ELECTROMAGNETISM

ELECTRO MAGNETIC INDUCTION

Electromagnetism created a revolution by leading to the devices called motors which convert electrical energy into mechanical energy. Experiments by scientists like Oersted and Faraday made a long leap by converting mechanical energy into electricity.

Electricity and magnetism are inter-related and are also inter-convertible. An electric current passing through a conductor produces a magnetic field which can be observed through the deflection of a magnetic compass needle placed near the conductor. This proves that moving electric charges produce magnetic fields. Electric motors work on this principle.

If a straight conductor is moved in a magnetic field an electric current is induced in it and this phenomenon is called the electromagnetic induction. The emf caused is the induced emf and the current is induced current. Electric generators work on this principle.

Oersted found the same by relative motion of a magnet with respect to a coil. Faraday's experiment proved that the strength of the induced current depends on several factors like the strength of the magnet, the speed of motion of the magnet, its orientation, the number of turns in the coil and the diameter of the coil. The induced current can be detected by a galvanometer.

Oersted's Experiments

In 1819, Oersted discovered that there was a deflection in the needle of a magnetic compass kept near a wire that was connected to a battery. This deflection occurred every time the battery was switched on and off. In Oersted's experiment, a compass was placed directly over a horizontal wire. He observed that:

(a) The needle pointed north when there was no current.
(b) The needle swung towards the east when the current flew north.
(c) The needle swung west when the current flew south.
(d) The needle swings were reversed when the compass is placed directly under the wire.

Since a magnetic needle can be deflected only due to the presence of a magnetic field, Oersted concluded that a magnetic field is created around a current-carrying wire in a circuit.

Faraday's Experiment

First Experiment

In the first experimental setup, a coil is connected to a Galvanometer.

- If a bar magnet with its north pole facing the coil, is moved towards or away from the coil, the Galvanometer needle deflects to the right and left side of zero reading respectively, showing the presence of a current in the coil.
- If the south pole of the magnet faces the coil. The Galvanometer needle deflects to the left side of zero reading as the magnet approaches the coil and deflects to the right when the magnet moves away from the coil, showing the presence of a current in the coil.
- The Galvanometer needle deflects only as long as the bar magnet is in motion. Once the bar magnet comes to rest the galvanometer needle settles down at “0” reading indicating that there is no current in the coil.

From all these observations, we can conclude that whenever there is relative motion between a bar magnet and a coil, an electric current is induced in the coils

Second Experiment

In the second experimental setup, there are two coils:

Coil 1 connected to a Galvanometer, Coil 2 connected to a battery
Due to the steady current in coil 2, a steady magnetic field is set up around the coil 2 and this magnetic field is also linked to the coil 1.

- If the coil 2 is kept stationary and coil 1 is moved towards coil 2, a current is induced in coil 1 and the galvanometer needle deflects to the l
- eft of “0”.
- If the coil 2 is kept stationary and coil 1 is moved away from coil 2, a current is induced in coil 1 and the galvanometer needle deflects to the right of “0”.
- If we keep coil 1 stationary and move coil 2 towards coil 1, a current is induced in coil 1 and a deflection is observed in the galvanometer needle to the left of “0”.

  Now if we keep coil 1 stationary and move coil 2 away from coil 1, a current is induced in coil 1 and a deflection is observed in the galvanometer needle to the right of “0”.

  From all these observations we can conclude that whenever there is relative motion between a current carrying coil and a closed coil in which a galvanometer is connected a current is induced in the closed coil.

Third Experiment

In the third experiment a tap key is provided in the coil 2 circuit. Here we can observe the
deflection of the galvanometer needle even when the two coils are

stationary. This deflection is observed only at those instants when the tap key is either switched on or off. This happens because of the change in magnetic field during switching on and off.

When a ferromagnetic material like an iron rod is placed co axially along the two coils, the effect of the magnetic field linked to the coil 2 increases due to the nature of the ferromagnetic material as it allows more number of magnetic lines of force to link within the area of the coil. Hence the deflection of the galvanometer needle increases indicating an increase in the induced current.

Force on a Straight Current Carrying Conductor

Lorentz found that a charge moving in a magnetic field, in a direction other than the direction of magnetic field, experiences a force, called Lorentz force.
As the current is due to the motion of charge, a conductor carrying current placed in a magnetic field, in the direction other than the direction of magnetic field, will also experience a force.

Magnitude of Force

The magnitude of the force acting on a current carrying conductor placed in a magnetic field in a direction perpendicular to it, depends on the following factors.

i. The force F is directly proportional to the current flowing in the conductor, i.e., $F \propto i$
ii. The force F is directly proportional to the magnetic field strength, i.e., $F \propto B$
iii. The force F is directly proportional to the length of the conductor, ie., $F \propto l$

Combining the above three relations, $F \propto iBl$

Or

$F = kiBl$

Or

$F = kBil$, where k is the constant whose value depends on the choice of units.

In S.I units, $k = 1$, so $F = Bil$
The direction of force on a current carrying conductor placed in a magnetic field is obtained by the Fleming's left hand rule.

Electric Motor

Electric motor is a device which converts electric energy in to mechanical energy. Electric motor works on the principle of force on a conductor carrying current moving in a magnetic field.

If an electric current is passed through a conductor placed normally in a magnetic field, a force acts on the conductor as a result of which the conductor begins to move and work is obtained. The direction of force acted can be found by using Fleming's left hand rule. This gives the basis for an electric motor.

