ELECTROMAGNETISM

Q.1 What is electromagnetism? Explain the magnetic field of a straight current carrying wire.

(Ans) Electromagnetism
The magnetism produced due to the effect of flow of electric current is called electromagnetism.

Explanation
Oerstead in 1820 stated that “whenever current is passed through a conducting wire beside electric field a magnetic field is also produced around the wire”.

Magnetic field of a straight current carrying wire:
Take a long straight wire, pass it vertically through a cardboard. Both ends of the wire are connected with the terminals of the battery. Sprinkle some iron fillings over the cardboard. When current is passed through the wire, the iron fillings are attracted towards the wire. This shows that magnetic field is produced around the wire. The direction of the field can be found by using a compass needle or by right hand rule.

Right hand rule
Grapes the conductor in right hand such that the thumb is in the direction of current, then the curled fingers show the direction of magnetic field. Magnetic field is clockwise, if current is downward and anticlockwise, if current is upward.

Q.2 State and explain magnetic field of a circular current carrying wire?
(Ans) After Oerstead an another scientist Ampere state that “when current is passed through a loop of a wire, then the loop behaves like a magnet. A magnetic field is produced around the loop. It means that when current is passed through a circular wire, the wire becomes a magnet. One face of the wire becomes North Pole and the other one is South Pole.
The magnetic lines of force are straight and parallel at the centre, shows that the field is uniform at the centre. While at the ends, the lines of force are circular and the field is non-uniform. The strength of the field depends upon the amount of current and number of turns of the loop.

Q.3 State and explain magnetic field of a solenoid?

(Ans) Solenoid

It is a conducting wire with insulation over it wounded closely in cylindrical form. When current is passed through a solenoid, then magnetic field is produced around it. A solenoid consists of a number of turns. Thus, the magnetic field of a solenoid is the sum of magnetic field produced in each turn.

Some common characteristics of the magnetic field of a solenoid are as;

- The end through which the magnetic lines emerge out is called North Pole and after circulation through which it enters is known as South Pole of the solenoid.
- The polarity of the magnetic field of a solenoid can be found by using a compass needle.

Q.4 State and explain magnetic force on a current carrying wire?

(Ans) When current passes through a wire then magnetic field is produced around it. The direction of the magnetic field may be clockwise or anticlockwise. When this current carrying wire is placed between the north and South Pole of a permanent magnet having magnetic field “B”. Then a magnetic force “F_m” is acting on this wire. This force can be practically demonstrated as:

Take a U-shaped magnet and pass a current carrying wire between the poles of the magnet. As shown in the following figure.
When the current is passed through the conducting wire, the wire will push side ways. This magnetic force “F<sub>m</sub>” acting on the wire of length “L” carrying a current “I” placed inside a magnetic field of intensity “B” is given by:

\[ F_m = BIL\sin \theta \]

Where “B” is magnetic field strength and its unit is tesla (T).

\[ B = \frac{F_m}{IL} \Rightarrow 1 \text{ tesla} = \frac{1 \text{ N}}{mA} \]

The direction of the force can be found by Fleming left hand rule.

**Left hand rule**

This rule state that “stretch the thumb, forefinger and middle finger of the left hand mutually at right angles to each other. If the forefinger points in the direction of magnetic field, the middle finger in the direction of current, then thumb would indicate the direction of the force.”

**Q.5 State and explain torque produced in a current carrying loop?**

(Ans) Torque is produced in a current carrying loop (coil), when placed inside a magnetic field. It is due to the interaction between the magnetic lines of force of permanent magnet and electromagnet. Consider a rectangular coil ABCD is placed inside the poles of a permanent magnet, such that it can rotate freely.

When the current is allowed to pass through the coil, a magnetic field is produced in it. As in sides AD and BC current is parallel to the field, thus no magnetic force acts on these sides. Where as in sides AB and CD current is perpendicular to the field, so magnetic force will acts upon these sides horizontally in opposite direction and the coil starts rotating. The magnitude of this rotation can be stated as;

\[ \tau = F_m \times d \]

\[ F_m = BIL \]
\[\tau = BIL \times d\]
\[A = L \times d\]
\[\tau = BIA\]

If the coil consists has "N" number of turns. Then
\[\tau = N\text{BIA}\]

Q.6  Sketch and describe a D.C motor.
(Ans)

D.C motor
An electric motor is a device that converts electrical energy into mechanical energy.

Construction
It consists of an armature that is placed between the poles of a permanent magnet, such that it can rotate. An armature is an iron core on which a number of turns of coil are wounded. The terminals of the coil are connected to a battery that provides current to the coil, to produce magnetism around the coil.

