Electromagnetic Induction

The electricity is generated when a conductor is moved in magnetic field. This was experimentally proved by the Michael Faraday for the first time.

Galvanometer.

- It is used to find the direction and magnitude of current passing through it.
- If there is no current, then there is no deflection.
- When current passes it deflects (right or left).
- The deflection increased with the increase in current.

Electromagnetic Induction.

Whenever there is a change in the magnetic flux linked with a coil, an ***emf*** is induced in the coil. This phenomenon is electromagnetic induction.

- The current induced is called **induced current**. And the voltage induced is called **induced emf**.
- ? Which are the factors affecting the direction of induced current.
  - Direction of magnetic field.
  - Direction of movement of conductor.
- ? Who discovered Fleming's Right Hand Rule and what does it say.
  - The British scientist **John Ambrose Fleming** discovered this rule.
  - It says the **relation** between the direction of magnetic field, the direction of movement of conductor and the direction of induced current.

Fleming's Right Hand Rule.

Imagine a conductor moving perpendicular to a magnetic field. Stretch the **forefinger**, **middle finger** and the **thumb** in mutually perpendicular directions. If the forefinger represents the direction of magnetic field, and the thumb represents the direction of motion of the conductor, then the **middle finger represents the direction of induced current.**

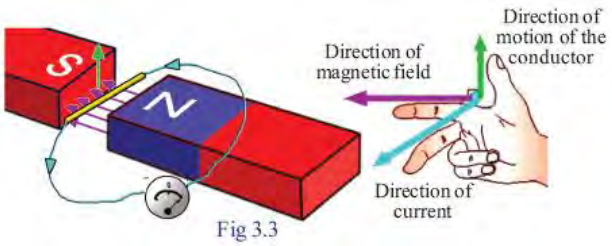
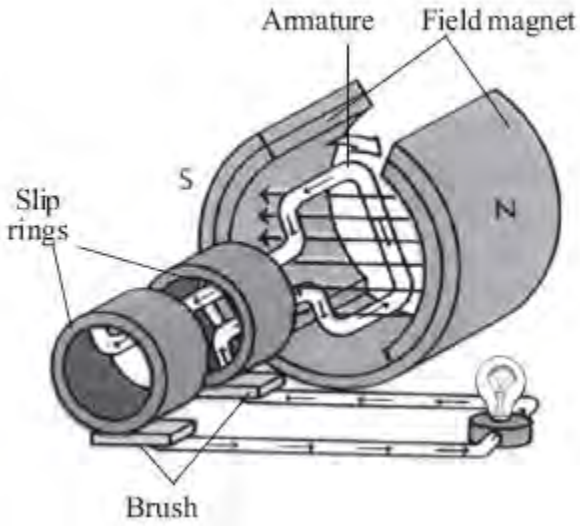


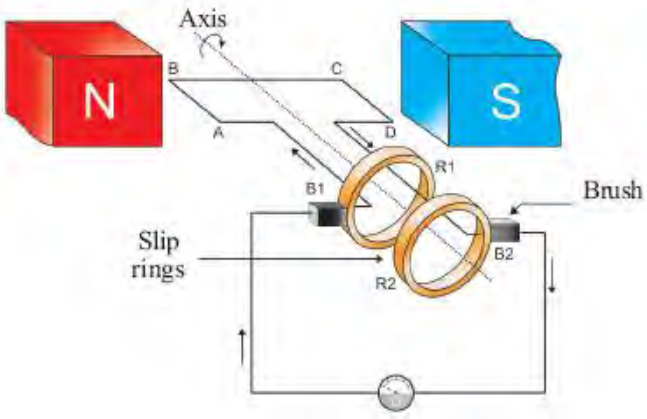
Fig 3.3

Alternating Current and Direct Current.

- A current that flows only in one direction continuously is called **DC** or Direct Current.
- The current that changes directions at regular intervals of time is called **AC** or Alternating Current.
- The **Generator** or **Cycle Dynamo** are the devices which produces electricity continuously by the movement of a **Magnet** or **Armature**.