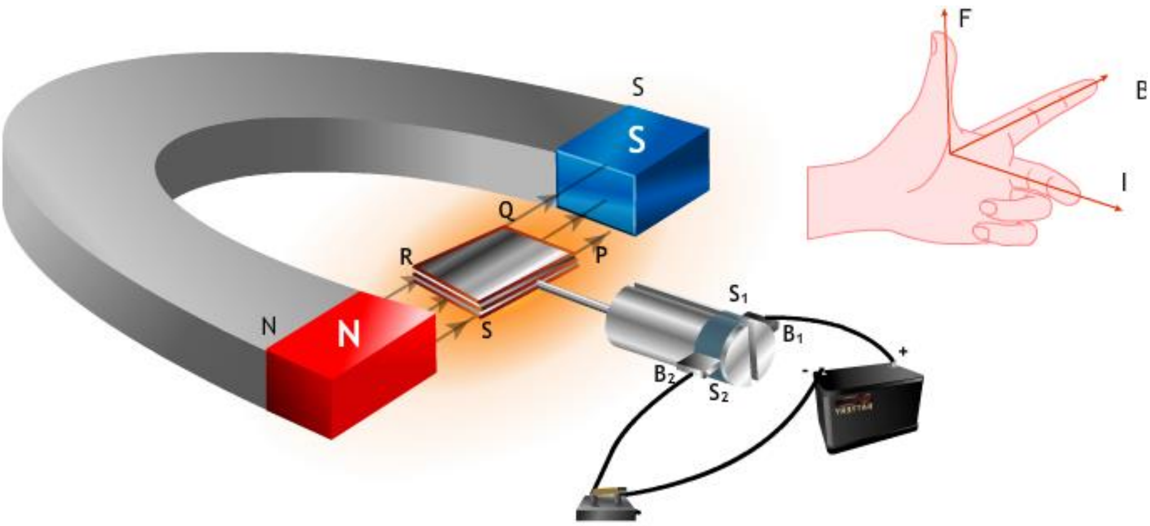
Working

An electric motor essentially consists of a coil as an armature, a split ring commutator for changing the direction of the current in the coil. There are two brushes linked with the split rings that maintain the contact with the armature for the current flow. Electric motor converts electrical energy to mechanical energy.

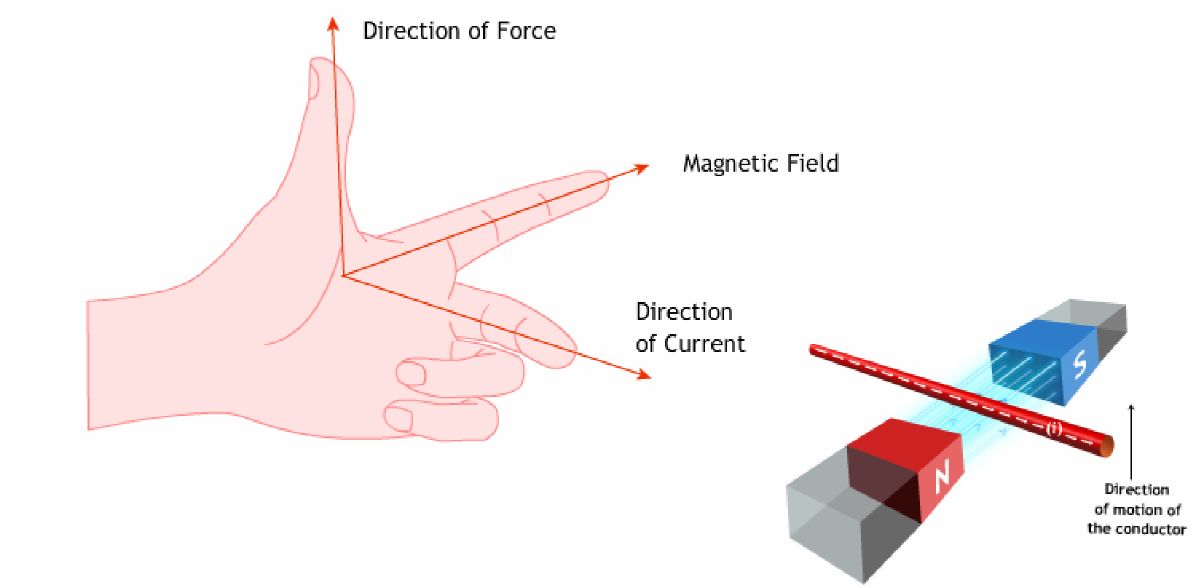
number of such loops form a coil and the coil is termed solenoid. If there is a soft iron core in the solenoid, it behaves like a magnet as long as there is current through the coil. Thus it is an electromagnet.

When an electric current passes through a conductor, a magnetic field is created around the conductor. This phenomenon is known as the magnetic effect of electricity.

A magnetic field is the extent of space surrounding a magnet where the magnet’s effect can be felt. Magnetic field lines represent the lines of action of the force acting on a unit North Pole placed in a magnetic field.



Fleming’s Left Hand Rule



If the forefinger, middle finger and thumb of the left hand are stretched such that they are at right angles to each other, then: The forefinger gives the direction of the magnetic field.

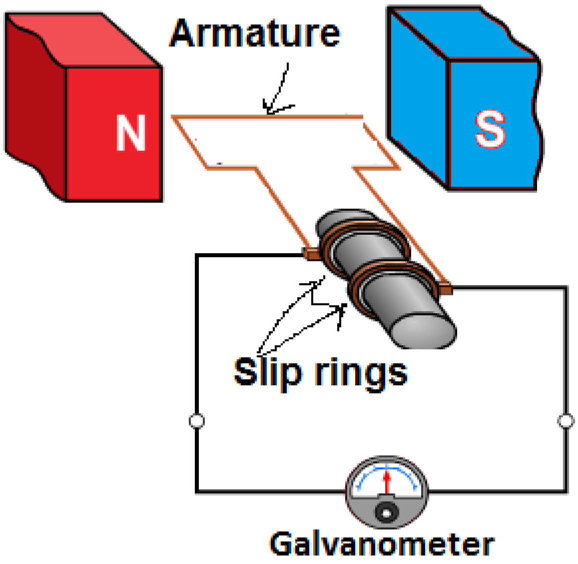
- The middle finger points in the direction of the current.
- The thumb gives the direction of the force acting on the current-carrying conductor placed in the external magnetic field.
- An electric motor converts electrical energy into mechanical energy using the magnetic effect of electricity.

