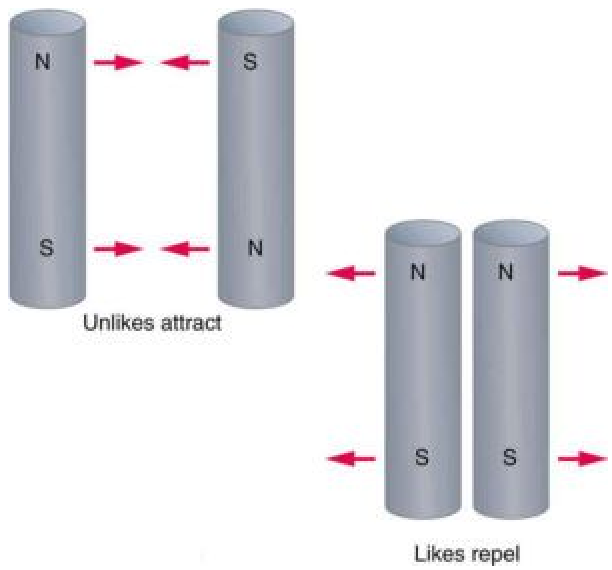
Magnetic field and Magnetic force

‘Opposites attract’. You must have heard this phrase quite often. But why do opposites attract? Where did this phrase originate from? This phrase comes from the magnet and its magnetic field. The opposite poles of a magnet attract each other. In actuality shouldn’t opposite poles repel and like poles attract each other? Isn’t it? ‘No’ you say. Well, then let us prove your theory below.

What is Magnetism?

A bar magnet attracts iron objects to its ends, called poles. One end is the north pole, and the other is the south pole. Magnetism is the phenomena arising from the force caused by magnets that produce fields which attract or repel other metallic objects. It is caused because of electrically charged particles. The force acting on the electrically charged particles in a magnetic field depends on the magnitude of the charge, the velocity of the particle, and its strength. Magnetism states that:

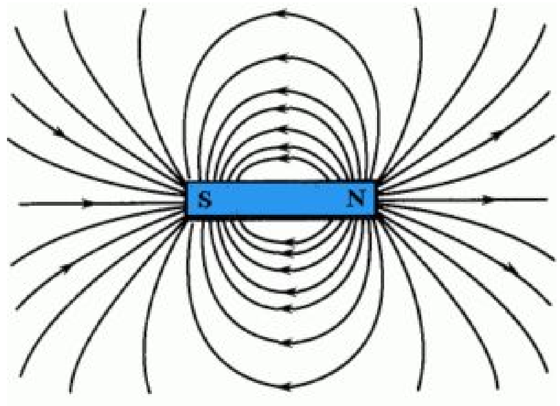
a. Opposite poles attract.
b. Like poles repel.



If two bar magnets are brought close together, the like poles will repel each other, and the unlike poles attract each other.

Magnetic field

When a positively charged particle moves in a uniform magnetic field, then the direction of the velocity of the particle is perpendicular to the field. The magnetic force always acts in a direction perpendicular to the motion of the charge.The space or the region around a magnet within which magnetic force is exerted on other magnet is called as the magnetic field.



To locate the magnetic field of a bar magnet, we use a magnetic compass. When a magnetic compass is kept away from the magnet, it doesn't deflect. When a magnetic compass is brought closer to the magnet it deflects. If the magnetic field lines are very close to each other in a particular region, then the strength of the magnetic field is very strong, and if the magnetic field lines are far away then the magnetic field is very weak.

It is expressed in the unit Tesla.

Magnetic force

The magnetic force is the force of attraction or repulsion that arises between electrically charged particles due to their motion The magnetic force between two moving charges may be described as the force exerted upon their charge by the magnetic field created by the other. This force causes the magnets to attract or repel one another.

