Chapter-11

1. Introduction to Electricity and Magnetism

Electricity and magnetism are closely linked phenomena:

- **Electricity** involves the flow of electric charges (electrons).
- **Magnetism** arises from moving charges and affects magnetic materials.

These two fields unify under **electromagnetism**, governing many modern technologies.

2. Direct Current (DC) vs Alternating Current (AC)

Direct Current (DC)

- **Definition:** Electric charge flows in **one constant direction.**
- **Sources:** Batteries, solar cells, DC generators.

Alternating Current (AC)

- **Definition:** Electric charge **periodically reverses direction.**
- **Characteristics:** Defined by **frequency** (Hz) and **waveform** (usually sine wave).

Comparison Table :-

Feature	DC	AC
Direction	Unidirectional	Reversing periodically
Source	Batteries, solar cells	Power plants, home outlets
Voltage & Current	Constant	Varies over time
Energy Transmission	Suitable for short distances	Ideal for long-haul transmission (reduces loss)
Frequency	0 Hz	50 Hz (Nepal/India), 60 Hz (US)
Waveform	Straight line	Sine wave
Applications	Electronics, small appliances	Homes, industries, lighting

3. Converting AC to DC

- **Bridge rectifier** - Uses diodes to convert AC to pulsating DC.
- **Filtering** - Capacitors smooth the DC output.
- **Voltage regulators** ensure constant DC level (e.g., for chargers).

4. Magnetic Effect of Electrical Current

4.1 Magnetic Field Around a Straight Wire

- Current generates a magnetic field in concentric circles.
- **Maxwell's Right-hand Thumb Rule:** Thumb along current, fingers show magnetic field direction.

4.2 Magnetic Field Around a Solenoid

A solenoid (coil of wire) acts like a bar magnet when carrying current.

Factors affecting field strength:

- Number of turns (N): Field $\propto$ N
- Electric current (I): Field $\propto$ I
- Core permeability: Higher permeability → stronger field
- Length and cross-sectional area
- Coil shape and current direction (rule of cork-screw)

At **ends** of solenoid, field lines expand outward.

5. Magnetic Flux

Magnetic Flux (Φ)

Definition:
Magnetic flux (Φ) measures the total magnetic field passing through a given area.

Formula:
$\Phi = B \times A \times \cos(\theta)$

Where:

θ = Angle between magnetic field and the normal (perpendicular) to the surface

Φ = Magnetic flux (in Weber, Wb)

B = Magnetic field strength (in Tesla, T)

A = Area through which the field lines pass (in m^2)

6. Motor Effect

- A current-carrying conductor in a magnetic field experiences a **force**.
- **Key Features:**
  - Force direction given by **Fleming's Left-hand Rule**:
    Thumb: Force, *Forefinger: Field*, *Middle: Current*
  - Magnetic Force on a Current-Carrying Conductor
  - **Formula:**
  - $F = B \times I \times L \times \sin(\theta)$
  - **Where:**
  - **F** = Magnetic force (in newtons, N)
  - **B** = Magnetic field strength (in tesla, T)
  - **I** = Current (in amperes, A)
  - **L** = Length of the conductor (in meters, m)

- θ = Angle between the conductor and the magnetic field

Applications:

- **DC motors** (fans, toys, small appliances)
  - Working principle: Force on coil causes rotation; commutator reverses current to maintain torque.
- Other applications: Speakers, electric drills

7. Electromagnetic Induction

Current induced in a conductor due to changing magnetic environment.

Key Points:

- Requires **magnetic field**, **changing flux**, and **conductor** moving or stationary.
- **Faraday's Laws**:
  1. Induced emf ∝ rate of change of magnetic flux.
  2. Direction predicted by Lenz's Law: Induced current opposes the flux change.

Devices:

- **Dynamo**: Generates DC via rotating coil + commutator.
- **AC Generator (Alternator)**: Generates AC using rotating coil + slip rings.

8. Sources of Electrical Power

- **Hydropower station:** Uses water flow to rotate turbines.
- **Thermal power plant:** Burns fuel to produce steam driving turbines.
- **Wind turbine:** Converts wind energy via rotor blades.
- **Nuclear power plant:** Nuclear fission heats water to produce steam.

9. Transformers

9.1 Types:

- **Step-up**: Increases voltage (lower current, longer transmission)
- **Step-down**: Decreases voltage (safer for household use)

9.2 Working Principle:

- Applies AC to primary coil → changing magnetic flux in core → induces emf in secondary coil.

9.3 Structure:

- Iron core (high permeability)
- Primary and secondary windings

- Insulation (oil, varnish) prevents electrical breakdown

9.4 Transformation Formula:

Formula:
Vs Vp = Ns Np

Where:
`Vs/Vp` = Voltage ratio
`Ns/Np` = Turns ratio

🧮 Working Example:

Transformer Voltage Calculation

Given:

- $V_p = 230$ V
- $N_p = 100$
- $N_s = 1000$

Formula:
$V_s = V_p \times (N_s / N_p)$

Calculation:
$V_s = 230 \times (1000 / 100) = 2300$ V

Therefore, the secondary voltage V_s is **2300 volts**.

10. Electric Generators

AC generators (alternators) use rotating coils in magnetic fields to produce electricity (rarely DC).

Interesting Facts

- Tesla's inventing of **AC power** resolved inefficiencies of earlier DC systems!
- **Hydropower stations** in Nepal (e.g., Kali Gandaki) provide clean energy.
- Transformers work only with **AC**, not DC.
- **Wind turbines** generate electricity at variable power depending on wind speed.

Quick Revision Summary

- **DC vs AC**: Uni vs bidirectional current; applications vary.
- **Magnetism from currents**: Straight wires, solenoids → field produced.
- **Motor effect**: Force on conductor in magnetic fields → rotation in motors.
- **Electromagnetic induction**: Current produced by changing flux (Faraday's laws).
- **Transformers**: Change voltage via winding ratios.

- **Power generation**: Hydropower, thermal, wind, and nuclear sources.

Common Misconceptions

- Confusing DC with AC (frequency absent in DC)
- Assuming generator produces DC without highlighting dynamo vs alternator
- Misapplying Fleming's rules
- Transformer works only with alternating current
- Neglecting transformer insulat ion and its importance