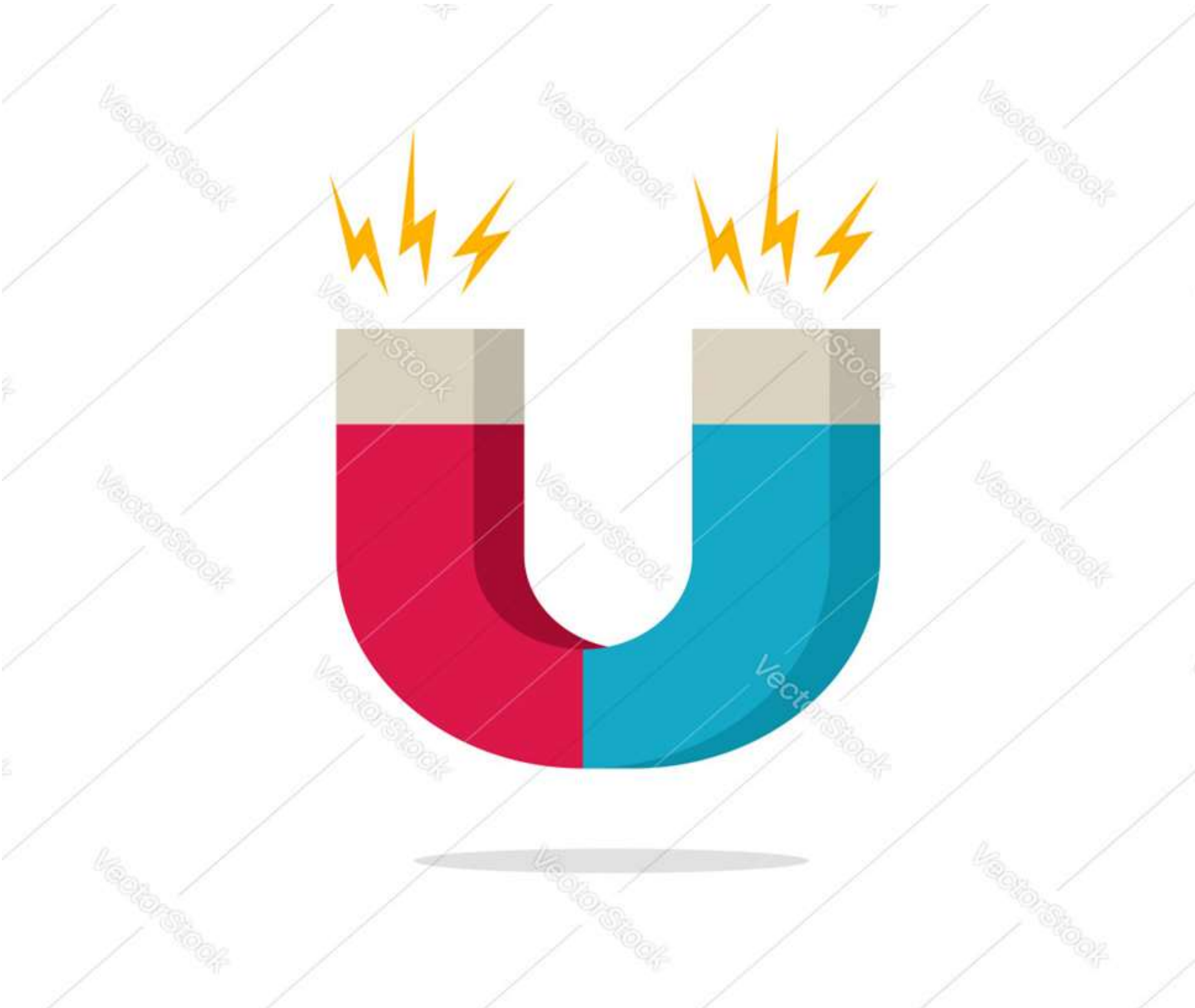


Mariam Mohamed Abdelaty

One: magnetic effect of electric current

Definitions:

Lesson 1: Magnetic Field

- **Magnetic Field:** An area around a magnet or a current-carrying conductor where magnetic forces can act.
- **Magnetic Field Lines:** Imaginary lines representing the direction and strength of a magnetic field.
- **Magnetic Flux (Φm):** The total number of magnetic field lines passing through a given surface area.
- **Magnetic Flux Density (B):** The strength of a magnetic field, measured in Tesla (T).

