General Physics

Lecture Five / Theoretical

Magnetism and Electromagnetism: A Deep Dive

First stage

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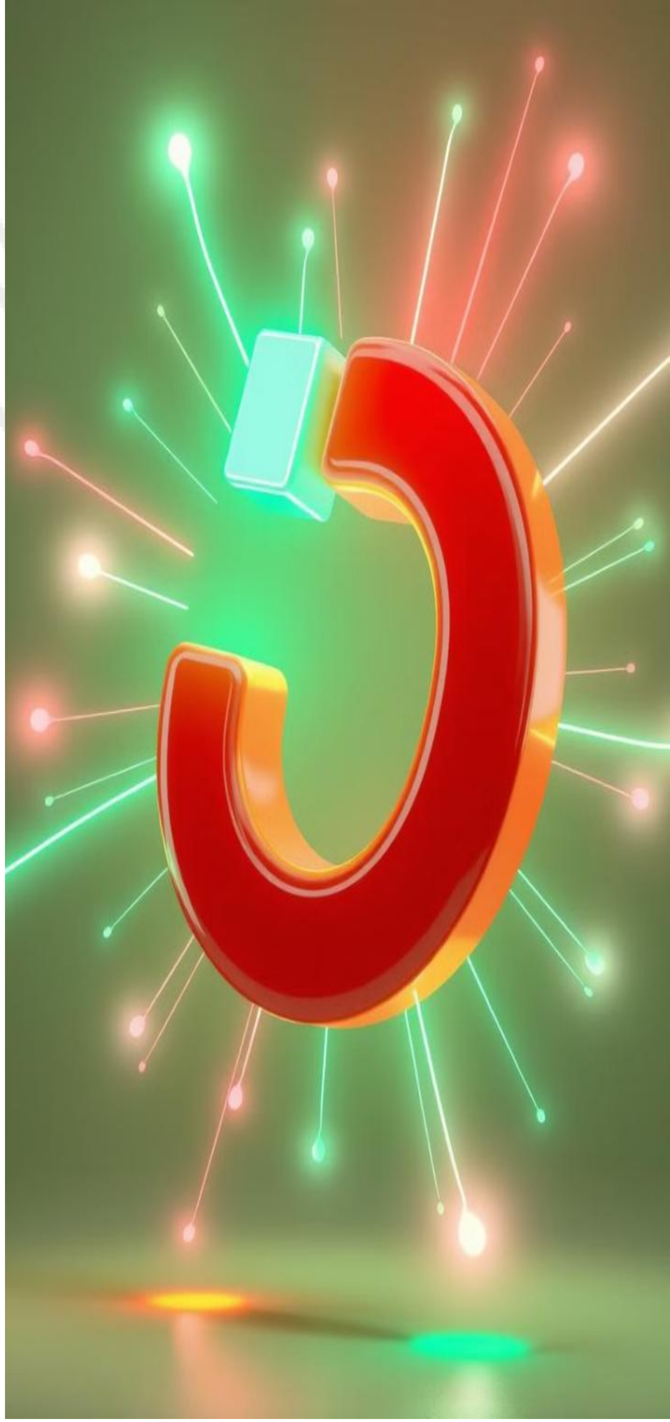
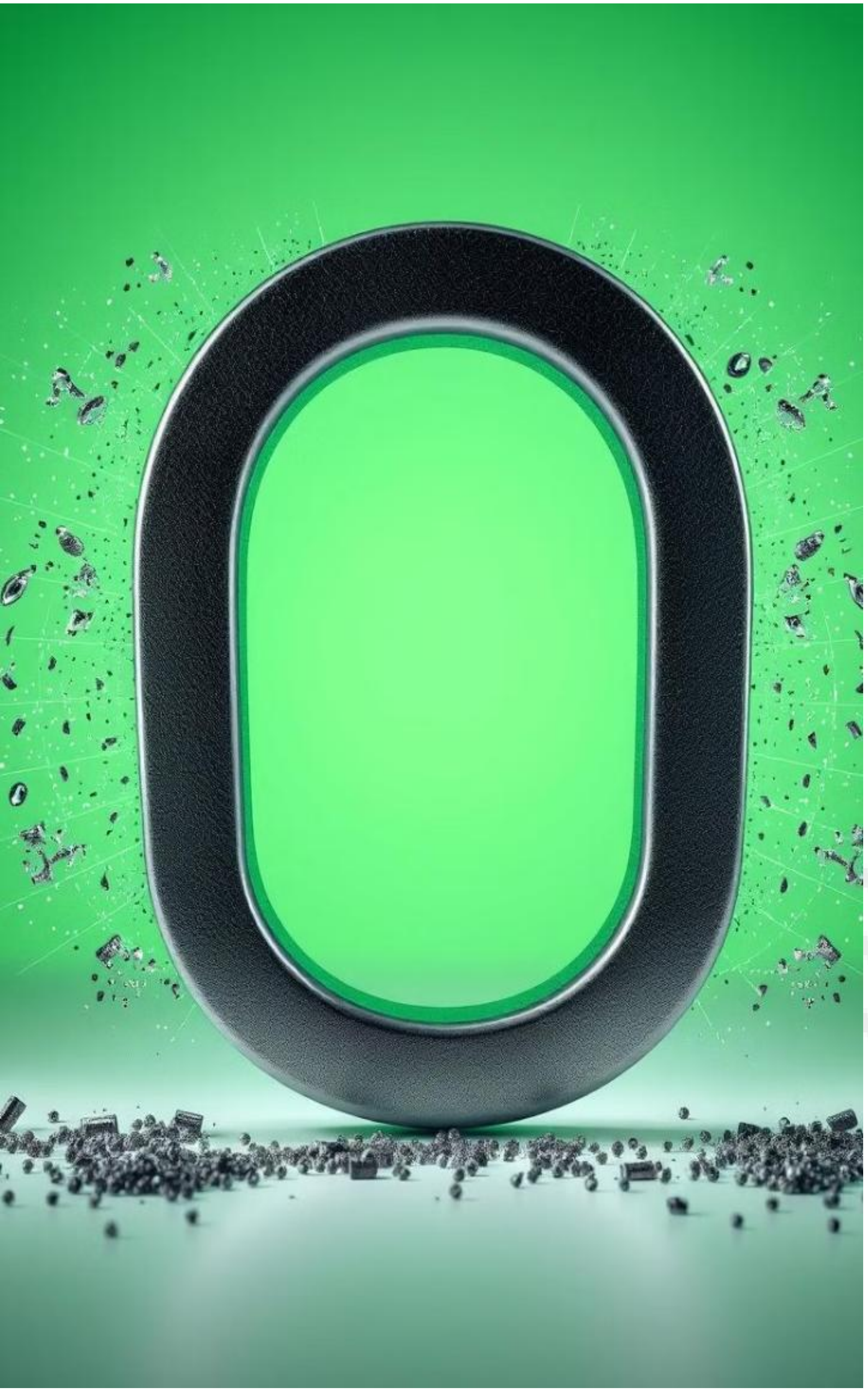
2024-2025

