5

MAGNETISM AND ELECTROMAGNETISM

MAGNETISM

The first known magnet is the mineral ore called **lodestone.** Lodestone is an oxide of iron (Fe_3O_4). This substance has the ability to attract small pieces of iron nails. Christian Han Ã–ersted in 1820 was able to show that electricity and magnetism are related by producing magnetism from an electric current flowing through a conductor.

OBJECTIVES

At the end of the topic, students should be able to:

- state the properties of magnet and the law of magnetic poles;
- explain magnetic induction;
- distinguish between;
  - magnetic and non-magnetic materials;
  - hard and soft magnetic materials;
- explain magnetic domains;
- state and describe ways of magnetising and demagnetising a magnet;
- identify the pole of the magnet produced.

Properties of magnets

1.Attraction of magnetic materials

Magnets attract strongly substances like iron, nickel, cobalt and their alloys. These substances are called **magnetic materials.**

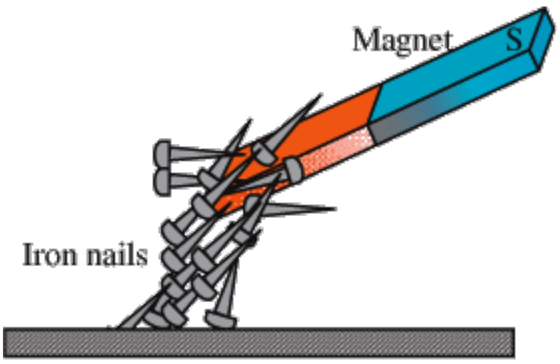


Figure 5.1a: Magnets attract small iron nails

2.Magnetic poles

Iron filings stick more at the ends of a magnet. These ends are called the poles of a magnet. Magnetic poles are always two; therefore, **a magnet is a dipole.** The force of attraction or repulsion is greatest at the poles.

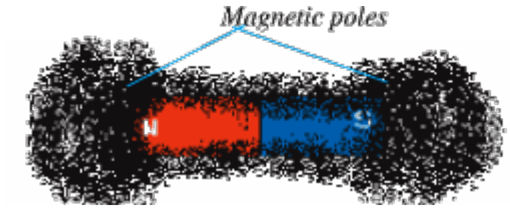


Figure 5.1b: Iron filings stick more at the magnetic poles

3.Direction of the poles of a suspended bar magnet

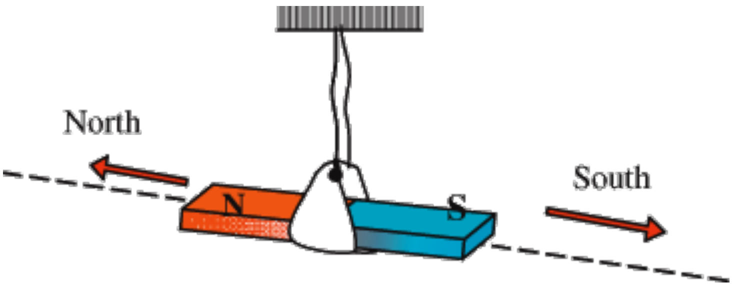


Figure 5.2a: Directional property of magnet

A bar magnet will settle with its axis roughly pointing north-south if it is suspended freely. The pole which points towards the north is called the **north-seeking pole** shortened as **N-pole;** the pole pointing towards the south is called the **south-seeking pole** or **S-pole.**

4.The law of magnetism

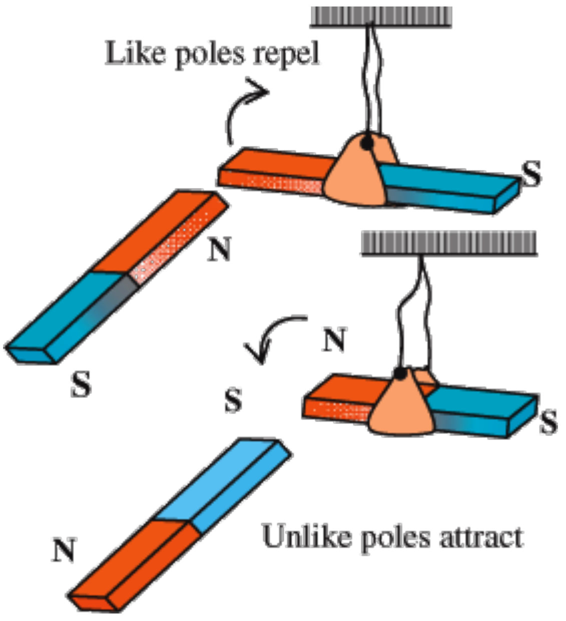


Figure 5.2b: Like poles repel unlike poles attract

The law of magnetic poles states that two like poles repel; two unlike poles attract.
N-pole of one magnet repels the N-pole another magnet but will attract an S-pole. Two S-poles of a magnet will repel each other.

