5. Magnetism and Matter

5.1. What are the properties of magnetic field lines?

i. Magnetic field lines are continuous closed loops.

ii. Tangent to the field line represents the direction of net field $\vec{B}$.

iii. The larger the number of field lines crossing unit area normally, the stronger is the magnitude of the magnetic field $\vec{B}$.

iv. Magnetic field lines do not intersect.

5.2 Is a bar magnet an equivalent current carrying solenoid?

Yes. Each turn of solenoid behaves as a small magnetic dipole. Therefore solenoid can be considered as arrangement of small magnetic dipoles placed in line with each other. The magnetic field produced by solenoid is identical to that produced by the magnet.

5.2. What is the force acting on a bar magnet placed in a uniform magnetic field?

Zero.

5.3. What is the torque when a bar magnet of dipole moment m is placed in a uniform magnetic field? When is torque maximum and minimum.

$\vec{\tau} = \vec{m} \times \vec{B}$ = m. B. sinθ

Torque is maximum if θ= 90 i.e. torque is maximum if the magnetic dipole is at right angles to applied magnetic field.

Torque is minimum if θ = 0 i.e. torque is minimum if the magnetic dipole is along the direction of applied magnetic field.

5.4. Give an expression for time period of oscillation when a magnetic needle placed in uniform magnetic field.

A small compass magnetic needle of magnetic moment $\vec{m}$ and moment of inertia I is made to oscillate in the magnetic field, $\vec{B}$.

Time period of oscillation is given by $T = 2\pi\sqrt{\frac{I}{m\,B}}$.

5.7. State and explain Gauss law in magnetism.

The net magnetic flux through any closed surface is zero.

Consider a small vector area element $\overrightarrow{\Delta s}$ of closed surface S. According to Gauss law in magnetism, net flux though closed surface, $\phi_B = \sum_{\text{all area element}} \vec{B}.\overrightarrow{\Delta s} = 0$.

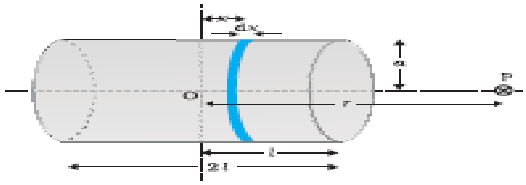
The implication of Gauss law is that isolated magnetic poles do not exist.

5.8. What is the cause of earth's magnetism?

Earths magnetism is due to electrical currents produced by the convective motion of mainly molten iron and nickel in the outer core of the earth.

5.9 . Show that a current carrying solenoid behaves as a magnet.

Let ‘r’ be radius of solenoid of length 2l.



To calculate magnetic field at a point on axis of solenoid, consider a small element of thickness ‘dx’ of solenoid at a distance ‘x’ from ‘o’.

Number of turns in this element = n.dx

If current ‘i’ flows through element ‘ndx’ the magnitude of magnetic field at P due to this element is

$$dB = \frac{\mu_0}{4\pi} \frac{2\pi (n\,dx) i\, a^2}{[(r-x)^2 + a^2]^{3/2}}$$

If point ‘p’ is at large distance from ‘o’ i.e. r >> l and r>> a then $[(r-x)^2 + a^2] = r^2$

$$dB = \frac{\mu_0}{4\pi} \frac{2\pi (n\,dx) i\, a^2}{[r^2]^{3/2}} = dB = \frac{\mu_0}{4\pi} \frac{2\pi (n\,dx) i\, a^2}{[r]^3}$$

The total magnetic field at ‘p’ due to the current ‘i’ in solenoid is

$$B = \int_{-l}^{l} dB = \int_{-l}^{l} \frac{\mu_0}{4\pi} \frac{2\pi\, ni\, a^2 dx}{[r]^3} = \frac{\mu_0}{4\pi} \frac{2\pi\, ni\, a^2}{[r]^3} [x]_{-l}^{l}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\pi\, ni\, a^2}{[r]^3} [l + l] = \frac{\mu_0}{4\pi} \frac{2\, i\, n\, \pi\, a^2\, .2l}{[r]^3}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\, i\, n\ A\, .2l}{[r]^3} = \frac{\mu_0}{4\pi} \frac{2\ (n\, .2l) iA}{[r]^3}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\, N\, i\ A}{[r]^3}$$

(N = No of turns of solenoid = n x 2l)

$$B = \frac{\mu_0}{4\pi}\frac{2\ m}{r^3}$$

This equation gives the magnetic of magnetic field at apt on axis of a solenoid.

This equation is similar to the expression for magnetic field on axis of a short bar magnet. Hence a solenoid carrying current behaves as a bar magnet.

5.10. What is magnetic declination?

Declination at the place is the angle between true geographic north direction and the north shown by the magnetic compass needle.

5.11. What is magnetic dip or inclination?

Magnetic dip at a place is the angle between the earth's total magnetic field at a place and horizontal drawn in magnetic meridian?

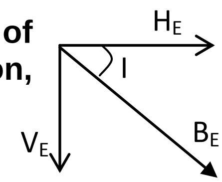
5.12. What are elements of earth's magnetic field? Mention them.

They are: (1) Magnetic declination (θ) at that place

(2) Magnetic inclination (δ) dip at that place

(3) Horigontal comp of earths magnetic field (BH) at that place.

5.13. What is the relation between horizontal component of earth's field H_E, vertical component of earth's field Z_E and inclination, I?



$Z_E = B_E \sin I$ or $H_E = B_E \cos I$ or $\tan I = \frac{Z_E}{H_E}$.

