Multiple Choice Questions 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 m
a) is non-zero and points in the z-direction by symmetry
b) points along the axis of the tortoid $m = m\hat{\phi}$
c) is zero, otherwise there would be a field falling as $1/r^3$ at large distances outside the toroid
d) is pointing radially outwards
Answer:
c) is zero, otherwise there would be a field falling as $1/r^3$ at large distances outside the toroid

5.2. 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^o with the axis of the earth. At Mumbai, declination is nearly zero. Then,
a) the declination varies between 11.3^o W to 11.3^o E
b) the least declination is 0^o
c) the plane defined by dipole axis and the earth axis passes through Greenwich
d) declination average over the earth must be always negative
Answer:
a) the declination varies between 11.3^o W to 11.3^o E

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
Answer:
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 >> 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's law for electrostatic fields
b) case (ii) contradicts Gauss's law for magnetic fields
c) case (i) agrees with $\oint E.dl = 0$
d) case (ii) contradicts $\oint H.dl = I_{em}$
Answer:
b) case (ii) contradicts Gauss's law for magnetic fields

5.5. A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field

of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2T at a temperature of 16K, the magnetisation will be
a) 32/3 Am^{-1}
b) 2/3 Am^{-1}
c) 6 Am^{-1}
d) 2.4 Am^{-1}
Answer:
b) 2/3 Am^{-1}

Multiple Choice Questions II

5.6. 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
Answer:
a) lines of B are necessarily continuous across S
d) lines of H cannot all be continuous across S

5.7. 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
Answer:
a) atomic currents
d) intrinsic spin of electron

5.8. A long solenoid has 1000 turns per meter and carries a current of 1 A. It has a soft iron core of μr = 1000. The core is heated beyond the Curie temperature Tc
a) the H field in the solenoid is 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 108
Answer:
a) the H field in the solenoid is unchanged but the B field decreases drastically
d) the magnetisation in the core diminishes by a factor of about 108

5.9. Essential difference between electrostatic shielding by a conducting shell and magneto static 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
Answer:
a) electrostatic field lines can end on charges and conductors have free charges
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

5.10. 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
Answer:
b) can be zero at specific points
c) can be positive or negative
d) is bounded

Very Short Answers

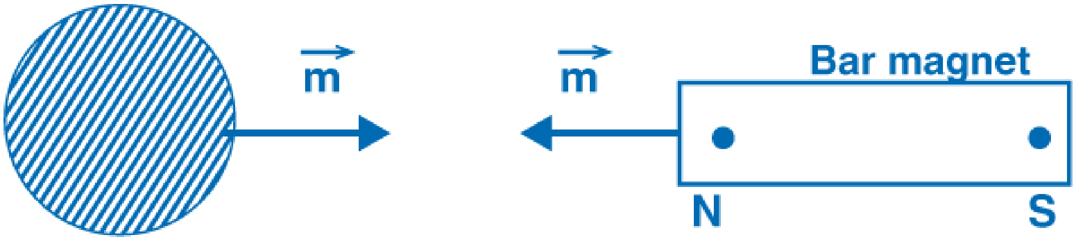
5.11. A proton has spin and magnetic moment just like an electron. Why then its effect is neglected in magnetism of materials?
Answer:
The comparison between the spinning of a proton and an electron is done by comparing their magnetic dipole moment which is given as
$\mu_p = eh/4\pi m_p$
$\mu_e = eh/4\pi m_e$
$\mu p/\mu e = me/mp = 1/1837 >> 1$
$\mu p << \mu e$

5.12. A permanent magnet in the shape of a thin cylinder of length 10 cm has M = 106 A/m. Calculate the magnetisation current Im.
Answer:
Intensity of magnetisation = 10^6 A/m
Length, l = 0.1 m
$M = I_M/l$
$I_M = Ml = 10^5$ A

5.13. Explain quantitatively the order of magnitude difference between the diamagnetic susceptibility of N_2 and Cu.
Answer:
Density of nitrogen = 28 g/ 22400 cc
Density of copper = 8 g/ 22400 cc
Ratio of densities = 16×10^{-4}
Diamagnetic susceptibility = density of nitrogen/density of copper = 1.6×10^{-4}

5.14. From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, paramagnetism, and ferromagnetism.
Answer:
The temperature dependence of susceptibility for a diamagnetism is not much affected by the temperature.
The temperature dependence of susceptibility for a paramagnetism and ferromagnetism is affected by the temperature that is as the temperature rises, the magnetic moments get disturbed.

