GOVERNMENT POLYTECHNIC LOHAGHAT,CHAMPAWAT

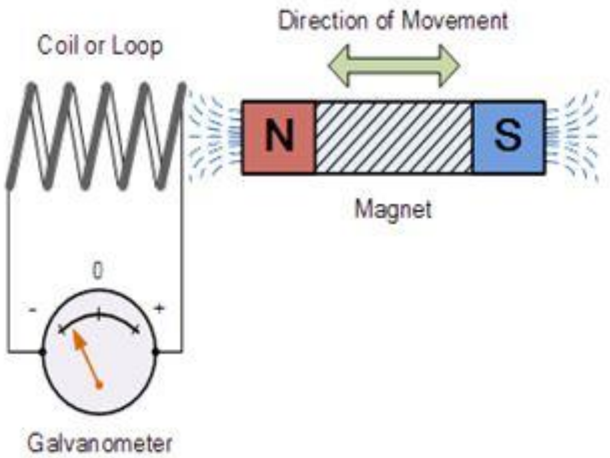
SUBJECT: PHYSICS SEMESTER : SECOND

Electromagnetic Induction and its Applications

Electromagnetic Induction or Induction is a process in which a conductor is put in a particular position and magnetic field keeps varying or magnetic field is stationary and a conductor is moving. This produces a Voltage or EMF (Electromotive Force) across the electrical conductor. Michael Faraday discovered Law of Induction in 1830.

Electromagnetic induction

Can moving objects produce electric currents? How to determine a relationship between electricity and magnetism? Can you imagine the scenario if there were no computers, no telephones, no electric lights. The experiments of Faraday has led to the generation of generators and transformers.

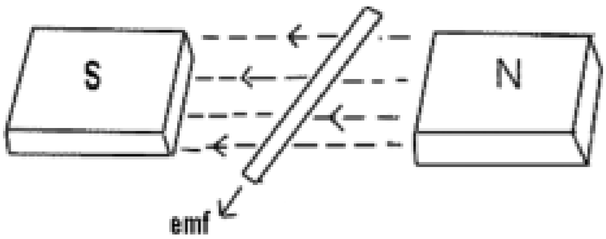


The induction of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called **'Electromagnetic Induction'.**

This either happens when a conductor is set in a moving magnetic field (when utilizing AC power source) or when a conductor is always moving in a stationary magnetic field

This law of electromagnetic induction was found by **Michael Faraday.** He organized a leading wire according to the setup given underneath, connected to a gadget to gauge the voltage over the circuit. So when a bar magnet passes through the snaking, the voltage is measured in the circuit. The importance of this is a way of producing electrical energy in a circuit by using magnetic fields and not just batteries anymore. The machines like generators, transformers also the motors work on the principle of electromagnetic induction.

Faraday's law of Electromagnetic Induction



Source: Electricaleasy

- First law: Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flows through it.
- Second law: The magnitude of the induced EMF is equal to the rate of change of flux linkages.

Based on his experiments we now have Faraday's law of electromagnetic induction according to which the amount of voltage induced in a coil is proportional to the number of turns and the changing magnetic field of the coil.

So now, the induced voltage is as follows:

$$e = N \times d\Phi/dt$$

where,

e is the induced voltage
N is the number of turns in the coil
Φ is the magnetic flux
t is the time

Lenz's law of Electromagnetic Induction

Lenz law of electromagnetic induction states that, when an emf induces according to Faraday's law, the polarity (direction) of that induced emf is such that it opposes the cause of its production.

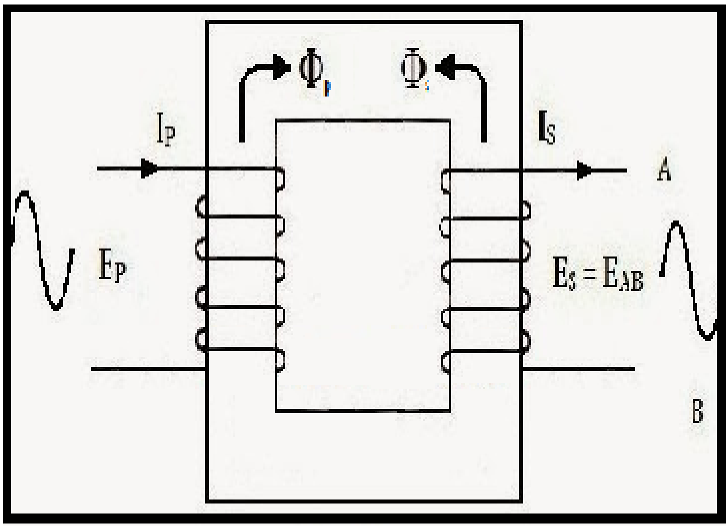
According to Lenz's law

$$E = -N\,(d\Phi/\,dt) \quad \text{(volts)}$$

Types of Inductance

Two types of inductance are there:

- Self Induction
- Mutual Induction



SELF INDUCTION:
If chaning current flowing a coil produces emf in the same coil, it is called self induction.

MUTUAL INDUCTION:
The changing current current through one coil produces emf in another coil is called mutual induction.

What is Self Induction?

When there is a change in the current or magnetic flux of the coil, an opposed induced electromotive force is produced. This phenomenon is termed as Self Induction. When the current starts flowing through the coil at any instant, it is found that that the magnetic flux becomes directly proportional to the current passing through the circuit. The relation is given as:

$\phi \propto I$
$\phi = L I$
Where L is termed as self-inductance of the coil or the coefficient of self-inductance. The self-inductance depends on the cross-sectional area, the permeability of the material or the number of turns in the coil.

