

MAGNETIC EFFECTS OF ELECTRIC CURRENTS

10th CLASS



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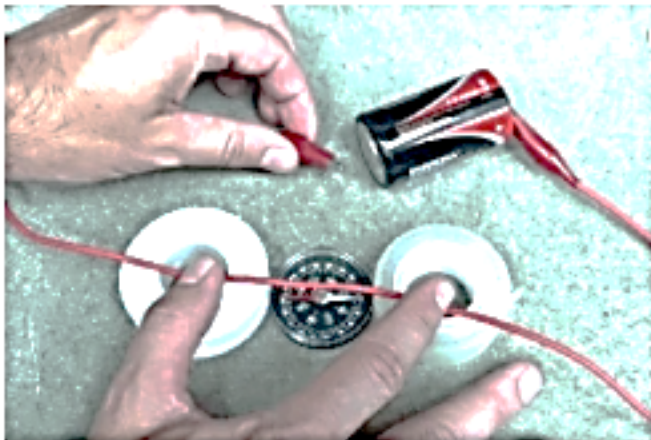
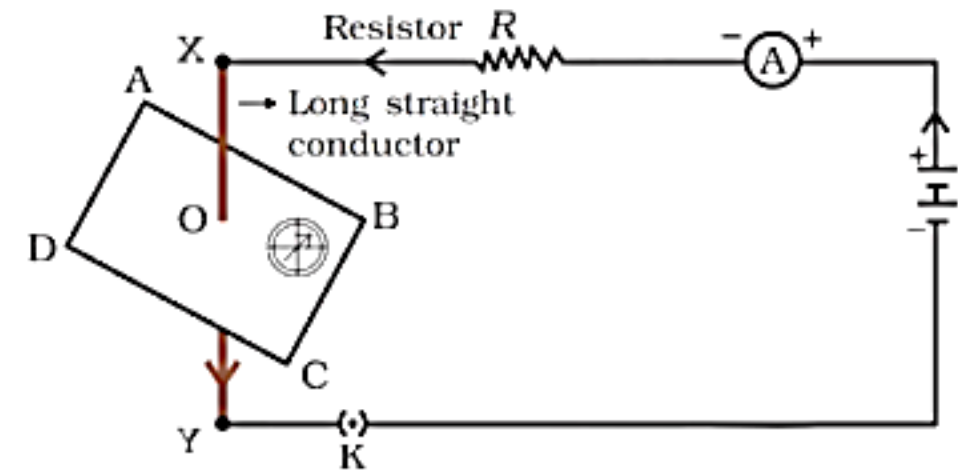
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INTRODUCTION

Electricity and **Magnetism** are linked to each other. It can be shown by an experiment.

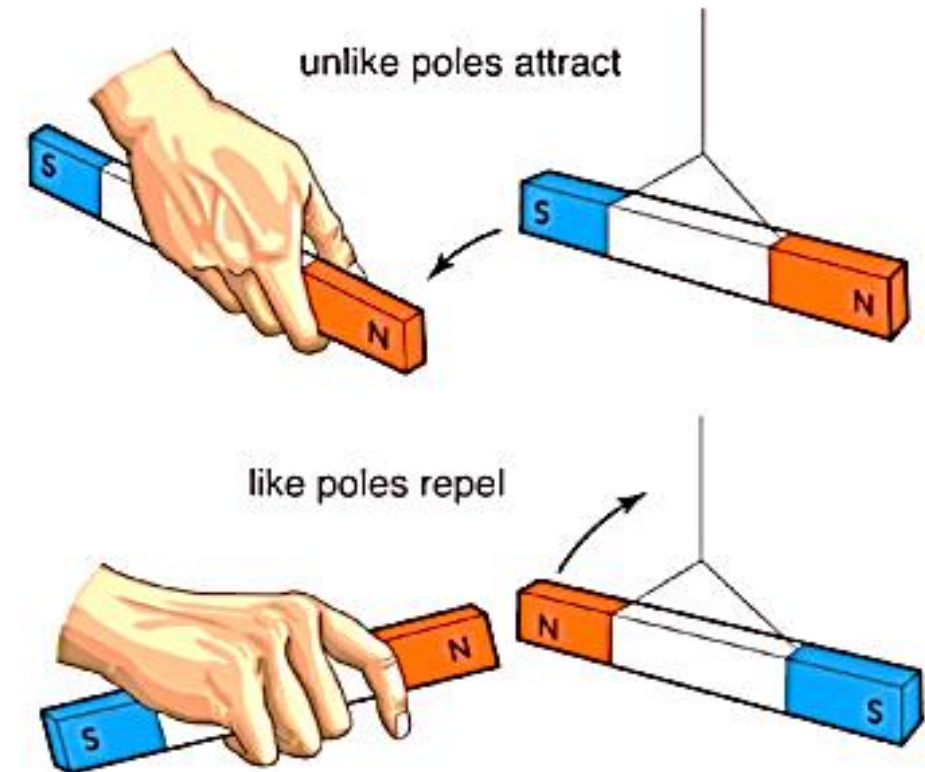
- Place a straight thick **copper wire** between the points X & Y in an electric circuit. The wire is kept perpendicular to the plane of paper.
- Horizontally place a **compass** near to copper wire.
- On passing the current, the compass needle is deflected. It means that electric current through the copper wire produces a **magnetic effect**.
- An electric current-carrying wire behaves like a **magnet**.



- Hans Christian Oersted (1820) accidentally discovered the deflection of compass needle in presence of electric current.
- Unit of magnetic field strength is oersted.

MAGNETIC FIELD AND FIELD LINES

- A compass needle is a small bar magnet. Its ends point towards **north** and **south** directions. It gets deflected when brought near a bar magnet.
- The end pointing towards north is called **north seeking (north pole)**. The other end pointing towards south is called **south seeking (south pole)**.
- **Like poles** of magnets **repel** and **unlike poles** attract each other.