Generator (AC).





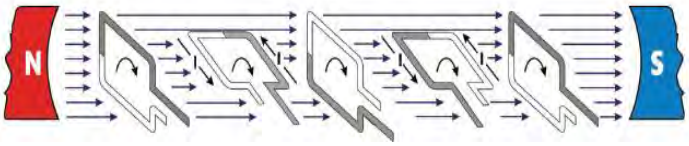
- What is a generator
  - The device which converts mechanical energy into electrical energy by making use of electromagnetic induction.
- What are the main parts
  - Field magnet (N,S).
  - Armature (ABCD).
  - Slip rings (R_1, R_2).
  - Graphite Brushes (B_1, B_2).
- What is the working principle
  - Electromagnetic induction.
- How do the current produce in the generator
  - By electromagnetic induction.
- What about the **current** obtained from a **cell** and by **electromagnetic induction**
  - The current obtained from the cell is unidirectional and is of the same magnitude.
  - The direction and magnitude of the current obtained by electromagnetic induction changes continuously.

ABCD indicates a turn of the armature coil. When the coil rotates about the axis in the clock wise direction, the portion **AB** moves upward and the portion **CD** moves downward.

- What is the direction of induced current in the portion AB
  - From A to B
- What is the direction of induced current in the portion CD
  - From C to D
- What is the direction of induced current in the coil ABCD
  - From A to D
- What is the direction of induced current in the external circuit.
  - From B_2 to B_1.

At this time the parts AB and CD are moving in a direction perpendicular to the direction of magnetic field. Hence the flow of electricity will be maximum.

When the armature turns by 90^0, the movement of the parts AB and CD are parallel to the direction of magnetic field. Hence the induced current will be zero.



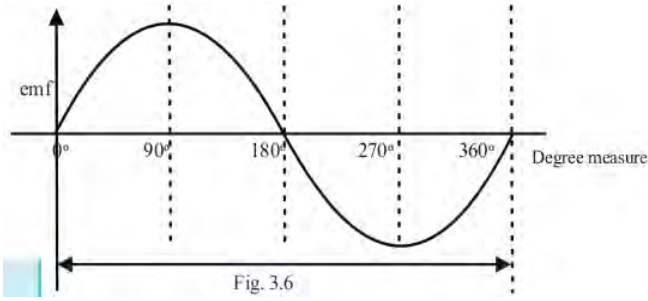


Fig. 3.6

	Time				
	0	**T/4**	**T/2**	**¾ T**	**T**
Angle of rotation of the armature.	**0^0**	**90^0**	**180^0**	**270^0**	**360^0**
Rate of change of flux.	*0*	*Maximum*	*0*	*Maximum in the opposite direction.*	*0*
Induced emf in volts. (V)	*0*	*Maximum*	*0*	*Maximum in the opposite direction.*	*0*

Period (T) – The time taken by the armature coil for a full rotation.

* The one complete rotation of the armature is called one **Cycle of AC.** The number of cycles per second is called **Frequency of AC.**
* The frequency of AC generated for distribution in our country is **50 Hz** (50 cycles per second). That means the armature coil is to rotate 50 times per second.
- What we have done to overcome the practical difficulties of a generator, especially to reduce the number of rotations
  - Increase the number of armature coil.
  - Increase the number of pole pieces of field magnet.
* 100 times the direction of current change in a second in the circuit when 50 Hz AC is used.
* The slip rings and the brushes help to bring the current which is produced in the armature to the outer circuit.
* The slip rings and the brushes are necessary only if the armature in generator is made to rotate. At this time the rubbing of slip rings

and brushes produce spark. For avoiding this we use magnet to rotate in the generators.

- What are the methods used to operate generators.
  - By using diesel or petrol engines.
  - By using water in dams.
- What type of current is produced in the armature
  - AC current.
- What type of current is brought to the external circuit (in the brushes)
  - AC current.