Lesson 2: Magnetic Field due to a Current-Carrying Straight Conductor

- **The magnetic flux density B**: It describes the density and direction of the field lines that pass through a certain area **A**. Or it is the total number of magnetic flux lines passing **normally** through a unit area around the point

$$B = \frac{\Phi_B}{A}$$

- **Magnetic permeability**: It is the ability of medium to penetrate the magnetic flux lines) **The measuring unit** Wb/m. A = T.m. /A

Lesson 4: Magnetic Field due to a Current-Carrying Solenoid

- **Neutral point**: **It is the point at which the total magnetic flux density vanishes**
- **The neutral point may be formed when two magnetic fields equal in magnitude and opposite in directions are met at a point**

Lesson 5: Magnetic Force on a Current-Carrying Conductor

- **Fleming's Left-Hand Rule:** A rule to determine the direction of the force, magnetic field, and current in a conductor.
- **The magnetic flux density can be defined**: (It is the magnetic force exerts on a wire of **1m** length carrying a current of intensity **1 A** and placed perpendicularly to the magnetic field.

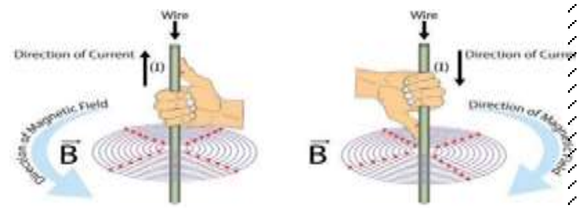
- **Tesla:** (It is the magnetic flux density which exerts a force of 1 N on a wire of 1m length carrying a current of intensity 1A placed perpendicularly to the magnetic field.) Or
- **Tesla: It** is the magnetic flux density when the total number of magnetic flux lines passing normally through a unit area around the point is 1 Wb

Lesson 6: Magnetic Torque on a Current-Carrying Coil

- **The magnetic dipole moment**: (It is the magnetic torque acting on a coil carrying current placed parallel to a uniform magnetic field of flux density of 1 tesla

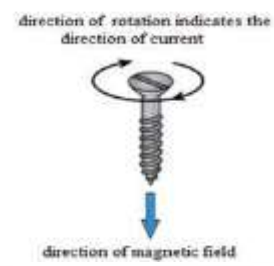
• Rules used to determine the direction of magnetic field:

1. The direction of magnetic field around a straight wire:



- ❖ **Ampere's Right-Hand Rule:** A rule to determine the direction of the magnetic field around a current-carrying conductor.

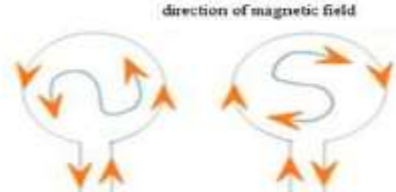
2. The direction of magnetic field around a circular coil



- ❖ **The right Corkscrew rule**: Rule used to determine the direction of the magnetic field resulting from an electric current in a circular coil.