MAGNETIC FIELD AND FIELD LINES

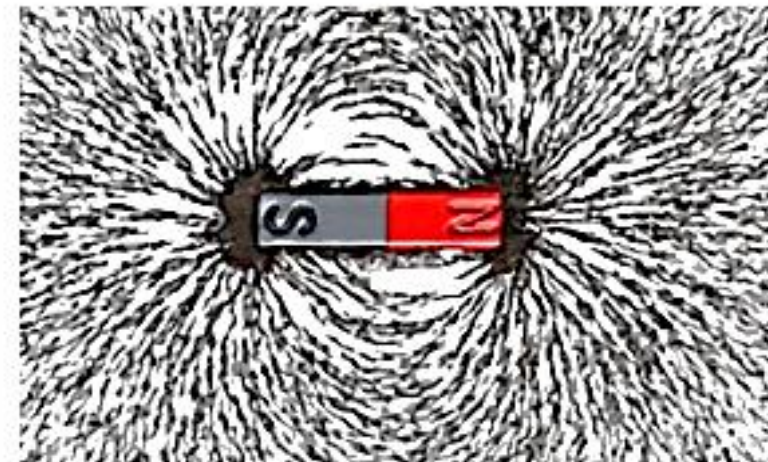
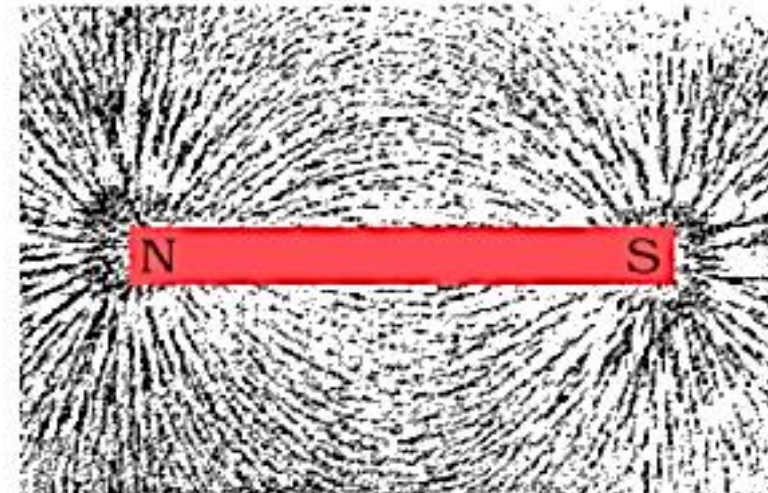
Experiments to obtain Magnetic field & Field lines

Experiment 1

- Fix a **white paper** on a drawing board and place a **bar magnet** in its centre.
- Sprinkle some **iron filings** uniformly around bar magnet.
- Tap the board gently. **Iron filings** near the magnet **align along the field lines**.

Reason: The magnet exerts an influence in its surrounding. So, the **iron filings experience a force** making them to arrange in a pattern.

- The area around a magnet that has **magnetic force** is called a **magnetic field**.
- The lines along which the iron filings align themselves represent **magnetic field lines**.



MAGNETIC FIELD AND FIELD LINES

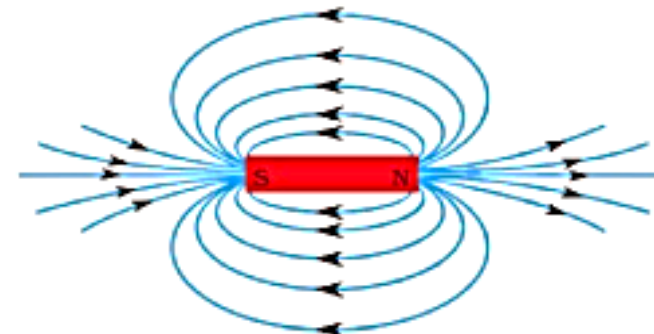
Experiments to obtain Magnetic field & Field lines

Experiment 2

- Place a bar magnet on white paper fixed on a drawing board. Mark the boundary of the magnet.
- Place a **compass** near the **north pole of the magnet**. The **south pole of the needle points towards the north pole of magnet**. Mark the position of two ends of the needle.
- Now move the needle to a new position such that its south pole occupies the position previously occupied by its north pole. In this way, proceed step by step till reach the magnet's south pole.
- Join the points marked on the paper by a smooth curve. This curve represents a **field line**.
- Repeat the above procedure and draw many lines. These lines are called **magnetic field lines**.
- The deflection in the compass needle increases as the needle is moved towards the poles.



Drawing a magnetic field line with the help of a compass needle



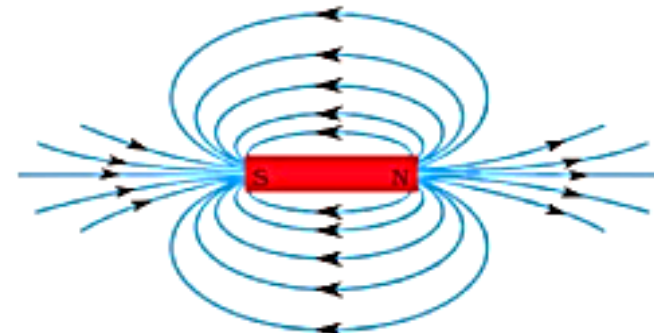
Field lines around a bar magnet

MAGNETIC FIELD AND FIELD LINES

- **Magnetic field** is a quantity that has both **direction** and **magnitude**. The direction of the magnetic field is taken as the direction in which north pole of the compass needle moves. Thus, the field lines emerge **from north pole** and merge at **south pole**. Inside the magnet, the direction of field lines is from south to north. Thus, the magnetic field lines are **closed curves**.
- Relative strength of the magnetic field is shown by the degree of closeness of the field lines. The field is stronger (i.e., greater force acting on the pole of another magnet) where the field lines are crowded.
- Two **field-lines do not cross** each other because the compass needle cannot point towards two directions at the point of intersection.



Drawing a magnetic field line with the help of a compass needle

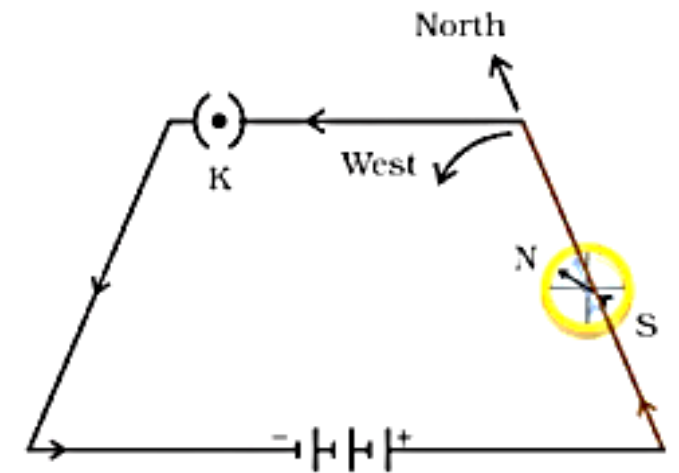
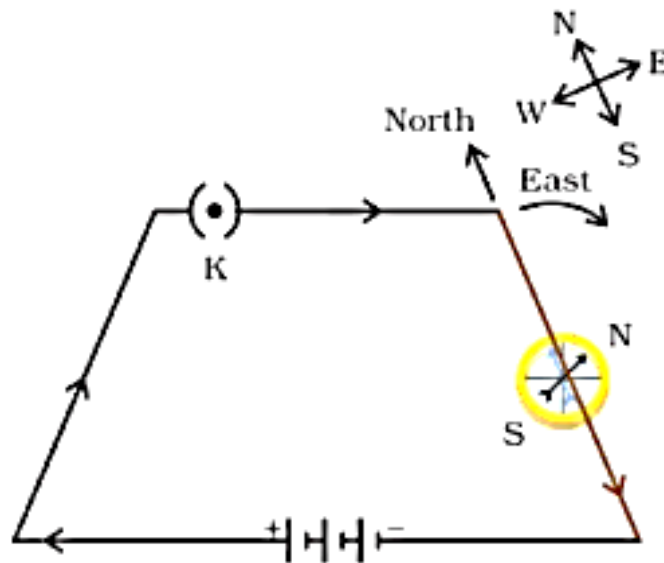


