Revision Notes

Class 10 Science

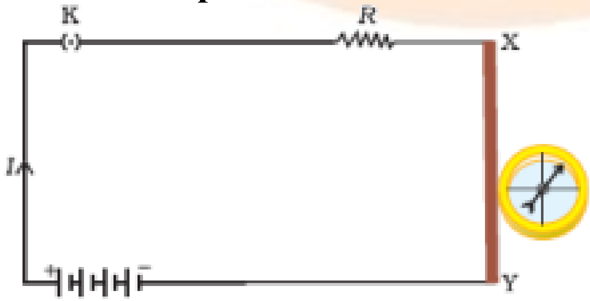
Chapter 13 - Magnetic Effects of Electric Current

- **Introduction:**
  - A magnet is a material that has the ability to attract metals such as iron, nickel, cobalt, and steel. There are two poles to a magnet: north and south.
  - When liberated, the two poles pursue the earth's north and south poles. Each component becomes a magnet when broken into parts.

- **Magnetic Field:**
  - A magnetic field is the area around a magnet where its influence can be felt by any other magnetic element.
  - The magnetic field is measured in Tesla or $Weber/m^2$ units.
  - Lines of Magnetic Fields
  - Externally, magnetic field lines exit the north pole of a magnet and enter the South Pole, forming closed loops.
  - At the poles, where the magnetic field strength is greatest, magnetic field lines are nearest. There are no magnetic field lines that cross one other.
  - The tangent at a place indicates the direction of the magnetic field at that point.

- **Natural Magnet:**
  - Magnetite or Lodestone (Fe_3O_4), a naturally occurring black iron ore, is a natural magnet.

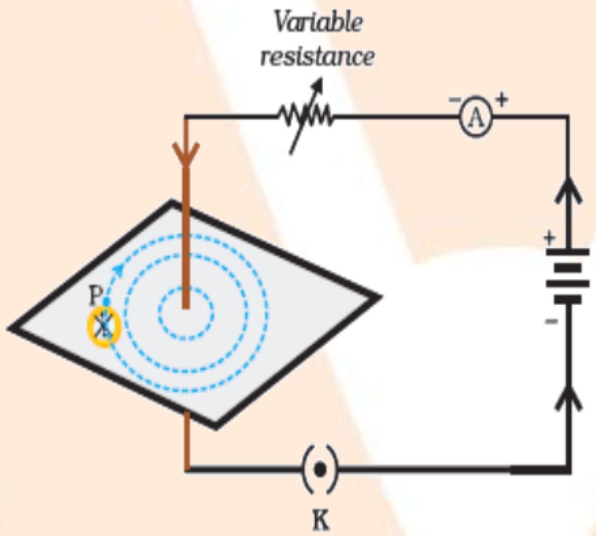
- **Oersted's Experiment:**



- The needle has been deflected, indicating that an electric current has caused a magnetic effect across the copper wire.
- As a result, we can say that electricity and magnetism are intertwined.

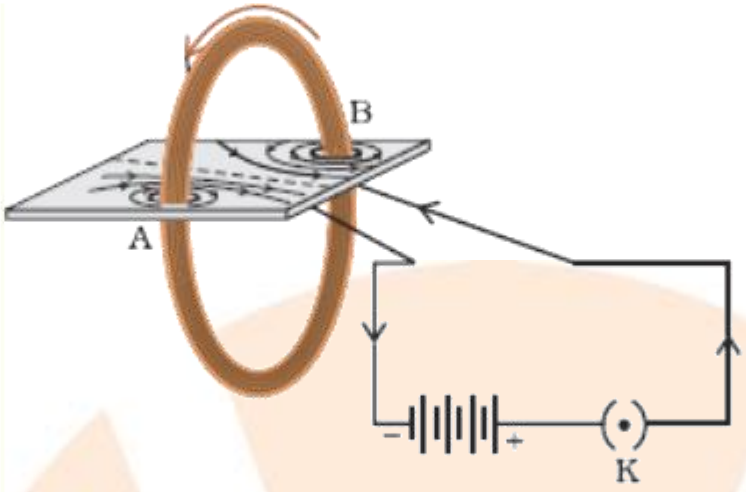
- **Magnet in a Magnetic Field:**
  - When a magnet is placed in a magnetic field, it aligns itself along the field lines with the North Pole facing the magnetic field's direction of travel.
  - Due to the contents of the earth, a magnetic field exists on its surface, causing it to behave like a magnet. As a result, a magnetic needle is employed to determine the direction on the earth's surface.