Generator (DC).

- If **split ring commutator** is used instead of slip rings, we will get DC.

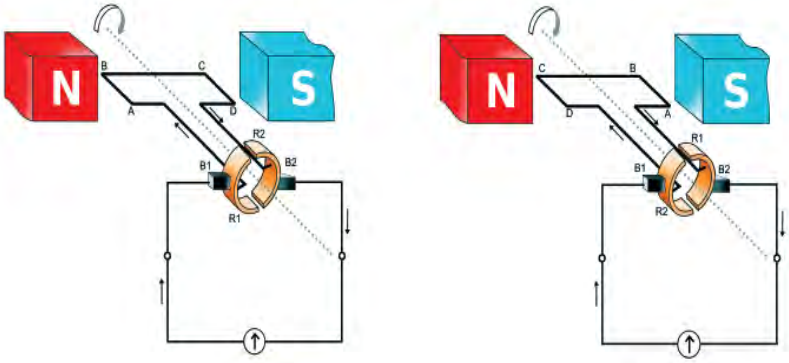
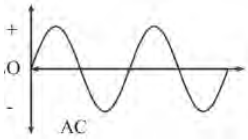


Fig. 3.7 (a) Fig. 3.7 (b)

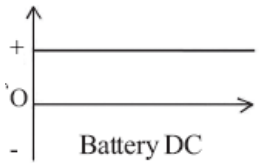
- What type of current is produced in the armature
  - AC current.
- What type of current is brought to the external circuit (in the brushes)
  - DC current.
- The B_1 is always in contact with the portion of the armature that moves upward and B_2 is always in contact with the portion of the armature that moves downward. As a result we get DC in the external circuit.
- What are the similarities between the DC motor and the DC generator
  - Permanent magnet.
  - Armature.
  - Split ring commutator.

1. **AC from AC Generator**.



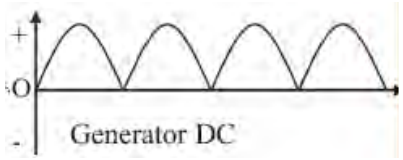
- Direction changes continuously.
- Strength changes. (emf increases and decreases.)
- So it is a **Pulsating current**.

2. **DC from a Battery.**



- Direction does not change.
- Strength does not change(emf does not increase or decrease.)
- So it is not a **Pulsating current**.

3. **DC from a DC Generator.**



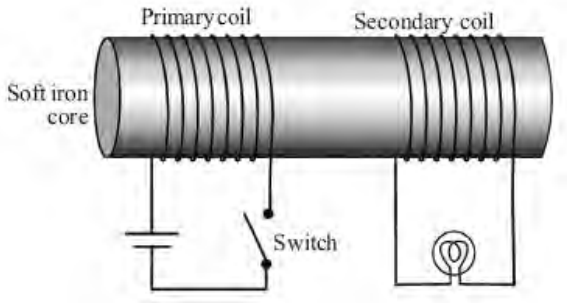
- Direction does not change.
- But strength changes. (emf increases and decreases.)
- So it is a **Pulsating current**.

Mutual Induction

Consider two coils of wire kept side by side. When the strength or direction of one coil changes, the magnetic flux around it changes. As a result an emf is induced in the second coil. This phenomenon is the mutual induction.

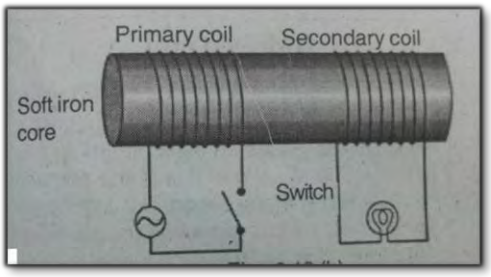
- **Primary coil:** The coil into which we give current for the production of magnetic field.
- **Secondary coil:** The coil in which induced emf is generated.

1. **DC** is used in the primary.



