GEE-TECH COACHING CENTRE **CLASS X**

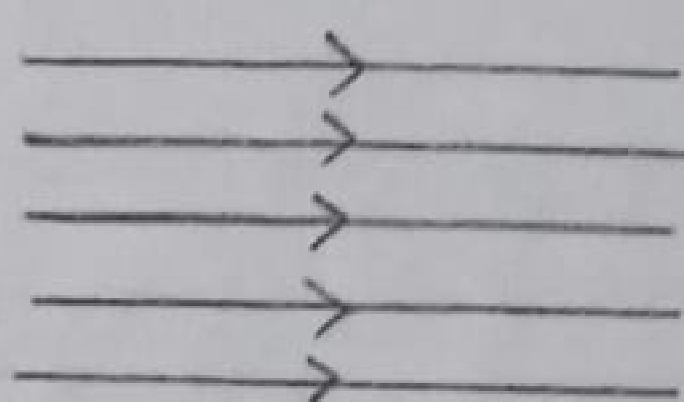
MAGNETIC EFFECTS OF ELECTRIC CURRENT

MAGNET – A magnet is an object which attracts pieces of iron, nickel, steel and cobalt. Magnets come in various shapes and sizes depending on their intended use. One of the most common magnet is BAR MAGNET, which is long, rectangular bar of uniform cross section. A magnet has two poles near its ends – NORTH POLE & SOUTH POLE. The end of a freely suspended magnet which points towards the north direction is called the north pole of the magnet and the one which points in south direction is called the south pole of the magnet. Like magnetic poles repel each other while unlike magnetic poles attract each other.

MAGNETIC FIELD – The space surrounding a magnet in which magnetic force is exerted (or experienced) is called a magnetic field. A compass needle placed near a magnet gets deflected due to the force exerted by the magnet and the iron filings also cling to the magnet due to magnetic force.

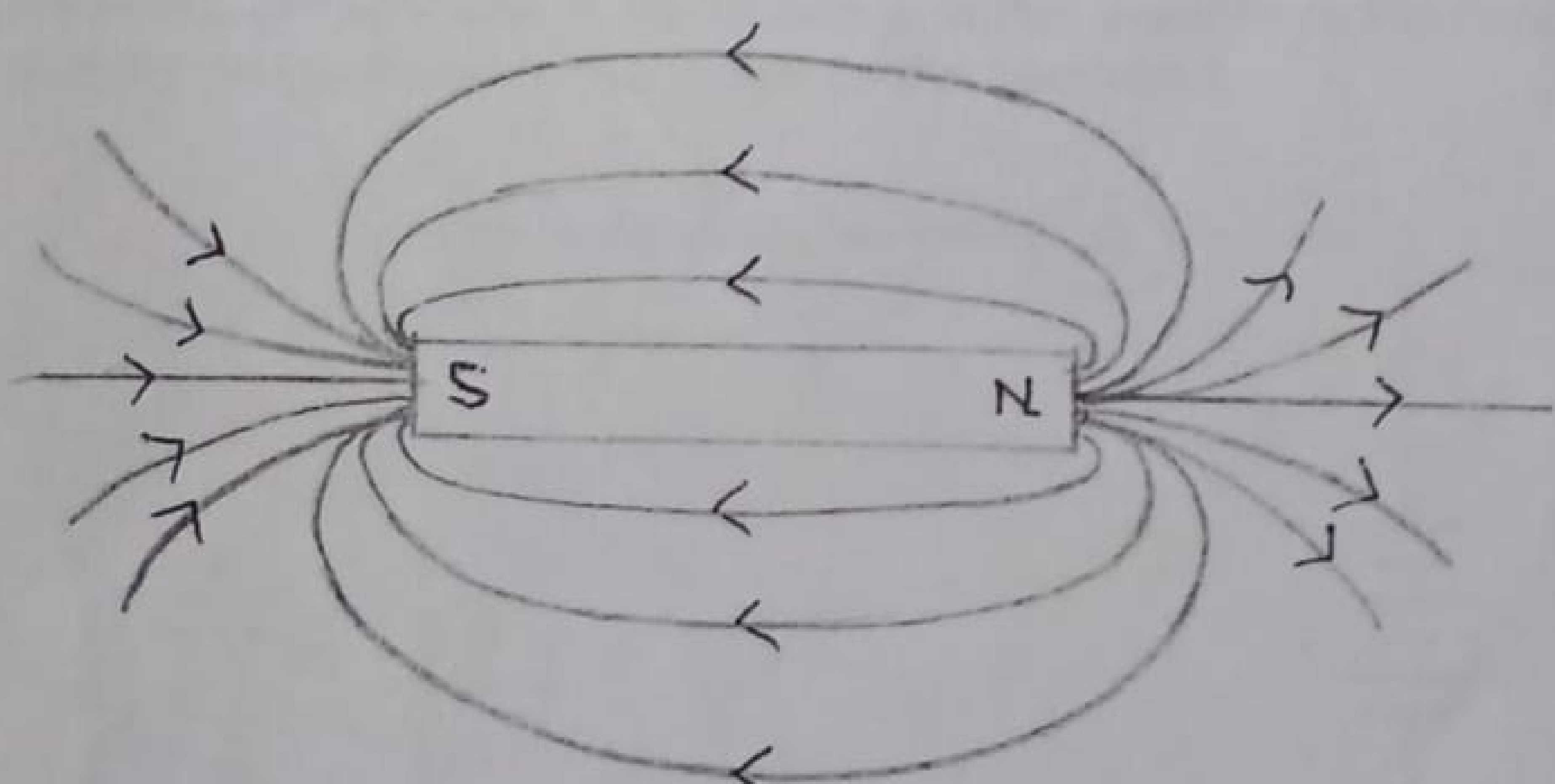
The magnetic field has both magnitude as well as direction. The direction of the magnetic field at a point is the direction of the resultant force acting on a hypothetical north placed at that point. The north end of the needle of a compass indicates the direction of magnetic field at a point where it is placed.

Uniform magnetic field is represented by equidistant and parallel field lines, all pointing in the same direction.



UNIFORM MAGNETIC FIELD

MAGNETIC FIELD LINES – Magnetic field lines are the lines drawn in a magnetic field along which a north magnetic pole would tend to move. The tangent at any point on the magnetic field line gives the direction of magnetic field at that point. Magnetic field lines due to a bar magnet can be drawn by using iron filings or compass. A compass consists of a tiny pivoted magnet usually in the form of a pointer which can turn freely in the horizontal plane. It gets deflected when brought near a bar magnet because the bar magnet exerts a magnetic force on the compass needle. The magnetic field lines around a bar magnet is shown below –



