4

MAGNETIC EFFECTS OF ELECTRIC CURRENT

INTRODUCTION

For most of the student magnetism means attraction of iron piece by magnet ,few of you may know that a current-carrying wire coil wrapped around an iron bar turns bar into a magnet, and about use of electromagnets in electric machinery.

Magnetism is generally defined as that property of a material which enables it to attract pieces of iron. A material possessing this property is known as a magnet. The word magnet is derived from the name of an island in Greece called magnesia where magnetic ore deposits were found.

In ancient times, both Greeks and Chinese knew about natural magnets, rare chunks of iron-rich mineral known as lodestones. The Chinese also knew that if you rubbed a steel needle against a lodestone, in a fixed direction, it also became a magnet. Around the year 1000, they furthermore found that if a magnet or lodestone was placed on a little "boat" floating in a bowl of water, it always pointed in a fixed direction and for a magnetized iron bar, that direction was always north-south. You could rotate the bowl, but the magnet would keep pointing in the same direction. In 1600 BC William Gilbert published a book De Magnete which gave an account of then known facts of magnetism. Due to their irregular shapes and weak attracting power natural magnets are rarely used. Lodestone or magnetite is natural magnet. Earth is also a natural magnet.

We now know that the Earth, too, is magnetic. From that came the magnetic compass, quickly copied by Arab navigators and then by Europeans. We may wonder today if lodestones did not exist, the compass might have stayed undiscovered for a long time, and would Columbus have ventured so far from land without it ?

If you dip a bar magnet into a cup of nails, nails will stick to it. But exactly, why? You know that magnets attract iron, but then you also note, some nails stick to other nails. Why that ?

Gilbert guessed that the reason was that ordinary iron turned into a magnet whenever it touched another magnet. Soft iron (not steel) loses its magnetism once it is taken away, but while in contact with a magnet, he proposed, it too acts like a magnet, and its polarity is always in a direction which helps it stick to the first magnet. Thus one nail attracts another. He proved his hunch by showing that such temporary magnets not only attracted, but could also repel.

In order to properly understand the principles of electricity, it is necessary to study magnetism and the effects of magnetism on electrical equipment. Magnetism and electricity are so closely related that the study of either subject would be incomplete without at least a basic knowledge of the other.

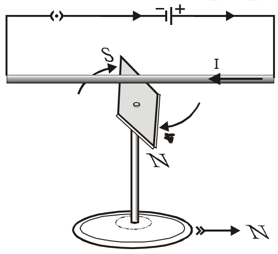
Much of today's modern electrical and electronic equipment could not function without magnetism. Modern computers, tape recorders, and video reproduction equipment use magnetized tape. High-fidelity speakers use magnets to convert amplifier outputs into audible sound. Electrical motors use magnets to convert electrical energy into mechanical motion; generators use magnets to convert mechanical motion into electrical energy.

In the chapter we will learn about magnetic field due to current carrying conductor and its benefits in detail.

OERSTED'S EXPERIMENT

After the invention of electric batteries. Electric currents were a hot scientific topic, but no one suspected they had anything to do with magnetism. A Danish professor, Hans Christian Oersted, prepared for some friends a science demonstration in his home. It included the heating of a wire by an electric current from a battery, and also some demonstrations of magnetism, using a compass on a stand .While carrying out the heating experiment, Oersted noted that every time he connected the current, the compass needle moved, too, something completely unexpected. No one else took notice. In the four months that followed he tried hard to make sense of the phenomenon; but he couldn't. The compass needle was neither attracted nor repelled, but tended to stand perpendicular to the wire.

Following Oersted's article, the effect was confirmed by Andre-Marie Ampere, he felt that if a current in a wire exerted a magnetic force on a compass needle, two such wires also should interact magnetically. In a series of ingenious experiments he showed that this interaction was simple and fundamental parallel (straight) currents attract, anti-parallel currents repel.

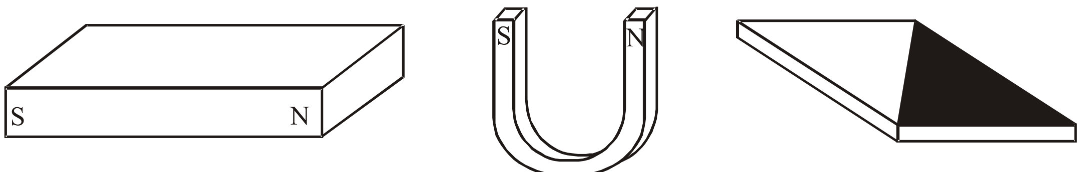


Oersted's experiment. Current in the wire deflects the compass needle.

The force between two long straight parallel currents was inversely proportional to the distance between them and proportional to the intensity of the current flowing in each .Loops of current attract or repel like magnets, coils with many loops multiplied the magnetic force, and Ampere guessed that iron atoms were magnetic because electric currents (soon named "Ampere currents") circulated in them.

Artificial magnets :

Magnets produced from magnetic materials are called Artificial magnets. They can be made in a variety of shapes and sizes and are used extensively in electrical apparatus.



Bar-magnet   U-shape magnet   Magnetic-needle

Artificial magnets are generally made from special iron or steel alloys which are usually magnetized electrically. The material to be magnetized is inserted into a coil of insulated wire and a heavy flow of electrons is passed through the wire. Magnets can also be produced by stroking a magnetic material with magnetite or with another artificial magnet. The forces causing magnetization are represented by magnetic lines of force.

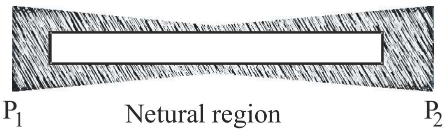
Artificial magnets are usually classified as permanent or temporary, depending on their ability to retain their magnetic properties after the magnetizing force has been removed. Magnets made from substances, such as hardened steel and certain alloys which retain a great deal of their magnetism, are called permanent magnets.. These materials are relatively difficult to magnetize because of the opposition offered to the magnetic lines of force as the lines of force try to distribute themselves throughout the material. The opposition that a material offers to the magnetic lines of force is called reluctance. All permanent magnets are produced from materials having a high reluctance.

A material with a low reluctance, such as soft iron or annealed silicon steel, is relatively easy to magnetize but will retain only a small part of its magnetism once the magnetizing force is removed. Materials of this type that easily lose most of their magnetic strength are called temporary magnets. The amount of magnetism which remains in a temporary magnet is referred to as its residual magnetism. The ability of a material to retain an amount of residual magnetism is called the retentivity of the material.

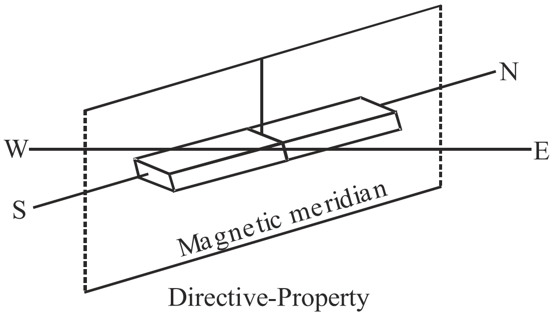
Magnets are also described in terms of the permeability of their materials, or the ease with which magnetic lines of force distribute themselves throughout the material. A permanent magnet, which is produced from a material with a high reluctance, has a low permeability. A temporary magnet, produced from a material with a low reluctance, would have a high permeability.

PROPERTIES OF BAR MAGNET

(1) Attractive Property and Poles : When a magnet is dipped into iron fillings it is found that the concentration of iron filings, i.e., attracting power of the magnet is maximum at two points near the ends and minimum at the centre. The places in a magnet where its attracting power is maximum are called poles while the place of minimum attracting power is called the neutral region.



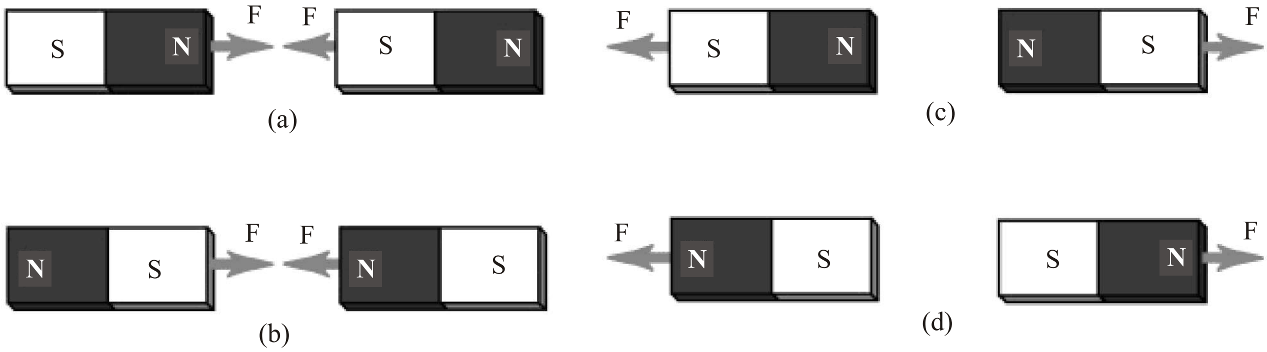
Attractive Property



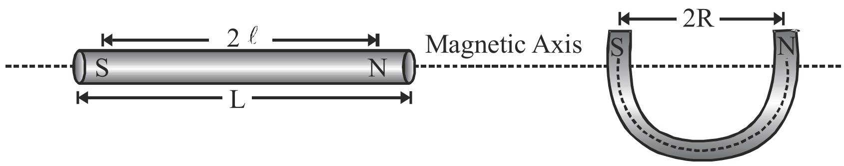
Directive-Property

(2) Directive Property and N-S Poles : When magnet is suspended its length becomes parallel to N-S direction. The pole pointing north is called the north pole while the other pointing south is called the south pole.

(3) Opposite poles (N and S) attract and like poles (N and N, or S and S) repel.



(4) Magnetic Axis and Magnetic Meridian : The line joining the two poles of a magnet is called magnetic axis and the vertical plane passing through the axis of a freely suspended or pivoted magnet is called magnetic meridian.



Effective length = 2ℓ
Actual length = L

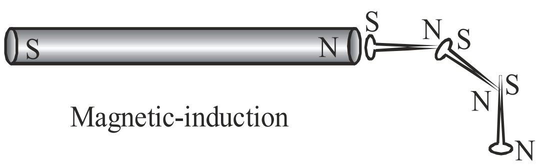
Effective length = 2R
Actual length = πR

(5) Magnetic Length (2ℓ) : The distance between two poles along the axis of a magnet is called its effective or magnetic length. As poles are not exactly at the ends, the effective length is lesser then the actual length of the magnet.

(6) Poles Exist in Paris : In a magnet the two poles are found to be equal in strength and opposite in nature. If a magnet is broken into number of pieces, each piece becomes a magnet with two equal and opposite poles. This shows that monopoles do not exist.

(7) Repulsion is a Sure Test of Polarity : A pole of a magnet attracts the opposite pole while repels similar pole. A sure test of polarity is repulsion and not attraction, as attraction can take place between opposite poles or a pole and a piece of unmagnetised magnetic material due to 'induction effect'.

(8) Magnetic Induction : A magnet attracts certain other substances through the phenomenon of magnetic induction i.e., by inducing opposite pole in a magnetic material on the side facing it as shown in fig.



Magnetic-induction

Activity :

- Fix a sheet of white paper on a drawing board using some adhesive material.
- Place a bar magnet in the centre of it.
- Sprinkle some iron filings uniformly around the bar magnet. A salt-sprinkler may be used for this purpose.
- Now tap the board gently.
- What do you observe?

Interesting:

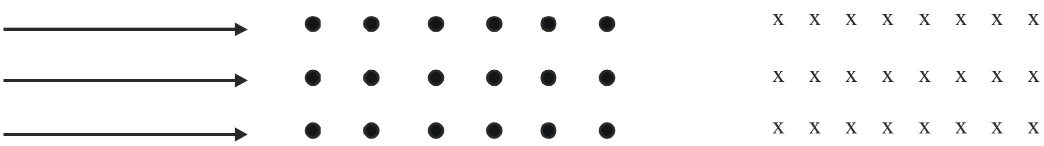
Seeds of two tomatoes varieties . Rocco and Monza were treated by passing them through an artificial magnetic field (MF) with a constant defined velocity before seeding. The seedlings obtained from MF treated and non MF-treated seeds were planted into the MF treated and non MF-treated plots. They were irrigated by MF-treated and non MF treated water.

Observations were made on early-yield, total-yield, beginning of blooming, and quality of fruit. While significant differences were not observed in Rocco, important MF effects were clearly seen on Monza. Yield increases on Monza in magnet treated plots were around 28–51 percent, especially in early yields, and Monza bloomed three-four days earlier.

MAGNETIC FIELD

The space around a magnet (or a current carrying conductor) in which its magnetic effect can be experienced is called the magnetic field. It is a quantity that has both direction and magnitude. Pictorically it is represented by magnetic lines of forces. Tangent to magnetic lines of forces given direction of magnetic field at that point. No two magnetic lines of force intersect each other.

The magnetic field in a region is said to be uniform if the magnitude of its strength and direction is same at all points in that region.



Uniform field in plane of paper — Uniform field perpendicular to plane of paper upwards — Uniform field perpendicular to plane of paper inwards

A magnetic field in a region is said to be uniform if the magnitude of its strength and direction is same at all the points in that region. The strength of magnetic field is also known as magnetic induction or magnetic flux density.

The SI unit of strength of magnetic field is Tesla (T)

1 Tesla = 1 newton ampere^{-1} metre^{-1} (NA^{-1}m^{-1}) = 1 Weber metre^{-2} (Wb m^{-2})

The cgs unit is gauss (G), 1 gauss (G) = 10^{-4} Tesla (T).

Activity : Take a small compass and a bar magnet.

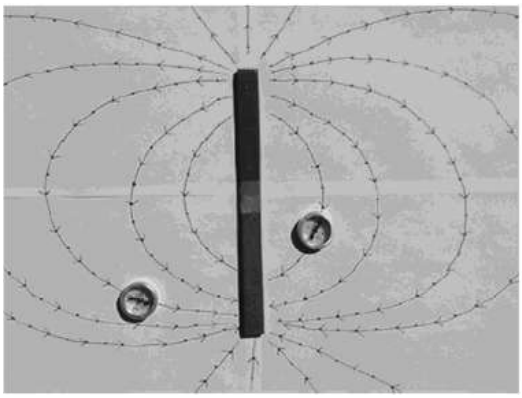
Place the magnet on a sheet of white paper fixed on a drawing board, using some adhesive material.

Mark the boundary of the magnet.

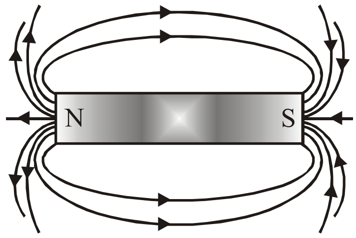
Place the compass near the north pole of the magnet. How does it behave? The south pole of the needle points towards the north pole of the magnet. The north pole of the compass is directed away from the north pole of the magnet.

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 you reach the south pole of the magnet.



