

Chapter Five

MAGNETISM AND MATTER



MCQ I

- 5.1** 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 x - y plane. Its magnetic moment $\mathbf{m}$
- (a) is non-zero and points in the z -direction by symmetry.
 - (b) points along the axis of the toroid ($\mathbf{m} = m\hat{\phi}$).
 - (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.
- 5.2** The magnetic field of 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 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 Earth axis passes through Greenwich.
- (d) declination averaged over Earth must be always negative.

5.3 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.

5.4 Consider the two idealized systems: (i) a parallel plate capacitor with large plates and small separation and (ii) a long solenoid of length $L \gg R$, radius of cross-section. In (i) $\mathbf{E}$ 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's law for electrostatic fields.
- (b) case (ii) contradicts Gauss's law for magnetic fields.
- (c) case (i) agrees with $\oint \mathbf{E} \cdot d\mathbf{l} = 0$.
- (d) case (ii) contradicts $\oint \mathbf{H} \cdot d\mathbf{l} = I_{en}$.

5.5 A paramagnetic sample shows a net magnetisation of 8 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 Am^{-1}
- (d) 2.4 Am^{-1} .

MCQ II

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

- (a) Lines of $\mathbf{B}$ are necessarily continuous across S .
- (b) Some lines of $\mathbf{B}$ must be discontinuous across S .
- (c) Lines of $\mathbf{H}$ are necessarily continuous across S .
- (d) Lines of $\mathbf{H}$ cannot all be continuous across S .

- 5.7** The primary origin(s) of magnetism lies in
- atomic currents.
 - Pauli exclusion principle.
 - polar nature of molecules.
 - intrinsic spin of electron.
- 5.8** 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 .
- The **H** field in the solenoid is (nearly) unchanged but the **B** field decreases drastically.
 - The **H** and **B** fields in the solenoid are nearly unchanged.
 - The magnetisation in the core reverses direction.
 - The magnetisation in the core diminishes by a factor of about 10^8 .
- 5.9** Essential difference between electrostatic shielding by a conducting shell and magnetostatic shielding is due to
- electrostatic field lines can end on charges and conductors have free charges.
 - lines of **B** can also end but conductors cannot end them.
 - lines of **B** cannot end on any material and perfect shielding is not possible.
 - shells of high permeability materials can be used to divert lines of **B** from the interior region.
- 5.10** Let the magnetic field on earth be modelled by that of a point magnetic dipole at the centre of earth. The angle of dip at a point on the geographical equator
- is always zero.
 - can be zero at specific points.
 - can be positive or negative.
 - is bounded.

VSA

- 5.11** A proton has spin and magnetic moment just like an electron. Why then its effect is neglected in magnetism of materials?
- 5.12** A permanent magnet in the shape of a thin cylinder of length 10 cm has $M = 10^6$ A/m. Calculate the magnetisation current I_M .
- 5.13** Explain quantitatively the order of magnitude difference between the diamagnetic susceptibility of N_2 ($\sim 5 \times 10^{-9}$) (at STP) and Cu ($\sim 10^{-5}$).

- 5.14** From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, paramagnetism and ferromagnetism.
- 5.15** A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. (i) In which direction will it move? (ii) What will be the direction of its magnetic moment?

SA

- 5.16** Verify the Gauss's law for magnetic field of a point dipole of dipole moment $\mathbf{m}$ at the origin for the surface which is a sphere of radius R .
- 5.17** Three identical bar magnets are rivetted together at centre in the same plane as shown in Fig. 5.1. This system is placed at rest in a slowly varying magnetic field. It is found that the system of magnets does not show any motion. The north-south poles of one magnet is shown in the Fig. 5.1. Determine the poles of the remaining two.
- 5.18** Suppose we want to verify the analogy between electrostatic and magnetostatic by an explicit experiment. Consider the motion of (i) electric dipole $\mathbf{p}$ in an electrostatic field $\mathbf{E}$ and (ii) magnetic dipole $\mathbf{m}$ in a magnetic field $\mathbf{B}$. Write down a set of conditions on $\mathbf{E}$, $\mathbf{B}$, $\mathbf{p}$, $\mathbf{m}$ so that the two motions are verified to be identical. (Assume identical initial conditions.)
- 5.19** A bar magnet of magnetic moment m and moment of inertia I (about centre, perpendicular to length) is cut into two equal pieces, perpendicular to length. Let T be the period of oscillations of the original magnet about an axis through the mid point, perpendicular to length, in a magnetic field $\mathbf{B}$. What would be the similar period T' for each piece?
- 5.20** Use (i) the Ampere's law for $\mathbf{H}$ and (ii) continuity of lines of $\mathbf{B}$, to conclude that inside a bar magnet, (a) lines of $\mathbf{H}$ run from the N pole to S pole, while (b) lines of $\mathbf{B}$ must run from the S pole to N pole.

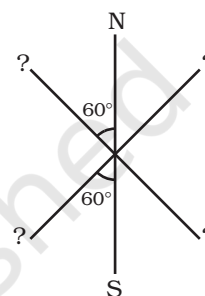


Fig. 5.1

LA

- 5.21** Verify the Ampere's law for magnetic field of a point dipole of dipole moment $\mathbf{m} = m\hat{\mathbf{k}}$. Take C as the closed curve running clockwise along (i) the z -axis from $z = a > 0$ to $z = R$; (ii) along the quarter circle of radius R and centre at the origin, in the first quadrant of x - z plane; (iii) along the x -axis from $x = R$ to $x = a$, and (iv) along the quarter circle of radius a and centre at the origin in the first quadrant of x - z plane.

5.22 What are the dimensions of χ , the magnetic susceptibility? Consider an H-atom. Guess an expression for χ , upto a constant by constructing a quantity of dimensions of χ , out of parameters of the atom: e , m , v , R and μ_0 . Here, m is the electronic mass, v is electronic velocity, R is Bohr radius. Estimate the number so obtained and compare with the value of $|\chi| \sim 10^{-5}$ for many solid materials.

5.23 Assume the dipole model for earth's magnetic field B which is given

$$\text{by } B_v = \text{vertical component of magnetic field} = \frac{\mu_0}{4\pi} \frac{2m \cos \theta}{r^3}$$

$$B_H = \text{Horizontal component of magnetic field} = \frac{\mu_0}{4\pi} \frac{\sin \theta m}{r^3}$$

$\theta = 90^\circ$ – latitude as measured from magnetic equator.

Find loci of points for which (i) $|\mathbf{B}|$ is minimum; (ii) dip angle is zero; and (iii) dip angle is $\pm 45^\circ$.

5.24 Consider the plane S formed by the dipole axis and the axis of earth. Let P be point on the magnetic equator and in S . Let Q be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angles at P and Q .

5.25 There are two current carrying planar coils made each from identical wires of length L . C_1 is circular (radius R) and C_2 is square (side a). They are so constructed that they have same frequency of oscillation when they are placed in the same uniform $\mathbf{B}$ and carry the same current. Find a in terms of R .