Field lines around a bar magnet

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Experiment to find the direction of the field

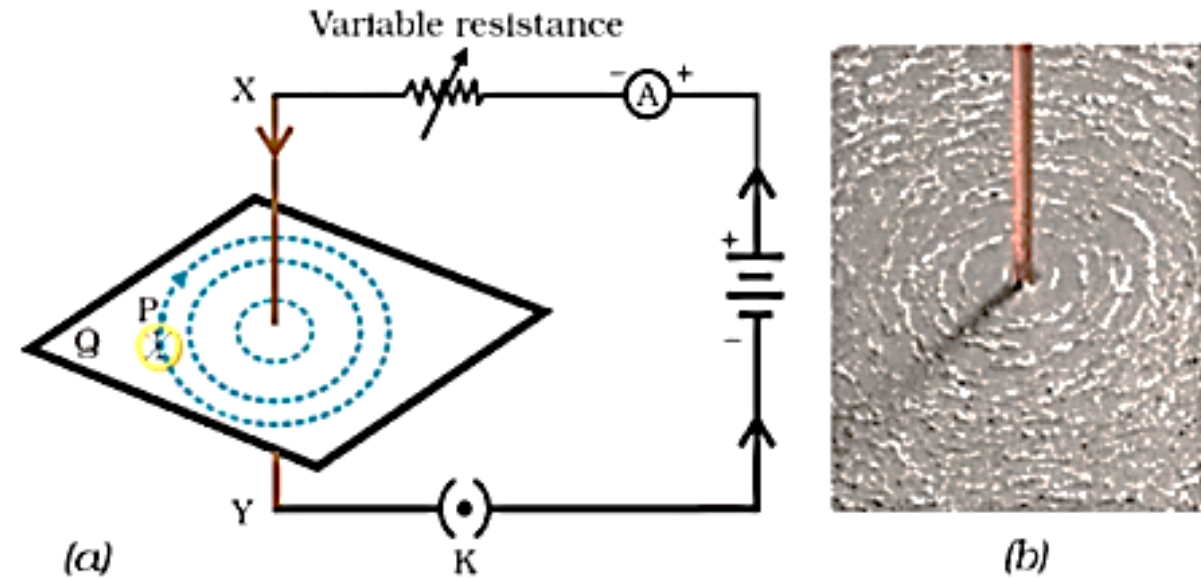
- Take a long straight copper wire, 2 or 3 cells of 1.5 V, and a plug key. Connect them in series.
- Place copper wire parallel to and over a compass needle.
- If the **current** flows from **N to S**, the **north pole** of the **compass needle** moves **towards east**.
- If the **current** flows from **S to N**, the needle moves in opposite direction (**towards west**).
- It means that the direction of magnetic field produced by the electric current is also reversed.



MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Magnetic Field due to a Current through a Straight Conductor

- Insert a straight thick **copper wire** through the centre, normal to the plane of a rectangular cardboard.
- Connect the copper wire vertically between the points X & Y, in series with a **battery (12 V)**, a **variable resistance (or rheostat)**, an **ammeter (0–5 A)** and a **plug key**.
- Sprinkle some **iron filings** uniformly on the cardboard.
- Close the key. Gently tap the cardboard a few times. The iron filings align as a pattern of **concentric circles**. They represent magnetic field lines around the copper wire.



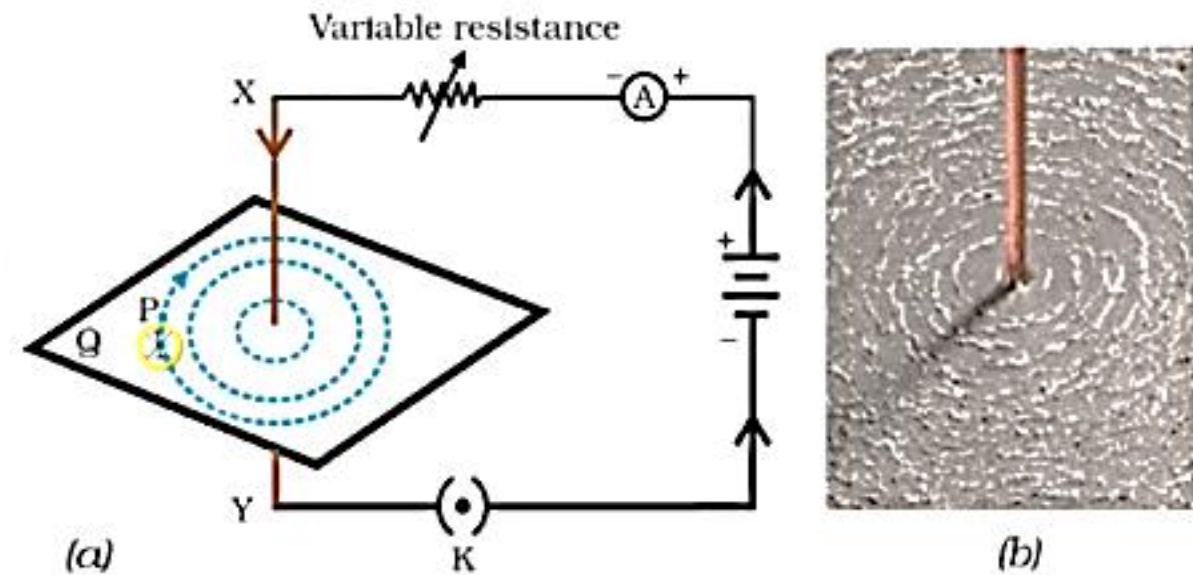
(a) A pattern of concentric circles. The arrows show the direction of the field lines.

(b) A close up of the pattern.

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Magnetic Field due to a Current through a Straight Conductor

- Place a compass at a point (say P) over a circle. The direction of the north pole of the compass needle gives the direction of the field lines at P.
- The **direction of magnetic field lines is reversed** if the **direction of current** through the copper wire is **reversed**.
- If we vary the current in the copper wire, the deflection in the needle also changes. If the current is increased, the deflection also increases. Thus, the magnitude of **magnetic field** produced at a given point **increases** as the **current through the wire increases**.