Examples of magnetic force is a compass, a motor, the magnets that hold stuff on the refrigerator, train tracks, and new roller coasters. All moving charges give rise to a magnetic field and the charges that move through its regions, experience a force. It may be positive or negative depending on whether the force is attractive or repulsive.The magnetic force is based on the charge, velocity and magnetic field of the object.

Force on a moving charge

If a charge moves through a magnetic field at an angle, it will experience a force. The equation is given by

F = qvB sin θ, where *q* is the charge, B is the magnetic field, v is the velocity, and θ is the angle between the directions of the magnetic field and the velocity. The motion of charge q moving with the velocity v in a magnetic field, has a force acting on it and this force is:

a. proportional to the charge q
b. proportional to the velocity v
c. perpendicular to both v and B
d. perpendicular to sinθ where θ is the angle between v and B

This is written as,

F

→

=q

v

→

×

B

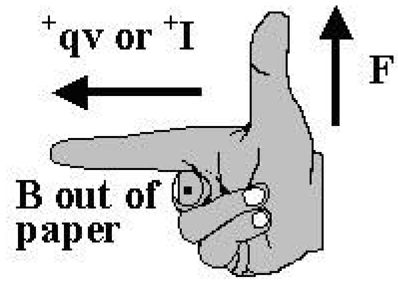
→

Right-Hand Rule

The direction of the force (F) can be found from the Right-hand rule.

It applies to the devices that use motion in a magnetic field to generate currents.

- Point your index finger along the direction of motion of charge v
- Rotate your middle finger away from your index finger between v and B
- Hold your thumb perpendicular to the plane formed by your index finger and middle finger
- Your thumb will then point in the direction of the force (F) if the charge q is positive.



(Source: engineering.com)

Solved Example For You

Q.Determine the magnetic force of 50 C charged particles moving with the velocity of 3m/s in a magnetic field of 1T? The direction of its field is same as the path of the second particle.

Sol: Given parameters, q= 50C, v= 3m/s and B= 1T

Since the path difference of the second particle is same as its field's direction,

Therefore, θ=0°

The magnitude force formula is

$F = q\,v\,B\,\sin\theta = 50 \times 3 \times 1 \times \sin\theta = 0$

Electromagnetic Induction and its Applications

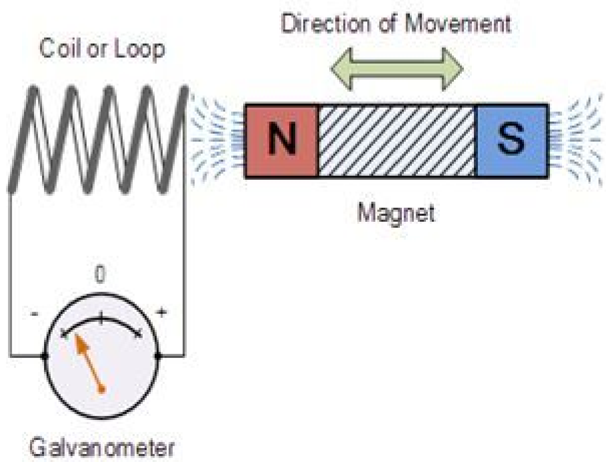
Electromagnetic Induction or Induction is a process in which a conductor is put in a particular position and magnetic field keeps varying or magnetic field is stationary and a conductor is moving. This produces a Voltage or EMF (Electromotive Force) across the electrical conductor. Michael Faraday discovered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

Electromagnetic induction

Suppose while shopping you go cashless and your parents use cards. The shopkeeper always scans or swipes the card. Shopkeeper does not take a photo of the card or tap it. Why does he swipe/scan it? And how does this swiping deduct money from the card? This happens because of the 'Electromagnetic Induction'.

Can moving objects produce electric currents? How to determine a relationship between electricity and magnetism? Can you imagine the scenario if there were no computers, no telephones, no electric lights.

The experiments of Faraday has led to the generation of generators and transformers.