- The bulb glows only at **two instants**. At the instants of **switching ON** and **switching OFF**. And it suddenly extinguishes.
- If the switch is **kept** in the **ON** position, the bulb **glows continuously**.
- Because the magnetic flux changes only at the instants of switching ON and OFF. If the switch is kept in the ON position, there is no change in the magnetic flux.

2. AC is used in the primary.

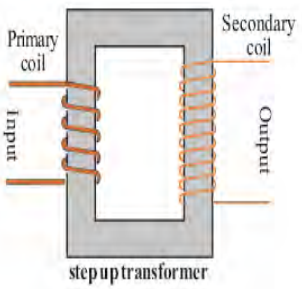


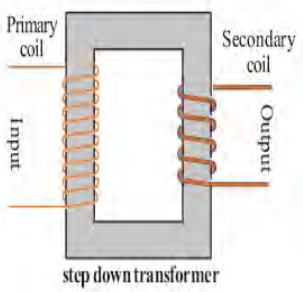
- If AC is given in the primary coil, emf will be continuously induced in the secondary coil.
- When the switch is kept ON in the primary, a varying magnetic field is formed around the soft iron core. The secondary is situated in this varying magnetic field. The flux change produced in the secondary coil induces an emf in it.

Transformer

It is a device for increasing and decreasing AC voltage without any change in its power.

- Working principle : Mutual Induction.
- Transformers are of **two types**.
  1. **Step up** transformer.
     The one which increases AC voltage.
  2. **Step down** transformer.
     The one which decreases AC voltage.





Step up	Step down.
○ Thick wires are used in the primary.	○ Thick wire is used in the secondary.
○ Voltage and number of turns are more in the secondary.	○ Voltage and number of turns are more in the primary.
○ Current is less in the secondary.	○ Current is more in the secondary.
○ Power is same in both primary and secondary.	○ Power is same in both primary and secondary.
○ $N_S > N_P$,	○ $N_S < N_P$,
○ $V_S > V_P$,	○ $V_S < V_P$,
○ $I_S < I_P$,	○ $I_S > I_P$,
○ $P_P = P_S$	○ $P_P = P_S$
○ $\frac{N_S}{N_P} > 1$	○ $\frac{N_S}{N_P} < 1$

- N_s – Number of turns in the secondary.
- N_p – Number of turns in the primary.
- V_s – Secondary voltage.
- V_P – Primary voltage.
- P_S – Secondary power.
- P_P – Primary power.
- I_S – Secondary current.
- I_P – Primary current.

The voltage (emf - **Ɛ**) in each turn of the primary and secondary coils will be the same.

- The **emf** in the primary is $V_P = N_p \times Ɛ$
- The **emf** in the secondary is $V_s = N_S \times Ɛ$

We can change voltage by changing the Number of Turns.

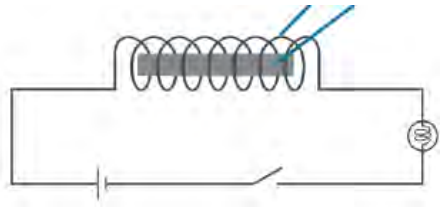
$$\frac{N_S}{N_P} = \frac{V_S}{V_P} = \frac{I_P}{I_S} \qquad P_P = P_S$$

Power = Voltage × Current

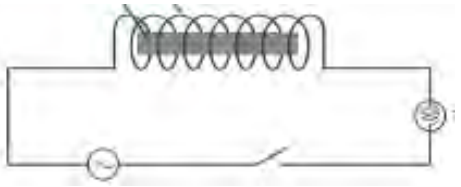
$P_p = I_p \times V_p$ $\qquad$ $P_s = I_s \times V_s$

Self Induction

As a result of the flow of a current through a solenoid, there is a chance of inducing an electric current in the same solenoid, which is due to the change in the magnetic field.



- In the above circuit, the bulb glows continuously when the switch is kept ON.
- The bulb gives a **light** with **high intensity**.
- When the switch is kept ON, a magnetic field is produced around it, which is **not a varying magnetic** field. So it does not produce an induced current or emf in the same solenoid.