- Join the points marked on the paper by a smooth curve. This curve represents a field line.
- Repeat the above procedure and draw as many lines as you can. You will get a pattern shown in Figure. These lines represent the magnetic field around the magnet. These are known as magnetic field lines.
- Observe the deflection in the compass needle as you move it along a field line. The deflection increases as the needle is moved towards the poles.



Activity : 3-D Magnetic field

Purpose : To explore the shape of magnetic fields.

Required Equipment/Supplies :

2 bar magnets, iron filings, strong horseshoe magnet sheet of clear plastic, 5 to 10 small compasses jar of iron filings in oil paper.

Discussion : A magnetic field cannot be seen directly, but its overall shape can be seen by the effect it has on iron filings.

Procedure :

Step 1: Vigorously shake the jar of iron filings. Select the strongest horseshoe magnet available. Place the jar over one of the poles of the magnet and observe carefully. Place the jar at other locations around the magnet to observe how the filings line up.

What happened to the iron filings when they were acted upon by the magnetic field of the magnet?

Step 2: From all your observations, draw a sketch showing the direction of the magnetic field all around your magnet, as observed from the side. Also, draw a sketch as viewed from the end of the magnet.

Step 3: Obtain two bar magnets and 5 to 10 small compasses. Note which end of each compass points toward the north. As you proceed with the activity, represent each compass as an arrow whose point is the north-pointing end.

Step 4: Trace one of the bar magnets on a piece of paper. Move the compasses around the magnet, and use arrows to draw the directions they point at each location. Link the arrows together by continuous lines to show the magnetic field.

Step 5: Obtain a small quantity of iron filings and a sheet of clear plastic. Place the plastic on top of one of the bar magnets, and sprinkle a small quantity of iron filings over the plastic. It may be necessary to gently tap or jiggle the plastic sheet. The filings will line themselves up with the magnetic field. In the following space, sketch the pattern that the filings make. Repeat this step using the other bar magnet.

Step 6: Repeat Step 5 for two bar magnets with like poles facing each other, such as N and N or S and S, and with unlike poles facing each other. Sketch the pattern of the filings in both situations.

Compare the methods of Steps 4 and 5 in terms of their usefulness in obtaining a quick and accurate picture of the magnetic field.

Are there any limitations to either method ? What generalizations can you make about magnetic field lines?

EARTH'S MAGNETIC FIELD

William Gilbert suggested that earth itself behaves like a huge magnet. This magnet is so oriented that its S pole is towards geographic north and N pole is towards the geographic south.

The earth behaves as a magnetic dipole inclined at small angle 11.5° to the earth's axis of rotation with its south pole pointing geographic north. The idea of earth having magnetism is supported by following facts.

(a) A freely suspended magnet always comes to rest in N-S direction. (b) A piece of soft iron buried in N-S direction inside the earth acquires magnetism. (c) Existence of neutral points. When we draw field lines of bar magnet we get neutral points where magnetic field due to magnet is neutralized by earth's magnetic field.

The magnetic field at the surface of earth ranges from nearly 30 μT near equator to about 60 μT near the poles. The magnetic field on the axis is nearly twice the magnetic field on the equatorial line.

Cause of earth's magnetism :

Sir William Gilbert first suggested the existence of a powerful magnet inside the earth. This is not possible because.

(a) Temperature inside earth is so high that it will not be possible for magnet to retain magnetism.

(b) If there was a magnet inside the earth then position of earth's magnetic poles would have not changed.

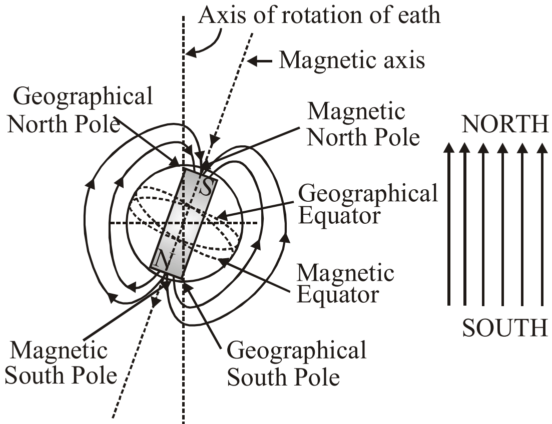
(c) The process of magnetisation of this magnet is not understood.

Grover suggested that earth's magnetism is due to flow of current near outer surface of earth. These currents are produced due to sun. The hot air rising from regions near equator while going towards north and south hemispheres gets electrifield. These then magnetise ferromagnetic materials near surface of earth.

According to another view earth's core has many conducting materials like iron and nickel in molten state. Conventional currents are produced in this semi fluid core due to rotation of earth about its axis which generates magnetism.

Another view says magnetism is due to presence of ionised gases in atmosphere. The high energy sun rays ionize gas atoms in upper layer of atmosphere. The radioactivity of atmosphere and cosmic rays also ionize the gases. Strong electric currents flow due to rotation of earth producing magnetism.

Thus most likely cause of earth's magnetism is the motion and distribution of charged materials in and outside the earth.



Some definitions :

Geographic Axis : It is straight line passing through the geographic poles of the earth. It is the axis of rotation of the earth. It is known as polar axis.

Geographic Meridian : It is a vertical plane passing through geographic north and south poles of the earth.

Geographic Equator : A great circle on the surface of the earth in a plane perpendicular to geographical axis is called geographic equator. All places on geographic equator are at equal distances from geographical poles.

Magnetic Axis : It is a straight line passing through the magnetic poles of the earth. It is inclined to geographic axis at nearly 11.5°.

Magnetic Meridian : It is a vertical plane passing through the magnetic north and south poles of the earth.

Magnetic Equator : A great circle on the surface of the earth in a plane perpendicular to magnetic axis is called magnetic equator. All places on magnetic equator are at equal distance from magnetic poles.

Angle of Declination (ϕ) : The angle between the magnetic meridian and geographic meridian at a place is called angle of declination.

(a) Isogonic Lines : Lines drawn on a map through places that have same declination are called isogonic lines.

(b) Agonic Line : The line drawn on a map through places that have zero declination is known as an agonic line.

Angle of dip or inclination : The angle through which the N pole dips down with reference to horizontal is called the angle of dip. At magnetic north and south pole angle of dip is 90°. At magnetic equator the angle of dip is zero.

(a) Isoclinic Lines : Lines drawn up on a map through the places that have same dip are called isoclinic lines.

(b) Aclinic Line : The line drawn through places that have zero dip is known as aclinic line. This is the magnetic equator.

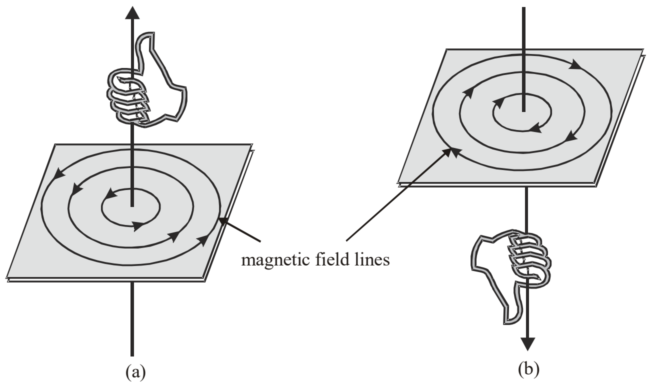
MAGNETIC FIELD DUE TO A CURRENT CARRYING CONDUCTOR

From oersted experiment followed by ampere we can conclude that a magnetic field is developed around a conductor when electric current is passed through it. This observation is called magnetic effect of electric current. The presence of a current in a wire near a magnetic compass affected the direction of the compass needle. We now know that current gives rise to magnetic fields, just as electric charge gave rise to electric fields.

Straight conductor: The magnetic field around a conductor carrying conductor is in the form of closed circular loops, in a plane perpendicular to the conductor, and is given by right hand thumb rule.

Right hand thumb rule. If we grasp the conductor in the palm of the right hand so that the thumb points in the direction of the flow of current, then the direction in which the fingers curl, gives the direction of magnetic field lines. For the current flowing through the conductor in the direction shown in fig. (a) or (b), the rule predict that magnetic field lines will be in anticlockwise direction, when seen from above.

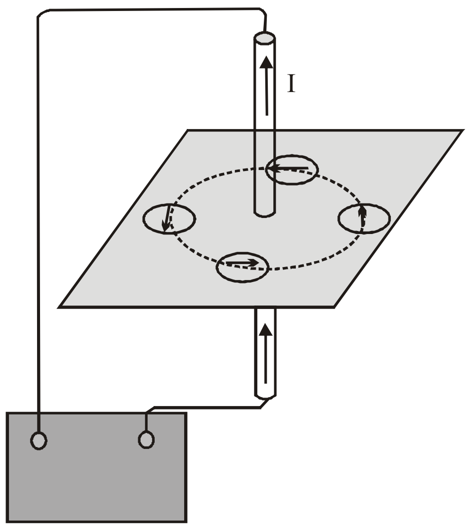
This rule is also called Maxwell's corkscrew rule. If we consider ourselves driving a corkscrew in the direction of the current, then the direction of the corkscrew is the direction of the magnetic field.



Ampere's swimming rule :

Imagine a man swimming along the wire, in the direction of current, (such that the current enters at his feet and leaves him at his head) and facing towards a compass needle placed underneath the wire, then the magnetic field produced is such that the north pole of the compass needle gets deflected towards his left hand.

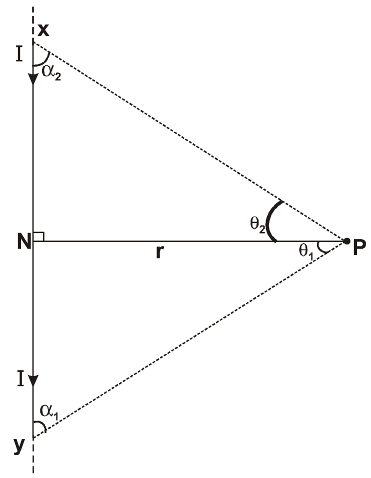
ACTIVITY



- Take a battery (12 V), a variable resistance (or a rheostat), an ammeter (0–5 A), a plug key, 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,
  as shown in Fig., in series with the battery, a plug and key.
- Sprinkle some iron filings uniformly on the cardboard. (You may use a salt sprinkler for this purpose.)
- 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.
- What do these concentric circles represent ? They represent the magnetic field lines.
- How can the direction of the magnetic field be found? Place a compass at a point (say P) over a circle. Observe the direction of the needle. The direction of the north pole of the compass needle would give the direction of the field lines produced by the electric current through the straight wire at point P. Show the direction by an arrow.
- Does the direction of magnetic field lines get reversed if the direction of current through the straight copper wire is reversed? Check it.

EXTRA EDGE

Magnetic field due to long straight conductor :



$$B = \frac{\mu_0 I}{4\pi r}(\sin\theta_1 + \sin\theta_2) \qquad \frac{\mu_0}{4\pi} = 10^{-7}\,\frac{\text{Tesla} - \text{m}}{\text{Amp.}}$$

If the conductor is infinitely long, then $\theta_1 = 90°$ and $\theta_2 = 90°$

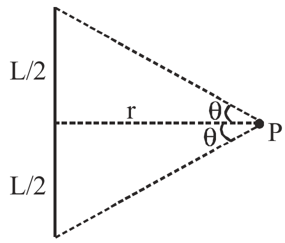
$$B = \frac{\mu_0 I}{4\pi r}\left[\sin\frac{\pi}{2} + \sin\left(\frac{\pi}{2}\right)\right] = \frac{\mu_0 I}{4\pi r}[1+1]\frac{\mu_0}{4\pi}\frac{2I}{r}$$

or $B = \dfrac{\mu_0 I}{2\pi r}$

If conductor is of infinite length but one end is in front of point P i.e. one end of conductor starts from point N then

$\theta_1 = 0°$ and $\theta_2 = 90°$

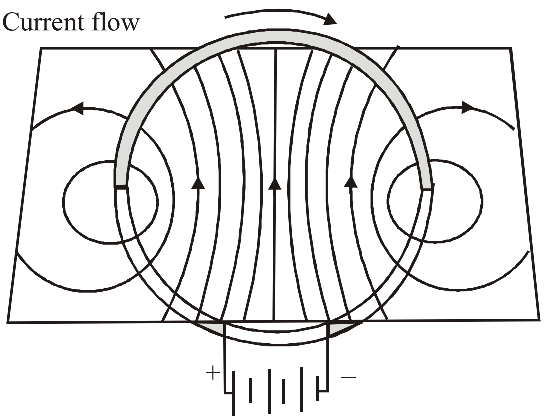
$$B = \frac{\mu_0 I}{4\pi r}$$



Conductor is finite length and point P is just in front of middle of the conductor

$$B = \frac{\mu_0 I}{4\pi r}(2\sin\theta) \quad ; \theta_1 = \theta_2 = \theta \; ; \; B = \frac{\mu_0 IL}{2\pi r\sqrt{L^2 + r^2}} \; ; \; \sin\theta = \frac{L/2}{\sqrt{\left(\frac{L}{2}\right)^2 + r^2}}$$

CIRCULAR LOOP

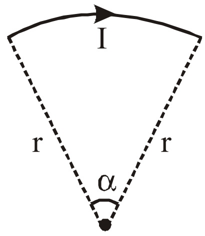


At every point of a current-carrying circular loop, the concentric circles representing the magnetic field around it would become larger and larger as we move away from the wire (Fig.). By the time we reach at the centre of the circular loop, the arcs of these big circles would appear as straight lines. 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.

EXTRA EDGE

Magnetic field at the centre of a circular current-carrying coil :

$$B = \frac{\mu_0 I}{2r}$$



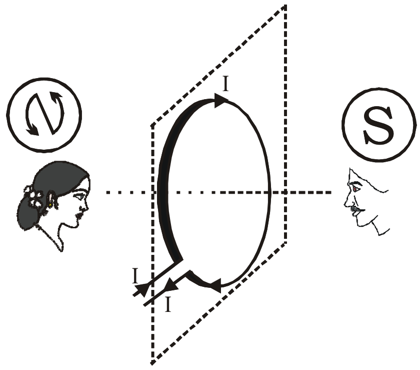
For a coil of n turns, $B = \dfrac{\mu_0 nI}{2r}$

Magnetic Field due to part of current carrying circular conductor (Arc) :

$$B = \frac{\mu_0 I}{4\pi r}\alpha$$

Magnetic field on the axis of a circular coil :

$$B = \frac{\mu_0 N I a^2}{2(a^2 + x^2)^{3/2}}$$



At the centre of the loop, x = 0

$$B = \frac{\mu_0 N I a^2}{2 a^3} \quad \text{or} \quad B = \frac{\mu_0 N I}{2 a}$$

In terms area A (= πa^2)of the circular current loop,
The quantity N I A is known as the magnetic dipole moment M of the current loop.

