnetic meridian with its North-pole pointing South. The neutral point is observed at a distance of 30 cm from its centre. Calculate the pole strength of the magnet. (Given, horizontal component of earth's field = 0.34 G)
(a) 4.3 Am (b) 5.2 Am
(c) 6.9 Am (d) 8.6 Am

61. A short bar magnet with the 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) zero (b) $2B_H$
(c) $\frac{\sqrt{5}}{2} B_H$ (d) $\sqrt{5}\, B_H$

62. A bar magnet is placed North-South with its North-pole due North. The points of zero magnetic field will be in which direction from centre of magnet?
(a) North-South
(b) East-West
(c) North-East and South-West
(d) North-East and South-West

63. At a certain place, horizontal component is $\sqrt{3}$ times the vertical component. The angle of dip at this place is
(a) zero (b) $\pi/3$
(c) $\pi/6$ (d) None of these

64. The angle of dip at a certain place where the horizontal and vertical components of the earth's magnetic field are equal is
(a) 30° (b) 90°
(c) 60° (d) 45°

65. At a certain place, the angle of dip is 30° and horizontal component of earth's magnetic field is 0.50 oersted. The earth's total magnetic field (in oersted) is
(a) $\sqrt{3}$ (b) 1
(c) $1/\sqrt{3}$ (d) $1/2$

66. At a certain place, the horizontal component of the earth's magnetic field is B_0 and the angle of dip is 45°. The total intensity of the field at that place will be
(a) B_0 (b) $\sqrt{2}\, B_0$
(c) $2B_0$ (d) B_0^2

67. The earth's magnetic induction at a certain point is 7×10^{-5} Wbm^{-2}. This is to be annulled by the magnetic induction at the centre of a circular conducting loop of radius 15 cm. The required current in the loop is
(a) 0.56 A (b) 5.6 A
(c) 2.28 A (d) 2.8 A

68. A bar magnet 20 cm in length is placed with its South-pole towards geographic North. The neutral points are situated at distance of 40 cm from centre of the magnet. If horizontal component of earth's field $= 3.2\times 10^{-5}$ T, then pole strength of magnet is
(a) 5 A-m (b) 10 A-m (c) 45 A-m (d) 20 A-m

69. When a magnet is placed vertically on horizontal board, number of neutral points obtained on the board is
(a) four (b) three (c) two (d) one

70. 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 $=\frac{T}{2}$
(b) Motion remains simple harmonic with new period $= 2T$
(c) Motion remains simple harmonic with new period $= 4T$
(d) Motion remains simple harmonic and the period stays nearly constant

71. A magnetic instrument placed in magnetic meridian has a small bar magnet. The magnet executes oscillations with a time period of 2 s in the earth's horizontal magnetic field of 24 μT. When a horizontal field of 18μT is produced opposite to the earth's field by placing a current carrying wire, the new time period of magnet will be
(a) 1 s (b) 2s
(c) 3s (d) 4 s

Topic 5
Magnetisation and Magnetic Intensity

72. Property of a bulk material called intensity of magnetisation is
(a) magnetic moment per unit volume
(b) net magnetic moment per unit volume
(c) a vector quantity and having unit of Am^{-1}
(d) Both (b) and (c)

73. Magnetic intensity is define by
(a) $H=\frac{B}{\mu_0}-I$ (b) $H=\frac{B}{\mu_0}+I$
(c) $H=\mu_0(I-B)$ (d) $H=\frac{2B}{\mu_0}-I$

74. ……… is a measure of how a magnetic material responds to an external field.
(a) magnetic field (b) angle of inclination
(c) magnetic susceptibility (d) angle of declination

75. Which one of the following is correct?
(a) $B=\mu H$ (b) $B=2\mu H$
(c) $B=\frac{\mu H}{2}$ (d) $B=\frac{\mu H}{4}$

76. $B=\mu_0\mu_r H$. In the given equation, μ_r is called
(a) relative magnetic permeability of substance
(b) magnetic susceptibility of substance
(c) magnetic permeability of substance
(d) Both (a) and (c)

77. A solenoid has core of a material with relative permeability 400. The windings of the solenoid are insulated from the core and carry a current of 2A.

If the number of turns is 1000 per metre, calculate H and M.
(a) 2×10^3 Am^{-1}, 8×10^5 Am^{-1}
(b) 1.0 Am^{-1}, 1.5×10^5 Am^{-1}
(c) 6.8×10^{-5} Am^{-1}, 1.2×10^{-5} Am^{-1}
(d) 2.1×10^{-4} Am^{-1}, -2.6×10^5 Am^{-1}

78. In the above question, B and the magnetising current is
(a) 1.0 T, 794 A (b) 4.2 T, 594 A
(c) 2.9 T, 698 A (d) 1.9 T, 494 A

79. The core of a toroid having 3000 turns has inner and outer radii 11 cm and 12 cm, respectively. The magnetic field in the core for a current of 0.70 A is 2.5 T. The relative permeability of the core is
(a) 685 (b) 880
(c) 448 (d) 790

80. An iron rod of 0.2 cm^2 cross-sectional area is subjected to a magnetising field of 1200 Am^{-1}. The susceptibility of iron is 599. The permeability will be
(a) 7.9×10^5 T m/A (b) 8.0×10^{22} T m/A
(c) 7.5×10^{-4} T m/A (d) 1.8×10^{-5} T m/A

81. Obtain the earth's magnetisation assuming that the earth's field can be approximated by a giant bar magnet of magnetic moment 8.0×10^{22} Am^2. The earth's radius is 6400 km.

(a) 7.9×10^5 Am^{-1} (b) 73 Am^{-1}
(c) 1.8×10^{-5} Am^{-1} (d) 1.0 Am^{-1}

82. The space inside a toroid is filled with tungsten whose susceptibility is 6.8×10^{-5}. The percentage increase in the magnetic field will be

(a) 0.0068% (b) 0.068%
(c) 0.68% (d) None of these

83. The horizontal component of flux density of earth's magnetic field is 1.7×10^{-6} T. The value of horizontal component of intensity of earth's magnetic field will be

(a) 2.45 Am^{-1} (b) 13.53 Am^{-1}
(c) 1.53 Am^{-1} (d) 0.35 Am^{-1}

84. Hysteresis loss is minimised by using

(a) alloy of steel
(b) shell type of core
(c) thick wire which has low resistance
(d) metal

Topic 6
Magnetic Properties of Materials

85. Which of the following substances have tendency to move from stronger to the weaker part of the external magnetic field?

(a) Paramagnetic (b) Diamagnetic
(c) Ferromagnetic (d) All of these

86. Diamagnetic substances are the ones in which resultant magnetic moment in an atom is

(a) zero (b) half
(c) one-fourth (d) three-fourth

87. The most exotic diamagnetic materials are

(a) conductors (b) superconductors
(c) semiconductors (d) poor conductors

88. If superconductors are cooled to very low temperature, then the exhibit perfect

(a) conductivity (b) diamagnetism
(c) Both (a) and (b) (d) Neither (a) nor (b)

89. When will the field lines be completely expelled?

(a) $\chi = -1$ and $\mu_r = 0$ (b) $-1\leq \chi$ and $\mu_r >> 1$
(c) $\chi \leq 1$ and $\mu_r << 1$ (d) $\chi = 1$ and $\mu_r = 1$

90. The phenomenon of perfect diamagnetism in super-conductors is called the

(a) Tidal effect (b) Meissner effect
(c) Humus effect (d) None of these

91. Which of the following are used for running magnetically levitated superfast trains?

(a) Diamagnets (b) Paramagnets
(c) Ferromagnets (d) Superconducting magnets

92. If a diamagnetic solution is poured into a U-tube and one arm of this U-tube is placed between 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

93. Which of the following possesses a permanent magnetic dipole moment of their own?

(a) Diamagnetic (b) Paramagnetic
(c) Copper (d) Lead

94. The magnetisation of a paramagnetic material is inversely proportional to the

(a) Curie's constant (b) absolute temperature
(c) susceptibility (d) permeability

95. Which of the following is correct for paramagnet materials?

(a) $M = C\dfrac{B_0}{T}$ (b) $M = 2C\dfrac{B_0}{T}$
(c) $M = B_0\dfrac{T}{C}$ (d) $M = C\dfrac{B_0}{2T}$

96. Curie's law is known as

(a) $\chi = C\dfrac{\mu_0}{T}$ (b) $\chi = C\dfrac{T}{\mu_0}$
(c) $\chi = 2C = \dfrac{\mu_0}{T}$ (d) $\chi = C\dfrac{T}{2\mu_0}$

97. For a paramagnetic material both χ and μ_r depend upon

(a) pressure (b) material
(c) temperature (d) Both (b) and (c)

98. The individual atoms (or ions or molecules) in a ferromagnetic material possess a dipole moment as in a paramagnetic material, so they interact with one another in such a way that they spontaneously align themselves in a common direction over a microscopic volume called

(a) domain (b) bulk
(c) group (d) None of these

99. In non-uniform magnetic field, the ferromagnetic sample tends to move towards the region of

(a) low field (b) high field
(c) Neither (a) nor (b) (d) Both (a) and (b)

100. When the external field is removed in ferromagnetic materials the magnetisation persists, such materials are called

(a) soft ferromagnetic materials
(b) hard ferromagnetic materials
(c) Neither (a) nor (b)
(d) Both (a) and (b)

101. In which type of material the magnetic susceptibility does not depend on temperature?

(a) Diamagnetic (b) Paramagnetic
(c) Ferromagnetic (d) Ferrite

102. Above Curie temperature

(a) a ferromagnetic substance becomes paramagnetic
(b) a paramagnetic substance becomes diamagnetic
(c) a diamagnetic substance becomes paramagnetic
(d) a paramagnetic substance becomes ferromagnetic

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

(a) paramagnetism (b) ferromagnetism
(c) no magnetic property (d) diamagnetism

104. The magnetic susceptibility of a paramagnet material at $-73°C$ is 0.0075. Its value at $-173°C$ will be

(a) 0.015 (b) 0.15 (c) 15.0 (d) 1.50

105. A domain in ferromagnetic iron is in the form of a cube of side length 1 μm. Estimate the number of iron atoms in the domain. The molecular mass of iron is 55 g/mol and its density is 7.9 g cm^{-3}.

(a) 8.65×10^{-10} atoms (b) 8.0×10^{-13} atoms
(c) 8.0×10^{5} atoms (d) 8.65×10^{10} atoms

106. In the above question, calculate the maximum possible dipole moment and magnetisation of the domain. (Given magnetic moment of individual atom $= 9.27 \times 10^{-24}$ units)

(a) 4×10^{4} Am^2, 2×10^{4} Am^{-1}
(b) 20×10^{-6} Am^2, 10×10^{-6} Am^{-1}
(c) 40×10^{-6} Am^2, 80×10^{-6} Am^{-1}
(d) 8.0×10^{-13} Am^2, 8.0×10^{5} Am^{-1}

107. A sample of paramagnetic salt contains 2.0×10^{24} atomic dipoles, each of dipole moment 1.5×10^{-23} JT^{-1}. The sample is placed under a homogenous magnetic field of 0.84 T and cooled to a temperature of 4.2 K. The degree of magnetic saturation achieved is equal to 15%. The total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K is

(a) 3×10^{3} JT^{-1} (b) $4\pi \times 10^{-6}$ JT^{-1}
(c) 7.9 JT^{-1} (d) 7×10^{4} JT^{-1}

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

(a) 4 T (b) 4.48 T (c) 7.9 T (d) 3 T

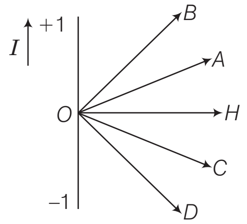
109. The susceptibility of magnesium at 300 K is 1.2×10^{-5}. At what temperature will the susceptibility increase to 1.8×10^{-5}?

(a) 100 K (b) 200 K (c) 300 K (d) 400 K

110. The coercivity of a small magnet where the ferromagnet gets demagnetised 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 demagnetised when inside the solenoid is **[JEE Main 2014]**

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

111. The variation of the intensity of magnetisation I with respect to the magnetising field H in a diamagnetic substance is described by the graph in figure.



(a) OD (b) OC
(c) OB (d) OA

112. The correct measure of magnetic hardness of a material is

(a) remanent magnetism (b) hysteresis loss
(c) coercivity (d) Curie temperature

113. Liquid oxygen remains suspended between two poles of magnet because it is

(a) diamagnetic
(b) paramagnetic
(c) ferromagnetic
(d) anti-ferromagnetic

114. If a diamagnetic substance is brought near the North or the South-pole of a bar magnet, then it is

(a) attracted by the both poles
(b) repelled by both the poles
(c) repelled by the North-pole and attracted by the South-pole
(d) attracted by the North-pole and repelled by the South-pole
(e) None of the above

115. At Curie point, a ferromagnetic material becomes

(a) non-magnetic (b) diamagnetic
(c) paramagnetic (d) strongly ferromagnetic

116. Those substance which at room temperature retain their ferromagnetic property for a long period of time are called
(a) permanent magnets (b) electromagnets
(c) ferromagnets (d) paramagnets

117. It is possible to make magnets out of
(a) iron and its alloys
(b) aluminium and its alloys
(c) copper and its alloys
(d) Both (a) and (b)

118. For making permanent magnet which material is better than soft iron?
(a) Steel (b) Chromium
(c) Copper (d) Nickel

119. Core of electromagnets are made of ferromagnetic materials which have
(a) high permeability (b) low retentivity
(c) Both (a) and (b) (d) None of these

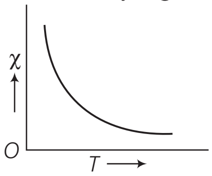
120. In which application the material goes through an AC cycle of magnetisation for a long period?
(a) Transformer cores (b) Telephone diaphragms
(c) Generator (d) Both (a) and (b)

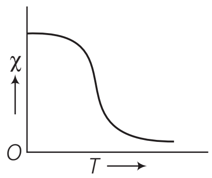
121. The hysteresis cycle for the material of permanent magnet is
(a) short and wide (b) tall and narrow
(c) tall and wide (d) short and narrow

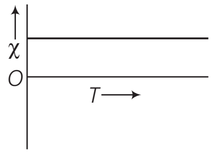
122. Permanent magnet has properties of retentivity and coercivity respectively
(a) high-high (b) low-low
(c) low-high (d) high-low

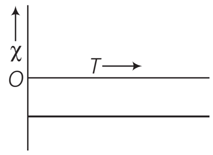
123. Electromagnets are made of soft iron because soft iron has
(a) low susceptibility and low retentivity
(b) low susceptibility and high retentivity
(c) high permeability and low retentivity
(d) high permeability and high coercivity

124. The variation of magnetic susceptibility (χ) with temperature for a diamagnetic substance is best represented by figure

(a) 

(b) 

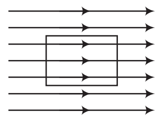
(c) 

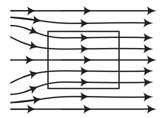
(d) 

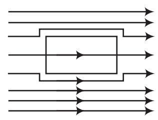
125. Ferromagnetism show their properties due to
(a) filled inner subshells
(b) vacant inner subshells
(c) partially filled inner subshells
(d) all the subshells equally filled

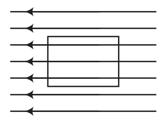
126. As magnetising field on a ferromagnetic material is increased, its permeability
(a) increases (b) decreases
(c) remains constant (d) Cannot say

127. A uniform magnetic field parallel to the plane of paper, existed in space initially directed from left to right. When a bar of soft iron is placed in the field parallel to it, the lines of force passing through it will be represented by figure.

