

CHAPTER-13

MAGNETIC EFFECTS OF ELECTRIC CURRENT

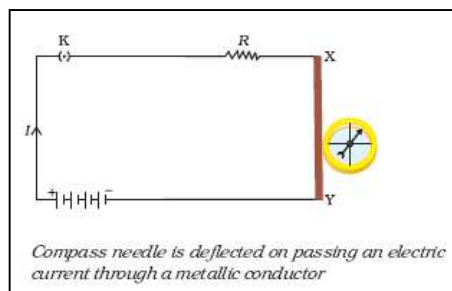
LEARNING OBJECTIVES:

Students will be able to:

- understand the relationship between electricity and magnetism.
- learn the properties of magnetic field lines.
- understand the use of righthand thumb rule.
- learn appropriate technique to perform the activity/experiment by himself/herself
- gain the skill to draw field lines around solenoid.
- find force on a current carrying conductor in a magnetic field
- understand the concept of electromagnetic induction.
- understand the principal behind working of electric motor.
- understand the principle of generator.
- apply theoretical knowledge in practical situation e.g. checking of fuse
- gain practical knowledge by studying domestic electric circuit.
- handle appliances at home more efficiently.

MAGNETIC EFFECT OF ELECTRIC CURRENT

The term magnetic effect of electric current means that an electric current flowing in a wire produces a magnetic field around it.



The electric current through the conductor has produced a **magnetic effect** which **deflects the needle**.

ACTIVITY

To find the pattern of magnetic field lines around a bar magnet

- Place a bar magnet in the centre of a sheet of white paper.
- Sprinkle some iron filings uniformly around the bar magnet.
- Tap the board gently.

OBSERVATION- The iron filings experience a force due to the magnet. The force thus exerted makes iron filings to arrange in a pattern.

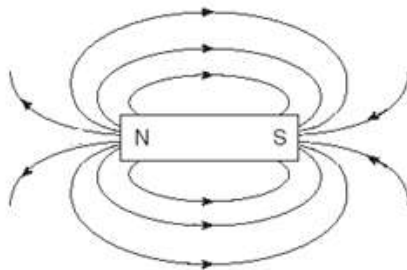
MAGNETIC FIELD (B)

The region surrounding the magnet, in which the force of the magnet can be experienced, is said to have a magnetic field.

MAGNETIC FIELD LINES

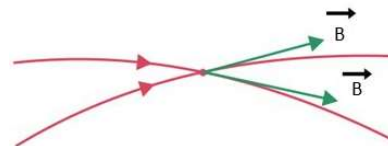
Magnetic field lines are the imaginary lines used to show magnetic field in a given region. These are also known as magnetic lines of forces.

FIELD LINES AROUND A BAR MAGNET



PROPERTIES OF MAGNETIC FIELD LINES

1. The field lines emerge from North Pole and merge at the South Pole outside the magnet. Inside the magnet, the direction of field lines is from its south pole to its north pole. Thus, the magnetic field lines are closed curves.
2. The relative strength of the magnetic field is shown by the degree of closeness of the field lines.
3. No two field-lines are found to cross each other or intersect each other, because, if they did, it would mean that at the point of intersection, the compass needle would point towards two directions, which is not possible.



- Magnetic field is a vector quantity that has both direction and magnitude.
- The direction of the magnetic field is taken to be the direction in which a north pole of the compass needle moves inside it.

UNIFORM MAGNETIC FIELD

A uniform magnetic field is represented by parallel and equidistant field lines.

UNIFORM MAGNETIC FIELD



Q1. Why does a compass needle get deflected when brought near a bar magnet?(Page 224 Q1)

Ans. A compass needle is, in fact, a small bar magnet. A compass needle gets deflected due to the forces acting on its poles due to the magnetic field of the bar magnet.

MAGNETIC FIELD DUE TO A CURRENT THROUGH A STRAIGHT CONDUCTOR

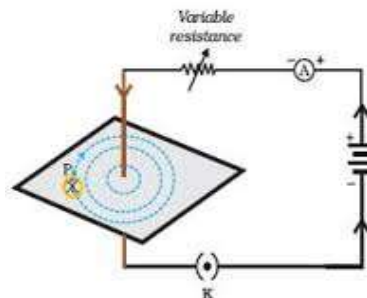
The magnetic field lines around a straight conductor carrying current are concentric circles whose centres lie on the wire.