Magnetic dipole moment of the current loop

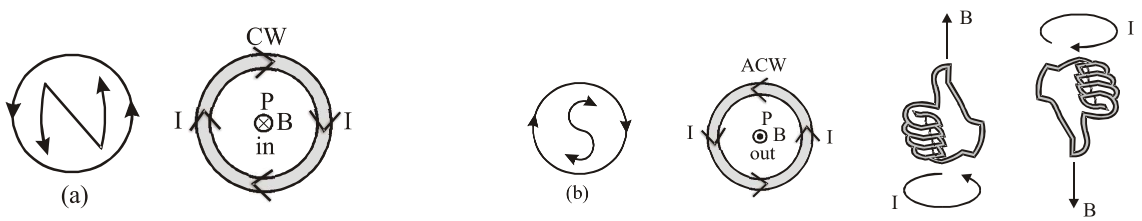
The current loop can be regarded as a magnetic dipole which produces its magnetic field and magnetic dipole moment of the current loop is equal to the product of ampere turns and area of current loop, we can write

$$B = \frac{\mu_0 N I A}{2 r(\pi a^2)} = \frac{\mu_0}{2\pi}\frac{N I A}{a^3} \quad \text{or} \quad B = \frac{\mu_0}{4\pi}\frac{2 N I A}{a^3} \qquad \therefore \; B = \frac{\mu_0}{4\pi}\frac{2M}{a^3}$$

If the observation point is far away from the coil, then a << x. So, a^2can be neglected in comparison to x^2.

$$\therefore \; B = \frac{\mu_0 N I a^2}{2x^3}. \quad \text{In terms of magnetic dipole moment, } B = \frac{\mu_0}{4\pi}\frac{2M}{x^3} \quad \left[B = \frac{\mu_0}{2\pi}\frac{N I A}{x^3} = \frac{\mu_0}{4\pi}\frac{2 N I A}{x^3}\right]$$

Right Hand Palm Rule. if we hold the thumb of right hand mutually perpendicular to the grip of the fingers such that the curvature of the finger represents the direction of current in the wire loop, then the thumb of the right hand will point in the direction of magnetic field near the centre of the current loop.

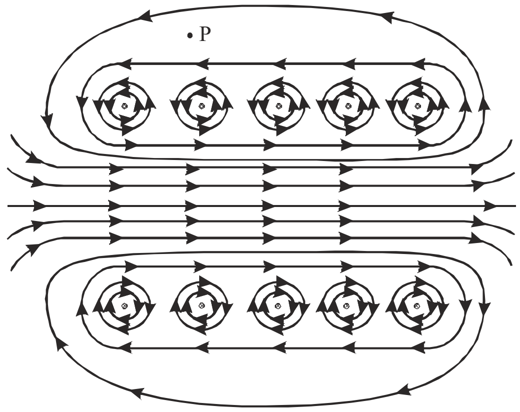


SOLENOID

Magnetic field of a solenoid

A solenoid is a long cylindrical helix. It is made by winding closely a large number of turns of insulated copper wire over a tube of card-board or china-clay. When electric current is passed through the solenoid, a magnetic field is produced around and within the solenoid.

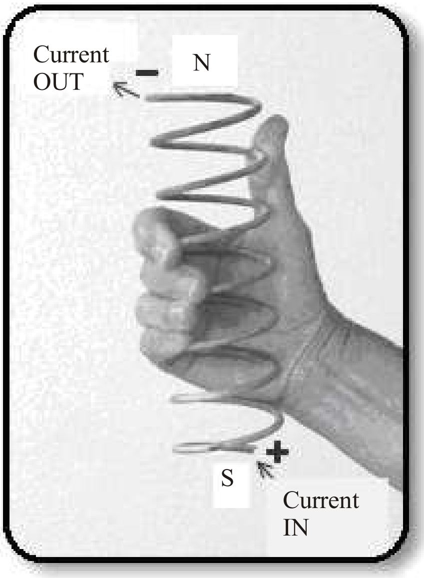
Figure shows the lines of force of the magnetic field due to a solenoid. The lines of force inside the solenoid are nearly parallel which indicate that the magnetic field 'within' the solenoid is uniform and parallel to the axis of the solenoid.



If a steady current flows through such a device, the magnetic fields produced by the loops reinforce one another in certain places, and cancel one another at other places. The result is that the solenoid produces an overall magnetic field similar to that produced by a bar magnet.

The polarity of the magnetic field (that is, which end is magnetic "north" or "south") can easily be worked out from the following rule, which is illustrated in the diagram:

If you grasp the solenoid in your right hand, so that your fingers curl around it in the direction of the conventional current flow, then your thumb will point to the north of the magnet



ELECTROMAGNET

A magnetic field is produced when an electric current flows through a coil of wire. This is the basis of the electromagnet. We can make an electromagnet stronger by doing these things:

- wrapping the coil around an iron core
- adding more turns to the coil
- increasing the current flowing through the coil.

The magnetic field around an electromagnet is just the same as the one around a bar magnet. It can, however, be reversed by turning the battery around. Unlike bar magnets, which are permanent magnets, the magnetism of electromagnets can be turned on and off just by closing or opening the switch

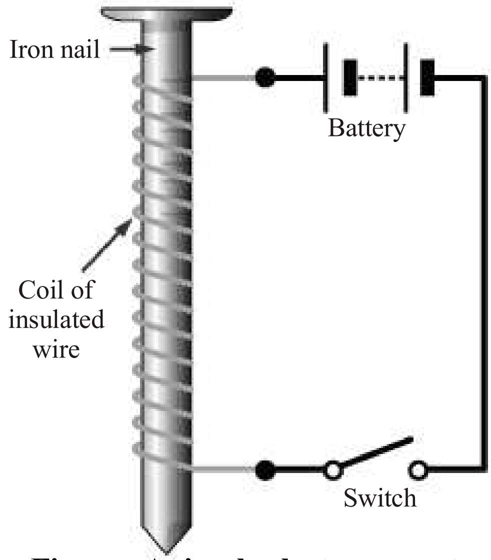


Figure : A simple electromagnet

Uses of electromagnet :

1. For lifting and transporting large masses of iron scrap, girders, plates etc., especially to places where it is not convenient to take the help of human labour.
Electromagnets are used to lift as much as 20-22 tonnes
of iron in a single lift. To unload the magnet at the desired place, the current in the electromagnet is switched off so that the load drops.

2. For loading furnaces with iron.

3. For separating magnetic substances such as iron from other debris (e.g. for separating iron from the crushed copper ore in copper mines).

4. For removing pieces of iron from wounds.

5. In several electrical devices such as electric-bell, telegraph, electric tram, electric motor, relay, microphone, loud speaker, etc.

6. In scientific research to study the magnetic properties of a substance in a magnetic field.

DC MOTOR

A d.c. motor converts direct current energy from a battery into mechanical energy of rotation.

Principle : It is based on the fact that when a coil carrying current is held in a magnetic field, it experiences a torque, which rotates the coil.

Construction : It consists of the five parts.

Armature : The armature coil ABCD consists of a large number of turns of insulated copper wire wound over a soft iron core.

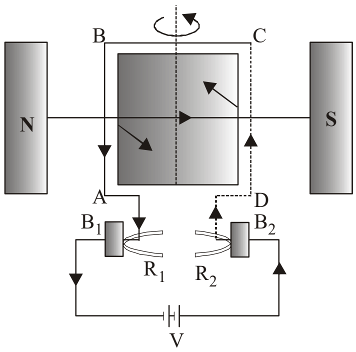
Field Magnet : The magnetic field is supplied by a permanent magnet NS.

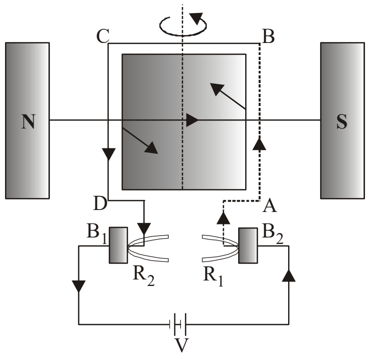
Split-rings or Commutator : These are two halves of the same ring. The ends of the armature coil are connected to these halves which also rotate with the armature.

Brushes : These are two flexible metal plates or carbon rods B_1 and B_2, which are so fixed that they constantly touch the revolving rings.

Battery : The battery consists of a few cells of voltage V connected across the brushes. The brushes convey the current to the rings, from where it is carried to the armature.

Working : The battery sends current through the armature coil in the direction shown in fig. Applying Fleming's Left Hand Rule, CD experiences a force directed inwards and perpendicular to the plane of the coil. Similarly, AB experiences a force directed outwards and perpendicular to the plane of the coil. These two forces being equal, unlike and parallel form a couple. The couple rotates the armature coil in the anticlockwise direction. After the coil has rotated through 180°, the direction of the current in AB and CD is reversed, fig. Now CD experiences an outward force and AB experiences an inward force. The armature coil thus continues rotating in the same i.e., anticlockwise direction.





Efficiency of the d.c. motor : Since the current I is being supplied to the armature coil by the external source of e.m.f. V, therefore, Input electric power = VI

According to Joule's law of heating, Power lost in the form of heat in the coil = I^2R

If we assume that there is no other loss of power, then Power converted into external work i.e.,

Output mechanical power = $VI - I^2R = (V - IR)\,I = EI$

$$\therefore \text{ Efficiency of the d.c. motor, } \eta = \frac{\text{Output mechanical power}}{\text{Input electric power}}$$

A d.c. motor delivering maximum output has an efficiency of only 50%.

Uses :

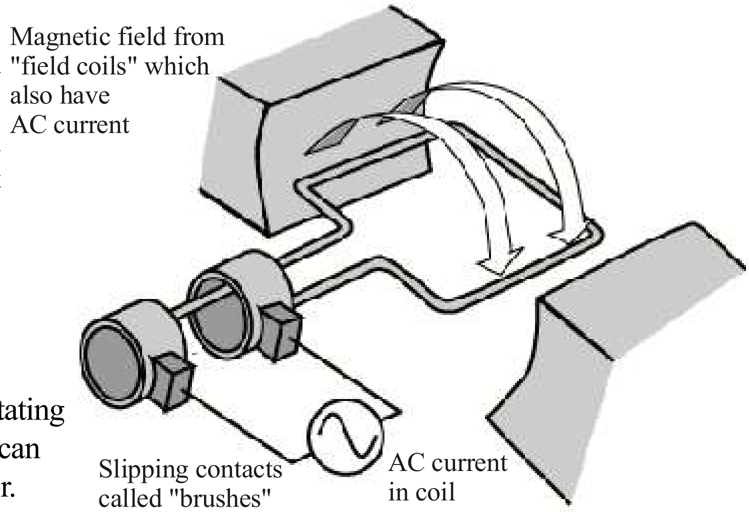
(1) The d.c. motors are used in d.c. fans (exhaust, ceiling or table) for cooling and ventilation.

(2) They are used for pumping water.

(3) Big d.c. motors are used for running tram-cars and even trains.

AC MOTOR

As in the DC motor case, a current is passed through the coil, generating a torque on the coil. Since the current is alternating, the motor will run smoothly only at the frequency of the sine wave. It is called a synchronous motor. More common is the induction motor, where electric current is induced in the rotating coils rather than supplied to them directly.

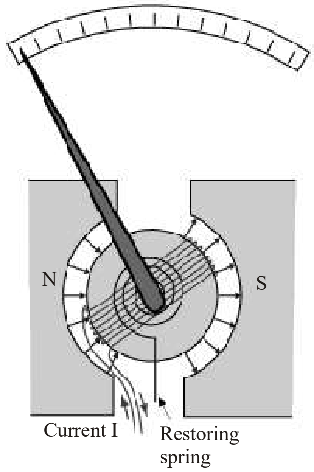


One of the drawbacks of this kind of AC motor is the high current which must flow through the rotating contacts. Sparking and heating at those contacts can waste energy and shorten the lifetime of the motor.

In common AC motors the magnetic field is produced by an electromagnet powered by the same AC voltage as the motor coil. The coils which produce the magnetic field are sometimes referred to as the "stator", while the coils and the solid core which rotates is called the "armature". In an AC motor the magnetic field is sinusoidally varying, just as the current in the coil varies.

GALVANOMETER

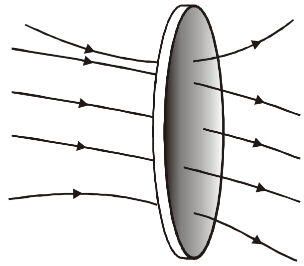
The torque on a current loop in a uniform magnetic field is used to measure electrical magnetic field is used to measure electrical currents. This current measuring device is called a moving coil galvanometer.



The galvanometer consists of a coil of wire often rectangular, carrying the current to be measured. There are generally many turns in the coil to increase its sensitivity. The coil is placed in a magnetic field such that the lines of B remain nearly parallel to the plane of wire as it turns.

This is achieved by having a soft iron cylinder placed at the center of the coil. Magnetic field lines tend to pass through the iron cylinder, producing the field configuration. The moving coil is hung from a spring which winds up as the coil rotates; this winding up produces a restoring torque proportional to the winding up (or twisting) of the spring, i.e. to the angular deflection of the coil. The coil comes to equilibrium when this restoring torque k balances the torque due to the magnetic field balances the torque due to the magnetic field.

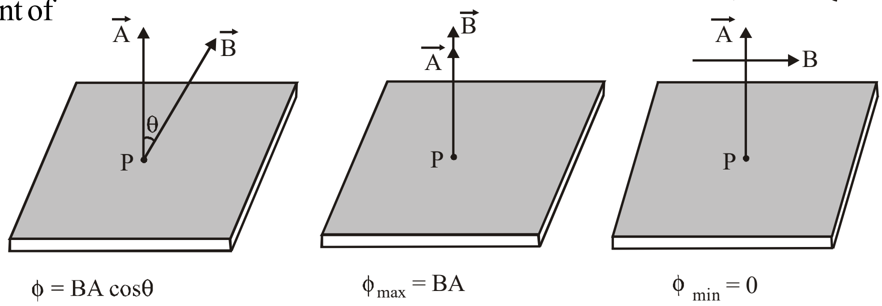
ELECTROMAGNETIC INDUCTION



Magnetic flux : To represent magnetic lines of forces quantitatively magnetic flux is used.

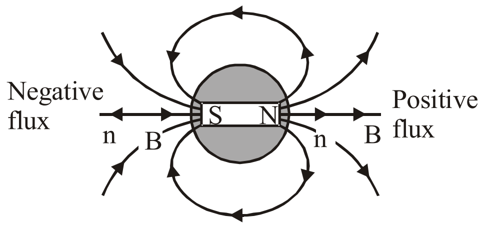
If the magnetic field $\vec{B}$ makes an angle θ with the normal to the surface as shown in fig. then the normal component of the field is B cos θ and in this case, the magnetic flux is given by

$\phi = BA\cos\theta$ or $\phi = \vec{B} \cdot \vec{A}$

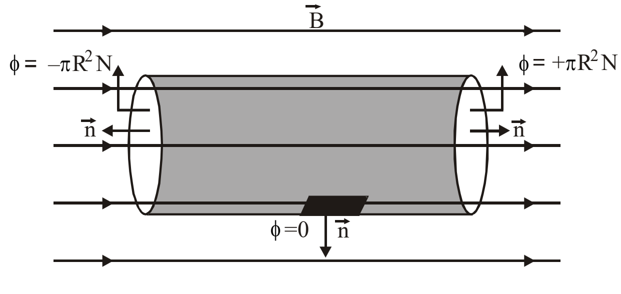


So, magnetic flux linked with a closed surface may be defined as the product of the surface area and the normal component of the magnetic field acting on that area. It may also defined as the dot or scalar product of magnetic field and surface area. Physically it represents total lines of induction passing through a given area.

