परमाणु ऊर्जा शिक्षण संस्था
(परमाणु ऊर्जा विभाग का स्वायत्त निकाय, भारत सरकार)
ATOMIC ENERGY EDUCATION SOCIETY
(An autonomous body under Department of Atomic Energy, Govt. of India)

DISTANCE TEACHING PROGRAMME

CLASS X SCIENCE

CHAPTER: MAGNETIC EFFECT OF CURRENT (MODULE 1/3)

Topics covered : 1. Magnetic field 2. Magnetic field lines 3. Magnetic field due to straight current carrying conductor 4. Magnetic field due to current carrying circular loop 5. Magnetic field due to current carrying solenoid and Electromagnet.

Introduction:

- **Magnet**: A magnet is a material which can attract substances like iron, nickel, cobalt steel etc. or it can deflect any magnetic compass needle.
- **Magnetic field**: The region around any magnet in which its magnetic behavior can be experienced is called as magnetic field. The strength of this magnetic field is measured by quantity magnetic field strength.
- **Magnetic field strength** is a quantity that has both direction and magnitude. The direction of the magnetic field strength is taken to be the direction in which a north pole of the magnetic compass needle moves inside it.
- Magnetic field strength is denoted by symbol **B** and its SI unit is **TESLA.**
- A bar magnet has two poles at its two ends where its magnetic attraction is maximum.
- These two poles are named as North Pole and South Pole. The end seeking towards geographic north of earth is called as North Pole and other end seeking towards geographic south of earth is called as South Pole. (Fig. A) Like poles repel to each other whereas opposite poles attract to each other.

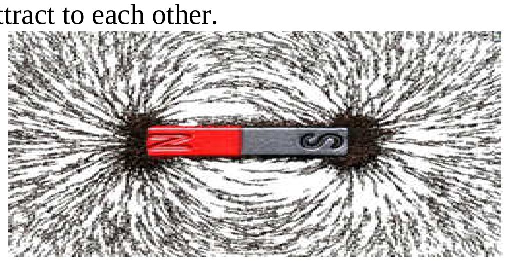

Fig. A A bar Magnet with its poles

- If any bar magnet is cut into two pieces then each piece become again a bar magnet with two poles. (Fig. B

Fig. B

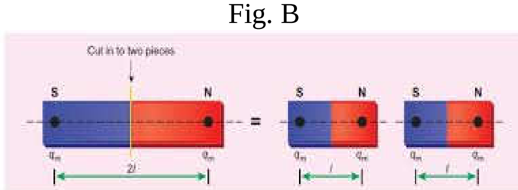

Figure 3.9 Properties of bar magnet

Magnetic effect of current: When electric current is passed through any wire then a field develops around that wire which attracts iron bodies and deflects magnetic compass needle, it is called as magnetic effect of current. Thus a current carrying wire behaves as bar magnet.

- Hans Oersted was the leading scientist who performed experiments related to electromagnetism. (Fig. C)

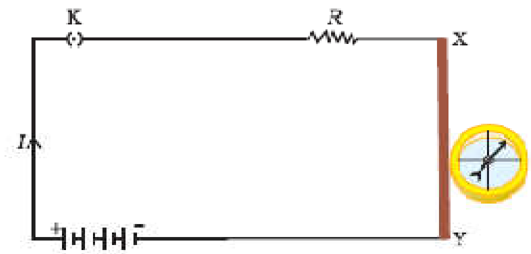

Figure C (Oersted experiment set up)

- 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 deflects in reverse direction. If we stop the flow of current, the needle comes at rest.

Hence, it can be concluded that electricity and magnetism are linked to each other. It shows that whenever the current will flow through the conductor, then a magnetic field will develop.

Magnetic field lines:

These are closed continuous curve along which a hypothetical north pole is free to move. These lines geometrically represent direction, strength and nature of magnetic field in any region. (Fig. D)

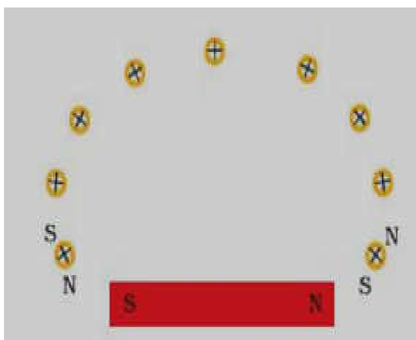

Figure D

Properties of Magnetic field lines:

- The tangent drawn at point to these lines gives direction of magnetic field strength at that point. (Fig. E)