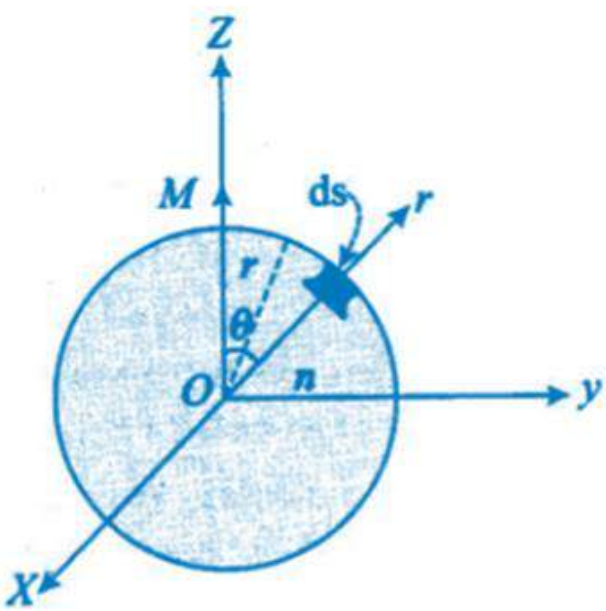
5.15. A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. i) In which direction will it move? ii) What will be the direction of it’s magnetic moment?
Answer:



i) The superconducting material will move away from the bar magnet.
ii) The direction of the magnetic moment will be from left to right.

Short Answers

5.16. Verify the Gauss's law for magnetic field of a point dipole of dipole moment m at the origin for the surface which is a sphere of radius R.
Answer:



P is the point at a distance r from O and OP, then magnetic field is given as:

$$B = \frac{\mu_0}{4\pi}\frac{2Mcos\theta}{r^3}\hat{r}$$

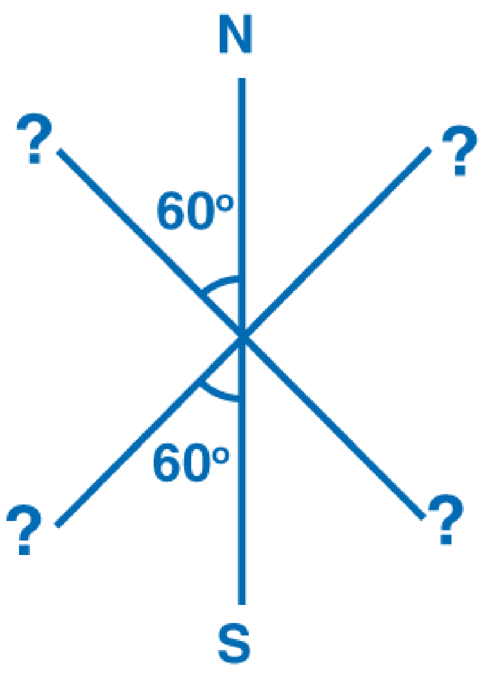
dS is the elementary area of the surface P, then
dS = r^2 (r^2 sin θ d θr)

$$\oint B.dS = \oint \frac{\mu_0}{4\pi}\frac{2Mcos\theta}{r^3}\hat{r}(r^2 sin\theta d\theta\hat{r})$$

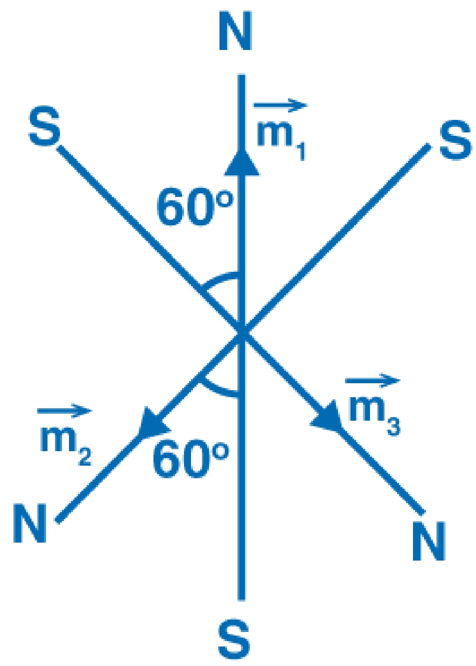
Solving the above we get,

$$\oint B.dS = -\frac{\mu_0}{4\pi}\frac{M}{2r}[1-1] = 0$$

5.17. Three identical bar magnets are riveted together at centre in the same plane as shown in the figure. 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 figure. Determine the poles of the remaining two.



Answer:



The system will have a net torque and the net force equal to zero as the system is in equilibrium.

5.18. Suppose we want to verify the analogy between electrostatic and magnetostatic by an explicit experiment. Consider the motion of i) electric dipole p in an electrostatic field E and ii) magnetic dipole m in a magnetic field B. Write down a set of conditions on E, B, p, m so that the two motion are verified to be identical.