Electric Generator

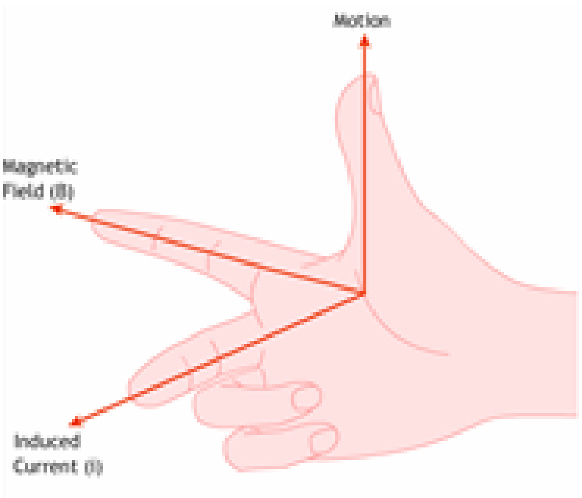
Electric generator work on this principle of electromagnetic induction. An electric generator or dynamo is used to convert mechanical energy into electrical energy, using electromagnetic induction.

Working

Electric generators have an armature which is free to rotate in a magnetic field. Its terminals are connected to two slip rings, which are further connected to two brushes and they are connected across a load resistance through which the generated electricity can be trapped. The rotation of the armature in the magnetic field changes the magnetic flux in the coil of the armature and an electric current is induced. As the direction of the induced current changes for every half rotation, it is called alternating current



Fleming's Right Hand Rule



Fleming's right hand rule gives the direction of the induced current in a conductor when it is moved in a magnetic field. Fleming's right hand rule states that if the index finger points in the direction of the magnetic field and the thumb indicates the direction of the motion of the conductor, then the middle finger indicates the direction of the induced current flow in the conductor. Transformers, which consist of a primary coil and a secondary coil, are based on this principle. The number of turns in the coils is selected based on the type of the transformer to be made, namely, step-up or step-down.

Electric Motor and Electric Generator

Electric Motor	Electric Generator
i. Electric motor is a device that converts electricity into mechanical energy.	i. Electric Generator is a device that converts mechanical energy into electricity.
ii. Working principle of electric motor: Electric motor works on the principle that when an insulated conductor coil is placed in a magnetic field and the current is passed through it, a force acts on the coil which rotates continuously.	ii. Working principle of electric generator: faraday laws of electromagnetic induction (i.e., when magnetic flux is cut by conductor, Electro motive force is induced. Or in other words If an insulated electric conductor coil is relatively in motion with a magnetic field Electro motive force is induced.) is the working principle of electric generator
iii. The direction of the force acted on the insulated electric conductor coil through which electric current is passing is determined	iii. The direction of the Induced electro motive force in the insulated electric conductor coil in which electric current

by using Fleming's left hand rule	is induced is determined by using Fleming's right hand rule

Alternating Current and Direct Current

Alternating current (AC) is the current induced by an AC generator. AC current changes direction periodically. Direct current (DC) always flows in one direction, but its voltage may increase or decrease. The current produced in hydroelectric power stations is alternating current. It changes its direction 50 times per second and hence its frequency is 50 Hz.

MAGNETIC EFFECT OF ELECTRIC CURRENT

Magnetic effect of electric current is one of the major effects of electric current in use, without the applications of which we cannot have motors in the existing world. A current carrying conductor creates a magnetic field around it, which can be comprehended by using magnetic lines of force or magnetic field lines. The nature of the magnetic field lines around a straight current carrying conductor is concentric circles with centre at the axis of the conductor.

Oersted's Experiments

Magnetic Field and Field Lines Due to a Current Carrying Straight Conductor

A current carrying conductor creates a magnetic field around it, which can be comprehended by using magnetic lines of force or magnetic field lines.

- The nature of the magnetic field lines around a straight current carrying conductor is concentric circles with centre at the axis of the conductor.
- The direction of the magnetic field lines of force around a conductor is given by the Maxwell's right hand grip rule or the right-handed cork screw rule.
- The strength of the magnetic field created depends on the current through the conductor.
- If the conductor is in the form of a circular loop, the loop behaves like a magnet.
- If the current in the loop is in the anticlockwise direction, a north pole is formed and if the current is in the clockwise direction a south pole is formed.

Force on a Straight Current Carrying Conductor

Lorentz found that a charge moving in a magnetic field, in a direction other than the direction of magnetic field, experiences a force, called Lorentz force.
As the current is due to the motion of charge, a conductor carrying current placed in a magnetic field, in the direction other than the direction of magnetic field, will also experience a force.
Magnitude of Force
The magnitude of the force acting on a current carrying conductor placed in a magnetic field in a direction perpendicular to it, depends on the following factors.

i. The force F is directly proportional to the current flowing in the conductor, i.e., $F \propto i$
ii. The force F is directly proportional to the magnetic field strength,

i.e., $F \propto B$
iii. The force F is directly proportional to the length of the conductor, ie., $F \propto l$