ACTIVITY

To plot the magnetic field lines around a straight current carrying conductor.

- Insert a thick wire through the centre, normal to the plane of a rectangular cardboard.
- Connect the ends of the wire with a battery, a variable resistance (or a rheostat), an ammeter and a plug key.
- Sprinkle some iron filings uniformly on the cardboard.
- Close the key so that a current flows through the wire.
- Gently tap the cardboard a few times.

OBSERVATION- It is observed that the iron filings align themselves showing a pattern of concentric circles around the copper wire.

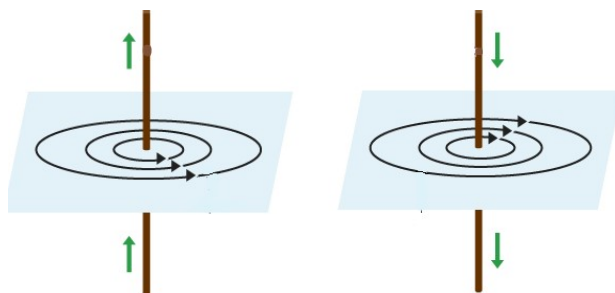


These concentric circles represent the magnetic field lines

The direction of magnetic field around a straight current carrying conductor can be determined by Right Hand Thumb Rule.

Right Hand Thumb Rule

When a current-carrying straight conductor is held in right hand such that the thumb points towards the direction of current, then fingers will wrap around the conductor in the direction of the field lines of the magnetic field.



Strength of magnetic field (B) due to a current-carrying conductor

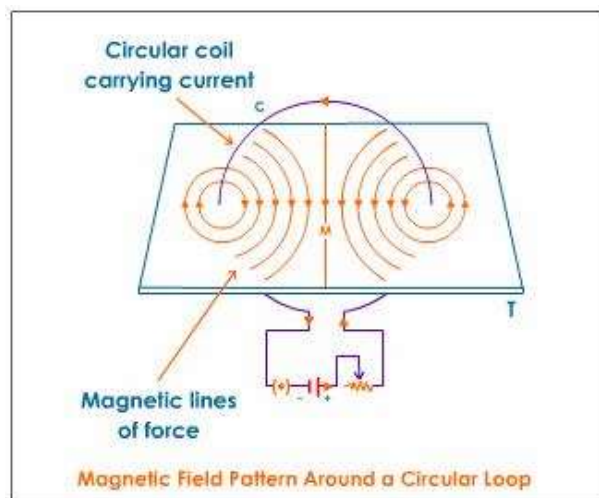
Amount of current (I)