- ❖ **Clockwise rule (polarity coil)**:

  Rule used to determine the direction of the magnetic field around a circular coil if the side at which the current is in a clockwise direction is the **South Pole** while the side of which the current is an antilock wise direction is the **North Pole**

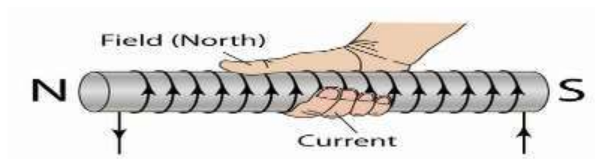


3. The direction of magnetic field around a solenoid

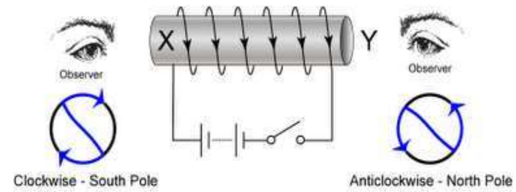
To determine the direction of the magnetic field resulting from an electric current in a Solenoid we have two rules

a) Amperes right hand rule:

If **the wrapped fingers:** point to the direction of current while the thumb points **to the North Pole** (the direction of magnetic field within the solenoid.



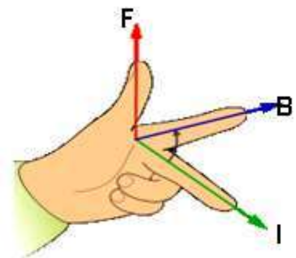
b) Clockwise rule (polarity coil):



The side at which the current is in a clockwise direction is the **South Pole** while the side of which the current is antilock wise direction is the **North Pole.**

4. **Fleming left hand rule**

❖ Used to determine the direction of the force (motion) of a straight wire carrying current in a magnetic Field



- The thumb, first finger and second finger of the left hand are all perpendicular to each other.
- The thumb points in the direction of motion of the wire.
- The pointer (first finger) points in the direction of the field
- The middle (second finger) points in the direction of the current through the wire

Laws:

1. **Magnetic flux (Φ_m)**

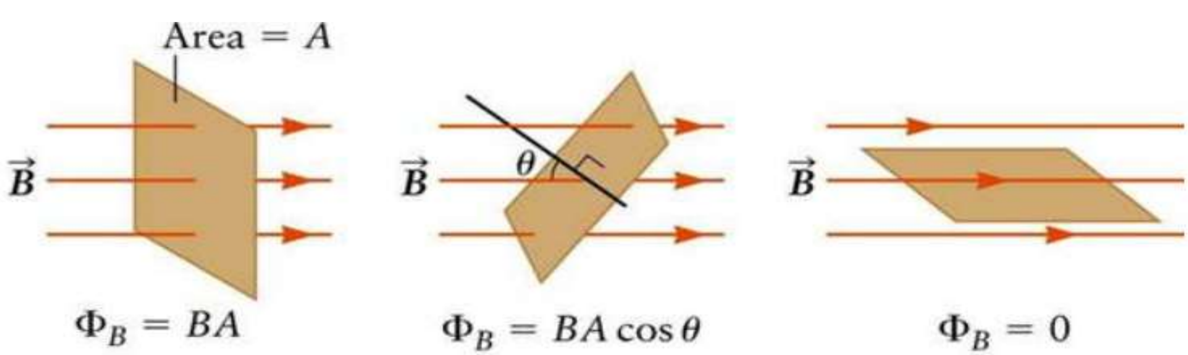
$$\Phi_m = B\ A\cos\theta$$

Φm: The magnetic flux through a surface (Weber)

B: the magnetic flux density (Tesla)

A: the surface area (m^2)

θ: the angle between the perpendicular to (normal to) surface and direction of magnetic field



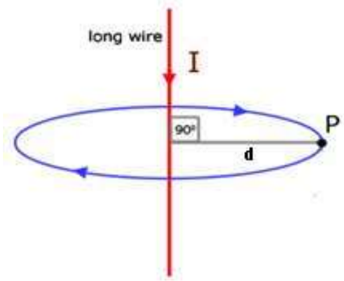
2. The magnetic flux density B

$$B = \frac{\Phi_B}{A}$$

- **The denser the field lines, the larger the magnetic flux density, which is measured in tesla (T) that equivalent to Weber/ m^2 (Wb /m^2)**

3. The magnitude of the magnetic field density (B) around a straight wire:

$$B = \frac{\mu I}{2 \pi d}$$



This relation is called **Ampere's circular law**

Where:

B: the magnetic field density **(Tesla)**

I: intensity of current passing through the wire **(Ampere)**.