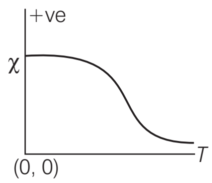
(a) 

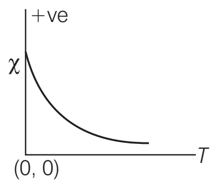
(b) 

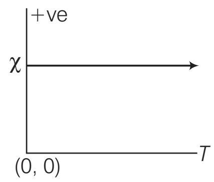
(c) 

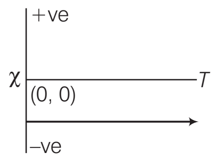
(d) 

128. The variation of magnetic susceptibility (χ) with absolute temperature T for a ferromagnetic is given in figure by

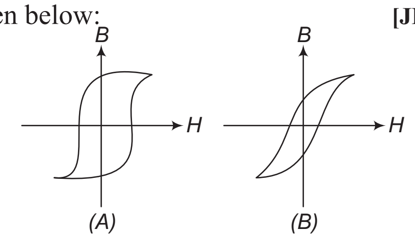
(a) 

(b) 

(c) 

(d) 

129. Hysteresis loops for two magnetic materials A and B are as given below: **[JEE Main 2016]**



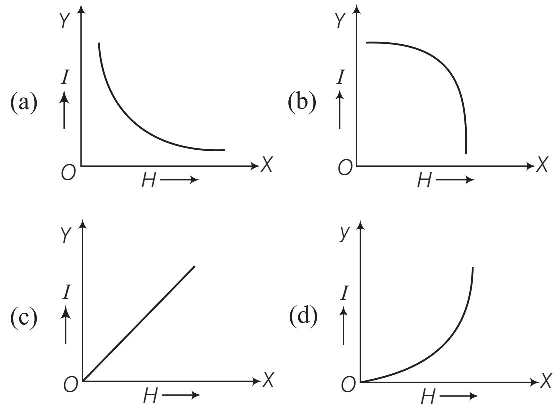
These materials are used to make magnets for electric generators, transformer core and electromagnet core. Then, it is proper to use
(a) A for electric generators and transformers
(b) A for electromagnets and B for electric generators
(c) A for transformers and B for electric generators
(d) B for electromagnets and transformers

130. The relative permeability of a substance X is slightly less than unity and that of substance Y is slightly more than unity, then
(a) X is paramagnetic and Y is ferromagnetic
(b) X is diamagnetic and Y is ferromagnetic
(c) X and Y both are paramagnetic
(d) X is diamagnetic and Y is paramagnetic

131. The susceptibility of a paramagnetic material is K at 27°C. At what temperature will its susceptibility be $K/2$?
(a) 600°C (b) 287°C (c) 34°C (d) 327°C

132. A rod of ferromagnetic material with dimensions $10\text{ cm} \times 0.5\text{ cm} \times 0.2\text{ cm}$ is placed in a magnetic field of strength $0.5 \times 10^4\text{ Am}^{-1}$ as a result of which a magnetic moment of 5 Am^2 is produced in the rod. The value of magnetic induction will be
(a) 0.54 T (b) 6.28 T (c) 0.358 T (d) 2.591 T

133. The current I-H curve for a paramagnetic material is represented by figure.



Special Format Questions

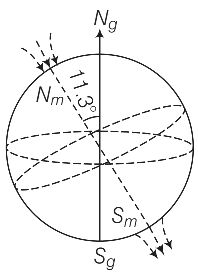
I. Assertion and Reason

Directions (Q. Nos. 135-144) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*
(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

134. Assertion The true geographic North direction cannot be found by using a compass needle.
Reason The magnetic meridian of the earth is along the axis of rotation of the earth.

135. Assertion 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.
Reason The magnetic poles are located where the magnetic field lines due to the dipole enter or leave the earth.

136. Consider the figure,



Assertion Unlike in the case of bar magnet, the field lines go into the earth at the North magnetic pole (N_m) and come out from the South magnetic pole (S_m).
Reason The magnetic North was the direction to which the North-pole of a magnetic needle pointed; the North-pole of a magnet was so named as it was the North seeking pole.

137. Assertion A magnetic needle, which is free to swing horizontally, would lie in the magnetic meridian and the North-pole of the needle would point towards the magnetic North-pole.
Reason The line joining the magnetic poles is tilted with respect to the geographic axis of the earth, the magnetic meridian at a point makes angle with the geographic meridian.

138. Assertion When magnetic field is applied to a diamagnetic substance, those electrons having orbital magnetic moment in the same direction slow down and those in the opposite direction speed up.
Reason This happens due to induced current in accordance with Lenz's law and the substance develops a net magnetic moment in direction opposite to that of the applied field and hence repulsion.

139. Assertion Susceptibility is defined or the ratio of intensity of magnetisation I to magnetic intensity H.
Reason Greater the value of susceptibility smaller value of intensity magnetisation I.

140. Assertion The pole of magnet cannot be separated by breaking into two pieces.
Reason The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

141. Assertion Substances which at room temperature retain their ferromagnetic property for a long period of time are called permanent magnets.

Reason Permanent magnet can be made by placing a ferromagnetic rod a solenoid and passing current through it.

142. Assertion Ferromagnetic substances are those which gets strongly magnetised when placed in an external magnetic field.

Reason The individual atoms (or ions or molecules) in a ferromagnetic material possess a dipole moment as in a paramagnetic material.

143. Assertion A paramagnetic sample displays greater magnetisation (for the same magnetising field) when cooled.

Reason The magnetisation does not depends on temperature.

II. Statement Based Questions Type I

■ **Directions** (Q. Nos. 145-149) *In the following questions, a statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(c) Statement I is correct but Statement II is incorrect.
(d) Statement I is incorrect but Statement II is correct.

144. Statement I The flux through a closed surface in that case is given by, $E \cdot \Delta S = \dfrac{q}{\varepsilon_0}$

Statement II According to Gauss's law for magnetism, the net magnetic flux through any closed surface is zero.

145. Statement I The susceptibility of diamagnetic materials does not depend upon temperature.

Statement II Every atom of a diamagnetic materials is not a complete magnet in itself.

146. Statement I Paramagnetic substances are those which get weakly magnetised when placed in an external magnetic field.

Statement II Paramagnetic substances have tendency to move from a region of weak magnetic field to strong magnetic field, *i.e.*, they get weakly attracted to a magnet.

147. Statement I Ferromagnetic substances are those which gets strongly magnetised when placed in an external magnetic field.

Statement II Ferromagnetic substances have strong tendency to move from a region of weak magnetic field to strong magnetic field, *i.e.*, they get strongly attracted to a magnet.

148. Statement I The ferromagnetic substances do not obey Curie law.

Statement II At Curie point a ferromagnetic substance start behaving as a paramagnetic substance.

Statement Based Questions Type II

149. Consider the statements given below.

I. The magnetic field lines of a magnet (or a solenoid) form continuous closed loops. This is unlike the electric dipole where, these field lines begin from a positive charge and end on the negative charge or escape to infinity.
II. The tangent to the field line at a given point represents the direction of the net magnetic field B at that point.
III. The larger the number of field lines crossing per unit area, the stronger the magnitude of the magnetic field B.
IV. The magnetic field lines intersect each other.

Which of the following statements are correct?

(a) I, II and IV
(b) I, III and IV
(c) II, III and IV
(d) I, II and III

150. Consider the statements given below.

I. The difference between the Gauss's law of magnetism and that for electrostatics is a reflection of the fact that isolated magnetic poles are not known to exist.
II. There are no sources or sinks of B, the simplest magnetic element is a dipole or a current loop.
III. All magnetic phenomena can be explained in terms of an arrangement of dipoles and/or current loops.

Choose the correct options from those given below.

(a) I and II are correct, III may be correct
(b) I and III are incorrect, II may be correct
(c) II and III are correct, I is incorrect
(d) I, II and III are correct

151. Which of the following statements is/are correct about magnetism?

I. The earth behaves as a magnet with the magnetic field pointing approximately from the geographic South to the North.
II. When a bar magnet is freely suspended, it points in the North-South direction. The tip which points to the geographic North is called the North-pole and the tip which points to geographic South is called the South-pole of magnet.

III. There is a repulsive force when North-poles (or South-poles) of two magnets are brought close together. Conversely, there is an attractive force between the North-pole of one magnet and the South-pole of other.

IV. We can isolate the North or South-pole of a magnet.

Which of the following statements are correct?

(a) I, II and IV
(b) I, II may be correct, III and IV are correct
(c) III and IV may be correct and I, II are correct
(d) I, II and III

152. I. The magnetic field lines of the earth resemble that of a (hypothetical) magnetic dipole located at the centre of the earth.

II. The location of the North magnetic pole is at a latitude of 79.74′′N and a longitude of 71.8′′W, a place somewhere in North Canada.

III. The magnetic South-pole is at 79.74′′S, 108.22′′E in the Antarctica.

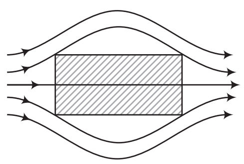
(a) I, II and III are correct
(b) I and III are correct but II may be correct
(c) I and II are incorrect and III is correct
(d) I and II are correct but III may be correct

153. Consider the given statement with respect to the figure showing a bar of diamagnetic material placed in an external magnetic field.

I. The field lines are repelled or expelled and the field inside the material is reduced.

II. When placed in a non-uniform magnetic field, the bar will tend to move from high to low field.

III. Reduction the field inside the material slight, being one part in 10^5.



Choose the correct options from these given below.

(a) I, II are correct, III may be correct
(b) I, III are correct, II may be correct
(c) II, III are correct, I may be correct
(d) I, II and III are correct

154. I. When an iron rod in the North-South direction is hammered repeatedly, it becomes a magnet.

II. A steel rod is striked with one end of a bar magnet a large number of times, always in the same sense to make a permanent magnet.

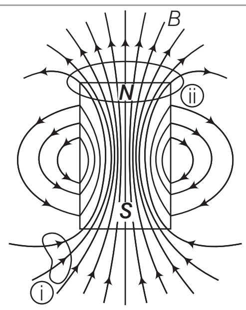
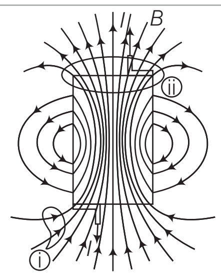
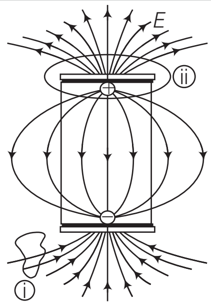
III. A permanent can be made by placing a ferromagnetic rod in a solenoid and passing a current.

Which of the following statements are in correct?

(a) I and II (b) II and III
(c) I, II and III (d) None of the above

III. Matching Type

155. Match the terms of Column I with the items of Column II and choose the correct option from the codes given below.

	Column I	Column II
A.		1. The field lines of a current carrying finite solenoid
B.		2. A field lines of electric dipole
C.		3. The field lines of a bar magnet

	A	B	C		A	B	C
(a)	2	1	3	(b)	3	1	2
(c)	1	2	3	(d)	2	3	1

156. Consider the expression for magnetic potential energy, match the terms of Column I with the items of Column II and choose the correct option from the codes given below.

	Column I		Column II
A.	Potential energy at $\theta = 90°$	1.	Minimum
B.	Potential energy at $\theta = 0°$	2.	Maximum
C.	Potential energy at $\theta = 180°$	3.	Zero

	A	B	C		A	B	C
(a)	3	1	2	(b)	1	2	3
(c)	2	1	3	(d)	1	3	2

157. With reference to electric dipole, match the terms of Column I with the items of Column II and choose the correct option from the codes given below.

Column I	Column II
A. Dipole moment	1. $2\mathbf{p}/4\pi\varepsilon_0 r^3$
B. Equatorial field for a short dipole	2. $-\mathbf{p}\cdot\mathbf{E}$
C. Axial field for a short dipole	3. $\mathbf{p}\times\mathbf{E}$
D. External field : Torque	4. $-\mathbf{p}/4\pi\varepsilon_0 r^3$
E. External field : Energy	5. $\mathbf{p}$

	A	B	C	D	E
(a)	3	1	2	5	4
(b)	5	4	1	3	2
(c)	4	2	5	1	3
(d)	2	4	5	3	1

158. With reference to magnetic dipole, match the terms of Column I with the terms of Column II and choose the correct option from the codes given below.

