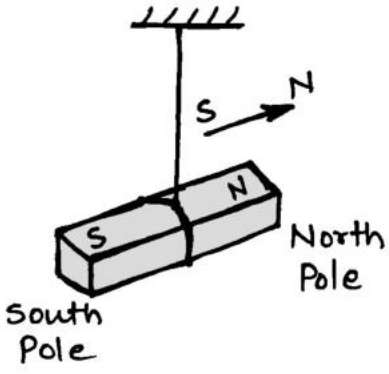
UNIT – 2
MAGNETIC EFFECT OF ELECTRIC CURRENT

Magnet is any substance that attracts iron or iron-like substances.

- Every magnet has two poles i.e. North pole and South pole.
- Like poles repel and unlike poles attract each other.
- A freely suspended bar magnet aligns itself in nearly north-south direction, its north pole stops towards north direction.



- Bar magnet, magnetic needle, horse shoe magnet are the different types of artificial magnet which are most commonly used.

MAGNETIC FIELD (Symbol $\vec{B}$) [CBSE 2012]

The space around a magnet in which its magnetic force can be experienced is called its magnetic field.

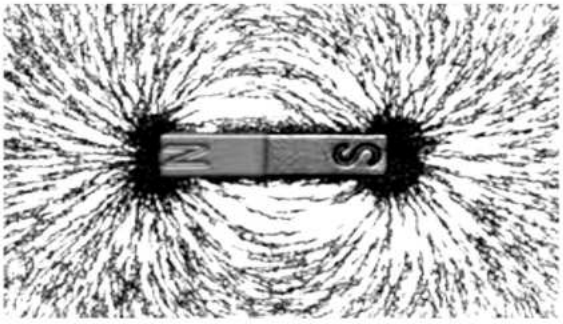
OR

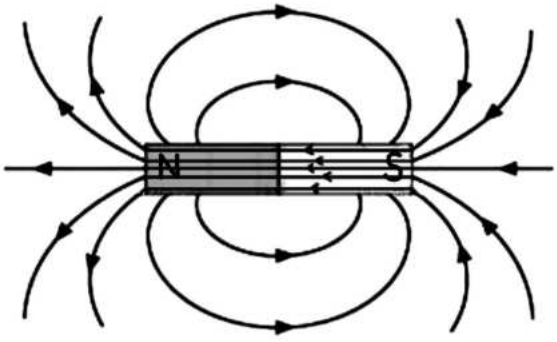
Magnetic field is the space around a magnet in which the force of attraction and repulsion due to the magnet can be detected by another magnet.

- Its SI unit is Tesla (T).
- It has both magnitude and direction.

MAGNETIC FIELD LINES

Magnetic field lines are the imaginary curves which are used to represent the magnitude and direction of the magnetic field at a place.





Properties of Magnetic field Lines

[CBSE 2014,16,11,12,13,19]

1.) Magnetic field lines are closed and continuous curves.

2.) Magnetic field lines emerge from North pole and end into south pole of the magnet.

3.) Magnetic field lines are directed from south to North pole inside the magnet.

4.) The tangent at any point on the magnetic field lines gives the direction of the magnetic field at that point.

5.) The magnetic field lines never intersect each other. If they do so then there will be two tangents at the point of intersection, so there will be two directions of the same magnetic field, which is not possible.

6.) Magnetic field lines are closer in stronger magnetic field and are far each other in weak magnetic field.

7.) If magnetic field lines are parallel and equidistant, they represent uniform magnetic field strength.

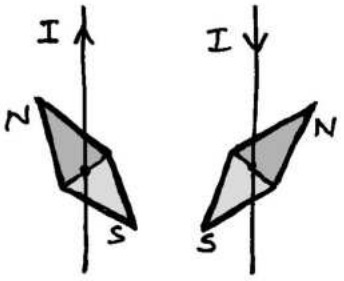
ORESTED'S EXPERIMENTS


Hans Christian Oersted

In 1820, Hans Christan Oersted Performed an important experiment which showed that there was a connection between electricity and magnetism.

➤ Orested found that when a Current carrying Conductor is placed parallel to the axis of a magnetic needle, the needle is deflected.

Means to say, around every current carrying conductor there is a magnetic field

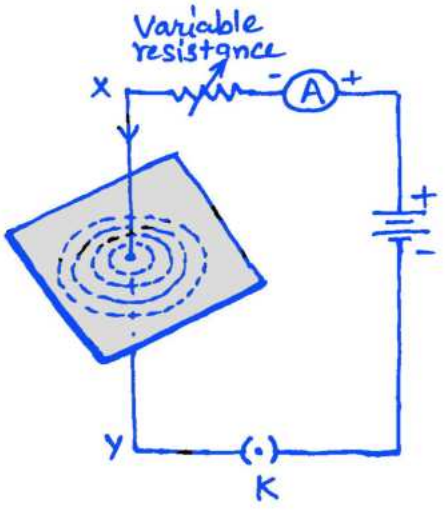


Magnetic Field due to Current Carrying straight Conductor

[CBSE 2019]

Take a thick straight conductor XY and pass it through the centre of a cardboard.