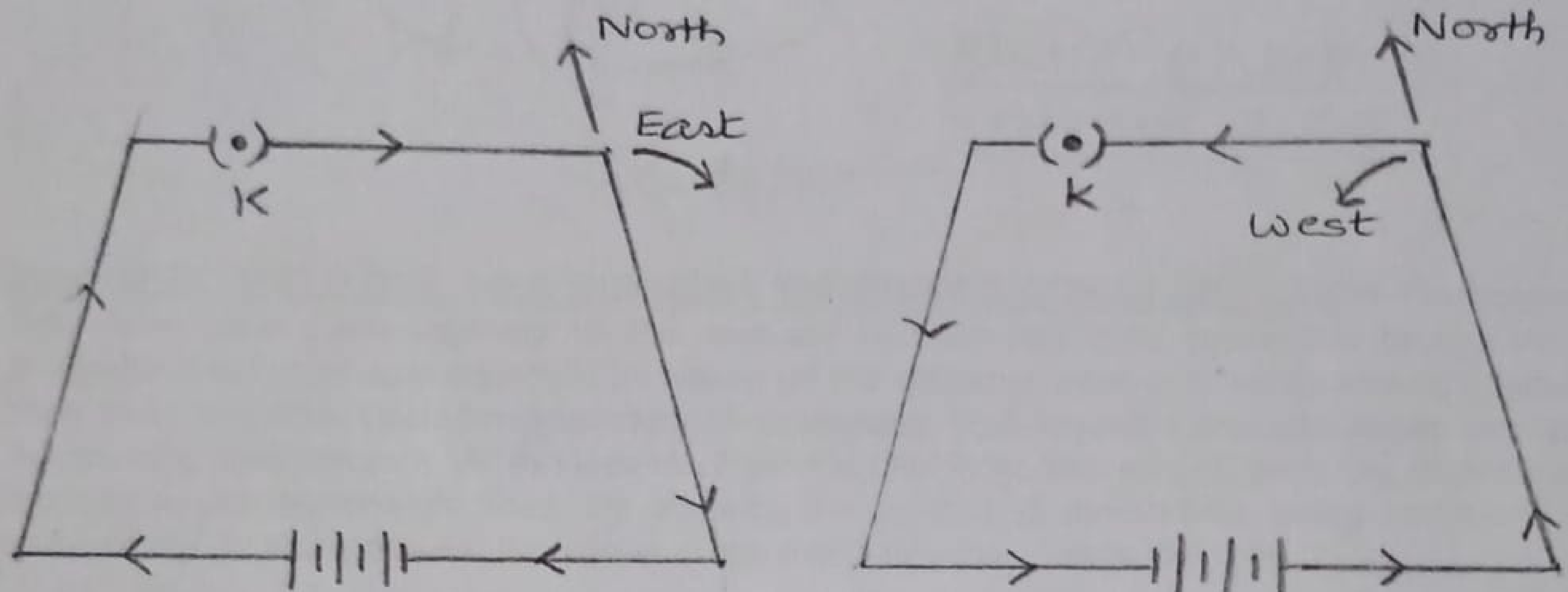
FIELD LINES AROUND A BAR MAGNET

Characteristics of magnetic field lines –

1. Magnetic field lines originate from the north pole of a magnet and ends at its south pole. Inside the magnet, the direction of the field lines is from south pole to north pole. Thus magnetic field lines are closed curves.

2. The magnetic field lines come closer to one another near the poles of a magnet where the magnetic field is strong. While these are widely separated at other places where the magnetic field is weak.
3. The magnetic field lines do not intersect or cross one another because if the two magnetic field lines intersect one another, then the resultant force on a north pole placed at the point of intersection will be along two directions, which is not possible.

MAGNETIC EFFECT OF CURRENT OR ELECTROMAGNETISM - The magnetic effect of current was first discovered by OERSTED in 1820. He observed that when an electric current is passed through a conducting wire, a magnetic field is produced around it. If a compass needle is placed in the vicinity of current carrying wire, The needle of the compass is found to deflect in one direction. The direction of the needle is reversed if the direction of the current in wire is reversed.

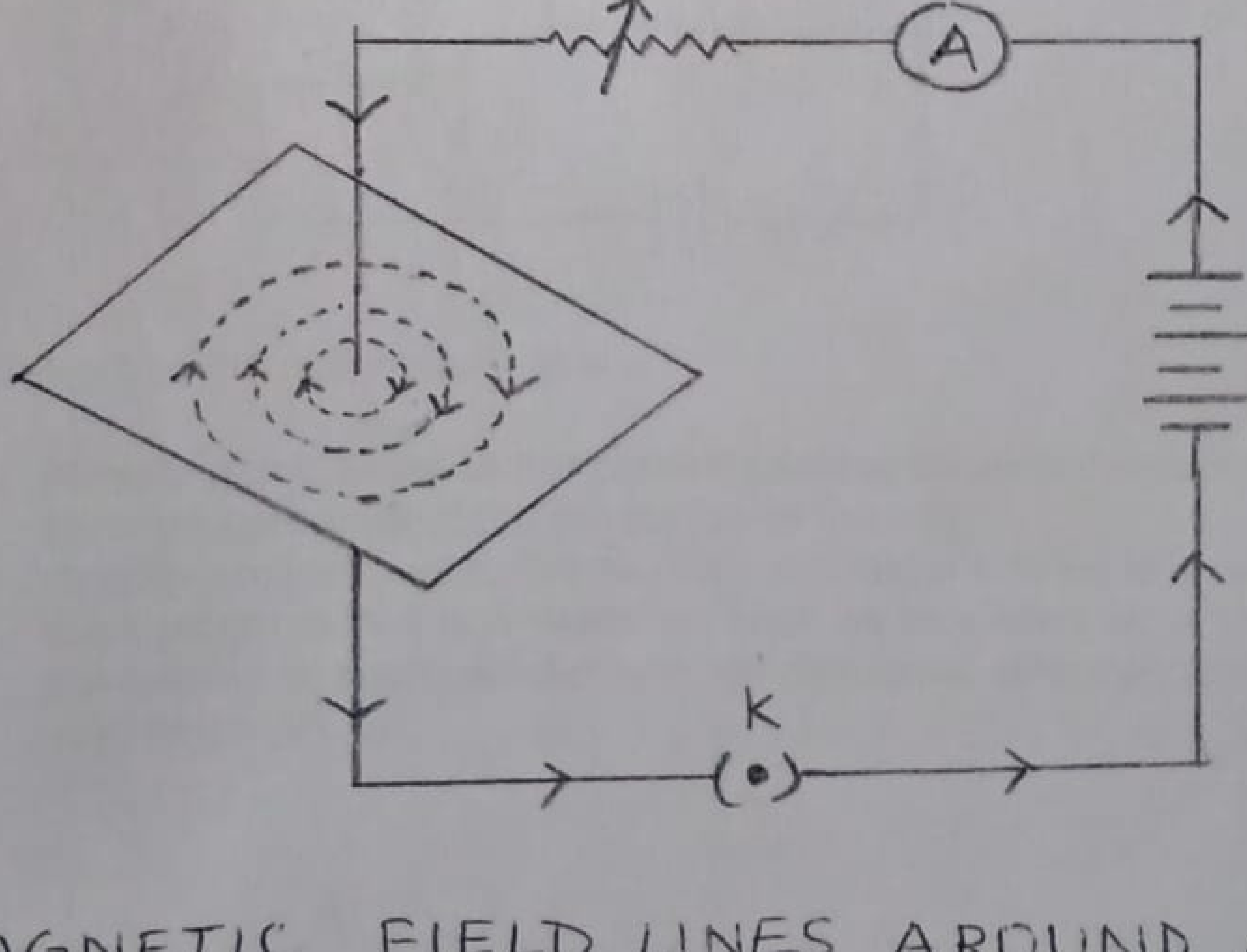


A SIMPLE ELECTRIC CIRCUIT IN WHICH A STRAIGHT COPPER WIRE IS PLACED PARALLEL TO & OVER A COMPASS NEEDLE

MAGNETIC FIELD DUE TO A CURRENT THROUGH A STRAIGHT CONDUCTOR – The magnetic field lines around a straight conductor carrying current are concentric circles whose centre lie on the wire.