Column I	Column II
A. Dipole moment	1. $-\mathbf{m}\cdot\mathbf{B}$
B. Equatorial field for a short dipole	2. $\mathbf{m}\times\mathbf{B}$
C. Axial field for a short dipole	3. $-\mu_0\mathbf{m}/4\pi r^3$
D. External field : Torque	4. $\mathbf{m}$
E. External field : Energy	5. $\mu_0 2\mathbf{m}/4\pi r^3$

	A	B	C	D	E
(a)	4	3	5	2	1
(b)	5	3	4	1	2
(c)	3	5	1	2	4
(d)	1	4	2	3	5

159. Match the terms of Column I with the items of Column II and choose the correct option from the codes given below.

Column I	Column II
A. Horizontal component	1. $B_E \sin I$
B. Vertical component	2. Z_E/H_E
C. $\tan I$	3. $B_E \cos I$

	A	B	C
(a)	3	2	1
(b)	2	3	1
(c)	3	1	2
(d)	1	3	2

160. Match the terms of Column I with the items of Column II and choose the correct option from the codes given below.

Column I	Column II
A. Negative susceptibility	1. Ferromagnetic
B. Positive and small susceptibility	2. Diamagnetic
C. Positive and large susceptibility	3. Paramagnetic

	A	B	C
(a)	3	2	1
(b)	1	2	3
(c)	2	3	1
(d)	2	1	3

161. Match the terms of Column I with the items of Column II and choose the correct option from the codes given below.

Column I	Column II
A. Diamagnetic	1. $\mu >> \mu_0, \mu_r >> 1$ and $\chi >> 1$
B. Paramagnetic	2. $-1 \le \chi < 0, 0 \le \mu_r < 1$ and $\mu < \mu_0$
C. Ferromagnetic	3. $0 < \chi < \varepsilon, 1 < \mu_r < 1 + \varepsilon$ and $\mu > \mu_0$

	A	B	C
(a)	1	2	3
(b)	2	3	1
(c)	2	1	3
(d)	3	2	1

IV. Passage Based Questions

■ **Directions** (Q. Nos. 163-164) *These questions are based on the following situation. Choose the correct options from those given below.*

The North-pole and South-pole of a bar magnet of length $2l$ is assigned a magnetic charge (also called pole strength) $+q_m$ and $-q_m$, respectively.

162. The magnetic moment of the bar magnet is

(a) $2q_m\ (2l)$ (b) $4q_m\ (2l)$

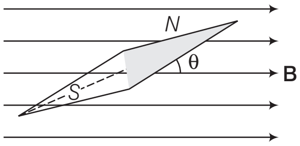
(c) $\frac{q_m}{2}\ (2l)$ (d) $q_m\ (2l)$

163. The field strength due to q_m at a distance r from it is given by

(a) $\frac{\mu_0 q_m}{2\pi r^2}$ (b) $\frac{2\mu_0 q_m}{\pi r^2}$ (c) $\frac{3}{4}\frac{\mu_0 q_m}{\pi r^2}$ (d) $\frac{\mu_0 q_m}{4\pi r^2}$

■ **Directions** (Q. Nos. 165-169) *These questions are based on the following situation. Choose the correct options from those given below.*

To determine the magnitude of $\mathbf{B}$ accurately, a small compass needle of known magnetic moment m and moment of inertia I is allowed to oscillate in the magnetic field. This arrangement is shown in figure.



164. The torque on the needle is

(a) $\tau = 2\,\mathbf{m}\times\mathbf{B}$ (b) $\tau = \mathbf{m}\times\mathbf{B}$

(c) $\tau = \mathbf{m}\times\mathbf{B}/2$ (d) $\tau = \mathbf{m}\times 2\,\mathbf{B}$

165. Which of the following represents a simple harmonic motion?

(a) $\frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta$ (b) $\frac{d\theta}{dt^2} = -\frac{mB}{I}\theta$

(c) $\frac{d^2\theta}{dt} = \frac{mB}{I}\theta$ (d) $\frac{d^2\theta}{dt^2} = \frac{mB}{I}\theta$

166. The time period of oscillation of the dipole is

(a) $2\pi\sqrt{\dfrac{2I}{mB}}$ (b) $2\pi\sqrt{\dfrac{I}{2mB}}$

(c) $4\pi\sqrt{\dfrac{I}{mB}}$ (d) $2\pi\sqrt{\dfrac{I}{mB}}$

167. The magnitude of the magnetic field if time period is T is

(a) $B=\dfrac{4\pi^2 I}{mT^2}$ (b) $B=\dfrac{2\pi^2 I}{mT^2}$

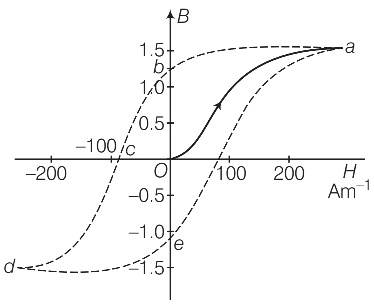
(c) $B=\dfrac{\pi^2 I}{2mT^2}$ (d) $B=\dfrac{3\pi^2 I}{2\,mT^2}$

168. The magnetic potential energy U_m is given by

(a) $U_m = -\,\mathbf{m}\cdot\mathbf{B}$ (b) $U_m = \mathbf{m}\cdot\mathbf{B}$

(c) $U_m = 2\mathbf{m}\cdot\mathbf{B}$ (d) $U_m = -\,2\mathbf{m}\cdot\mathbf{B}$

■ **Directions** (Q. Nos. 170-172) *Answer the following questions based on given figure.*



169. From the figure, the retentivity or remanence is

(a) value of B at $H = 0$

(b) value of B at $H = 100$

(c) value of B at $H = -100$

(d) value of B at $H = -10$

170. The coercivity of the material is

(a) value of H at c (b) value of H at b

(c) value of H at e (d) value of H at d

171. For a given value of H, B is not unique but depends on the magnetic history of the sample. This phenomenon is called

(a) coercivity (b) remanence

(c) retentivity (d) hysteresis

V. More than One Option Correct

172. A magnetic dipole is placed North-South P_1, P_2, Q_1, Q_2 are four points at the same distance from the dipole towards North, South, East and West respectively. The directions of magnetic fields due to the dipole are same at

(a) P_1 and P_2 (b) Q_1 and Q_2

(c) P_1 and Q_1 (d) P_2 and Q_2

173. The magnetic field lines of magnet

(a) are continuous

(b) are called magnetic line of force

(c) intersect each other

(d) are emerging from one face and entering into the other face.

174. A horizontal circular loop carries a current that loops anti-clockwise when viewed from above. It is replaced by an equivalent magnetic dipole N-S which of the following is true?

(a) The line N-S should be along a diameter of the loop

(b) The line N-S should be perpendicular to the plane of the loop

(c) South pole should be below the loop

(d) North pole should be above the loop

175. A circular coil of 16 terms and radius 10 cm carrying a current of 0.75 A rests with its plane normal to an external field of magnitude 5.0×10^{-2} T.

(a) Magnetic moment of the coil is 0.377 JT^{-1}

(b) If coil oscillates about its stable equilibrium with a frequency of 0.2/s, then moment of inertia of the coil will be 1.2×10^{-4} kg-m^2

(c) If coil oscillates about its stable equilibrium with a frequency of 0.3/s, then moment of inertia of the coil will be 3.2×10^{-4} kg-m^2

(d) If the moment of inertia is 4×10^{-2}, then coil oscillates with frequency of 3/s

176. Diamagnetism substances

(a) are those which have tendency to move from stronger to the weaker part of the external magnetic field

(b) Develops a net magnetic moment in direction opposite to that of the applied

(c) The most exotic diamagnetic materials are non-superconductors

(d) None of the above

177. Which of the following characteristic are correct associated with a ferromagnetic material?

(a) It is strongly attracted by a magnetic

(b) It tends to move from a region of strong magnetic field to a region of weak magnetic field

(c) It origin is the spin of electron

(d) Above the Curie temperature, it exhibits paramagnetic properties

NCERT & NCERT Exemplar Questions

NCERT

178. A short bar magnet placed with its axis at 30º with a uniform external magnetic field of 0.25 T experiences a torque of magnitude equal to 4.5×10^{-2} J. What is the magnitude of magnetic moment of the magnet?
(a) 0.36 J/T (b) 0.63 J/T (c) 0.64 J/T (d) 0.60 J/T

179. A short bar magnet of magnetic moment, $m = 0.32\ \text{JT}^{-1}$ is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field, which orientation would correspond to its (a) stable and (b) unstable equilibrium? What is the potential energy of the magnet in each case?
(a) 8.4×10^{-2} J, 4.8×10^{-2} J
(b) -4.8×10^{-2} J, 4.8×10^{-2} J
(c) 0.32×10^{-2} J, -0.32×10^{-2} J
(d) -23×10^{-2} J, 0.23×10^{-2} J

180. A bar magnet of magnetic moment 1.5 J/T lies aligned with the direction of a uniform magnetic field of 0.22 T. What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment to the field direction.
(a) 0.66 J (b) 0.44 J
(c) 0.33 J (d) None of these

181. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its North tip pointing down at 22º with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.35 G. The magnitude of the earth's magnetic field at the place will be
(a) 0.68 G (b) 0.38 G
(c) 0.83 G (d) 0.86 G

182. At a certain location in Africa, a compass points 12º West of the geographic North. The North tip of the magnetic needle of a dip circle placed in the plane of magnetic meridian points 60º above the horizontal. The horizontal component of the earth's field is measured to be 0.16 G. The magnitude of the earth's field at the location will be
(a) 0.23×10^{-4} T (b) 0.18×10^{-4} T
(c) 0.32×10^{-4} T (d) 0.81×10^{-4} T

183. A short bar magnet of magnetic moment $5.25 \times 10^{-2}\ \text{JT}^{-1}$ is placed with its axis perpendicular to the earth's field direction. Magnitude of the earth's field as the plane is given to be 0.42 G. Ignore the length of the magnet in comparison to the distance involved.
(i) At what distance from the centre of the magnet, the resultant field is inclined at 45° with the earth's field on normal bisector?
(a) 5 cm (b) 6 cm
(c) 7 cm (d) 8 cm
(ii) At what distance from the centre of the magnet, the resultant field is inclined at 45° with the earth's field on its axis?
(a) 7.3 cm (b) 3.6 cm
(c) 3.7 cm (d) 6.3 cm

184. A compass needle free to turn in a horizontal plane is placed at the centre of circular coil of 30 turns and radius 12 cm. The coil is in a vertical plane making an angle of 45º with the magnetic meridian. When the current in the coil is 0.35 A, the needle points West to East. The horizontal component of the earth's magnetic field at the location will be
(a) 3.9×10^{-5} T (b) 9.3×10^{-5} T
(c) 4.9×10^{-5} T (d) 9.5×10^{-5} T

NCERT Exemplar

185. 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 ($\mathbf{m} = m\,\phi$)
(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

186. 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

187. 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

188. 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 cross-section. In (i) **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 below.

(a) Case (i) contradicts Gauss' law for electrostatic fields

(b) Case (ii) contradicts Gauss' law for magnetic fields

(c) Case (i) agrees with $\oint \mathbf{E} \cdot d\mathbf{l} = 0$.

(d) Case (ii) contradicts $\oint \mathbf{H} \cdot d\mathbf{l} = I_{en}$

189. A paramagnetic sample shows a net magnetisation of $8\ \text{Am}^{-1}$ when placed in an external magnetic field of 0.6 T at a temperature of 4 K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16 K, the magnetisation will be

(a) $\frac{32}{3}\ \text{Am}^{-1}$ (b) $\frac{2}{3}\ \text{Am}^{-1}$

(c) $6\ \text{Am}^{-1}$ (d) $2.4\ \text{Am}^{-1}$

190. S is the surface of a lump of magnetic material.

(a) Lines of **B** are necessarily continuous across S

(b) Some lines of **B** must be discontinuous across S

(c) Lines of **H** are necessarily continuous across S

(d) Lines of **H** cannot all be continuous across S

191. The primary origin (*s*) of magnetism lies in

(a) atomic currents

(b) Pauli exclusion principle

(c) polar nature of molecules

(d) intrinsic spin of electron

192. A long solenoid has 1000 turns per metre and carries a current of 1 A. It has a soft iron core of $\mu_r = 1000$. The core is heated beyond the Curie temperature, T_C.