- **Magnetic Field around a Current Carrying Straight Conductor:**



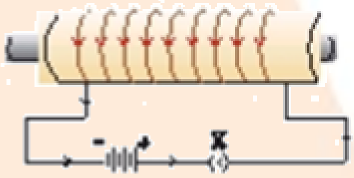
When the current in the copper wire is altered, the needle deflection varies as well. In reality, as the current rises, the deflection rises with it.
It means that when the current through the wire increases, the magnitude of the magnetic field produced at a given spot grows.

- **Magnetic Field around a Current Carrying Circular Conductor:**

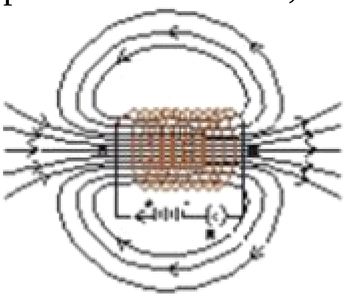


A current-carrying wire's magnetic field at a particular place is directly proportional to the current flowing through it.
The field produced by a circular coil with n turns is n times larger than that produced by a single turn.

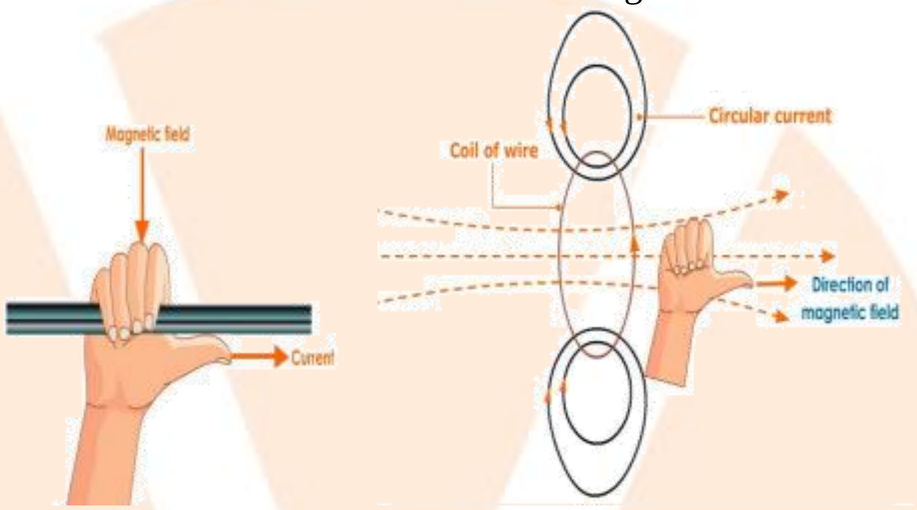
- **Magnetic Field Due To a Solenoid:**
  A solenoid is a coil comprising several circular turns of insulated copper wire wrapped tightly in the shape of a cylinder.



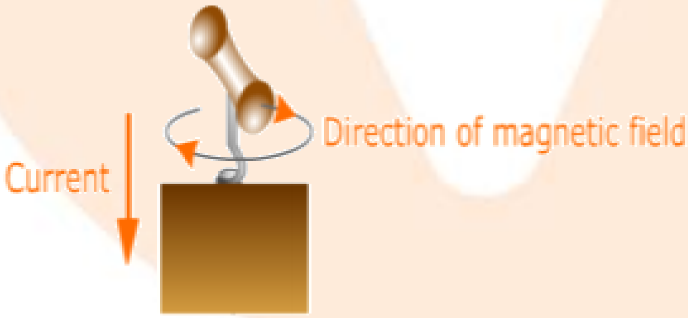
A solenoid's magnetic field lines are seen in the diagram below. The solenoid's one end acts as a magnetic north pole, while the other acts as a magnetic south pole.
Pole:
Inside the solenoid, the field lines are in the shape of parallel straight lines. This means that the magnetic field inside the solenoid is the same at all places. That means, the field inside the solenoid is uniform.



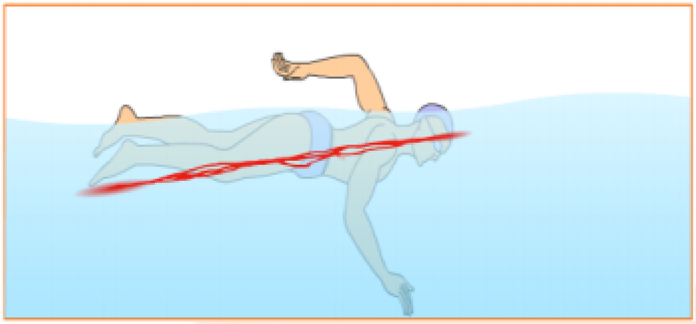
- **Rules for Determining Direction of Magnetic Field:**
  - The direction of the curled fingers points in the direction of the magnetic field if a straight conductor is clutched in the palm of the right hand with the thumb pointing along the path of current flow.
  - For circular conductors, use the right hand thumb rule.
  - The thumb points in the direction of the magnetic field if the circular current's direction matches with the curled fingers' direction.



