CHAPTER # 15 **ELECTROMAGNETISM**

ELECTROMAGNETISM:

The branch of physics in which we study about magnetic effects of currents is called electromagnetism.

MAGNETIC EFFECT OF CURRENT:

Ampere discovered that whenever a current passes through a conductor then it produces a magnetic field around that conductor. This magnetic field can be increased by increasing the value of current. The direction of this magnetic field can be found by using right hand rule.

RIGHT HAND RULE:

Hold a current carrying conductor in your right hand in such a way that the thumb is pointed in the direction of current. The curl of the finger of right hand would indicate the direction of magnetic field.

SOLENOID: A solenoid is a cylindrical coil of a wire which consists of many loops. It is closely and tightly wound in a cylindrical shape. When some current passes through a solenoid then it behaves like a bar magnetic. It means that its one end becomes north pole and the other end becomes south pole.

ELECTROMAGNETIC: It is a type of temporary magnetic in which magnetic properties are created, when some current passes through a conductor.

ELECTROMAGNETIC INDUCTION:

The processes of generating an induced current in a circuit by changing the magnetic flux (number of magnetic field lines) through it is called electromagnetic induction.

MAGNETIC FLUX:

The number of magnetic field lines passing through a certain area is called magnetic flux.

MAXIMUM FLUX: If area is held perpendicular to the direction of magnetic field lines then flux will be maximum.

MINIMUM FLUX: If area is held parallel to the direction of magnetic field lines flux will be minimum.

FARADAY LAW OF ELECTROMAGNETIC INDUCTION:

STATEMENT: The value of induced e.m.f in a circuit is directly proportional to rate of change of magnetic flux through it.

EXPLANATION:

According to Faraday law of electromagnetic induction when a coil is moved toward or way from a magnet then magnetic flux through the coil changes. As a result of this change in magnetic flux an e.m.f is induced in the coil. The value of this induced e.m.f is directly proportional to rate of change of magnetic flux. The same result is obtained if the magnet is moved towards or away from the coil.

FACTOR'S AFFECTING INDUCED E.M.F:

The magnitude of induced e.m.f in a circuit depends upon two factors.

i) Speed of relative motion of the coil and the magnet. ii) Number of turns in a coil.

DIRECTION OF INDUCED E.M.F:

LENZ'S LAW: Lenz devised a rule to find the direction of current induced in a circuit.

According To Lenz's Law: "**The direction of an induced current in a circuit is always such that it opposes the cause that produce it**".

MUTUAL INDUCTION: The process of producing induced current in one coil due to change of current in nearby coil is called "mutual induction.

EXPLANATION:

Consider two coils "**A**" and "**B**" placed very close to each other. The first coil "**A**" is connected with battery and a switch. This coil is called "primary coil." The second coil "**B**" is connected with galvanometer and a switch. This is called a "secondary coil." Initially there is no current passing through the coil because the switch is open. But when the switch is closed then a current begins to flow in the primary coil. Since the current in the primary coil is changed therefore due to this change in current in primary coil, magnetic flux through the primary coil also changes. As the two coils are placed very near to each other. Therefore the change of magnetic flux in the primary coil also links with the secondary coil. As a result of this change in flux an e.m.f is induced in the secondary coil. Due to this e.m.f a current is also induced in the secondary coil.

TRANSFORMER:

Transformer is an electrical device which is used to increase or decrease the value of alternating voltage.

PRINCIPLE: Transformer works on the principle of mutual induction. According to this principle changing electric current in one coil induces an e.m.f in another coil.

CONSTRUCTION AND WORKING: A simple transformer consist of two coils of copper wound on different sides of a rectangular iron core. One coil is called primary coil and the second coil is called secondary coil.

PRIMARY COIL: The coil which is connected with alternating current power supply is called primary coil.

SECONDARY COIL: The coil from which power is supplied to the external circuit is called secondary coil.

CHANGE OF FLUX: When primary coil is connected with A.C power supply then due to passage of current the magnetic flux through the coil changes. The iron core further increases this magnetic flux to very large value. Since the two coils are placed very near to each other. Therefore the change of magnetic flux in the primary coil also links with the secondary coil. As a result an e.m.f is induced in the secondary coil.

EQUATION OF TRANSFORMER: The equation of transformer is $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

V_p = voltage of primary coil — V_s = Voltage of secondary coil

N_p = Number of turns of primary coil — N_s = Number if turns of secondary coil

STEP UP TRANSFORMER: Such a transformer in which voltage across secondary coil is greater than the voltage of primary coil is called a step up transformer. $V_s > V_p$

For a step up transformer the number of turns of secondary coil must be greater than number of turns of primary coil. $N_s > N_p$

STEP DOWN TRANSFORMER: Such a transformer in which voltage across secondary coil is less than voltage of primary coil is called step down transformer. $V_s < V_p$

For a step down transformer the numbers of turn of secondary coil must be less than number of turns of primary coil. $N_s < N_p$

POWER OF TRANSFORMER:

In an ideal transformer the electric power delivered to the secondary coil is equal to the power supplied to the primary coil.

$$P_{input} = P_{output}$$

$$V_p I_p = V_s I_s$$

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

The above relation shows that in a transformer the voltage and the current are inversely related to each other. It means that in a transformer if the value of voltage increases than value of current decreases.

HIGH VOLTAGE TRANSMISSION: Usually the electric power is generated at places which are for from the places where the electric power is consumed. There is a possibility that very large part of electrical energy can be lost due to resistance or heating effect of current. To minimize this power loss the voltage level is increased to a very large value. Due to this high voltage the value of current becomes small. As a result very small amount of current is lost during long transmission. In this way power loss can be minimized.

