4. MOVING CHARGES AND MAGNETISM

Single Page Simple Synopsis

The chapter **Moving Charges and Magnetism** establishes the foundation of electromagnetism. It explores how electric currents (moving charges) produce magnetic fields, the forces these fields exert on moving charges and conductors, and how devices like galvanometers and cyclotrons work.

CORE CONCEPTS

1. **Magnetic Field ($\vec{B}$):** A region around a magnetic material or a moving charge within which the force of magnetism acts.
2. **Lorentz Force:** The total force ($\vec{F}$) experienced by charge q moving with velocity v in both electric ($\vec{E}$) and magnetic fields ($\vec{B}$) is given by $\vec{F}=q(\vec{E}+\vec{v}\times\vec{B})$
3. **Motion of a charge in a Magnetic Field:**
   - **Parallel/Anti-parallel (θ= 0° or 180°):** The charge travels in a straight line.
   - **Perpendicular (θ = 90°):** The charge traces a circular path of radius $r=\frac{mv}{qB}$
   - **Angle θ:** The charge follows a helical path.
4. **Core Laws :**
   - **Biot-Savart Law:** This law determines the magnetic field ($d\vec{B}$) generated by a small current element $(Id\vec{l})$ at a distance (r). **Formula:** $d\vec{B}=\frac{\mu_0}{4\pi}\frac{I(d\vec{l}\times\vec{r})}{r^3}$
   - **Ampere's Circuital Law:** This law relates the integrated magnetic field around a closed loop to the electric current passing through that loop. **Formula:** $\oint\vec{B}.d\vec{l} = \mu_0 I_{enc}$
5. **Magnetic Field** at the center of a circular coil carrying current I is $B=\frac{\mu_0 I}{2r}$
6. **Force** between 2 parallel conductors carrying currents I_1, I_2 separated by a distance d is $f=\frac{\mu_0 I_1 I_2}{2\pi d}$
7. **Torque** on a rectangular current loop of area A with N turns carrying current I, in a uniform magnetic field $\vec{B}$ is $\tau=\vec{M}\times\vec{B}$. Here the magnetic dipole moment is $\vec{M}=NI\vec{A}$
8. **Cyclotron:** A particle accelerator that uses alternating electric fields and strong magnetic fields to accelerate charged particles .
9. **Moving Coil Galvanometer:** A device used to detect small electric currents.
10. **Solenoid** is a long, tightly wound helical coil of wire. It generates a strong, controlled and nearly uniform magnetic field when an electric current passes through it.

Real Life Examples

•**Electric motors (Fans),** Loud Speakers, Magnetic Trains, particle accelerators, MRI machines

IMP. IPE POINTS

1. **Oersted** found that a magnetic field($\vec{B}$) is always produced around a current carrying conductor.

2. The **magnetic force** on a **charged particle** moving in a magnetic field B is
$\vec{F} = Bqv \sin\theta$ (or) $\vec{F} = q[\vec{v} \times \vec{B}]$

3. The **magnetic force** on a **conductor** of length l carrying current I in a magnetic field B is $\vec{F} = BIl \sin\theta$ (or) $\vec{F} = I[\vec{l} \times \vec{B}]$

4. A charged particle entering a magnetic field B at right angle with velocity v will move in circular path of radius $r = \frac{mv}{qB}$

5. If electric and magnetic fields are perpendicular to each other, they are called **crossed E and B fields.** If the net force on a charged particle entering the crossed fields is zero, then the velocity of the particle is
$$v = \frac{E}{B}$$
Such a setup is called **velocity selector.**

6. **Cyclotron** is a device used to accelerate positively charged particles. Crossed electric and magnetic fields are used in it.

7. **Biot-Savart law:** $dB = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta}{r^2}$

8. **Ampere's law:** $\oint \vec{B}.d\vec{l} = \mu_0 I$

Field due to a long conductor $B = \frac{\mu_0}{2\pi} \frac{I}{r}$

9. Magnetic field induction on the **axis of a coil** carrying current is $B_x = \frac{\mu_0 NIR^2}{2(x^2 + R^2)^{3/2}}$

10. At the **centre of coil,** magnetic field induction is $B_0 = \frac{\mu_0 NI}{2R}$

11. **Force between two parallel conductors** carrying currents
$$F_{ba} = \frac{\mu_0 I_a I_b}{2\pi r} l \text{ (or) } f = \frac{F_{ba}}{l} = \frac{\mu_0 I_a I_b}{2\pi r}$$

12. **Torque** on a coil carrying current in a magnetic field: $\tau = BIA \sin\theta$

13. Magnetic dipole moment of a **current loop**: $M = IA$

14. Magnetic dipole moment of **revolving electron**: $M = \frac{evr}{2}$

15. **Formula for MCG:** $\phi = \left(\frac{BAN}{C}\right) I$

16. **Shunt resistance:** $r_s = \frac{R_G}{n-1}$
R_G = Resistance of galvanometer.
$n = \frac{I}{I_G} = \frac{\text{new current}}{\text{old current}}$

17. **Formula for Voltmeter:** $V = i_G (R + R_G)$
High resistance: $\frac{V}{I_G} - R_G = R$

18. Velocity of light in Vacuum $C_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$
μ_0 = magnetic permeability of free space
ε_0 = electric permittivity of free space

19. Current sensitivity $\frac{\phi}{I} = \frac{NAB}{K}$

20. Voltage sensitivity $\frac{\phi}{V} = \left(\frac{NAB}{K}\right) \frac{I}{R}$