$$B \propto I$$

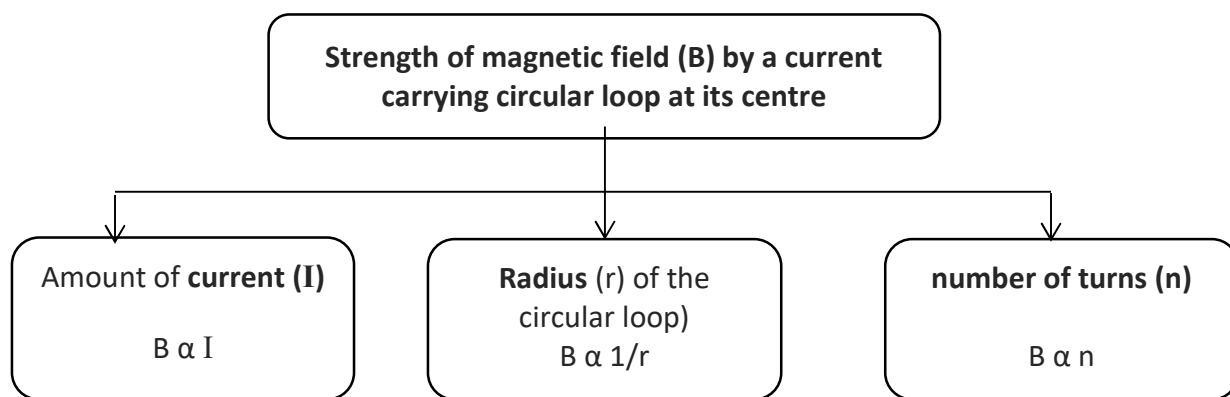
Distance (d) from the conductor

$$B \propto 1/d$$

MAGNETIC FIELD DUE TO A CURRENT THROUGH A CIRCULAR LOOP



- At every point of a current-carrying circular loop, the concentric circles represent the magnetic field around it.
- The concentric circles become larger and larger as we move away from the wire.
- At the centre of the circular loop, the lines appear as straight lines.
- If there is a circular coil having n turns, the field produced is n times as large as that produced by a single turn. This is because the current in each circular turn has the same direction, and the field due to each turn then just adds up.
- The magnetic field is maximum at the center of this loop.



HW Questions

Q1. 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 at a point directly above it? (NCERT Page 228 Ex 13.1)

Q2. Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop. (NCERT Page 229 Q1)

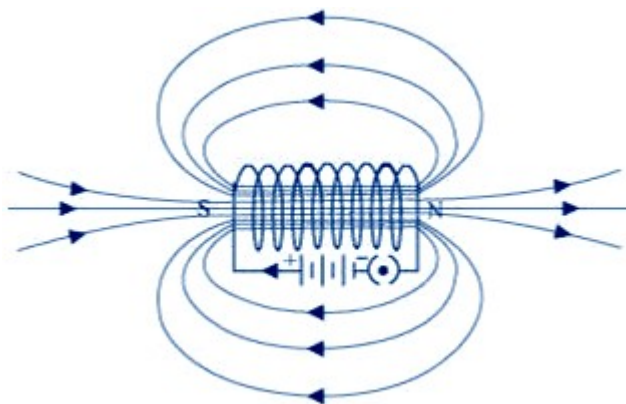
Inside the loop: Pierce inside the table

Outside the loop: Appear to emerge out of the table

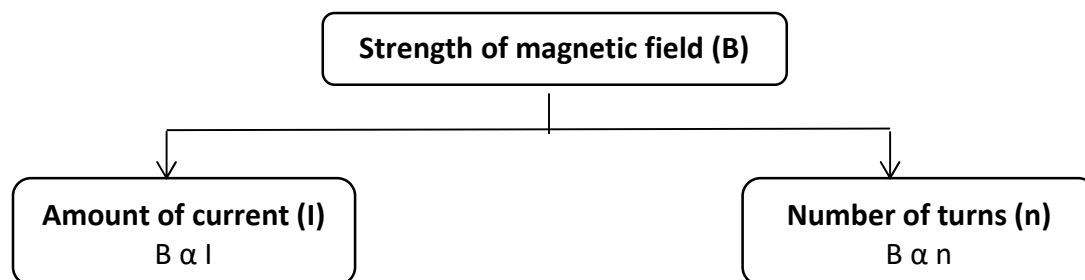
MAGNETIC FIELD DUE TO A CURRENT IN A SOLENOID

Solenoid: A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called a solenoid.

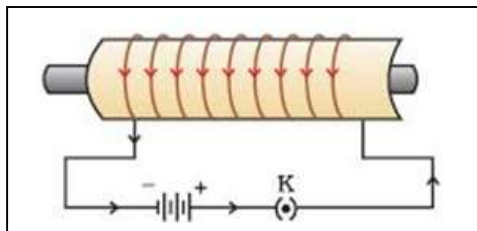
- The magnetic field produced by a current carrying solenoid is similar to the magnetic field produced by a bar magnet. One end of the solenoid acts like a north pole and the other end the South Pole.



- Magnetic field is uniform inside the solenoid and represented by parallel field lines.
- The polarity of the solenoid can be changed by reversing the direction of the current.
- Solenoid can be used to magnetise a magnetic material like soft iron (electromagnet)



Electromagnet- An electromagnet consists of a core of soft iron wrapped around with a coil of insulated copper wire that is magnetized only when electric current is passed.