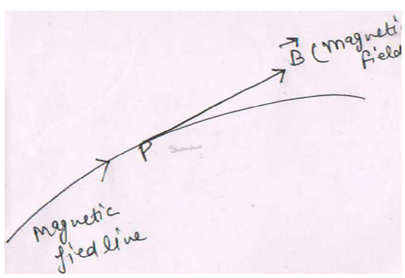

Figure E

- The direction of magnetic field lines outside the magnet is always from North Pole to South Pole of bar magnet and is denoted by an arrow. Inside the magnet, the direction of field lines is from its south pole to North Pole. Thus magnetic field lines are closed curves. (Fig. F)

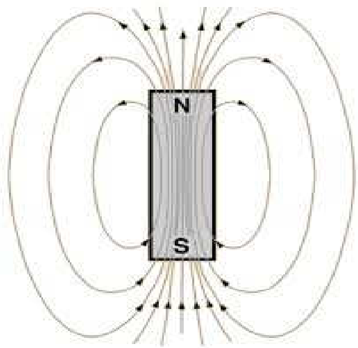

Figure F (magnetic field lines due to bar magnet)

- The strength of magnetic field is expressed by the closeness of magnetic field lines.
- Closer the lines, more will be the strength and farther the lines, less will be the magnetic field strength. (Fig. G)

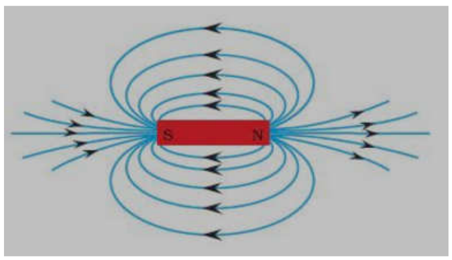

Figure G

- No two magnetic field lines will intersect each other. If they intersect, then at point of intersection the compass needle will show two directions of magnetic field which is not possible.

Magnetic Field due to straight current carrying conductor wire:

Activity: We take copper wire and insert it through a card board perpendicular to its plane and then connect both ends of wire with battery, plug key & rheostat (variable resistance). (Fig. H)

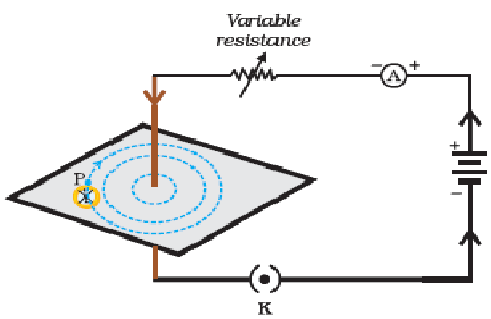

Figure H

Now if we spread iron filings uniformly on card board and switch on the current then we observe following observations:

- On passing current through the wire there occurs deflection in iron filings and this deflection increases when strength of current increases.

Now if a compass needle is placed near the wire keeping current constant then we observe that deflection in needle increases when it is near the wire and when it is at more distance from wire then deflection in needle decreases.

- Further if we tap the card board slightly then iron filings arrange themselves in circular pattern.

Conclusions:

- Magnetic field strength due to current carrying straight wire **directly proportional** to current in wire.
- Magnetic field strength due to current carrying wire is **inversely proportional** to the distance of observation point from the wire.
- Magnetic field lines pattern due to current carrying wire are in **circular shape.**

Maxwell Right handed thumb rule:

This rule gives the direction of magnetic field due to current carrying wire.

Statement: Imagine that we are holding a current-carrying straight conductor in our right hand such that the thumb points towards the direction of current. Then our fingers will wrap around the conductor in the direction of the field lines of the magnetic field, this is known as the right-hand thumb rule

So we can conclude that if direction of current in wire is upward then magnetic field line pattern will be anticlockwise and if current direction is downward then magnetic field line pattern will be clockwise in the plane of wire. (Figure I)