Combining the above three relations, $F \propto iBl$

Or

$F = kiBl$

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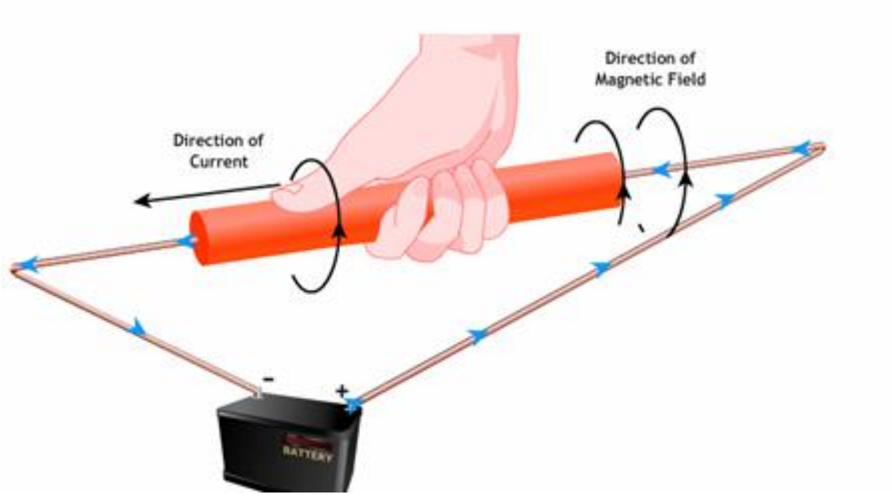
$F = kBil$, where k is the constant whose value depends on the choice of units.

In S.I units, $k = 1$, so $F = Bil$
The direction of force on a current carrying conductor placed in a magnetic field is obtained by the Fleming's left hand rule.
Rules to Find the Direction of Magnetic Field
The direction of magnetic field at a point is determined by using a compass needle. But theoretically the direction of the magnetic field produced due to the flow of electric charges in a conductor is determined by some rules as the following.

i. Right hand thumb rule
ii. Maxwell’s cork-screw rule
iii. Clock-S rule
iv. SNOW Rule
v. Fleming's Left Hand Rule

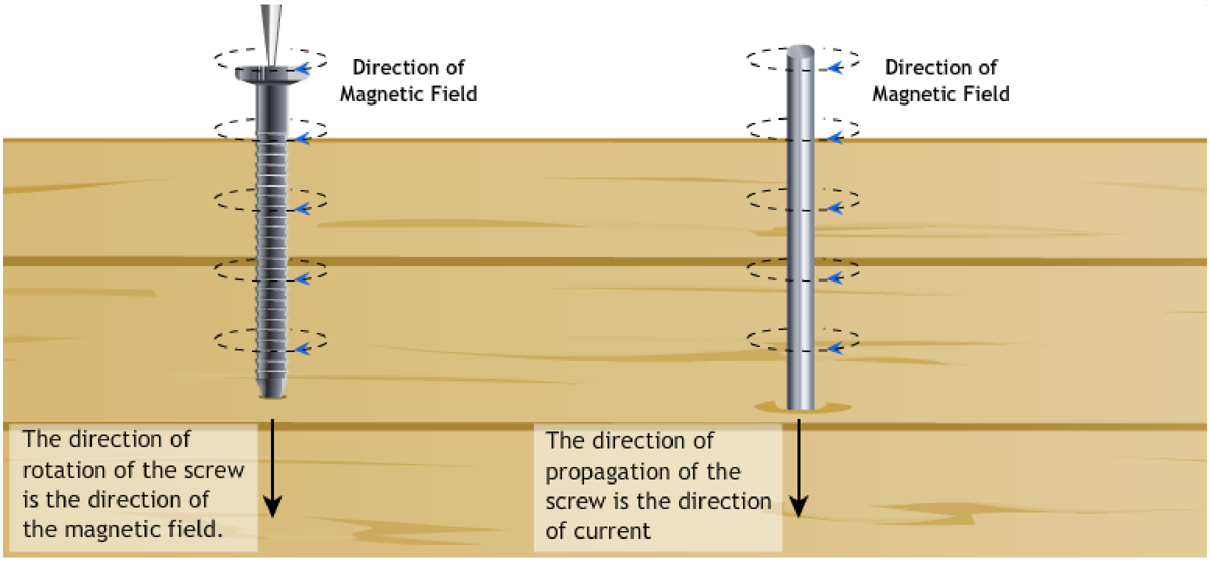
Right Hand Thumb Rule



Right hand thumb rule states that if we hold the conductor in the right hand such that the thumb points in the direction of electric current, then the direction in which the fingers curl gives the direction of the magnetic field

If we point thumb down wards in the direction of the current, the magnetic field would be represented by the curled fingers as the circles around the conductor. So, if it is viewed from the above plane this field lines will be clockwise circles, but the direction of the magnetic field at any point on this circular magnetic lines is in the direction of the tangent drawn to the circular magnetic lines at the desired points.

Maxwell's cork-screw rule:



Maxwell' cork screw rule is also known as Maxwell's right hand thumb rule. If the head of a cork-Screw is rotated such that the tip of the screw advances in the direction of electric current, then the direction of rotation of the head of the screw represents the direction of the magnetic field around the conductor.

A magnetic field caused by a current-carrying conductor consists of sets of concentric lines of force. The direction of the magnetic field lines depends on the direction of the current passed through the conductor.

Clock-S Rule

Clock-S rule is rule which helps us to find the formation of magnetic South Pole due to electromagnetic induction in a current carrying conducting coil.

According to clocks rule if one face of a current carrying conducting coil is placed such that one face of the coil is faced to us and current is moving in the clockwise direction with respect to us then the face of the coil which is faced to us becomes as a magnetic south pole and the other face behaves as the north magnetic pole.

A current carrying conductor in the form of a rectangular loop behaves like a magnet and when suspended in an external magnetic field experiences force.