When we sprinkle some iron filling on cardboard, these arrange themselves in concentric circles.



➤ This show that there exist a magnetic field around a straight current carrying Conductor and it is in the form of Concentric circles with the conductor at the centre.

Factors upon which the strength of magnetic field depends:

(i) Current flowing through the conductor $B \propto I$

(ii) Distance (r) from the conductor $B \propto \frac{1}{r}$

or $B \propto \frac{I}{r}$

[CBSE 2011, 13, 19]

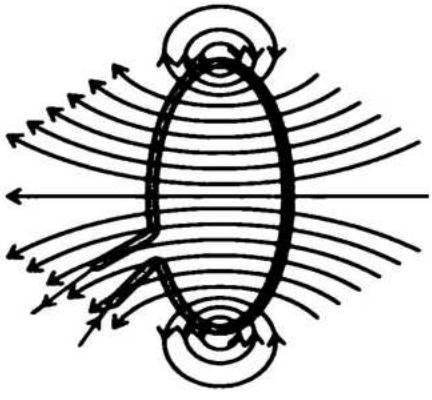
RIGHT HAND THUMB RULE → [Given by Maxwell]

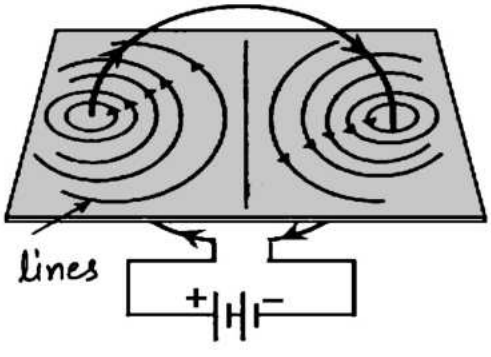
[CBSE 2011, 12, 13]

According to it imagine the current carrying straight conductor in your Right hand such that the thumb points in the direction of the current, then the direction of curling of fingers gives the direction of magnetic field lines.

MAGNETIC FIELD DUE TO CURRENT CARRYING COIL

[CBSE 2017]





Important Conclusions

(i) The magnetic field lines near the coil are concentric circles.

(ii) At the centre of the circular loop, magnetic field lines appear as straight lines, hence the field at the centre of the coil can be taken to be uniform.

(iii) Magnetic field is maximum at the centre of the coil.

(iv) At the centre, the magnetic field lines are along the axis of the circular loop, or perpendicular to the plane of the coil.

(v) Magnetic field strength increased if either current in the coil is increased or number of turns in the loop are increased.

➤ Factors on which strength of magnetic field depends:

(i) Current flowing through the coil $B \propto I$

(ii) Radius of the coil $B \propto \frac{1}{r}$

(iii) Number of turns in the coil $B \propto N$

or $\boxed{B \propto \frac{NI}{R}}$ [CBSE 2014]

CLOCK RULE

➤ The polarity at the faces of the loop is determined by the **Clock** rule.

Looking at the face of loop, if the current around that face is in anticlockwise direction, then the face has North polarity, while if the current around that face is in clockwise direction, then the face has South polarity.

Q. CBSE 2013 Give two uses of magnetic compass.

Sol. (i) It is used as navigation device in remote areas like ship and jet lines.

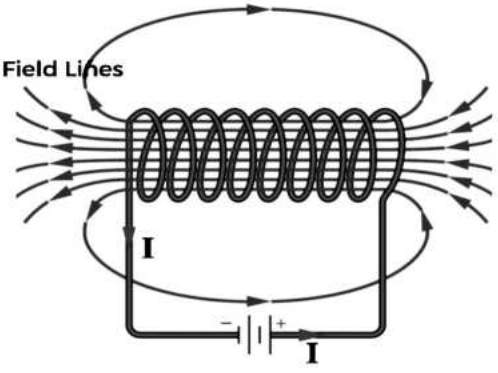
(ii) To plot the magnetic field of a bar magnet.

MAGNETIC FIELD DUE TO CURRENT IN A SOLENOID

[CBSE 2015, 17]

An insulated copper wire wound on a cylinderical cardboard (or plastic) whose length is greater than its diameter is called a Solenoid.

It looks like a helical spring.



- Magnetic field of a solenoid is similar to that of a bar magnet.
- Magnetic field inside a solenoid is uniform, and acts along the axis of the solenoid.
- The end of the solenoid at which current flows in an anticlockwise direction acts as north pole.
- The end of the solenoid at which current flows in a clockwise direction acts as a south pole.