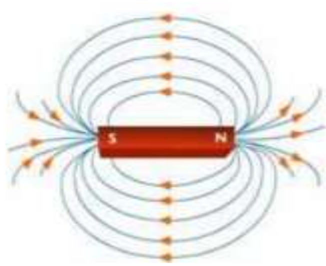
d: The distance of the point from the wire **(meter)**.

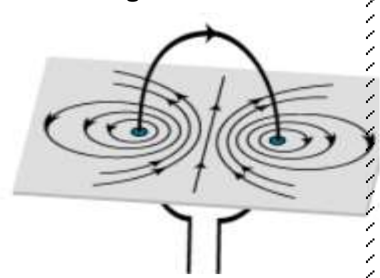
μ: magnetic Permeability of medium **($\mu_{air} = 4\pi\ 10^{-7}$ Wb/m. A)**

4. The magnitude of the magnetic field density (B) around a circular coil:

❖ The magnetic field density at center of the circular coil can be given by the following relation:

$$B = \frac{\mu NI}{2r}$$





Where:

B: the magnetic flux density **(Tesla)**

I: intensity of current passing through the wire **(Ampere)**.

r: the radius of the circular coil **(meter)**.

μ: Permeability of medium **(μair = 4π 10^{-7} Wb/m. A)**

❖ If a straight wire of length (*l*) is bent to form circular coil of radius (r) and of turn's number (N), then $\boxed{l = \text{circumference of the circular coil} = 2\pi r N}$

5. The magnitude of the magnetic field density (B) around a solenoid:

The density of magnetic field at a point on its interior axis can be given by the following relation

$$B = \frac{\mu NI}{L}$$

Where:

B: the magnetic field density around a solenoid **(Tesla)**

I: intensity of current passing through the coil **(Ampere)**.

L: the length of the solenoid **(meter)**.

μ: Permeability of medium **(μair = 4π 10^{-7} Wb/m. A)**

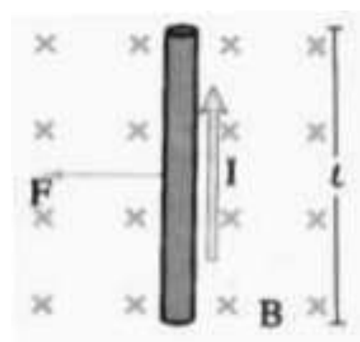
N: the number of turns of wire in the solenoid

$$B = \mu n I$$

Where **n** is the number of turns per unit length $n = \frac{N}{L}$

6. The magnetic force acting on a wire carrying current placed in a uniform magnetic field (F):

$$F = B I L$$



- **Where:**

(B) is in Tesla (Weber / m^2)

(I) is in ampere

(L) is in meter

(F) is in Newton

- **In general, when a wire carrying current placed in a uniform magnetic field makes an angle (θ) with the magnetic field, then**

$$F = B I l \sin \theta$$

Where θ is the angle between the wire and the magnetic field

- **The factors affecting the force acting on a current - carrying wire suspended at right angles to a magnetic field:**

1) The length of the wire (L) F α L

2) The current in the wire (I) F α I

3) The magnetic flux density (B) F α B

Note that

a) When a wire makes an angle θ with the magnetic field

$F = l\,I\,B \sin\theta$

b) When the wire is placed perpendicular to the magnetic field ($\theta = 90^\circ$ or 270°)

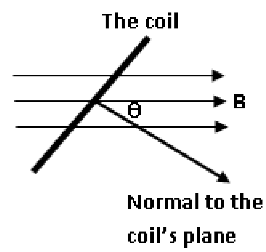
$F = l\,I\,B_{\perp}$

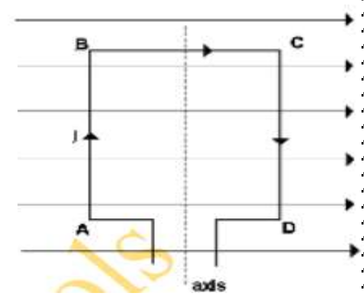
Therefore the force is maximum value

c) The wire is placed parallel to the magnetic field ($\theta = 0^\circ$ or 180°) Therefore the wire does not move $F = 0$