The strength of an electromagnet can be increased by:

- Increasing the current through solenoid
- Increasing the number of turns of the solenoid.

Use of soft iron core in an electromagnet- to increase the strength of the solenoid.

Uses of electromagnets

- Used in cranes to lift heavy iron pieces.
- Used in many devices like electric bell, electric horn, telephone receiver, microphones, radio set, loudspeakers etc.
- Used in medical practices for removing iron pieces from wounds.

ELECTROMAGNET	PERMANENT MAGNET
An electromagnet is a temporary magnet as it can be readily demagnetized by stopping the current through the solenoid.	A permanent magnet cannot be readily demagnetized.
Strength can be changed.	Strength cannot be changed.
Polarity can be changed by changing the direction of the current.	Polarity is fixed and cannot be changed.
Generally strong magnet	Generally weak magnet

Q. Choose the correct option. The magnetic field inside a long straight solenoid-carrying current

(a) is zero. (b) decreases as we move towards its end.

(c) increases as we move towards its end.

(d) is the same at all points.(NCERT Page 230 Q3)

(d) same at all points

Q. List three sources of magnetic fields.

(NCERT Back ExerciseQ7)

1) Electromagnets

2) Current carrying conductors

3) Permanent Magnets

FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

When a current carrying conductor is placed in a magnetic field it **experiences a force**. Working of motor is based on this principle.

ACTIVITY

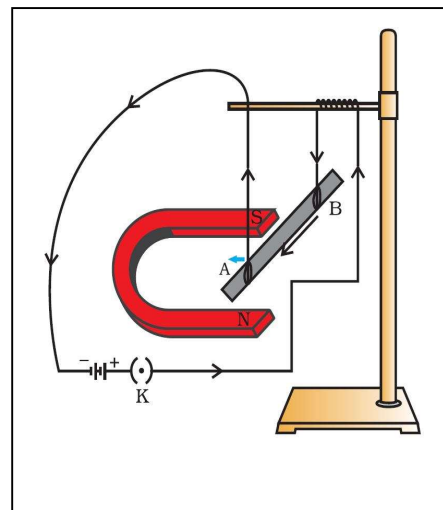
A current carrying aluminium rod is placed between the two poles of a horse-shoe magnet with magnetic field directed upwards.

OBSERVATION

- The rod gets displaced towards left.
- If the current is reversed, rod gets displaced towards right.

CONCLUSION

- A force is exerted on the current-carrying aluminium rod when it is placed in a magnetic field.
- If the direction of current through the conductor is reversed, the direction of force is reversed.
- If the direction of field of the magnet is reversed, the direction of force is again reversed.
- Displacement of the rod is largest (or the magnitude of force is highest) when the direction of current is perpendicular to the direction magnetic field.



Rule to determine the direction of force:

Fleming's Left Hand Rule

According to this rule, stretch the thumb, forefinger 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.

The factors on which the force on a current carrying conductor when placed in magnetic field depends

Magnetic field (B)

Current (I)

Length of conductor (l)

$$F \propto B I l$$

Devices that use current-carrying conductors and magnetic fields –

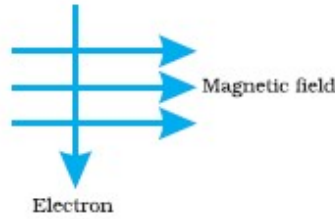
electric motor, electric generator, loudspeakers, microphones and measuring instruments

Q1. An electron enters a magnetic field at right angles to it, as shown. The direction of force acting on the electron will be: (NCERT Page 231 Ex: 13.2)

- (a) to the right.
- (b) to the left.
- (c) out of the page.
- (d) into the page.

d) into the page

(Using Fleming's left hand rule)



Q2. Which of the following property of a proton can change while it moves freely in a magnetic field?

- (a) mass
 - (b) speed
 - (c) velocity
 - (d) momentum
- (NCERT Page 231 Q1)

Velocity and momentum

Q3. In Activity 13.7, how do we think the displacement of rod AB will be affected if (i) current in rod AB is increased; (ii) a stronger horse-shoe magnet is used; and (iii) length of the rod AB is increased?