Factors on which the strength of magnetic field depends:

(i) Current flowing throughth the solenoid $B \propto I$

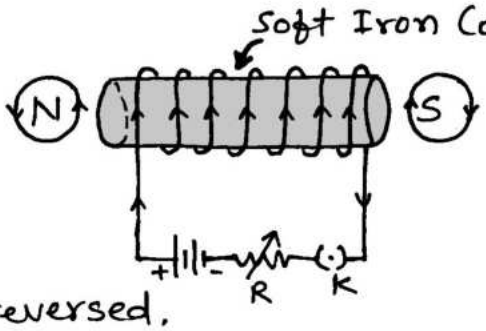
(ii) Number of turns per unit length of the solenoid $B \propto n$

$n = \frac{N}{l}$ where N = total number of turns
l = length of the solenoid.

or $\boxed{B \propto nI}$

ELECTROMAGNETS

An electromagnet is a temporary strong magnet. It is usually prepared by placing a soft iron core inside a solenoid, or by winding a large number of turns of an insulated copper wire on a cylinderical soft iron core.



- Soft iron is used as core because it can be magnetised and demagnetised easily.
- On reversing the direction of current in the solenoid, the polarities of the electromagnet also reversed.

Uses of Electromagnets:

(i) In electrical devices such as electric bell, electric fan, electric motor, microphone etc.

(ii) For lifting and transporting large masses of iron in the form of griders, plates etc.

(iii) In scientific research, to study the magnetic properties of a substance in magnetic field.

PERMANENT MAGNET

A permanent magnet is made from steel. steel has more retentivity than soft iron. Therefore, once magnetised, it does not loss magnetism easily.

- Carbon steel, chromium steel, Cobalt and tungsten steel, Alnico (alloy of Aluminium, Nickel, Iron and Cobalt) are used to make very strong permanent magnets.
- The polarities of permanent magnet is fixed and cannot be reversed

Uses of Permanent Magnets

Permanent magnets are used in electric meters such as galvenometer, ammeter, voltmeter etc, and in microphones, Loudspeakers also.

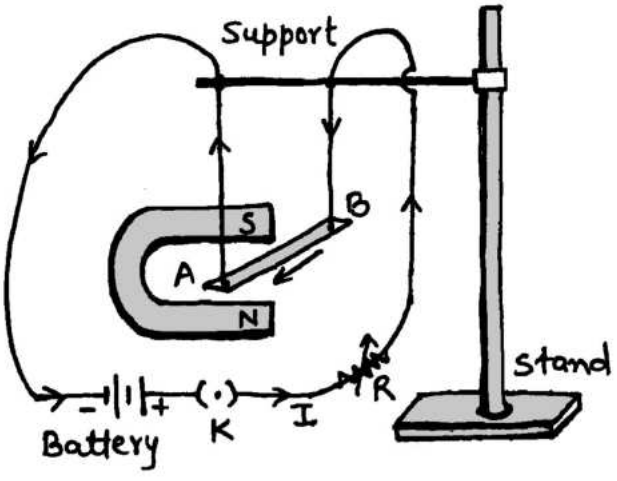
Force on a current Carrying Conductor in magnetic field

When a current carrying conductor is placed in a magnetic field, it experiences a force, except it is placed parallel to the magnetic field.

Experiment -

(i) Take a small aluminium rod. using two connecting wires suspend it horizontally.

(ii) Place a strong horse-shoe magnet in such a way that the rod lies between the two poles with the magnetic field directed upwards.



(iii) Connect the aluminium rod in series with a battery, a Key and a rheostat.

(iv) When current is passed through the aluminium rod from end A to B, then it is observed that the rod is displaced towards the left.

(v) If the direction of current flowing through the rod is reversed, then the direction of displacement is towards the right.

Conclusion -

- Force is exerted on current current carrying Al rod when it is placed in magnetic field.
- Direction of force is reversed when direction of current through conductor is reversed.

Note when a current carrying conductor is perpendicular to the magnetic field, force experienced is maximum.

[CBSE 2014]

Magnitude of the force depends on: [CBSE 2012]

(i) Current in the conductor $F \propto I$

(ii) Length of the conductor $F \propto l$

(iii) Magnitude of the magnetic field $F \propto B$

or $F \propto IlB$

or $F = KIlB$

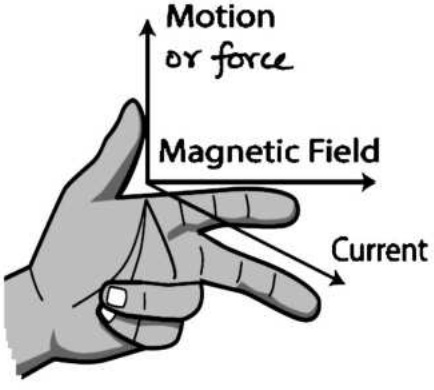
in SI unit proportionality Constant $K = 1$

So that $\boxed{F = IlB}$

FLEMING'S LEFT HAND RULE [CBSE 2011, 18]

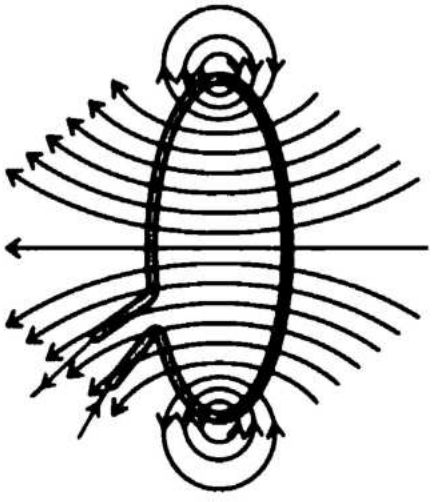
Stretch the thumb, fore finger and middle finger of your left hand such that they are mutually perpendicular.