7. The magnetic torque acting on a coil

$\tau = B\,I\,A\,N \sin\theta$





The magnetic torque measured in N.m = T.A.m^2

The factors affecting Torque of couple on a rectangular coil carrying current in a magnetic field: (τ)

1) magnetic flux density **(τ α B)** (at constant other factors)

2) the current intensity **(τ α I)** (at constant other factors)

3) the area of the coil's plane **(τ α A)** (at constant other factors)

4) number of turns of the coil **(τ α N)** (at constant other factors)

5) the angle between perpendicular to coil's plane and the magnetic flux lines

Note that

When the perpendicular to coil's plane makes an angle θ with the magnetic field

$$\tau = B\,IAN \sin\theta$$

b) When the perpendicular to coil's plane perpendicular to the magnetic field
($\theta = 90^\circ$ or 270°) (the coil's plane is parallel to the magnetic field)

$$\tau = B\,IAN$$

Therefore the magnetic torque is maximum value

c) When the perpendicular to coil's plane parallel to the magnetic field ($\theta = 0^\circ$ or 180°)
(the coil's plane is perpendicular to the magnetic field)

$$\tau = 0$$

Therefore the coil does not rotate

8. The magnetic dipole moment (|md|) (magnetic moment of the loop)

Magnetic dipole moment = normal to the coil's plane

$$|m_d| = IAN = \tau_{max}/B$$

The magnetic dipole moment measured in **$A.m^2$ = N.m./ T**

- **The magnitude of the magnetic dipole moment depends on**

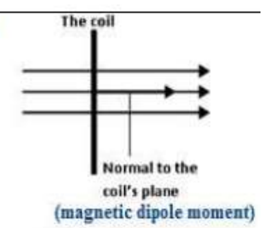
1) the current intensity **($|md| \propto I$)** (at constant other factors)

2) the area of the coil's plane **($|md| \propto A$)** (at constant other factors)

3) number of turns of the coil **($|md| \propto N$)** (at constant other factors)

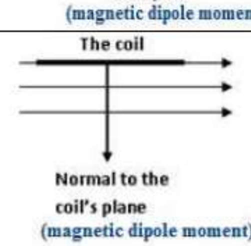
(Magnetic dipole moment is parallel to magnetic flux lines)
(The coil's plane is perpendicular to magnetic flux lines)

$$\tau = 0$$
$$\theta = 0^\circ$$



(Magnetic dipole moment is perpendicular to magnetic flux lines)
(The coil's plane is parallel to magnetic flux lines)

$$\tau_{max} = B\,IAN$$
$$\theta = 90^\circ$$



Unit Two: Electromagnetic Induction

Lesson 1: Meaning of Electromagnetic Induction and Faraday's Law

1. **Introduction**
   - Discovery of magnetic fields produced by electric currents (Oersted).
   - Faraday's breakthrough: Magnetic fields can produce electric currents (electromagnetic induction).
   - Applications: Generators, transformers, and electric equipment.
2. **Electromagnetic Induction**
   - Definition: Induced electromotive force (emf) and current are generated in a conductor by a changing magnetic field.
3. **Faraday's Experiment**
   - Description of setup (coil, magnet, galvanometer).
   - Observations: Motion of the magnet generates emf and current.
4. **Faraday's Laws**
   - First Law: Relative motion between a conductor and a magnetic field induces emf.
   - Second Law: Magnitude of emf is proportional to the rate of change of magnetic flux.
   - Mathematical Expression:

$$\text{emf} = -N\frac{\Delta\Phi_m}{\Delta t}$$

where $\Delta\Phi_m$ is the change in magnetic flux and Δt is the time interval.