The magnitude of magnetic field produced by a straight current carrying conductor at a given point is –

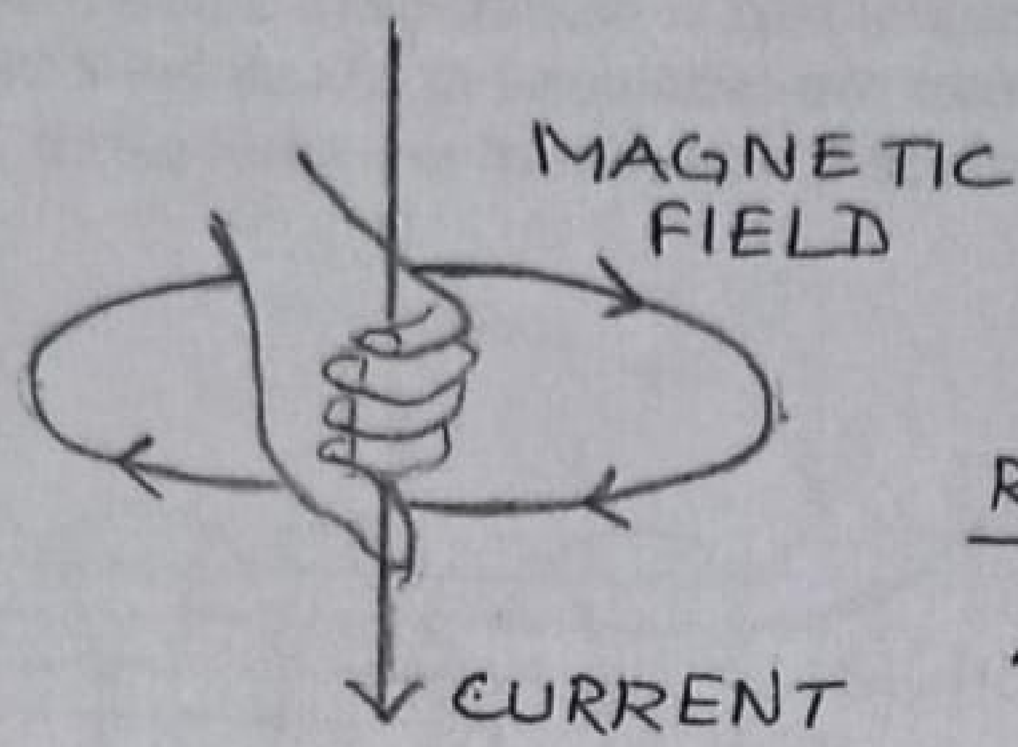
1. directly proportional to the current passing through conductor.
2. Inversely proportional to the distance of that point from the conductor
3. directly proportional to the length of the conductor



MAGNETIC FIELD LINES AROUND A STRAIGHT CURRENT CARRYING CONDUCTOR

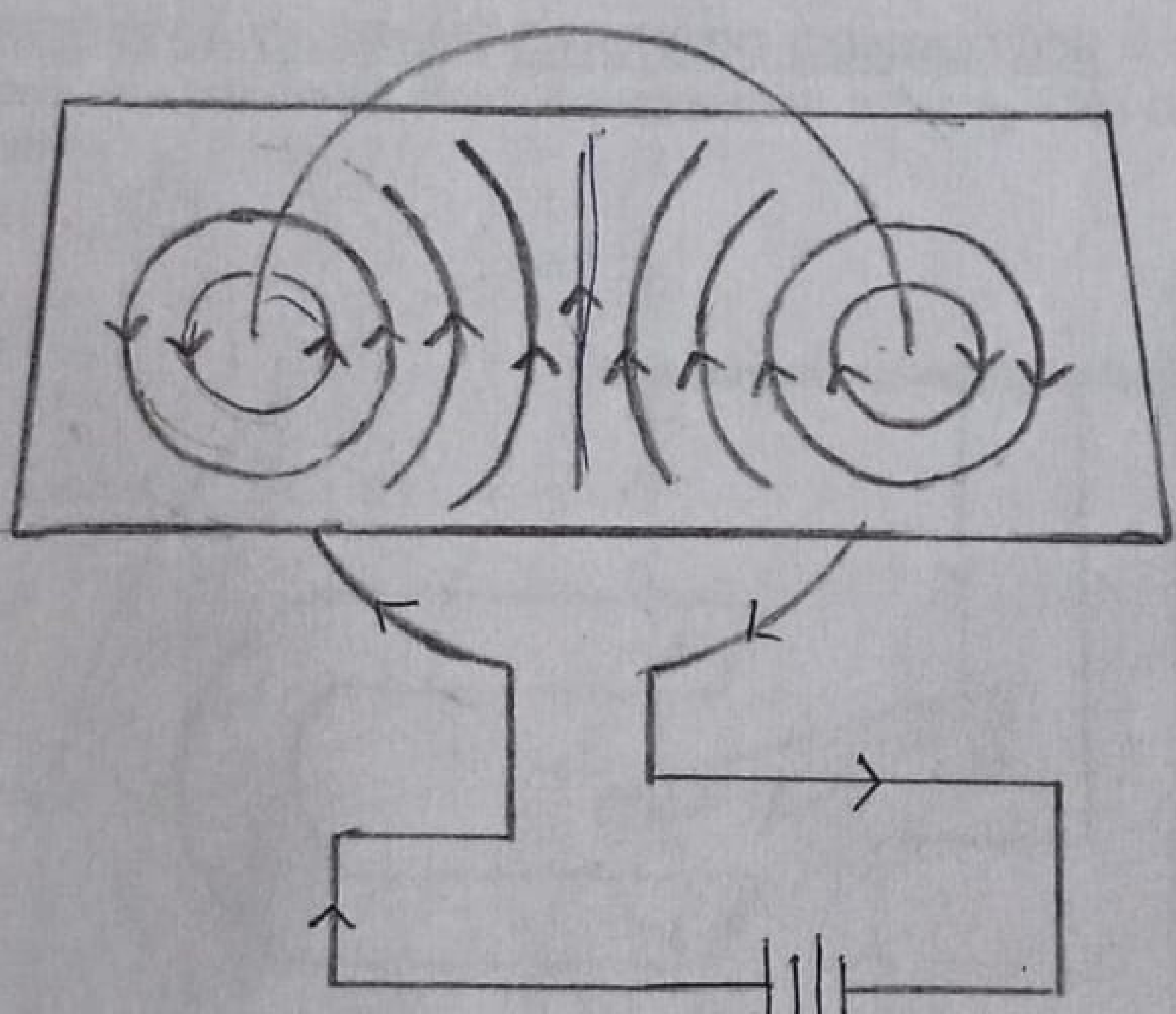
The direction of the magnetic field associated with a straight current carrying conductor is given by right hand thumb rule.

Right – Hand Thumb Rule – If we imagine the linear conductor to be hold in right hand such that the thumb points in the direction of current, then the curvature of the fingers around the conductor will represent the direction of magnetic field lines.



RIGHT-HAND THUMB RULE

MAGNETIC FIELD DUE TO A CURRENT THROUGH A CIRCULAR LOOP – The magnetic field lines near each segment of the wire are circular and form concentric circles. As the magnetic field produced depends inversely on the distance from a current carrying conductor thus the concentric circles representing the magnetic field around it become larger and larger on moving away from it. At the centre of the circular loop, the arcs of such big circles would appear as almost straight lines. By applying the right hand thumb rule, every section of wire contributes to the magnetic field lines in the same direction within the loop.



