12.MAGNETIC EFFECTS OF ELECTRIC CURRENT

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❖ Topics:

❖ 1. Introduction

❖ 2.Magnetic field & Field lines

❖ 3. Magnetic field due to a current

a) through a straight conductor

b) through a circular loop

c) In a solenoid.

❖ 4. Force on a current carrying conductor in a magnetic field.

❖ 5. Domestic electric circuits.

❖ 1. Introduction:

❖ Hans Christian Oersted in 1820, discovered that a compass needle got deflected when a current carrying conductor(or wire) was placed nearby it.

❖ According to him, the deflection of the compass needle was due to the magnetic field produced by the electric current known as the "magnetic effect of electric current".

❖ Any change in the direction of current will also show a variation in the direction of deflection

❖ It was concluded that electricity and magnetism are related(or linked) to each other.

❖ Electric current produces magnetism i.e.,electromagnetism.

❖ His research was later used in radio, television and fiber optics etc.

❖ The unit of magnetic field strength is named Oersted in his honour.

❖ Oersted Experiment- Behavior current-carrying wire

ACTIVITY 1

❖ **Aim:** To study the Oersted experiment (or)

To show that a current-carrying wire behaves like a magnet.

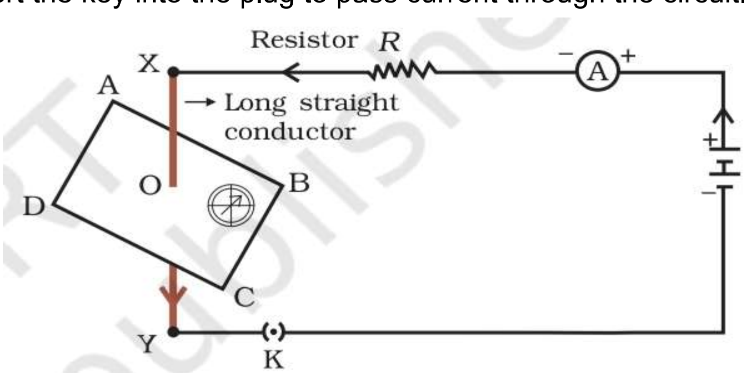
❖ **Materials Required:** Copper wire, battery, plug key, resistor, paper, and a compass needle.

❖ **Procedure:**

❖ Place a straight, thick copper wire between points X and Y in an electric circuit. The wire XY is kept perpendicular to the paper's plane.

❖ Horizontally, place a small compass near the copper wire and note its needle's position.

❖ Insert the key into the plug to pass current through the circuit.



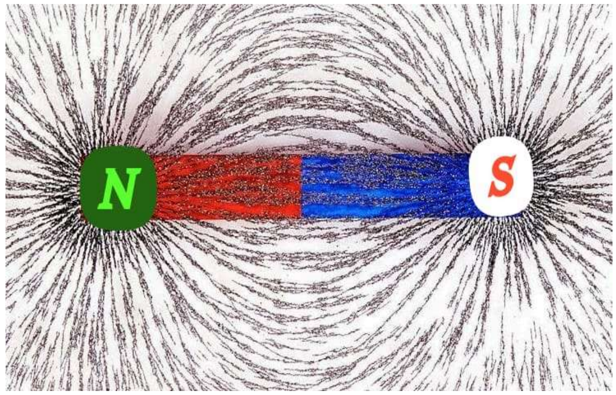
- On passing the current through the copper wire XY in the circuit, the compass needle which is placed near the conductor gets deflected.
- If we reverse the direction of current, the compass needle deflect in reverse direction.
- If we stop the flow of current, the needle comes at rest.
- **Conclusion:**
- i) Hence, it concludes that electricity and magnetism are linked to each other.It shows that whenever the current will flow through the conductor, then the magnetic field around it will develop.
- ii)) A magnetic needle can only be deflected by a magnetic field, therefore a current-carrying conductor behaves like a magnet.
- **Magnet:** A magnet is an object which attracts a piece of iron, steel, cobalt & Nickel.
- Magnet is also called dipole because of its two poles.
- Like poles are repel each other andUnlike poles are attract each other.
- **Bar magnet:**
- A bar magnet is a long rectangular bar of uniform cross-sectional area which attracts Fe, Co, Ni and steel is called bar magnet
- **Magnetic compass:**
- A navigational instrument that indicates direction by utilizing Earth's magnetic field is called magnetic compass.
- Compass needle behaves as a small magnet whose one end always towards north & other towards south.
- **2.Magnetic field & Magnetic field lines:**
- **Magnetic field:**
- The space or region surrounding a magnet in which magnetic force is experienced, is called a magnetic field. (or)
- The region around a magnet in which the force of a magnet can be detected is called the Magnetic field.
- A magnetic field is a vector quantity and represented by B.
- **Units:** SI (large) units: Tesla(T)
  CGS (small) units: gauss
- **Relation:** 1Tesla = 10^4 gauss
- **Direction:** The direction of magnetic field at a point is the direction of the resultant force acting on a hypothetical north pole at that point.
- **Magnetic field lines:**
- The imaginary lines representing magnetic fields around a magnet are known as magnetic field lines.
- A magnetic field line is a path along which a hypothetical free north pole tends to move towards the south pole.