If the first finger points in the direction of magnetic field and the second finger in the direction of current, then the thumb will point in the direction of motion or the force acting on the Conductor.



Q. CBSE 2014 "The magnetic field produced at its centre by a coil of n turns is n times as large as produced by a single turn." Give reason to justify this statement.

Sol. On applying the right hand rule, the magnetic field lines due to all the turns of the coil are in the same direction within the loop.



As the number of turns in the coil increased the magnetic field strength also increased because the direction of current in each turn is same, and the field due to various turns added up.

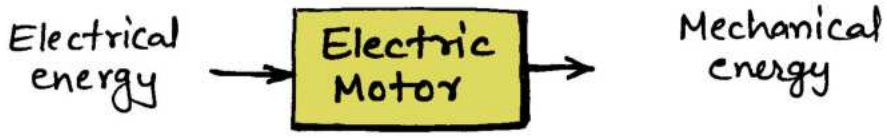
Q. CBSE 2011 Why does a current carrying conductor experience a force in a magnetic field ?

Sol. When a electric current flows through a conductor, it produces a magnetic field. The produced magnetic field exerts a force on a magnet placed near the conductor.

According to the Newton's third law of motion, magnet must also exert equal and opposite force on the current carrying conductor. Hence magnetic field exerts a force on a current carrying conductor.

ELECTRIC MOTOR (DC MOTOR) [CBSE 2018,19]

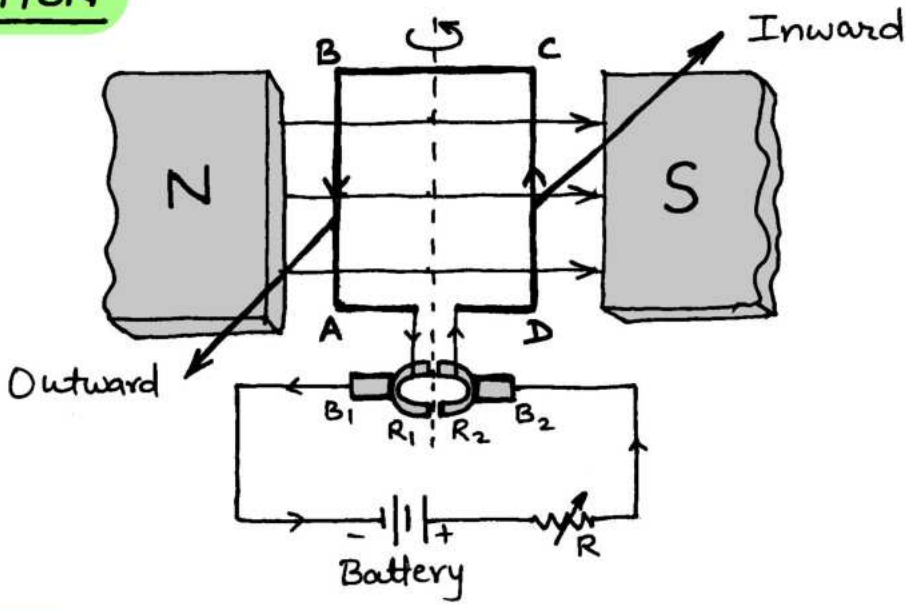
An electric motor is a device which converts electrical energy into mechanical energy.



➤ Principle

It is based on the fact that when a current carrying loop (coil) is placed in a magnetic field, it experiences a torque. Due to this torque, the coil begins to rotate and work (mechanical energy) is obtained.

➤ CONSTRUCTION



(i) **Armature :** It is a rectangular coil, consist of a large number of turns of insulated copper wire wound over a soft iron.

(ii) **Field Magnet :** The coil is placed between the two poles of permanent magnets.

(iii) **Brushes :** These are a pair of carbon (or copper) brushes B_1 and B_2 and touch the revolving rings.

(iv) **Split-ring :**

These are two halves of a metal ring. The ends of the coil are connected to the two halves of the split rings.

➤ **Working -**

When current flows through the coil, the arms AB and CD experience the magnetic force. On applying flemings left hand rule, force acting on arm AB is outward and on arm CD it act inwards.

Since these two forces are equal in magnitude and opposite in direction so they form a couple and the torque of the couple rotate the armature in clockwise direction.

After completing half revolution by the armature, the direction of current in arm AB and CD is reversed. Now the arm AB experience force inward and arm CD in outward direction.

Again the two forces are equal in magnitude and opposite in direction, so they form a couple and the torque and rotate the armature in clockwise direction.

Thus, the armature of DC motor rotates in the same direction.

