Chapter – 12

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'. In other words, electric current can produce magnetism.

Magnetic Field & Magnetic Field Lines

The space surrounding a magnet in which magnetic force is exerted, is called a magnetic field. A compass needle placed near a magnet gets deflected due to the magnetic 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 magnetic field at a point is the direction of the resultant force acting on a hypothetical north pole placed at that point.

The magnetic field lines are the lines drawn in a magnetic field along which a north magnetic pole would move. The magnetic field lines are also known as magnetic lines of force. The direction of a magnetic field line at any point gives the direction of the magnetic force on a north pole placed at that point. Since the direction of magnetic field line is the direction of force on a north pole, so the magnetic field lines always begin from the N-pole of a magnet and end on the S-pole of the magnet

Magnetic Field Due to A Current-Carrying Conductors

Take a long straight copper wire, two or three cells of 1.5 V each, and a plug key.

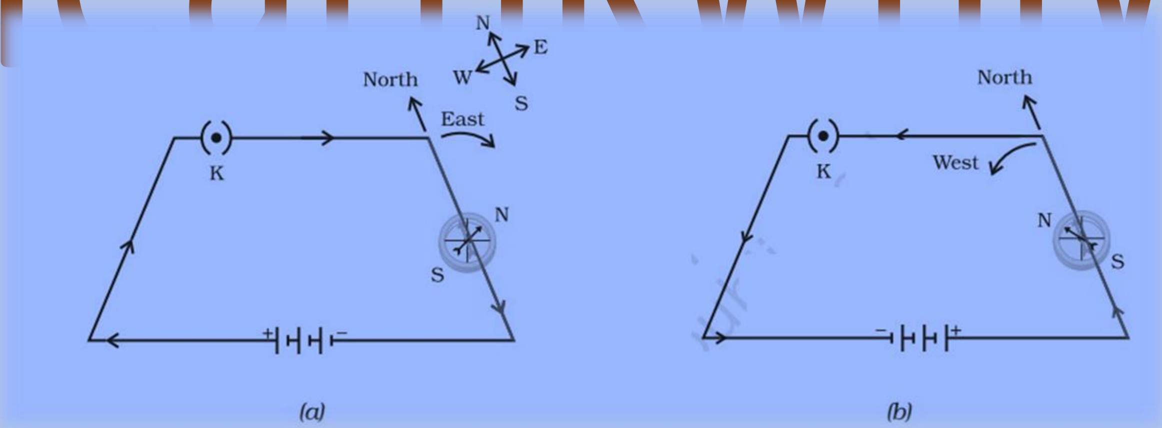
Connect all of them in series.

Place the straight wire parallel to and over a compass needle.

Plug the key in the circuit. ν Observe the direction of deflection of the north pole of the needle. If the current flows from north to south , the north pole of the compass needle would move towards the east.

Replace the cell connections in the circuit . This would result in the change of the direction of current through the copper wire, that is, from south to north.

Observe the change in the direction of deflection of the needle. You will see that now the needle moves in opposite direction, that is, towards the west . It means that the direction of magnetic field produced by the electric current is also reversed



Magnetic Field due to Straight Current-Carrying Conductor

Take a battery (12 V), a variable resistance (or a rheostat), an ammeter (0–5 A), a plug key, connecting wires and a long straight thick copper wire.

Insert the thick wire through the centre, normal to the plane of a rectangular cardboard. Take care that the cardboard is fixed and does not slide up or down.