Magnetic field lines around a bar magnet

ACTIVITY 2

- **Aim:** To obtain magnetic field lines around a bar magnet by using iron filings.

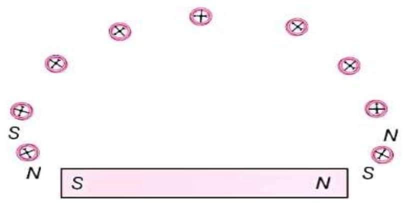
- **Materials Required:** A strong bar magnet, iron filings, drawing board, a sheet of paper, and adhesive material.
- **Procedure:**
- Fix a white sheet of paper to a drawing board.
- Place the bar magnet on the paper.
- Sprinkle iron filings uniformly on the paper.
- Gently tap the drawing board and observe the pattern of the field lines.



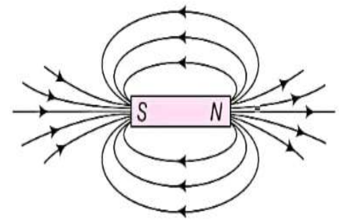
- **Observation:** A bar magnet has a magnetic field that can be detected by iron filings around it.
- **Conclusion:** The pattern of the iron filings around the magnet represents the magnetic field in the form of magnetic field lines.
- **Explanation:**
- The magnet exerts a force in the surrounding region, called the magnetic field.
- This magnetic field affects the iron filings, making them experience a force.
- As a result, the filings align along invisible lines of force, called magnetic field lines.
- The pattern formed represents these field lines.

ACTIVITY 3

- **Aim/Objective:** To obtain magnetic field lines around a bar magnet by using a compass needle.
- **Materials Required:** A bar magnet, a compass needle, a sheet of white paper, a drawing board, and adhesive material.
- **Procedure:**
- Take a small compass and a bar magnet.
- Use adhesive material to fix the magnet to a sheet of white paper on a drawing board.
- Mark the magnet's boundary.
- Place the compass near the North pole of the magnet.
- Mark the position of both ends of the compass needle.
- Move the needle so that its South pole is now at the position previously occupied by its North pole.
- Continue this process step-by-step until you reach the magnet's South pole.



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

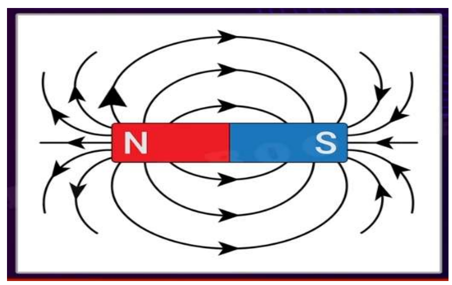


(b) Field lines around a bar magnet

- ❖ Connect the marked points with a smooth curve. This curve represents a field line.
- ❖ Repeat the procedure to draw more lines to get the full pattern.
- ❖ **Conclusion/Discussion:** Magnetic field lines represent the direction and strength of the magnetic field at a specific point.

❖ Properties /characteristics of Magnetic Field Lines:

- ❖ Magnetic field lines have both direction and magnitude.
- ❖ The direction of the magnetic field is defined as the direction in which the north pole of a compass needle points.