➤ **Speed of rotation of motor can be increased by:**

- increasing the strength of magnetic field
- increasing the number of turns in the coil
- increasing the current in the coil
- increasing the area of the coil

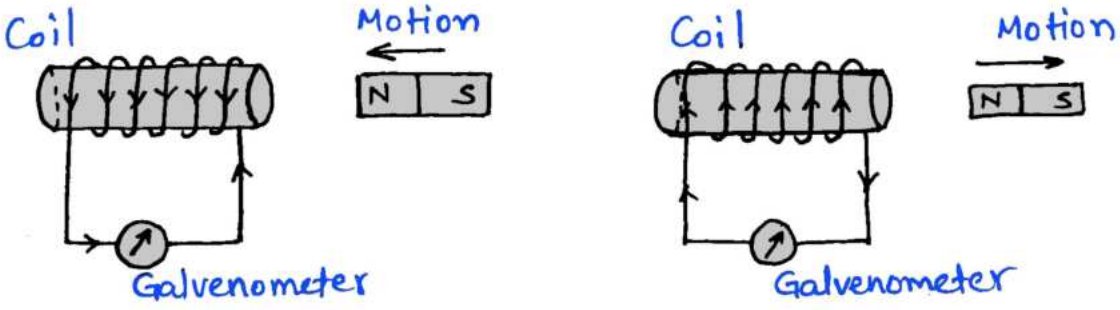
➤ **Uses of DC Motor -**

In pumping water, electric fans, various toys, electric cars, tap recorder, hair dryers etc.

ELECTROMAGNETIC INDUCTION [CBSE 2014, 16, 11]

Whenever the number of magnetic field lines or magnetic flux passing through a circuit changes a voltage or current is produced in the circuit. This phenomenon is known as 'electromagnetic induction'.

Faraday's Experiments



(i) When a bar magnet moves towards or away from the closed coil, galvenometer shows a deflection.

(ii) The deflection in the galvenometer indicates that current is flowing through the coil. This current is called induced current.

(iii) The direction of induced current is reversed if direction of motion or the polarity of the magnet is reversed.

(iv) The current in the coil (i.e. deflection in the galvenometer) increased by the rapid motion of coil or magnet.

Faraday's Laws of Electromagnetic Induction

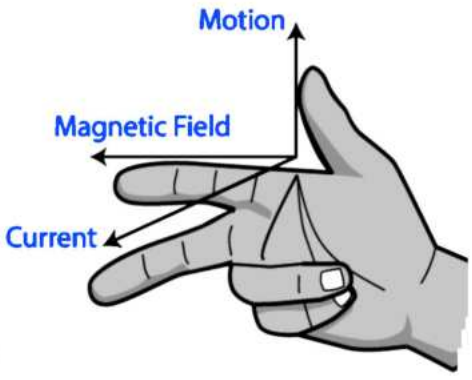
(i) **First Law:** Whenever there is a change in magnetic flux linked with a coil changes, a current or emf (voltage) is induced.

(ii) **Second Law:** The magnitude of induced emf (voltage) is directly proportional to the rate of change of magnetic flux.

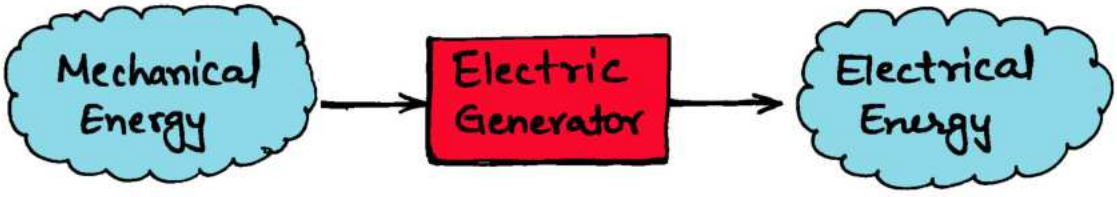
FLEMING'S RIGHT HAND RULE [CBSE 2014]

Stretch the thum, first finger and middle finger of the right hand so that they are mutually perpendicular to each other.

If the first finger points in the direction of magnetic field, thumb points in the direction of motion of the conductor then the middle finger points in the direction of induced current.



ELECTRIC GENERATOR

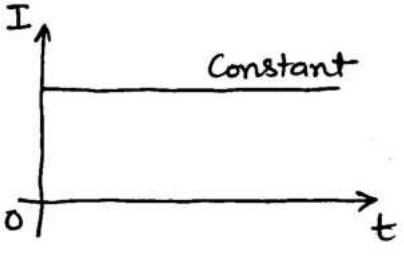


It is a device used for generating electric current by converting mechanical energy into electrical energy on the principle of electromagnetic induction.

DIRECT CURRENT :

An electric current which always flows in the same direction and does not change its direction with time

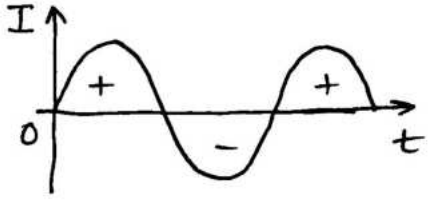
Sources → Cell, battery, DC generator, and solar cell.



ALTERNATING CURRENT :

An electric current which changes its direction after a fixed time interval is called alternating current.