- **The cork screw rule of Maxwell:**
  If the current through a conductor is represented by the direction of linear motion of a cork screw, then the magnetic field is represented by the direction of rotation of the cork screw.



- **Ampere's swimming rule:**
  If a guy swims along a current-carrying wire with his face constantly facing the magnetic needle, current entering his feet and exiting his head, the magnetic needle's North Pole will always be deflected towards his left hand.

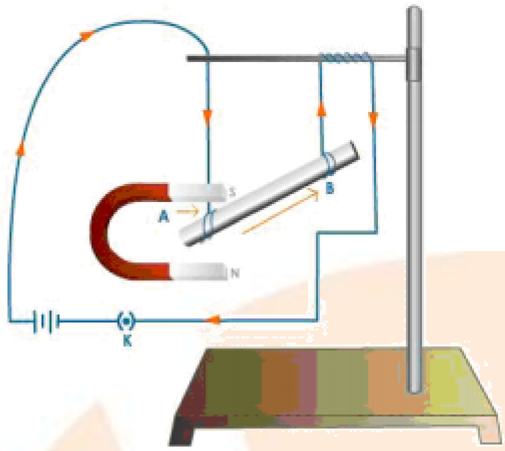


- **Magnetizing a Material:**
  The material can exhibit magnetic properties once it has been magnetised.

- **Permanent Magnets:**
  A permanent magnet is one that retains its magnetic properties after it has been magnetised. This is a property of steel.

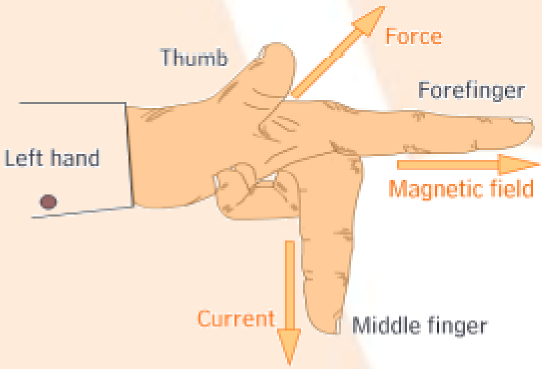
- **Electromagnets and Their Applications:**
  - When a piece of magnetic material, such as soft iron, is placed inside the coil, a strong magnetic field produced inside the solenoid can be used to magnetise it.
  - An electromagnet is a magnet that has been formed in this way.
  - Electric bells, loudspeakers, telephone diaphragms, and electric fans all use electromagnets.
  - Cranes also employ massive electromagnets to transport large loads.

- **Force on Current Carrying Conductor in a Magnetic Field:**



When a current-carrying conductor is put in a magnetic field, it is subjected to a force. When the current in the conductor is reversed, the direction of force is reversed as well.

- **Fleming's Left Hand Rule:**

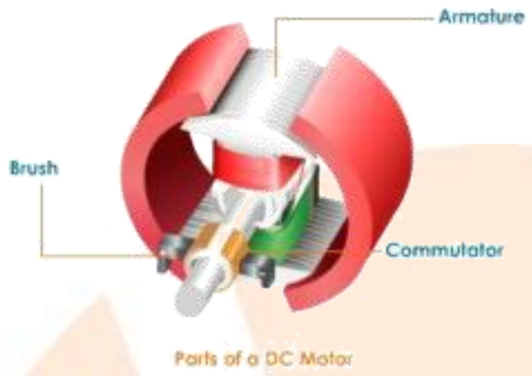


When the thumb, forefinger, and middle finger of the left hand are held perpendicular to each other, with the forefinger pointing in the direction of the magnetic field and the middle finger pointing in the direction of the current, the thumb points in the direction of the force exerted on the conductor, according to Fleming's left hand rule.

- **Electric Motor:**
A device that converts electrical energy into magnetic energy is known as an electric motor.

- **DC Motor:**
Principle: Torque acts on a rectangular coil carrying electricity when it is put in a magnetic field, causing it to revolve continually.
When the coil spins, the shaft connecting to it rotates as well, allowing it to perform mechanical tasks.