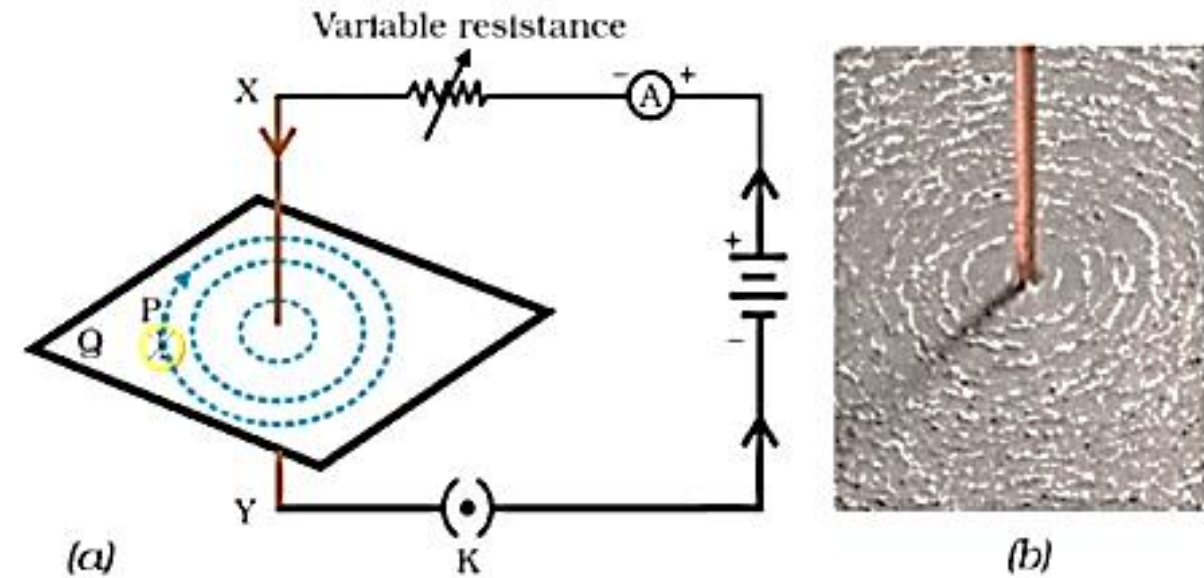
(a) A pattern of concentric circles. The arrows show the direction of the field lines.

(b) A close up of the pattern.

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Magnetic Field due to a Current through a Straight Conductor

- If the compass is placed at a farther point (say Q) from the conducting wire, deflection in the needle decreases. Thus, **magnetic field** produced by current in the conductor **decreases** as the **distance increases** (inversely proportional).
- The concentric circles representing magnetic field around a current-carrying straight wire become larger as we move away from it.



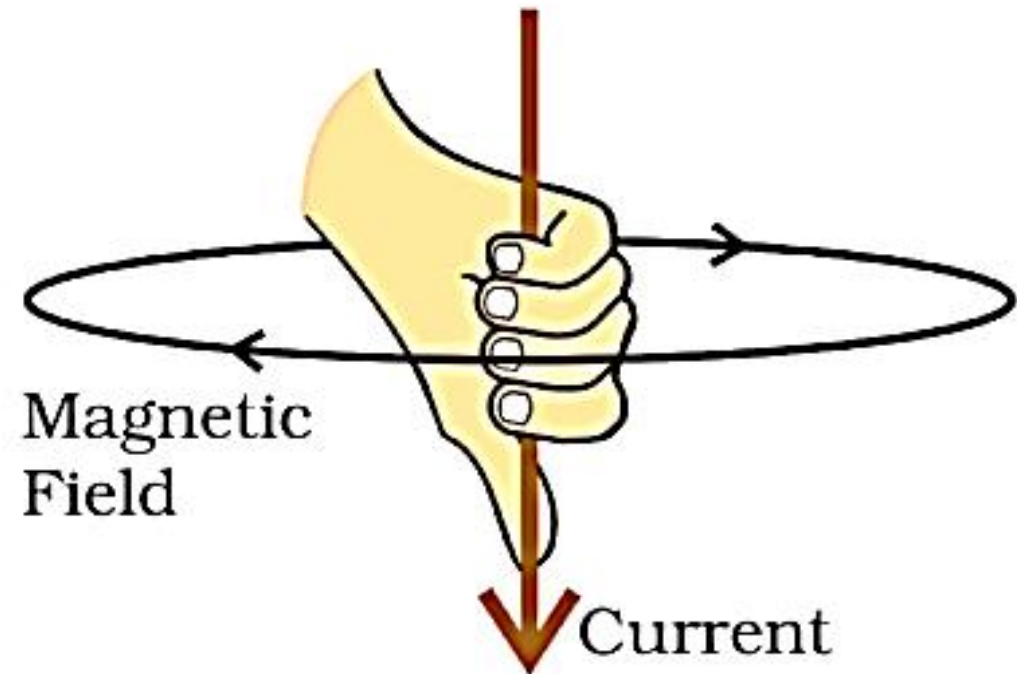
(a) A pattern of concentric circles. The arrows show the direction of the field lines.

(b) A close up of the pattern.

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Right-Hand Thumb Rule

- It is an easy way to find the **direction of magnetic field** associated with a current-carrying conductor.
- Imagine a current-carrying straight conductor is held in right hand such that the thumb points towards the direction of current. Then the fingers will wrap around the conductor in the direction of the magnetic field lines. This is called **Right-hand thumb rule** (Maxwell's corkscrew rule).



Right-Hand Thumb Rule

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

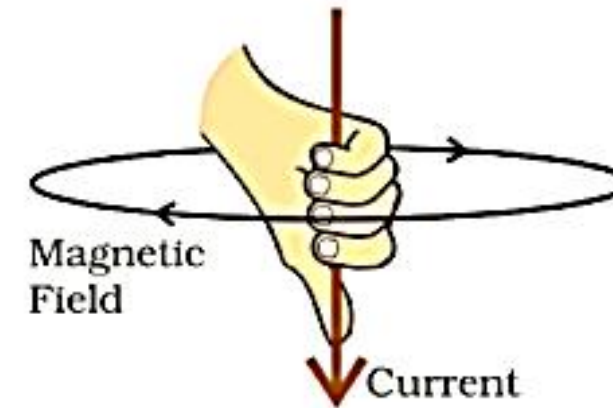
Right-Hand Thumb Rule

Problem

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?

Solution

Applying the right-hand thumb rule, magnetic field (at any point below or above the wire) turns clockwise in a plane perpendicular to the wire, when viewed from east end, and anti-clockwise, when viewed from the west end.