Magnetic induction

Magnetism can be induced in an iron or steel bar if it is held near a magnet. The iron bar becomes a magnet and attracts other smaller iron or steel nails. The magnetism in the iron bar is called **induced magnetism.** The pole of the induced magnet nearest to the permanent magnet is opposite to the pole of the permanent magnet. If the pole of the permanent magnet is N-pole, the pole of the induced magnet nearest to it is S-pole.

The process of forcing or inducing magnetism in a material by bringing a magnet near it is called magnetic induction.

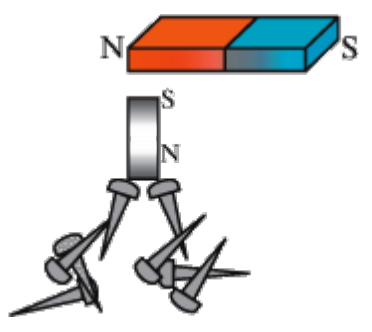


Figure 5.3: Iron bar magnetised by induction

If the permanent magnet is kept close to the iron bar and small iron nails brought near the bar; the bar attracts the nails. When the bar is held with hand and the permanent magnet withdrawn, the nails will fall off. The iron bar is a magnet only when the permanent magnet is close to it; the magnetism in the iron bar is **temporary.** When a steel bar is used in place of the iron bar, the iron nails remain attracted to the steel bar even when the permanent magnet is withdrawn. The magnetism in the steel bar is **permanent.**

Magnetic and non-magnetic materials

Materials which are attracted by a magnet, are called **magnetic materials.** Examples of magnetic materials are iron, steel, nickel cobalt and alloy their metals. **A magnet does not attract non-magnetic materials.** These include glass, rubber, copper, zinc, tin, aluminium and most metals and non-metals.

Soft and hard magnetic materials

Materials which become a magnet easily but lose their magnetism once the magnet inducing the magnetism is removed, are called ***soft magnetic materials.*** Iron and mu-metal are good examples of soft magnetic materials. They do not retain their magnetism for a long time and are used to make **temporary magnets.** The induced magnetism in them is stronger than that of steel. **Hard magnetic materials** are difficult to magnetise but retain their magnetism for a long time. Steel, nickel and cobalt are hard magnetic materials. They are used to produce **permanent magnets.**

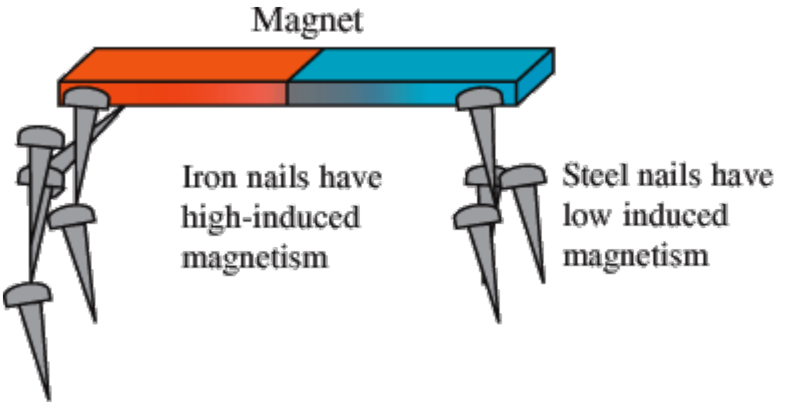


Figure 5.4: Induced magnetism is more for iron than steel

Temporary and permanent magnets

A temporary magnet does not retain its magnetism for a long time. Immediately the source of its magnetism is removed, it loses the magnetism in it. Soft magnetic materials like iron and mu-metal are used in making temporary magnets because these materials do not keep their magnetism if the source of magnetism is removed. *Permanent magnets keep their magnetism long after the source of magnetism had been withdrawn.* They are made from materials like steel, ticonal, alicomax, cobalt and nickel. These materials do not easily become magnets, but once they are magnetised, keep their magnetism for a long time. The induced magnetism in them is weak. Permanent magnets have different shapes as shown in Figure 5.5.