- **Construction and Working:**
  Parts of a DC Motor

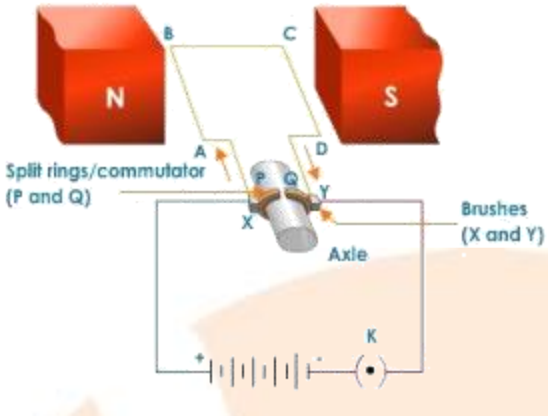


- **Armature:**
  A rectangular coil of insulated copper wire wound on a soft iron core makes up a D.C. motor. The armature is made up of this coil coiled on a soft iron core. The coil is positioned between the cylindrical concave poles of a magnet and is mounted on an axle.

- **Commutator:**
  A commutator is a device that reverses the direction of current flow. A commutator is a copper ring that is divided into two sections, C1 and C2. The split rings are installed on the motor's axle and are shielded from one another. These rings are attached to the coil's two ends. They spin in time with the coil. A battery is linked to the commutator rings. The cables from the batteries are attached to the brushes, which are in touch with the rings, rather than the rings themselves.

- **Brushes:**
  - Brushes are two thin strips of carbon that press on the two split rings, and the split rings revolve between them.
  - A D.C. source is used to power the carbon brushes.

- **The Operation of a DC Motor:**
  When the coil is turned on, it creates a magnetic field surrounding the armature. Rotation is caused by the left side of the armature being pushed away from the left magnet and attracted towards the right.



A Simple Electric Motor

The brushes lose contact with the commutator as the coil turns through 90°, and the current stops flowing through the coil.
The coil, on the other hand, continues to turn due to its own momentum.
When the coil passes past 180°, the sides are switched. As a result, commutator ring C1 now contacts brush B2, whereas commutator ring C2 contacts brush B1. As a result, the current keeps flowing in the same direction.

- The efficiency of the DC Motor Increases by:
  - Increasing the coil's number of turns.
  - Increasing the current's strength.
  - Increasing the coil's cross-sectional area.
  - Increasing the radial magnetic field's strength.

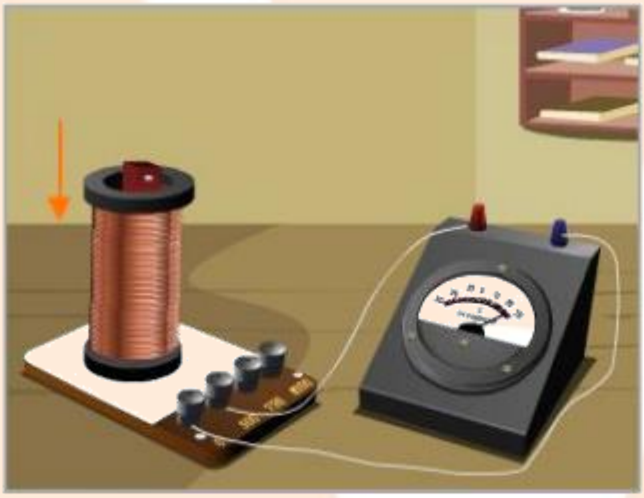
- **Electromagnetic Induction (EMI):**
  Electromagnetic induction is a phenomena in which an emf or current is induced in a conductor as a result of a change in the magnetic field around the conductor.


To Demonstrate Electromagnetic Induction

The English physicist Michael Faraday was the first to demonstrate that a magnet may generate a current.

He tested this by moving a magnet in front of a coil of wire linked to a galvanometer.
He noticed a deflection in the galvanometer, indicating that it had been induced by a current.
Induced current is the current generated by the relative motion of the coil and the magnet.
Electromagnetic induction is a phenomena in which an emf or current is induced in a conductor as a result of a change in the magnetic field around the conductor. By moving a bar magnet in and out of a coil of wire, Faraday came to a few conclusions.

- **Experiment:**



The North pole of the magnet is moved into the coil of wire

- **Observation:**
The current is induced in the coil due to the relative motion between the magnet and the coil, as indicated by the deflection in the galvanometer.

The North Pole of the Magnet is Moved out of the Coil of Wire

- **Observation:**
  When the identical pole of the magnet is moved in the other direction, the deflection in the galvanometer is reversed.

The Magnet is Held Stationary Inside the Coil of Wire

- **Observation:**
  The galvanometer pointer returns to zero, indicating that the deflection in the galvanometer will remain as long as the magnet and coil are in relative motion.

The South Pole of the Magnet is Moved into the Coil of Wire

- **Observation:**
  When the opposite pole is moved in the same direction, the deflection in the galvanometer is reversed.