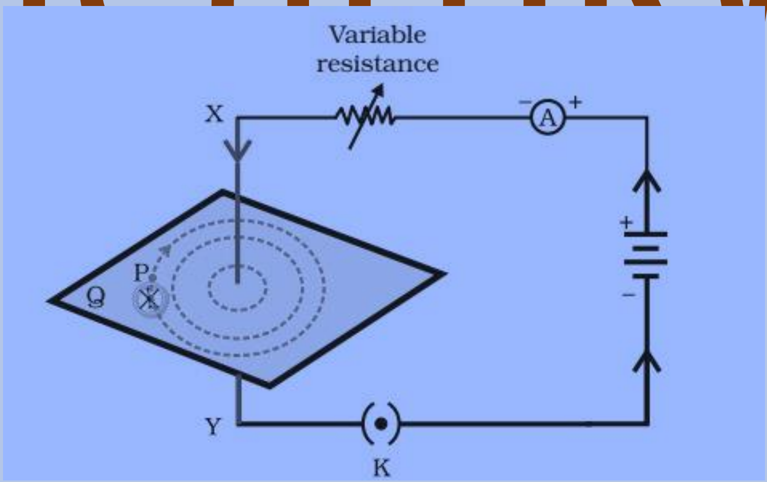
Connect the copper wire vertically between the points X and Y, in series with the battery, a plug and key.

Sprinkle some iron filings uniformly on the cardboard.

Keep the variable of the rheostat at a fixed position and note the current through the ammeter.

Close the key so that a current flows through the wire. Ensure that the copper wire placed between the points X and Y remains vertically straight

Gently tap the cardboard a few times. Observe the pattern of the iron filings. You would find that the iron filings align themselves showing a pattern of concentric circles around the copper wire.



the deflection of the compass needle placed at a given point if the current in the copper wire is changed

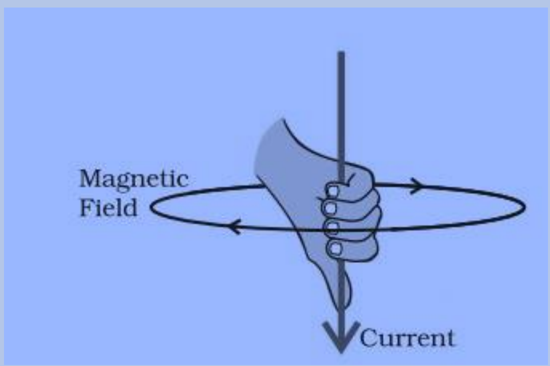
if the current is increased, the deflection also increases. It indicates that the magnitude of the magnetic field produced at a given point increases as the current through the wire increases

What happens to the deflection of the needle if the compass is moved away from the copper wire but the current through the wire remains the same?

place the compass at a farther point from the conducting wire (say at point Q). the deflection in the needle decreases. Thus the magnetic field produced by a given current in the conductor decreases as the distance from it increases., it can be noticed that the concentric circles representing the magnetic field around a current-carrying straight wire become larger and larger as we move away from it.

Right-hand thumb rule

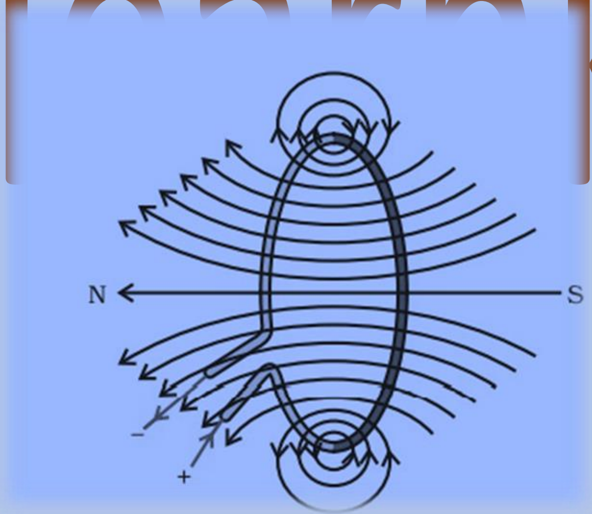
Imagine that you are holding a current-carrying straight conductor in your right hand such that the thumb points towards the direction of current. Then your fingers will wrap around the conductor in the direction of the field lines of the magnetic field. This is known as the right-hand thumb rule*