ELECTROMAGNET: Magnetic effect of current is called electromagnet. This effect is used in many devices like relay, electric bell, etc. Soft iron can easily be magnitized and demagnitized.

REALY: Realy is a device which is used to control a large value of current with the help of a small current. A realy is basically and electrical switch that opens and closes under the control of another electrical circuit. The first circuit is called “Input circuit”. It supply current to the electromagnet. As a result of this current the electromagnet is magnetized and attracts one end of the iron armature. This armature then closes the contacts and allows the current to flow in the second circuit.

CONCEPTUAL QUESTIONS

15.2: Suppose you have a coil of wire and a bar magnet. Describe how you could use them to generate an electric current?

Ans: When a coil is moves towards or away from a magnet then magnetic flux through the coil changes and as a result an e.m.f is induced in the coil. Due to this induced e.m.f electric current is generated in the coil.

15.6: What is the difference between a generator and a motor?

Ans: Generator is a electrical device which generates or produces electrical energy where as motor is an electrical device which uses electrical energy. Also generator converts mechanical energy into electrical energy whereas the motor converts electrical energy into mechanical energy.

15.7: What reverses the direction of electric current in the armature coil of D.C motor?

Ans: In a D.C motor a device known as commutator which consist of two split rings. These split rings are used to reverse the direction of current. Split rings change their positions with carbon brushes after regular interval. In this way they are able to reverse direction of current.

NUMERICAL PROBLEMS

15.1: A transformer is needed to convert a mains 240V supply into a 12V supply. If there are 2000 turns on the primary coil, then find the number of turns on the secondary coil.

Given:

Voltage of primary coil = V_p = 240 volt

Voltage of secondary coil = V_s = 12 Volt

Number of turns in primary coil = N_p = 2000

Number of turns in secondary coil = N_s =?

Solution:

We know

$$\frac{Vs}{Vp} = \frac{Ns}{Np}$$

putting values;

$$\frac{12}{240} = \frac{Ns}{2000}$$

$$N_s = 2000 \text{ x } \frac{12}{240}$$

15.2: A step-up transformer has a turn ratios of 1 : 100. An alternating supply of 20V is connected across the primary coil. What is the secondary voltage?

Given:

Turns ratio = 1: 100

Number of turns in primary coil = N_p = 1

Number of turns in secondary coil = N_s = 100

Voltage of primary coil = V_p = 20 volt

Voltage of secondary coil = V_s =?

Solution: We know that:

$$\frac{Vs}{Vp} = \frac{Ns}{Np}$$

$$\frac{Vs}{20} = \frac{100}{1}$$

V_s = 100 x 20

V_s = 2000 Volts

$N_s = 100$

15.3: A step-down transformer has a turns ration of 100 : 1. An ac voltage of amplitude 170V is applied to the primary. If the current in the primary is 1.0 mA, what is the current in the secondary?

Given:

Turns ratio = 100 : 1

Number of turns in primary coil = N_p = 100

Number of turns in secondary coil = N_s = 1

Voltage of primary coil = V_p = 170 volt

Current in secondary coil = V_s =?

Current of primary coil = I_p = 1 mA = 1 x 10^{-3} A

Voltage of secondary coil = V_s =?

Solution: We know that

$$\frac{Vs}{Vp} = \frac{Ns}{Np}$$

$$\frac{Vs}{170} = \frac{1}{100}$$

$$V_s = \frac{1}{100} \times 170$$

$$V_s = 1.7 \text{ volts}$$

Now using formula of power,

$$P_{input} = P_{output}$$

$$V_p I_p = V_s I_s$$

$$(170)(1 \times 10^{-3}) = (1.7) I_s$$

$$\frac{170 \times 1}{1.7} \times 10^{-3} = I_s$$

$$100 \times 10^{-3} = I_s$$

$$\frac{100}{10^3} = I_s$$

$$\frac{100}{100} = I_s$$

$$\frac{1}{10} = I_s$$

15.4: A transformer, designed to convert the voltage from 240V a.c mains to 12V, has 4000 turns on the primary coil. How many turns should be on the secondary coil? If the transformer were 100% efficient, what current would flow through the primary coil when the current in the secondary coil was 0.4A?

Given:

Voltage of primary coil = V_p = 140 volt

Voltage of secondary coil = V_s = 12 volt

Number of turns in primary coil = N_p = 4000

Number of turns in secondary coil = N_s =?

Current in primary coil = I_p =?

Current in secondary coil = is = 0.4 A

Solution: We know that

$$\frac{Vs}{Vp} = \frac{Ns}{Np}$$

$$\frac{12}{240} = \frac{Ns}{4000}$$

$$\frac{12}{240} \times 4000 = N_s$$

$$200 = N_s$$

We know that in transformer

$$P_{input} = P_{output}$$

$$V_p V_s = I_p I_s$$

$$(240)(I_p) = (12)(0.4)$$

$$I_p = \frac{(12)(0.4)}{240} = 0.02 \text{ A}$$

15.5: A power station generates 500MW of electrical power which is fed to a transmission line. What current would flow in the transmission line, if the input voltage is 250 kV?

Given:

Electrical power = P = 500 MW

$$P = 500 \times 10^6 \text{ W}$$

$I_s = 0.1$ A	Input Voltage = V = 250 KV $V = 250 \times 10^3$ V Current = I =? **Solution**: We know that $P = V \times I$ $500 \times 10^6 = (25 \times 10^3) \propto I$ $\frac{500 \times 10^6}{250 \times 10^3} = I$ $\frac{500}{250} = \times 10^{6-3} = I$ $2 \times 10^3 = I$ $I = 2000$ A