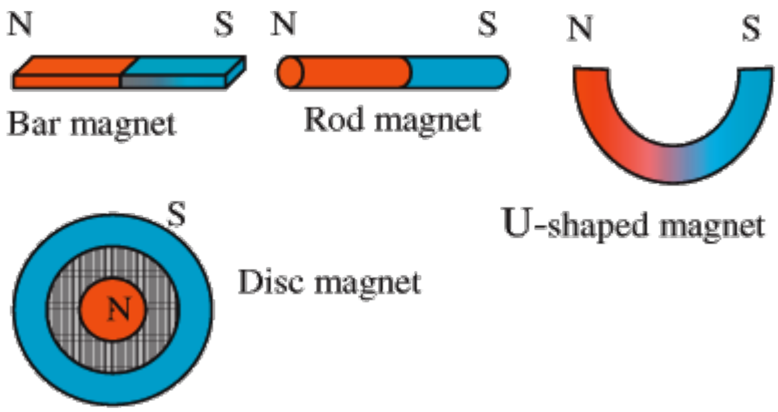


Figure 5.5: Different shapes of magnet

Test for a magnet

An induced magnet is able to attract magnetic materials. Attraction of a substance does not make a material a magnet. It only shows that the substance is a magnetic material. A magnetic material cannot repel a magnet; therefore, if a magnet repels a substance it proves conclusively that the substance is a magnet. **Repulsion is the only sure test for a magnet.**

Theory of magnetism

*A magnet is a **dipole** having both N-pole and S-pole.* If a magnet is divided into two more parts, each part is a magnet with both N-pole and S-pole (see Figure 5.6)

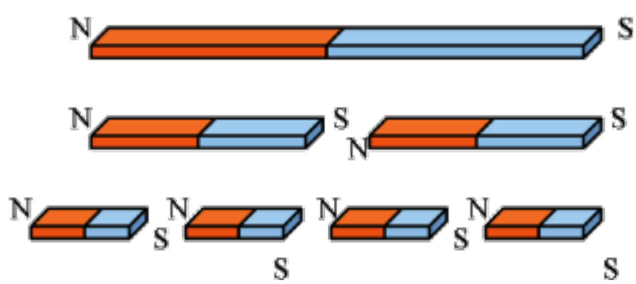


Figure 5.6: Breaking a magnet produces more magnets

Continuous division will produce a magnet, which is a molecule of the substance. **The molecular magnet is called a dipole.** The molecular theory of magnet suggests that a magnet is made up of many small magnets or molecular magnets. These molecular magnets, known as dipole, align (line up) with their N-pole pointing in one direction. The dipoles or atomic magnets point in different direction in a magnetic material, which is not magnetised. The resultant or net magnetism in such a material is zero because the N-pole of one atomic magnet is cancelled by the S-pole of another atomic magnet such that there is no resultant pole at the ends.

Domains

Atomic magnets align in groups of millions of atoms called domain. The atomic magnets align in one direction in a **ferromagnetic material.** When the material is not magnetised, the domains point in all directions such that the resultant magnetism in the material is zero. If a magnet is positioned near the material, the domains align in one direction making the material to have a strong resultant magnetism.

Magnetic saturation

The strength of a magnet depends on the number of atomic magnets aligned in the same direction. A material whose dipoles are not completely aligned in one direction can still increase its strength.

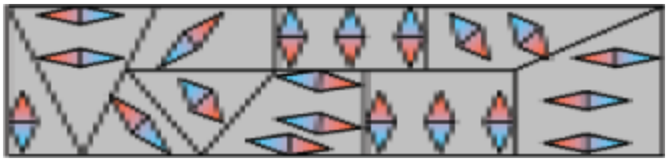


Figure 5.7 Domains of steel that are not magnetized point in different directions

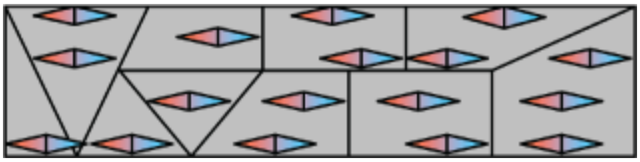


Figure 5.8 Domains of steel that are magnetized point in one direction

The maximum strength of a magnet is attained when all the atomic magnets or dipoles are fully aligned in one direction. **A magnet in which all the dipoles are fully aligned is said to be saturated.** Magnetic saturation occurs when the strength of a magnet cannot be further increased.

Source of atomic magnetism

Atoms consist of charged particles. The electrons are moving constantly round the nucleus and spin about its axis. **The orbital motion and the spinning of the electrons produce an atomic current, which sets up a magnetic field.** In many materials, the magnetic field produced by the electrons cancel out such that the resultant magnetic field is zero. Magnetic materials are divided into **diamagnetic, paramagnetic** and **ferromagnetic** based on how the atomic magnets behave in a magnetic field of a stronger magnet.