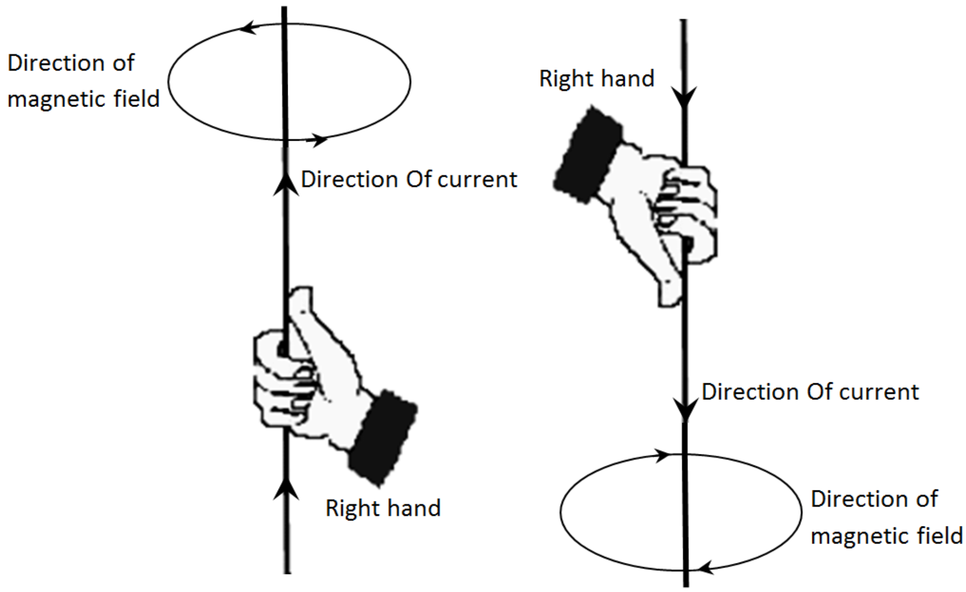

Figure I (Right hand thumb rule)

- **Problem: 1** 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?
  Sol. The current is in the east-west direction. Applying the right-hand thumb rule, we get that the direction of magnetic field at a point below the wire is from north to south. The direction of magnetic field at a point directly above the wire is from south to north.
- **Problem 2:** Which of the following correctly describes the magnetic field near a long straight wire?
  (a) The field consists of straight lines perpendicular to the wire.
  (b) The field consists of straight lines parallel to the wire.
  (c) The field consists of radial lines originating from the wire.
  (d) The field consists of concentric circles centered on the wire.
  Sol. Correct option is d

Magnetic Field due to a Current through a Circular Loop:

- We know that the magnetic field produced by a current-carrying straight wire depends inversely on the distance from it. Similarly at every point of a current-carrying circular loop, the concentric circles representing the magnetic field around it would become larger and larger as we move away from the wire. By the time we reach at the centre of the circular loop, the arcs of these big circles would appear as straight lines. Every point on the wire carrying current would give rise to the magnetic field appearing as straight lines at the center of the loop. (Figure J)
- Magnetic field strength due to current carrying circular loop is **directly proportional** to current in loop and number of turns in loop.
- Magnetic field strength due to current carrying circular loop is **maximum at its center** .Further smaller the radius of loop greater the magnetic field at its center.

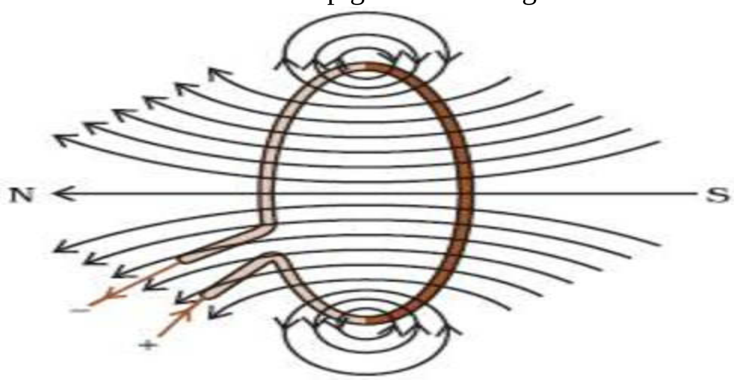

Figure J (Magnetic field due current carrying circular loop)

- Direction of magnetic field due to current carrying circular loop can be found by Right hand palm rule according to which If the direction of the circular current coincides with the direction of the curled fingers then the thumb points in the direction of the magnetic field. (Fig. K)

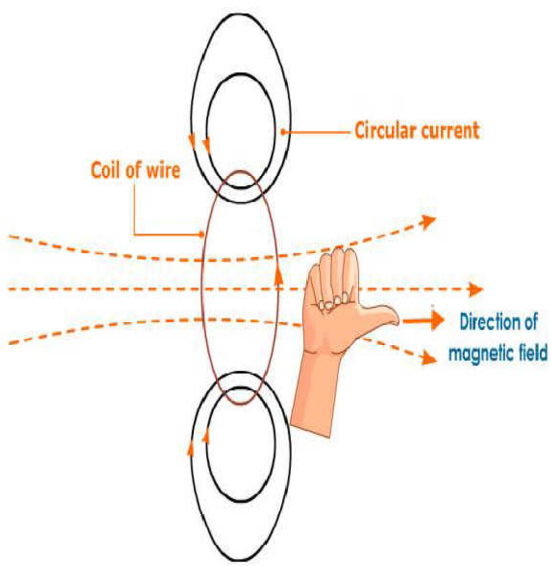

Figure K (Direction of magnetic field due to current carrying cicular loop)

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. (Fig. L)

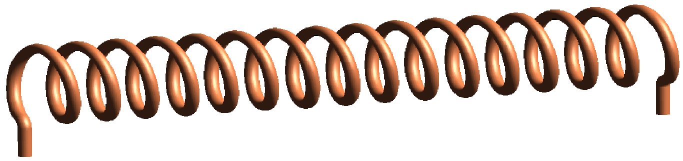

Figure L (Solenoid)