Magnetic Field due to a Circular Loop Carrying Current

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. By applying the right hand rule, it is easy to check that every section of the wire contributes to the magnetic field lines in the same direction within the loop.



the magnetic field produced by a current-carrying wire at a given point depends directly on the current passing through it. Therefore, 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

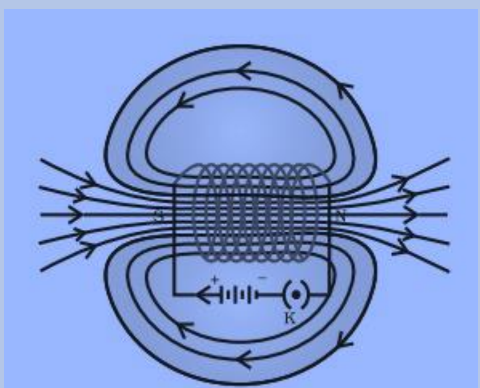
"This rule is also called Maxwell's corkscrew rule. If we consider ourselves driving a corkscrew in the direction of the current, then the direction of the rotation of corkscrew is the direction of the magnetic field "

Magnetic Field due to a Solenoid

The solenoid is a long coil containing many close turns of insulated copper wire.

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 behaves as a magnetic north pole, while the other behaves 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 the same at all points inside the solenoid. That is, the field is uniform inside the solenoid. A strong magnetic field produced inside a solenoid can be used to magnetise a piece of magnetic material, like soft iron, when placed inside the coil . The magnet so formed is called an electromagnet.



FORCE ON CURRENT-CARRYING CONDUCTOR PLACED IN A MAGNETIC FIELD

French scientist Andre Marie Ampere (1775–1836) suggested that the magnet must also exert an equal and opposite force on the current-carrying conductor.

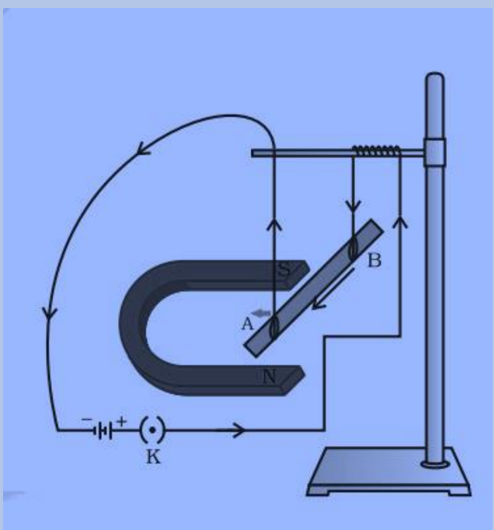
Take a small aluminium rod AB (of about 5 cm). Using two connecting wires suspend it horizontally from a stand,

Place a strong horse-shoe magnet in such a way that the rod lies between the two poles with the magnetic field directed upwards. For this put the north pole of the magnet vertically below and south pole vertically above the aluminium rod .

Connect the aluminium rod in series with a battery, a key and a rheostat. ν **Now pass a current through the aluminium rod from end B to end A**

It is observed that the rod is displaced towards the left.

Reverse the direction of current flowing through the rod and observe the direction of its displacement. It is now towards the right



The displacement of the rod in the above activity suggests that a force is exerted on the current-carrying aluminium rod when it is placed in a magnetic field. It also suggests that the direction of force is also reversed when the direction of current through the conductor is reversed.