Overview of Magnetism

- Magnetism is one of the four fundamental forces of forces of nature, alongside gravity, the weak force, and force, and the strong force. It governs the interaction interaction between objects with magnetic properties. properties. Associated with materials like iron, nickel, and cobalt.





Magnetic Fields

1

Every magnet generates a a magnetic field, an invisible invisible area surrounding surrounding the magnet where magnetic forces exert exert influence.

2

Magnetic field lines, represented by imaginary lines, depict the direction and and strength of the magnetic magnetic field. They always always loop from the north north pole to the south pole. pole.

3

The Earth itself acts as a giant magnet, generating a generating a global magnetic field that protects us protects us from harmful solar radiation.

Types of Magnets

- **Natural Magnets:**
    - Found in nature (e.g., lodestone).
- **Permanent Magnets:**
    - Retain their magnetic properties (e.g., refrigerator magnets).
- **Temporary Magnets:**
    - Become magnetic only in the presence of a magnetic field.
- **Electromagnets:**
    - Created by passing electric current through a coil of wire

Electromagnetism

What is Electromagnetism?

The interaction between electricity and magnetism.

Discovered by Hans Christian Orsted in .1820

Key Concept:

Moving electric charges generate magnetic fields.

Applications:

Motors, generators, transformers, and MRI machines.

Differences Between Magnetism and Electromagnetism

ASPECT	MAGNETISM	ELECTROMAGNETISM
Source	Natural or permanent magnets	Electric current
Strength	Fixed	Adjustable
Applications	Compasses, fridge magnets	Motors, generators, transformers

Faraday's Law of Electromagnetic Induction

What is Faraday's Law?

Faraday's Law of Electromagnetic Induction, discovered by Michael Faraday in 1831, states that:

A changing magnetic field induces an electromotive force (EMF) in a conductor.

In simpler terms:

If you move a magnet near a coil of wire or change the magnetic field around a conductor, an electric current will be generated in the conductor.

The induced EMF is proportional to the rate of change of the magnetic flux through the conductor.

The mathematical expression for Faraday's Law is:

What is Faraday's Law?

Faraday's Law of Electromagnetic Induction, discovered by Michael Faraday in 1831, states that:

$$\varepsilon = -N\frac{\Delta\phi_B}{\Delta T}$$

Where:

ε: Induced electromotive force (EMF) in volts (V).

N: Number of turns in the coil.

ϕ_B : Magnetic flux (ϕ_B = B.A cos θ) where *B* is the magnetic field strength, *A* is the area of the loop, and θ is the angle between the magnetic field and the normal to the surface in weber.

ΔT: Time interval over which the magnetic flux changes.

- The negative sign indicates the direction of the induced EMF (Lenz's Law), which opposes the change in magnetic flux.

Problem 1: Basic Calculation of Induced EMF

A coil with 50 turns has a magnetic field of $0.2\,\mathrm{T}$ passing through it. The area of the coil is $0.1\,\mathrm{m}^2$. If the magnetic field decreases uniformly to $0\,\mathrm{T}$ in $0.5\,\mathrm{s}$, calculate the induced EMF.

Solution:

1. Magnetic flux through the coil initially:

$$\Phi_B = B \cdot A \cdot \cos\theta$$

Assuming $\theta = 0^\circ$ (magnetic field is perpendicular to the surface):

$$\Phi_B = 0.2 \cdot 0.1 \cdot \cos(0^\circ) = 0.02\,\mathrm{Wb}\,(\mathrm{weber})$$

2. Change in magnetic flux:

$$\Delta\Phi_B = \Phi_{B,\mathrm{final}} - \Phi_{B,\mathrm{initial}} = 0 - 0.02 = -0.02\,\mathrm{Wb}$$

3. Induced EMF:

$$\mathcal{E} = -N\frac{\Delta\Phi_B}{\Delta t}$$

Substituting values:

$$\mathcal{E} = -50 \cdot \frac{-0.02}{0.5} = 50 \cdot 0.04 = 2\,\mathrm{V}$$

Answer: The induced EMF is $2\,\mathrm{V}$.