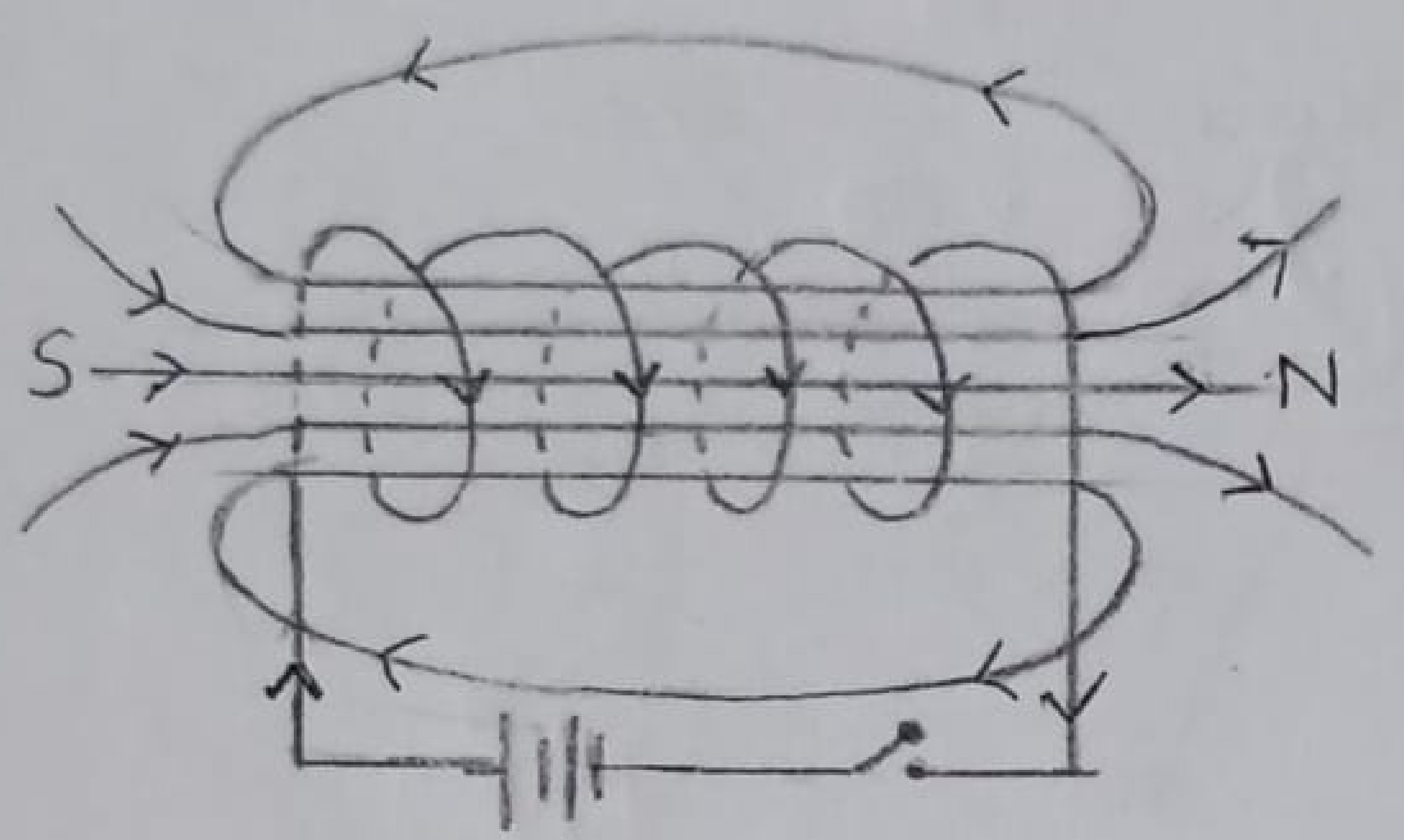
MAGNETIC FIELD LINES PRODUCED BY A CURRENT-CARRYING CIRCULAR LOOP.

The strength of the magnetic field is –

1. directly proportional to the current passing through conductor.
2. Inversely proportional to the radius of the coil
3. directly proportional to the number of turns – If there is a circular coil having 'n' turns, the field produced is n times as large as 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.

MAGNETIC FIELD DUE TO A CURRENT CARRYING SOLENOID – The **SOLENOID** is a coil of many turns of insulated copper wire wrapped closely in the shape of a cylinder. When an electric current flows through a solenoid, a magnetic field is set up which is similar to the magnetic field of a bar magnet. Hence –

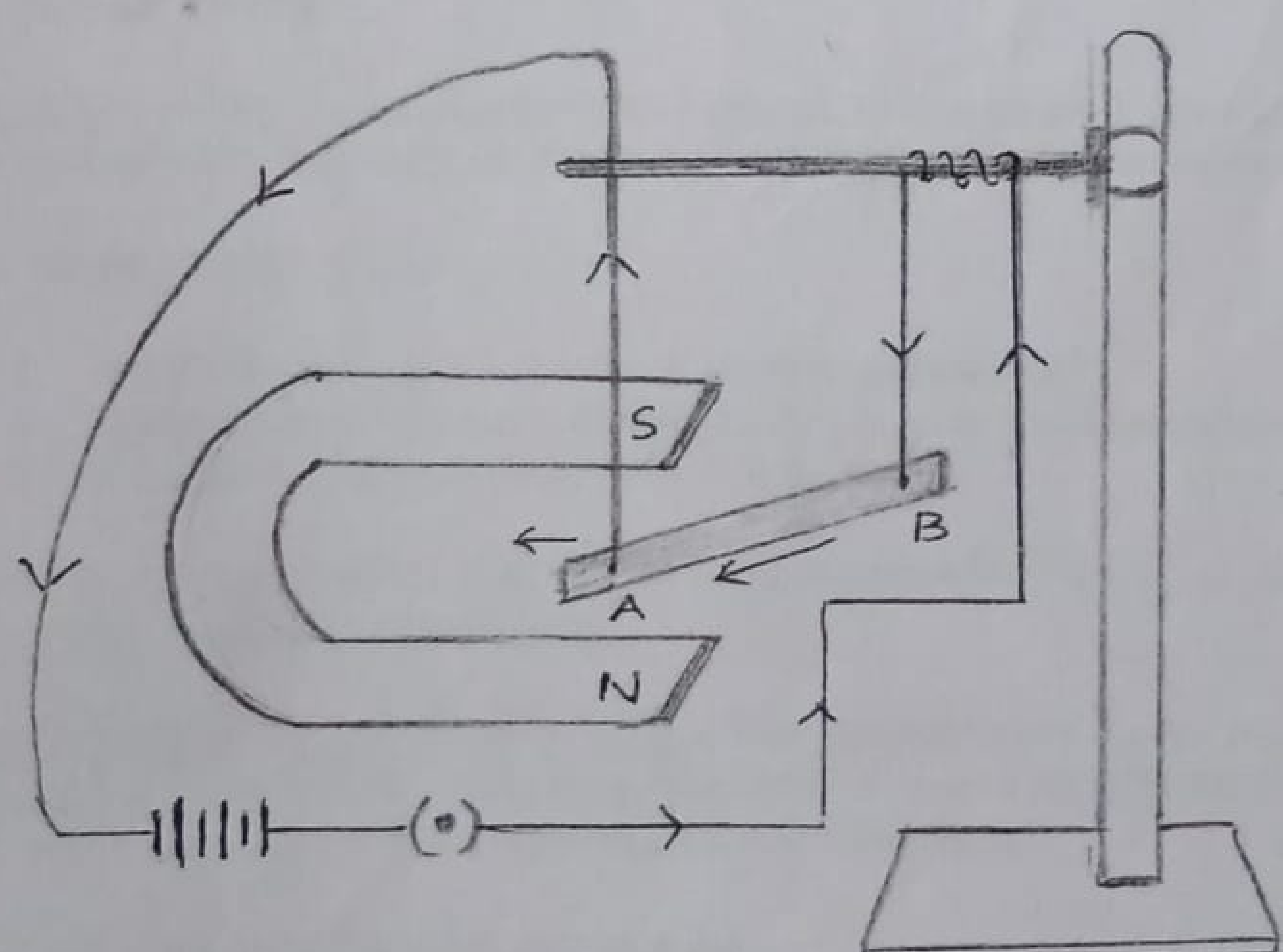
1. Magnetic field inside the solenoid is in the form of parallel straight lines. This indicates that magnetic field is same at all points or uniform inside the solenoid.
2. Magnetic field outside the solenoid is non uniform. It decreases at the end.
3. Magnetic field lines inside the solenoid are from south pole to north pole and outside the solenoid, these lines are from north to south pole.