Answer:

$pE \sin \theta = \mu B \sin \theta$

$pE = \mu B$

$E = cB$

$pcB = \mu B$

$p = \mu/c$

5.19. A bar magnet of magnetic moment m and moment of inertia I 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 B. What would be the similar period T' for each piece?

Answer:

T is the time period

I is the moment of inertia

m is the mass of magnet

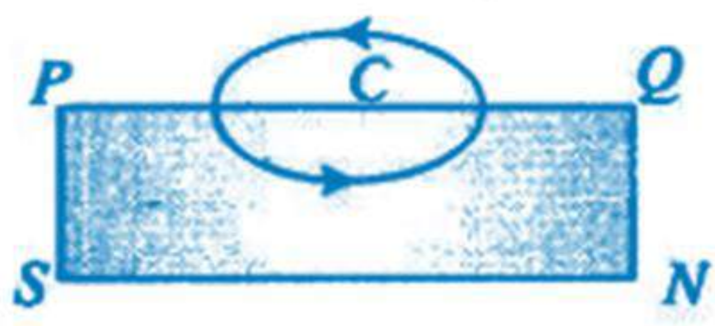
B is the magnetic field

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

Magnetic dipole moment M' = M/2

Time period is given as T' = T/2

5.20. Use i) the Ampere's law for H and ii) continuity of lines of B, to conclude that inside a bar magnet a) lines of H run from the N pole to S pole, while b) lines of B must run from the S pole to N pole.
Answer:



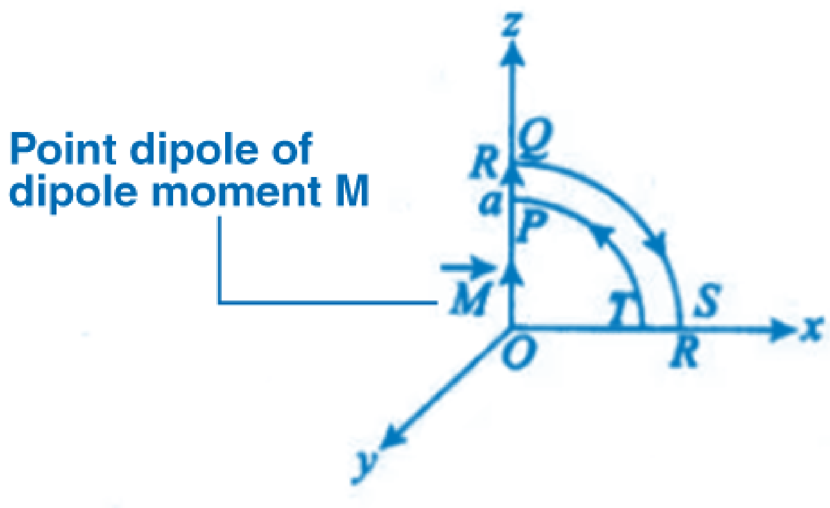
C is the amperian loop which is given as

$$\int_Q^P \vec{H} \cdot \vec{dl} = \int_Q^P \frac{\vec{B}}{\mu_0} \cdot \vec{dl}$$

Solving the above equation we get the angle between $\vec{H}$ and $\vec{dl}$ more than 90° so that cos θ is negative.

Long Answers

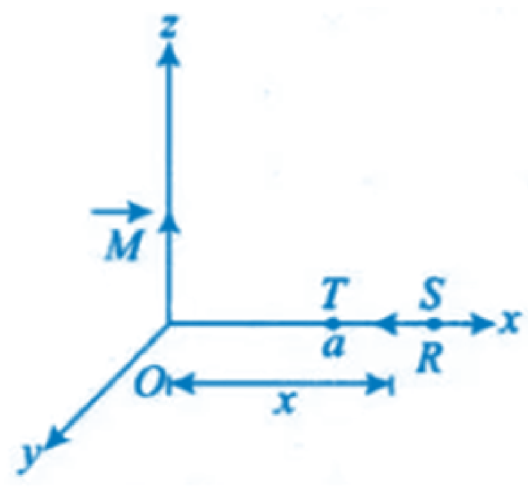
5.21. Verify the Ampere's law for magnetic field of a point dipole of dipole moment $m = m\hat{k}$ Take C as the closed curve running clockwise along i) the z-axis from z = a > 0 to z = R; ii) along the quarter circle of radius R and centre at the origin, in the first quadrant of x-z plane; iii) along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



Along z-axis, magnetic field = $\mu_0 M/4\pi(1/a^2-1/R^2)$

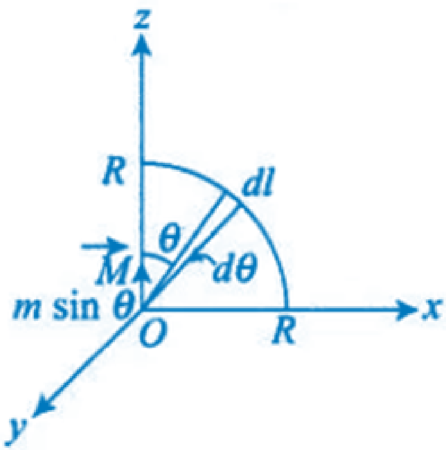
b)
Magnetic field at point A on the circular arc is = $\mu_0 m/4\pi R^2$

c)



The magnetic moment is 0

d)



The magnetic moment is 0

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 quanity of dimensions of χ, out of parameters of the atom: e, m, v, R and μ0. 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 | χ| equivalent to 10^{-5} for many solid materials.