   - **Lenz's Rule**: Negative sign indicates that induced emf opposes the change causing it.

Lesson 2: Lenz's Law

1. **Lenz's Law Statement**
   - "The induced current flows in a direction to oppose the change producing it."
2. **Explanation**
   - Motion of the magnet:
     - Approaching magnet induces a like pole, creating repulsion.

- Withdrawing magnet induces an unlike pole, creating attraction.

3. **Factors Affecting Induced Current**
   - Direction of motion.
   - Direction of magnetic field.
4. **Applications of Lenz's Law**
   - Magnetic flux variation in solenoids and coils.

Lesson 3: Mutual and Self-Induction

1. **Mutual Induction**
   - Definition: Induction of emf in a secondary coil due to current variation in a primary coil.
   - Examples of emf generation:
     - Movement of coils relative to each other.
     - Current variation using rheostats or switches.
   - Formula

$$\text{emf}_2 = -M\frac{\Delta I_1}{\Delta t}$$

2. **Self-Induction**

- Definition: Induction of emf in the same coil due to its own varying current.
- Formula

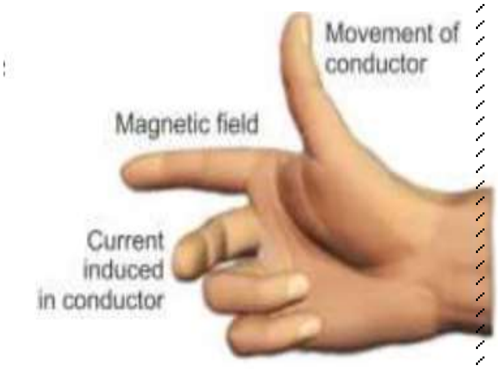
$$\text{emf} = -L\frac{\Delta I}{\Delta t}$$

Factors affecting self-induction:

- Coil geometry (size, length, and turns).
- Distance between turns.
- Magnetic permeability of core material.

Lesson 4: The Electric Generator (Dynamo)

1. **Induced emf in a Straight Wire**
    - When a conductor moves perpendicularly to a magnetic field, emf is induced.
    - Formula for emf: $emf = B\ell v \sin\theta$ where B is magnetic flux density, ℓ is the wire length, v is velocity, and θ is the angle of motion relative to the field.

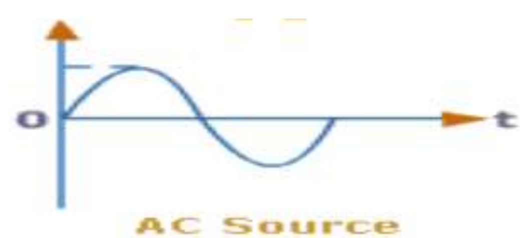


2. **Fleming's Right-Hand Rule**
    - Thumb: Direction of motion.
    - Pointer: Direction of magnetic field.
    - Middle finger: Direction of induced current.

<u>**Current Types:**</u>

1. **Direct Current (DC):**
    - Flows in one direction.
    - Constant intensity and produces a steady magnetic field.
    - Frequency = 0.
    - Examples: Batteries, DC dynamos.

2. **Alternating Current (AC):**
    - Reverses direction periodically.
    - Produces a variable magnetic field.
    - Has a frequency (f).
    - Examples: AC dynamos.

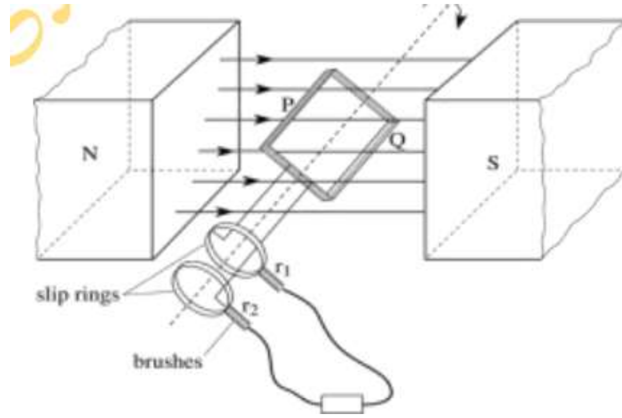


AC Generator (Dynamo):

1. **Principle:**
    - Converts mechanical energy into electrical energy.
    - Based on electromagnetic induction.