Source → AC Generator (or Dynemo)



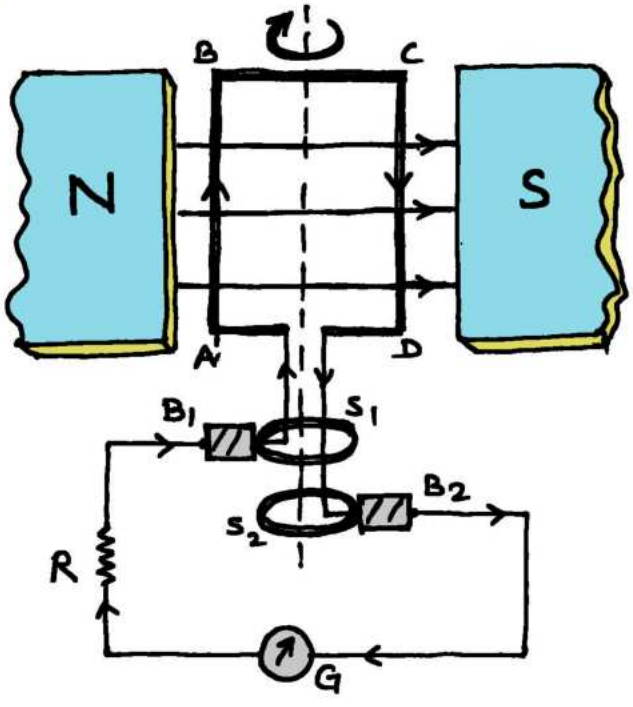
AC GENERATOR

An AC Generator converts mechanical energy into electrical energy.

Principle - Electromagnetic Induction

When a coil is rotated in a magnetic field, the number of magnetic field lines (or magnetic flux) passing through the coil changes continuously. Hence an emf (or voltage) is induced in the coil and a current starts flowing in it.

Construction -



(i) **ARMATURE -** It is a rectangular coil having a large number of turns of insulated copper wire wound over a soft iron core.

(ii) **FIELD MAGNETS -** These are powerful permanent magnet to produce a strong magnetic field.

(iii) **SLIP RINGS -** The two free ends of the coil are connected to two copper rings S_1 and S_2 called slip rings.

(iv) **Brushes -** These are two carbon pieces B_1 and B_2 called 'brushes', which remains stationary pressing against the slip-rings S_1 and S_2 respectively.

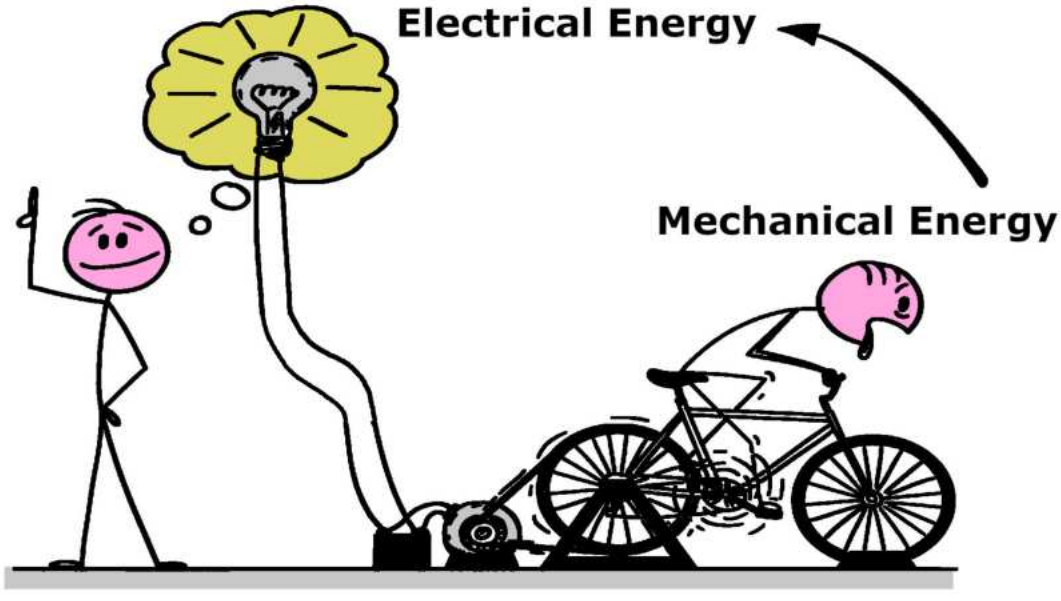
The brushes are connected to the external circuit in which current is to be supplied by the generator.

➤ **Working: -** Suppose the coil is rotating clockwise and is horizontal at any time. At this time the arm AB of the coil is moving up and the arm CD is moving down.

By Fleming's right hand rule the current flows from C to D in the arm CD and from A to B in the arm AB. The current in the external circuit is from Brush B_2 to B_1.

As the coil rotates from its vertical position, the arm AB moves down and the arm CD is moving up. Hence the direction of current in the coil reversed according to the Fleming's right hand rule.

Thus the current in the external circuit is from B_1 to B_2.