(a) The **H** field in the solenoid is (nearly) unchanged but the **B** field decreases drastically

(b) The **H** and **B** fields in the solenoid are nearly unchanged

(c) The magnetisation in the core reverses direction

(d) The magnetisation in the core diminishes by a factor of about 10^8

193. Essential difference between electrostatic shielding by a conducting shell and magnetostatic shielding is due to

(a) electrostatic field lines can end on charges and conductors have free charges

(b) lines of **B** can also end but conductors cannot end them

(c) lines of **B** cannot end on any material and perfect shielding is not possible

(d) shells of high permeability materials can be used to divert lines of **B** from the interior region

194. Let the magnetic field on the earth be modelled by that of a point magnetic dipole at the centre of the earth. The angle of dip at a point on the geographical equator

(a) is always zero

(b) can be zero at specific points

(c) can be positive or negative

(d) is bounded

Answers

1.	(b)	**2.**	(d)	**3.**	(c)	**4.**	(a)	**5.**	(c)	**6.**	(a)	**7.**	(b)	**8.**	(a)	**9.**	(c)	**10.**	(b)	**11.**	(a)	**12.**	(d)	**13.**	(b)	**14.**	(d)	**15.**	(c)
16.	(d)	**17.**	(b)	**18.**	(c)	**19.**	(a)	**20.**	(b)	**21.**	(b)	**22.**	(b)	**23.**	(a)	**24**	(d)	**25.**	(d)	**26.**	(d)	**27.**	(d)	**28.**	(d)	**29.**	(c)	**30.**	(a)
31.	(a)	**32.**	(b)	**33.**	(c)	**34.**	(a)	**35.**	(b)	**36.**	(b)	**37.**	(b)	**38.**	(c)	**39.**	(c)	**40.**	(a)	**41.**	(a)	**42.**	(d)	**43.**	(a)	**44.**	(c)	**45.**	(d)
46.	(c)	**47.**	(a)	**48.**	(d)	**49.**	(a)	**50.**	(b)	**51.**	(a)	**52.**	(b)	**53.**	(d)	**54.**	(b)	**55.**	(c)	**56.**	(c)	**57.**	(d)	**58.**	(c)	**59.**	(c)	**60.**	(d)
61.	(d)	**62.**	(b)	**63.**	(c)	**64.**	(d)	**65.**	(c)	**66.**	(b)	**67.**	(b)	**68.**	(c)	**69.**	(d)	**70.**	(b)	**71.**	(d)	**72.**	(d)	**73.**	(a)	**74.**	(c)	**75.**	(a)
76.	(a)	**77.**	(a)	**78.**	(a)	**79.**	(a)	**80.**	(c)	**81.**	(b)	**82.**	(a)	**83.**	(b)	**84.**	(d)	**85.**	(b)	**86.**	(a)	**87.**	(b)	**88.**	(c)	**89.**	(a)	**90.**	(b)
91.	(d)	**92.**	(b)	**93.**	(b)	**94.**	(b)	**95.**	(a)	**96.**	(d)	**97.**	(a)	**98.**	(a)	**99.**	(b)	**100.**	(b)	**101.**	(a)	**102.**	(a)	**103.**	(a)	**104.**	(a)	**105.**	(d)
106.	(d)	**107.**	(c)	**108.**	(b)	**109.**	(b)	**110.**	(c)	**111.**	(c)	**112.**	(c)	**113.**	(b)	**114.**	(b)	**115.**	(c)	**116.**	(a)	**117.**	(a)	**118.**	(a)	**119.**	(c)	**120.**	(d)
121.	(c)	**122.**	(a)	**123.**	(c)	**124.**	(d)	**125.**	(c)	**126.**	(b)	**127.**	(b)	**128.**	(a)	**129.**	(d)	**130.**	(d)	**131.**	(d)	**132.**	(b)	**133.**	(c)	**134.**	(c)	**135.**	(b)
136.	(a)	**137.**	(b)	**138.**	(c)	**139.**	(c)	**140.**	(b)	**141.**	(b)	**142.**	(c)	**143.**	(b)	**144.**	(d)	**145.**	(b)	**146.**	(b)	**147.**	(b)	**148.**	(d)	**149.**	(d)	**150.**	(d)
151.	(d)	**152.**	(a)	**153.**	(d)	**154.**	(b)	**155.**	(b)	**156.**	(a)	**157.**	(b)	**158.**	(a)	**159.**	(c)	**160.**	(c)	**161.**	(b)	**162.**	(d)	**163.**	(d)	**164.**	(b)	**165.**	(a)
166.	(d)	**167.**	(a)	**168.**	(a)	**169.**	(a)	**170.**	(a)	**171.**	(d)	**172.**	(a, b)	**173.**	(a,b, d)	**174.**	(c,d)	**175.**	(a, b)	**176.**	(a, b)	**177.**	(a,c, d)	**178.**	(a)	**179.**	(b)	**180.**	(c)

Hints *and* Explanations

1. (*b*) The tip of a bar magnet which points to the geographic North is called North-pole.

2. (*d*) The pattern of iron fillings suggests that the magnet has two poles similar to the positive and negative charge of an electric dipole.

3. (*c*) The pattern of iron filling permits us to plot the magnetic field lines.

4. (*a*) No, the magnetic force is always normal to B (remember magnetic force = $q\mathbf{v}\times\mathbf{B}$. It is misleading to call magnetic field lines as lines of force.

5. (*c*) The resemblance of magnetic field lines for a bar magnet and a solenoid suggest that a bar magnet may be thought of as a large number of circulating currents in analogy with a solenoid. Cutting a bar magnet in half is like cutting a solenoid.

We get two smaller solenoids with weaker magnetic properties. The field lines remain continuous, emerging from one face of the solenoid and entering into the other face.

6. (*a*) Cutting a bar magnet in half is like cutting a solenoid, such that we get two smaller solenoids with weaker magnetic properties.

7. (*b*) The magnetic dipole moment m associated with a current loop was defined to be $m = NIA$ where, N is the number of turns in the loop.

8. (*a*) The magnitude of the magnetic moment of the solenoid is $m = n\,(2l)\,(I)\,(\pi a^2)$, where $2l$ is the length and a is the radius of the solenoid.

9. (*c*) Magnitude of the magnetic moment of the solenoid is,

$$m = n\,(2l)\,I\,(\pi a^2)$$

Thus, $$B = \frac{\mu_0}{4\pi}\cdot\frac{2M}{r^3}$$

10. (*b*) As, we know, magnetic dipole moment $\mathbf{m} = m(2\mathbf{l})$, so hole reduces the effective length of the magnet and hence magnetic moment reduces.

11. (*b*) The magnetic moment, $M = ml$

$$l = \frac{\pi}{3}\times r \Rightarrow \quad r = \frac{3l}{\pi}$$

$\therefore$ New magnetic moment

$$M' = M\times r = M\times\frac{3l}{\pi} = \frac{3M}{\pi}$$

12. (*d*) Pole strength does not depend on length.
So, strength of the two pieces will remain same.

13. (*b*) Magnetic moment $m_s = NIA \quad\Rightarrow\quad m_s = 0.40\ \text{Am}^2$

$$\Rightarrow \quad 0.40 = 1000\times I\times 2\times 10^{-4}$$

$$\Rightarrow \quad I = 0.40\times 10^4/(1000\times 2) = 2\text{A}$$

14. (*d*) If q_m is strength of each pole, then $m = q_m\times l$. When the wire is bent into L shape effective distance between the poles

$$= \sqrt{(l/2)^2 + (l/2)^2} = l/\sqrt{2}$$

$$\therefore \quad m' = q_m\times\frac{l}{\sqrt{2}} = \frac{m}{\sqrt{2}} \quad (m \text{ will remain unchanged})$$

15. (*c*) Magnetic moment, $m = IA = I\,(\pi r^2)$, and $l = 2\pi r$

$$r = \sqrt{\frac{m}{\pi I}}$$

The length of the wire $\quad l = 2\pi\sqrt{\frac{m}{\pi I}} = \sqrt{\frac{4\pi m}{I}}$

16. (*d*) As $P_m = q_m\times 2l,\ q_m = \dfrac{P_m}{2l}$.

Here, q_m (and not m) denotes the pole strength as m denotes magnetic moment. Further, as $\pi r = 2l$ or $r = 2l/\pi$

Distance between the two poles, $2l' = 2r = \dfrac{4l}{\pi}$

Magnetic moment $P'_m = q_m\times 2l' = \left(\dfrac{P_m}{2l}\right)\left(\dfrac{4l}{\pi}\right) = 2P_m/\pi$

17. (*b*) As magnetic moment $\propto$ pole strength $\propto$ area of cross-section *i.e.,* $m\propto q_m\propto A$.

$$m_1 : m_2 : m_3 = 1:2:6$$

18. (*c*) Magnetic moment is from S to N

$$M_{\text{net}} = \sqrt{m^2 + m^2 + 2m^2\cos\theta}$$

M_{net} will be maximum, if $\cos\theta$ is maximum, $\cos\theta$ will be maximum when θ will be minimum so, at $\theta = 30°$
M_{net} will be maximum.

19. (*a*) Here, $2l = 3\ \text{cm},\ d_1 = 24\ \text{cm}$ and $d_2 = 48\ \text{cm}$

As the magnet is short

$$\frac{B_1}{B_2} = \frac{d_2^3}{d_1^3} = \left(\frac{48\ \text{cm}}{24\ \text{cm}}\right)^3 = 8$$

20. (*b*) Area of the given loop is A

= (area of two circles of radius $\dfrac{a}{2}$ and area of a square of side a)

$$= 2\pi\left(\frac{a}{2}\right)^2 + a^2 = \left(\frac{\pi}{2}+1\right)a^2$$

$$|\,\mathbf{M}\,| = IA = \left(\frac{\pi}{2}+1\right)a^2 I$$

From screw law, direction of M is outwards or in positive Z-direction.

$$\therefore \quad M = \left(\frac{\pi}{2}+1\right)a^2 I\,\hat{\mathbf{k}}$$

21. (*b*) The magnetic field at large distance due to a bar magnet of magnetic moment $\mathbf{m}$ can be obtained from the equation for electric field due to an electric dipole of dipole moment $\mathbf{p}$ by making the following replacements

$$\mathbf{E}\to\mathbf{B},\ \ \mathbf{p}\to\mathbf{m},\ \frac{1}{4\pi\varepsilon_0}\to\frac{\mu_0}{4\pi}$$

The equatorial field ($\mathbf{B}_E$) of a bar magnet at a distance r, for $r >> l$ is the size of the magnet

$$\mathbf{B}_E = -\frac{\mu_0 \mathbf{m}}{4\pi r^3}$$

22. (*b*) The axial field of a bar magnet for $r >> l$ is $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$

23. (*a*) Magnetic field due to bar magnets exerts force on moving charges only. Since, the charge is at rest, zero force acts on it.

24. (*d*) Magnetic field at equatorial line

$$B_E = \frac{\mu_0 m}{4\pi r^3} = \frac{10^{-7} \times 0.4}{(0.5)^3} = \frac{10^{-7} \times 0.4}{0.125}$$
$$= 3.2 \times 10^{-7}\,\text{T}$$

Magnetic field at axial line $B_A = \frac{\mu_0 2m}{4\pi r^3} = 6.4 \times 10^{-7}\,\text{T}$

25. (*d*) If d_1 is distance of point X one axial line and d_2 is distance of point Y on equatorial line.

Then, $B_A = \frac{\mu_0}{4\pi}\frac{2m}{d_1^3}, B_E = \frac{\mu_0}{4\pi}\cdot\frac{m}{d_2^3}$

As, $B_A = B_E$

$\therefore$ $\frac{\mu_0 2m}{4\pi d_1^3} = \frac{\mu_0 m}{4\pi d_2^3} \Rightarrow d_1^3 = 2d_2^3$

$\Rightarrow$ $d_1 / d_2 = 2^{1/3}$

26. (*d*) The magnetic moment of the magnet

$$\tau = mB \sin\theta, \theta = 30°,$$

hence, $\sin\theta = 1/2$ $\quad(\because 1\,\text{G} = 10^{-4}\text{T})$

Thus, $0.016 = m \times (800 \times 10^{-4}\,\text{T}) \times (1/2)$

$\Rightarrow$ $m = 160 \times 2 / 800 = 0.40\,\text{Am}^2$

27. (*d*) Here, $\theta = 30°, B = 0.25\,\text{T}, \tau = 4.5 \times 10^{-2}\,\text{J}$

As, $\tau = mB\sin\theta$

Magnetic moment of the magnet

$$m = \frac{\tau}{B\sin\theta} = \frac{4.5 \times 10^{-2}\,\text{J}}{(0.25\,\text{T} \times \sin 30°)} = 0.36\,\text{JT}^{-1}$$

29. (*c*) The time period of oscillation is

$$T = \frac{6.70}{10} = 0.67\,\text{s}$$
$$B = \frac{4\pi^2 I}{mT^2} = \frac{4 \times (3.14)^2 \times 7.5 \times 10^{-6}}{6.7 \times 10^{-2} \times (0.67)^2} = 0.01\,\text{T}$$

30. (*a*) The most stable position is $\theta = 0°$ and the most unstable position is $\theta = 180°$, work done is given by

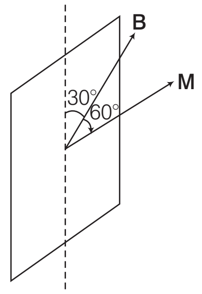
$$W = U_m\,(\theta = 180°) - U_m\,(\theta = 0°)$$
$\Rightarrow$ $= 2\,mB = 2 \times 0.40 \times 800 \times 10^{-4} = 0.064\,\text{J}$

31. (*a*) For unstable equilibrium $\mathbf{m}$ is to be anti-parallel to $\mathbf{B}$. In this case, $\theta = 180°$. Thus,

$$U = -\,mB\cos 180° = -\,mB\,(-1) = mB$$
$$= (0.32\,\text{JT}^{-1})\,(0.15\,\text{T}) = 4.8 \times 10^{-2}\,\text{J}$$

32. (*b*) Given, $N = 50, B = 0.2\,\text{Wbm}^{-2}, I = 2\text{A}$

$$\theta = 60°, A = 0.12 \times 0.1 = 0.012\,\text{m}^2$$



Thus, torque required to keep the coil in stable equilibrium

i.e., $\tau = NIAB\sin\theta$

$= 50 \times 2 \times 0.012 \times 0.2 \times \sin 60°$

$= 50 \times 2 \times 0.12 \times 0.2 \times \frac{\sqrt{3}}{2} = 0.20\,\text{Nm}$

33. (*c*) Work done $W = \int_0^\theta mB\sin\theta\,d\theta = mB\,(1 - \cos\theta)$

(as $\Delta W = \tau\,d\theta = mB\sin\theta\,d\theta$)

34. (*a*) As we know, torque *i.e.*, $\tau = mB\sin\theta, \frac{d\tau}{d\theta} = mB\cos\theta$. It will be maximum when $\theta = 0°$.