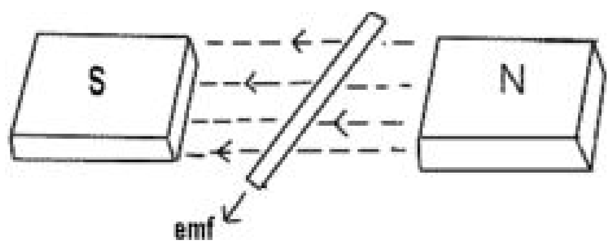


The induction of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called ‘Electromagnetic Induction’.

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

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

Faraday's law of Electromagnetic Induction



Source: Electricaleasy

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

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

So now, the induced voltage is as follows:

$e = N \times d\Phi dt$

where,

e is the induced voltage

N is the number of turns in the coil

Φ is the magnetic flux

t is the time

Video on Electromagnetic Induction

Lenz's law of Electromagnetic Induction

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

According to Lenz's law

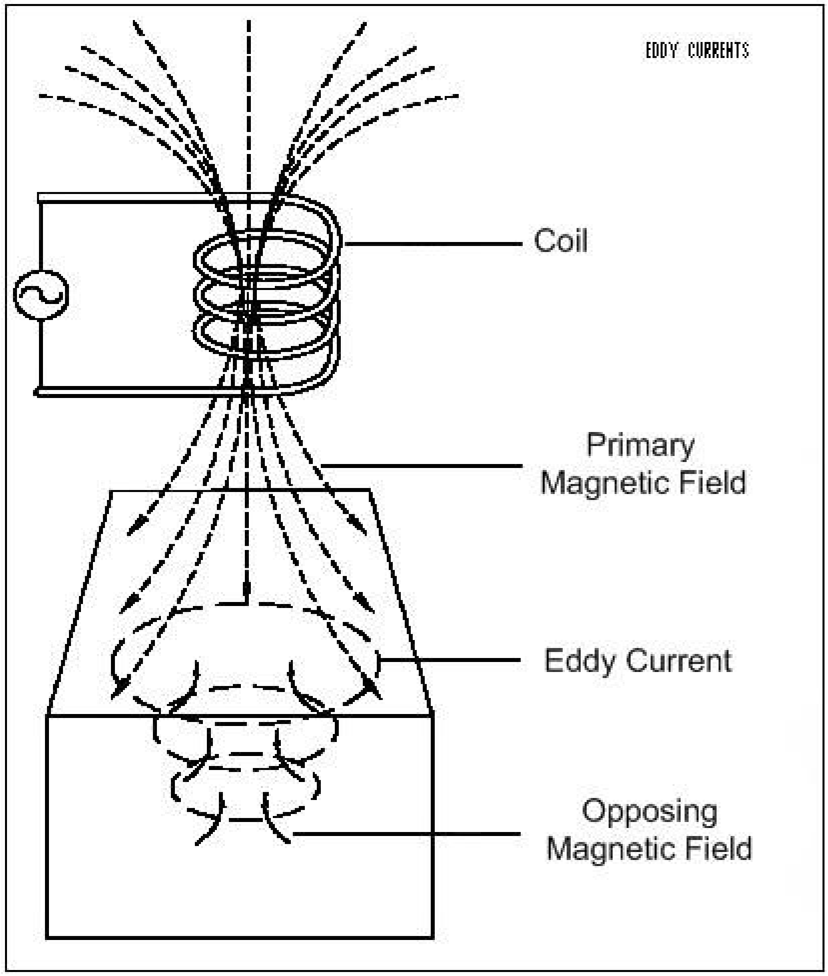
$E = -N (d\Phi/ dt)$ (volts)

Eddy currents

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

- In the brakes of some trains. During braking, the brakes expose the metal wheels to a magnetic field which generates eddy currents in the wheels. The magnetic interaction between the applied field and the eddy currents slows the wheels down. The faster the wheels spin, the stronger is the effect, meaning that as the train slows the braking force is reduces, producing a smooth stopping motion.