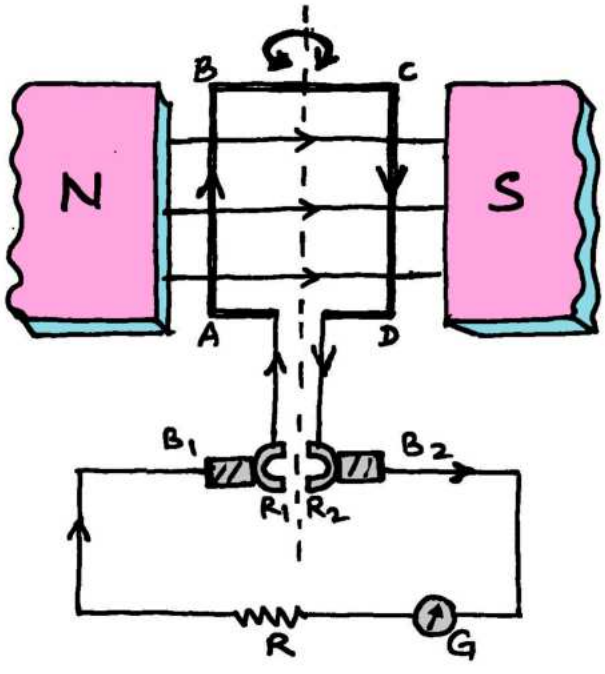


DC GENERATOR

➤ **Principle –** Direct-Current generator is also based on the Principle of Electromagnetic induction.

When a coil is rotated in a strong magnetic field, the number of magnetic field lines (or magnetic flux) linked with the coil changes continuously. Hence an emf (or voltage) is induced in the coil and a current starts flowing in it.

Construction –



(i) **ARMATURE –** It is a rectangular coil having a large number of turns of insulated copper wire wound over a soft iron core.

(ii) **FIELD MAGNETS –** These are powerful permanent magnet to produce a strong magnetic field.

(iii) **Split Rings or Commutator –**

It consist of two halves of a copper rings R_1 and R_2. The ends of the armature coil are connected to the split rings R_1 and R_2.

(iv) **Brushes** –

These are two carbon pieces B_1 and B_2 called 'brushes', which remains stationary, pressing against the split rings R_1 and R_2 respectively.

The brushes are connected to the external circuit in which current is to be supplied by the generator.

Working –

As the armature coil rotates, the magnetic flux linked with the coil changes. Hence an emf (or voltage) is induced in the coil and a current starts flowing in it.

Suppose the coil rotates clockwise and is horizontal at any time. At this time the arm AB of the coil is moving up and the arm CD is moving down.

By fleming's right-hand rule the current flows from A to B in the arm AB and from C to D in the arm CD. And the current in the external circuit is from brush B_2 to B_1.

Since in split rings or commutator, one brush is at all times in contact with the arm moving up in the field, while the other brush is in contact with the arm moving down.

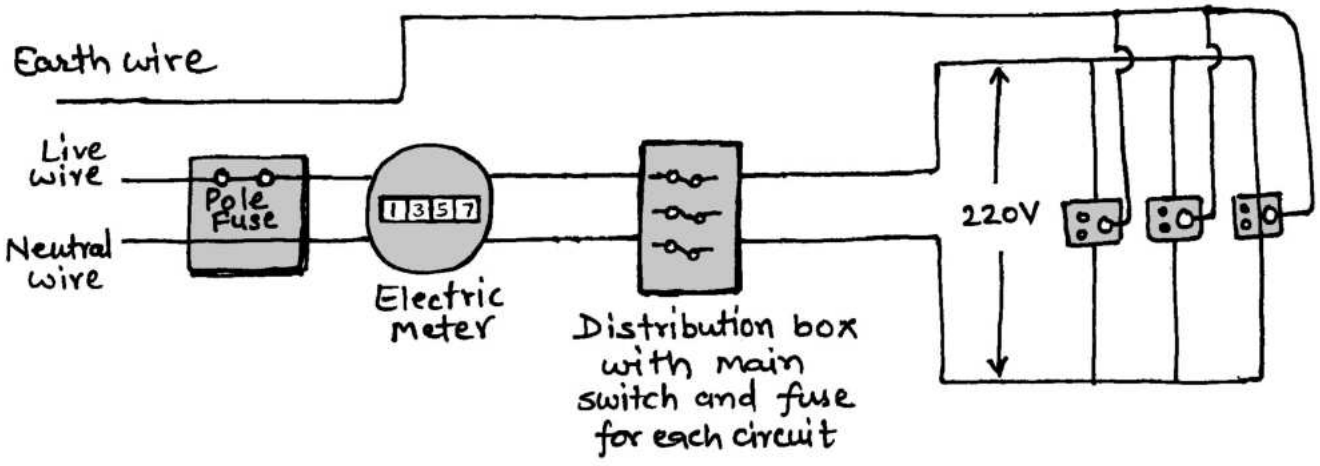
Thus a unidirectional current (DC) is produced.