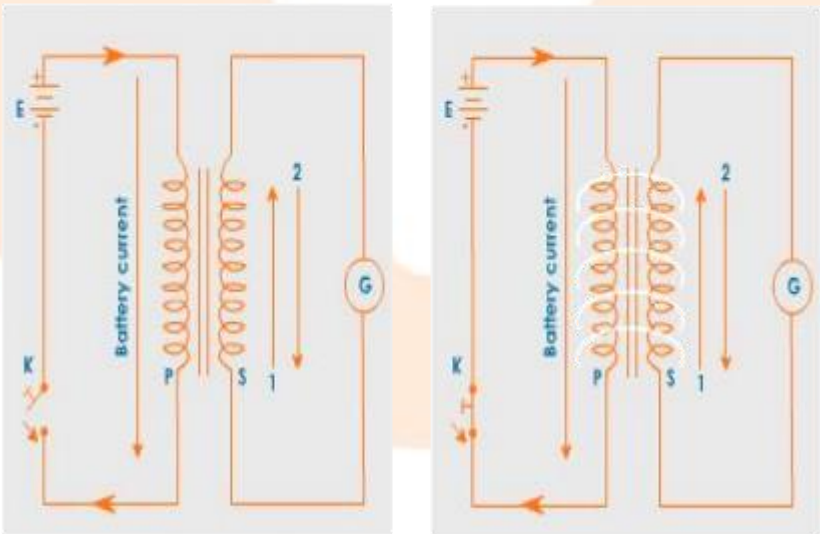
The Number of Turns of the Coil is Increased

- **Observation:**
The number of turns in the coil affects the deflection in the galvanometer; the more turns in the coil, the higher the deflection. Because the magnetic field travels around each loop of wire in the coil, the magnetic field changes more as the number of coils increases. In and out of the coil, the magnet moves quicker. If the magnet is moved faster, the deflection is greater. That is, when the magnet moves quicker, the rate at which the current is induced increases.

- **Mutual Induction:**
  - Mutual induction is the phenomenon of producing induced emf in one coil as a result of a current shift in an adjacent coil. To further comprehend this, let us conduct an experiment.
  - As indicated, place two coils P and S near to one other.
  - Connect the primary coil P to a battery and a key, and the secondary coil S to a sensitive galvanometer G.
  - The galvanometer shows a deflection whenever the key is pressed or released. By pressing and releasing the key, you can now see the deflection of the galvanometer needle. Because the current passing through the first coil causes a current in the secondary coil, the needle deflects.

Mutual Induction

- **What Causes Mutual Induction?**
  - When you hit the key K, current begins to flow through the coil P, increasing the magnetic flux associated with P.
  - Because S is so close to P, the magnetic flux associated with S increases as well. Induced emf and, as a result, induced current are produced in S.
  - According to Lenz's law, the arrow marked 1 indicates the direction of induced current in S.

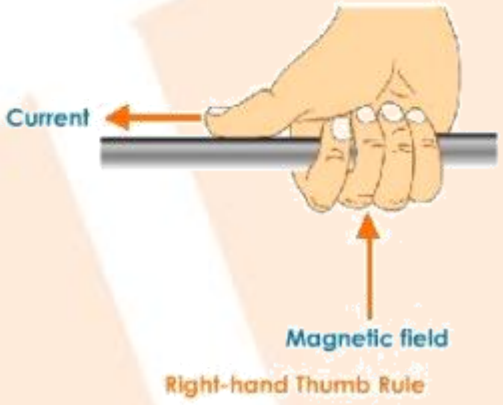


Mutual Induction

  - When the key is released, the magnetic flux associated with the coils drops, causing induced current to flow in the direction indicated by the
  -

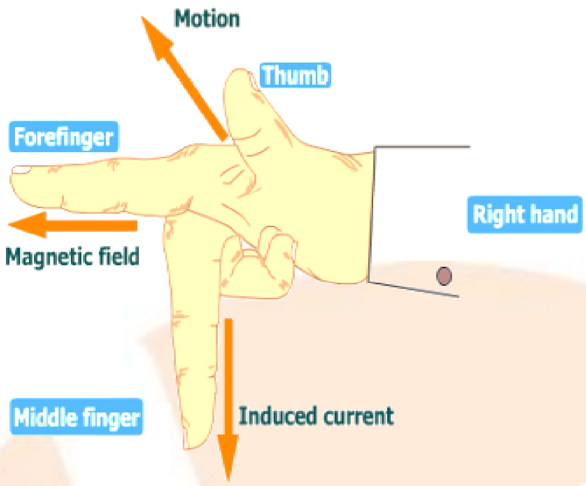
arrow marked 2. The development of induced emf in the secondary coil during the make or break of current in the primary coil is known as mutual induction.

- **Rules for Determining the Direction of Induced Current:**
  - Fleming's Right Hand Rule can be used to determine the direction of induced current.