- There are few galvanometers having a fixed core which are of nonmagnetic metallic material. When the coil oscillates, the eddy currents that generate in the core oppose the motion and bring the coil to rest.
- Induction furnace can be used to prepare alloys, by melting the metals. The eddy currents generated in the metals produce high temperature enough to melt it.



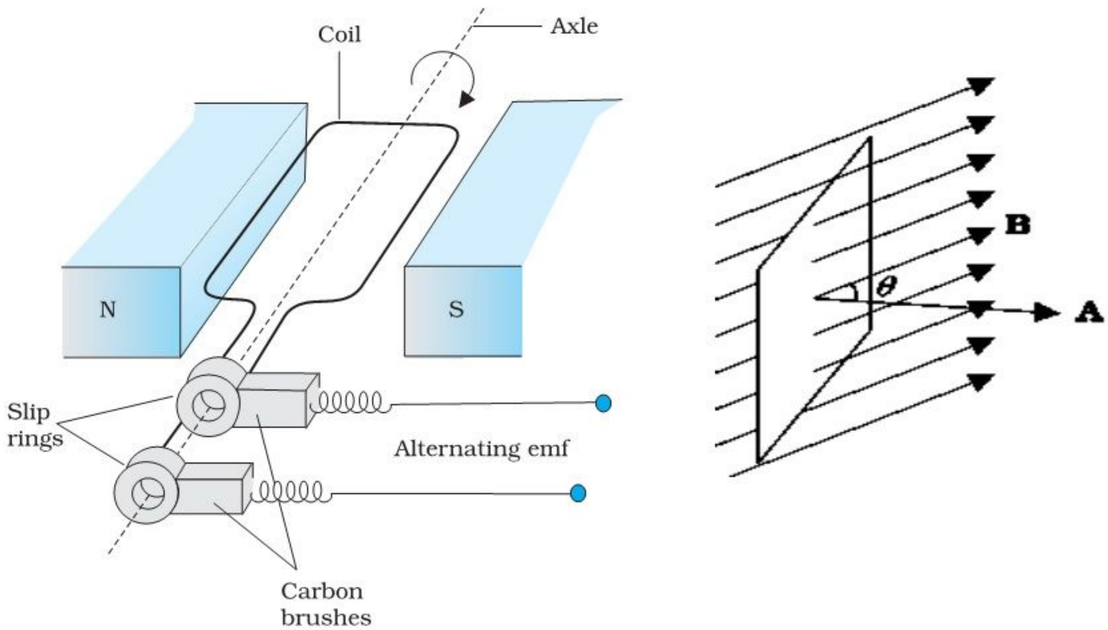
Source: Geocities

Applications of Electromagnetic Induction

1. Electromagnetic induction in AC generator
2. Electrical Transformers
3. Magnetic Flow Meter

Electromagnetic induction in AC generator

One of the important application of electromagnetic induction is the generation of alternating current.



Source: Physics365

The AC generator with an output capacity of 100 MV is a more evolved machine. As the coil rotates in a magnetic field B, the effective area of the loop is A cosθ, where θ is the angle between A and B. This is a method of producing a flux change is the principle of operation of a simple ac generator. The axis of rotation coil is perpendicular to the direction of the magnetic field. The rotation of the coil causes the magnetic flux through it to change, so an emf keeps inducing in the coil.

Electrical Transformers

Another important application of electromagnetic induction is an electrical transformer. A transformer is a device that changes ac electric power at one voltage level to another level through the action of a magnetic field. A step-down transformer is the one in which the voltage is higher in the primary than the secondary voltage. Whereas the one in which the secondary voltage has more turns is a step-up transformer. Power companies use a step transformer to boost the voltage to 100 kV, that reduces the current and minimizes the loss of power in transmission lines. On the other end, household circuits use step-down transformers to decrease the voltage to the 120 or 240 V in them.