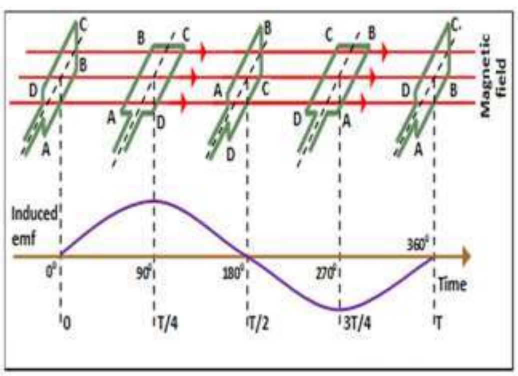
2. **Main Components:**

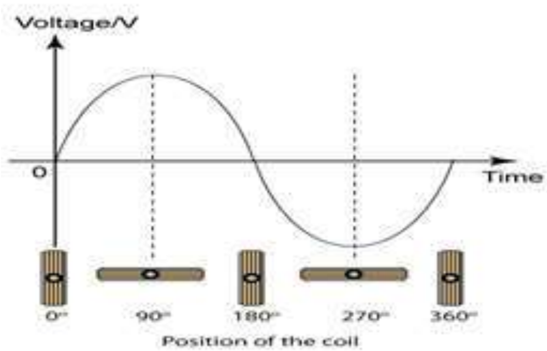
- **Field Magnet:** Produces a radial magnetic field.
- **Armature:** Rotating coil with multiple turns on a laminated iron core.
- **Slip Rings:** Transfer current from the coil to the external circuit.
- **Graphite Brushes:** Maintain electrical contact with slip rings.



3. **Working:**

- As the coil rotates, its sides cut magnetic field lines, changing the magnetic flux linked with the coil.
- This change induces a current in the coil, with variable intensity and direction.
- The direction of the induced current is determined by Fleming's right-hand rule.
- The induced current reverses direction every half rotation of the coil.
- As a result, the induced current is alternating in nature.
- The frequency of the alternating current corresponds to the number of armature rotations per second.





4. **Induced EMF in a Coil:**

- For a coil with N turns, area A, frequency f, and angle θ.

$$\mathrm{emf}_{\mathrm{coil}} = ABN(2\pi f)\sin\theta$$

- Induced current:

Electric Transformer:

$$I = \frac{\text{emf}_{\text{coil}}}{R}$$

1. **Purpose:**
   - Converts low AC voltage to high AC voltage (step-up) or vice versa (step-down).
2. **Components:**
   - **Primary and Secondary Coils:** Insulated coils wound on a soft iron core.
   - **Laminated Iron Core:** Reduces energy loss due to eddy currents.
3. **Transformer Formula:**
   - Voltage ratio:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

- Current ratio:

$$\frac{I_p}{I_s} = \frac{V_s}{V_p}$$

4. **Efficiency:**
   - Defined as the ratio of output power to input power:

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} \times 100$$

   - For ideal transformers:

$$\eta = 100\%$$

   - Practically, efficiency is less than 100% due to energy losses (e.g., heat, eddy currents).