  - Stretch the right hand's forefinger, middle finger, and thumb such that they are all perpendicular to one another. The direction of the magnetic field is shown by the forefinger, the direction of conductor motion is indicated by the thumb, and the direction of induced current in the conductor is indicated by the middle finger.
  - The above-mentioned phenomenon is used to power the electric generator.

- **The Right Hand Rule of Fleming:**
  - Fleming's Right Hand Rule - Stretch the right hand's forefinger, middle finger, and thumb such that they are all perpendicular to one other.
  - The direction of the magnetic field is shown by the forefinger, the direction of conductor motion is indicated by the thumb, and the direction of induced current in the conductor is indicated by the middle finger.

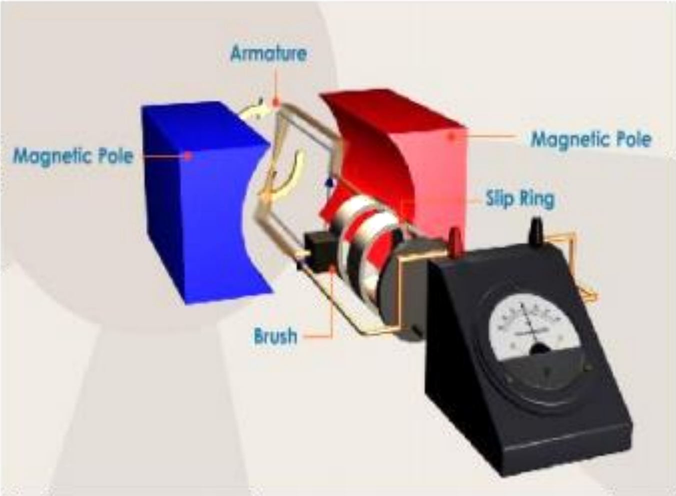


- **Electric Generator (AC):**
  - Mechanical energy is converted into electrical energy by the electric generator.
  - DC and AC generators are the two types of generators:
  - A cycle dynamo and a car dynamo are both examples of DC generators. They generate DC.

- **Generators** - Generators - Generators - Generators - Generators In power plants and industries, generators or alternators are utilised to generate AC.

- **The Basics of an AC Generator:**
  When a straight conductor is rapidly moved in a magnetic field, it induces a current in the conductor. It is based on the electromagnetic induction phenomena.

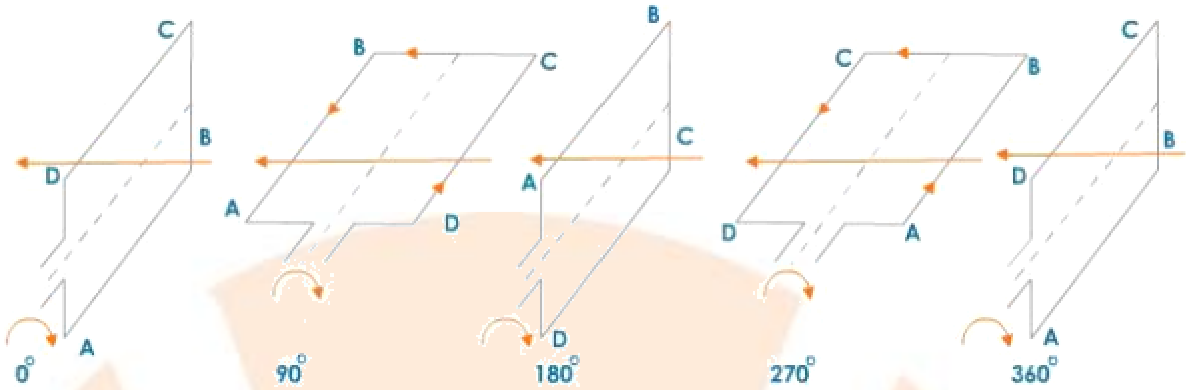
- **Construction:**
  The AC Generator's Main Components:
  A magnet with concave cylindrical poles, an armature, and a current collecting system make up an AC generator.
  Slip rings and brushes make up the present collection system.



Parts of an AC Generator

- Armature is a soft iron core around which a coil of insulated copper wire with a large number of turns is coiled. Magnetic poles are cylindrical and concave. A radial magnetic field is created by the concave poles.
- The armature's ends are joined by two slip rings. They spin in time with the coil. Metal slip rings that are isolated from one other are used.
- There are two carbon brushes, B1 and B2. Each brush has one end that is connected to an external circuit and the other end that is in touch with the rotating slip rings. Brushes are linked to a galvanometer and do not revolve with the coil in this case.
- A diesel engine, flowing water, steam, or high-speed wind rotate the axle mechanically from the outside.