- In the above circuit, the bulb glows continuously when the switch is kept ON.
- The bulb gives a **light** with **low intensity.**
- When AC passes through the solenoid, a changing magnetic field is produced around it. Due to this an induced emf is generated inside the solenoid.
- This induced emf is in the opposite direction of the applied voltage. Hence this is a **Back emf**. This back emf **reduces the effective voltage** in the circuit.

SELF INDUCTION.

The change in magnetic flux due to the flow of an AC in a solenoid will generate a back emf in the same solenoid in a direction opposite to the applied voltage.

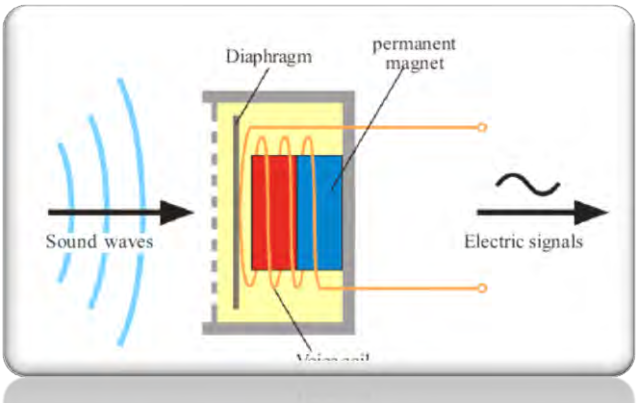
Inductor

Symbol

- An inductor is an insulated copper wire wound in a helical shape (coil).
- It is a device which works on the principle of self induction.
- **Uses.**
  - Used to oppose changes in electric current in a circuit.
  - Used to reduce the current to the desired value without loss of power.
- ? Inductors are widely used in AC circuits. Why
  - The can reduce the electric current in the AC circuit without the loss of power (without the energy loss in the form of power.)
- ? If resistors are used instead of inductors, what will be the disadvantage
  - When we use the resistors we loss electrical energy in the form of heat (power loss).
- ? Inductors are not used in DC circuits. Why
  - They oppose the change in electric current, which is the AC. But in DC circuits, there is no change in electric current. So it has nothing to do in the DC circuits.

Moving Coil Microphone

- Working principle – Electromagnetic induction.
- Main parts.
  - Diaphragm
  - Permanent magnet.
  - Voice coil or moving coil.



- Energy changes = sound energy – mechanical energy – electrical energy.
- **Working.**
  - When the sound wave falling on the diaphragm, it stars to vibrate which leads to the vibration of the voice coil placed in a magnetic field.
  - As a result electrical signals corresponding to the sound waves are generated in the voice coil.

- The weak signals obtained from the microphone are strengthened by an **amplifier** and this process is called **amplification**.
- The strengthened signals from the amplifier are sent to the loud speaker. Then it reproduces the sound.

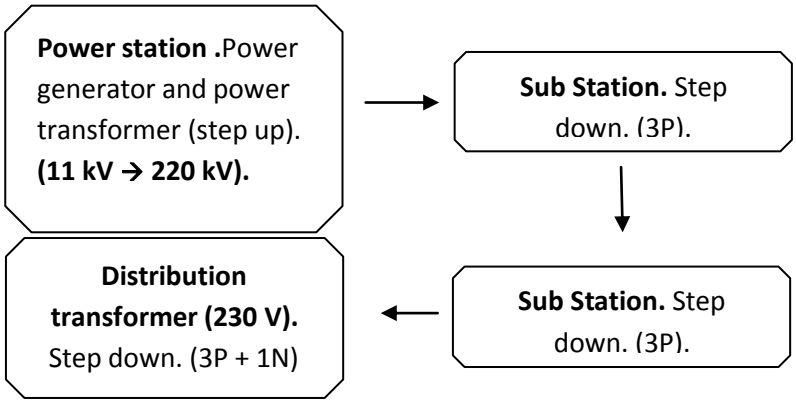
Power Transmission and Distribution

- **Power stations:**
  - Here the electricity is generated on a large scale for distribution.
  - Here the **Three Phase AC generators** are used. (3 armatures and 1 magnet.)