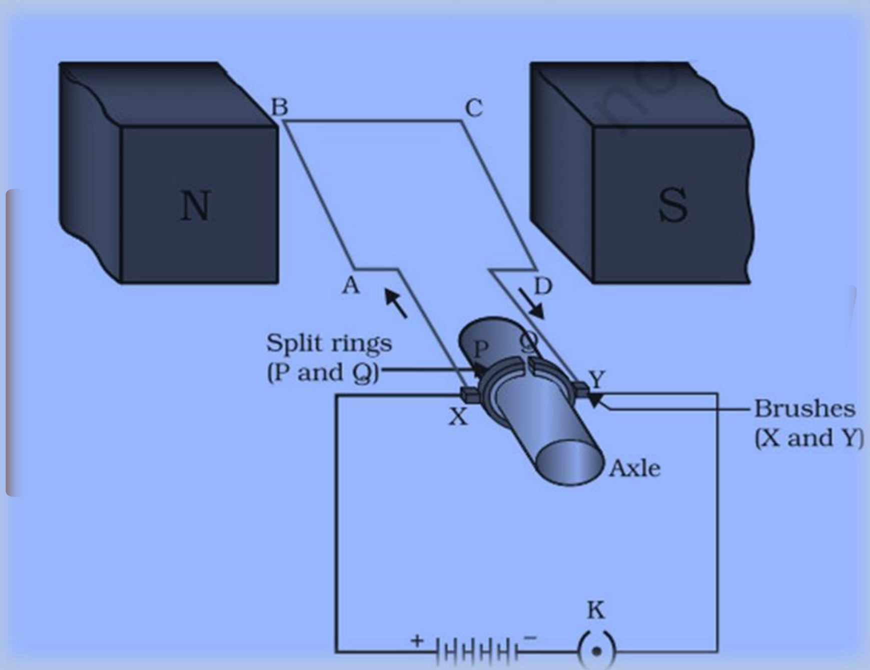
change the direction of field to vertically downwards by interchanging the two poles of the magnet. It is once again observed that the direction of force acting on the current-carrying rod gets reversed. It shows that the direction of the force on the conductor depends upon the direction of current and the direction of the magnetic field. Experiments have shown that the displacement of the rod is largest (or the magnitude of the force is the highest) when the direction of current is at right angles to the direction of the magnetic field.

we considered the direction of the current and that of the magnetic field perpendicular to each other and found that the force is perpendicular to both. The three directions can be illustrated through a simple rule, called 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.

THE ELECTRIC MOTOR

An electric motor is a rotating device that converts electrical energy to mechanical energy. Electric motor is used as an important component in electric fans, refrigerators, mixers, washing machines, computers, MP3 players etc.

An electric motor, consists of a rectangular coil ABCD of insulated copper wire. The coil is placed between the two poles of a magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field. The ends of the coil are connected to the two halves P and Q of a split ring. The inner sides of these halves are insulated and attached to an axle. The external conducting edges of P and Q touch two conducting stationary brushes X and Y, respectively,



Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y. Notice that the current in arm AB of the coil flows from A to B. In arm CD it flows from C to D, that is, opposite to the direction of current through arm AB. On applying Fleming's left-hand rule for the direction of force on a current-carrying conductor in a magnetic field

The force acting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards. Thus the coil and the axle O, mounted free to turn about an axis,

rotate anti-clockwise. At half rotation, Q contacts the brush X and P with brush Y. Therefore, the current in the coil gets reversed and flows along the path DCBA. A device that reverses the direction of flow of current through a circuit is called a commutator.

In electric motors, the split ring acts as a commutator. The reversal of current also reverses the direction of force acting on the two arms AB and CD. Thus the arm AB of the coil that was earlier pushed down is now pushed up and the arm CD previously pushed up is now pushed down. Therefore the coil and the axle rotate half a turn more in the same direction. The reversing of the current is repeated at each half rotation, giving rise to a continuous rotation of the coil and to the axle.

ELECTROMAGNETIC INDUCTION

magnetism (or magnets) can produce electric current. The production of electricity from magnetism is called electromagnetic induction.

The current produced by moving a straight wire in a magnetic field (or by moving a magnet in a coil) is called induced current. The phenomenon of electromagnetic induction was discovered by a British scientist Michael Faraday and an American scientist Joseph Henry independently in 1831. The process of electromagnetic induction has led to the construction of generators for producing electricity at power stations.