Positive and negative flux : In case of a body present in a field, either uniform or non-uniform
Out ward flux is taken to be positive while inward negative.



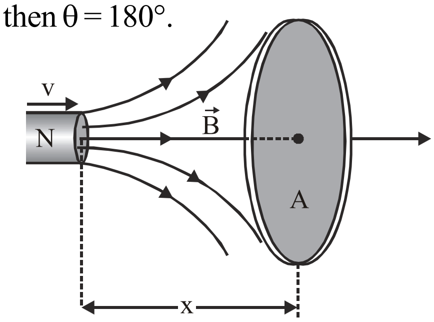
Total flux = 0
Nonuniform field



Total flux = 0
uniform field

If the normal drawn on the surface is in the direction of the field, then the flux is taken as positive.
In this case, θ is 0°. or $\theta < 90°$ then the flux is taken as positive.
If the normal on the surface is opposite to the direction of the field, then $\theta = 180°$.
In this case, the magnetic flux is taken as negative.

Magnetic flux density, $B = \frac{\phi}{A}$

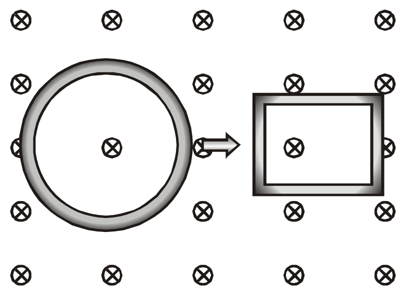


Flux changes as B changes

Different ways which can vary the magnetic flux :
Magnetic flux in planar area $\vec{A}$ due to an uniform magnetic field $\vec{B}$
$$\phi = B A \cos\theta$$
So flux linked with a circuit will change only if field B, area A, orientation θ or any combination of these changes.

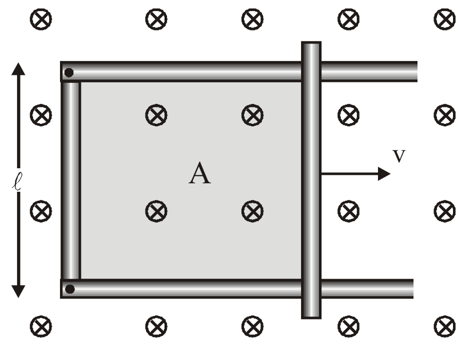
(1) By varying the magnetic field $\vec{B}$ with time :
Due to motion of magnet B will change with time.Or if magnetic field produced due to current carrying loop then due to change in current change in B will occur with time.

(2) By varying the area of the conducting loop $\vec{A}$ with time :
The second method of inducing a change in flux is to vary the area of the conducting loop with time.
(a) Change in Shape of the loop : Consider a square loop of side "**a**" placed perpendicular to a uniform and steady magnetic field B. Suppose the square loop transforms into a circular loop of the same circumference.



Initial area of the loop $= a^2$
The initial flux through the loop $\phi_i = Ba^2$
The final radius of the circular loop $r = \frac{4a}{2\pi} = \frac{2a}{\pi}$
The final flux through the loop $\phi_f = B\pi r^2 = \frac{4Ba^2}{\pi}$
The net change in flux $(\phi_f - \phi_i) = Ba^2\left(\frac{4}{\pi} - 1\right)$

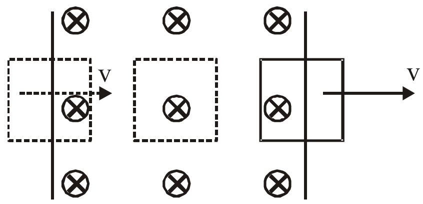
(b) Rod Translating in a Π Circuit : Consider a U shaped or a Π shaped conducting wire placed with its plane perpendicular to a uni -form magnetic field $\vec{B}$.
A conducting rod is placed on this wire so as to short the two arms of the U as shown in fig. Let the distance between the two arms of the U be ℓ.
We now have a closed conducting loop resting in a uniform magnetic field with one of the sides of the loop free to move.
Now suppose the rod translates to the right with a speed v.
Then with time, the area enclosed by this loop will keep increasing and with it the flux through the loop will also change.



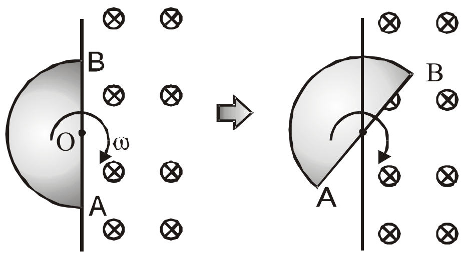
Flux changes as A changes

(3) Loop entering or leaving a finite region of magnetic field :

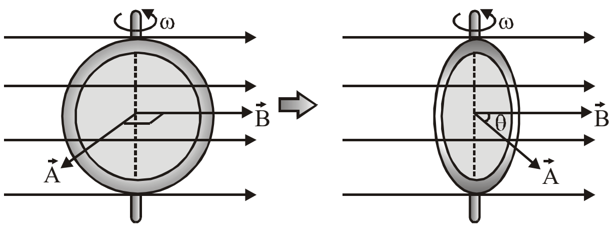
(a) Rectangular loop passing through magnetic field : Method for creating a loop with a time varying area is to have a closed loop enter or leave a region of magnetic field. Here the actual area of the loop does not change with time.
However, the effective area of the loop through which magnetic field lines pass, varies with time.



(b) Loop rotating in and out of a finite region of magnetic field : Consider a semicircular loop placed at the edge of a magnetic field. The loop rotates with an angular velocity ω about an axis perpendicular to the plane of the paper and passing through O. As the loop rotates, the area immersed in the magnetic field varies with time.



(4) Effect of time varying angle between the area vector and the magnetic field vector :
Consider a circular loop placed in an uniform magnetic field $\vec{B}$ such that the plane of the loop is initially parallel to the magnetic field. Let us now rotate the loop about its diameter with a constant angular velocity ω with time and consequently the flux through the loop also varies ($\phi = BA\cos\theta$) Since θ varies so ϕ also varies.



The flux linked with a loop C will not change with time :
If B, A and θ does not change with time, then $\phi = BA\cos\theta = B(N\pi R^2)\cos 0 = N\pi R^2 B$ = const.

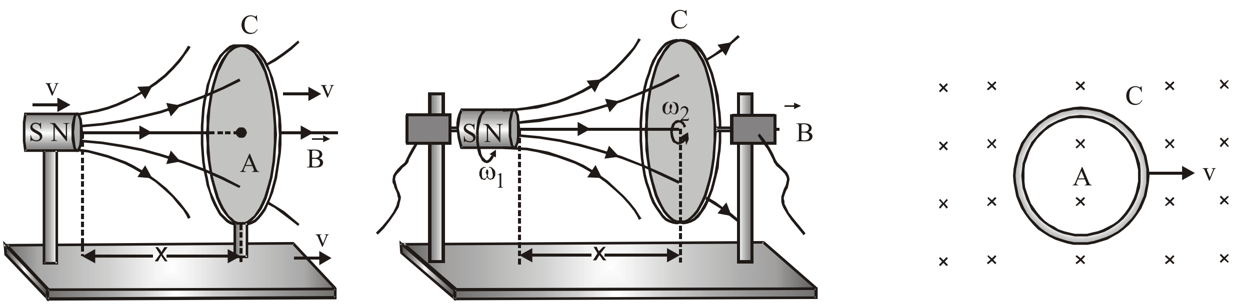
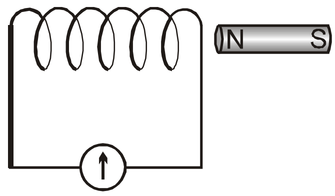
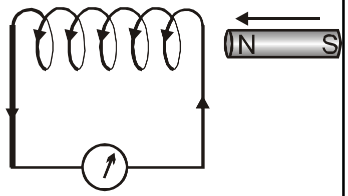
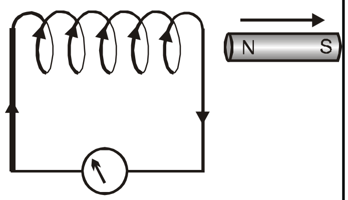
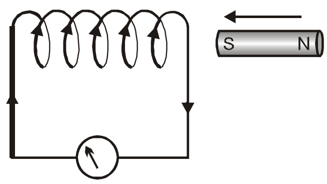
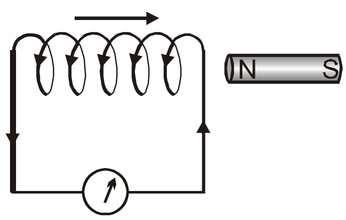


Figure : Flux is linked with loop but not changing with time.

In 1831, Michael Faraday carried out numerous experiments in his attempt to prove that electricity could be generated from magnetism. Within the course of a few weeks, the great experimentalist not only had clearly demonstrated this phenomenon, now known as electromagnetic induction, but also had developed a good conception of the processes involved.
When a bar magnet is thrust into a coil connected to an electric circuit, a current is caused to flow in the circuit to which the coil is attached. If the magnet is withdrawn, the direction of the current is reversed. Such currents are called induced currents. The size of the current depends on how fast the magnet moves in or out of the coil, and the number of loops in the coil. The phenomenon of inducing a current by changing the magnetic field in a coil of wire is known as electromagnetic induction. This phenomenon underpins the design of all electric generators.

FARADAY'S EXPERIMENTS AND OBSERVATION

Experiment	**Observation**	
1. Place a magnet near a conducting loop with a galvanometer in the circuit.	No current flows through the galvanometer.	
2. Move the magnet towards the loop.	The galvanometer register a current.	
3. Reverse the direction of motion of the magnet	The galvanometer deflection reverses	
4. Reverse the polarity of the magnet and move the magnet towards the loop	The galvanometer deflection reverses	
5. Keep magnet fixed and move the coil towards the magnet	The galvanometer register a current.	
6. Increases the speed of the magnet	The deflection increases	
7. Increase the strength of the magnet	The deflection increases	
8. Increase the diameter of the coil	The deflection increases	
9. Fix the speed of the magnet but repeat the experiment with the magnet closer to the coil.	The deflection increases	

10.	Move the magnet at an angle to the plane of the coil.	Deflection decreases Deflection is maximum when the magnet moves perpendicular to the plane of the coil. Deflection is zero when the magnet moves parallel to the plane of the coil.
11.	Increase the number of turns of the coil	Magnitude of current increases.

COIL-COIL EXPERIMENTS

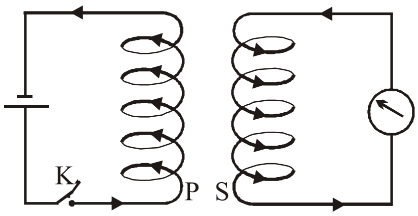
A coil known as primary (P) is connected in series with the source battery (B) and a tap key (K). Another coil called as secondary (S) is placed closed to the primary coil but not perpendicular to one another.

The following observations are made

(i) When the key is pressed, the galvanometer shows a momentary deflection.

(ii) When the current becomes steady i.e. key is kept pressed, the deflection is zero.

(iii) When the key is released, the galvanometer again shows a momentary deflection, but now in the opposite direction.



These observations reveal that as long as there is a change in current in P., an e.m.f. is induced in S. This phenomenon in which an e.m.f. is induced in a coil due to a varying current in a neighbouring coil is called mutual induction.

It can also be seen that on keeping K pressed i.e. steady current flowing through P, but on moving S away or towards P, the galvanometer shows deflection, in either case in the opposite directions.

These observations show that an e.m.f is induced in the coil, whenever there is a relative motion between the magnet and the coil.

Faraday's laws of electro-magnetic induction :

Whenever there is change in the magnetic flux associated with a circuit, an e.m.f. is induced in the circuit.

The magnitude of the induced e.m.f. (e) is directly proportional to the time rate of change of the magnetic flux through the circuit.

$e \propto \frac{\Delta\phi}{\Delta t}$ or $e = k\frac{\Delta\phi}{\Delta t}$; k = const. of proportionality depending upon the system of units used.

In the S.I. system, emf 'e' is measured in volt and $\frac{\Delta\phi}{\Delta t}$ in Wb/sec.

In MKS or SI system, these units are so chosen that k = 1, and 1 Volt = 1 Wb/sec

Faraday's laws do not give the direction of the induced e.m.f. or current.

Induced current or e.m.f. lasts only for the time for which the magnetic flux is changing.

If the coil has N turns, then the emf will be induced in each turn and the emf's of all the turns will be added up. If the turns of coil are very close to each other, the magnetic flux passing through each turn will be same.

So, the induced emf in the whole coil $e = N\frac{\Delta\phi}{\Delta t}$

$N\phi$ = number of 'flux linkages' in the coil.

FLEMING'S RIGHT HAND RULE

Fleming's right hand rule gives the direction of the induced e.m.f. and current in a straight conductor moving perpendicular to the direction of magnetic field.

Statement : Stretch out the thumb, fore finger and middle finger of the right hand mutually perpendicular to each other. If the fore finger points in the direction of magnetic field, the thumb in the direction of motion of the conductor, then the middle finger will point out the direction of induced current or induced e.m.f.

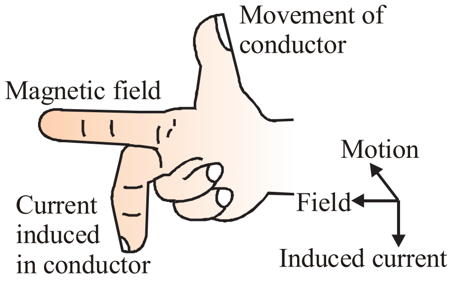


Figure : Fleming's right-hand rule

LENZ'S LAW

The direction of the induced current e.m.f. is given by Lenz's law :

The direction of the induced current is such that it oppose the change in the magnetic flux that causes the induced current or e.m.f. i.e. induced current tries to maintain flux.

On combining Lenz's law with Faraday's laws $e = -\frac{\Delta\phi}{\Delta t}$

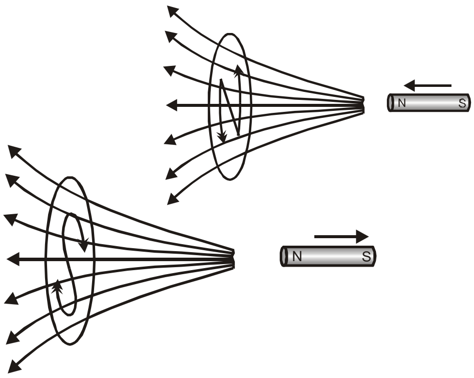
–ve sign indicating that the induced e.m.f. opposes the change in the magnetic flux.

The Lenz's Law is consistent with the law of conservation of energy.