35. (*b*) Potential energy PE $= -\,mB\,(\cos\theta_2 - \cos\theta_1)$

When $\theta_1 = 90°$ (position of zero PE), $\theta_2 = \theta$

$$\text{PE} = -\,mB\cos\theta$$

36. (*b*) Given, work done $= W$ and $\theta = 60°$

We know that

$$W = MB(1 - \cos\theta) = MB(1 - \cos 45°) = MB\left(1 - \frac{1}{\sqrt{2}}\right)$$

Hence, torque

$$|T| = MB\sin 45° = \frac{W \times \sqrt{2}}{\sqrt{2} - 1} \times \frac{1}{\sqrt{2}} = \frac{W}{\sqrt{2} - 1}$$

37. (*b*) Work done in rotating a magnet (from angle 0 to θ) is given by

$$W = \int_0^\theta \tau\,d\theta$$

where, τ = torque and $d\theta$ = angular change.

Also, $\tau = MB\sin\theta = \int_0^\theta MB\sin\theta\,d\theta$

$$= MB\int_0^\theta \sin\theta d\theta = MB(-\cos\theta)_0^\theta$$
$$= MB\,(-\cos 120° + \cos 0°) \Rightarrow MB\,(1 + \frac{1}{2}) = \frac{3}{2}MB$$

38. (*c*) In this case, work done

$$W = MB(\cos\theta_1 - \cos\theta_2)$$
$$10 = MB\,(\cos 0° - \cos 30°) \quad (\because \text{Given}, W = 10\,\text{J})$$
$$= MB\left(1 - \frac{\sqrt{3}}{2}\right) \Rightarrow MB = \frac{20}{2 - \sqrt{3}}$$

Torque, $\tau = MB\sin 30°$

$$= \frac{20}{2-\sqrt{3}} \times \frac{1}{2} = \frac{10}{2-\sqrt{3}} \text{ N-m}$$

39. (*c*) When magnetic dipole is rotated from initial position θ_1 to final position θ_2, then work done $= MB(\cos\theta_1 - \cos\theta_2)$

Given, $\theta_1 = 0°, \theta_2 = 60°$

Magnetic moment, $M = 2 \times 10^4 \text{ JT}^{-1}$

Magnetic field, $B = 6 \times 10^{-4}$ T

So, $$W = MB\left(1 - \frac{1}{2}\right) \quad \left(\because \cos 0° = 1 \text{ and } \cos 60° = 1/2\right)$$

$$= \frac{2 \times 10^4 \times 6 \times 10^{-4}}{2} = 6 \text{ J}$$

40. (*a*) Work done in rotating the dipole from θ_1 to θ_2 is

$$W = -MB(\cos\theta_2 - \cos\theta_1)$$

***Case* I** $W_1 = -MB(\cos 90° - \cos 0°) = MB$ ...(i)

***Case* II** $W_2 = -MB(\cos 60° - \cos 0°)$

$$= -MB\left(\frac{1}{2} - 1\right) = \frac{1}{2}MB \quad \text{...(ii)}$$

From Eqs. (i) and (ii), $W_2 = \frac{1}{2}W_1$

As $W_1 = nW_2$

$\therefore$ $n = 2$

41. (*a*) Consider a small vector area element $\Delta\mathbf{S}$ of a closed surface S as shown in figure. The magnetic flux through $\Delta\mathbf{S}$ is defined as $\Delta\phi_B = \mathbf{B}\cdot\Delta\mathbf{S}$ where, $\mathbf{B}$ is the field at $\Delta\mathbf{S}$.

42. (*d*) We divide S into many small area elements and calculate the individual flux through each. Then, the net flux ϕ_B is

$$\phi_B = \sum_{\text{all}} \Delta\phi_B = \sum_{\text{all}} \mathbf{B}\cdot\Delta\mathbf{S} = 0$$

where, all stands for 'all area elements $\Delta\mathbf{S}$'.

43. (*a*) According to Gauss' law, electrostatic flux through a closed surface is given by, $\phi = \sum \mathbf{E}\cdot\Delta\mathbf{S} = \frac{q}{\varepsilon_0}$

44. (*c*) Gauss's law for magnetism is the net magnetic flux through any closed surface is zero.

45. (*d*)

(a) **Wrong** Magnetic field lines can never emanate from a point, as shown in figure over any closed surface, the net flux of B must always be zero, *i.e.*, pictorially as many field lines should seem to enter the surface, as the number of lines leaving it. The field lines shown, in fact, represent electric field of a long positively charged wire. The correct magnetic field lines are circling the straight conductor.

(b) **Wrong** Magnetic field line as (like electric field lines) can never cross each other, because otherwise the direction of field at the point of intersection is ambiguous. There is further error in the figure magnetostatic field lines can never form closed loops around empty space.

A closed loop of static magnetic field line must enclose a region across which a current is passing. By contrast, electrostatic field lines can never form closed loops, neither in empty space nor when the loop encloses charges.

(c) **Right** Magnetic lines are completely confined within a toroid. Nothing wrong here in field lines forming closed loops, since each loop encloses a region across which a current passes. Note, for clarity of figure only a few field lines within the toroid have been shown. Actually, the entire region enclosed by the windings contains magnetic field.

(d) **Wrong** Field lines due to a solenoid at its ends and outside cannot be so completely straight and confined; such a thing violates Ampere's law. The lines should curve out at both ends and meet eventually to form closed loops.

46. (*c*) Earth's magnetic field is of the order of 10^{-5} T.

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

48. (*d*) The pole near the geographic North-pole of the earth is called the North magnetic pole. Likewise, the pole near the geographic South-pole is called the South magnetic pole.

51. (*a*) Dip is the angle that the total magnetic $\mathbf{B}_E$ of the earth makes with the surface of the earth.

54. (*b*) The equatorial field is $B_E = \frac{\mu_0 m}{4\pi r^3}$

$$B_E = 0.4 \text{ G} = 4 \times 10^{-5} \text{ T}$$

Dipole moment, $$m = \frac{4 \times 10^{-5} \times (6.4 \times 10^6)^3}{\mu_0/4\pi}$$

$$= 4 \times 10^2 \times (6.4 \times 10^6)^3 \quad (\because \mu_0/4\pi = 10^{-7})$$

$$= 1.05 \times 10^{23} \text{ Am}^2$$

55. (*c*) $$\cos 60° = \frac{H_E}{B_E}$$

Magnetic field $$B_E = \frac{H_E}{\cos 60°} = \frac{0.26}{(1/2)} = 0.52 \text{ G}$$

56. (*c*) As θ is with B, therefore according to tangent law,

$$H = B\tan\theta = \frac{B\sin\theta}{\cos\theta} \quad \text{or} \quad B\sin\theta = H\cos\theta$$

57. (*d*) $$\tan\theta' = \frac{Z_E}{H'_E} = \frac{Z_E}{H_E\cos\alpha} = \frac{\tan\theta}{\cos\alpha} = \frac{\tan\theta}{\cos 30°}$$

$\Rightarrow$ $\tan\theta = \cos 30°, \tan\theta'$

$$= \cos 30° \tan 45°$$

$$= \frac{\sqrt{3}}{2} \quad (\alpha = 30°, \theta = 45°)$$

$$\theta = \tan^{-1}\frac{\sqrt{3}}{2}$$

58. (*c*) As, we know time of vibration,

$$t_1 = 3 = 2\pi\sqrt{\frac{I}{MR}} \qquad \ldots\text{(i)}$$

where, R is resultant intensity of earth's field and time of vibration of a magnetic needle

i.e., $$t_2 = 3\sqrt{2} = 2\pi\sqrt{\frac{I}{MH}} \qquad \ldots\text{(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{1}{\sqrt{2}} = \sqrt{\frac{H}{R}} = \sqrt{\frac{R\cos\delta}{R}} = \sqrt{\cos\delta} \quad \Rightarrow \cos\delta = \frac{1}{2} \Rightarrow \delta = 60^\circ$$

59. (*c*) At magnetic equator, $V = 0$

$\therefore$ $$\tan\phi = \frac{V}{H} = 0 \quad \Rightarrow \quad \delta = 0$$

i.e., value of angle of dip is zero.

60. (*d*) Here, $2l = 30\,\text{cm}$

$$l = 15\text{ cm} = 0.15\text{ m}, r = 30\text{ cm} = 0.30\text{ m}$$

$$B_H = 0.34\text{ G} = 0.34 \times 10^{-4}\text{ T}$$

When magnet is placed with its North-pole pointing South, neutral point is obtained on its axial line.

Therefore, at the neutral point.

(B_H = Horizontal component of earth's magnetic field)

$$B_{\text{axial}} = B_H$$

or $$\frac{\mu_0}{4\pi} \times \frac{2mr}{(r^2 - l^2)^2} = B_H$$

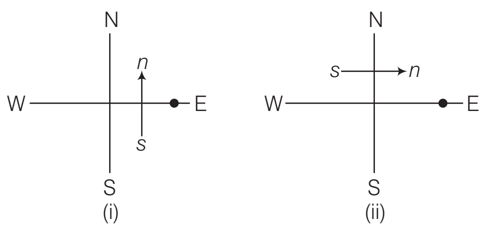
$\therefore$ $$m = \frac{4\pi}{\mu_0} \times \frac{B_H\,(r^2 - l^2)^2}{2r}$$

$$= \frac{1}{10^{-7}} \times \frac{0.34 \times 10^{-4} \times (0.30^2 - 0.15^2)^2}{2 \times 0.30}$$

$$= \frac{0.34 \times 10^{-4} \times (0.0675)^2}{10^{-7} \times 2 \times 0.30} = 2.582\text{ Am}^2$$

The pole strength of the magnet, $q_m = \dfrac{m}{2l} = \dfrac{2.582}{0.30} = 8.606\,\text{Am}$

61. (*d*) At neutral point P



In Fig. (ii), net magnetic induction at P = resultant of $\dfrac{\mu_0}{4\pi}\dfrac{2m}{d^3}$

$= 2B_H$ along horizontal and B_H along vertical,

i.e., $$B_R = \sqrt{(2B_H)^2 + (B_H)^2} = \sqrt{5}B_H$$

62. (*b*) Points of zero magnetic field *i.e.,* neutral points lie on equatorial line of magnet *i.e.,* along East and West.

63. (*c*) Angle of dip, $\tan\delta = \dfrac{Z_E}{H_E}$ or $\delta = \dfrac{B_V}{B_H}$

i.e., $$\tan\delta = \frac{Z_E}{H_E} = \frac{Z_E}{\sqrt{3}Z_E} = \frac{1}{\sqrt{3}}$$

$\therefore$ $$\delta = 30^\circ = \pi/6\,\text{rad}$$

64. (*d*) Angle of dip, $\tan\delta = \dfrac{Z_E}{H_E} = \dfrac{H_E}{H_E} = 1$

$\therefore$ $$\delta = 45^\circ$$

65. (*c*) Magnetic field $B_E = \dfrac{H_E}{\cos\delta} = \dfrac{0.50}{\cos 30^\circ} = \dfrac{0.50 \times 2}{\sqrt{3}} = \dfrac{1}{\sqrt{3}}$

66. (*b*) We know, $H_E = B_E \cos\delta$

$\therefore$ Magnetic field $B_E = \dfrac{H_E}{\cos\delta} = \dfrac{B_0}{\cos 45^\circ} = \sqrt{2}\,B_0$

67. (*b*) According to magnetic field,induced at the centre of a circular loop *i.e.,*

$$B = \frac{\mu_0 i}{2r} \Rightarrow 7 \times 10^{-5} = \frac{4\pi \times 10^{-7} \times i}{2 \times 5 \times 10^{-2}}$$

$\therefore$ Current in the circular loop

i.e., $$i = \frac{7 \times 10^{-5}}{4\pi \times 10^{-6}} = 5.6\text{ A}$$

68. (*c*) Here, $2l = 20\,\text{cm}$, $l = 10\,\text{cm}$, $d = 40\,\text{cm}$

As neutral point,

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

$\Rightarrow$ $$3.2 \times 10^{-5} = \frac{10^{-7} \times 2m\,(0.4)}{15 \times 15 \times 10^{-4}}$$

$\therefore$ $$m = \frac{3.2 \times 15 \times 15 \times 10^{-4} \times 10^{-5}}{0.8 \times 10^{-7}} = 9$$

and pole strength of magnet

i.e., $$q_m = \frac{m}{2l} = \frac{9}{0.2} = 45\text{ A-m}$$

69. (*d*) At one point only, horizontal component of earth's magnetic field may balance the field due to vertical magnet (which is vertical being along the axis of the magnet).

70. (*b*) The time period of a bar magnet in a magnetic field is given by

$$T = 2\pi\sqrt{\left(\frac{I}{MB}\right)}$$

where, I is moment of inertia of bar magnet, M is magnetic moment and B is magnetic induction.

When mass is made 4 times, moment of inertia I becomes 4 times (as $I = mr^2$, $I \propto m$). From the above equation of time period $T \propto \sqrt{I}$. So, T becomes twice as mass is quadrupled.

71. (*d*) Time period in vibration magnetometer is given by

$$T = 2\pi\sqrt{\frac{I}{M \times B_H}} \Rightarrow T \propto \frac{1}{\sqrt{B_H}}$$

So, for two different cases

$$\Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{(B_H)_2}{(B_H)_1}} \Rightarrow \frac{2}{T_2} = \sqrt{\frac{6}{24}} = \frac{1}{2} [\because (B_H)_2 = 24 - 18 = 6]$$

$$\therefore \quad T_2 = 4 \text{ s}$$

72. (*d*) Magnetisation of a substance is given by magnetic moment per unit volume and having unit of Am^{-1}.

73. (*a*) Magnetic intensity is define by $H = \dfrac{B}{\mu_0} - I$

74. (*c*) Magnetic susceptibility is a measure of how a magnetic material responds to an external field.

75. (*a*) We know,

Total magnetic field $\mathbf{B} = \mu_0(\mathbf{H} + I)$ ... (i)

Also, $I = \chi\mathbf{H}$ (where, χ is magnetic susceptibility) ... (ii)

From Eqs. (i) and (ii),

$$\mathbf{B} = \mu_0(\mathbf{H} + \chi\mathbf{H})$$

$$\Rightarrow \mathbf{B} = \mu_0(1+\chi)\mathbf{H}$$

$$\Rightarrow \mathbf{B} = \mu_0\mu_r\mathbf{H}, \text{ where } \mu_r = (1+\chi)$$

or $\mathbf{B} = \mu\mathbf{H}$. Here, μ is the magnetic permeability of the substance.