(NCERT Page 232 Q2)

In all three cases the displacement of rod will increase as $F \propto B I L$

Q4. A positively-charged particle (alpha-particle) projected towards west is deflected towards north by a magnetic field. The direction of magnetic field is (NCERT Page 232 Q3)

- (a) towards south
- (b) towards east
- (c) downward
- (d) upward

d) upward, (Using Fleming's left hand rule)

Q5. Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of magnetic field? (NCERT Back Exercise Q10)

Vertically downward, (Using Fleming's left hand rule)

Q6. When is the force experienced by a current-carrying conductor placed in a magnetic field

largest? (NCERT Back Exercise Q9)

When direction of current is perpendicular to direction of magnetic field

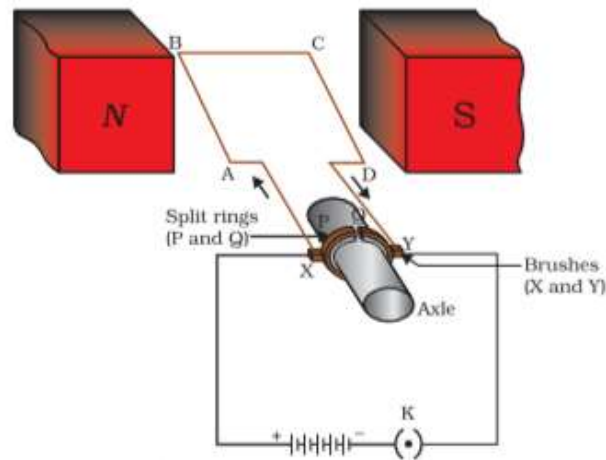
ELECTRIC MOTOR

An electric motor is a device that converts electric energy into mechanical energy.

Electric motor is used as an important component in electric fans, refrigerators, mixers, washing machines, computers, MP3 players etc.

Principle of motor

Electric motor is based on the fact that a current carrying coil when placed perpendicular to the magnetic field experiences a force whose direction is governed by Fleming's left hand rule.



CONSTRUCTION

1. **Armature coil**- a rectangular coil ABCD of insulated copper wire wound on a soft iron core which rotates when current is passed through it.
2. **Strong magnetic field**-The coil is placed between the two poles of a strong magnet such that arm AB and CD are perpendicular to the direction of the magnetic field.
3. **Split ring type commutator**-The ends of the coil are connected to the two halves P and Q of a split ring. Commutator reverses the direction of current in armature coil.
4. **Axle**: The inner sides of split rings are insulated and attached to an axle.
5. **Brushes**- Two stationary carbon brushes X and Y press against the commutator. These brushes act as a conducting link between commutator and battery.
6. **Battery**-It is connected across the carbon brushes. It supplies current to the armature coil.

WORKING

- 1) When current flow through coil, arm AB and CD experience magnetic force.
- 2) On applying Fleming's Left-hand rule, arm AB of coil experiences force in downward direction and arm CD experiences force in upward direction.
- 3) Both these forces are equal and opposite.
- 4) Thus, the coil rotates in anticlockwise direction until the coil is in vertical position.
- 5) At half rotation, the contact of commutator and brushes break.
- 6) Supply of current to coil is cut off. Hence no force acts on arms of coil. But coil goes on rotating due to inertia of motion of coil until Q makes contact with brush X and P with brush Y.
- 7) Direction of current in arm AB and CD is reversed and flows along the path DCBA.
- 8) Thus, the coil rotates again in anticlockwise direction.
- 9) The coil of d.c. motor continues to rotate in same direction. Hence electrical energy is converted into mechanical energy.

Q. What is the role of the split ring in an electric motor?

(NCERT Page 233 Q3)

The split ring in the electric motor also known as a commutator reverses the direction of current flowing through the coil after every half rotation of the coil. Due to this the coil continues to rotate in the same

Commercial motors use:

- (i) An electromagnet in place of permanent magnet.
- (ii) Large number of turns of the conducting wire in the coil.
- (iii) A soft iron core on which coil is wound plus the coils, is called the armature.
- (iv) This enhances the power of the motor.