Working
When current is passed through the coil, the interaction between the electromagnet and permanent magnet causes armature to rotate. This turn causes the machines to run. For example Washing machine, water pump, sewing machine, electric fan etc.

Q.7  Write a note on moving coil loudspeaker.
(Ans) The device that converts electrical signals to sound waves is called loudspeaker.

Principle
The basic principle of a loudspeaker is “a current carrying conductor experience a force in a magnetic field.”

Construction
It consists of a permanent magnet with a central cylindrical pole and a surrounding ring pole. This arrangement creates a strong magnetic field in the gap between the poles. It has a short cylinder with a coil wounded on it, which moves backward and forward. A paper cone is attached to the coil which produce sound when moves back and forth.
Working
When an alternating current from a radio or record player passes through the coil, it forces the paper cone to move in or out to produce sound waves.

Q.8 State and explain electromagnetic induction?
(Ans) Electromagnetic induction
The phenomenon in which an induced emf produced in a close loop by changing the magnetic flux through the loop is called electromagnetic induction.

Explanation
Michael Faraday in 1830 proved that when the magnetic flux through a close loop is changed, then an induced current is produced in the loop.

Magnetic flux
The number of magnetic lines passing through a certain area of the loop is called magnetic flux.

Faraday laws of electromagnetic induction
1. When the north pole of a magnet is brought closer to the loop, a current is produced and the needle of the ammeter connected with the loop shows deflection.
   If the magnet is taken away, then the needle will deflect in other direction.

2. Similarly if the loop is moved towards the magnet or away from magnet. Then the current is produce in similar way in experiment (1).

3. If magnet is held stationary with respect to the loop, then no current is produced in the loop.
Faraday experiments state that when magnetic flux through a loop is changed, then the induced emf is produced. This emf is directly proportion to the time rate of change magnetic flux. Mathematically

$$emf \propto \frac{\Delta \phi}{\Delta t}$$

$$emf = N \frac{\Delta \phi}{\Delta t}$$

Where “N” is constant and shows the number of turns of the loop.

Q.9 Write a note on A-C Generator.

(Ans) A-C Generator

A device that converts mechanical energy into electrical energy.

Principle

It works on the principle of electromagnetic induction.

Construction

It consists of a rectangular coil placed inside the poles of a permanent magnet. The coil is connected with the slip rings that are rotated with the coil. The carbon brushes are situated near the slip rings that are in contact with the external circuit.

[Diagram of A-C Generator]

Working

When the coil rotates between the poles of the magnet, the magnetic flux linked with the coil changes. The changing magnetic flux causes an induced emf in the coil and current is produced in the coil. This induced current changes its direction after every half-cycle i.e when the coil is rotated through 180°. In this way, an alternating current is produced in the circuit.

Q.10 State and explain mutual induction?

(Ans) Mutual induction

The phenomenon in which an induced emf is produced in a secondary coil due to change of the current in the primary coil is called mutual induction.

Explanation

Consider two coils i.e primary and secondary coils are placed at a small distance from each other. The primary coil is connected with a battery through a switch and rheostat, while the secondary coil is connected to a galvanometer. When the current of the primary coil is varied, an induced
emf is produced in the secondary coil that is observed through galvanometer.

Q.11  Write a note on transformer.
(Ans)
Transformer
It is a device used to step up or step down the A.C voltage. It works on the principle of electromagnetic induction.

Construction
A transformer consists of two coils wound over the iron core. One is primary coil while the other is secondary coil. The number of turns of the primary coil is denoted by “N_p” while that of the secondary coil is “N_s”. The input A.C voltage of the primary coil is “V_p” and of the secondary coil is “V_s”.

Mathematically
Basic equation of the transformer can be stated as;

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

A transformer is said to be step up if the number of turns of the secondary coil is greater than the number of turns of the primary coil. Mathematically

$$N_s > N_p$$

A transformer is said to be step down if the number of turns of the primary coil is greater than the number of turns of the secondary coil. Mathematically

$$N_p > N_s$$
SHORT QUESTIONS

1. In what ways are electric and magnetic field similar? In what ways are they different?
A. **Similarities**
   - Electric and magnetic field are represented by lines of force.
   - Electric and magnetic field deflect charge particles.

   **Differences**
   - Source of electric field is static charges while the source of magnetic field is moving charges.
   - Electric field can change the magnitude and direction of a charge body. Magnetic field can only change the direction of a charge body.