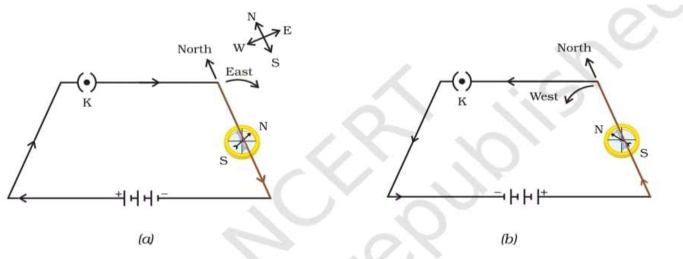


- ❖ Field lines originate from the north pole of a magnet and enter the south pole.
- ❖ The direction of M.F. lines are always N-S outside the magnet & South to North inside the magnet.
- ❖ These lines are closed & continuous curves and never intersect each other.
- ❖ These lines show the direction and strength of the M.F.
- ❖ The closeness or density of M.F. lines tell us about the strength of the M.F. in that area and Strength of M.F.$\propto$ degree of closeness.
- ❖ M.F. strength is more at the poles & less at the middle of bar magnet

Magnetic effects of electric current

ACTIVITY 4

- ❖ **Aim:** To show that the direction of magnetic field from a current is dependent on the direction of current or To show the magnetic effects of electric current.
- ❖ **Materials Required:** Copper wire, two or three cells, a plug key, and a compass needle.
- ❖ Procedure:
- ❖ Take a long, straight copper wire, two or three 1.5 V cells, and a plug key. Connect them in series as shown in Fig. (a).
- ❖ Place the straight wire parallel to and over a compass needle.
- ❖ Plug the key into the circuit.



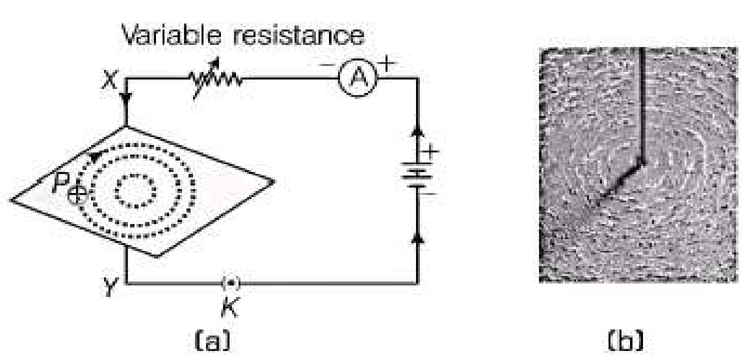
- Observe the direction of the compass needle's North pole deflection. If the current flows from North to South, the North pole of the needle will move towards the East.
- Reverse the cell connections in the circuit, as shown in Fig. (b). This changes the current's direction to flow from South to North.
- Observe the change in the needle's deflection direction.
- **Observation:** The needle moves in the opposite direction, towards the West. This means the direction of the magnetic field produced by the current has reversed.

3. MAGNETIC FIELD DUE TO A CURRENT

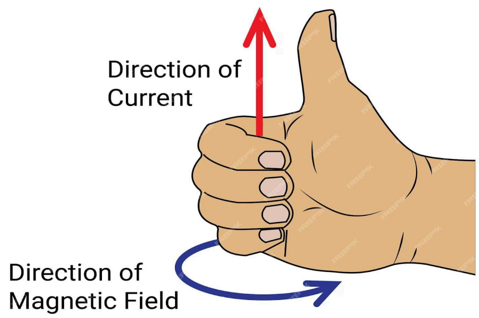
A. Magnetic field due to a straight current-carrying conductor

ACTIVITY 5

- **Aim:** i)To study the magnetic field lines due to a straight current-carrying conductor.
  ii)To find the direction of the magnetic field lines.
  iii)To show that a current-carrying wire behaves like a magnet
- **Materials Required:** Battery (12 V), rheostat, an ammeter (0-5 A), plug key, long thick straight copper wire, and cardboard.
- **Procedure:**
- Insert the thick copper wire through the center of a rectangular cardboard, ensuring the cardboard is fixed and doesn't slide.
- Connect the copper wire vertically between points X and Y in series with the battery and a plug key, as shown in Fig. (a).
- Sprinkle some iron filings uniformly on the cardboard.
- Set the rheostat at a fixed position and note the current on the ammeter.
- Close the key to allow current to flow through the wire. The copper wire must remain vertically straight.
- Gently tap the cardboard a few times. Observe the pattern of the iron filings. You will see a pattern of concentric circles around the wire.