MAGNETIC FIELD DUE TO A CURRENT CARRYING SOLENOID

A strong magnetic field inside a solenoid can be used to magnetize a piece of magnetic material, like soft iron, when placed inside the coil. The magnet so formed is called **ELECTROMAGNET.**

FORCE ON A CURRENT CARRYING CONDUCTOR – When a current carrying conductor is placed in a magnetic field, it experience a force. This can be demonstrated in the following activity –



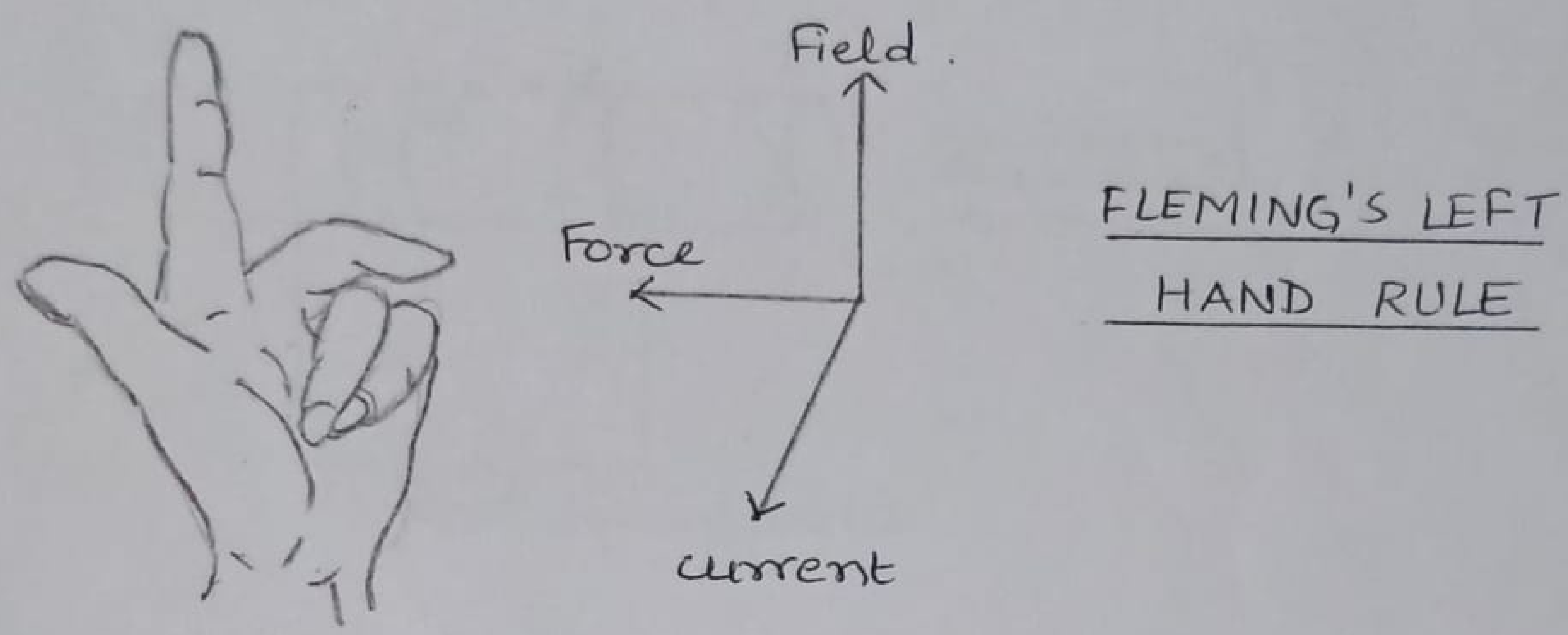
FORCE ON A CURRENT CARRYING CONDUCTOR IN A MAGNETIC FIELD

When the current is passed through aluminium rod (A B) placed in a magnetic field, force is exerted on the rod. Direction of the force is reversed –

1. On changing the direction of the current
2. The direction of field to vertically downwards by interchanging the two poles of magnet.

It shows that the direction of force on the conductor depends on the direction of current and direction of magnetic field. The displacement of the rod is found to be largest (or the magnitude of the force is highest) when the direction of current is at right angles to the direction of magnetic field and it is minimum or zero when the directions of current and magnetic field are parallel to each other.

The direction of the force on a current carrying conductor in a magnetic field is given by **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 the current, then the thumb will point in the direction of motion or the force acting on the conductor.



Devices that use current carrying conductors and magnetic fields include electric motor, electric generator, loudspeaker, microphone etc.

<u>ELECTRIC MOTOR</u> – Electric motor is a device that converts electrical energy into mechanical energy.

<u>Principle</u> – When a rectangular coil is placed in a magnetic field and current is passed through it, a torque (or force) acts on the coil which rotates it continuously.

The commercial motor use –

1. An electromagnet in place of permanent magnet.
2. Large number of turns of conducting wire in the current carrying coil
3. *A soft iron core on which the coil is wound*

The iron core on which the coil is wound, plus the coils, is called an **ARMATURE.** This enhances the power of the motor.

<u>ELECTROMAGNETIC INDUCTION</u> - The phenomenon in which electric current is induced in a circuit because of changing magnetic field is called **ELECTROMAGNETIC INDUCTION** and the current induced is known as **INDUCED CURRENT.**

<u>Different ways to induce current in a coil</u> -

1. Relative motion between –

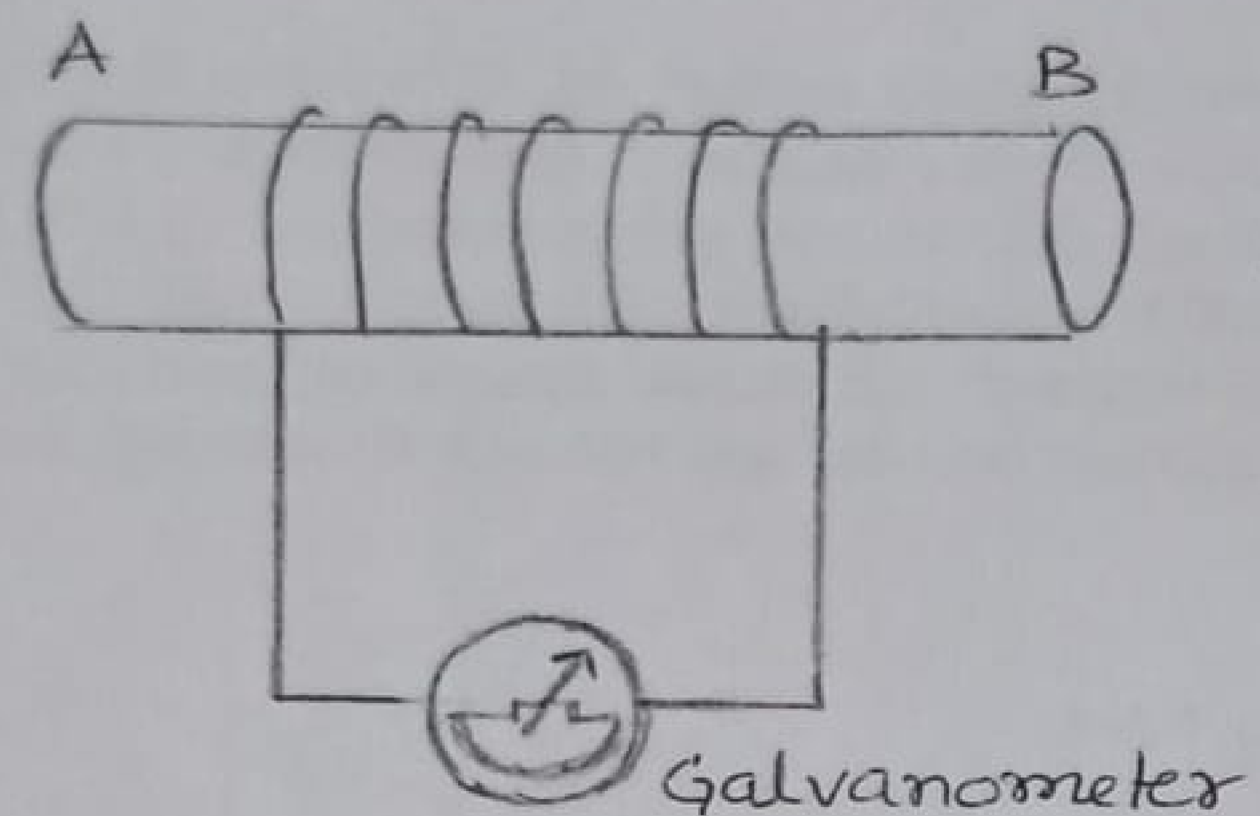
   (a) A coil and a magnet
   (b) A coil and a current carrying conductor

2. Change in the current in conductor placed near the coil.

The presence of induced current is detected by an instrument called **GALVANOMETER.** It is connected in series in the circuit. Its pointer remains at zero for zero current flowing through it. It can deflect either to left or to the right of the zero mark depending upon the direction of the current.