77. (*a*) (i) The field H is dependent of the material core and is

$$H = nI = 1000 \times 2.0 = 2 \times 10^3 \text{ Am}^{-1}$$

(ii) Magnetisation, $M = (B - \mu_0 H)/\mu_0$

So,
$$B = \mu_r\mu_0 H$$
$$= 400 \times 4\pi \times 10^{-7} (\text{NA}^{-2}) \times 2 \times 10^3 (\text{Am}^{-1})$$
$$= 1.0 \text{ T}$$
$$I = (B - \mu_0 H)/\mu_0$$
$$= (\mu_r\mu_0 H - \mu_0 H)/\mu_0$$
$$= (\mu_r - 1)H = 399 \times H = 8 \times 10^5 \text{ Am}^{-1}$$

78. (*a*) The magnetising current I_m is the additional current that needs to be passed through the windings of the solenoid in the absence of the core which would given a B value as in the presence of the core.

Thus, $B = \mu_r n_0 (I + I_m)$ using $I = 2\text{A}$, $B = 1\text{T}$, we get

$$I_m = 794 \text{ A}$$

79. (*a*) Mean radius of the toroid,

$$R = \frac{(11+12)\text{cm}}{2} = 11.5 \text{ cm} = 11.5 \times 10^{-2} \text{ m}$$

$$I = 0.70 \text{ A}, B = 2.5 \text{ T}, N = 3000$$

As, $B = \mu H, H = nI$

and $\mu_r = \mu/\mu_0, B = \mu_r\mu_0 nI$

Thus, $\mu_r = \dfrac{B}{\mu_0 nI} = \dfrac{B}{\mu_0(N/2\pi R)I}$

$$= \frac{2.5 \text{ T} \times 2\pi\,(11.5 \times 10^{-2} \text{m})}{(4\pi \times 10^{-7} \text{Tm/A})\,(3000) \times (0.70)} \text{A} = 685$$

80. (*c*) Relative permeability of the core

$$\mu = \mu_0\mu_r = \mu_0(1 + \chi_m) \qquad (\because \mu_r = 1 + \chi_m)$$
$$= (4\pi \times 10^{-7} \text{ Tm/A})(1 + 599)$$
$$= 7.5 \times 10^{-4} \text{TmA}^{-1}$$

81. (*b*) $I = \dfrac{\mathbf{M}}{V} = \dfrac{8.0 \times 10^{22} \text{Am}^2}{(4/3)\pi R^3} = \dfrac{8.0 \times 10^{22} \text{ Am}^2}{(4/3)(3.14)(6.4 \times 10^6 \text{ m})^3}$

$$= 73 \text{ Am}^{-1}$$

82. (*a*) When space inside the toroid is filled with air,

$$B_0 = \mu_0 H.$$

When filled with tungsten, we get

$$B = \mu H = \mu_0\mu_r H = \mu_0(1 + \chi_m)H$$

Percentage increase in magnetic field

$$= \frac{(B - B_0) \times 100}{B_0} = \frac{\mu_0\chi_m H \times 100}{\mu_0 H} = \chi_m \times 100$$
$$= 6.8 \times 10^{-5} \times 100 = 0.0068\ \%$$

83. (*b*) $B = 1.7 \times 10^{-5}$ T, $H = ?$

Horizontal component of intensity of earth is magnetic field.

$$H = \frac{B}{\mu_0} = \frac{1.7 \times 10^{-5}}{4\pi \times 10^{-7}} = 13.53 \text{ Am}^{-1}$$

86. (*a*) Electrons in an atom orbiting around nucleus possess orbital angular momentum. These orbiting electrons are equivalent to current-carrying loop and thus possess orbital magnetic moment. Diamagnetic substances are the ones in which resultant magnetic moment in an atom is zero.

87. (*b*) The most exotic diamagnetic material are superconductors.

88. (*c*) If superconductors are cooled to very low temperature, then they exhibit both perfect conductivity and perfect diamagnetism.

89. (*a*) The field lines are completely expelled when $\chi = -1$ and $\mu_r = 0$.

90. (*b*) The phenomenon of perfect diamagnetism in superconductors is called the **Meissner effect.**

91. (*d*) Superconducting magnets are used for running magnetically levitated superfast trains.

92. (*b*) A diamagnetic liquid moves from stronger parts of magnetic field to weaker parts. Therefore, the meniscus of the level of solution will fall.

94. (*b*) Experimentally, one finds that the magnetisation of a paramagnetic material is inversely proportional to the absolute temperature T.

For paramagnetic materials, $M = C\dfrac{B_0}{T}$

97. (*d*) For a paramagnetic material both χ and μ_r depend not only on the material, but also (in a simple fashion) on the sample temperature. As the field is increased or the temperature is lowered, the magnetisation increases until it reaches the saturation value M_s, at which point all the dipoles are perfectly aligned with the field.Beyond this Curie's law is no longer valid.

98. (*a*) The individual atoms (or ions or molecules) in a ferromagnetic material possess a dipole moment as in a paramagnetic material. However, they interact with one another in such a way that they spontaneously align themselves in a common direction over a macroscopic volume called domain.

99. (*b*) In a ferromagnetic material the field lines are highly concentrated. In non-uniform magnetic field, the sample tends to move towards the region of high field.

100. (*b*) In some ferromagnetic materials the magnetisation persists. Such materials are called hard magnetic materials or hard ferromagnets. Alnico, an alloy of iron, aluminium, nickel, cobalt and copper, is one such material.

101. (*a*) The magnetic susceptibility of a material is a measure of the ease with which a specimen of that material can be magnetised in a magnetising field. For a diamagnetic substance, magnetic susceptibility (χ_m) is independent of temperature.

102. (*a*) Ferromagnetism decreases with rise in temperature. If we heat a ferromagnetic substance, then at a definite temperature, the ferromagnetic property of the substance suddenly disappears and the substance becomes paramagnetic. The temperature above which a ferromagnetic substance becomes paramagnetic is called the Curie temperature of the substance.

103. (*a*) Nickel exhibits ferromagnetism because of a quantum physical effect called exchange coupling in which the electron spins of one atom interact with those of neighbouring atoms. The result is alignment of the magnetic dipole moments of the atoms, in spite of the randomising tendency of atomic collisions. This persistent alignment is what gives ferromagnetic materials their permanent magnetism.

If the temperature of a ferromagnetic material is raised above a certain critical value, called the Curie temperature, the exchange coupling ceases to be effective.

104. (*a*) Magnetic susceptibility *i.e.,* $\chi_{m_1} = 0.0075, T_1 = -73°\text{C}$

$$T_1 = (-73 + 273)\text{K} = 200 \text{ K}$$

$$\chi_{m_2} = ?, T_2 = -173°\text{C} = (-173 + 273) \text{ K} = 100 \text{ K}$$

As we know, $\chi_m = \dfrac{1}{T} = \dfrac{\chi_{m_2}}{\chi_{m_1}} = \dfrac{T_1}{T_2} = \dfrac{200}{100} = 2$

$$\therefore \quad \chi_{m_2} = 2\chi_{m_1} = 2 \times 0.0075 = 0.015$$

105. (*d*) The volume of cubic domain is

$$V = (10^{-6})^3 \text{ m}^3 = 10^{-18}\text{m}^3 = 10^{-12} \text{ cm}^3$$

It's mass = Volume × Density

$$= 7.9 \text{ g cm}^{-3} \times 10^{-12} \text{ cm}^3 = 7.9 \times 10^{-12} \text{ g}$$

It is given that Avogadro's number *i.e.,* 6.023×10^{23} of iron atoms have a mass of 55 g. Hence, the number of atoms in the domain is

$$N = \frac{7.9 \times 10^{-12} \times 6.023 \times 10^{23}}{55} = 8.65 \times 10^{10} \text{atoms}$$

106. (*d*) The maximum dipole moment $m_{\max}$ is achieved when all the atomic moments are perfectly aligned.

Thus, $m_{\max} = (8.65 \times 10^{10})(9.27 \times 10^{-24})$

$$= 8.0 \times 10^{-13} \text{ Am}^2$$

The consequent magnetisation is

$$M_{\max} = m_{\max} / \text{Domain volume}$$
$$= 8.0 \times 10^{-13} \text{ Am}^2 / 10^{-18} \text{ m}^3$$
$$= 8.0 \times 10^5 \text{ Am}^{-1}$$

107. (*c*) According to Curie's law, $\chi_m = \dfrac{C}{T}$

As, magnetic susceptibility

$$\chi_m = \frac{M}{H}, M = \frac{m}{V} \quad \text{and} \quad H = \frac{B}{\mu}$$

$$\frac{m/V}{B/\mu} = \frac{C}{T} \quad \text{or} \quad m = \frac{CV}{\mu}\left(\frac{B}{T}\right)$$

For a given sample, CV/μ = constant

Thus, $m = (B/T)$ or $\dfrac{m_1}{m_2} = \dfrac{B_1/T_1}{B_2/T_2}$

$$B_1 = 0.84 \text{ T}, B_2 = 0.98 \text{ T}$$
$$T_1 = 4.2 \text{ K}, T_2 = 2.8 \text{ K}$$

Thus, $\dfrac{m_1}{m_2} = \dfrac{0.84/4.2}{0.98/2.8} = 4/7$ or $m_2 = (7/4)\, m_1$

Initial total magnetic moment of the sample *i.e.,*

$$m_1 = 15\% \text{ of } (2.0 \times 10^{24})(1.5 \times 10^{-23} \text{ JT}^{-1}) = 4.5 \text{ JT}^{-1}$$

Thus, $m_2 = (7/4)(4.5 \text{ JT}^{-1}) = 7.9 \text{ JT}^{-1}$.

108. (*b*) $R = 15 \text{ cm} = 15 \times 10^{-2} \text{ m}$

$N = 3500, \mu_r = 800, I = 1.2$ A.

Clearly, n (number of turns per unit length) = $N / 2\pi R$

Since, magnetic field *i.e.,* $B = \mu H = \mu_r \mu_0 nI$,

(as $\mu_r = \mu/\mu_0$ and $H = nI$)

$$B = 800\,(4\pi \times 10^{-7} \text{ Tm/A}) \times \frac{3500}{2\pi\,(15 \times 10^{-2} \text{ m})} \times (1.2 \text{ A})$$

$$= 4.48 \text{ T}$$

109. (*b*) As magnetic susceptibility, $\chi_m = \dfrac{C}{T}, \dfrac{\chi_m}{\chi_{m'}} = \dfrac{T'}{T}$

or temperature of magnesium *i.e.,*

$$T' = \left(\frac{\chi_m}{\chi_{m'}}\right) T = \left(\frac{1.2 \times 10^5}{1.8 \times 10^5}\right) 300 = 200 \text{ K}$$

110. (*c*) For solenoid, the magnetic field and needed to be magnetised the magnet

$$B = \mu_0 nI$$

$$\Rightarrow \quad 3 \times 10^3 = \frac{100}{0.1} \times I \quad \Rightarrow \quad I = 3 \text{ A}$$

111. (*b*) For a diamagnetic substance, I is negative and $-I \times H$. Therefore, the variation is represented by *OC* or *OD*. As magnetisation is small. So, *OC* is better choice than *OD*.

112. (*c*) The correct measure of hardness of a material is its coercivity; *i.e.*, the field strength required to be applied in opposite direction to reduce the residual magnetism of the specimen to zero.

113. (*b*) Liquid oxygen is paramagnetic because its atoms possess permanent magnetic dipole moment.

114. (*b*) If a diamagnetic substance is brought near the North or South-pole of a bar magnet, it is feebly repelled by both the poles of magnet such as antimony, copper, gold and silver.

115. (*c*) At Curie temperature, ferromagnetic becomes paramagnetic.

116. (*a*) Substance which at room temperature retain their ferromagnetic property for a long period of time are called permanent magnets.

117. (*a*) The material should have a high permeability. Steel is one favoured choice. It has a slightly smaller retentivity than soft iron but this is outweighed by the much smaller coercivity of soft iron. Other suitable materials for permanent magnets are alnico, cobalt, steel and ticonal.

119. (*c*) Core of electromagnets are made of ferromagnetic materials which have high permeability and low retentivity. Soft iron is a suitable material for electromagnets.

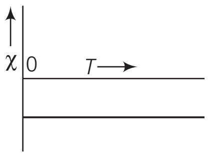
120. (*d*) In certain applications, the material goes through an AC cycle of magnetisation for a long period. This is the case in transformer cores and telephone diaphragms. The hysteresis curve of such materials must be narrow. The energy dissipated and the heating will consequently be small. The material must have a high resistivity to lower eddy current losses.

121. (*c*) Permanent magnet should have large coercivity and large retentivity. Therefore, the hysteresis cycle of the material should be tall and wide.

122. (*a*) The materials for a permanent magnet should have high retentivity (so that the magnet is strong) and high coercivity (so that the magnetisation is not wiped out by stray magnetic fields).

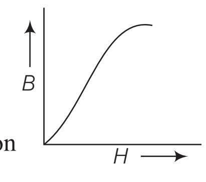
123. (*c*) Electromagnets are made of soft iron because soft iron has high permeability and low retentivity.

124. (*d*) For diamagnetic substances, the magnetic susceptibility is negative, and it is independent of temperature. Therefore, choice (d) is correct in figure.

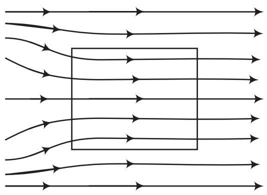


125. (*c*) Partially filled inner subshells are responsible for ferromagnetic behaviour of such substances.

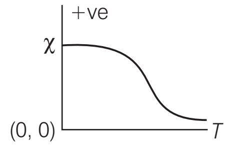
126. (*b*) $\mu = \frac{B}{H}$; when H increases B also increases so μ remains constant. In ferromagnetic subtance, *B*-*H* curve is not straight line but a curve. Slope decreases on higher H.