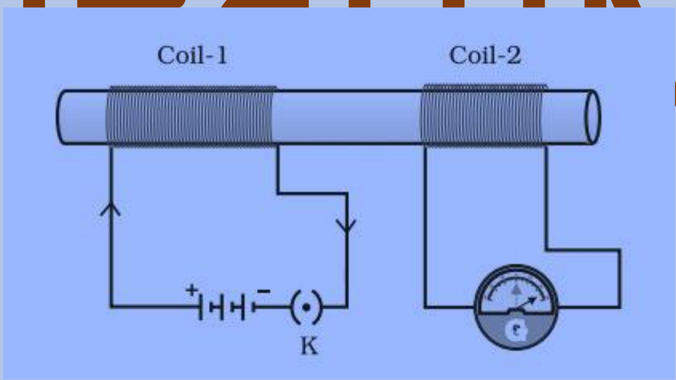
A galvanometer is an instrument which can detect the presence of electric current in a circuit.

Take two different coils of copper wire having large number of turns (say 50 and 100 turns respectively). Insert them over a non-conducting cylindrical roll.

Connect the coil-1, having larger number of turns, in series with a battery and a plug key. Also connect the other coil-2 with a galvanometer as shown.

Plug in the key. Observe the galvanometer. Is there a deflection in its needle? You will observe that the needle of the galvanometer instantly jumps to one side and just as quickly returns to zero, indicating a momentary current in coil-2.

Disconnect coil-1 from the battery. You will observe that the needle momentarily moves, but to the opposite side. It means that now the current flows in the opposite direction in coil-2



the current in coil-1 reaches either a steady value or zero, the galvanometer in coil-2. a potential difference is induced in the coil-2 whenever the electric current through the coil–1 is changing (starting or stopping). Coil-1 is called the primary coil and coil-2 is called the secondary coil.

As the current in the first coil changes, the magnetic field associated with it also changes. Thus the magnetic field

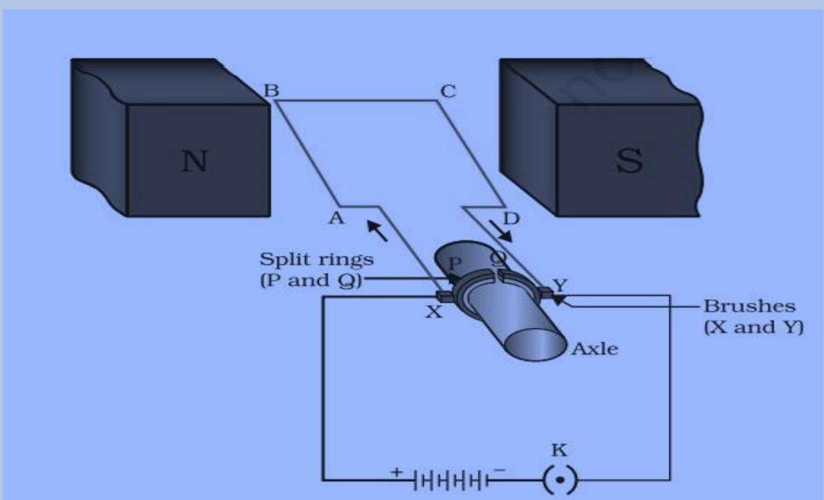
lines around the secondary coil also change. Hence the change in magnetic field lines associated with the secondary coil is the cause of induced electric current in it.

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

ELECTRIC GENERATOR

An electric generator, consists of a rotating rectangular coil ABCD placed between the two poles of a permanent magnet. The two ends of this coil are connected to the two rings R1 and R2. The inner side of these rings are made insulated. The two conducting stationary brushes B1 and B2 are kept pressed separately on the rings R1 and R2, respectively.

The two rings R1 and R2 are internally attached to an axle. The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field. Outer ends of the two brushes are connected to the galvanometer to show the flow of current in the given external circuit.



When the axle attached to the two rings is rotated such that the arm AB moves up (and the arm CD moves down) in the magnetic field produced by the permanent magnet.