Some examples of inducing current is described below –

1. In this experiment, when a north pole of a bar magnet is moved towards the coil (as shown in the figure), there is a momentary deflection in the galvanometer (say towards right) thus indicating the presence of current in the coil AB. The deflection becomes zero the moment the motion of magnet stop.



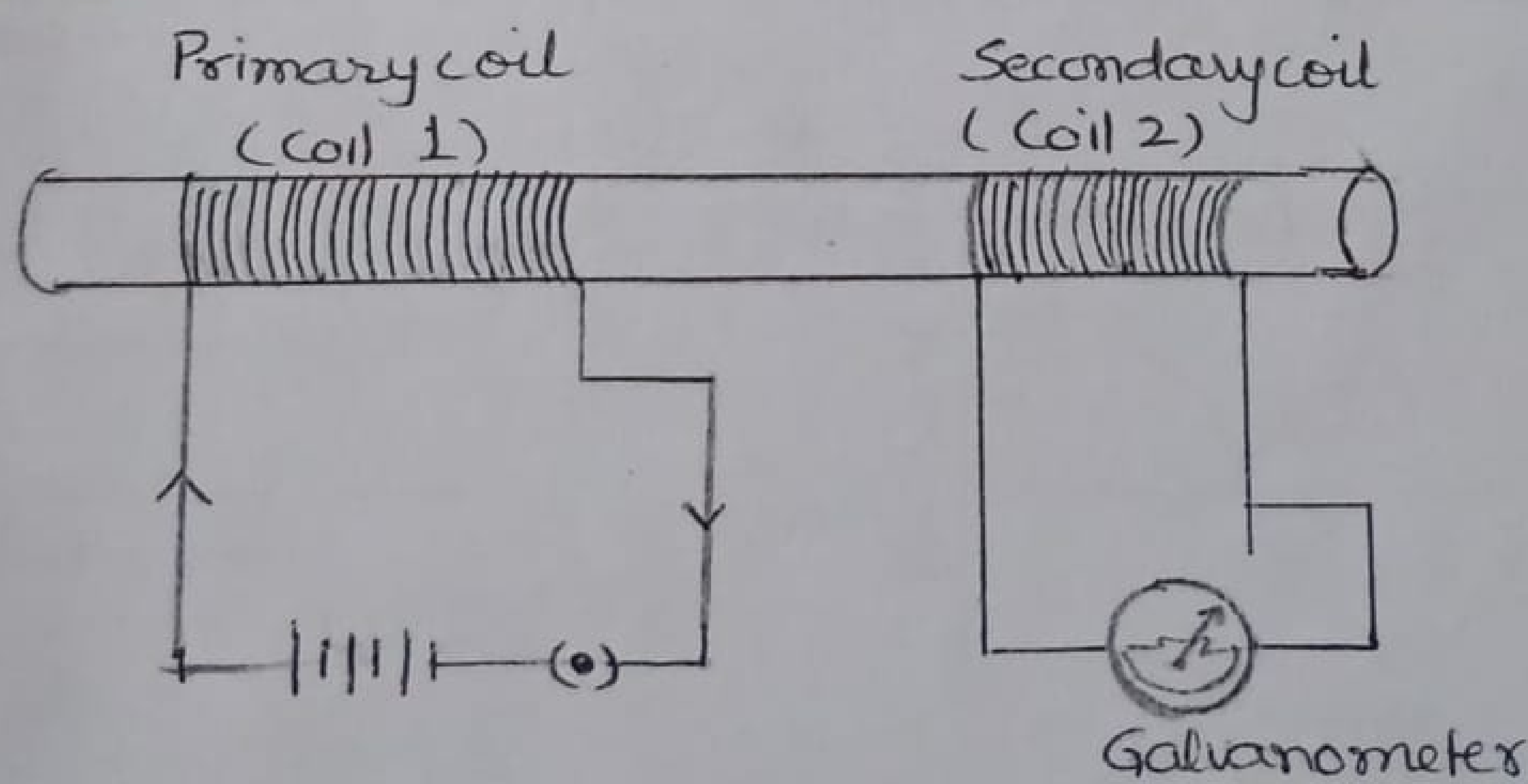
Now withdraw the north pole of the magnet away from the coil, the deflection in galvanometer is towards left showing that current is set up now in opposite direction.

Place the magnet stationary at a point near to the coil keeping the north pole towards B and coil is moved towards the magnet. Galvanometer shows deflection towards right. Similarly needle move towards left when the coil is moved away from the magnet.

If we move south pole of the magnet towards the end B of coil, the deflection will be towards left.

This shows that motion of a magnet with respect to the coil produces an induced potential difference, which sets up an induced current In the circuit.