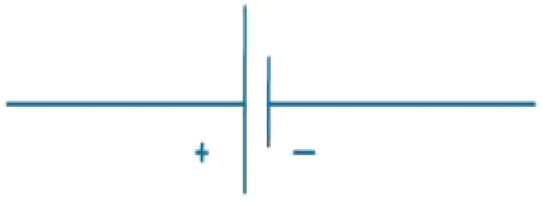
- **Working:**
  - The armature changes its relative orientation with respect to the magnetic field as it rotates along an axis perpendicular to the field.
  - As a result, the flux is constantly altering over time.
  - An emf is produced by a shift in magnetic flux.
  - An electric current passes through the armature if the outer terminals are linked to an external circuit.
  - The galvanometer needle deflection indicates that an emf has been induced. After every half rotation of the coil, the direction of the induced emf is reversed.
  - As a result, the current changes direction twice in one coil revolution.
  - Take a look at the diagram below to see how the direction of current changes:



- Alternating current is a type of current that alternates its direction at regular intervals (AC).
- A split-ring type commutator must be utilised to create a direct current (DC) generator. One brush is always in contact with the arm travelling up in the field, while the other brush is always in contact with the arm travelling down. In such a generator, a unidirectional current is generated.
- The frequency of the AC current produced in India is 50 hertz (Hz). The coil rotates at a rate of 50 revolutions per second for one second. In one second, the current changes direction 100 times in 50 rotations.

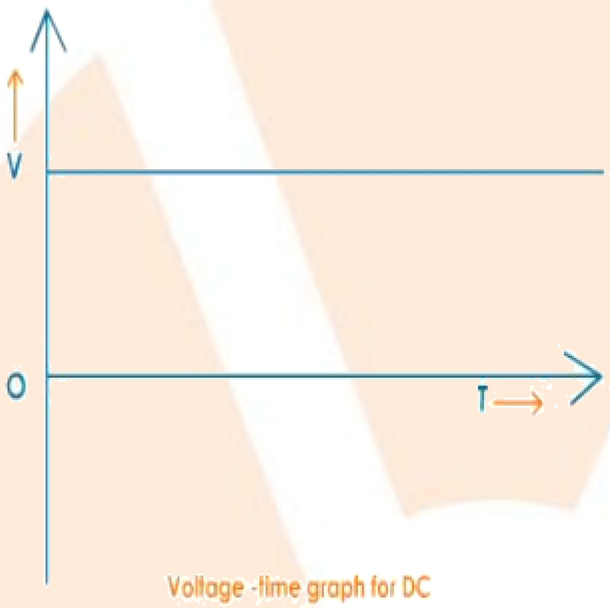
- **DC Generator:**
  - The output generated here is one-way.
  - To do this, the slip rings are replaced with split rings.
  - A split-ring type commutator must be utilised to create a direct current (DC) generator. One brush is always in contact with the arm travelling up in the field, while the other brush is always in contact with the arm travelling down. In such a generator, a unidirectional current is generated.
  - alternating current

- **Direct current:**
  DC, occurs when the current flows in the same direction. The current generated by a cell or battery is one-way. As a result, it's a DC source. In an electrical circuit, it is represented as:



Cell

The voltage V/s time graph for a DC source is represented as follows:



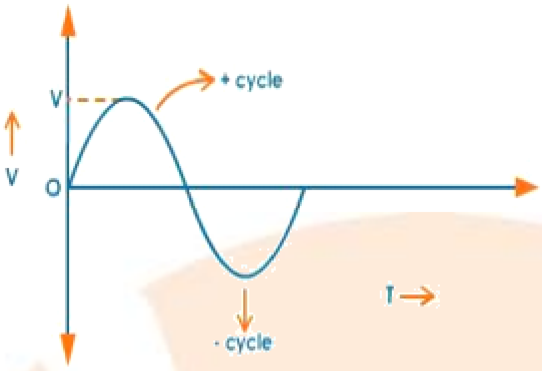
Voltage -time graph for DC

The +ve and -ve terminals are fixed.

- **Alternating Current:**
  - Alternating current is defined as a current that changes direction at regular intervals.
  - The majority of power plants produce AC current.
  - In an electrical circuit, it is represented as:

Symbol for AC

The voltage V/s time graph for an AC source is represented as follows:



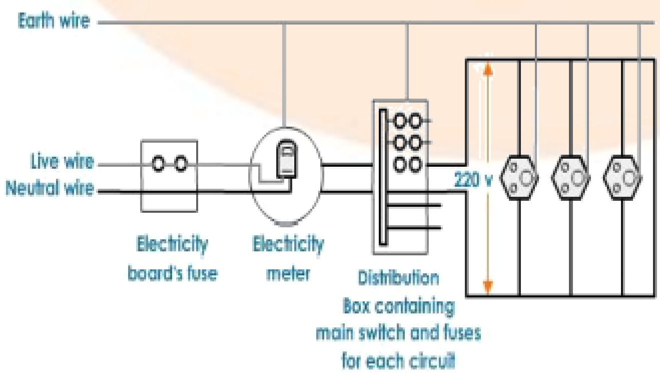
Voltage-time Graph for AC

The current changes direction every half cycle, hence there are no stable terminals.