The induced e.m.f. is produced at the cost of mechanical work done by an external agent in the magnet and coil experiment. When the N-pole of the magnet is moved towards the coil, the face of the coil facing the north pole acts like a north pole. (This can be found by Flemings' Right hand Rule).

As the magnet is moved towards the coil, the magnetic flux linked with the coil increases.

To oppose this increase in flux, e.m.f. induced in the coil has to be in such a direction as to reduce the increase in flux. The external agent has to do some work against this force of repulsion between the two N-pole. This is converted into electrical energy as shown in fig. Similarly if the magnet with its N-pole is moved away from the coil, then the face of the coil acts like a South pole and hence the flux linked with the coil tends to decrease. The induced current or e.m.f. must now be in a direction so as to increase the flux as shown in fig.



The external agent has to do work against this force of attraction between the N and S poles and this is converted into electrical energy.

If suppose, on moving the N pole of the magnet towards the coil, a south polarity is induced on the face of the coil, then the magnet would be attracted to the coil, and there would be a continuous increase in magnetic flux linked with the coil leading to a continuous increase in e.m.f. without any expenditure of energy and this would violate the principle of conservation of energy.

Determination of the direction of the induced current in a circuit (Using Lenz's Law)

Lenz's law : "when the magnetic flux through a loop changes, a current is induced in the loop such that the magnetic field due to the induced current opposes the change in the magnetic flux through the loop".

The above rule can be systematically applied as follows to determine the direction of induced currents.

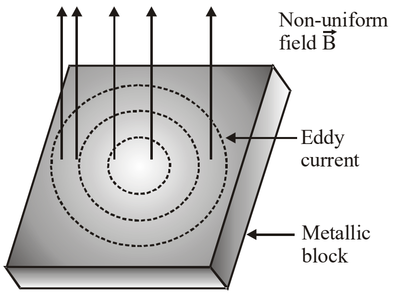
(A) Identify the loop in which the induced current is to be determined

(B) Determine the direction of the magnetic field in this loop (i.e., in or out of the loop)

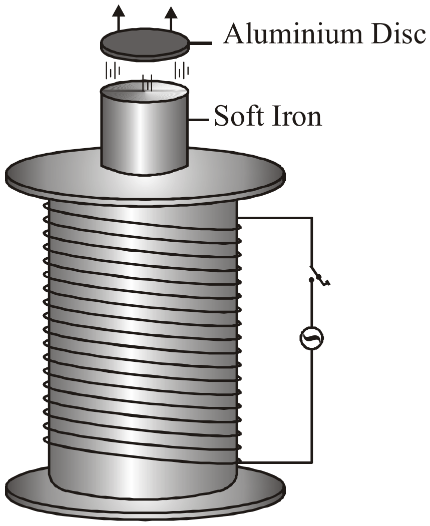
(C) The direction of flux is the same as the direction of the magnetic field

Determine if the flux through the loop is increasing or decreasing (due to change in area, or change in B)
(D) Choose the appropriate current in the loop that will oppose the change in flux i.e.,
a. If the flux is into the paper and increasing, the flux due to the induced current should be out of the paper.
b. If the flux into the paper and decreasing, the flux due to the induced current should be into the paper.
c. If the flux is out of the paper and increasing, the flux due to the induced current should be into the paper.
d. If the flux is out of the paper and decreasing, the flux due to induced current should be out of the paper.
The above description is the physical interpretation of Lenz's law.

EDDY CURRENTS (FOUCAULT CURRENTS)



The induced circulating currents produced in a metal itself due to change in magnetic flux linked with the metal are called eddy currents.
These currents were discovered by Foucault, so they are also known as Foucault Currents.
The direction of eddy currents is given by Lenz's law
.
Eddy currents produced in a metallic block moving in a non-uniform magnetic field are shown in fig.



Demonstration of Eddy Currents
Jumping Disc : An aluminium disc is placed over the core of an electro-magnet. When the circuit is closed i.e., alternating current flows in the circuit, the disc jumps up to a certain height.
When the current through the solenoid increases, the magnetic flux along the axis of the solenoid increases. Consequently, the magnetic flux linked with the disc also increases. Due to the change in magnetic flux, induced currents (i.e. eddy currents) are produced in the disc and it is slightly magnetised.
If the upper face of the core of the electromagnet acquires north polarity, then according to Lenz's law, the lower face of the disc will also acquire North polarity. Due to the force of repulsion between the lower face (N-pole) of the disc and upper face (N-pole) of the core of the electro-magnet, the disc jumps upto a certain height.

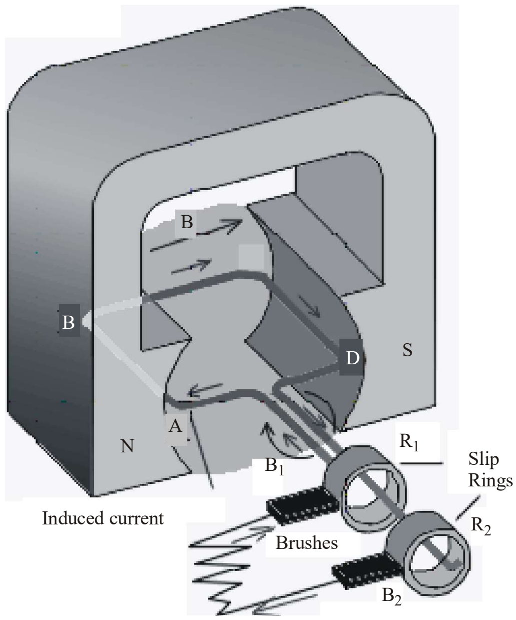
Useful application of eddy currents :
Like friction, eddy currents are helpful in some fields and have to be increased, while in some other fields they are undesirable and have to be minimised.
(1) Dead heat galvanometer. (2) Energy meter. (3) Speedometer.
(4) Electric brakes. (5) Single phase AC motor. (6) Induction furnace. (7) Diathermy

ELECTRIC GENERATOR

The large generators present in hydroelectric power plants depend on magnets for their operation. They convert the kinetic anergy in moving water into electricity. Generators in fossil-fueled and nuclear-fueled power plants harness the kinetic energy in moving steam in the same way.
Electrical current can be generated by moving a metal wire through a magnetic field. This applies both to alternating current (AC) and direct current (DC) electricity. When a coil of conducting wire is rotated in a magnetic field, electromagnetic induction results in an induced current flowing through the loop. In this way, mechanical energy is converted to electrical energy. The device is called a generator or dynamo.

The generator will produce an electromotive force that will vary sinusoidally with the angle made by the coil and the applied field. Thus the direction of the current will vary and the current so produced is called an alternating current. A better name for the device is alternator.
Note that this is analogous to an electric motor: the motor converts electrical energy into mechanical energy, while the alternator converts mechanical energy into electrical energy. The alternator does not create electricity out of nothing.

Working of 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 R_1 and R_2. The inner side of these rings are made insulated. The two conducting stationary brushes B_1 and B_2 are kept pressed separately on the rings R_1 and R_2, respectively. The two rings R_1 and R_2 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. Let us say the coil ABCD is rotated clockwise in the arrangement. 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 B_2 to B_1.
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 B_1 to B_2. 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 (abbreviated as AC). This device is called an AC generator.

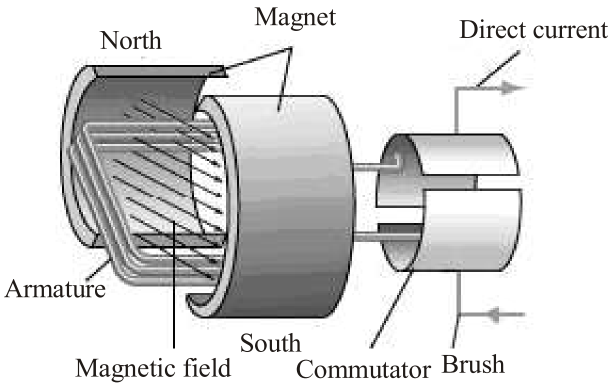


Figure : Split-ring type commutator

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.
The difference between the direct and alternating currents is that the direct current always flows in one direction, whereas the alternating current reverses its direction periodically. Most power stations constructed these days produce AC. In India, the AC changes direction after every 1/100 second, that is, the frequency of AC is 50 Hz. An important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.

DOMESTIC ELECTRIC CIRCUITS

Electricity from power stations is transmitted to homes through high voltage power lines. Electric potentials as high as 220 000 V AC are used. The electrical potential is decreased to 220 V AC with the help of step-down transformer before it enters the home. A cable containing three colour-coded wires enters the home. One wire is red, one is black, and one is green. The red wires are called live wires (or positive). Another wire with the black insulation is called neutral wires (or negative). There is an electrical potential difference of 220 V AC between a red and a black wire. The earth wire, which has insulation of green colour, 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. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

Fuses and Circuit Breakers : A fuse is a safety device that acts as a switch. Fuses are connected into the circuit close to the source. As a result all the current flowing in the circuit passes through the fuse. When too much current flows, the fuse heats up sufficiently to bum out. This creates an air gap and no more current flows. Other kinds of fuses are cartridge fuses and knife blade fuses. The essential part is the fuse wire or a blade with a low melting point. Most homes built in recent years use circuit breakers instead of fuses in their electrical panels. A circuit breaker is connected in the same place as a fuse would be, and it performs the same function. Unlike a fuse, however, it does not bum out. When too much current flows, the circuit breaker simply opens like a switch. Then, when the problem that caused the excess current has been corrected, you can close the breaker again.

The Circuit Breaker Panel : At the home, the electricity first passes through an electric meter. The electric meter records the amount of electric energy used in the home. Then the electricity enters a circuit breaker panel. (In some older homes it may enter a fuse panel.) In this panel there is a master circuit breaker. The master circuit breaker can be operated manually to cut off the electricity to the entire home. It opens automatically if the current exceeds the -rated value. In homes that have a 100 A service, the master circuit breaker will allow up to 100 A to pass before it pops open. There are three strips of conducting metal called bus bars in the breaker panel. The red wire is connected to one, the black wire to another, and the white wire to the third. As a result, two of the bus bars are live and one is neutral.

Electric Circuits in the Home :

In homes, the supply of electric power is received through a main supply (also called mains). 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 V.

At the metre-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. Often, two separate circuits are used, one of 15 A current rating for appliances with higher power ratings such as geysers, air coolers, etc. The other circuit is of 5 A current rating for bulbs, fans, etc. The earth wire, which has insulation of green colour, 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. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

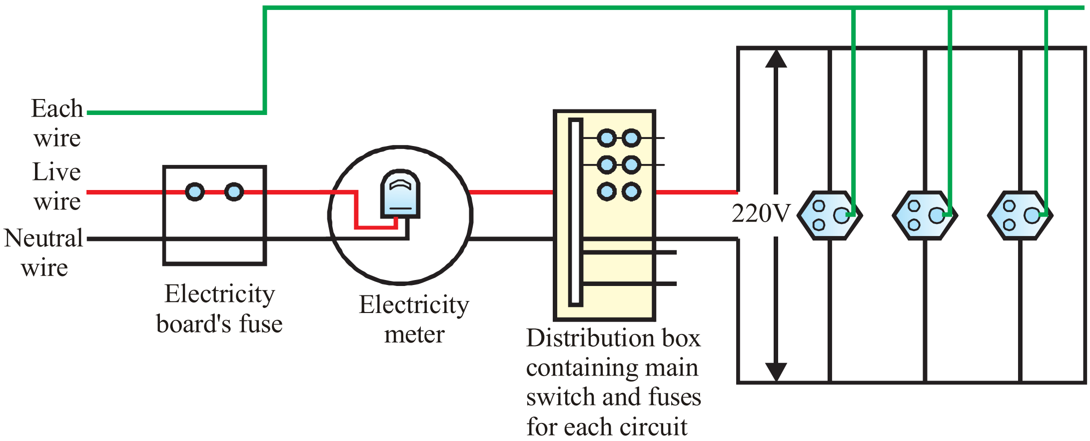


Figure : A schematic diagram of one of the common domestic circuits

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. Electric fuse is an important component of all domestic circuits.

Causes of Overloaded Circuits :

There are two main causes of overloaded circuits. First, an appliance or a conducting wire can develop a short circuit. Now the current is no longer limited by the load. In this case, current passes from the live wire to the neutral wire or from the live wire to the ground wire without passing through the load. The current becomes very large very fast. This heats up the circuit.

Second, too many appliances can be plugged into the same circuit. Each appliance draws a certain current. The combination can draw too much current and the circuit again heats up.

A circuit breaker is designed to prevent overloading. It trips and opens the circuit as soon as the circuit becomes too hot.

ADDITIONAL EXAMPLES

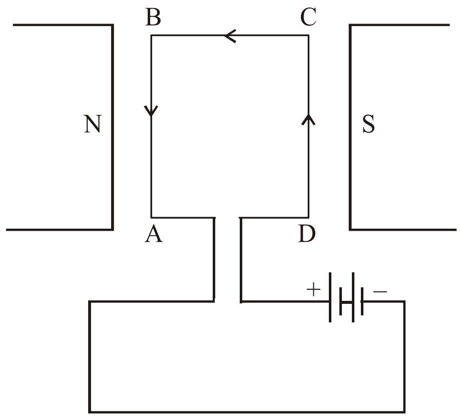
Example 1 :

A rectangular coil ABCD is placed between the pole pieces of a horse-shoe magnet as shown in figure.

(i) What is the direction of force on each arm ?

(ii) What is the effect of the forces on the coil ?

(iii) How is the effect of force on the coil changed if the terminals of the battery are interchanged ?



Sol. (i) In figure, the current in the coil is in direction DCBA. By Fleming's left hand rule, on the arm AB, the force is outward at right angles to the plane of the coil. On the arm BC no force acts. On the arm CD, the force is inwards perpendicular to the plane of the coil. On the arm DA, no force acts.

(ii) The force on the arms AB and CD are equal in magnitude, but opposite in direction. They form a clockwise couple. So the coil will rotate clockwise with the arm AB coming out and the arm CD going in.

(iii) On interchanging the terminals of the battery, the coil will rotate anticlockwise.

Example 2 :

What precaution should be taken to avoid the overloading of domestic electric circuits?

Sol. (a) Too many electrical appliances should not be operated on a single socket.

(b) Too many high power rating electrical appliances should not be switched on at the same time.

Example 3 :

List the properties of magnetic lines of force.

Sol. (i) The direction of the magnetic field is indicated by the arrow in the line at any point (Tangent).

(ii) The field lines come out of the north pole and get into the south pole (closed loops are formed).

(iii) The strength of magnetic field is indicated by the closeness of the field lines. Closer the lines, more will be the strength and farther the lines, lesser will be the field strength.

(iv) No two field lines will intersect each other if they intersect there will be two different directions for field at the same point which is not impossible.

Example 4 :

Why don't two magnetic lines of force intersect each other?

Sol. Two magnetic lines of force never intersect each other. If the lines intersect, then at the point of intersection there would be two directions (the needle would point towards two directions) for the same magnetic field, which is not possible.

Example 5 :

Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop.