The rate of change of magnetic flux in the coil is given as,

$e = - d\phi/dt = - d(LI)/dt$
or $e = - L\, dI/dt$

Self Inductance Formula

$$L = N\phi/I$$

Where,

- L is the self inductance in Henries
- N is the number of turns
- Φ is the magnetic flux
- I is the current in amperes

What is Mutual Induction?

We take two coils, and they are placed close to each other. The two coils are P- coil (Primary coil) and S- coil (Secondary coil). To the P-coil, a battery, and a key is connected wherein the S-coil a galvanometer is connected across it. When there is a change in the current or magnetic flux linked with two coils an opposing electromotive force is produced across each coil, and this phenomenon is termed as Mutual Induction. The relation is given as:

$\phi \propto I$
$\phi = M I$

Where M is termed as the mutual inductance of the two coils or the coefficient of the mutual inductance of the two coils.

The rate of change of magnetic flux in the coil is given as,

$e = -\, d\phi/dt = -\, d(MI)/dt$
$e = -\, M\, dI/dt$

Mutual Inductance Formula

$$M=\mu_0\mu_r NA/l$$

Where,

- μ_0 is the permeability of free space
- μ_r is the relative permeability of the soft iron core
- N is the number of turns in coil
- A is the cross-sectional area in m^2
- l is the length of the coil in m

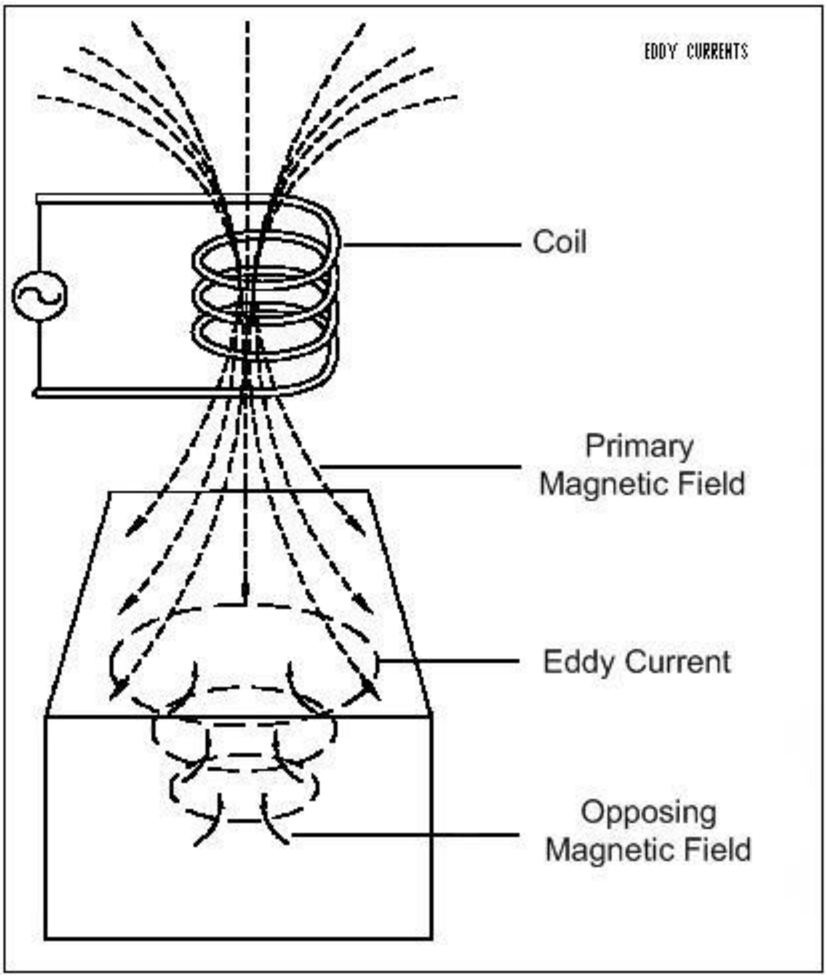
Difference between Self and Mutual Inductance

Self induction	**Mutual induction**
Self inductance is the characteristic of the coil itself.	Mutual inductance is the characteristic of a pair of coils.
The induced current opposes the decay of current in the coil when the main current in the coil decreases.	The induced current developed in the neighboring coil opposes the decay of the current in the coil when the main current in the coil decreases.
The induced current opposes the growth of current in the coil, when the main current in the coil increases.	The induced current developed in the neighboring coil opposes the growth of current in the coil when the main current in the coil increases.

Eddy currents

By Lenz law of electromagnetic induction, the current swirls in such a way as to create a magnetic field opposing the change. Because of the tendency of eddy currents to oppose, eddy currents cause a loss of energy. Eddy currents transform more useful forms of energy, such as kinetic energy, into heat, which isn’t generally useful. In many applications, the loss of useful energy is not particularly desirable, but there are some practical applications. Like:

- In the brakes of some trains. During braking, the brakes expose the metal wheels to a magnetic field which generates eddy currents in the wheels. The magnetic interaction between the applied field and the eddy currents slows the wheels down. The faster the wheels spin, the stronger is the effect, meaning that as the train slows the braking force is reduces, producing a smooth stopping motion.
- There are few galvanometers having a fixed core which are of nonmagnetic metallic material. When the coil oscillates, the eddy currents that generate in the core oppose the motion and bring the coil to rest.
- Induction furnace can be used to prepare alloys, by melting the metals. The eddy currents generated in the metals produce high temperature enough to melt it.



Source: Geocities

Applications of Electromagnetic Induction

1. Electromagnetic induction in AC generator
2. Electrical Transformers

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