By applying Fleming’s right-hand rule, the induced currents are set up in these arms along the directions AB and CD. Thus an induced current flows in the direction ABCD. If there are larger numbers of turns in the coil, the current generated in each turn adds up to give a large current through the coil. This means that the current in the external circuit flows from B2 to B1 .

After half a rotation, arm CD starts moving up and AB moving down. As a result, the directions of the induced currents in both the arms change, giving rise to the net induced current in the direction DCBA.

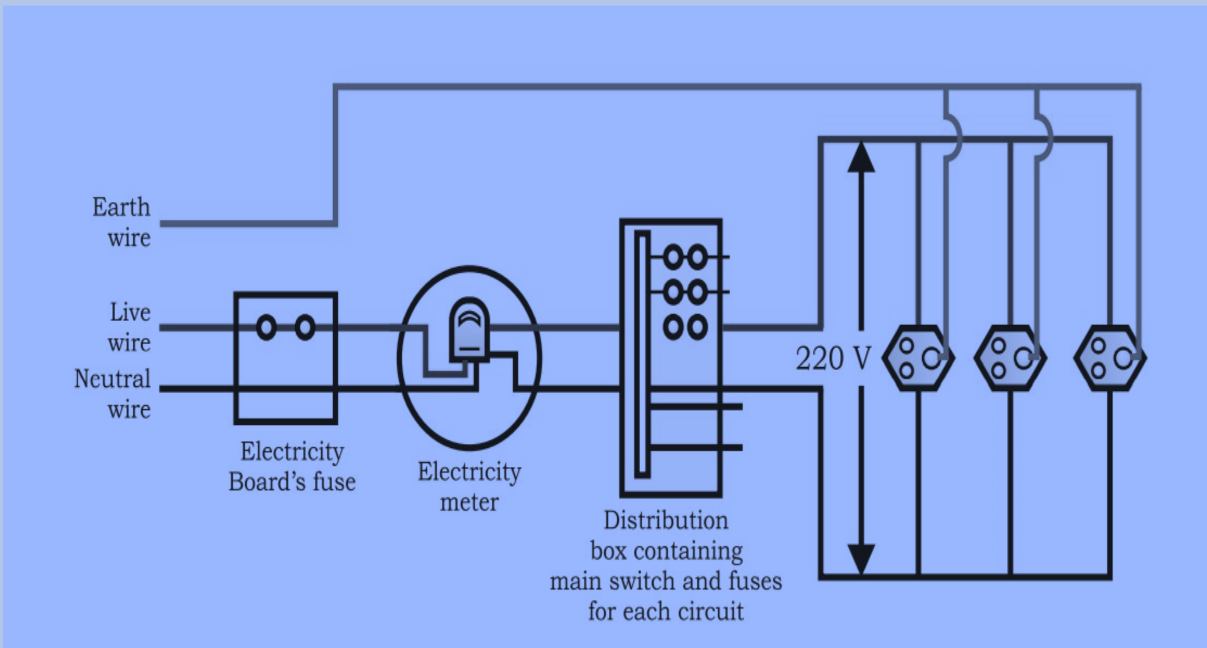
The current in the external circuit now flows from B1 to B2. Thus after every half rotation the polarity of the current in the respective arms changes. Such a current, which changes direction after equal intervals of time, is called an alternating current. This device is called an AC generator.

To get a direct current (DC, which does not change its direction with time), a split-ring type commutator must be used. 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.

Thus a unidirectional current is produced. The generator is thus called a DC generator.

DOMESTIC ELECTRIC CIRCUITS

In each separate circuit, different appliances can be connected across the live and neutral wires. Each appliance has a 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



A fuse in a circuit prevents damage to the appliances and the circuit due to overloading. Overloading can occur 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.) In such a situation, the current in the circuit abruptly increases. This is called short-circuiting. The use of an electric fuse prevents the electric circuit and the appliance from a possible damage 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.