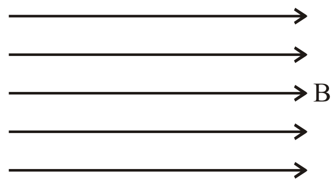
Sol. Direction of magnetic field inside the loop – Perpendicular to the plane of paper inward and

Direction of magnetic field outside the loop – Perpendicular to the plane of paper outward.

Example 6 :

The magnetic field in a given region is uniform. Draw a diagram to represent it.

Sol. Equidistant parallel lines indicate an uniform magnetic field.



Example 7 :

State Fleming's left-hand rule.

Sol. Stretch the first three fingers of the left hand mutually perpendicular to echo other such that the forefinger points the direction of magnetic field, the middle finger points the direction of current, then the thumb will indicate the direction of force experienced by the conductor. It is to be applied when the current and field are perpendicular to each other.

Example 8 :

What is the principle of an electric motor?

Sol. Electric motor works on the principle of force experienced by a current carrying conductor in a magnetic field. The two forces in the opposite sides are equal and opposite. Since they act in different lines they bring rotational motion.

Example 9 :

What is the role of the split ring in an electric motor?

Sol. Split ring facilitates the contacts with the ends of the rectangular coil to keep the rotation continuous and not a reversal after every 180°.

Example 10 :

Explain different ways to induce current in a coil.

Sol. (i) A current is induced in a coil when a magnet is moved relative to the fixed coil.

(ii) A current is also induced in a coil when it is moved relative to a fixed magnet.

(iii) Not any current is induced in a coil when the coil and magnet both are stationary relative to one another.

(iv) When the direction of motion of magnet or coil is reversed, the direction of current induced in the coil also gets reversed.

Example 11 :

State the principle of an electric generator.

Sol. Generator works on the principle of Electromagnetic induction. When a coil is rotated in magnetic field, then there will be induced current flowing in it. The direction of the induced current can be found using the Fleming's right hand rule.

Example 12 :

Name some sources of direct current.

Sol. Some of the sources of direct current are dry cell battery, car battery and dc generator.

Example 13 :

Which sources produce alternating current ?

Sol. Some of the sources produce alternating current are bicycle dynamos, car alternators and power house generators.

Example 14 :

Name two safety measures commonly used in electric circuits and appliances.

Sol. (i) Electric fuse (ii) Earthing of metal bodies of electrical appliances.

Example 15 :

An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect? Explain.

Sol. Power, $P = 2\ kW = 2 \times 1000\ W = 2000\ W$, Voltage $V = 220V$, current drawn, $I = ?$

Power, $P = V \times I$; $I = \frac{P}{V} = \frac{2000}{220} = 9A$

The current drawn by this electric oven is 9A whereas the fuse in the circuit is only 5A capacity. When a high current of 9A flows through the 5A fuse, the fuse wire will get heated too much, melt and break the circuit. Therefore, when a 2kW power rating electric oven is operated in a circuit having 5A fuse, the fuse will blow off cutting off the power supply in this circuit.

Example 16 :

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.

Example 17 :

List three sources of magnetic fields.

Sol. (a) Natural and artificial magnets. (b) Electromagnets (c) A current carrying conductor produces magnetic field.

Example 18 :

How does a solenoid behave like a magnet? Can you determine the north and south poles of a current–carrying solenoid with the help of a bar magnet? Explain.

Sol. The magnetic field produced by a current-carrying solenoid is similar to the magnetic field produced by a bar magnet. In fact, one end of the solenoid behaves as a magnetic north pole, while the other behaves as a south pole.

We can determine the north and south poles of a current-carrying solenoid with the help of a bar magnet.

Bring the north pole of a bar magnet near both the ends of a current-carrying solenoid. The end of solenoid which will be repelled by the north pole of bar magnet will be its north pole, and the ends of solenoid which will be attracted by the north pole of bar magnet will be its south pole.

Example 19 :

When is the force experienced by a current–carrying conductor placed in a magnetic field largest?

Sol. The force experienced by a current-carrying conductor placed in a magnetic field is largest when the direction of current is at right-angles to the direction of the magnetic field.

Example 20 :

A magnet is dropped in a very long copper tube. Even in the absence of air resistance it acquires a constant terminal velocity. Explain why?

Sol. When the magnet is dropped in a copper tube, eddy currents are produced in the tube. These eddy currents produce the magnetic field which opposes the motion of the magnet. After some time, the opposing force becomes equal to the gravitational pull on the magnet. Thus the net force acting on the magnet is zero and hence the magnet acquires a constant velocity.

Example 21 :

A coil of insulated copper wire is connected to a galvanometer. What will happen if a bar magnet is (i) pushed into the coil, (ii) withdrawn from inside the coil, (iii) held stationary inside the coil?

Sol. (i) When a bar magnet is pushed into the coil, a momentary deflection is observed in the galvanometer. This deflection indicates that a momentary current is produced in the coil.

(ii) When a bar magnet is held stationary inside the coil, there is no deflection in the galvanometer. It indicates that no current is produced in the coil.

(iii) When the bar magnet is withdrawn from the coil, the deflection of galvanometer is in opposite direction. It indicates that a current of an opposite direction is produced.

Example 22 :

Two circular coils A and B are placed closed to each other. If the current in the coil A is changed, will some current be induced in the coil B? Give reason.

Sol. If the current in coil A is changed, some current will be induced in the coil B. Coil A is called the primary coil and coil B 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.

Example 23 :

Explain the underlying principle of an electric generator. What is the function of brushes?

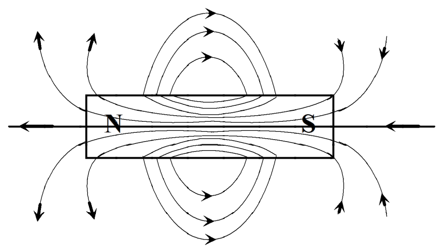
Sol. Principle : It is based on the principle of electromagnetic induction, which is the process of producing induced current in a coil by relative motion between a magnet and the coil.

Function of brushes : The brushes carry the contact from rings to external load resistance.

CONCEPT MAP

MAGNETIC EFFECTS OF ELECTRIC CURRENT

* **Magnetism** was thought to be a special property of certain natural occurring substances called '**lodestone**' (which means 'way stone'). These are **natural magnet** which contains magnetite (Fe_3O_4) an ore of iron. Now magnets can also be made artificially. The horseshoe magnet, which is shaped like the letter 'U' is commonly used in laboratories.
* If a magnet is suspended freely it always orients itself in the direction of Geographical North and South Pole. The end of the magnet which points towards north is called the north seeking or **North Pole of the magnet** and the end that points towards south is the south seeking or **South Pole of the magnet**.
* This property of the magnet is used to construct an instrument called **magnetic compass** to find direction during navigation. The magnetic compass that we use today has a small, light magnet, called the magnetic needle. **Thus every magnet is characterized by two poles which are inseparable in any case**.
* In bar, rod and horseshoe magnets, the north or south poles are either indicated by the letters N and S or only the north pole is indicated by a dot. In disc and ring magnets, one face is the North Pole while the other is the South Pole. Permanent magnets are used in loudspeakers, microphones, ammeters, voltmeters, speedometers etc.
* **It is also observed that like poles repel each other and unlike pole attracts each other.**
* **Electricity and Magnetism**:
  H.C.Oersted discovered that a current carrying wire deflects a magnetic compass needle in a same way; it got deflected by a magnet. Thus electric current produces magnetic field.
  Even in the permanent magnets the magnetic field is produced due to the miniature current in the atoms due to the motion of electrons around the nucleus.
* **Magnetic field and field lines** – The region around a magnet in which the force of attraction and repulsion can be detected, is called magnetic field. The most convenient way of describing a magnetic field is by drawing lines called the **magnetic field lines**. They are drawn such that tangent at any point gives the direction of magnetic force.

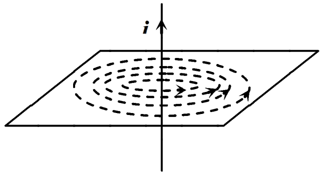


The characteristics of magnetic lines of forces are

1. All field lines starts from North Pole and go into the South Pole and they continue inside the magnet too.
2. The relative strength of the magnetic field is shown by the degree of closeness of the field lines. The field is stronger, if field lines are more crowded.
3. No two-field lines are found to intersect each other. Reason : if they did it would mean that at the point of intersection the needle would point towards two directions which is not possible.
   SI Unit of magnetic field is **Tesla (T).**
   1 T = 10^4 Gauss.

CONCEPT MAP

* **Magnetic field due to current carrying straight conductor**
Magnetic field at the distance r from the wire : $B = \frac{\mu_0 i}{2\pi r}$

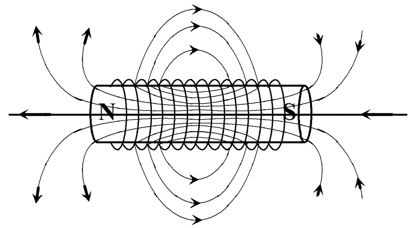


The direction of magnetic field is found by **Maxwell's Right-hand Thumb Rule** which states that If a straight current carrying wire is imagined to be held in the right hand, with the thumb stretched along the direction of the current, the direction of the magnetic field produced by the current is in the direction in which the fingers are curled.

Magnetic field at the center of a coil

$$B = \frac{\mu_0 i}{2r}$$

* **Magnetic field due to a current carrying solenoid** :
When a long insulated wire is tightly wound in the shape of a spring, such that the turns lie side by side and are closely spaced, we get a solenoid. Generally, winding wire over a non conducting cylindrical tube makes a solenoid. A solenoid differs from a circular coil in the sense that the length of the solenoid is much greater than its diameter. If n be the number of turns per unit length, then



MAGNETIC EFFECTS OF ELECTRIC CURRENT

* **Magnetic field inside a long solenoid**
$$B = \mu_0 ni$$
The direction of magnetic field is parallel to the axis of the solenoid and determined by right hand thumb rule as in circular loop.
• μ_0 is a constant whose value is $4\pi \times 10^{-7}$ Tm/A
* **Force on a current carrying conductor in magnetic field** – Magnet exert force on a moving charge and hence on a current carrying conductor.
The force due to magnetic field B acting on a charge q moving with velocity v is
$F = qvB$
The force due to magnetic field B acting on a conductor of length ℓ carrying current i is
$F = i \ell B$
The direction of the force on a moving positive charge or on the current carrying conductor is determined by **Fleming's left-hand Rule** which states that, If the forefinger, second finger and thumb of the left hand are stretched at right angles to each other, with the forefinger in the directions of the field and the second finger in the direction of the current then the thumb indicates the direction of the force.
* **Electromagnets :** A magnet formed temporarily due to the magnetic field of a current is called an electromagnet.
A strong magnetic field produced in the coil can be used to magnetize a piece of magnetic material, when it is placed within the coil carrying current.
If the rod is hard steel and if the magnetic field of the coil is strong enough, permanent magnets can be produced.
Material used in the formation of permanent magnet are carbon steel, chromium

CONCEPT MAP

MAGNETIC EFFECTS OF ELECTRIC CURRENT

steel, cobalt and tungsten steel, and some of the alloys such as **Nipermag** [alloy of iron, nickel, aluminum and titanium] **and Alnico** [an aluminum-nickel-cobalt alloy of iron]. Permanent magnets of these alloys are many times as strong as those of ordinary steel. Such permanent magnets are used in microphones, loudspeakers, electric clocks and many other devices like ammeters, voltmeter and speedometers.

* **Electromagnetic induction (EMI)**- The phenomenon in which an electric current is induced in a circuit because of a varying magnetic field or the relative motion of the circuit in a magnetic field is called electromagnetic induction.
* **Fleming's Right-hand Rule** – If the forefinger, second finger and thumb of the right hand are stretched at right angles to each other, with the forefinger in the direction of the field and thumb in the direction of motion of the wire then the current in the wire is in the direction of the second finger.
* **Domestic electric circuits** : The electric power lines enter our house through three wires-**the live wire, the neutral wire and the earth wire**. The live wire is maintained at 220V. The neutral wire is maintained close to zero potential. The earth wire is maintained at zero potential by connecting it to large plates buried in the ground, and in general no current passes through it. The current comes from the live wire and after going through the appliances returns through the neutral wire. An appliance that consumes relatively low power, e.g. a tube light or a fan has just two terminals of live and neutral wires. Appliances such as heaters, electric irons, refrigerators etc, have third terminal, called the earth terminal.

* **Fuse** – The fuse is the most common safety device used in electric circuits. It is connected to the live lines of each section of a building wiring. A fuse is simply a metallic wire of low melting point, fixed between the terminals of the fuse plug. When the fuse plug is in its socket, the live line continues through the fuse wire. If there is any overheating in the circuit fuse wire melts immediately, this breaks the circuit, preventing an accident. The fuse is also used in electric appliances such as TV, invertors, amplifiers, etc. The maximum current allowed by a fuse is printed on it.
* **Circuit Breakers**- A circuit breaker can be used in place of a fuse. A circuit breaker has a switch and a solenoid connected in series in the live line of a circuit. A heavy soft-iron core lies partially in the solenoid. When a current exceeds a particular value through the solenoid, the core gets pulled in, and hits the switch to open it and break the circuit. The switch can be turned on again manually once the electrical fault is rectified.
* **Earthing of electric appliances** – Usually, electric appliances with high power rating such as heaters, irons etc, have a terminal for connecting the earth wire, in addition to terminals for the live and neutral wires. The earth wire is connected to the metallic body of the appliances. This is done to avoid shocks in case of a fault. Suppose due to some reason the insulation of the live wire inside an electric iron gets burnt at a place. If a person accidentally touches the metallic body of the iron, he/she will get an electric shock. However with the earth wire properly connected to the metallic body, the current will quickly go to the earth and protects us from electric shock.

QUESTION BANK

EXERCISE - 1

Q.1 What do you conclude from Oersted's experiment ?

Q.2 Name the types of electromagnets commonly used.

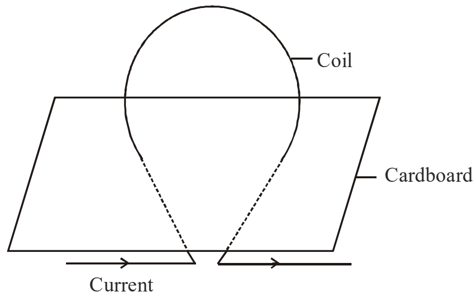
Q.3 Can we produce electricity from magnetism ?

Q.4 Does the A.C. generator have any slip ring ?

Q.5 A 0.4m wire, stretched horizontally, carries an electric current of 15A from east to west, in a magnetic field whose magnetic field intensity is 0.1 N/Am, directed vertically downwards. What is
(a) the magnitude of the magnetic deflecting force on the wire, and
(b) its direction ?

Q.6 A straight conductor passes vertically through a cardboard sprinkled with iron filings. Show the setting of the iron filings when a weak current is passed in the downward direction. What changes occur if,
(i) the strength of the current is increased.
(ii) the single conductor is replaced by several parallel conductors with current flowing in the same. direction.