SNOW Rule

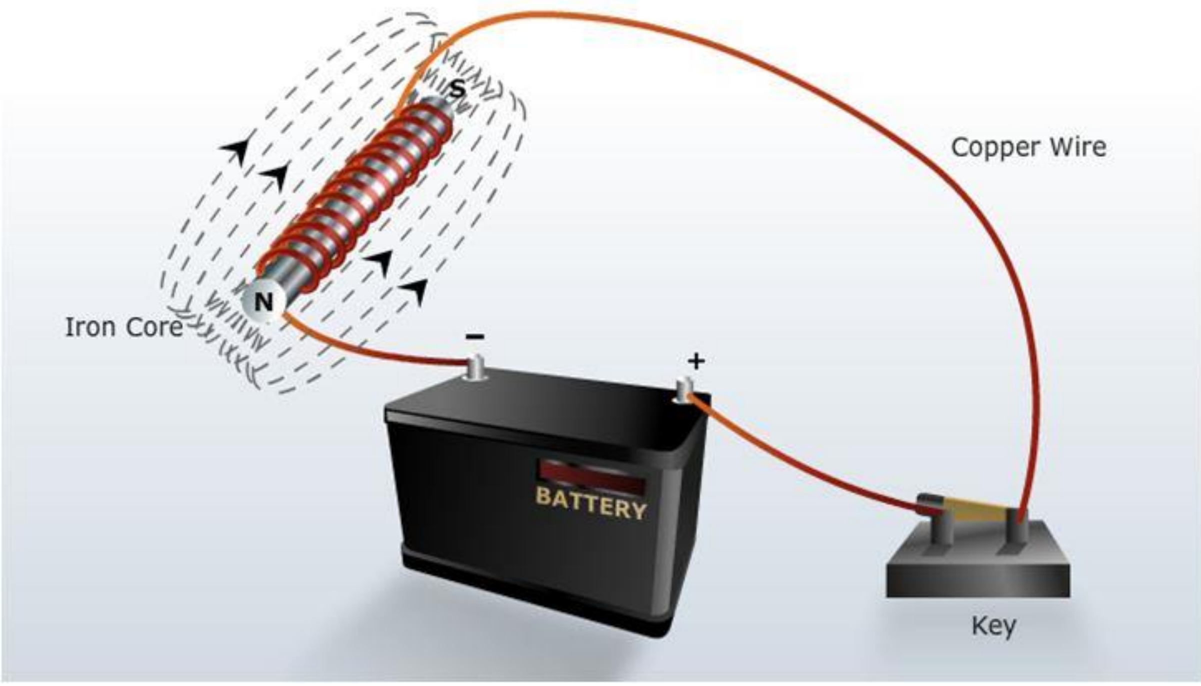
SNOW rule states that if the current is flowing in an electric circuit from South to North direction and a magnetic compass is placed Over the conducting wire, the needle of the compass deflects in the direction of west.

Magnetic Field Due to Current in a Loop

A current carrying conductor in the form of a rectangular loop behaves like a magnet and when suspended in an external magnetic field experiences force. The direction of the force is given by Fleming's left hand rule. This gives the basis for an electric motor. An electric motor essentially consists of a coil as an armature, a split ring commutator for changing the direction of the current in the coil. There are two brushes linked with the split rings that maintain the contact with the armature for the current flow. Electric motor converts electrical energy to mechanical energy.
A number of such loops form a coil and the coil is termed solenoid. If there is a soft iron core in the solenoid, it behaves like a magnet as long as there is current through the coil. Thus, it is an electromagnet.

Electromagnet

An electromagnet is a magnet made up of a coil of insulated wire wrapped around a soft iron core that is magnetised only when current flows through the conducting wire.



In the process of making electro magnets we pass the electricity through the magnetic substances. Steel retains magnetism even after stopping the electric supply whereas the iron loses the magnetism completely after stopping the power supply. So Iron is preferred to make electro magnet than steel

The South – North polarity of a permanent magnet can be changed by changing the direction of the current in the coil. Its strength can be changed by changing the current in it or by changing the number of turns in it.

Uses of an Electromagnet

1. For loading furnaces with iron.
2. For separating magnetic substance such as iron from other debris.
3. For removing pieces of iron from wounds.

4. For the lifting and transporting large masses of iron scrap, girders, plates etc.,
5. In the electrical devices such as electric bells , Telegraphs, electric trams, electric motors, relays, microphones ,loud speakers, etc.,
6. In specific research, to study the magnetic properties of a substance in the magnetic field

Permanent Magnet

As the alignment of the molecular magnets produced during the magnetization is disturbed easily some substances like soft iron are used to make electromagnets (temporary magnets). Whereas the alignment of the molecular magnets produced during the magnetization remains permanent some substances steel is used to make permanent magnets.

Permanent Magnet	Electro Magnet
1. The South – North polarity of a permanent magnet is fixed and they cannot be changed.	1.The South – North polarity of a permanent magnet can be changed by changing the direction of the current in the coil.
2. Its strength cannot be changed or altered.	2. Its strength can be changed by changing the current in it or by changing the number of turns in it.
3. Its magnetic field is permanent unless it loses its magnetism due rough handling	3. Its magnetic field is temporary as it magnetic

or heating or hammering or to any similar reason.

field is produced due to the passing a current.

