G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY
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Permanently Affiliated to JNTUA, Ananthapuramu
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Department of Electrical and Electronics Engineering

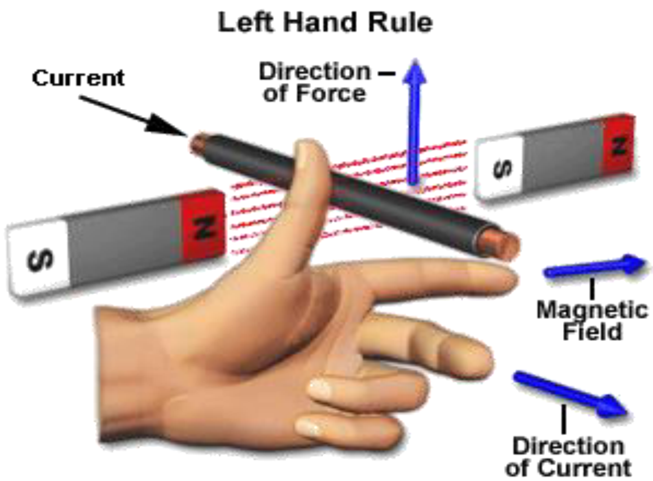
Bridge Course
On
Electrical Machines-I

ELECTRICAL MACHINES-I

Fleming Left Hand rule and Fleming Right Hand rule:

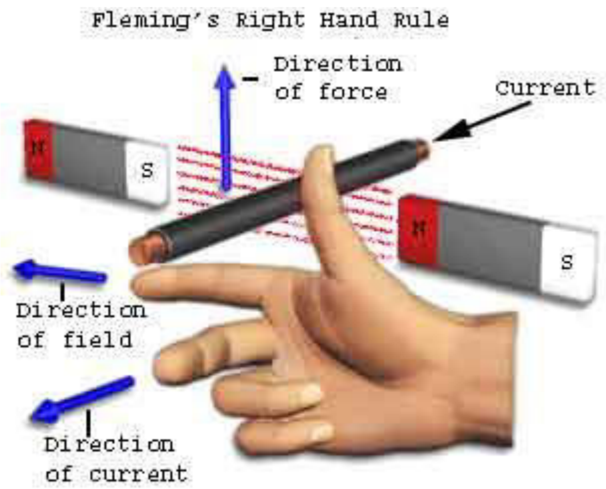
Whenever, a current carrying conductor comes under a magnetic field, there will be force acting on the conductor and on the other hand, if a conductor is forcefully, there is a relation between magnetic field, current and force. This relation is directionally determined by Fleming brought under a magnetic field, there will be an induced current in that conductor. In both of the phenomenon's Left Hand rule and Fleming Right Hand rule respectively. Directionally means these rules do not show the magnitude but show the direction of any of the three parameters (magnetic field, current, force) if the direction of other two are known. Fleming Left Hand rule is mainly applicable for electric motor and Fleming Right Hand rule is mainly applicable for electric generator. In late 19th century, John Ambrose Fleming introduced both these rules and as per his name, the rules are well known as Fleming left and right hand rule.

Fleming Left Hand rule:



It is found that whenever an current carrying conductor is placed inside a magnetic field, a force acts on the conductor, in a direction perpendicular to both the directions of the current and the magnetic field. In the figure it is shown that, a portion of a conductor of length L placed vertically in a uniform horizontal magnetic field strength H, produced by two magnetic poles N and S. If i is the current flowing through this conductor, the magnitude of the force acts

Fleming Right Hand Rule:



As per Faraday's law of electromagnetic induction, whenever a conductor moves inside a magnetic field, there will be an induced current in it. If this conductor gets forcefully moved inside the magnetic field, there will be a relation between the direction of applied force, magnetic field and the current. This relation among these three directions is determined by This rule states "Hold out the right hand with the first finger, second finger and thumb at right angle to each other. If forefinger represents the direction of the line of force, the thumb points in the direction of motion or applied force, then second finger points in the direction of the induced current.

Lenz Law of Electromagnetic Induction:

Lenz's law is named after the German scientist H. F. E. Lenz in 1834. Lenz's law obeys Newton's third law of motion (i.e to every action there is always an equal and opposite reaction) and the conservation of energy (i.e energy may neither be created nor destroyed and therefore the sum of all the energies in the system is a constant).

Lenz law is based on Faraday's law of induction, so before understanding Lenz's law; one should know what is Faraday's law of induction? When a changing magnetic field is linked with a coil, an emf is induced in it. This change in magnetic field may be caused by changing the magnetic field strength by moving a magnet towards or away from the coil, or moving the coil into or out of the magnetic field as desired. Or in simple words, we can say that the magnitude of the emf induced in the circuit is proportional to the rate of change of flux.