ELECTROMAGNETIC INDUCTION

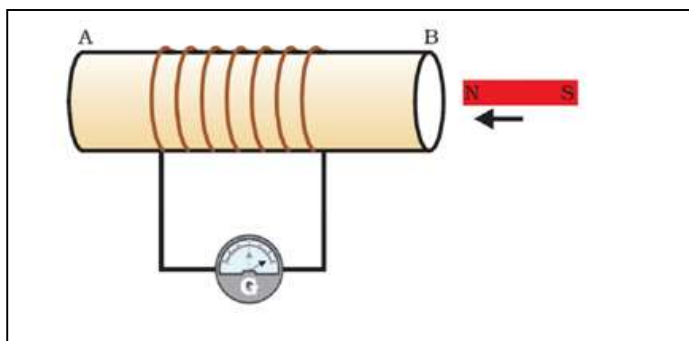
The process, by which a changing magnetic field in a conductor induces a current in another conductor placed nearby, is called electromagnetic induction.

It was discovered by **Michael Faraday**.

Galvanometer: It is an instrument that can detect the presence of a current in a circuit.

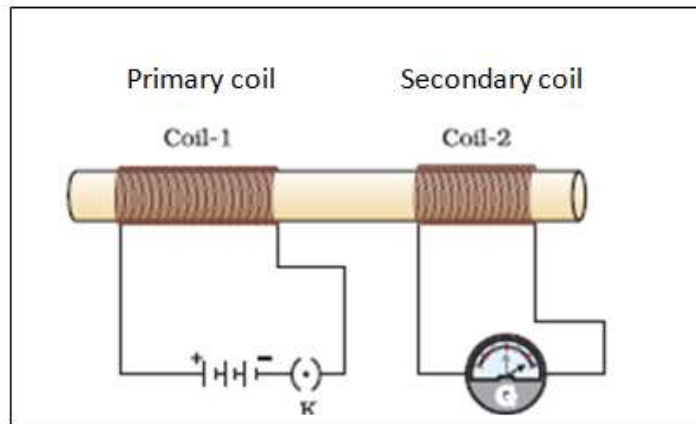
I. EMI by moving a magnet

Moving a bar magnet towards a coil sets up a current in the coil circuit, as indicated by deflection in the galvanometer needle.



- **Bar magnet pushed into the coil:** Momentary deflection in galvanometer indicating a momentary induced current in the coil (due to change in magnetic field).
- **Bar magnet withdrawn from the coil:** Momentary deflection in galvanometer in opposite direction indicating a momentary induced current in the coil (due to change in magnetic field).
- **Bar magnet is held stationary inside the coil:** No deflection in galvanometer, no current is produced.

II. EMI by using two coils



- **When key is plugged in:** The galvanometer shows momentary deflection indicating a momentary induced current in coil-2 (due to change in magnetic field)
- **When key is plugged out:** The galvanometer shows momentary deflection but in opposite direction, indicating a momentary induced current in opposite direction in coil-2.
- **When current in coil-1 is changed:** A magnetic field is set up around it. This changing magnetic field also links with coil-2 and hence some current is induced in coil-2 due to EMI, hence galvanometer shows deflection.
- **When steady current flows through the coil 1:** There is no deflection in the galvanometer because there is no change in magnetic field around the coil. Hence, no induced current is set up in the coil.

Different ways to induce current in a conductor

- (i) By moving coil in a magnetic field
- (ii) By changing magnetic field around coil

Rule to determine the direction of induced current:

Fleming's right-hand rule:

According to this rule, stretch the thumb, forefinger and middle finger of right hand so that they are perpendicular to each other. If the forefinger indicates the direction of the magnetic field and the thumb shows the direction of motion of conductor, then the middle finger will show the direction of induced current.

Q. Two circular coils A and B are placed closed to each other. If the current in the coil A is changed, will some current be induced in the coil B? Give reason. (NCERT back Exercise Q14)

Yes, a current is induced in the coil B. When the current in the coil A is changed, the magnetic field associated with it also changes. As coil B is placed close to coil A, so a current is induced in the coil B.