- Magnetic field line pattern inside long solenoid is in form of straight lines, which implies that there exist uniform magnetic field inside long solenoid along its axis which is same at all points. (Fig. M)

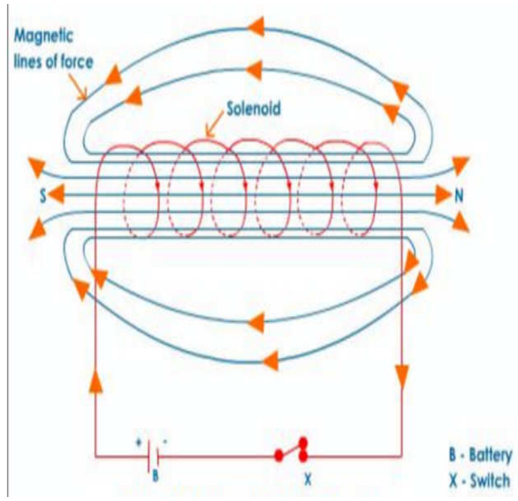

Figure M (Magnetic field line due to solenoid)

- Magnetic field strength at points situated at outside of solenoid is almost zero.
- A current carrying solenoid behaves as bar magnet. One end of solenoid in which current appears anticlockwise behaves as North Pole whereas other end in whish current will appear to flow in clockwise direction will behave as South Pole. (Fig. N)

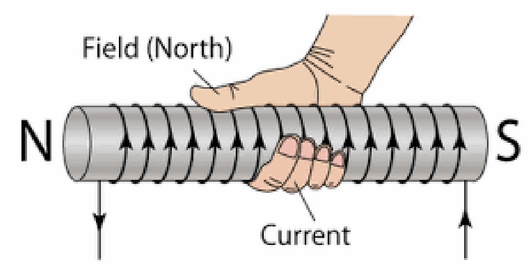

Figure N(Solenoid Equivalent to bar magnet)

- The magnetic field strength produced along axis of solenoid directly proportional to :
  (a) The number of turns (b) Strength of current in the solenoid turns
- **Electromagnet**: Strong magnetic field inside the solenoid can be used to magnetize a magnetic material for example soft iron, when it is placed inside the coil. The magnet so formed is called electromagnet. It is a temporary magnet. (Fig. O)

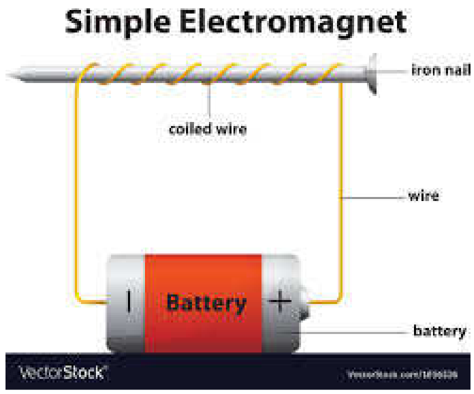

Figure O

- Electromagnets are used in electric bells, loudspeakers, telephone diaphragms and electric fan. Giant electromagnets are also used in cranes to carry materials in bulk.
- **Problem 3 :** Draw the magnetic field pattern due to uniform magnetic field

  Sol. See given figure P

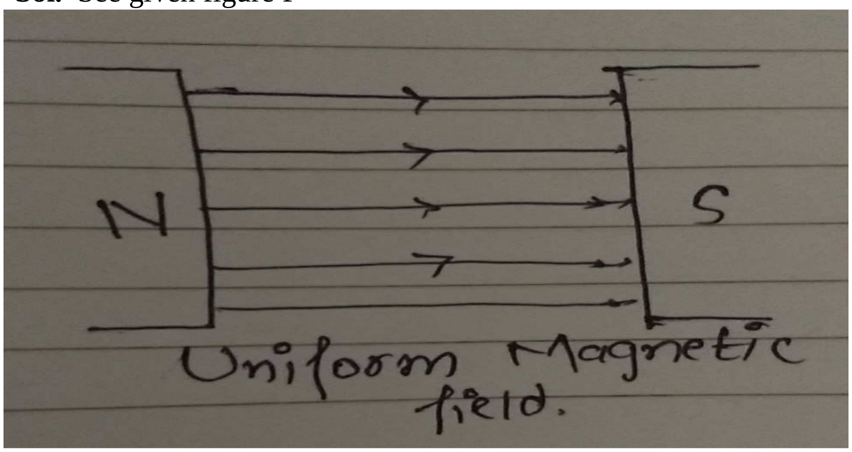

Figure P (uniform magnetic field)

- **Problem 4:** 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

Sol. Correct option is d

Refernces : NCERT Science X class , Wikipedia, H C Verma Physics

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