Scientific Term Questions on Unit 2

1. **What is the scientific term for:**
   - The process of generating an emf when a conductor cuts through magnetic field lines.
     (Electromagnetic Induction)

- A current that flows in one direction only and has a constant intensity and direction.
  (Direct Current or DC)

- The current that flows alternately in two opposite directions and periodically changes intensity.
  (Alternating Current or AC)

- A rule used to determine the direction of induced current in a wire when it moves in a magnetic field.
  (Fleming's Right Hand Rule)

- A device used to convert mechanical energy into electrical energy.
  (AC Generator or Dynamo)

- The magnetic field generated due to the flow of alternating current in a circuit.
  (Variable Magnetic Field)

- Induced currents that circulate in closed paths within a conductor, caused by a change in magnetic flux, and produce heating effects.
  (Eddy Currents)

- A device used to increase or decrease the alternating voltage in a circuit.
  (Transformer)

- The ratio of output electric power to the input electric power in a transformer.
  (Transformer Efficiency)

- The device is used to transfer power between two circuits through electromagnetic induction.
  (Electric Transformer)

- A material used in the core of a transformer to minimize energy losses due to eddy currents.
  (Laminated Soft Iron Core)

- The ratio of the number of turns in the secondary coil to the number of turns in the primary coil of a transformer.
  (Transformer Ratio)

Comparison Questions

1. Compare Direct Current (DC) and Alternating Current (AC):

Property	Direct Current (DC)	Alternating Current (AC)
Direction of Flow	Flows in one direction only.	Flows alternately in two opposite directions.

Property	Direct Current (DC)	Alternating Current (AC)
Intensity	Constant intensity.	Intensity varies periodically.
Magnetic Field	Produces a steady magnetic field.	Produces a variable magnetic field.
Frequency	Zero frequency.	It has a certain frequency.
Source	Produced by a battery or DC dynamo.	Produced by an AC dynamo.

2. **Compare Step-Up Transformer and Step-Down Transformer:**

Property	Step-Up Transformer	Step-Down Transformer
Voltage	Increases the output voltage.	Decreases the output voltage.
Current	Decreases the output current.	Increases the output current.
Turns Ratio	Secondary coil has more turns than primary.	Primary coil has more turns than secondary.
Usage	Used in power transmission to reduce energy loss.	Used in households and industries for safety.

3. **Compare AC Generator (Dynamo) and Transformer:**

Property	AC Generator	Transformer
Function	Converts mechanical energy into electrical energy.	Transfers electric power between circuits.
Principle	Based on electromagnetic induction.	Based on electromagnetic induction.
Power Conversion	Converts mechanical to electrical power.	Changes voltage (step-up or step-down).
Components	Field magnet, armature, slip rings, brushes.	Primary coil, secondary coil, soft iron core.

4. **Compare Primary Coil and Secondary Coil in a Transformer:**

Property	Primary Coil	Secondary Coil
Purpose	Connected to the input voltage source.	Provides the output voltage.
Voltage	Receives input voltage (VP).	Delivers output voltage (VS).
Number of Turns	Can be greater, equal, or less than secondary.	It depends on the transformer type (step-up or step-down).

5. **Compare Eddy Currents and Induced Current in a Coil:**

Property	Eddy Currents	Induced Current in a Coil
Nature	Circulates in closed paths within a solid conductor.	Flows through a wire or coil.
Cause	Change in magnetic flux through a conductor.	Relative motion between a conductor and magnetic field.
Effects	It produces heat and energy loss.	Useful for generating electrical power.
Applications	Used in induction heating.	Used in dynamos and transformers.

6. **Compare Efficiency in an Ideal and Practical Transformer:**

Property	Ideal Transformer	Practical Transformer
Efficiency	100% ($\eta = 1$).	Less than 100% ($\eta < 1$) due to losses.
Power Losses	No power losses.	Losses due to eddy currents, hysteresis, etc.

7. comparison between Back Induced EMF and Forward Induced EMF

Property	Back Induced EMF	Forward Induced EMF
Cause	Induced when the magnetic flux increases or the primary coil moves closer to the secondary coil.	Induced when the magnetic flux decreases or the primary coil moves away from the secondary coil.
Situations	- Switching **on** the current in the primary coil. - **Increasing** the current intensity in the primary coil using a rheostat. - **Moving** the primary coil closer to or inside the secondary coil.	- Switching **off** the current in the primary coil. - **Decreasing** the current intensity in the primary coil using a rheostat. - **Moving** the primary coil away from (or out of) the secondary coil.

WITH MY BEST WISHES