5.14. Define magnetisation of a sample.

Magnetisation of a sample is its net magnetic dipole moment per unit volume.

$\vec{M} = \frac{\vec{m}_{net}}{V}$.

5.15. What is the unit of magnetisation?

Am^{-1}.

5.16. Define magnetic intensity.

The degree to which a magnetic field can magnetise a material is represented in terms of magnetic intensity

Magnetic intensity of a material is the ratio of external magnetic field to the permeability of free space.

Magnetic intensity of a material, $\vec{H} = \frac{B_0}{\mu_0}$, where B_0 - external magnetic field, μ_0 - permeability of free space. For a solenoid $B_0 = \mu_0 nI$, and $\frac{B_0}{\mu_0} = n\,I = \vec{H}$ - depends on current.

5.17. What is the unit of magnetic intensity, $\vec{H}$?

Am^{-1}.

5.18. What is the relation between magnetic field $\vec{B}$, magnetic intensity $\vec{H}$ and magnatisation $\vec{M}$ of a specimen?

$\vec{B} = \vec{B_0} + \vec{B_m} = \mu_0(\vec{H} + \vec{M})$, where $\vec{B_0} = \mu_0\vec{H}$ due to current in the solenoid, $\vec{B_m} = \mu_0\vec{M}$ is due to nature of the material inside the solenoid.

5.19. What is magnetic susceptibility?

The ratio of magnetisation developed in the material to the magnetic intensity is called magnetic susceptibility.

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

5.20. Write the relation between magnetic intensity, magnetic field and susceptibility.

$\vec{B} = \mu_0(1 + \chi)\vec{H} = \mu H$.

5.21. What is the relation between magnetic relative permeability and susceptibility?

$\mu_r = 1 + \chi$.

5.22. What is the relation between magnetic relative permeability and permeability of the medium?

$\mu = \mu_0\mu_r$. μ is the permeability of medium , μ_0 is permeability of free space , and μ_r is relative permeability of the medium.

5.22. Define permeability .

Permeability of a substance is the ability of the substance to allow magnetic field lines to pass through it.

5.23. Distinguish between dia, para and ferro magnetism with examples.

	Diamagnetic material	Paramagnetic material	Ferromagnetic material
1	Weakly repelled by magnetic	Weakly attracted by magnetic	Strongly attracted by magnetic
2	When placed in a magnetic field it is weakly magnetized in a direction opposite to that of	When placed in a magnetic field it is weakly magnetized in the direction of applied field.	When placed in a magnetic field it is strongly magnetized in the direction of applied field.

	applied field.		
3	μ_r is slightly less than 1	μ_r is slightly more than 1	
4	When placed in a magnetic field flux density (B) inside the material is less than in air.	When placed in a external magnetic field, flux density (B) than in air.	When placed in a magnetic field the flux density (B) inside the material is much large than in air.
5	X_m (susceptibility) doesnot change with temperature	X_m varies inversely as the temperature of substance	X_m decreases with rise temperature
6	Intensity of magnetization a small and negative value	I has small and positive value	I has large positive value
7	X_m has small negative value	X_m has small positive value.	X_m has very high positive value.

5.26. State and explain Curie's law for paramagnetism.

The magnetisation of a paramagnetic material is inversely proportional to the absolute temperature until saturation.

If T is the absolute temperature of a paramagnet then magnetisation

$M \propto {}^{1}/_{T}$ or $M = C\frac{B_0}{T}$ or $\chi = C\frac{\mu_0}{T}$,

where C – Curie's constant.

At saturation all the dipoles orient in the direction of external field.

5.27. Distinguish between hard and soft ferromagnetic materials with examples.

After removal of external magnetic field if magnetisation remains, they are called hard ferromagnetic materials. Ex: Alnico.

After removal of external magnetic field if magnetisation disappears, they are called soft ferromagnetic materials. Ex: Iron.

5.28. Define Curie temperature.

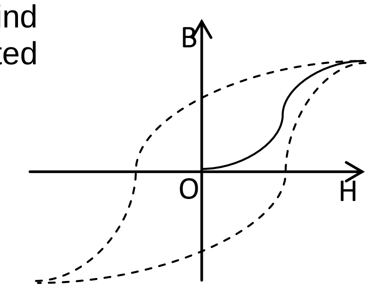
Curie temperature is the temperature above which a ferromagnetic substance becomes a paramagnetic substance.

5.29. Mention the expression for susceptibility in the paramagnetic phase of ferromagnetic material at absolute temperature T above Curie temperature T_C.

Magnetic susceptibility $= \frac{C}{T - T_C}$, where C – constant.

5.30. What is magnetic hysteresis?

The phenomenon of lagging of flux density (B) behind the magnetizing force (H) in a ferromagnetic material subjected to cycles of magnetization is known as hysteresis.



5.31. What is magnetic hysteresis loop?

The magnetic hysteresis loop is the closed B – H curve for cycle of magnetisation of ferromagnetic material.

5.32. What is retentivity or remanence of ferromagnetic material?

The value of B at H = 0 in a B – H loop is called retentivity or remanence.

5.33. What is coercivity?

The value of H at B = 0 in a B – H loop is called coercivity.

5.34. What are permanent magnets?

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

5.35. Which type of materials are required for permanent magnets? Give examples.

Materials having high retentivity, high coercivity and high permeability are required for permanent magnets. Ex: Steel, Alnico.

5.36. Which type of materials are required for electromagnets? Give example.

Materials having high retentivity and low coercivity are required for electromagnets. Ex: Iron.

5.37. What does area of hysteresis loop represent?

Area represents energy dissipated or heat produced.