? What are the major types of power stations and how do they produce mechanical energy for the

- Hydro electric power stations – water stored in a dam.
  Eg: moolamattom, kuttyadi, mullapperiyar
- Thermal power stations – heat energy.
  Eg: kayamkulam,
- Nuclear power stations – nuclear energy.

- In the world the large scale electricity production is done by electromagnetic induction.



- In India electricity is produced at **11kV or 11000V** and **230 V** is supplied to the domestic consumptions.

Transmission Loss

- When electricity is transmitted to distant places there is loss of energy in the conductors in the form of heat. This is known as transmission loss.
  - * Transmission of electricity to distant places is done at a high voltage. This will reduce the problems of transmission loss to some extent.
  - * According to the Joules Law $\mathbf{H = I^2Rt}$, the heat is generated. We have to reduce the **I** or **R** or **t**.
    Since power transmission is a continuous process, reducing the **t** is not practically possible. To reduce the **R**, we have to decrease the length or increase the thickness which is not possible.
    So heat loss can be reduced by reducing the current.
  - * When we reduce the current, the power decreases by **P = IV**. So we can reduce the **I** without change in its **P** by increasing the **V**
- The **V** is increases up to **220 Kv** at the power station itself. As a result the current and the energy loss in the form of heat decrease.

Distribution Transformer

- We get 230 V for house hold purposes and 400 V for industrial purposes from this transformer.
- 3 (3P) wires are going in and 4 (3P + 1N) wires are coming out.
- The potential of
  - Neutral point 0V
  - Neutral line 0V
  - Earth 0V
- The potential difference b/w
  - Phase and neutral 230V
  - Phase and earth 230V
  - Neutral and earth 0V
- The phase and neutral lines are needed for house hold electrification.

Household Electrification

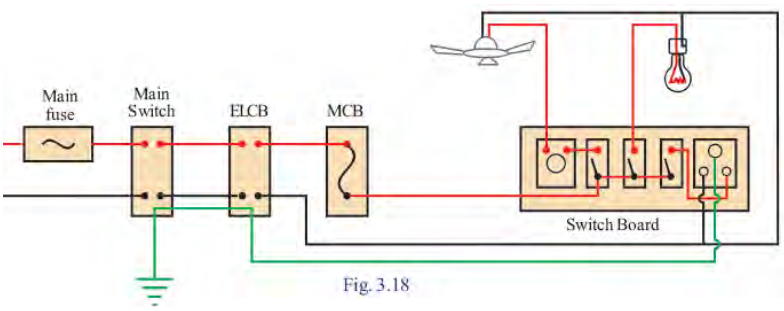


Fig. 3.18

- The **Watt hour meter** connected first when the electric line reaches our home. It measures the quantity of electricity consumed in **KWh** unit.
- **Fuse** and **Switch** are connected in phase line and they are connected in series.
- The **Main switch** is used to completely cut off the electric supply when we need any repair in the internal wiring.
- **House hold devices** are connected in **parallel**. There is a third line other than the phase and the neutral is the **EARTH LINE** (**E**).
- Colours used for wires..
  - Phase line Red
  - Neutral line Black
  - Earth line Green
- In the **Three pin socket** the Earth wire is connected in the larger pin.

Why electrical appliances should be earthed.

Sometimes the insulation of a phase line (live line) may get damaged and may come in contact with the metallic body of the devices. When such device is connected to the mains, we happen to touch any part of the metallic body, very high current flows through our body to the earth and we get an electric shock.

When the body of the device is connected to the earth wire, the electric current will flow into the earth through the earth connection.

? What are the advantages of **connecting** devices in **parallel**
  - Devices working according to the marked power.
  - Each device has its own switch.
  - The overall resistance of the circuit is reduced.