DOMESTIC ELECTRIC CIRCUITS

(i) **Electric Cable –**

This cable has three separate insulated wire.

(a) Live wire (Positive) → red insulation Cover
(b) Neutral wire (Negative) → black insulation Cover
(c) Earth wire → Green insulation Cover



(ii) **Pole Fuse –** It is connected in the live wire just before the meter or at the pole.

(iii) **Energy Meter –** This meter records the electric energy units (KWh) used by Customer.

(iv) **Main Fuse –** It is connected in the live wire coming from the outcoming terminal of the meter.

(v) **Main Switch –** It is connected in the live and neutral wire after the main fuse. This switch is used to cut off the connections of live as well as neutral wires from the main supply.

(vi) **Distribution board –** It is a box from which wire go to different parts of the house through fuses.

(vii) **House wiring –**

(a) Tree System (b) Ring System

ELECTRIC FUSE


symbol of fuse

A fuse is a device which allows a certain limit of current in a circuit.

- It is a alloy [lead (75% + tin 25%)]
  The melting point of this material is low and melts at 200°c approximately.
- It is used in series to limit the current in an electric circuit, so that it easily melts due to overheating when excessive current passes through it.
- A fuse is always connected between live wire in series.

SHORT CIRCUITING and OVERLOADING [CBSE 2011]

- Short circuiting occurs when the live wire and neutral wire come into contact or touch each other. In this case, the resistance of the circuit becomes very small and a very large current flows through the circuit, whic produces large amount of heat and sparking at the point of short circuiting.
- Overloading means flow of current in the circuit beyond a specified limit.

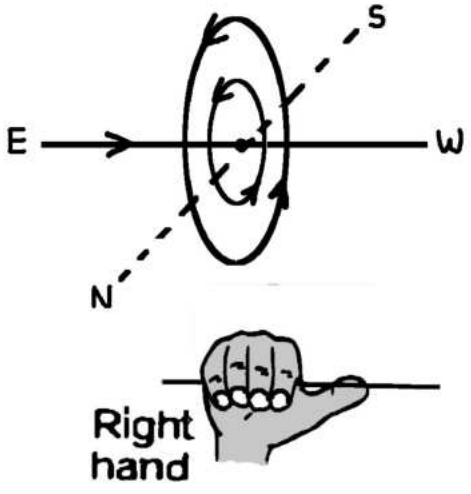
  Overloading occurs due to an accidental rise in the supply voltage. Sometimes overloading occurs due to connecting to many appliances of high power rating to a single socket.

CBSE 2014

Electricity supplied to our homes (AC) →
- Alternating voltage 220 - 225 V
- Frequency of AC 50 Hz

Q. A current through a horizontal power line flows in East to west direction. What is the direction of magnetic field at a point directly below it and a point directly above it?

Sol. Since the current is in the East-West direction, therefore by applying the right hand rule we get the direction of magnetic field at a point below the wire is from North to South and the direction of magnetic field at a point directly above the wire is from South to North.

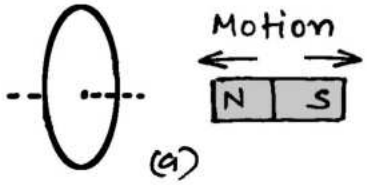


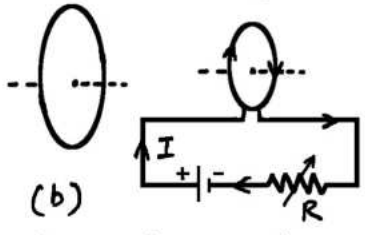
Q. CBSE 2011 In what way can the magnitude of the induced current be increased?

Sol. The magnitude of the induced current can be decreased by rapidly increasing or decreasing the magnetic flux or the number of magnetic field lines passing through the circuit or a closed coil.

Q. CBSE 2011,14 List two different ways of inducing current in a coil.

Sol. (a) Moving a magnet towards or away from the coil.
(b) Changing current in the neighbouring coil.





Q. CBSE 2011 Why it is not advisable to handle domestic electrical circuit with wet hands?

Sol. Wet hands are good conductor of electricity. Any leakage of current in domestic circuit may give electric shock while using it.

Q. CBSE 2011 Why is the alternating current preferred over direct current ? List any three reasons.

Sol.

(i) The generation of AC is cheaper than DC.

(ii) AC can be transmitted to large distances without much heat loss in the wires.

(iii) Alternating voltage or current can be easily stepped up or stepped down by using a transformer.

(iv) AC can be converted into DC by a rectifier circuit.

Q. CBSE 2014 Two identical looking bars A and B are given, one of which is definetely magnetised. How would one ascertain whether or not both are magnetised ? If only one is magnetised, how does one ascertain which one ?

Sol.

➤ On bringing different ends of two bars close to one another, repulsion occurs in any one situation, then both the bars A and B are magnetised.

If force is always attractive, then one of them is always magnetised.

➤ To check whether A or B is magnetised, place the bar B on a table. Hold the bar A in the hand and lower its one end on the middle of bar B. If there is attraction, then bar A is magnetised otherwise the bar B is magnetised.