- Place a compass on a circle and observe its needle's direction. The direction of the North pole indicates the direction of the magnetic field lines.
- **Observation:** A pattern of concentric circles is observed around the copper wire, which represents the magnetic field lines and a current-carrying wire behaves like a magnet.
- The direction of the North pole indicates the direction of the magnetic field lines.
- **Right-Hand Thumb Rule:**
- If you imagine holding the wire with your right hand, with your thumb pointing in the direction of the current, the direction your fingers curl around the wire indicates the direction of the magnetic field lines.

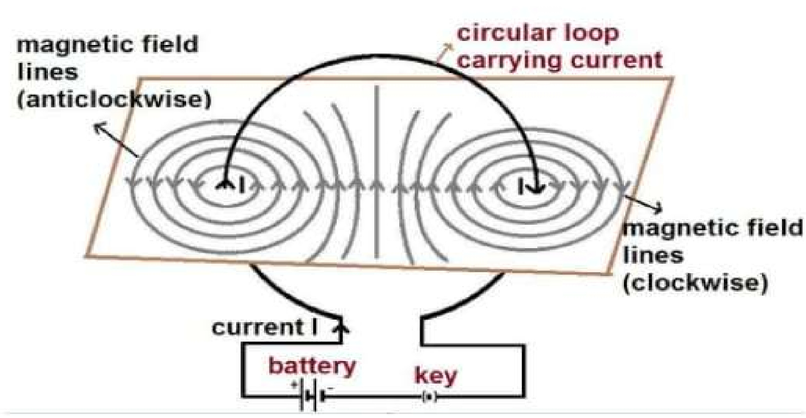


- The right-hand thumb rule, also known as Maxwell's cork screw rule, helps "determine the direction of the magnetic field around a current-carrying wire".

B. Magnetic field due to a current-carrying circular loop

ACTIVITY 6

- **Aim:** To study the magnetic field due to a current-carrying circular loop(coil).
- Materials Required: Rectangular cardboard, a circular coil with multiple turns, iron filings, a plug key, and a battery.
- **Procedure:**
- Take a rectangular cardboard with two holes and insert a circular loop(coil) through them, normal to the cardboard's plane.

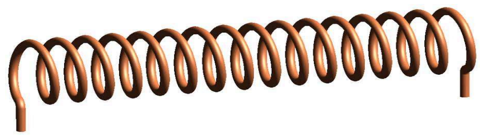


- Connect the loop's ends in series with a battery, a key.
- Sprinkle iron filings uniformly on the cardboard and Plug the key.
- Gently tap the cardboard a few times and note the pattern of the iron filings.

- **Observation:** The magnetic field lines near the loop (coil) are circular and concentric.
- The direction of the magnetic field at the center is perpendicular to the loop's plane, and its strength is maximum at the center.

C. Magnetic Field Due to a Current in a Solenoid

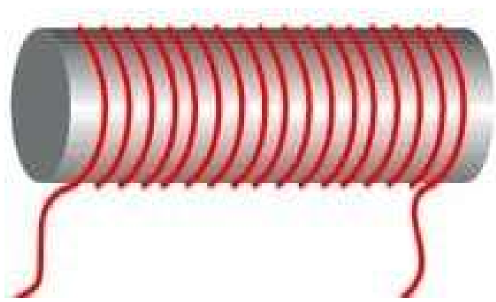
- **Definition:** A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called a solenoid.



