5. MAGNETISM AND MATTER

Single Page Simple Synopsis

Magnetism and Matter explores the magnetic properties of materials, the Earth's magnetic field, and how matter behaves under external magnetic fields.

Key terms and Concepts:

1. **Bar Magnet** possesses a directive property (aligning North-South when suspended freely) and an attractive property.
   - **Magnetic Poles:** Magnets always exist as dipoles (North and South poles)
   - **Magnetic Field Lines:** Continuous closed loops that emerge from the North pole and enter the South pole externally.
2. **Gauss's Law for Magnetism:** The total magnetic flux (ϕ) passing through any closed surface is zero, expressed mathematically as $\oint \vec{B}.d\vec{S} = 0$
3. **Magnetic Properties of Materials:**
   - **Diamagnetic:** Materials are weakly repelled by magnets. **Ex:** Water, copper, bismuth, gold.
   - **Paramagnetic:** Materials are weakly attracted by magnets. **Ex:** Aluminum, calcium, oxygen.
   - **Ferromagnetic:** Materials are strongly attracted by magnets. **Ex:** Iron, cobalt, nickel. Their atomic dipoles align spontaneously to form strong clusters called domains.
4. **Magnetization Parameters**
   - **Magnetic Intensity ($\vec{H}$):** The applied externally magnetic field strength that magnetizes a material.
   - **Intensity of Magnetizaion ($\vec{M}$):** The magnetic moment per unit volume induced in a material $\vec{M} = \frac{\vec{m}_{net}}{V}$
   - **Magnetic Permeability (μ):** The ability of a material to allow magnetic lines of force to pass through it.
   - **Magnetic Susceptibility (χ):** How easily a material can be magnetized. **Formula:** $\chi = \mu_r - 1$.
5. **Curie's Law:** For paramagnetic materials, susceptibility is inversely proportional to absolute temperature (T): **Formula** $\chi = C/T$ (where C is Curie's constant).
6. **Earth's Magnetism (Geomagnetism):** The Earth behaves like a **Giant bar magnet.** To specify Earth's magnetic field completely at any point, we need 3 Magnetic Elements:
   - **Magnetic Declination (θ):** The angle between the geographic meridian and magnetic meridian at a given place.
   - **Magnetic Inclination / Dip (ϕ):** The angle made by the total magnetic field vector of the earth with the horizontal surface.
   - **Horizontal Component of Earth's Magnetic Field (H_E):** The component of the earth's magnetic field along the horizontal direction ($H_E = B_E\cos\phi$).

Real Life Examples

- **Magnetic needles** for Navigation, Headphones, speakers, Freezer doors, MRI, Electric motors- blenders, Washing machines

IMP. IPE POINTS

1. **Coulomb's inverse square law** is

$$F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{d^2}; \quad m: \text{pole strength}$$

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2. **Magnetic field** due to an isolated pole of strength m is

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

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3. **Axial field** of a small bar magnet is $B_A = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$

M= Magnetic moment

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4. **Equatorial field** of a small bar magnet is

$$B_E = \frac{\mu_0}{4\pi}\frac{M}{r^3}$$

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5. **Intensity of magnetisation(M)** of a sample is defined as the net magnetic moment per unit volume.

$$M = \frac{m_{net}}{V}$$ **SI unit:** A m^{-1}.

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6. The magnetic moment of a **solenoid** is

$$\bar{M} = NI\bar{A}$$

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7. Magnetic induction inside a solenoid is $B = \mu_0 nI$

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8. Magnetic intensity inside a solenoid is $H = nI$

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9. A solenoid acts like a bar magnet.

The axial field of a solenoid is $B = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$

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10. Relation between B and H is $B = \mu H$

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11. Relation between B, H, χ_m is $B = \mu_0 H(1+\chi_m)$

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12. **Declination (D)** is the angle between the geographic meridian and the magnetic meridian at a given place.

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13. **Inclination or dip (I)** is the angle between the earth's magnetic field and the horizontal axis.

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14. **Vertical component** of Earth's magnetic field is $B_V = B\sin i$ (i=inclination or dip)

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15. **Horizontal component** of Earth's magnetic field is $B_H = B\cos i$

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16. Relation between B_V and B_H

$$\tan i = \frac{B_V}{B_H} \text{ and } B = \sqrt{B_H^2 + B_V^2}$$

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17. **Paramagnetic substances** are weakly magnetised in the direction of magnetising field.

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18. **Diamagnetic substances** are weakly magnetised in **opposite** direction to that of magnetising field .

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19. **Ferro magnetic substances** are **strongly magnetised** in the direction of magnetising field.

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20. The value of B retained in a ferromagnetic material, after reducing H on it to zero, is called **retentivity** or remanence.

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21. The magnetising field intensity required to remove the residual magnetism (B) in ferromagnetic material is called **coercivity**.

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22. For soft iron, retentivity and coercivity are less.

That is why soft iron is used in electromagnets.

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23. Time period of oscillating magnetic needle in a uniform magnetic field is

$$T = 2\pi\sqrt{\frac{I}{MB}}; \quad I=\text{Moment of inertia}$$

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24. The susceptibility is $\chi = \frac{M}{H}$

where M is intensity of magnetisation.

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25. **Gauss law** for magnetism is $\oint \vec{B}.d\vec{S} = 0$

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26. **Torque** on a current loop in a magnetic field is $\tau = (n\,i\,A)\,B\sin\theta = MB\sin\theta$

$\bar{\tau} = \bar{M}\times\bar{B}$