Solved Examples For You

Q. A straight wire length 0.20 m moves at a steady speed of 3.0 ms^{-1} at right angles to magnetic field of flux density 0.10 T. e.m.f induced across ends of wire is

1. 0.5 V

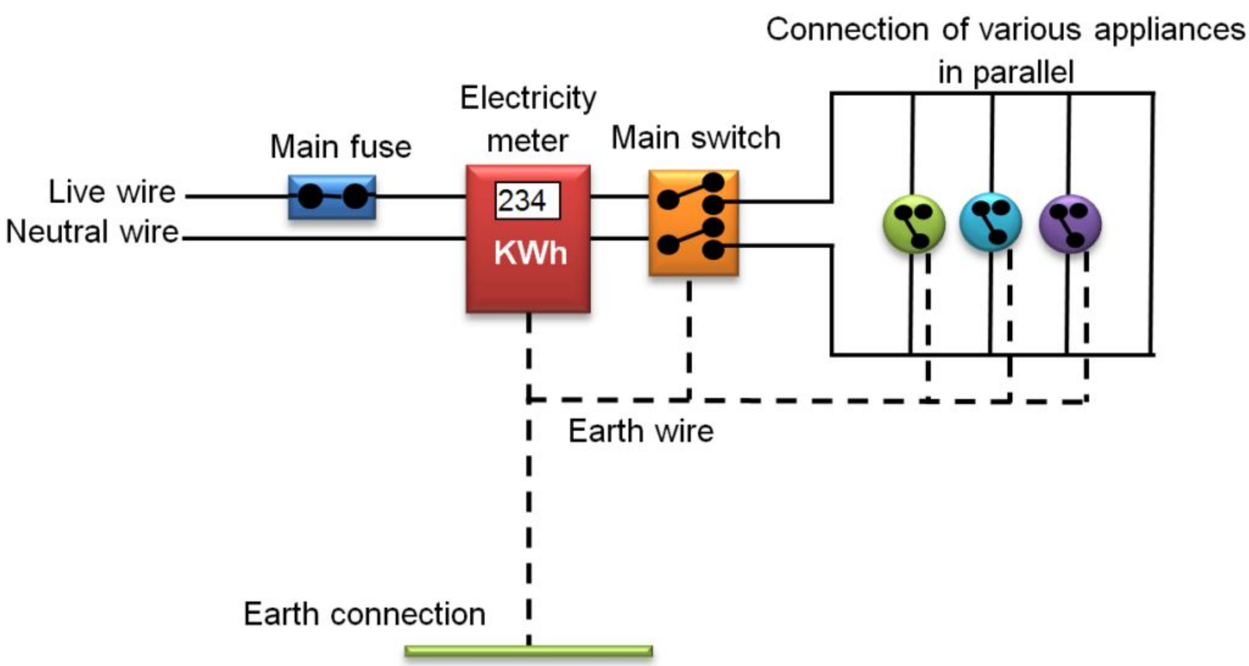
2. 0.06 V
3. 0.05 V
4. 0.04 V

Answer: 0.06 V

Domestic Electric Circuits

What is electricity? Today, electricity has become an essential part of our lives and its hard to imagine life without it. Our households are full of electrical appliances such as an electric bulb, electric bell, electric fan, iron, electric heater, refrigerator, washing machine, etc. Do you know where does this electricity in our house come from? They come from 'electric circuits'. So, let us study more about electric circuits below.

What is an electric circuit?



(Source: FunScience)

In our homes, either the overhead electric poles or underground cables support the power supply flowing through the main supply. One of the wires in this supply covered with insulation in the color red is the live wire (or positive), and another wire colored black is the neutral wire (or negative). At the meter-board, these wires pass into an electric meter through the main fuse. The main switch, live wire, and the neutral wire are in connection to the line wires in our homes; these wires then supply electricity to separate electric circuits within the house.

How does the distribution of electricity happen?

The spinning turbines produce electricity, that flows into the power lines and to our homes. Electricity moves through the wires very fast.