ACTIVITY 7

- **Aim:** To study the pattern of the magnetic field produced by a current-carrying solenoid and to compare it with the magnetic field of a bar magnet or To study the Magnetic Field due to a Current in a Solenoid
- **Materials Required:** Insulated copper wire, Cylindrical cardboard, Battery, Key, Connecting wires, Magnetic compass and Soft iron rod (optional – to make an electromagnet).
- **Procedure:**
- Wind insulated copper wire closely in many turns over the cylindrical tube to form a solenoid.
- Connect the ends of the solenoid to the battery through a key.
- Place a magnetic compass at different points around the solenoid to observe the direction of the magnetic field lines.
- Note that inside the solenoid, the compass needle aligns along parallel straight lines indicating a uniform field.
- Compare the magnetic field pattern outside the solenoid with that of a bar magnet (having north and south poles).
- Insert a soft iron rod inside the solenoid to observe the strengthening of the magnetic effect (formation of an electromagnet).
- **Observation:**
- The field lines inside the solenoid are parallel and equally spaced, indicating a uniform magnetic field.
- One end of the solenoid behaves like a north pole, and the other like a south pole, similar to a bar magnet.
- Outside the solenoid, the magnetic field resembles that of a bar magnet with curved field lines emerging from the north pole and entering the south pole.
- Inserting a soft iron rod increases the strength of the magnetic field (electromagnet formation).
- **Conclusion:**
- A current-carrying solenoid produces a magnetic field similar to that of a bar magnet.
- The magnetic field inside a solenoid is uniform and strong.
- The polarity of the solenoid depends on the direction of current and can be determined using the right-hand rule.

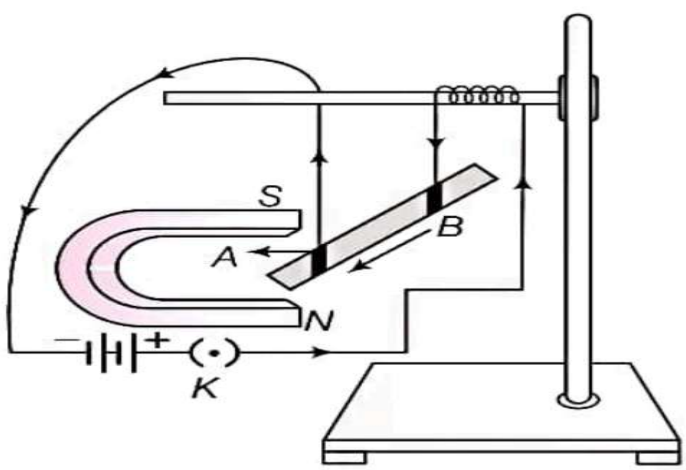
- **Properties of the magnetic field inside a solenoid:**
- The magnetic field lines inside the solenoid are in the form of parallel straight lines.
- This indicates that the magnetic field is uniform inside the solenoid.
- The pattern of the magnetic field lines around a current-carrying solenoid is similar to that of a bar magnet.
- One end of the solenoid behaves as a north pole, while the other end behaves as a south pole.
- A strong magnetic field produced inside a solenoid can be used to magnetize a piece of magnetic material, like soft iron, forming an electromagnet.
- Placing a soft iron core inside the solenoid produces an electromagnet.



4. Force on a current carrying conductor in a magnetic field.

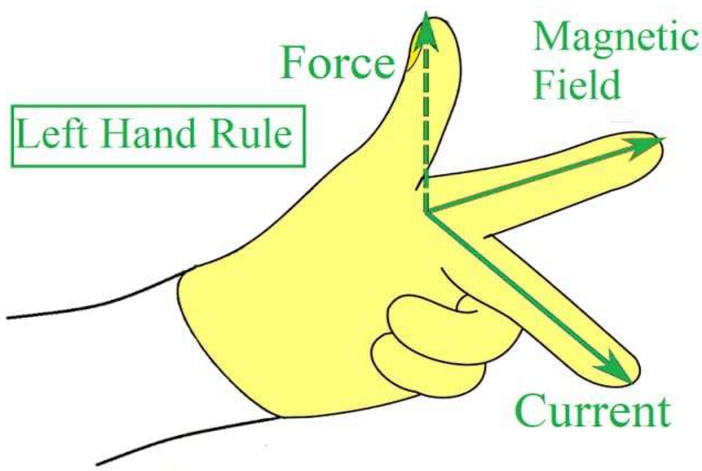
ACTIVITY 8

- **Aim:** To show that a force is exerted on a current-carrying conductor placed in a strong magnetic field.
- **Materials Required:** A conducting rod AB, connecting wires, a horseshoe magnet, a battery, a switch, and a clamp stand.
- **Procedure:**
- Connect the conducting rod AB to the battery and a key.



Current-carrying conductor *AB* placed in a strong magnetic field.