Q.7 The diagram shows a current carrying coil passing through a sheet of stiff cardboard. Draw three lines of magnetic field on the cardboard.
State two factors on which the magnitude of magnetic field at the centre of coil, depends.



Q.8 Draw a labelled diagram to make an electromagnet from a soft iron bar. Mark the polarity at its ends. What precaution would you observe ?

Q.9 When can an electric charge give rise to a magnetic field ?

Q.10 Describe a set up for plotting the magnetic lines of force in a straight conductor.

Q.11 State a low, which determines the direction of magnetic field round a current carrying wire.

Q.12 What is the direction of magnetic field at the centre of a coil carrying current in (i) clockwise (ii) anticlockwise direction ?

Q.13 Why does a current carrying, freely suspended solenoid rest along a particular direction ?

Q.14 What is an electromagnet ? State the factors on which the strength of the magnetic field of an electromagnet depends. What is the purpose of the iron core ?

Q.15 State two ways through which the strength of an electromagnet can be increased.

Q.16 Why is soft iron used as the core of the electromagnet used in electric bell ?

Q.17 State three factors on which, the magnitude of force on a current carrying conductor placed in a magnetic field, depends. Can this force be zero for some position of the conductor ?

Q.18 How will the direction of force be changed, if the current is reversed in the conductor placed in a magnetic field?

Q.19 What is electromagnetic induction ? Describe one experiment to demonstrate the phenomenon of electromagnetic induction.

Q.20 State two factors on which the magnitude and direction of induced emf depend.

Q.21 How would you demonstrate that a momentary current can be obtained by the suitable use of a magnet and a coil of wire ? What is the source of energy associated with the current so obtained ?

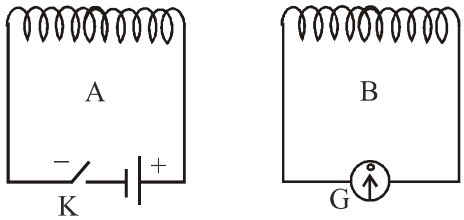
Q.22 State Fleming's right hand rule.

Q.23 State the principle of a simple a.c. generator.

Q.24 A flat coil of wire rotates at a constant rate about an axis which is at right angles to a uniform magnetic field. Indicate, with the help of a graph, how the induced emf varies during one complete rotation of the coil.

Q.25 A flat rectangular coil is rotated between the pole pieces of a horse-shoe magnet. In which position of the coil with respect to the magnetic field, will the emf (i) be maximum (ii) be zero and (iii) change direction ?

Q.26 Two coils A and B are placed as shown in figure. The coil A is connected to a battery and a key K while the coil B is connected to a centre zero galvanometer G. What will you observe in the galvanometer G when



(i) the key K is closed. (ii) the key K is opened

(iii) with the key K closed, the coil A is moved rapidly towards the coil B.

(iv) with the key K closed, the coil B is moved rapidly towards the coil A.

(v) with the key K closed, the coils A and B are moved away from each other.

Q.27 What do you mean by an electromagnet ? With the help of diagrams show the two types of electromagnets. Give two uses of electromagnets.

Q.28 How will you experimentally show that a current-carrying conductor experiences a force when kept in a magnetic field ?

Q.29 Briefly describe the principle, construction and working of an AC generator or dynamo.

Q.30 Predict the direction of induced current in the situations described by the following fig. (1) to (5).

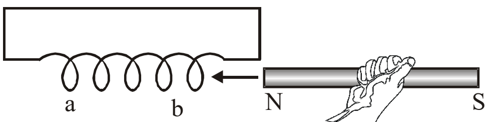


Fig. 1

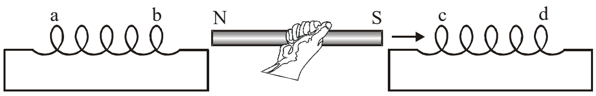


Fig. 2

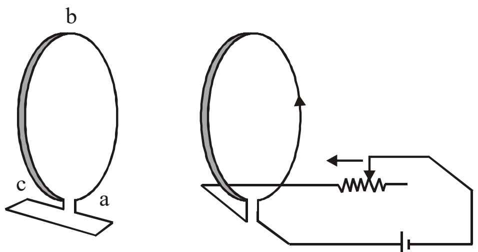


Fig. 3

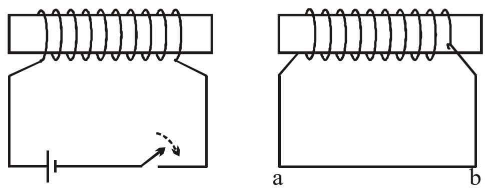


fig. 4

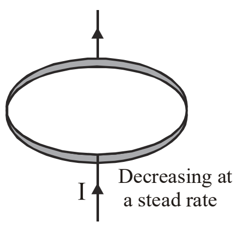


Fig.5

EXERCISE - 2

FILL IN THE BLANKS :

Q.1 A compass needle is a .... magnet.

Q.2 Field lines are used to represent a ....

Q.3 Field lines are shown closer together where the magnetic field is ....

Q.4 A metallic wire carrying an electric current has associated with it a .... field.

Q.5 The field lines about the wire consist of a series of concentric circles whose direction is given by the .... rule.

Q.6 The phenomenon of .... is the production of induced current in a coil placed in a region where the magnetic field changes with .... The magnetic field may change due to a .... between the coil and a magnet placed near to the coil. If the coil is placed near to a current-carrying conductor, the magnetic field may change either due to a change in the .... through the conductor or due to the relative motion between the .... and .... The direction of the induced current is given by the .... rule.

Q.7 A generator converts mechanical energy into .... energy. It works on the basis of ....

Q.8 In our houses we receive AC electric power of .... with a frequency of ....

Q.9 One of the wires in this supply is with red insulation, called ....

Q.10 .... is the most important safety device, used for protecting the circuits due to short-circuiting or overloading of the circuits.

Q.11 The magnetic lines of force are the lines drawn in a magnetic field along which a .... pole would move.
Q.12 An electric current can be used for making temporary magnets known as ....
Q.13 The unit of magnetic field is ....
Q.14 The S.I. unit of magnetic flux ....
Q.15 The frequency for A.C. (alternating current) in USA is ....

TRUE-FALSE STATEMENTS –
Q.16 An electric motor converts mechanical energy into electrical energy.
Q.17 An electric generator works on the principle of electromagnetic induction.
Q.18 The field at the centre of a long circular coil carrying current will be parallel straight lines.
Q.19 A wire with a green insulation is usually the live wire of an electric supply.
Q.20 A magnetic field exists in the region surrounding a magnet, in which the force of the magnet can be detected.
Q.21 The earth wire that has green insulation and this is connected to a metallic body deep inside earth.
Q.22 The pattern of the magnetic field around a conductor due to an electric current flowing through it depends on the shape of the conductor.

EXERCISE - 3

Q.1 Choose the correct option(s).
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.
Q.2 Which of the following property of a proton can change while it moves freely in a magnetic field –
(A) mass (B) speed (C) velocity (D) momentum
Q.3 A positively-charged particle (alpha-particle) projected towards west is deflected towards north by a magnetic field. The direction of magnetic field is –
(A) towards south (B) towards east (C) downward (D) upward
Q.4 A rectangular coil of copper wires is rotated in a magnetic field. The direction of the induced current changes once in each –
(A) two revolutions (B) one revolution (C) half revolution (D) one-fourth revolution
Q.5 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 centred on the wire.
Q.6 The phenomenon of electromagnetic induction is –
(A) the process of charging a body.
(B) the process of generating magnetic field due to a current passing through a coil.
(C) producing induced current in a coil due to relative motion between a magnet and the coil.
(D) the process of rotating a coil of an electric motor.
Q.7 The device used for producing electric current is called a
(A) generator (B) galvanometer (C) ammeter (D) motor
Q.8 The essential difference between an AC generator and a DC generator is that –
(A) AC generator has an electromagnet while a DC generator has permanent magnet.
(B) DC generator will generate a higher voltage. (C) AC generator will generate a higher voltage.
(D) AC generator has slip rings while the DC generator has a commutator.
Q.9 At the time of short circuit, the current in the circuit –
(A) reduces substantially (B) does not change (C) increases heavily (D) vary continuously

Q.10 A magnet is placed vertically on a paper. Then the number of neutral points obtained on the paper is –
(A) zero (B) one (C) two (D) three

Q.11 The direction of induced current is obtained by –
(A) Fleming's left hand rule (B) Right hand thumb rule
(C) Biot and Savart rule (D) Fleming's right hand rule

Q.12 A small magnet is placed perpendicular to a uniform magnet field. The forces acting on the magnetic will result in–
(A) Rotational motion (B) Translatory motion
(C) No motion at all (D) Translational and rotational motion both

Q.13 In an electric motor, conversion takes place of –
(A) Chemical energy into electrical energy (B) Electrical energy into mechanical energy
(C) Electrical energy into light (D) Electrical energy into chemical energy

Q.14 A charge of 1.6×10^{-19} coulomb enters in the magnetic field of 2 weber/m² normally with a velocity of 10^5 m/sec. The force on the charge will be –
(A) 3.2×10^{-14} N (B) 3.2×10^{-19} N (C) 1.6×10^{-14} N (D) zero

Q.15 The magnetic field at a point due to a current carrying conductor is directly proportional to the –
(A) current flowing through the conductor (B) Distance from the conductor
(C) Voltage across the conductor (D) Resistance of the conductor

Q.16 Which one of the following substances is the magnetic substances –
(A) Mercury (B) Iron (C) Gold (D) Silver

Q.17 Magnetic lines do not intersect one-another because –
(A) they are at a distance (B) they are in the same direction (C) they are parallel to another
(D) at the point intersection there will be two direction of the magnetic force which is impossible

Q.18 Instrument can be shielded from outside magnetic effects by surrounding them with –
(A) Rubber shield (B) Glass shield (C) Iron shield (D) Brass shield

Q.19 The vertical plane which passes through the magnetic axis of a freely suspended magnetic at rest is called –
(A) Magnetic meridian (B) Geographical meridian (C) North meridian (D) South meridian

Q.20 By removing the inducing magnet, the induced magnetism is –
(A) Finished after some time (B) Finished just after
(C) Not finished for a long time (D) Not charged

Q.21 The similar magnets of steel are .... than the magnets of soft iron –
(A) stronger (B) of equal strength (C) weaker (D) none of the above

Q.22 The line joining the places which have zero value of dip is known as –
(A) aclinic line (B) Isoclinic line (C) Isogonic line (D) Isometric line

Q.23 A bar of soft iron is placed flat on the table. A bar magnet is taken and its south pole is placed on one end of the bar of soft iron. The magnet is held almost vertically. The bar is stroked from one end to the other with magnet. On the other end of the bar, magnet is lifted and again placed on the first end and the bar is again stroked. The end of the bar where the magnet is lifted will be –
(A) south pole (B) no pole (C) south and north both type (D) north pole

Q.24 The angle of decilination at a place is the angle –
(A) between the vertical plane and the geographical meridian
(B) between the vertical plane and the magnetic meridian
(C) between the geographical meridian and the magnetic meridian
(D) between the geographical meridian and horizontal plane

Q.25 The magnetism is a magnet is mainly doe to –
(A) The orbital motion of the electrons (B) The spin motion of the electrons
(C) The nuclear charge (D) None of the above

Q.26 Places of equal inclination are joined by lines on a map. These lines are known as –
(A) Aclinic lines (B) Isoclinic lines (C) Isogonic lines (D) Agonic lines

Q.27 When the north pole of a strong magnet is brought near to the north pole of a weak magnet then they will –
(A) Attract each other (B) repel each other
(C) first attract and then repel (D) first repel and then attract

Q.28 A magnet can be demagnetised by –
(A) Hammering the magnet (B) Putting it in the water
(C) Cooling it (D) Putting in contact with iron

Q.29 The effective length of the magnet is –
(A) the complete length of the magnet (B) the distance between the two poles of the magnet
(C) the half of the length of the magnet (D) the square of the length of the magnet

Q.30 When the bars of bismuth are placed between the magnetic poles they set their length –
(A) perpendicular to the lines of force (B) along the lines of force
(C) neither perpendicular nor along the lines of force (D) In any direction

Q.31 Two bars of soft iron exactly alike are given. One of them is a magnet. Without using any thing more, how would you find which is a magnet –
(A) By bringing two bars near and noting which one is attracting. The attracting one is a magnet
(B) By bringing two bars near and noting which one is repelling. One which repells is an ordinary iron.
(C) By rubbing one bar with the other and noting which becomes magnet. The bar which is magnetised is an ordinary iron
(D) One bar is placed flat horizontal on the table and the other bar is held vertical with its one end on the middle of first bar. If there is attraction between the two, the vertical bar is magnet otherwise ordinary iron.

Q.32 Magnetic storms are due to –
(A) the rotation of the earth (B) the revolution of the earth
(C) the rainy season (D) the appearance off sun spots

Q.33 The current in a generator armature is AC because
(A) the magnetic field reverses at intervals (B) the current in the field coils is AC
(C) the rotation of the armature causes the field through it to reverse
(D) the commutator feeds current into it in opposite directions every half cycle

Q.34 Lenz's law is derived from the law of conservation of –
(A) Momentum (B) energy (C) charge (D) magnetism

Q.35 Which of the following processes will not produce new magnetic poles –
(A) cutting a bar magnet in half (B) turning on a current in a solenoid
(C) running a current through a straight wire (D) placing an iron rod in contact with a magnet

Q.36 Magnetic field lines start –
(A) on N-poles (B) on S-poles
(C) on current-carrying wires (D) Nowhere

Q.37 The conductivity of a magnetic substance for the lines of force with respect to air is called the –
(A) Magnetic induction (B) magnetic permeability
(C) magnetic flux density (D) intensity of magnetisation

Q.38 Magnetic field lines form circles in the space –
(A) near a permanent magnet (B) around a current-carrying wire
(C) inside a solenoid (D) inside a current-carrying loop

Q.39 The angle of inclination of the axis of the magnetic needle to the horizontal plane when suspended freely and is at rest is known as –
(A) angle of inclination (B) angle of variation (C) angle of declination (D) none of the above

Q.40 A tesla is equivalent to a –
(A) newton per coulomb (B) newton per ampere-meter
(C) ampere per newton (D) newton per ampere-second

Q.41 The place were the angle of dip is 90° are known as –
(A) geographical poles of the earth (B) magnetic equator
(C) magnetic poles of the earth (D) none of the above

Q.42 A vertical wire carries a current upward. The magnetic field north of the wire will be directed –
(A) upward (B) eastward (C) westward (D) northward

Q.43 The magnetic flux is expressed in –
(A) dynes (B) Oerested (C) Gauss (D) Weber

Q.44 The current in the armature of a motor is reversed every half cycle due to the action of a(n)
(A) armature (B) field coil (C) brush (D) commutator.