Answer:

χm = I/H = intensity of magnetisation/magnetising force

χ is dimensionless as I and H has same units

$\chi = 10^{-4}$

5.23. Assume the dipole model for earth's magnetic field B which is given by Bv = vertical component of magnetic field = $\mu_0/4\pi$ 2m cos θ/r^3, BH = horizontal component of magnetic field = $\mu_0/4\pi$ 2m sin $\theta m/r^3$, θ = 90º latitude as measured from magnetic equator. Find loci of points for which i) |B| is minimum ii) dip angle is zero, and iii) dip angle is ±45º.

Answer:

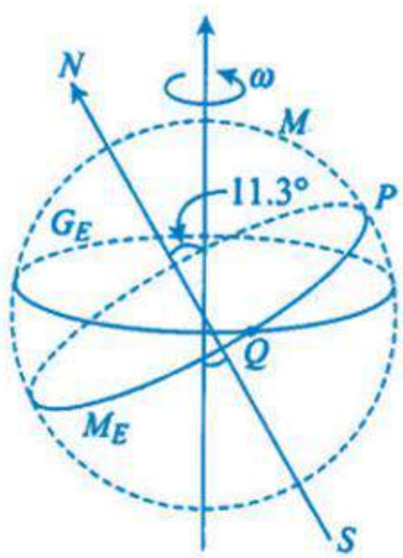
a) |B| is minimum at the magnetic equator.

b) Angle of dip is zero when θ = π/2

c) When dip angle is ±45º θ = $\tan^{-1}$ is the locus.

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 angle at P and Q.

Answer:

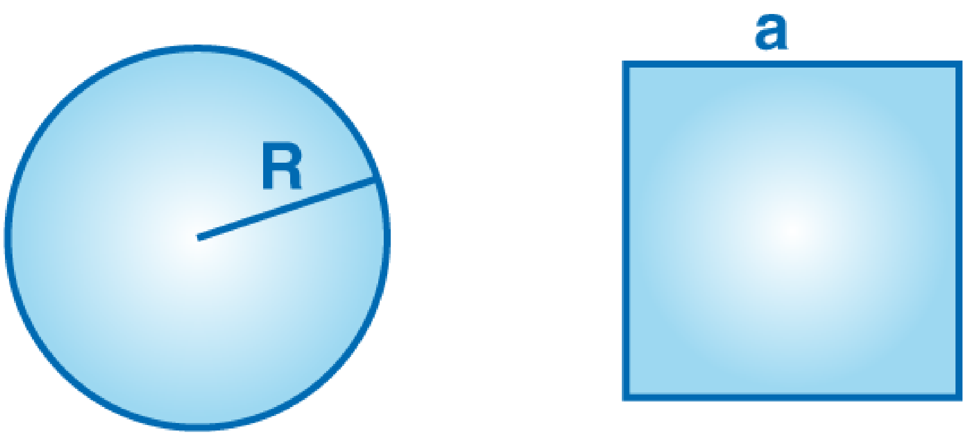


Point P is in the plane, S is in the north and the declination is zero.
The declination is zero for point P as the point lies in the plane S formed by the dipole axis and the axis of the earth
The angle of dip is zero for point Q as the point Q lies on the magnetic equator and the angle of declination is 11.3°.

5.25. There are two current carrying planar coils made each from identical wires of length L. C1 is circular and C2 is square. They are so constructed that they have same frequency of oscillation when they are placed in the same uniform B and carry the same current. Find a in terms of R.

Answer:

C_1 is the circular coil with radius R, length L, and no.of turns per unit length n1 = L/2πR
C_2 is the square with side a, perimeter L, and no.of turns per unit length n2 = L/4a



Magnetic moment of $C_1 = m_1 = n_1 i A_1$
Magnetic moment of $C_2 = m_2 = n_2 i A_2$
$m_1 = LiR/2$
$m_2 = Lia/4$
Moment of inertia of $C_1 = I_1 = MR^2/2$
Moment of inertia of $C_2 = Ma^2/12$
Solving the above, we get, $a = 3R$