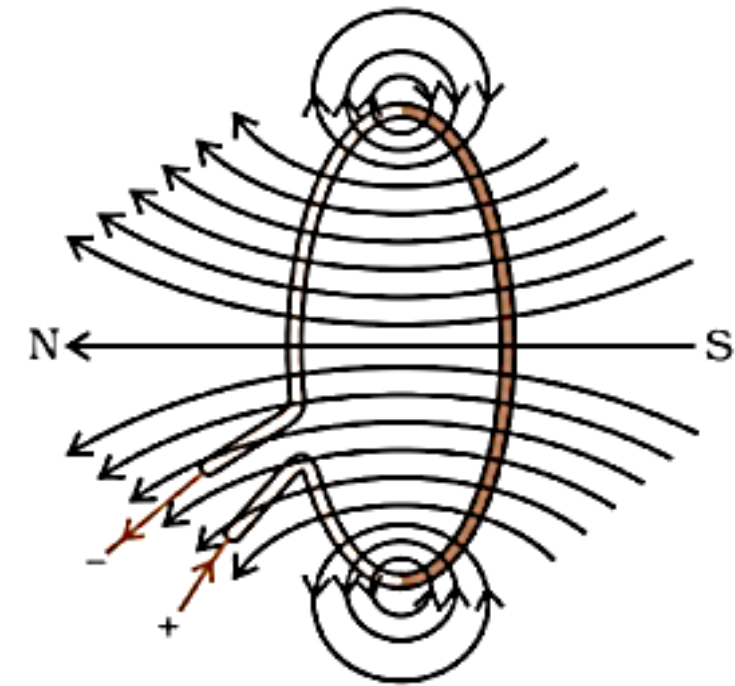


Right-Hand Thumb Rule

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Magnetic Field due to a Current through a Circular Loop

- Bend a straight wire to form a **circular loop** and pass a current through it. Here, the concentric circles around every point of circular loop become larger as the distance from the wire increases.
- At the centre of the circular loop, the arcs of these big circles appear as straight lines. Every point on the wire give rise to the magnetic field appearing as straight lines at the centre of loop. By applying **right-hand rule**, every section of the wire contributes to the magnetic field lines in same direction within the loop.
- Magnetic field produced by a current-carrying wire at a point depends directly on the current passing through it. So, for a **circular coil** with 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 just adds up.



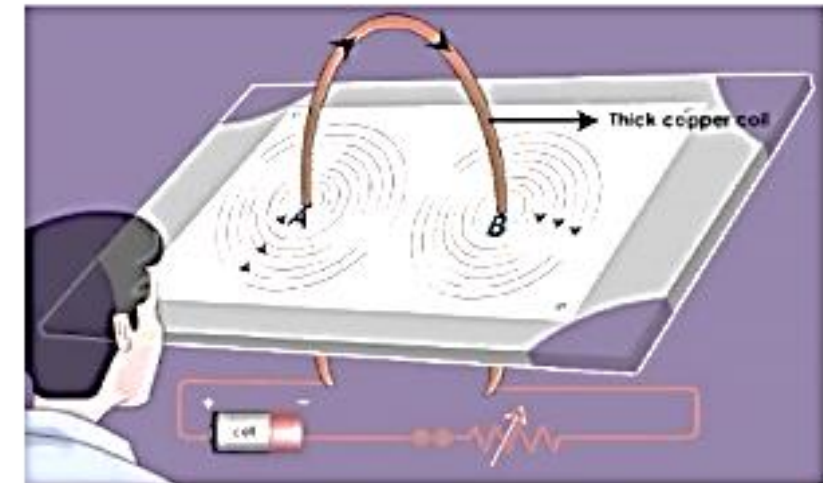
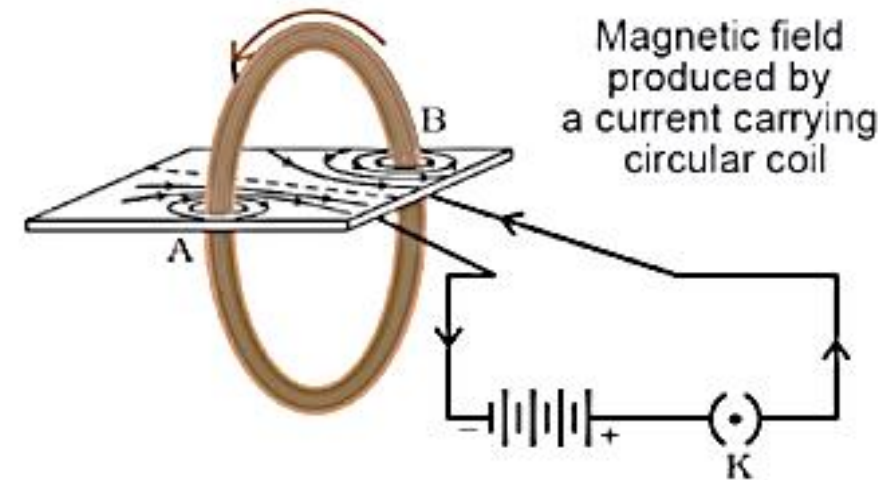
Magnetic field lines produced by a current-carrying circular loop

MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Magnetic Field due to a Current through a Circular Loop

Experiment

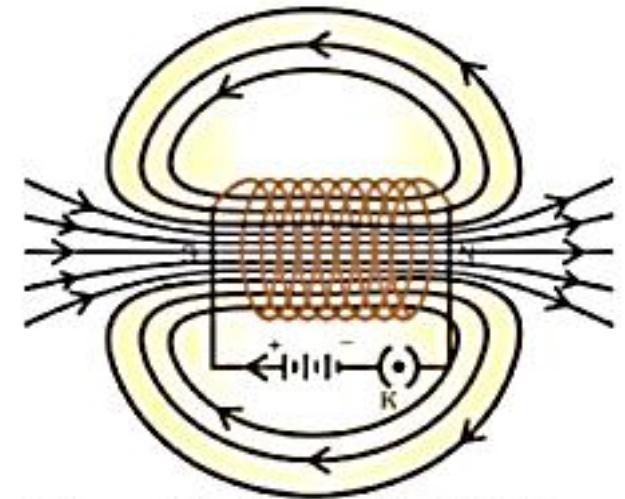
- Take a rectangular **cardboard** having two holes.
- Insert a **circular coil** having large number of turns through them, normal to the plane of the cardboard.
- Connect the ends of the coil in series with a battery, a key and a rheostat.
- Sprinkle **iron filings** uniformly on the cardboard.
- Plug the key and tap the cardboard gently a few times.
- **Concentric circle** patterns of the iron filings emerge on the cardboard. At the centre, it appears as **straight line**.