Lenz's law states that when an emf is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such, that it produces an current that's magnetic field opposes the change which produces it.

The negative sign used in Faraday's law of electromagnetic induction, indicates that the induced emf (ε) and the change in magnetic flux ($\delta\Phi_B$) have opposite signs.

$$\mathcal{E} = -N\frac{\partial \Phi_B}{\partial t},$$

Where,

ε=Induced emf

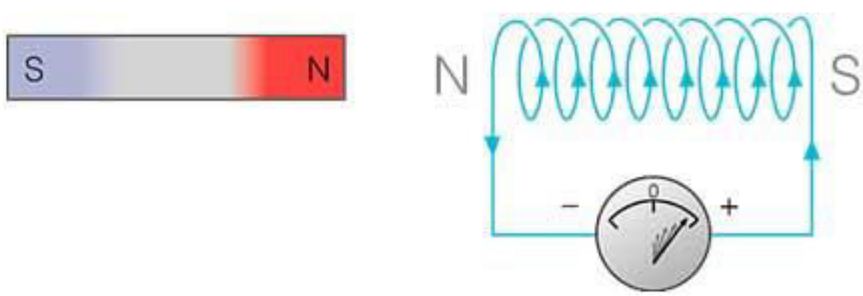
$\delta\Phi_B$ = change in magnetic flux

N = No of turns in coil

Explanation of Lenz's Law

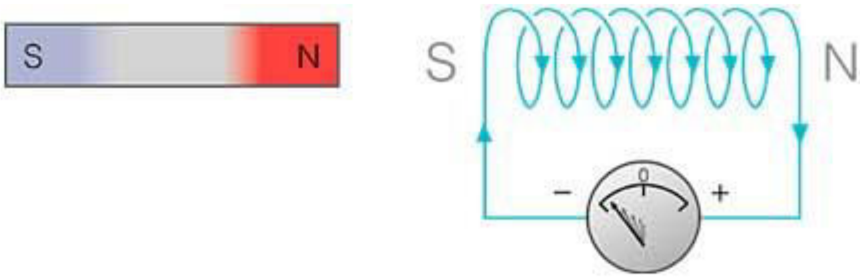
For understanding Lenz's law, consider two cases :

CASE-I When a magnet is moving towards the coil.

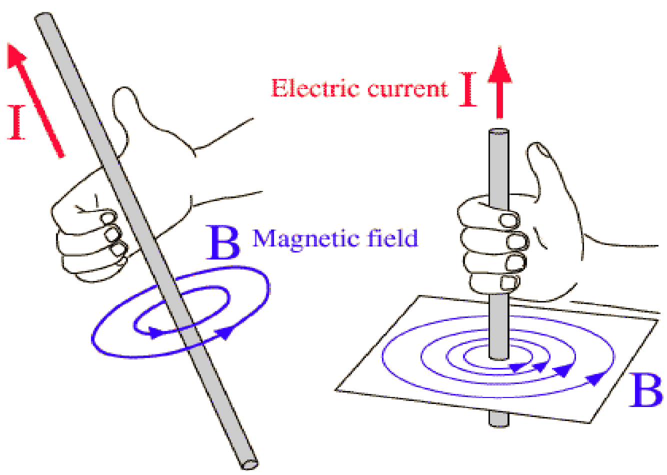


When the north pole of the magnet is approaching towards the coil, the magnetic flux linking to the coil increases. According to Faraday's law of electromagnetic induction, when there is change in flux, an emf and hence current is induced in the coil and this current will create its own magnetic field. Now according to Lenz's law, this magnetic field created will oppose its own or we can say opposes the increase in flux through the coil and this is possible only if approaching coil side attains north polarity, as we know similar poles repel each other. Once we know the magnetic polarity of the coil **side, we can** easily determine the direction of the induced current by applying right hand rule. In this case, the current flows in anticlockwise direction.

CASE-II When a magnet is moving away from the coil

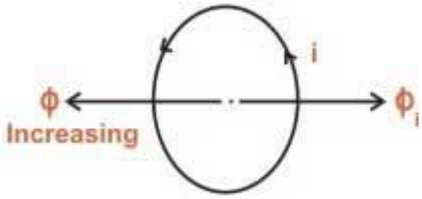


When the north pole of the magnet is moving away from the coil, the magnetic flux linking to the coil decreases. According to Faraday's law of electromagnetic induction, an emf and hence current is induced in the coil and this current will create its own magnetic field. Now according to Lenz's law, this magnetic field created will oppose its own or we can say opposes the decrease in flux through the coil and this is possible only if approaching coil side attains south polarity, as we know dissimilar poles attract each other. Once we know the magnetic polarity of the coil side, we can easily determine the direction of the induced current by applying right hand rule. In this case, the current flows in clockwise direction.