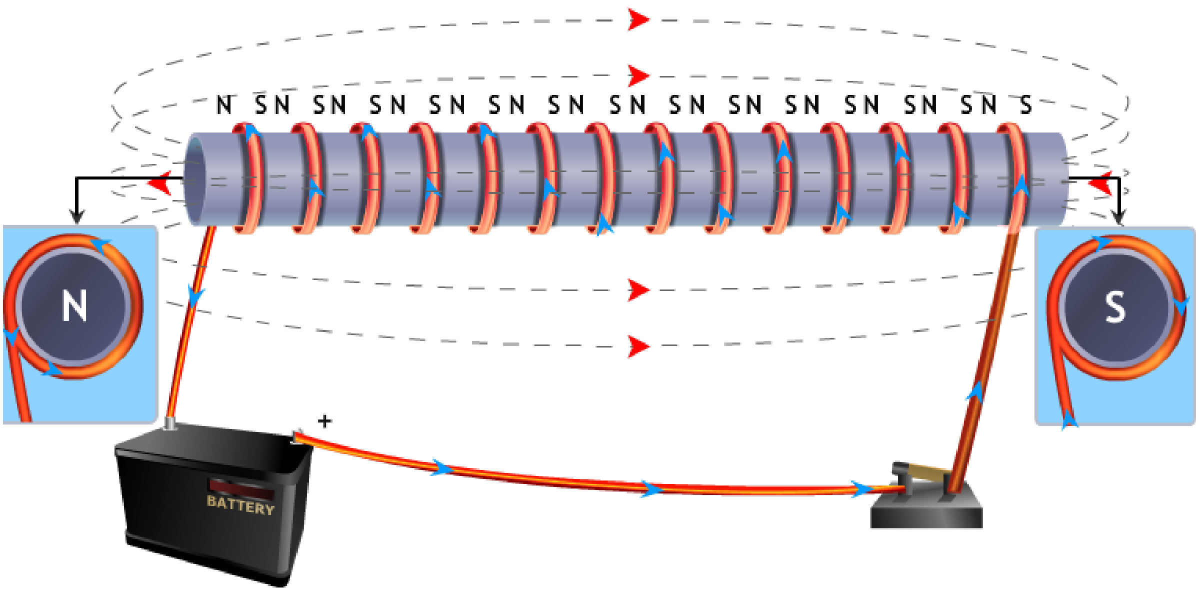
Solenoid

The solenoid is an electro magnet which is a long cylindrical coil of wire consisting of a large number of turns bound together very tightly.

Note
The length of the coil should be longer than its diameter.

Magnetic Field Due to a Solenoid

Solenoid is a coil of a number of turns of insulated copper wire closely wrapped in shape of a cylinder. Magnetic field around a current carrying solenoid is as shown in the figure.



Theses appear to be similar to that of a bar magnet. One end of the solenoid behaves like North Pole and the other end behaves like the South Pole. Magnetic field lines inside the solenoid are in the form of parallel straight lines. This means that the field is same at all the points inside the solenoid.

When soft iron rod is placed inside the solenoid, it behaves like an electro magnet. The use of soft iron as core in the solenoid produces the strongest magnetism.

A solenoid consists of an insulated conducting wire wound on a cylindrical tube made of plastic or cardboard.

Electric Motor

The direction of the force is given by Fleming’s left hand rule. This gives the basis for an electric motor. An electric motor essentially consists of a coil as an armature, a split ring commutator for changing the direction of the current in the coil. There are two brushes linked with the split rings that maintain the contact with the armature for the current flow. Electric motor converts electrical energy to mechanical energy.

A number of such loops form a coil and the coil is termed solenoid. If there is a soft iron core in the solenoid, it behaves like a magnet as long as there is current through the coil. Thus it is an electromagnet.

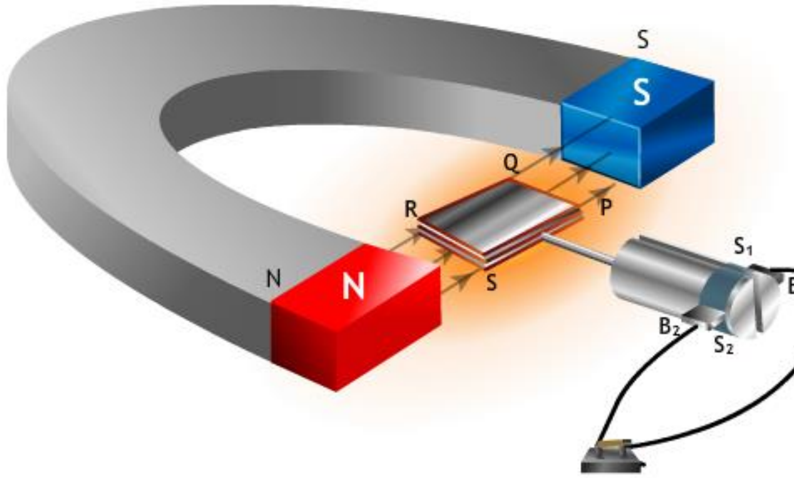
When an electric current passes through a conductor, a magnetic field is created around the conductor. This phenomenon is known as the magnetic effect of electricity.

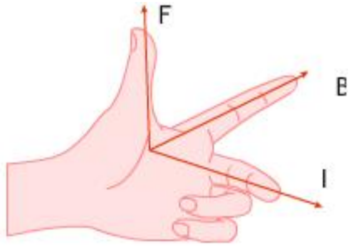
A magnetic field is the extent of space surrounding a magnet where the magnet’s effect can be felt.
Magnetic field lines represent the lines of action of the force acting on a unit North Pole placed in a magnetic field.

Electric Bell

An electric bell consists of an iron core, on which is wound a wire as a coil. One end of the coil is connected to one terminal of a battery, and the other end to a steel rod that acts like a spring for the hammer touching the screw contact. The other terminal of the battery is connected to the screw contact with a switch in the middle.

Working





Electric current flows through the coil when the switch is ON, and the iron core acts as an electromagnet. The iron core attracts the hammer towards it. The hammer hits the bell and produces a sound. The circuit breaks at the screw contact when the hammer moves towards the iron core. At this point, the iron core ceases to be an electromagnet. The hammer is pulled back to its original position due to the spring action of the steel rod, and then touches the contact again to complete the circuit. The circuit is completed and current flows through the coil again, and the hammer strikes the bell again. The process repeats itself and you hear a ringing sound since the hammer keeps hitting the bell, until the switch is released.