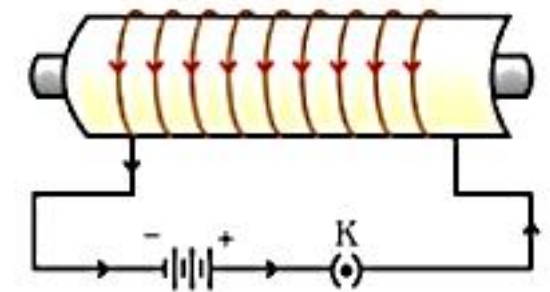
MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

Magnetic Field due to a Current in a Solenoid

- A **solenoid** is a coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder.
- The pattern of the magnetic field lines around a current-carrying solenoid looks similar to the pattern of the field around a bar magnet.
- One end of the solenoid behaves as a magnetic north pole and the other as the south pole. The field lines inside the solenoid are in the form of parallel straight lines. This indicates that the magnetic field is same (uniform) at all points inside the solenoid.
- If a magnetic material (e.g. soft iron) is placed inside a current-carrying solenoid, it becomes magnetised. The magnet so formed is called an **electromagnet**.



Solenoid - Magnetic field lines

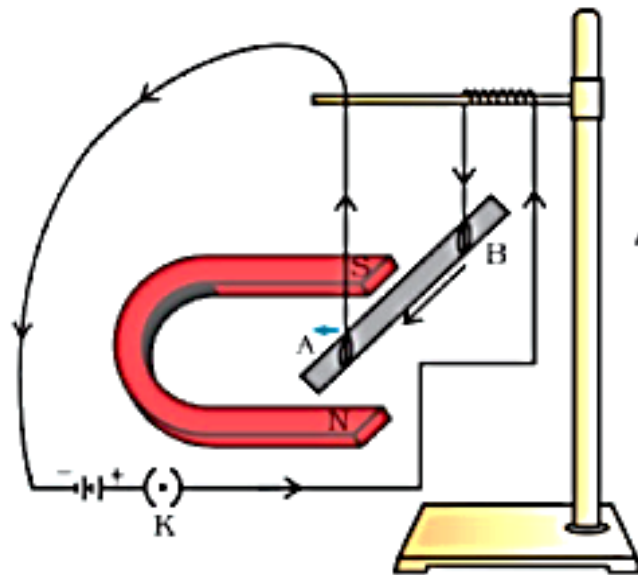


An electromagnet

FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD



- An **electric current** through a conductor produces a **magnetic field**. This field exerts a force on a magnet placed near the conductor.
- French scientist **Andre Marie Ampere** (1775–1836) suggested that the magnet also exerts an equal and opposite force on the current-carrying conductor. This can be demonstrated through an activity.



A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field

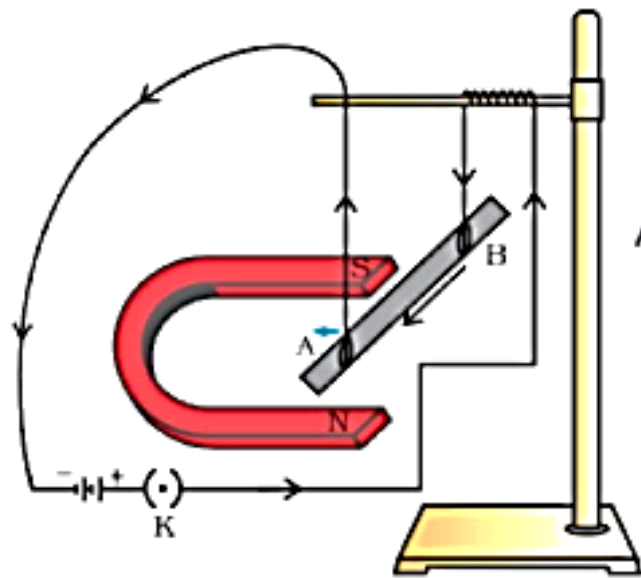
The displacement of the rod (AB) suggests that

- ❖ A force is exerted on the **current-carrying aluminium rod** when it is placed in a **magnetic field**.
- ❖ **Direction of force** is also **reversed** when the **direction of current** through the conductor is **reversed**.

FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD



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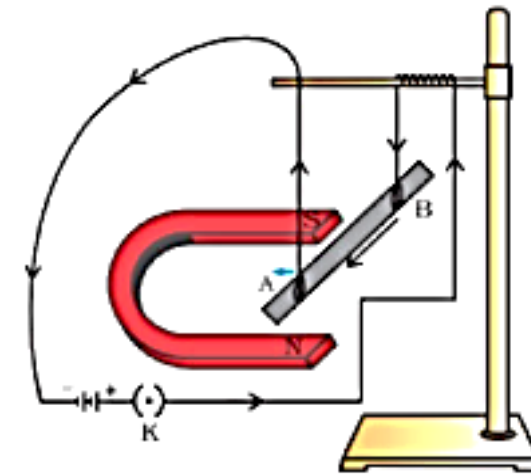


A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field

Change the direction of field to vertically downwards by interchanging the two poles of the magnet. Again, the direction of force acting on the current-carrying rod gets reversed. It shows that the **direction of the force** on the conductor depends upon the **direction of current** and the **direction of magnetic field**.

FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

- Displacement of the rod is largest (or magnitude of the force is highest) when the direction of current is at right angles to the direction of the magnetic field.
- Direction of the force can be found through **Fleming's left-hand rule**. Stretch the **thumb, forefinger** and **middle finger** of left hand perpendicular to each other.
 - **First finger** → direction of magnetic field.
 - **Second finger** → direction of current.
 - **Thumb** → direction of motion or the force acting on the conductor.



A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field



FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

Electric motor, electric generator, loudspeakers, microphones & measuring instruments are the devices that use current-carrying conductors & magnetic fields.

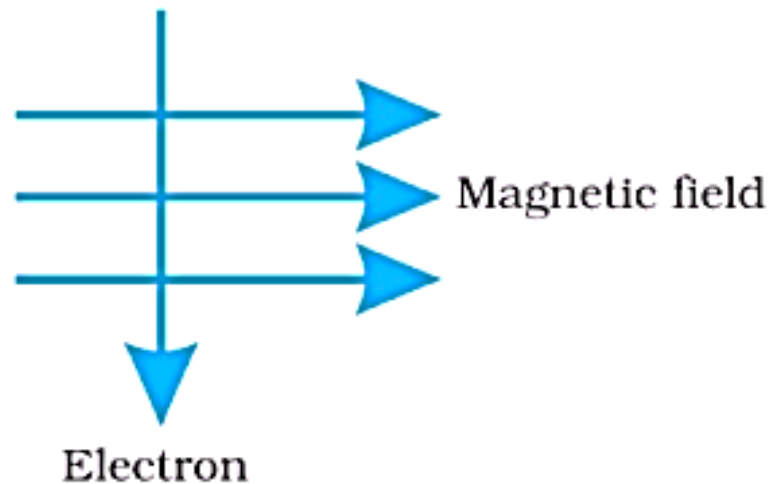


FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

Problem

An electron enters a magnetic field at right angles to it, as shown below. The direction of force acting on the electron will be

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



Solution

Answer is (d).