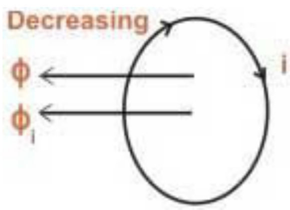


The Lenz law can be summarized as under:

If the magnetic flux Φ linking a coil increases, the direction of current in the coil will be such that it will oppose the increase in flux and hence the induced current will produce its flux in a direction as shown below (using right hand thumb rule).



If magnetic flux Φ linking a coil is decreasing, the flux produced by the current in the coil is such, that it will aid the main flux and hence the direction of current is as shown below,



Faraday Law of Electromagnetic Induction:

In 1831, Michael Faraday, an English physicist gave one of the most basic laws of electromagnetism called Faraday's law of electromagnetic induction. This law explains the working principle of most of the electrical motors, generators, electrical transformers and inductors. This law shows the relationship between electric circuit and magnetic field. Faraday performs an experiment with a magnet and coil. During this experiment, he found how emf is induced in the coil when flux linked with it changes. He has also done experiments in electro-chemistry and electrolysis.

Faraday's Laws:

Faraday's First Law:

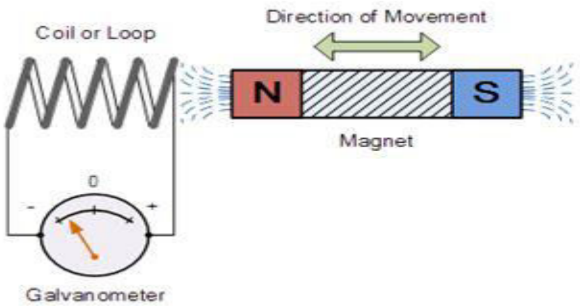
Any change in the magnetic field of a coil of wire will cause an emf to be induced in the coil. This emf induced is called induced emf and if the conductor circuit is closed, the current will also circulate through the circuit and this current is called induced current. Method to change magnetic field:

1. By moving a magnet towards or away from the coil
2. By moving the coil into or out of the magnetic field.
3. By changing the area of a coil placed in the magnetic field
4. By rotating the coil relative to the magnet.

Faraday's Second Law:

It states that the magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil. The flux linkage of the coil is the product of number of turns in the coil and flux associated with the coil.

Faraday Law Formula



Consider a magnet approaching towards a coil. Here we consider two instants at time T_1 and time T_2.
Flux linkage with the coil at time, $T_1 = N\Phi_1$ Wb
Flux linkage with the coil at time, $T_2 = N\Phi_2$ wb
Change in flux linkage = $N(\Phi_2 - \Phi_1)$
Let this change in flux linkage be, $\Phi = \Phi_2 - \Phi_1$
So, the Change in flux linkage = $N\Phi$
Now the rate of change of flux linkage = $N\Phi / t$
Take derivative on right hand side we will get The rate of change of flux linkage = $Nd\Phi/dt$
But according to Faraday's law of electromagnetic induction, the rate of change of flux linkage is equal to induced emf.

$$E = N\frac{d\phi}{dt}$$

Applications of Faraday Law:

Faraday law is one of the most basic and important laws of electromagnetism. This law finds its application in most of the electrical machines, industries and medical field etc.

- Electrical Transformers

- It is a static ac device which is used to either step up or step down voltage or current. It is used in generating station, transmission and distribution system. The transformer works on Faraday's law.
- Electrical Generators
- The basic working principle of electrical generator is Faraday's law of mutual induction. Electric generator is used to convert mechanical energy into electrical energy.
- Induction Cookers
- The Induction cooker, is a most fastest way of cooking. It also works on principle of mutual induction. When current flows through the coil of copper wire placed below a cooking container, it produces a changing magnetic field. This alternating or changing magnetic field induces an emf and hence the current in the conductive container, and we know that flow of current always produces heat in it.
- Electromagnetic Flow Meters
- It is used to measure velocity of blood and certain fluids. When a magnetic field is applied to electrically insulated pipe in which conducting fluids are flowing, then according to Faraday's law, an electromotive force is induced in it. This induced emf is proportional to velocity of fluid flowing .
- Form the bases of Electromagnetic Theory
- Faraday's idea of lines of force is used in well known Maxwell's equations. According to Faraday's law, change in magnetic field gives rise to change in electric field and the converse of this is used in Maxwell's equations.
- Musical Instruments
- It is also used in musical instruments like electric guitar, electric violin etc.