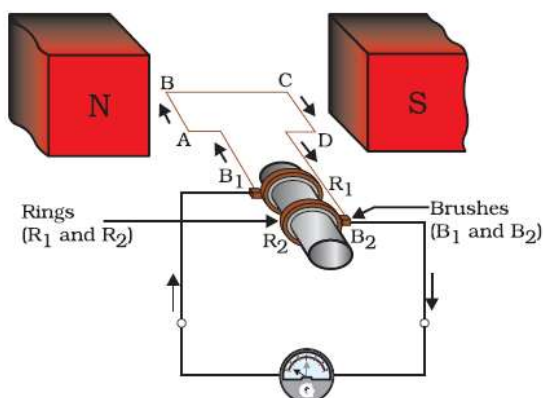
Electric Generator

An electric generator is a device that converts mechanical energy into electric energy.

Principle of generator

Electric generator is based on the principle of **Electromagnetic Induction**.

When a coil is rotated in a uniform magnetic field, then current is induced in the coil whose direction is governed by Fleming's right hand rule.



Construction

1. **Armature coil**- a rectangular coil ABCD of insulated copper wire wound on a soft iron core
2. **Strong magnetic field**-The coil is placed between the two poles of a magnetic field.
3. **Slip Rings**: Two disjoint C-shaped rings R1 and R2 are internally attached to the Axle. Ends of the coil are connected to R1 and R2. The inner portion of these rings are made of non-conducting material
4. **Axle**: The slip rings are placed on the axle which is made to rotate freely from an external source.
5. **Brushes**: The outside of the slip rings are connected to conducting stationary brushes B1 and B2. B1 and B2 is kept pressed on R1 and R2 respectively.
6. **Galvanometer**- The outer ends of the brushes are connected to the galvanometer to detect the current.

Working

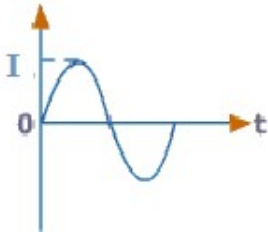
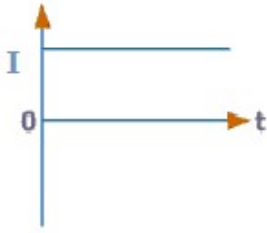
1. The axle is rotated such that it moves in the clockwise direction that is AB moves up and CD moves down.
2. According to Fleming's Right Hand rule, the induced current is setup in the coil in the direction ABCD. The induced current flows in the circuit through B2 to B1
3. After half a rotation, arm CD starts moves up and AB moves down.
4. According to Fleming's Right Hand rule, the induced current is setup in the coil in the direction DCBA. This means that the external current flows from B1 to B2.
5. Thus after every half rotation of the coil, the current changes direction. This is called an AC current.

AC current (Alternating current) : Changes its direction after equal intervals of time. It is easier to transmit this current over long distances due to lesser loss of energy and hence this is the current that is supplied to our houses from the electricity department.

D.C. GENERATOR

DC Generator: It is a device which convert mechanical energy into electrical energy.

DC Generator has split ring commutator instead of slip rings. With this arrangement, one brush is at all times in contact with the arm moving up in the field, while the other is in contact with the arm moving down.

ALTERNATING CURRENT	DIRECT CURRENT
Current which changes in magnitude and direction at regular intervals of time.	Current always flow in one direction.
Frequency of ac produced in India is 50Hz.	Frequency of dc is zero.
Sources of ac: power plants, ac generator.	Sources of dc; cell, dc generator.
	

- **Advantage of AC over DC**

An important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.

- **Disadvantage of AC**

AC cannot be stored and Dc can be stored.

- **In India, the AC changes direction after every 1/100 second, the frequency of AC is 50 Hz.**

Q1. Name some sources of direct current.

(NCERT Page 237 Q2)

cell, dc generator.

Q2. Which sources produce alternating current?

(NCERT Page 237 Q3)

power plants, ac generator

Q3. A rectangular coil of copper wires is rotated in a magnetic field. How does the direction of the induced current change?

(NCERT Page 237 Q4)

The direction of induced current changes once in each half revolution.