The direction of force is perpendicular to the direction of magnetic field and current as given by Fleming's left-hand rule. The direction of current is taken opposite to the direction of motion of electrons. The force is therefore directed into the page.

FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

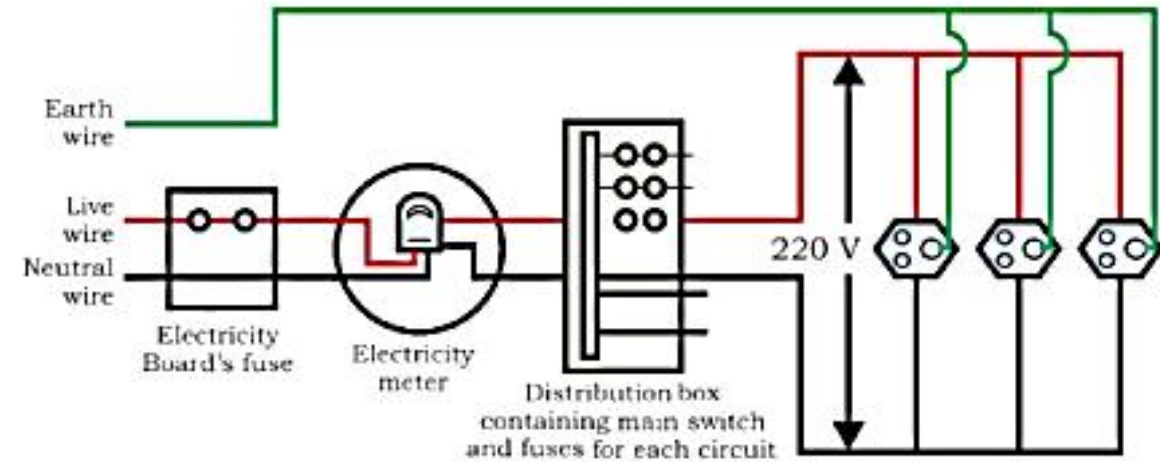
Magnetism in medicine

- Electric impulses carrying through the nerves can produce a temporary magnetic field. These fields are very weak (one-billionth of the earth's magnetic field).
- Heart and brain can produce significant magnetic field.
- The magnetic field inside the body is used to obtain the images of body parts. This technique is called **Magnetic Resonance Imaging (MRI)**. These images help in medical diagnosis.



DOMESTIC ELECTRIC CIRCUITS

- In homes, electric power is supplied through a **main supply (mains)**, supported through overhead **electric poles** or by **underground cables**. In this, one wire is with **red insulation cover (live wire or positive)** and other wire is with **black insulation (neutral wire or negative)**.
- In our country, the **potential difference** between the two is **220 V**.
- At the **meter-board**, these wires pass into an electricity meter through a **main fuse**. Through the main switch, they are connected to the line wires. These wires supply electricity to separate circuits in the house.

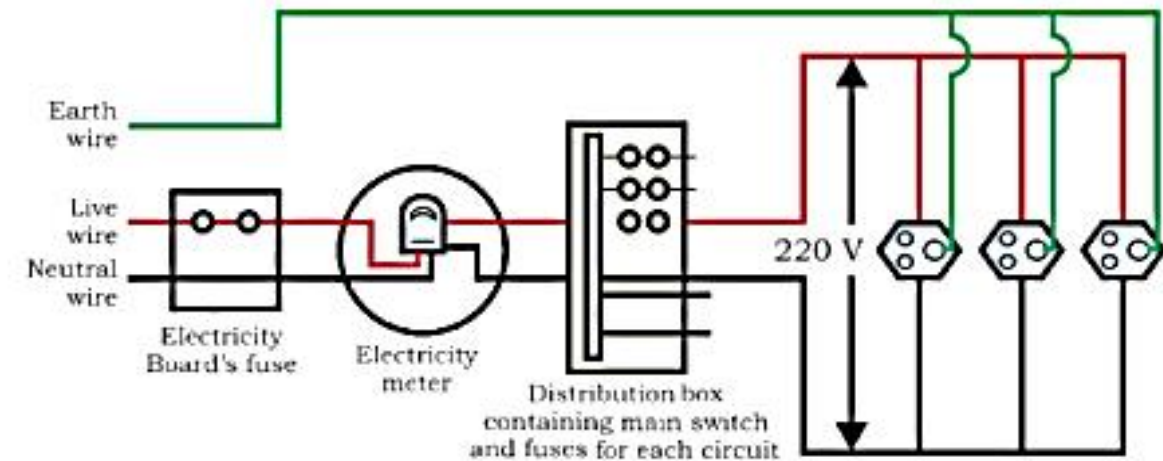


A schematic diagram of a common domestic circuits

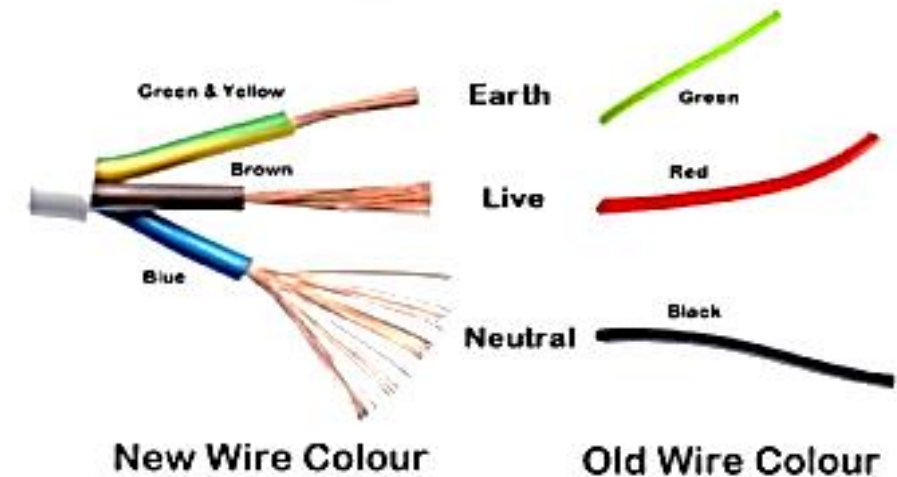


DOMESTIC ELECTRIC CIRCUITS

- Often, two separate circuits are used:
 - ❖ **15 A current** rating for appliances with higher power ratings such as **geysers, air coolers, etc.**
 - ❖ **5 A current** rating for **bulbs, fans, etc.**
- The **earth wire (green insulation)** is connected to a metal plate deep in the earth near the house. This is a safety measure for metallic appliances (e.g., electric press, toaster, table fan, refrigerator, etc.). The metallic body is connected to the earth wire to provide a **low-resistance conducting path** for current. It ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and prevents severe electric shock.