Electric Motor

Electric motor is a device which converts electric energy in to mechanical energy. Electric motor works on the principle of force on a conductor carrying current moving in a magnetic field.

If an electric current is passed through through a conductor placed normally in a magnetic field, a force acts on the conductor as a result of which the conductor begins to move and work is obtained. The direction of force acted can be found by using Fleming's left hand rule. This gives the basis for an electric motor.

Working

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Force on a Current Carrying Conductor in a Magnetic Field

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As the current is due to the motion of charge, a conductor carrying current placed in a magnetic field, in the direction other than the direction of magnetic field, will also experience a force. This can be demonstrated.

- The experiment set up consists of a conductor AC, which is free to move in a magnetic field of strength B between the poles of a horseshoe magnet.
- The length of the conductor is normal to the direction of the magnetic field.

- The ends A and C of the conductor are connected to a rheostat, key and a battery in series.
- It is experimentally observed that when no current passes through the conductor, no force acts on the conductor, and it does not move.
- When the key is pressed and current passes through the conductor, a force ‘F’ acts on the conductor in a direction perpendicular to the plane containing the direction of the current and the magnetic field.
- Due to this force, the conductor begins to move in the direction of the force.
- If the direction of the current through the conductor is reversed, the direction of its motion is also reversed, indicating a reversal in the direction of the force.
- Also, on reversing the direction of the magnetic field, the direction of motion of the conductor is reversed, indicating a reversal in the direction of the force.
- When the conductor is placed such that the current in it is parallel to the direction of the magnetic field, it does not move, indicating that the force on it is zero.

Magnitude of Force

It is found that the magnitude of the force acting on a current carrying conductor placed in a magnetic field in a direction perpendicular to it, depends on the following factors.

i. The force F is directly proportional to the current flowing in the conductor, i.e., $F \propto i$
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Oersted found the same by relative motion of a magnet with respect to a coil. Faraday's experiment proved that the strength of the induced current depends on several factors like the strength of the magnet, the speed of motion of the magnet, its orientation, the number of turns in the coil and the diameter of the coil. The induced current can be detected by a galvanometer. Fleming’s right hand rule gives the direction of the induced current in a conductor when it is moved in a magnetic field. Transformers are based on this principle, which consist of a primary coil and a secondary coil. The number of turns in the coils is selected based on the type of the transformer to be made, namely, step-up or step-down.

Electric generators work on the same principle. They have an armature which is free to rotate in a magnetic field. Its terminals are connected to two slip rings, which are further connected to two brushes and they are connected across a load resistance through which the generated electricity can be trapped. The rotation of the armature in the magnetic field changes the magnetic flux in the coil of the armature and an electric current is induced. As the direction of the induced current changes for every half rotation, it is called alternating current. The current at the power plants is distributed through transmission lines at a high voltage and hence the lines are referred to as high tension power lines. At the substations, these are stepped down to a lower voltage and supplied to houses at a low voltage. A domestic electric circuit essentially contains mains, a fuse, live or line, neutral and earth wires. From the poles supply cables bring the current to the mains. Within the house, all the equipment is connected in parallel combination.

Electromagnetic induction (EMI) is the process of generating an electromotive force by moving a conductor through a magnetic field.

The electromotive force generated due to electromagnetic induction is called induced emf.
The current due to induced emf is called induced current. Fleming's right hand rule states that if the index finger points in the direction of the magnetic field and the thumb indicates the direction of the motion of the conductor, then the middle finger indicates the direction of the induced current flow in the conductor.

An electric generator is used to convert mechanical energy into electrical energy, using electromagnetic induction.

Alternating current (AC) is the current induced by an AC generator. AC current changes direction periodically. Direct current (DC) always flows in one direction, but its voltage may increase or decrease.

Electrical components and wires fitted in a household to supply electricity to various appliances form a domestic electric circuit. The main supply cable has two wires: Live wire and neutral wire. Domestic electric circuits have earth wires to save users from severe electric shocks. An electric fuse is a safety device used to protect an electric circuit against excessive current.

LENZ'S LAW

Electromagnetic induction is the phenomenon in which an electromotive force and electric current due to it are induced in a coil whenever there is a change in the magnetic flux associated with the coil. The magnitude of the induced electromotive force is directly proportional to the rate of change of magnetic flux associated with the coil. It also depends on the number of turns in the coil and the area of its cross-section. The direction of the induced EMF is given by the following two rules