- ❖ Place a strong horse shoe magnet so the rod AB is between its poles. The magnetic field should be directed upwards, with the N-pole vertically below the rod and the S-pole vertically above it.
- ❖ Plug in the key.
- ❖ **Observation:** A current-carrying rod AB experiences a force that is perpendicular to its length and the magnetic field.
- ❖ **Fleming's Left-Hand Rule:**
- ❖ Stretch the thumb, forefinger, and middle finger of your left hand so that they are mutually perpendicular to each other. Then
- ❖ The thumb will point in the direction of the force or motion of the conductor(F).
- ❖ The forefinger points in the direction of the magnetic field(M).
- ❖ The middle finger points in the direction of the electric current(C)



- ❖ Fleming's Left-Hand Rule provides a simple way to find the direction of the force on a current-carrying conductor placed in a magnetic field.

5. Domestic electric circuits

Domestic Electric Circuits

Electric Power Supply to Homes

Main supply (mains) reaches homes through overhead electric poles or underground cables.
Live wire → red insulation, positive potential.
Neutral wire → black insulation, negative potential.
Earth Wire→Green insulation,Connected to a metal plate deep in the earth near the house.
Purpose of Earth wire: Safety → prevents electric shock by providing a low-resistance path for leakage current from metallic appliances (e.g., refrigerator, toaster).
Potential **d**ifference between **live and neutral** in India = **220** V.

Distribution in Homes

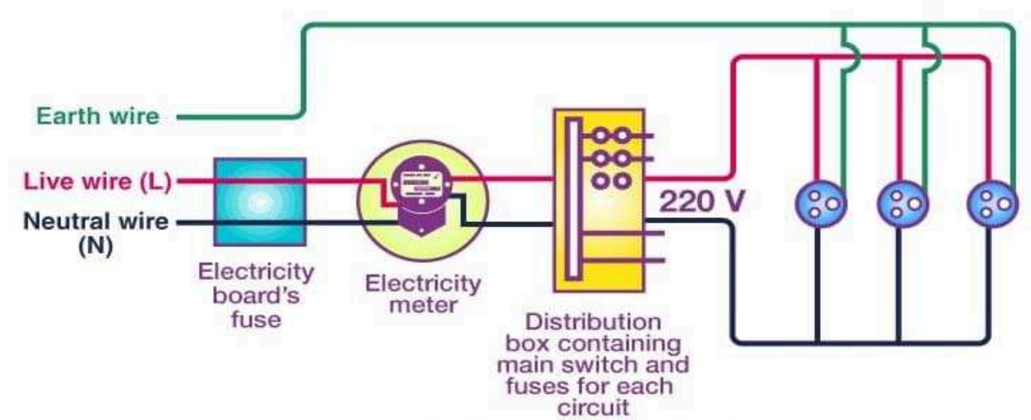
Wires from mains enter the electricity meter via main fuse.
From meter → main switch → distribution box → different circuits in the house.

Two types of circuits:

1)15 A circuit – high power appliances (geysers, electric irons, air coolers, etc.).

2) 5 A circuit – low power appliances (bulbs, fans, etc.).

Circuit Diagram



Domestic Electric Circuit

Shows live wire, neutral wire, and earth wire connections.
Appliances connected in parallel so each gets equal potential difference (220 V).

Electric Fuse

Definition: A fuse is an electrical safety device designed to protect circuits from overcurrents
It has low melting & high resistivity and works by melting a thin wire made with tin and lead
Function: Prevents damage to appliances and circuits by breaking or opening the circuit if current exceeds safe limit(short circuiting and overloading).

Short Circuiting

Definition: When the live wire and neutral wire come in contact directly or through a conducting wire, the circuit resistance becomes almost zero, causing a large current to flow, which is called short circuiting.
Result: It heats the wire dangerously and may lead to fire.

Overloading

Definition: When many high-power electrical appliances are switched on at the same time (or connected to the same socket) , they draw excessive current from the circuit, which is called overloading.
Result: Excessive current heats the wire and can cause fire hazards.

MCB: A miniature circuit breaker (MCB) is an Electrical Switch that automatically switches off the electrical circuit during an overload condition as well as a faulty condition.
Comparing fuse and MCB: Nowadays we use an MCB in a low-voltage electrical network instead of a fuse.Because the fuse may not sense it but the MCB does it in a more reliable way. MCB is much more sensitive to overcurrent than a fuse.