- **Domestic Electric Circuits:**
  Electric power is typically generated in locations that are remote from where it is consumed. Electricity is generated at 11,000 volts at the generating station. This voltage alternates at a 50 Hz frequency.

  To reduce energy loss during transmission, power is transported over long distances at high voltage.

- **Domestic Wiring:**
  The live wire, neutral wire, and earth wire are the three wires that bring electricity into our home. We use a colour code for insulating these wires to minimise confusion. The live wire is red, whereas the neutral wire is black. The earth cable is insulated with green plastic. The live wire has a 220 volt potential, while the neutral wire has no potential. As a result, the potential difference between the live and neutral wires is 220 volts.



A Schematic Diagram of one of the Common Domestic Circuits

- The earth wire is constructed of copper and is substantially thicker. It's connected to a copper plate buried deep underground on one end. The earth is connected to the electric metre, which is subsequently connected to the main switch.
- Electricity is delivered to our homes via a main supply, which is either supported by above electric poles or underground wires.
- The live and neutral wires from the electric pole enter a box with a primary fuse F1 installed directly outside our house. The live wire is linked in series with the fuse. This is because the live wire is the sole one with a high potential of 220 volts, whereas the neutral wire has no potential.
- F1 has a high amperage rating of roughly 50 amperes. As a result, it prevents any damage to the entire electrical wiring entering the house, such as fire, caused by a short-circuit or overload.
- The two lines then enter the electricity metre, which keeps track of how much electricity we use in kilowatt-hours (kWh). The electric supply department of our city erected this metre.
- The two wires that emerge from the metre are then connected to a main switch in a distribution box. For customer safety, another fuse F2 is connected in series with the live wire in this box.
- In a house, there are two different circuits: lighting circuit and power circuit. The lighting circuit, which uses a 5 A fuse, is used to power electric bulbs, fans, radios, TVs, and tube lights, while the power circuit, which uses a 15 A fuse, is used to power electric heaters, electric irons, geysers, and refrigerators, among other things.
- The distribution circuits are always linked together in parallel. Even if a defect or short-circuiting occurs in one line of a parallel circuit, the corresponding fuse blows, keeping the other circuits and appliances intact and preventing damage to the entire house. The power-fuse will blow if a short-circuit happens in the power circuit, but our lights will continue to burn because the lighting circuit is untouched.
- All other electrical equipment can use the main line's steady voltage. As illustrated in the diagram, in addition to the two wires, a third wire known as the ground wire enters our home.
- The earth is connected to the electric metre first, and then to the main switch. This cable, together with the live and neutral wires, is then run into the rooms.

- **Electric Fuse:**
  - The term "electric fuse" refers to a device that limits the current in an electric circuit. The fuse protects the circuit as well as the electrical equipment from damage.
  - The fuse wire is usually made of a lead and tin alloy. It has a low melting point and will break the circuit if the current is too high. The maximum current allowed across the circuit determines the thickness and length of the fuse wire.
  - In the beginning of the electric circuits, it is connected in series.
  - The fuse wire becomes heated and melts when the circuit current exceeds a preset value owing to voltage variations or short-circuiting. As a result, the connection is broken as illustrated in the diagram, and no current flows. The appliance will not be damaged as a result of this.

- **Causes of Damage to Electric Circuits:**
  Overloading
  - When a significant number of high-power electrical appliances (such as an electric iron or a water heater) are turned on at the same time, the circuit draws an enormous amount of current. This is known as overloading, and it can lead to overheating of the wire and a fire. It can also occur as a result of an unintentional increase in supply voltage.

- **Short-circuiting:**
  - When the live and neutral wires of an electric circuit come into direct touch, a short circuit develops. The wires may come into contact with each other due to a faulty connection or the insulation wearing away. This condition causes the wires to overheat, resulting in a fire.

- **Earthing of Electrical Appliances:**
  - The metal of an electrical equipment is 'earthed' to prevent electric shocks. The term "earthed" refers to a metal wire (copper) that connects the appliance's metal case to the earth (at zero potential). The earth wire has one end that is buried deep in the ground and the other end that is attached to the three pin socket.
  - The metal casing of the electrical appliance will remain at zero potential when it is switched on because it is in contact with the earth wire in the three pin socket. It thereby protects us from receiving an electric shock even if we unintentionally contact it.