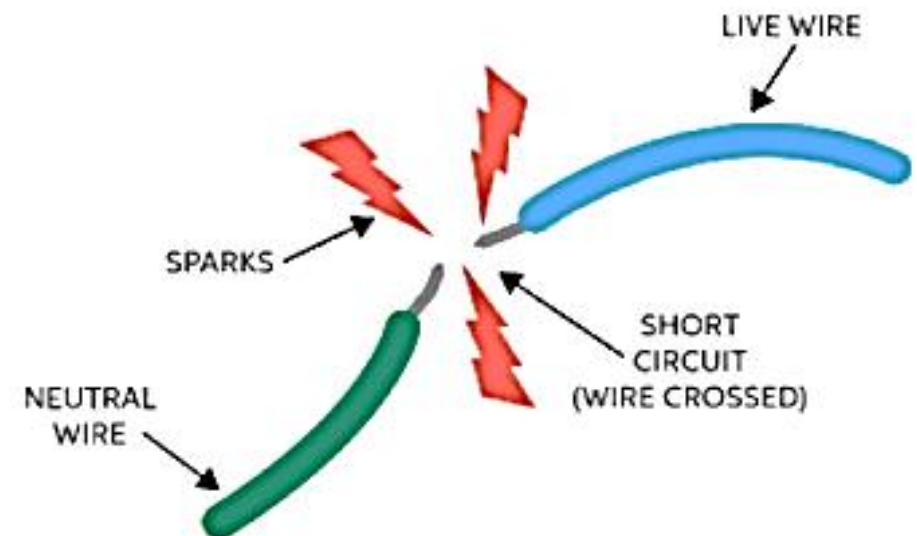
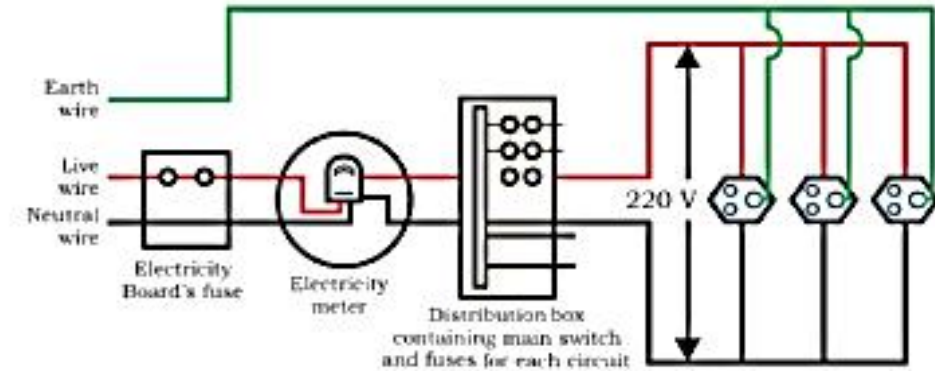


A schematic diagram of a common domestic circuits



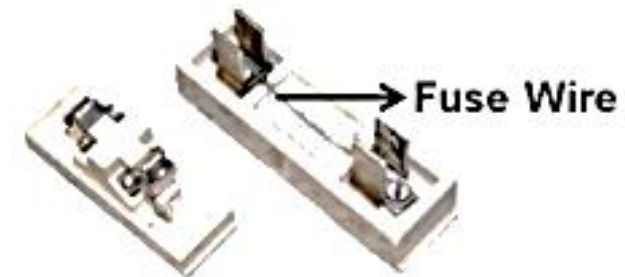
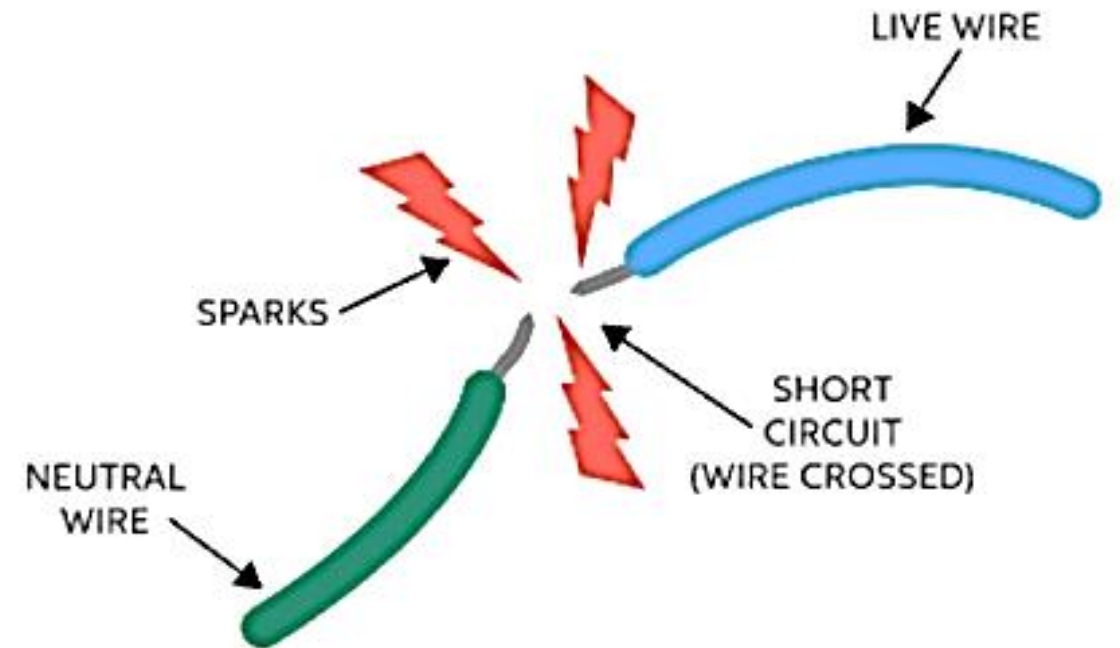
DOMESTIC ELECTRIC CIRCUITS

- In each separate circuit, different appliances can be connected across live and neutral wires. Each appliance has a separate switch to ON/ OFF the flow of current. The appliances are connected in **parallel** so that they have same potential difference.
- When the **live wire** and **neutral wire** come into direct contact, it causes **overloading**. This occurs due to
 - Damaged insulation of wires or fault in the appliance.
 - Accidental hike in voltage.
 - Connection of many appliances to a single socket.



DOMESTIC ELECTRIC CIRCUITS

- Due to overloading, the current in the circuit abruptly increases. This is called **short-circuiting**.
- An **electric fuse** can prevent the damage to the circuit and appliance by stopping unduly high electric current. The Joule heating in the fuse melts it to break the electric circuit.



Thank's
you