127. (*b*) When a bar of soft iron is placed in the uniform magnetic field which is parallel to it because of large permeability of soft iron, magnetic lines of force prefer to pass through it. Concentration of lines in soft iron bar increases as shown in figure.



128. (*a*) As temperature of ferromagnetic material is raised, its susceptibility χ remains constant first and then decreases as shown in figure.



129. (*d*) Area of hysteresis loop is proportional to net energy absorbed per unit volume by the material, as it taken over a complete cycle of magnetisation.

For electromagnets and transformers energy loss should be low. *i.e.,* thin hysteresis curves.

Also $B = 0$, when $H = 0$ and $|H|$ should be small when $B = 0$.

130. (*d*) As $\mu_r < 1$ for substance X, it must be diamagnetic and $\mu_r > 1$ for substance Y, is must be paramagnetic.

131. (*d*) For a paramagnetic material,

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

$$\therefore \quad \frac{K_2}{K_1} = \frac{T_1}{T_2} \Rightarrow \frac{K/2}{K} = \frac{27+273}{T_2}$$

$$\Rightarrow \quad T_2 = 600\text{ K} = 600 - 273 = 327°\text{C}$$

132. (*b*) Here, $V = (10 \times 0.5 \times 0.2)\text{ cm}^3$

$1\text{ cm}^3 = 10^{-6}\text{m}^3$

$$H = 0.5 \times 10^4\text{ Am}^{-1}, M = 5\text{ Am}^2, B = ?$$

Intensity of magnetisation *i.e.,*

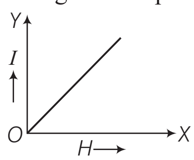
$$I = \frac{M}{V} = \frac{5}{10^{-6}} = 5 \times 10^6\text{ Am}$$

From $B = \mu_0 (I + H)$

Magnetic induction

i.e., $\quad B = 4\pi \times 10^{-7} (5 \times 10^6 + 0.5 \times 10^4) = 6.28\text{ T}$

133. (*c*) In a paramagnetic material, $I \propto H$. Therefore, the graph between H and I is a straight line represented by in figure



134. (*c*) A compass is simply a needle shaped magnet that mounted so that it can rotate freely about a vertical axis. When it is held in a horizontal plane, the North-pole end of the needle points, generally, towards the geomagnetic North-pole (really a South magnetic pole). Thus, true geographic North direction cannot be found by using a compass needle. Now, vertical plane passing through the magnetic axis of earth's magnet is called magnetic meridian.

136. (*a*) If one looks at the magnetic field lines of the earth one sees that unlike in the case of a bar magnet, the field lines go into the earth at the North magnetic pole (N_m) and come out from the South magnetic pole (S_m).

The convention arose because the magnetic North was the direction to which the North-pole of a magnetic needle pointed; the North-pole of a magnet was so named as it was the North seeking pole.

Thus, in reality, the North magnetic pole behaves like the South-pole of a bar magnet inside the earth and *vice-versa.*

137. (*b*) A magnetic needle which is free to swing horizontally would, lie in the magnetic meridian and the North-pole of the needle would point towards the magnetic North-pole.

The line joining the magnetic poles is tilted with respect to the geographic axis of the Earth, the magnetic meridian at a point makes angle with the geographic meridian.

139. (*c*) From the relation, susceptibility of the material is

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

Thus, it is obvious that greater the value of susceptibility of a material greater will be the value of intensity of magnetisation *i.e.*, more easily it can be magnetised.

146. (*b*) Paramagnetic substances are those which get weakly magnetised when placed in an external magnetic field. They have tendency to move from a region of weak magnetic field to strong magnetic field, *i.e.*, they get weakly attracted to a magnet.

147. (*b*) Ferromagnetic substances are those which gets strongly magnetised when placed in an external magnetic field. They have strong tendency to move from a region of weak magnetic field to strong magnetic field, *i.e.*, they get strongly attracted to a magnet.

149. (*d*)

(I) The magnetic field lines of a magnet (or a solenoid) form continuous closed loops. This is unlike the electric dipole where these field lines begin from a positive charge and end on the negative charge or escape to infinity.

(II) The tangent to the field line at a given point represents the direction of the net magnetic field **B** at that point.

(III) The larger the number of field lines crossing per unit area, the stronger on the magnitude of the magnetic field **B**.

(IV) The magnetic field lines never intersect, for if they did the direction of the magnetic field would not be unique at the point of intersection.

150. (*d*) The difference between the Gauss's law of magnetism and that for electrostatic is a reflection of the fact that isolated magnetic poles (also called monopoles) are not known to exist. There are no sources or sinks of **B**; the simplest magnetic element is a dipole or a current loop. All magnetic phenomena can be explained in terms of an arrangement of dipoles and/or current loops. Thus, Gauss's law for magnetism is

'The net magnetic flux through any closed surface is zero.'

151. (*d*)

(I) The earth behaves as a magnet with the magnetic field pointing approximately from the geographic South to the North.

(II) When a bar magnet is freely suspended, it points in the North-South direction. The tip which points to the geographic North is called the North pole and the tip which points to the geographic South is called the South-pole of the magnet.

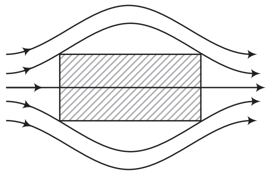
(III) There is a repulsive force when North poles (or South-poles) of two magnets are brought close together. Conversely there is an attractive force between the North-pole of one magnet and the South-pole of the other.

(IV) We cannot isolate the North or South-pole of a magnet. If a bar magnet is broken into two halves, we get two similar bar magnets with somewhat weaker properties. Unlike electric charges, isolated magnetic North and South poles known as magnetic monopoles do not exist.

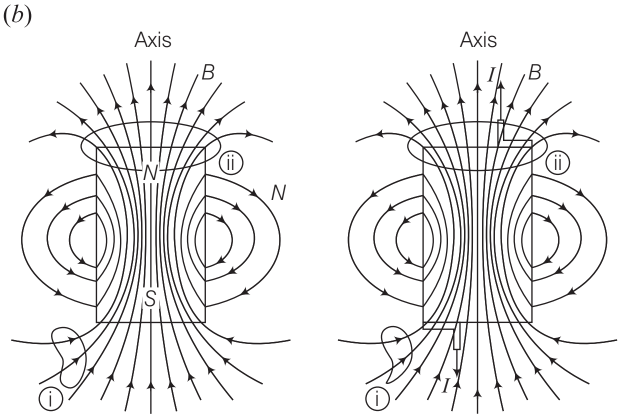
152. (*a*) The magnetic field lines of the earth resemble that of a (hypothetical) magnetic dipole located at the centre of the earth. The axis of the dipole does not coincide with the axis of rotation of the earth but is presently tilted by approximately 11.3° with respect to the later.

In this way of looking at it, the magnetic poles are located, where the magnetic field lines due to the dipole enter or leave the earth. The location of the North magnetic pole is at a latitude of 79.74′′ N and a longitude of 71.8′′ W, a place somewhere in North Canada. The magnetic South-pole is at 79.74′′ S, 108.22′′E in the Antarctica.

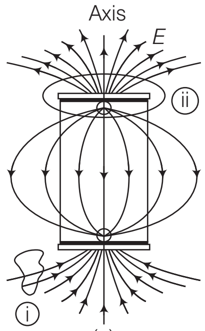
153. (*d*) Figure shows a bar of diamagnetic material placed in an external magnetic field. The field lines are repelled or expelled and the field inside the material is reduced, this reduction is slight, being one part in 10^5. When placed in a non-uniform magnetic field, the bar will tend to move from high to low field.



155. (*b*)



(a) (b)



(c)

The field lines of (a) a bar magnet (b) a current-carrying finite solenoid and (c) electric dipole. At large distances, the field lines are very similar. The curves labelled (i) and (ii) are closed Gaussian surfaces.

156. (*a*) Since, the magnetic potential energy U_m is given by,

$$U_m = \mathbf{m} \cdot \mathbf{B} = -mB\cos\theta$$

A. For $\theta = 90°$,

$$U_m = -mB\cos 90° = 0$$

B. For $\theta = 0°$,

$$U_m = -mB\cos 0° = -mB$$

The potential energy is minimum and hence the needle is in most stable position.

C. For $\theta = 180°$,

$$U_m = -mB\cos 180° = +mB$$

The potential energy is maximum and hence the needle is in unstable position.

157. (*b*) The dipole analogy

	Electrostatic	Magnetism
	$1/\varepsilon_0$	μ_0
Dipole moment	$\mathbf{p}$	$\mathbf{m}$
Equatorial field for a short dipole	$-\mathbf{p}/4\pi\varepsilon_0 r^3$	$-\mu_0\mathbf{m}/4\pi r^3$
Axial field for a short dipole	$2\mathbf{p}/4\pi\varepsilon_0 r^3$	$\mu_0 2\mathbf{m}/4\pi r^3$
External field torque	$\mathbf{p}\times\mathbf{E}$	$\mathbf{m}\times\mathbf{B}$
External field energy	$-\mathbf{p}\cdot\mathbf{E}$	$-\mathbf{m}\cdot\mathbf{B}$

156. (*a*) Vertical component, $Z_E = B_E \sin I$

Horizontal component, $H_E = B_E \cos I$

which gives $\tan I = \dfrac{Z_E}{H_E}$

160. (*c*) In terms of the susceptibility χ, a material is diamagnetic if χ is negative, para-if χ is positive and small and ferro-if χ is large and positive.

161. (*b*)

Diamagnetic	Paramagnetic	Ferromagnetic
$-1 \le \chi < 0$	$0 < \chi < \varepsilon$	$\chi >> 1$
$0 \le \mu_r < 1$	$1 < \mu_r < 1+\varepsilon$	$\mu_r >> 1$
$\mu < \mu_0$	$\mu > \mu_0$	$\mu >> \mu_0$

162. (*d*) Some text books assign a magnetic charge (also called pole strength $+q_m$ to the North-pole and $-q_m$ to the South-pole of a bar magnet of length $2l$ and magnetic moment $q_m(2l)$.

163. (*d*) The field strength due to q_m at a distance r from it is given by $\mu_0 q_m / 4\pi r^2$.

164. (*b*) The torque on the needle is

$$\tau = \mathbf{m}\times\mathbf{B}$$

Magnitude of torque, $\tau = mB\sin\theta$

165. (*a*) Torque on the needle

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

Here, τ is restoring torque and θ is the angle between $\mathbf{m}$ and $\mathbf{B}$.

Therefore, in equilibrium $I\dfrac{d^2\theta}{dt^2} = -mB\sin\theta$

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

$$I\frac{d^2\theta}{dt^2} \approx -mB\,\theta \quad \text{or} \quad \frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta$$

This represents a simple harmonic motion.

166. (*d*) The square of the angular frequency is $\omega^2 = mB/I$ and the time period is,

$$T = 2\pi\sqrt{\frac{I}{mB}} \quad \text{or} \quad B = \frac{4\pi^2 I}{mT^2}$$

167. (*a*) The magnitude of the magnetic field is $B = \dfrac{4\pi^2 I}{mT^2}$.

168. (*a*) An expression for magnetic potential energy can also be obtained on lines similar to electrostatic potential energy.

The magnetic potential energy U_m is given by

$$U_m = \int \tau(\theta)\,d\theta = \int mB\sin\theta\,d\theta$$

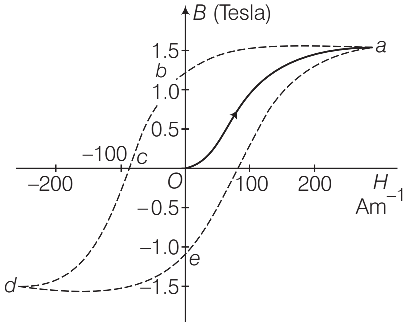
$$= (-mB\cos\theta) = -\mathbf{m}\cdot\mathbf{B}$$

169. (*a*) The relation between B and H in ferromagnetic materials is complex. It is often not linear and it depends on the magnetic history of the sample. Figure depicts the behaviour of the material as we take it through one cycle of magnetisation. Let the material be unmagnetised initially. We place it in a solenoid and increase the current through the solenoid. The magnetic field B in the material rises and saturates as depicted in the curve Oa. This behaviour represents the alignment and merger of domains until no further enhancement is possible. It is pointless to increase the current (and hence the magnetic intensity H) beyond this. Next, we decrease H and reduce it to zero.

At $H = 0$, $B \neq 0$.

This is represented by the curve ab. The value of B at $H = 0$ is called retentivity or remanence. In figure, $B_R \sim 1.2$ T, where the subscript R denotes retentivity.

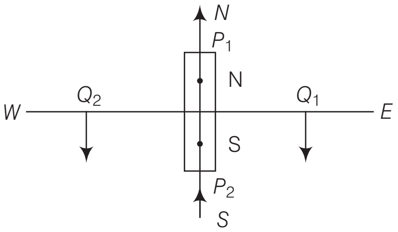
The domains are not completely randomised even though the external driving field has been removed.



170. (*a*) When the current in the solenoid is reversed and slowly increased. Certain domains are flipped until the net field inside stands nullified. This is represented by the curve *bc*. The value of H at c is called coercivity. In figure $H_c \sim -90\ \text{Am}^{-1}$. As the reversed current is increased in magnitude, we once again obtain saturation.

171. (*d*) For a given value of H, B is not unique but depend on previous history of the sample. This phenomenon is called hysteresis.

172. (*a,b*) It is clear, the direction of magnetic fields due to dipole are same at (P_1, P_2) and at (Q_1, Q_2)



174. (*c,d*) Field due to circular loop carrying current is perpendicular to the plane of the loop. As, current is anti-clockwise so, North pole lies above the loop and South pole lies below the loop.