In just a second, electricity can travel around the world several times. From the power station where the electricity is produced, it flows to large transmission lines held up by huge towers. The transmission lines carry large amounts of electricity to substations in cities and towns.

Distribution lines carry small amounts of electricity from the substations to houses. When we turn on the TV, electricity flows through wires inside the set, producing pictures, and sound.
Three-phase electrical generation and transmission are an efficient and common use of the conductors as each conductor can utilize its current-rating fully in transporting power from generation through transmission and its distribution can occur for final use.

The metallic assemblage of an electric iron, toaster, table fan, fridge, constitutes the earth wire, giving a low-protection directing way for the current. In this way, it guarantees that any leakage of the current from the metallic body of the machine keeps its capability to that of the earth, and the person doesn't get a serious electric shock. Various appliances constitute live and impartial wires.

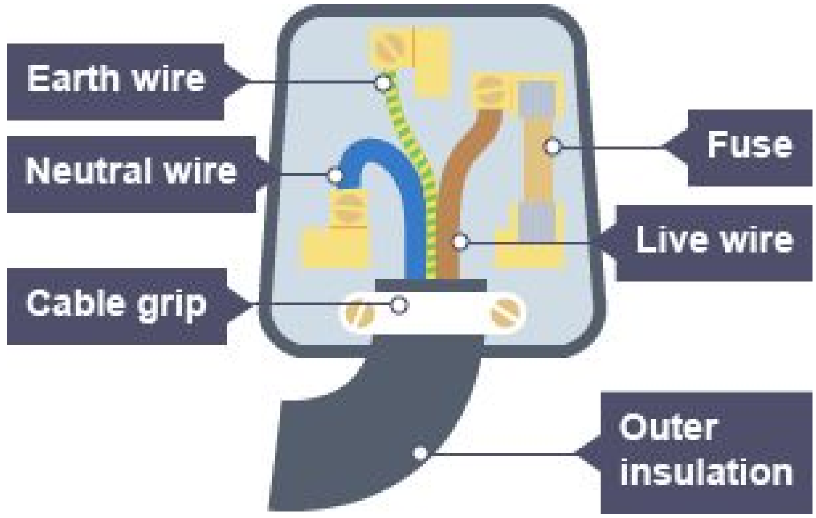
Learn more about the Torque on Current Loop, Magnetic Dipole.

Electric fuse

An electric fuse is used as a safety device for the protection of electric circuits and appliances due to short-circuiting or overloading of the electric circuits. The electric fuse is a piece of wire having a very low melting point and high resistance. When a high current flows through the electric circuits due to short circuit or overloading, the fuse wire heats up and melts. The circuit is broken and the current stops flowing thereby saving the electric circuits and appliance from any damages. The capacities of fuse wire are rated as 1A, 2A, 3A, 5A, 10A, and 15A. An electric composes pure tin or alloy of copper and tin.