Watt -Hour Meter

- It is used to measure electrical energy in the unit **kilowatt hour** (also known as **unit**).
- Equation used to calculate electrical energy used.

$$\text{Energy in kilowatt hour} = \frac{\text{Power in watt} \times \text{time in hour}}{1000}$$

Safety measures in household electrification

1. Safety fuse.
2. MCB (Miniature circuit breaker), ELCB (Earth leakage circuit breaker).
3. Three pin plug and Earthing.

MCB and ELCB.

MCB	ELCB
• It is used in the place of fuse wire in branch circuits. • It automatically switching off the circuit when there is an excess flow of current due to short circuit and over loading. • After rectifying the circuit, we can switch ON the MCB. • It works based on the heating and magnetic effect of electric current.	• It helps to break the circuit automatically when there is a current leak due to insulation failure or any other reason. • A person touching a device does not get an electric shock. • We can also use RCCB (residual current circuit breaker) instead of ELCB which ensures more safety.

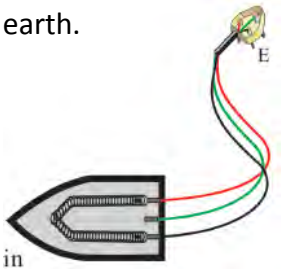
? What are the differences b/w ordinary fuse and MCB.
  - The fuse melts and breaks when excess current flow through it, which makes an open circuit.
  - But MCB automatically switching OFF and after rectifying, we can switch ON.
  - The fuse works only by the heating effect. But MCB works based on heating effect and magnetic effect.

? What is the advantage of MCB over a safety fuse.
  - It automatically switching OFF.

? What is the function of ELCB or RCCB in the circuit.
  - It making the circuit safe when there is an excess flow of current.

Three pin plug and Earthing.

In order to ensure safety, three pin plugs are used in some devices. If the phase line comes into contact with the metallic body due to defects In the insulation and we happen to touch any part of this, we will get an electric shock. The third pin of a Three Pin Plug is connected with the earth line and the metallic body of the instrument is connected to the earth line which helps to flow the current to the earth.



- How does the Earth pin differ from the other pins
  - The **length** and the **thickness** of the earth pin is **more** than that of other pins.
  - Due to the more thickness, the resistance decreased. So the current can flow the earth easily and properly.
  - Since the earth pin is longer, it comes in contact with the socket first and disconnected last.

Those working in AC	Those working in DC
▪ Refrigerator ▪ TV ▪ Computer. ▪ Fan.	▪ Calculator. ▪ Remote. ▪ Torch. ▪ Mobile phone.

Rectifier.

- It is a device that converts AC into DC.
- It contains a step down transformer and a **Diode** (it conducts current only in one direction.).

Electric Shock

Electric shock occurs when we touch bare wires or cable with damaged insulation or when lightning strikes. Severe injuries may occur when current flows through our body.

In addition to the electric shock, blisters may also occur. If somebody gets an electric shock, the main switch should be switched off immediately. Separate the electrocuted person using a dry wooden piece or a dry insulator material. Never touch the affected person using bare hands.

Precautions

- Never handle electric equipments or operate switches when the hands are wet.
- Insert plug pins into socket and withdraw them only after switching off.
- Do not operate devices of high power using ordinary sockets.
- Wear rubber footwear while operating electric devices.
- Do not touch the interior parts of the cable TV adapters. Ensure that there is an insulated cap for the adapters.
- Do not fly kites near electric lines.
- Do not use table fan to dry hair.
- Ensure that there are no tall buildings or tall trees near electric lines.
- Ensure that the main switch and ELCB are switched off when maintenance work is being carried out at home.

How to provide the first aid:

- Raise the temperature of the body by massaging.
- Give artificial respiration.
- Massage the muscles and bring them to the original condition.
- Start first aid for the functioning of the heart (Apply pressure on the chest regularly)
- Take the person to the nearest hospital immediately.