2. A wire carrying a current is placed in a magnetic field \( B \). (a) Under what circumstances, if any, will the force on the wire be zero? (b) Under what circumstances, if any, will the force on the wire be maximum?
A. Force on a current carrying wire inside a magnetic field is given by;
   \[
   F_m = BIL\sin\theta
   \]
   (a) If the angle between the current and magnetic field \( B \) is zero, then force will be zero. Mathematically
   \[
   F_m = BIL\sin\theta
   \]
   \[
   F_m = BIL\sin0^\circ
   \]
   \[
   \sin0^\circ = 0
   \]
   \[
   F_m = 0
   \]
   (b) If the angle between the current and magnetic field \( B \) is \( 90^\circ \), then force will be maximum. Mathematically
   \[
   F_m = BIL\sin\theta
   \]
   \[
   F_m = BIL\sin90^\circ
   \]
   \[
   \sin90^\circ = 1
   \]
   \[
   F_m = BIL
   \]

3. What would happen if the primary winding of transformer is connected to a battery?
A. A transformer works on the principle of electromagnetic induction. When we vary an alternating current, the transformer starts working. In case of direct current a transformer cannot work, as battery provide direct current. Therefore, if we connect primary winding of transformer to a battery, nothing will happen.
4. What are the similarities between motor and generator? What are the differences?

A. Similarities
- Motor and generator are both electrical devices.
- A D.C generator can be used as D.C motor.

Differences
- A motor converts electrical energy to mechanical energy, while a generator converts mechanical energy into electrical energy.
- A motor works on the principle of torque acts on a current carrying wire inside a magnetic field, while a generator works on Faraday law of electromagnetic induction.

NUMERICAL PROBLEMS

1. A wire 1m long carries a current of 5A. The wire is at right angle to a uniform magnetic field. The force on the wire is 0.2N. What is the magnetic induction B of the field?

   Given data
   \[ L = 1m \]
   \[ F_m = 0 \cdot 2N \]
   \[ I = 5A \]
   \[ \theta = 90^\circ \]
   \[ B = ? \]

   We know that
   \[ F_m = BIL\sin\theta \]
   \[ B = \frac{F_m}{IL\sin\theta} \]
   \[ B = \frac{0 \cdot 2}{5 \times 1 \times \sin 90^\circ} = \frac{0 \cdot 2}{5} \]
   \[ B = 0 \cdot 04T \]

2. A wire 10cm long is at right angle to a uniform magnetic field. The field has magnetic induction 0.06T. The current through the wire is 4A. What force acts on wire?

   Given data
\[ L = 10 \text{cm} = 0 \cdot 1 \text{m} \]
\[ I = 4 \text{A} \]
\[ \theta = 90^\circ \]
\[ B = 0 \cdot 06 \text{T} \]
\[ F_m = ? \]
We know that
\[ F_m = BIL\sin \theta \]
\[ F_m = 0 \cdot 06 \times 4 \times 0 \cdot 1 \times \sin 90^\circ \]
\[ F_m = 0 \cdot 024 \times 1 = 0 \cdot 024N \]

3. A step up transformer has 200turns on its primary coil and 3000 turns on its secondary coil. The primary coil is supplied with an alternating current at 90V. What is the voltage in the secondary circuit?

Given data
\[ N_P = 200 \]
\[ N_S = 30000 \]
\[ V_P = 90V \]
\[ V_S = ? \]
We know that
\[ \frac{V_S}{V_P} = \frac{N_S}{N_P} \]
\[ V_S = \frac{N_S}{N_P} \times V_P = \frac{3000}{200} \times 90 \]
\[ V_S = 1350V \]

4. A transformer steps down the main supply from 240V to 12V which is supplied to a 12V lamp. What is the turn’s ratio of the winding?

Given data
\[ V_P = 240V \]
\[ V_S = 12V \]
\[ \frac{N_S}{N_P} = ? \]

We know that
\[ \frac{V_S}{V_P} = \frac{N_S}{N_P} \]
\[ \frac{N_S}{N_P} = \frac{12}{240} \]
\[ \frac{N_S}{N_P} = \frac{1}{20} \]

5. How many turns are required on the secondary of a 240V mains transformer, which has 4800 turns on the primary and is to operate a 6V lamp?

Given data
\[ V_P = 240V \]
\[ V_S = 12V \]
\[ N_P = 4800 \]
\[ N_S = ? \]

We know that
\[ \frac{V_S}{V_P} = \frac{N_S}{N_P} \]

\[ N_S = \frac{V_S}{V_P} \times N_P \]

\[ N_S = \frac{6}{240} \times 4800 \]

\[ N_S = 120 \]