Safety measures

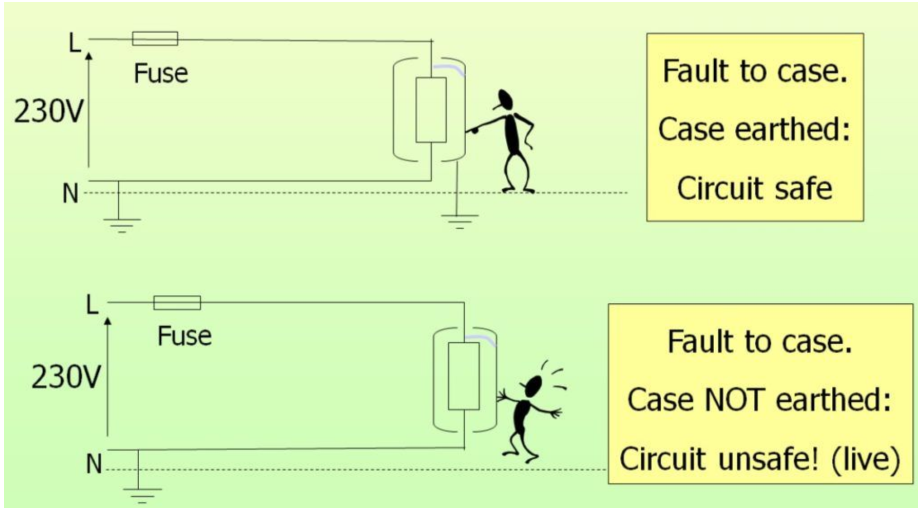
Insulation



The materials which have very high resistivity offer a very high resistance to the flow of the electric current and are insulating materials. These materials play an important role in the domestic wiring as they protect us from shock and also prevent the leakage of the current. Insulators can withstand overloading within permissible limits for a short period of time. They should have the following properties:

- High thermal resistance.
- Insulators should be fireproof.
- They should be durable and readily available.
- Insulators must be non-absorbent of moisture.

Earthing



When an iron box is in use, the metallic body's current increases to 110V. If we accidentally come in contact with such a metallic body we are sure to get an electric shock. To avoid shock due to current leakage in electrical appliances the metallic body of the appliance should be in connection with the earth/ground. Suppose due to some defect, the insulation of the live wire inside iron burns, then the live wire may touch the metallic body of the iron. For this purpose, a separate wire, ' the earth wire', runs all through the circuits along with live and neutral wires.

Usually, an electric appliance such as a heater, an iron box, etc. come with the installation of all the three wires namely live, neutral and earth wires. Metal bodies of all the appliances are therefore always in connection with the earth wire. The free end of the earth wire is attached to a copper plate buried deep in the ground. This leaves the body of the electrical appliances at the same potential (zero) as the earth and hence when we touch the metal body we do not get a shock. This is done to avoid accidental shock. Earthing is thus a safety device incorporated in an electric circuit to protect the operator.

Learn more about Magnetic Force and Magnetic Field.

Short-circuiting and overloading

- The use of an electric fuse prevents the electric circuit and the appliance from a possible damage by stopping the flow of high electric currents. There are faults in electrical circuits due to which heavy current may flow through the circuit that results in the overheating of live wires. Short-circuiting takes place when a naked live wire touches a naked neutral wire. Normally sub-standard wires wear out soon and may cause short-circuiting.
- Overloading of electrical circuit occurs, when the number of appliances operated on the circuit at the same time exceeds the limits the circuit wiring can withstand. We know that in domestic circuits all the appliances are connected in parallel. In

parallel circuits, as we add more and more appliances more current is drawn from the supply. If the total current drawn by all the appliances at a particular time exceeds, the bearing capacity of that wire, the wires of the domestic wiring heat up, leading to ‘overloading’. It may happen because of connecting too many devices to the same (one single) socket.

Precautions while using electric circuits

- For household wiring, always use good quality wires having proper thickness and insulation. An ISI mark must be there on any plugs, sockets, switches and electrical appliances in use.
- All the wire connections should be tight and an insulating tape should all the wire connections. Replacement of defective switches, sockets, plugs, etc. must happen immediately.
- The placement of all the switches in your household electrical wiring circuit should happen on the live wire of the circuit so that when the switch it off, the appliance disconnects from the live wire and on touching the device you do not get a shock.
- Switch off the mains before you start working on a repair job on an electrical circuit.

- In case of an electrical accident, switch off the main switch of the electrical supply. Try to insulate the person who has received a shock. In any case, do not touch him directly.
- While earthing and installing a fuse for the household electric circuits, one should be precautious. Ensure that the fuses are placed on live wires and are of proper current rating.

Solved Example For You

Q. The potential of live wire is:

a. o V c. 220 V

b. 300 V d. 1000 V

Sol: c. 220 V

From electric poles situated in our street, two insulated wires L and N come to our house. These two wires are called Neutral wire and Livewire the potential of these two wires are zero volts and 220V.