175. (*a,b*) (a) Magnetic moment of the coil

$$M = nIA = 16 \times 0.75 \times \pi(0.1)^2$$
$$= 16 \times 0.75 \times 3.14 \times 0.1 \times 0.2 = 0.377\ \text{JT}^{-1}$$

(b) Frequency of oscillation of the coil

$$f = \frac{1}{2\pi}\sqrt{\frac{M \times B}{I}}$$

Squaring on both the sides, we get

$$f^2 = \frac{1}{4\pi} \cdot \frac{MB}{I}$$

$$\Rightarrow \quad I = \frac{MB}{4\pi^2 f^2} = \frac{0.377 \times 5 \times 10^{-2}}{4 \times 3.14 \times 3.14 \times 2 \times 2}$$

$$\Rightarrow \quad I = 1.2 \times 10^{-4}\ \text{kg-m}^2$$

(c) Moment of inertia

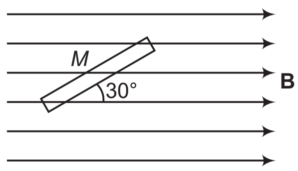
$$I = \frac{MB}{4\pi^2 f^2} = \frac{0.377 \times 5 \times 10^{-2}}{4 \times 3.14 \times 3.14 \times 3 \times 3} = 5.3 \times 10^{-5}\ \text{kg-m}^2$$

(d) Frequency of oscillation of the coil

$$f = \frac{1}{2\pi}\sqrt{\frac{M \times B}{I}} \quad \Rightarrow \quad f = 0.54/\text{s}$$

178. (*a*) Given, uniform magnetic field $B = 0.25$ T

The magnitude of torque $\tau = 4.5 \times 10^{-2}$ J



Angle between magnetic moment and magnetic field $\theta = 30°$.

Torque experienced on a magnet placed in external magnetic field

$$\tau = \mathbf{M} \times \mathbf{B}$$
$$\tau = MB \sin\theta \qquad (\because \mathbf{A} \times \mathbf{B} = AB \sin\theta)$$
$$4.5 \times 10^{-2} = M \times 0.25 \times \sin 30°$$

Magnitude of magnetic moment of the magnet

$$M = \frac{4.5 \times 10^{-2}}{0.25 \times \sin 30°} = \frac{4.5 \times 10^{-2} \times 2}{0.25 \times 1}\left(\because \sin 30° = \frac{1}{2}\right)$$
$$= 0.36\ \text{JT}^{-1}$$

Thus, the magnitude of magnetic moment of the magnet is $0.36\ \text{JT}^{-1}$.

179. (*b*) Given, magnetic moment of magnet $m = 0.32\ \text{JT}^{-1}$

The magnitude of magnetic field $B = 0.15$ T

(i) For stable equilibrium, the angle between magnetic moment (**m**) and magnetic field (**B**) is $\theta = 0°$

($\because$ In this position, it will be in a direction parallel to magnetic field thus no torque will act on it.)

$\because$ The potential energy of the magnet

$$U = -\,\mathbf{m} \cdot \mathbf{B}$$
$$= -\,mB \cos\theta \qquad (\because \mathbf{A} \cdot \mathbf{B} = AB \cos\theta)$$
$$= -\,0.32 \times 0.15 \cos 0° = -\,4.8 \times 10^{-2}$$

J

Thus, for the stable equilibrium the potential energy is -4.8×10^{-2} J.

(ii) For the unstable equilibrium, the angle between the magnetic moment and magnetic field is 180°.

(In this position, it will be in a direction perpendicular to magnetic field thus maximum torque will act on it.)

$$\theta = 180°$$

Potential energy of the magnet

$$U = -\,mB \cos 180°$$
$$= -\,0.32 \times 0.15\,(-1) = 4.8 \times 10^{-2}\ \text{J}$$

Thus, for the unstable equilibrium the potential energy is 4.8×10^{-2} J.

180. (*c*) (i) Given, magnetic moment of magnet

$$M = 1.5\ \text{JT}^{-1}$$

Uniform magnetic field $B = 0.22$ J

Angle $\theta_1 = 0°$ and $\theta_2 = 90°$

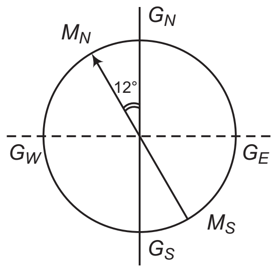
Work done in rotating the magnet from angle θ_1 to angle θ_2

$$W = -MB(\cos\theta_2 - \cos\theta_1)$$
$$= -1.5 \times 0.22(\cos 90° - \cos 0°) = 0.33 \text{ J}$$

181. (*b*) Given, angle of dip $\delta = 22°$

Horizontal component of the earth's magnetic field

$H = 0.35$ G



Let the magnitude of the earth's magnetic field at the place is R.

Using the formula, $H = R\cos\delta$

or $$R = \frac{H}{\cos\delta} = \frac{0.35}{\cos 22°} = \frac{0.35}{0.9272} = 0.38 \text{ G}$$

Thus, the value of the earth's magnetic field at that place is 0.38 G.

182. (*c*) Given, angle of declination, $\theta = 12°$ West

Angle of dip $\delta = 60°$

Horizontal component of earth's magnetic field

$$H = 0.16 \text{ G}$$

Let the magnitude of earth's magnetic field at that place is R.

Using the formula, $H = R\cos\delta$

$$R = \frac{-H}{\cos\delta} = \frac{0.16}{\cos 60°} = \frac{0.16 \times 2}{1}$$
$$= 0.32 \text{ G} = 0.32 \times 10^{-4} \text{ T}$$

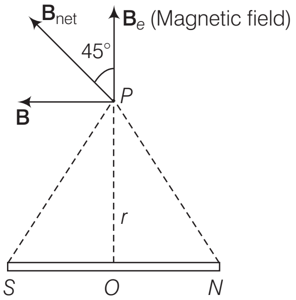
The earth magnetic field lies in a vertical plane 12° West of geographical meridian at an angle 60° above the horizontal.

183. (*a*) (i) **At normal bisector**

Let r is the distance between axial line and point P.

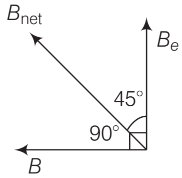
The magnetic field at point P, due to a short magnet

$$B = \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3} \qquad \ldots\text{(i)}$$



The direction of B is along PA, *i.e.*, along N-pole to S-pole.

According to the vector analysis,



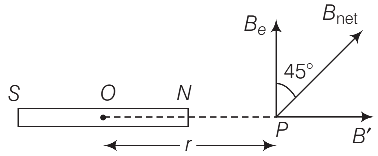
$$\tan 45° = \frac{B\sin 90°}{B\cos 90° + B_e}$$
$$1 = \frac{B}{B_e} \quad \text{or} \quad B = B_e$$
$$0.42 \times 10^{-4} = \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3}$$
$$0.42 \times 10^{-4} = \frac{10^{-7} \times 5.25 \times 10^{-2}}{r^3}$$
$$r^3 = \frac{5.25 \times 10^{-9}}{0.42 \times 10^{-4}} = 12.5 \times 10^{-5}$$
$$r = 0.05 \text{ m} \quad \text{or} \quad r = 5 \text{ cm}$$

(ii) **When point lies on axial line**

Let the resultant magnetic field B_{net} makes an angle 45° from B_e.

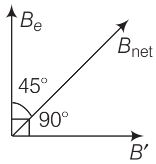
The magnetic field on the axial line of the magnet at a distance of r from the centre of magnet

$$B' = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3} \qquad (S \text{ to } N)$$



Direction of magnetic field is from S to N.

According to the vector analysis,



$$\tan 45° = \frac{B'\sin 90°}{B'\cos 90° + B_e}$$
$$1 = \frac{B'}{B_e}$$

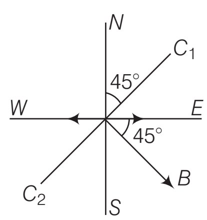
or $$B_e = B'$$

$$\Rightarrow \quad 0.42 \times 10^{-4} = \frac{\mu_0}{4\pi} \times \frac{2m}{r^3}$$
$$\Rightarrow \quad 0.42 \times 10^{-4} = \frac{10^{-7} \times 2 \times 5.25 \times 10^{-2}}{r^3}$$
$$\Rightarrow \quad r^3 = \frac{10^{-9} \times 2 \times 5.25}{0.42 \times 10^{-4}} = 2.5 \times 10^{-5}$$
$$r = 0.063 \text{ m or } 6.3 \text{ cm}$$

184. (*a*) Given, number of turns in the coil $n = 30$

Current in the coil $I = 0.35$ A

Radius of circular coil = 12 cm = 0.12 m



Let N-S be the line of magnetic meridian, the coil is placed at an angle of 45° with the magnetic meridian. C_1 and C_2 be the plane of coil. The needle points West to East. The magnetic field produced due to the coil is B. The direction of B is along the axis of coil *i.e.,* it makes an angle of 45° with East. The needle points West to East only if the direction of magnetic field B is at 45° from East.

Use the formula, magnetic field produced by a current carrying coil

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi I}{r} = \frac{10^{-7} \times 2 \times 3.14 \times 0.35 \times 30}{0.12}$$

$$= 1.83 \times 10^{-6} \times 30 = 5.49 \times 10^{-5} \text{ T}$$

Restoring torque due to $H = MH \sin 90° = MH$

Deflecting torque due to B

$$= MB \sin 45° = MB \sin 45°$$

So $\quad MH = MB \sin 45°$

The horizontal component of magnetic field

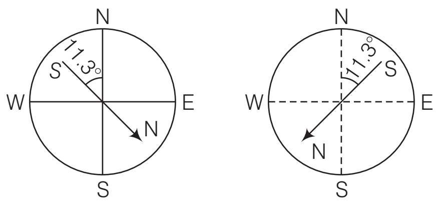
$$H = B \sin 45° = 5.49 \times 10^{-5} \times \frac{1}{\sqrt{2}} = 3.9 \times 10^{-5} \text{ T}$$

185. (*c*) In case of toroid, the magnetic field is only confined inside the body of toroid in the form of concentric magnetic lines of force and there is no magnetic field outside the body of toroid. This is because the loop encloses no current. Thus, the magnetic moment of toroid is zero.

In general, if we take r as a large distance outside the toroid, then $m \propto \frac{1}{r^3}$. But this case is not possible here.

186. (*a*) For the earth's magnetism, 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 approxmately 11.3° with respect to the later. This results into two situations as given in the figure ahead.



Hence, the declination varies between 11.3° W to 11.3° E.

187. (*d*) As we know a permanent magnet is a substance which at room temperature retain ferromagnetic property for a long period of time.

The individual atoms in a ferromagnetic material possess a dipole moment as in a paramagnetic material.

However, they interact with one another in such a way that they spontaneously align themselves in a common direction over a macroscopic volume called domain. Thus, we can say that in a permanent magnet at room temperature, domains are all perfectly aligned.

188. (*b*) As Gauss' law states, $\oint_S \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$ for electrostatic field. It does not contradict for electrostatic fields as the electric field lines do not form continuous closed path.

According to Gauss' law in magnetic field,

$$\oint_S \mathbf{E} \cdot d\mathbf{S} = 0$$

It contradicts for magnetic field, because there is a magnetic field inside the solenoid and no field outside the solenoid carrying current but the magnetic field lines form the closed path.

189. (*b*) As Curie law explains, we can deduce a formula for the relation between magnetic field induction, temperature and magnetisation.

i.e., $\quad I \text{ (magnetisation)} \propto \frac{B \text{ (magnetic field induction)}}{t \text{ (temperature in kelvin)}}$

$$\Rightarrow \quad \frac{I_2}{I_1} = \frac{B_2}{B_1} \times \frac{t_1}{t_2}$$

Let us suppose, here $I_1 = 8 \text{ Am}^{-1}$

$$B_1 = 0.6 \text{ T}, t_1 = 4 \text{ K}$$

$$B_2 = 0.2 \text{T}, t_2 = 16 \text{K}$$

$$I_2 = ?$$

$$\Rightarrow \quad \frac{0.2}{0.6} \times \frac{4}{16} = \frac{I_2}{8} \quad \Rightarrow \quad I_2 = 8 \times \frac{1}{12} = \frac{2}{3} \text{ Am}^{-1}$$

190. (*a,d*) Magnetic field lines for magnetic induction $(\mathbf{B})$ form continuous lines. So, lines of **B** are necessarily continuous across S.

Also, magnetic intensity $(\mathbf{H})$ varies for inside and outside the jump. So, lines of **H** cannot all be continuous across S.

191. (*a,d*) The primary origin of magnetism lies in the fact that the electrons are revolving and spinning about nucleus of an atom, which gives rise to current called atomic current.

This atomic currents gives rise to magnetism. The revolving and spinning about nucleus of an atom is called intrinsic spin of electron.

192. (*a,d*) Here, for solenoid $\mathbf{H} = nI$.

$$\Rightarrow \quad \mathbf{H} = 1000 \times 1 = 1000 \text{ Am}$$

Thus, **H** is a constant, so it is nearly unchanged.

But $\quad B = \mu_0 \mu_r \, n I = \mu_0 n I \mu_r = k \text{ (constant)} \mu_r$.

Thus, from above equation, we find that **B** varies with the variation in μ_r.

Now, for magnetisation in the core, when temperature of the iron core of solenoid is raised beyond Curie temperature, then it behave as paramagnetic material, where

and $\quad (\chi_m)_{\text{Fero}} \approx 10^3$ and $(\chi_m)_{\text{Para}} \approx 10^{-5}$

$$\Rightarrow \quad \frac{(\chi_m)_{\text{Fero}}}{(\chi_m)_{\text{Para}}} = \frac{10^3}{10^{-5}} = 10^8$$

193. (*a,c,d*) Electrostatic shielding is the phenomenon to block the effects of an electric field. The conducting shell can block the effects of an external field on its internal content or the effect of an internal field on the outside environment.

Magnetostatic shielding is done by using an enclosure made of a high permeability magnetic material to prevent a static magnetic field outside the enclosure from reaching objects inside it or to confine a magnetic field within the enclosure.