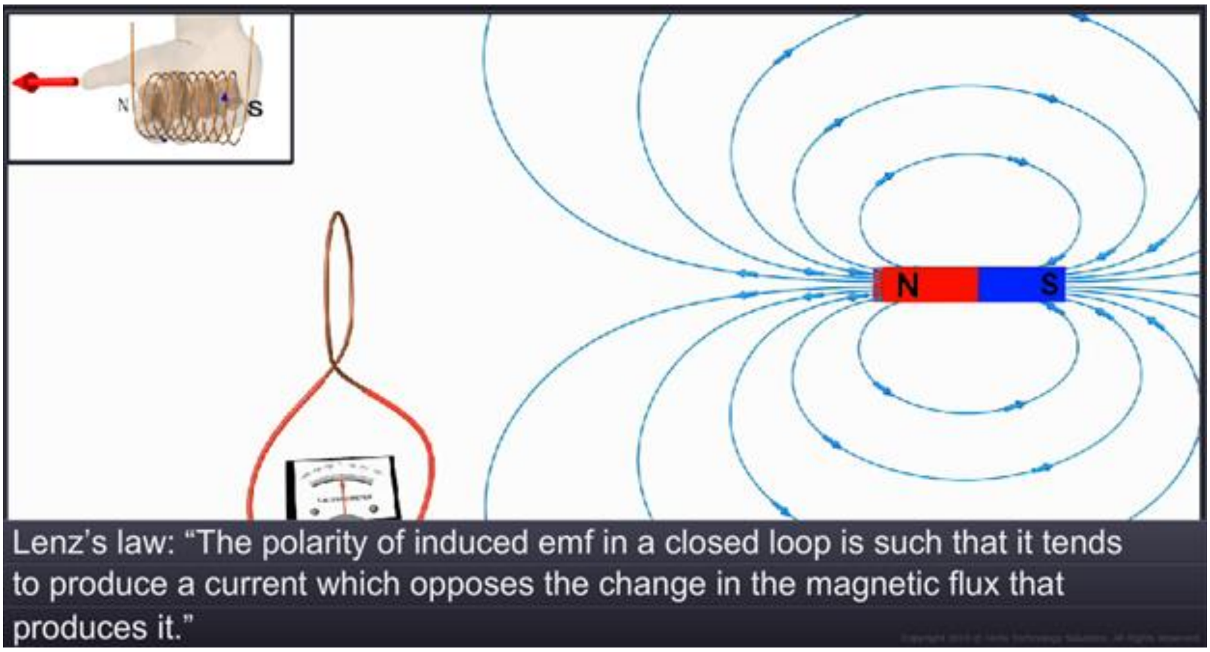
i. Fleming's right hand rule
ii. Lenz's law.

Lenz's law states that: "The polarity of induced emf in a closed loop is such that it tends to produce a current which opposes the change in the magnetic flux that produces it."

According to Lenz's law, in all cases of electromagnetic induction, the direction of induced current is such that it opposes the cause that produces it. Lenz's law also complies with the law of conservation of energy.

We can put this statement in simple terms as "If a current is induced by an increasing flux, it will weaken the original flux. If a current is induced by a decreasing flux, it will strengthen the original flux."

Lenz's law helps us in identifying the polarity of the induced emf in a coil.



TRANSFORMERS

A transformer is a device used to increase or decrease the voltage of an alternating current. It is used in power transmission to reduce power losses and to increase the efficiency of power supply. A transformer changes voltage, but not the frequency of the alternating current. There are two types of transformers. They are step-up transformer and step-down transformer. A step-up transformer is used to increase a low voltage alternating e.m.f. to a high voltage alternating e.m.f. A step-down transformer is used to decrease a high voltage alternating e.m.f. to a low voltage alternating e.m.f.

Principle

When magnetic flux changes in a coil, an alternating induced current is generated in it and the magnitude of e.m.f. of current induced depends upon the number of turns in the coil. This is called electromagnetic induction. Transformers work on the principle of mutual induction. According to the principle of mutual induction, when two coils are placed close to each other and if one of them carries a time varying current, then a current is induced in the other coil.

Construction

A transformer consists of a laminated core made from thin rectangular frames of soft iron. The frames are placed one over another and insulated from each other by lacquer, a kind of varnish. On one arm of the core, a coil, ‘P,’ of insulated copper wire is wound. This coil is called the primary coil and is connected to an alternating voltage source, whose voltage is to be stepped up or stepped down. On the other arm, another coil, S, of insulated copper wire is wound. This is the secondary coil. The induced alternating EMF is obtained as an output from the terminals of this coil. Let N_p and N_s be the number of turns in the primary and secondary coils, respectively. The ratio N_s/N_p is called the “turns ratio” or “transformer ratio”.

If the secondary coil has a greater number of turns than the primary ($N_s/N_p > 1$), then the voltage gets stepped up, i.e., the output voltage is higher than the input voltage. This type of a transformer is called a ‘step-up’ transformer. In this type of a transformer, there is less current in the secondary coil than in the primary coil. Conversely, if the secondary coil has less turns than in the primary coil ($N_s/N_p < 1$), the transformer is called a ‘step-down’ transformer. In such a case, the output voltage is less than the input voltage. That is, the voltage is stepped down, or reduced, and the current increases.

The magnitude of e.m.f. induced in the secondary coil depends on two factors: (i) the ratio of the number of turns in the secondary coil to the number of turns in the primary coil and (ii) the magnitude of e.m.f. applied in the primary coil. Hence we can write

E.m.f. across secondary coil/E.m.f. across primary coil = No. of turns in primary coil/No. of turns in secondary coil

$$E_s/E_p = N_s/N_p$$

Factors on Which Energy Loss in a Transformer Depends

In an ideal transformer there should be no loss of energy. However, in reality, all transformers incur small energy losses due to various factors, such as:

- Heat in the coils
- Eddy currents in the core
- Hysteresis loss in the core
- Magnetic field link loss

Transformer Cannot Be Used with A DC

A transformer cannot be used with direct current since its working is based on changing magnetic flux produced by a time-varying current of a given frequency in one coil inducing a varying current of the same frequency in the other coil. Since the magnitude of direct current does not vary with time, a transformer cannot be used with direct current.

Uses of Transformers

A major use of transformers is in power transmission lines. Transformers are used in networks that transmit electricity over long distances. we use a step-up transformer to increase the voltage and consequently decrease the current in the transmission line. This reduces the loss of energy as heat. The voltage is then stepped down at various substations and utility poles, before it reaches your home in the range of 220 to 240 volt.

Typically, when electricity is transmitted at high voltages, the voltage is in a multiple of 11. Thus, we have electricity being transmitted at 66, 33, 22 and 11 kilovolt. When electricity reaches city from the generating stations, it is typically stepped down to 6.6, 3.3 or 1.1 kilovolt. At the sub-station in your area, it is stepped down to 440 volt for three-phase circuits, and 220 to 240 volt for single-phase circuits. In India, domestic electricity supply is at 220 to 240 volts, but in the US, it is at 110 volt.