2. Take two different coils of copper wire having large number of turns and connected as shown in the figure.

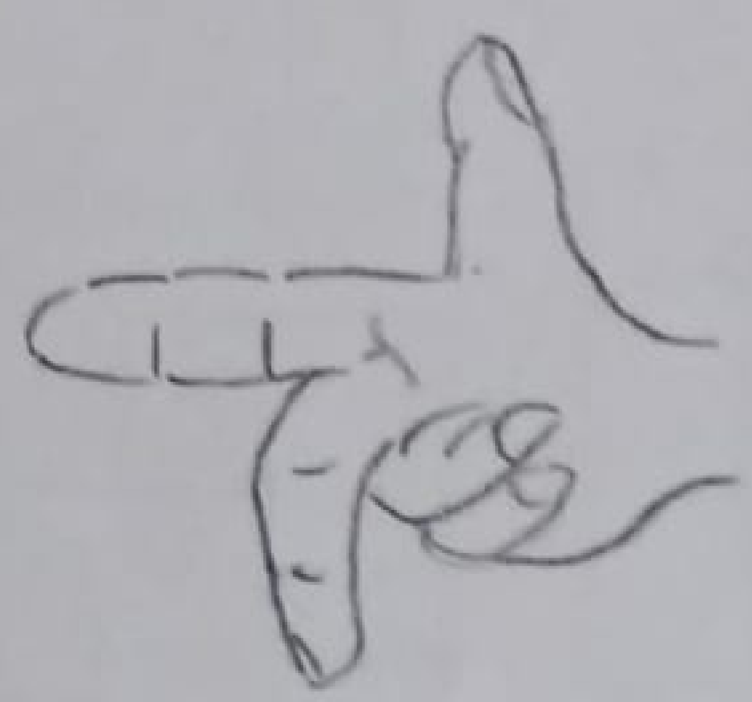


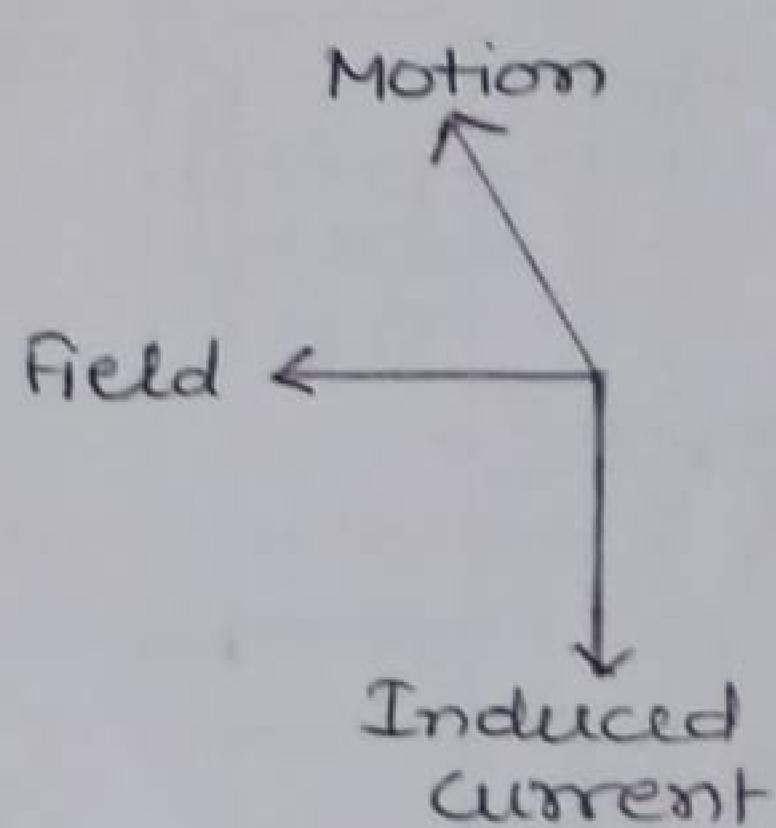
CURRENT IS INDUCED IN COIL-2 WHEN CURRENT IN COIL-1 IS CHANGED.

When we switch on the current in primary coil, there is a deflection in galvanometer to on side and then quickly returns to zero indicating momentary current in the secondary coil or coil 2. When we switch off the current, again the needle in galvanometer moves momentarily but to the opposite side. It means that now the current flows in opposite direction. This can be explained as follows –

When we switched on the current in coil 1 or primary coil, current increases from zero to some value in a very short time and similarly when we switch it off current decreases from some value to zero. As the current in the first coil changes, the magnetic field associated with it also changes. Thus the magnetic field lines associated with the secondary coil also change. Hence the change in magnetic field lines associated with the secondary coil induces the current in it.

The induced current is found to be highest when the direction of the motion of the coil is at right angles to the magnetic field. The direction of induced current is given by **FLEMING'S RIGHT HAND RULE.** According to this rule, stretch the thumb, forefinger and middle finger of right hand so that they are mutually perpendicular. If the forefinger indicates the direction of the magnetic field and the thumb shows the direction of motion of the conductor, then the middle finger will give the direction of the induced current.



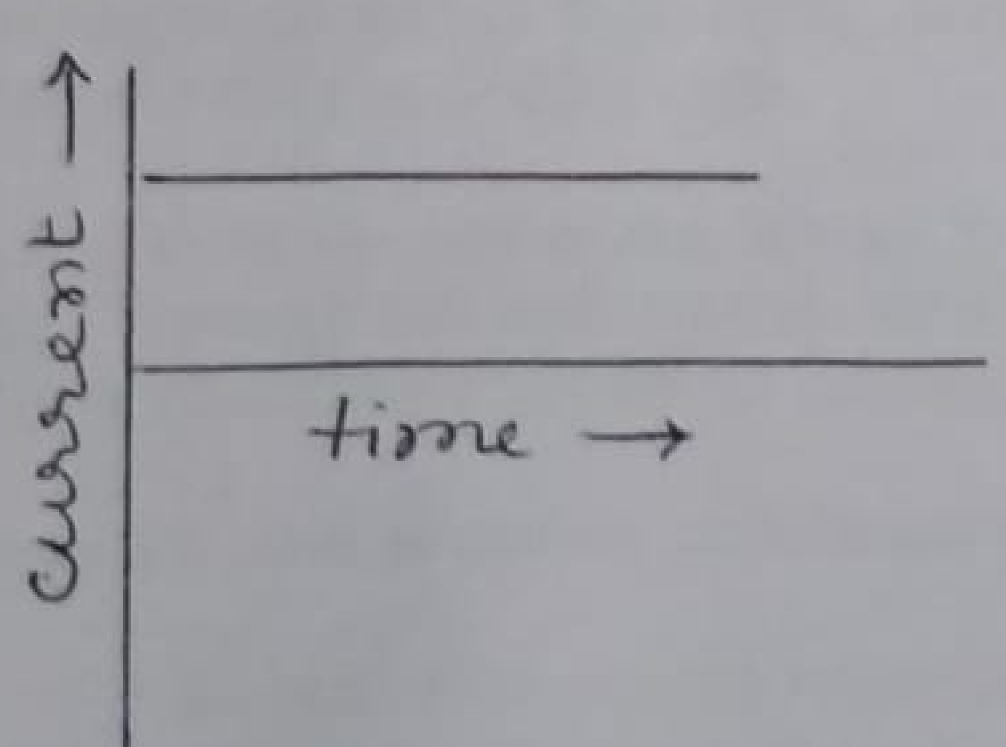


FLEMING'S RIGHT HAND RULE

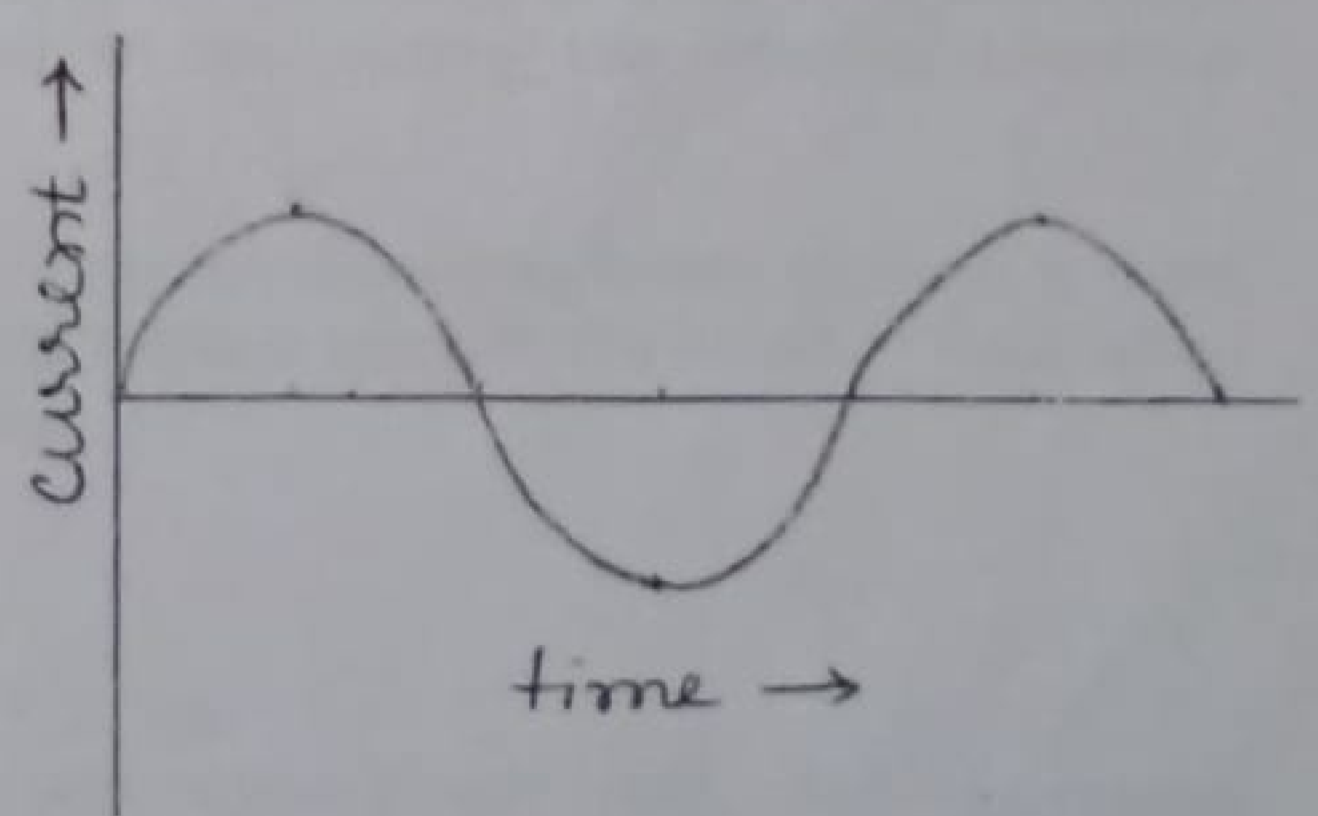
ELECTRIC GENERATOR – An electric generator is a device which converts mechanical energy into electrical energy.