Q.45 For dynamo which one of the following statements is correct –
(A) It converts the electrical energy into light energy
(B) It converts the kinetic energy into heat energy
(C) It converts the mechanical energy into electrical energy
(D) It converts the electrical energy into mechanical energy

Q.46 When current flows in a wire, it creates –
(A) an electric field outside (B) a magnetic field around it
(C) both the electric and magnetic fields (D) neither the electric field nor the magnetic field

Q.47 A soft iron bar in introduced inside a current carrying solenoid. The magnetic field inside the solenoid.
(A) will become zero (B) will decrease (C) will increase (D) will remain unaffected

Q.48 The magnetic lines of force, inside a current carrying solenoid, are –
(A) along the axis and are parallel to each other
(B) perpendicular to the axis and equidistance from each other
(C) circular and they do not intersect each other
(D) circular at the ends but they are parallel to the axis inside the solenoid.

Q.49 For making a strong electromagnet, the material of the core should be –
(A) soft iron (B) steel (C) brass (D) laminated steel strips

Q.50 In a moving coil galvanometer, the magnetic pole pieces are made cylindrical and a soft iron core is placed at the centre of the coil to make the magnetic field –
(A) strong (B) strong and radial (C) uniform (D) strong and uniform

Q.51 In an electric motor, the energy transformation is –
(A) from electrical to chemical (B) from chemical to light
(C) from mechanical to electrical (D) from electrical to mechanical

Q.52 In which of the following cases does the electromagnetic induction occur –
(A) a current is started in a wire held near a loop of wire
(B) the current is stopped in a wire held near a loop of wire
(C) a magnet is moved through a loop of wire (D) a loop of wire is held near a magnet

Q.53 The direction of induced current is obtained by –
(A) Fleming's left hand rule (B) Maxwell's cork-screw rule
(C) Ampere's rule (D) Fleming's right hand rule

Q.54 Which of the following has its working based on electromagnetic induction –
(A) Ammeter (B) Voltmeter (C) Transformer (D) Galvanometer

Q.55 Which of the following is not true –
(A) Induction precedes attraction (B) We cannot isolate a single pole (C) We can magnetise an iron ring
(D) A permanent magnet retains its magnetism even when heated on a flame.

Q.56 Wrist watches are made antimagnetic by shielding their machinery with –
(A) plastic sheets (B) a metal of high conductivity
(C) a magnetic substance of low permeability (D) a magnetic substance of high permeability

Q.57 Which of the following statement is not correct –
(A) The dip angle is the angle between the horizontal and earth's total magnetic field.
(B) Neutral points are obtained where the earth's magnetic field is perpendicular to that due to a magnet
(C) A magnetic field is a region in which a magnetic force can be detected.
(D) Magnetic fields are vector quantities

Q.58 When a bar magnet is broken into two pieces –
(A) we will have a single pole on each piece (B) each piece will have two like poles
(C) each piece will have two unlike poles (D) each piece will be lose magnetism

Q.59 The permanent magnets are kept with soft iron pieces at ends as keepers –
(A) to magnetise the soft iron pieces (B) to increase the strength of the magnets
(C) to avoid self demagnetisation (D) for physical safety of the magnets

Q.60 A small magnet is placed perpendicular to a constant magnetic field. The forces acting on the magnet will result in–
(A) rotation (B) translation (C) no motion at all (D) rotation as well as translation

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EXERCISE - 4

MATCH THE COLUMN–

Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **column I** have to be matched with statements (p, q, r, s) in **column II**.

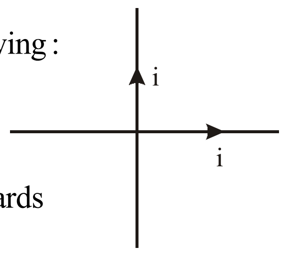
Q.1 Match the following :

Column I	Column II
(A) Work done by the magnetic force may be	(p) zero
(B) Work done by the pseudo force may be	(q) ±ve, zero
(C) Frictional work	(r) Conservative
(D) Change in kinetic energy of charge particle in magnetic field	(s) Non conservative

Q.2 Column II gives approximate values of magnetic fields due to source given in column I

Column I	Column II
(A)At surface of neutron star	(p) 10^{-10} T
(B) Near big electromagnet	(q) 1.5 T
(C) At earth surface	(r) 10^{8} T
(D) In interstellar space	(s) 10^{-4} T

Q.3 Equal currents i flow in two wires along x and y axis as shown. Match the following :



Column I	Column II
(A) Magnetic field in first quadrant	(p) inwards
(B) Magnetic field in second quadrant	(q) outwards
(C) Magnetic field in third quadrant	(r) may be inwards or outwards
(D) Magnetic field in fourth quadrant	

ASSERTION & REASON TYPE

Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason). Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement -1 is True, Statement-2 is False.
(D) Statement -1 is False, Statement-2 is True.
(E) Statement -1 is False, Statement-2 is False.

Q.4 **Statement 1 :** A direction current flows through a metallic rod, produced magnetic field only outside the rod.
Statement 2 : There is no flow of charge carriers inside the rod.

Q.5 **Statement 1 :** A proton moves horizontally towards a vertical long conductor having an upward electric current. It will deflect vertically downward.
Statement 2 : Seeing the proton and the conductor from the side of the proton, the magnetic field at the site of the proton will be towards right. Hence the force $\vec{F} = q\vec{v} \times \vec{B}$ will deflect the proton vertically downward.

Q.6 **Statement 1 :** Force experienced by moving charge will be maximum if direction of velocity of charge is parallel to applied magnetic field.
Statement 2 : Force on moving charge is independent of direction of applied magnetic field.

Q.7 **Statement 1 :** A neutral body may experience a net nonzero magnetic force.
Statement 2 : The net charge on a current carrying wire is zero, but it can experience a force in a magnetic field.

Q.8 **Statement 1 :** There is no change in the energy of a charged particle moving in a magnetic field although a magnetic force is acting on it.
Statement 2 : Work done by centripetal force is always zero.

Q.9 **Statement 1 :** When two long parallel wires, hanging freely are connected in series to a battery, they come closer to each other.
Statement 2 : Wires carrying current in opposite direction repel each other.

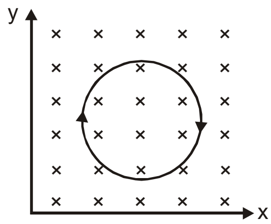
Q.10 **Statement 1 :** A solenoid tends to expand, when a current passes through it.
Statement 2 : Two straight parallel metallic wires carrying current in same direction repel each other.

EXERCISE - 5

PREVIOUS YEARS COMPETITION PROBLEMS

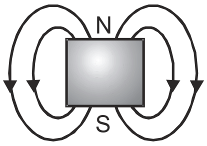
Q.1 A charged particle moves through a magnetic field in a direction perpendicular to it. Then the-
(A) Speed of the particle remains unchanged. (B) Direction of the particle remains unchanged.
(C) Acceleration remains unchanged. (D) Velocity remains unchanged.

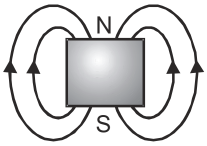
Q.2 A current carrying circular loop is placed in x-y plane fig.
Magnetic field is switched in z-direction. The loop will-
(A) Move towards + x (B) Move towards – x
(C) Contracts (D) Expands

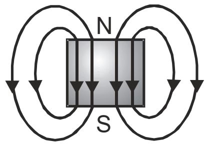


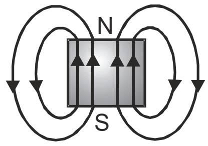
Q.3 Two long conductors, separated by a distance d carry currents I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its direction is reversed. The distance is also increased to 3d. The new value of the force between them is -
(A) – 2F (B) F/3 (C) – 2F/3 (D) – F/3

Q.4 The magnetic field lines due to a bar magnet are correctly shown in-

(A) 

(B) 

(C) 

(D) 

Q.5 The magnetic lines of force inside a bar magnet –
(A) are from north-pole to south-pole of the magnet.
(B) do not exist.
(C) depend upon the are of cross-section of the bar magnet.
(D) are from south-pole to north-pole of the magnet.

Q.6 The materials suitable for making electromagnets should have-
(A) low retentivity and high coercivity (B) low retentivity and low coercivity
(C) high retentivity and low coercivity (D) high retentivity and high coercivity

Q.7 A magnetic needle is kept in a non-uniform magnetic field. It experiences
(A) a force and a torque (B) a force but not a torque
(C) a torque but not a force (D) neither a force nor a torque

Q.8 Magnetic effect of current was discovered by –
(A) Faraday (B) Oersted (C) Ampere (D) Bohr

Q.9 The direction of magnetic lines of forces close to a straight conductor carrying current will be –
(A) Along the length of the conductor (B) Radially outward
(C) circular in a plane perpendicular to the conductor (D) Helical

Q.10 A current carrying wire in the neighbourhood produces –
(A) No field (B) electric field only
(C) magnetic field only (D) electric and magnetic fields

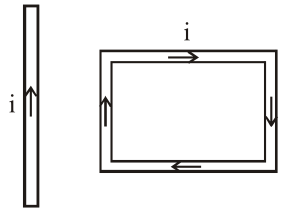
Q.11 A magnetic field can be produced by –
(A) A moving charge (B) A changing electric field (C) None of these (D) Both of these

Q.12 An electron is travelling horizontally towards east. A magnetic field in vertically downward direction exerts a force on the electron along –
(A) East (B) West (C) North (D) South

Q.13 A magnetic field
(A) Always exerts a force on a charged particle
(B) Never exerts a force on a charged particle
(C) Exerts a force, if the charged particle is moving across the magnetic field lines
(D) Exerts a force, if the charged particle is moving along the magnetic field lines

Q.14 Two free parallel wires carrying currents in opposite direction –
(A) Attract each other (B) Repel each other
(C) Neither attract nor repel (D) Get rotated to be perpendicular to each other

Q.15 A rectangle loop carrying a current i is situated near a long straight wire such that the wire is parallel to the one of the sides of the loop and is in the plane of the loop. If a steady current I is established in wire as shown in figure, the loop will –



(A) Rotate about an axis parallel to the wire
(B) Move away from the wire or towards right
(C) Move towards the wire
(D) Remain stationary

EXERCISE - 6

PREVIOUS YEAR BOARD QUESTIONS

Q.1 What constitutes the field of a magnet ?

Q.2 How can you show that the magnetic field produced by a given electric current in the wire decreases as the distance from the wire increases ?

Q.3 How is the strength of the magnetic field at a point near a wire related to the strength of the electric current flowing in the wire?

Q.4 An alternating electric current has a frequency of 50 hz. How many times does it change its direction in one second?

Q.5 What will be the frequency of an alternating current if its direction changes after every 0.01 s?

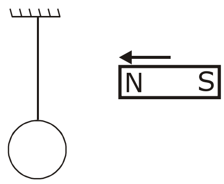
Q.6 State the rule to determine the direction of magnetic field around a current carrying conductor.

Q.7 How will the magnetic field intensity at the centre of a circular coil carrying current change, if the current through the coil is doubled and the radius is halved?

Q.8 In which direction would a compass needle align if taken a geographic (i) North and (ii) South ?

Q.9 Name the physical quantity whose S.I. unit is Wb - m^2. Is it a scalar quantity or vector quantity?

Q.10 Give the direction of induced current in the wire loop, when the magnet moves forward as shown in the figure.



Q.11 What is the difference between direct and alternating currents ? Write one important advantage of using alternating current.

Q.12 Differentiate between short circuiting and overloading of electric circuits. How does a fuse protect an electric circuit?

Q.13 State Faraday's law of electromagnetic induction.

Q.14 How does the strength of the magnetic field at the centre of a circular coil of wire depend on :
(i) the radius of the coil
(ii) the number of turns of wire in the coil
(iii) the strength of current flowing in the coil ?

Q.15 The flow of a current in a circular loop of wire creates a magnetic field at its centre. How may existence of this field be detected ? State the rule which helps to predict the direction of this magnetic field.

Q.16 What is the relation for force experienced by a current carrying straight conductor placed in a magnetic field ? Under what condition is this force maximum ?

Q.17 (a) What is meant by a 'magnetic field' ?
(b) How is the direction of magnetic field at a point determined ?
(c) Describe an activity to demonstrate the direction of the magnetic field generated around a current carrying conductor.
(d) What is the direction of magnetic field at the centre of current carrying circular loop ?

Q.18 (a) What is an electromagnet ?
(b) List any of its two uses.
(c) What is the purpose of the soft iron core used in making an electromagnet ?

Q.19 (a) What are 'magnetic field lines' ? How is the direction of a magnetic field at a point determined ?
(b) List three properties of magnetic field lines.

Q.20 Why is pure iron not used for making permanent magnets? Name one materials used for making permanent magnets. Describe how permanent magnets are made electrically. State two examples of electrical instruments made by using permanent magnets.

Q.21 State Fleming's left hand rule. Describe the working of an electric motor. What is the function of split ring commutator in motor?

ANSWER KEY

EXERCISE - 1

(2) (i) Bar type (ii) Horse shoe type **(3)** Yes. **(4)** The A.C. generator has two slip rings. **(5)** (a) 0.6 N

(30) (1) along a $\rightarrow$ b (2) along b $\rightarrow$ a , along d $\rightarrow$ c (3) along cba
(4) along a $\rightarrow$ b (5) No induced current since field lines lie in the plane of the loop.

EXERCISE - 2

(1) small **(2)** magnetic field **(3)** greater. **(4)** magnetic **(5)** right-hand
(6) electromagnetic induction, time, relative motion, current, coil, conductor, Fleming's right-hand
(7) electrical, electromagnetic induction. **(8)** 220 V, 50 Hz. **(9)** live wire **(10)** Fuse
(11) north magnetic **(12)** electromagnets **(13)** tesla **(14)** Weber
(15) 60 Hz **(16)** False **(17)** True **(18)** True
(19) False **(20)** True **(21)** True **(22)** True

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10	11
A	D	C,D	D	C	D	C	A	D	C	B	D
Q	12	13	14	15	16	17	18	19	20	21	22
A	A	B	A	A	B	D	C	A	B	C	A
Q	23	24	25	26	27	28	29	30	31	32	33
A	D	C	B	B	A	A	B	A	D	D	C
Q	34	35	36	37	38	39	40	41	42	43	44
A	B	C	D	B	B	A	B	C	C	D	D
Q	45	46	47	48	49	50	51	52	53	54	55
A	C	B	C	A	A	B	D	A,B,C	D	C	D
Q	56	57	58	59	60						
A	D	B	C	C	D						

EXERCISE - 4

(1) (A) $\rightarrow$ p, (B) $\rightarrow$ q, (C) $\rightarrow$ s, (D) $\rightarrow$ p **(2)** (A) $\rightarrow$ r, (B) $\rightarrow$ q, (C) $\rightarrow$ s, (D) $\rightarrow$ p
(3) (A) $\rightarrow$ r, (B) $\rightarrow$ q, (C) $\rightarrow$ r, (D) $\rightarrow$ p
(4) (E) **(5)** (A) **(6)** (E) **(7)** (A) **(8)** (A) **(9)** (B) **(10)** (E)

EXERCISE - 5

Q	1	2	3	4	5	6	7	8	9	10	11
A	A	D	C	D	D	C	A	B	C	C	D
Q	12	13	14	15							
A	D	C	B	C							

EXERCISE - 6

(5) 50 Hz. **(7)** Four times