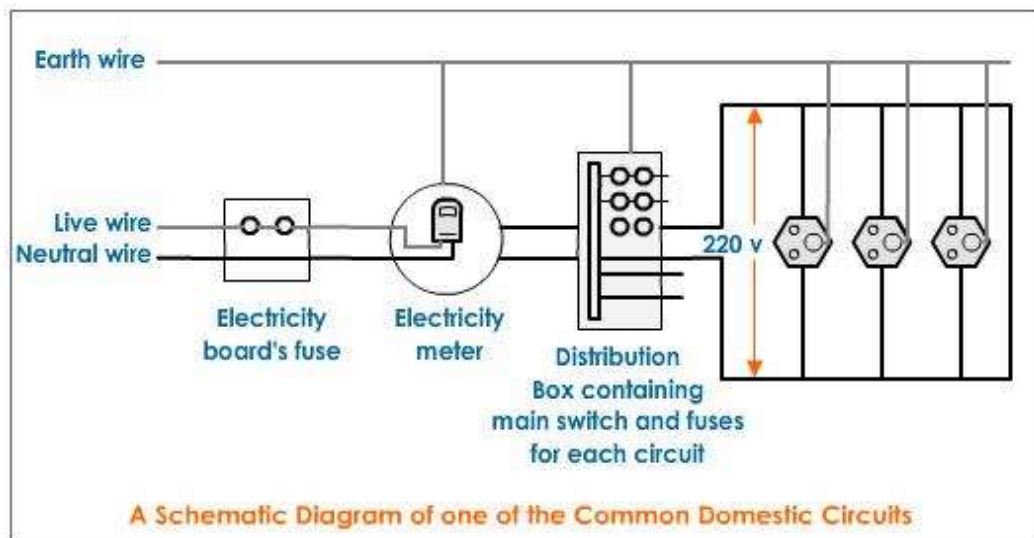
DOMESTIC ELECTRIC CIRCUITS

Features of domestic electric circuit:

- Different appliances are connected in parallel.
- Each appliance has independent on/off switch which is joined to live wire.
- Two separate circuits are used, one of 15A for higher power rating appliances and another of 5A for bulbs, fans, tubes etc. (lower power rating appliances).
- Electric fuses of appropriate capacities are used.
- The potential difference between live and neutral wire in India is 220 V.

The three wires in the domestic circuit are:

- **Live wire:** (red insulated, positive)
- **Neutral wire:** (black insulated, negative)
- **Earth wire:** (green insulated, neutral)



Pole → Main supply → Fuse → Electricity meter → Distribution box → To separate circuits

EARTH WIRE

Function: Earth wire is used as a safety measure, especially for those appliances that have a metallic body, for example, electric press, toaster, table fan, refrigerator, etc.

Working: The metallic body of electrical appliances is connected to the earth wire, which is usually connected to a metal plate deep in the earth near the house. This provides a low-resistance conducting path for the current. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

OVERLOADING

- It is caused by accidental hike in the supply voltage.
- It is caused by connecting too many appliances of high power rating like geyser, heater, refrigerator, motor etc. to a single socket. It leads to a high current which causes fire.

SHORT CIRCUIT

- Short-circuiting occurs when the live wire and the neutral wire come into direct contact. This occurs when the insulation of wires is damaged or there is a fault in the appliance.
- Short circuiting can result in overloading

ELECTRIC FUSE

Electric fuse is a safety device which prevents the electric circuit and the appliance from a possible damage due to short-circuiting or overloading by stopping the flow of unduly high electric current. The Joule heating that takes place in the fuse melts it to break the electric circuit.

Q. An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect? Explain. (NCERT Page 238 Q2)

Ans. $P = V \times I$

So, $P/V = 2000 \text{ W}/220 \text{ V} = 9.09 \text{ A}$

The current drawn by oven is 9.09A which exceeds the safe limit of 5 A. therefore; fuse will melt and break the circuit.

HW QUESTIONS

Q1. Name two safety measures commonly used in electric circuits and appliances. (NCERT Page 238 Q1)

Fuse and earth wire

Q2. What precaution should be taken to avoid the overloading of domestic electric circuits?

(NCERT Page 238 Q3)

- Too many appliances should not be connected to a single socket.
- Too many appliances should not be used at the same time.
- Fuse should be connected in the circuit.