Principle – It is based on electromagnetic induction i.e. when a conductor is moved in a magnetic field, then a current is induced in the conductor.

DIRECT CURRENT (DC) AND ALTERNATING CURRENT (AC) – A current which flows only in one direction is called direct current. Electrochemical cells and DC generator are examples of direct current.



DIRECT CURRENT



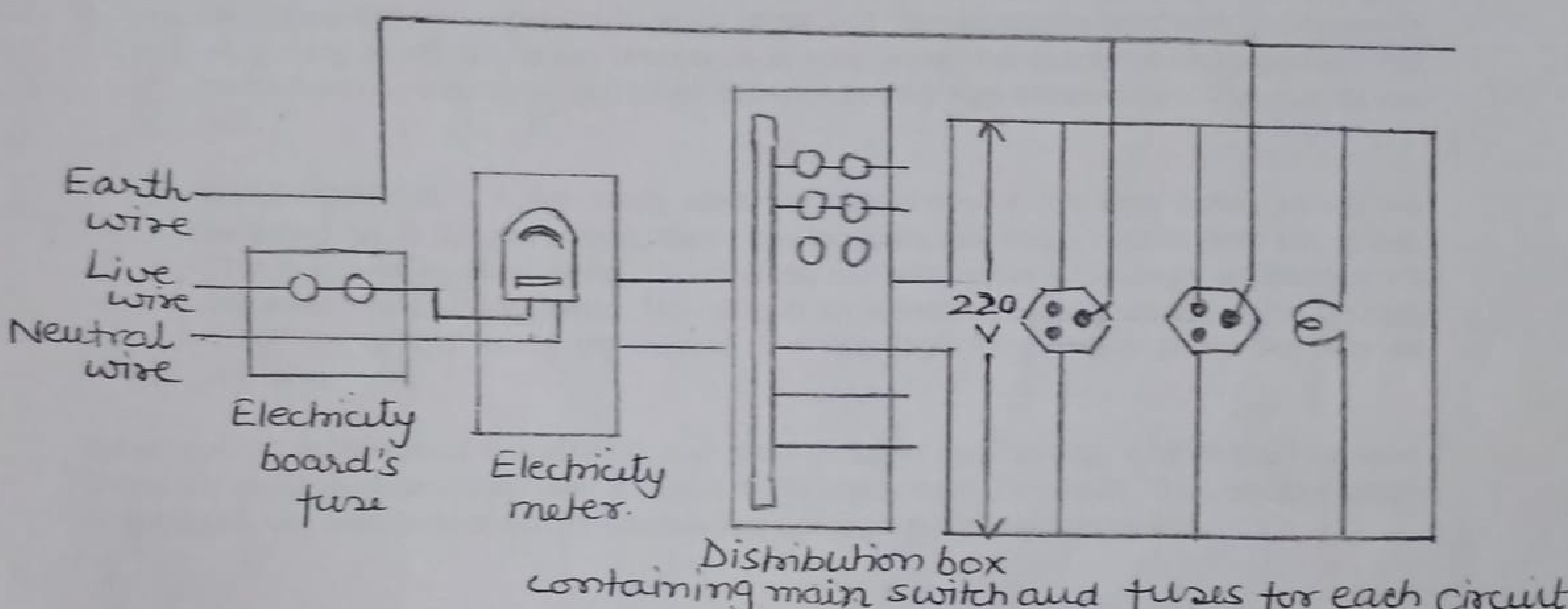
ALTERNATING CURRENT

A current which reverse its direction periodically is called alternating current. Power house generators and car alternators are examples of AC sources.. In India AC changes direction every 1/100 sec. i.e. the frequency of AC is 50 Hz.

The important advantage of AC over DC.is that electric power can be transmitted over long distance without much loss of energy. This is because for AC, voltage can be easily increased with transformer. For same power, if we increase voltage, then current will decrease and there will be less loss of energy in the form of heat.

Disadvantage of AC is that it is more dangerous than DC as AC attracts a person while DC repel. Secondly AC cannot be used for electrolysis or electroplating.

DOMESTIC ELECTRIC CIRCUITS – The schematic diagram of one of the common electric circuit is shown below.



A SCHEMATIC DIAGRAM OF DOMESTIC CIRCUIT

In our homes, we receive supply of electric power through a main supply, either supported through overhead electric poles or by underground cables. One of the wires in this supply, usually with red insulation cover, is called **LIVE WIRE** (or positive). Another wire, with black insulation, is called **NEUTRAL WIRE** (or negative). In our country, the potential difference between the two is 220 volts.

At the meter-board in the house, these wires pass into an electricity meter through a main fuse. Through the main switch they are connected to the line wires in the house. These wires supply electricity to separate circuits within the house.

Generally, two separate circuits are used –

1. Circuit of 5A current rating for bulbs, fans, T.V. etc.
2. Circuit of 15A current rating for appliances with higher power rating such as geysers, heaters, air conditioners etc.

In each separate circuit, different appliances can be connected across the live wire and neutral wires. Each appliance has separate switch to 'ON'/'OFF' the flow of current through it. In order that each appliance has equal potential difference, they are connected parallel to each other.

In addition to live and neutral wires, there is one more wire called **EARTH WIRE** which has insulation of green colour. It is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, especially for those appliances that have a metallic body, for example electric press, toaster, table fan, refrigerator etc. The metallic body is connected to the earth wire, which provides a low resistance conducting path for the current. This is called **EARTHING.** Thus it ensures that any leakage of current to the metallic body of the appliance keeps its potential to the earth and the user may not get a severe electric shock.

ELECTRIC FUSE is important component of all domestic circuits and is always connected in live wire. It prevent any damage to the appliances when there is excess current in the circuit which can flow in domestic wiring under two circumstances – short circuiting and overloading.

1. **SHORT CIRCUITING** - If the plastic insulation of the live wire and neutral wire gets torn, then the two wires touch each other and the resistance of circuit so formed is very, very small. Since the resistance is very small, the current flowing through the wires become very large and heats the wire to very high temperature. This can cause fire.

2. **OVERLOADING** - If too many electrical appliances of the high power rating are switched on at the same time, they draw an extremely large current from the circuit. This is known as overloading. Overloading can also occur if too many appliances are connected to a single socket. Now due to an extremely large current flowing through them, the copper wiring get heated to a very high temperature and a fire may be started.

When current in the circuit increases due to short circuit or overloading, it heats the fuse wire. Since the melting point of fuse wire is low, it melts and breaks the circuit. Thus electric supply is automatically switched off before there is any damage to electric appliances.