Principle of DC Generator:

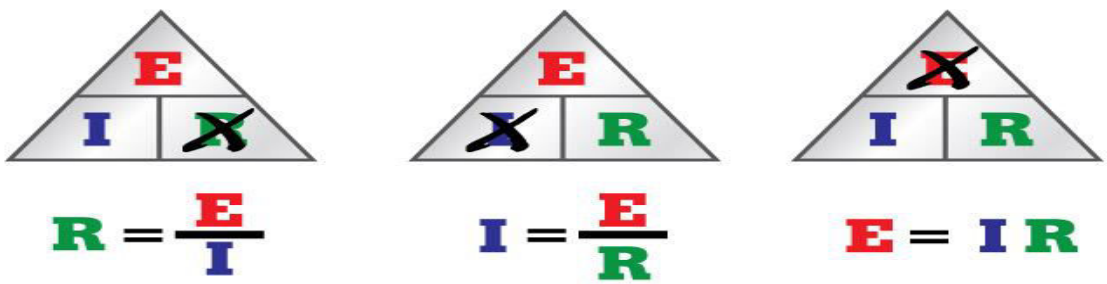
There are two types of generators, one is ac generator and other is DC generator. Whatever may be the types of generators, it always converts mechanical power to electrical power. An AC generator produces alternating power. A DC generator produces direct power. Both of these generators produce electrical power, based on same fundamental principle of Faraday's law of electromagnetic induction. According to this law, when a conductor moves in a magnetic field it cuts magnetic lines of force, due to which an emf is induced in the conductor. The magnitude of this induced emf depends upon the rate of change of flux (magnetic line force) linkage with the conductor. This emf will cause a current to flow if the conductor circuit is closed.

Working or Operating Principle of DC Motor:

A DC motor in simple words is a device that converts electrical energy (direct current system) into mechanical energy. It is of vital importance for the industry today.

Ohm's Law:

The law stating that the direct current flowing in a conductor is directly proportional to the potential diff erence betweenits ends. It is usually formulated as *V* = IR, where *V* is the potential difference, or voltage, *I* is the current, and *R* isthe resistance of the conductor.



Electric power:

Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second.

Electric power is usually produced by electric generators, but can also be supplied by sources such as electric batteries. It is usually supplied to businesses and homes by the electric power industry through an electric power grid. Electric power is usually sold by the kilowatt hour (3.6 MJ) which is the product of power in kilowatts multiplied by running time in hours. Electric utilities measure power using an electricity meter, which keeps a running total of the electric energy delivered to a customer.

Electromotive force (emf)

Electromotive force, also called emf (measured in volts), is the voltage developed by any source of electrical energy such as a battery or dynamo. It is generally defined as the electrical potential for a source in a circuit. A device that supplies electrical energy is called electromotive force or emf. Emfs convert chemical, mechanical, and other forms of energy into electrical energy. The product of such a device is also known as emf.

Voltage

Voltage, electric potential difference, electric pressure or electric tension (formally denoted Δ*V* or Δ*U*, but more often simply as *V* or *U*, for instance in the context of Ohm's or Kirchhoff's circuit laws) is the difference in electric potential energy between two points per unit electric charge. The voltage between two points is equal to the work done per unit of charge against a static electric field to move the test charge between two points. This is measured in units of *volts* (a joule per coulomb).

Electric current

An electric current is a flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte, or by both ions and electrons .The SI unit for measuring an electric current is the ampere, which is the flow of electric charge across a surface at the rate of one coulomb per second. Electric current is measured using a device called an ammeter.

Torque

Torque, moment, or moment of force is rotational force Just as a linear force is a push or a pull, a torque can be thought of as a twist to an object. Mathematically, torque is defined as the cross product of the vector by which the force's application point is offset relative to the fixed suspension point (distance vector) and the force vector, which tends to produce rotational motion.

The magnitude of torque depends on three quantities: the force applied, the length of the *lever arm* connecting the axis to the point of force application, and the angle between the force vector and the lever arm.

Force

In physics, a force is any interaction that, when unopposed, will change the motion of an object. A force can cause an object with mass to change its velocity (which includes to begin moving from a state of rest), i.e., to accelerate. Force can also be described intuitively as a push or a pull. A force has both magnitude and direction, making it a vector quantity. It is measured in the SI unit of newtons and represented by the symbol F.

Electric Field:

The field or space around a charge particle where its force can be experienced by any other charged particle is called the electric field of former charge. Electric field is also known as electrostatic field intensity.

Magnetic Field:

Magnetic fields can be defined in a number of ways, depending on the context. However, in general terms, it is an invisible field that exerts magnetic force on substances which are sensitive to magnetism. Magnets also exert forces and torques on each other through the magnetic fields they create.

Magnetic Flux:

Magnetic flux is a measurement of the total magnetic field which passes through a given area. It is a useful tool for helping describe the effects of the magnetic force on something occupying a given area. The measurement of magnetic flux is tied to the particular area chosen. We can choose to make the area any size we want and orient it in any way relative to the magnetic field.