Diamagnetic materials

They resist being attracted by a magnet. If they are positioned in a strong magnetic field, they move towards the weak part of the field.

Paramagnetic materials

They have less resistance to magnetic field compared to diamagnetic materials. If they are placed in a strong magnetic field, they become weak magnet and are attracted weakly towards the magnet.

Ferromagnetic materials

The molecules of ferromagnetic materials are small magnets. If a ferromagnetic material is brought in a field of a strong magnet, their atomic molecules align in one direction; therefore, they become strongly attracted towards the magnet.

Methods of making magnets or magnetization

To produce a magnet from steel, all the domains will be made to align in one direction. Lining up atomic magnet of a ferromagnetic material to make it a magnet can be done in one of the following ways:

1.Passing direct current through a coil with the steel bar inside

2.Stroking the steel bar with one pole of a magnet

3. Hitting the steel bar with a hammer in the earthâ€™s magnetic field when it is pointing approximately north – south.

1.The electrical method

The steel bar or soft iron bar is placed inside a coil called **solenoid.** When a direct current is passed through the coil and the bar withdrawn in the N – S direction, it becomes a magnet.

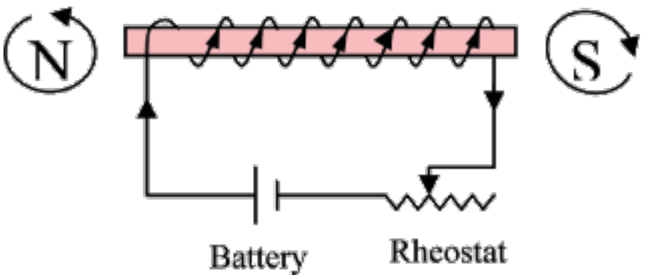


Figure 5.9a : Electrical method

How to find the poles of the magnet produced

- The direction of current flowing through the coil determines the poles of the magnet produced. If the current flows in a clockwiSe direction from one end of the coil, that end, is a **S-**pole. If the direction of current through the coil is following in the aNticlockwise direction from the other end, it is a **N**-pole.
- Right hand grip rule: If the coil is gripped with a right hand such that the fingers point in the direction of current, the thumb points towards the N-pole.

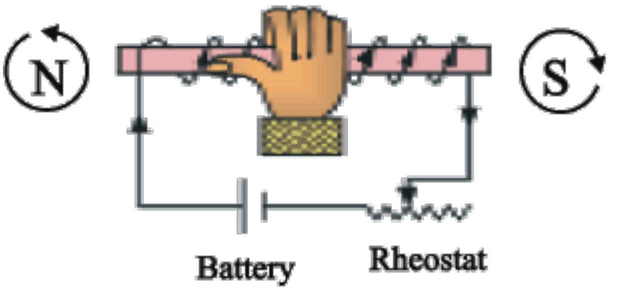


Figure 5.10 : Electrical method

2.Stroke or touch method

A magnet is used to stroke a steel bar many times. The bar becomes a magnet after it had been stroked. Two ways of making a material become a magnet by stroking are: stroking with a single magnet and stroking with two magnets.

Single touch or stroke method

The steel bar is stroked as shown in Figure 5.11 many times in the same direction using either the N-pole or S-pole of a magnet. If N-pole is used, the steel bar becomes a magnet after stroking with S-pole at the end where the stroking N-pole left the bar. The disadvantage of single touch method is that one of the poles is not at the end.

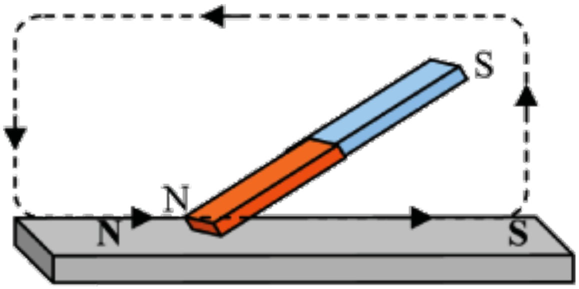


Figure 5.11 : Single touch method

a) Double touch or stroke method

The double touch method is used to produce a magnet with both poles at the ends. The steel bar is stroked with two magnets; one N-pole and the other, an S-pole, at the same time. At the end of stroking, the steel bar becomes a magnet with N-pole at the end where the S-pole left the bar. An S-pole is formed at the end where the N-pole leaves the bar.

3. Hitting the bar in the earthâ€™s magnetic field

If a steel bar is held parallel to the earthâ€™s magnetic field, pointing approximately north-south and hammered many times, it becomes a magnet.

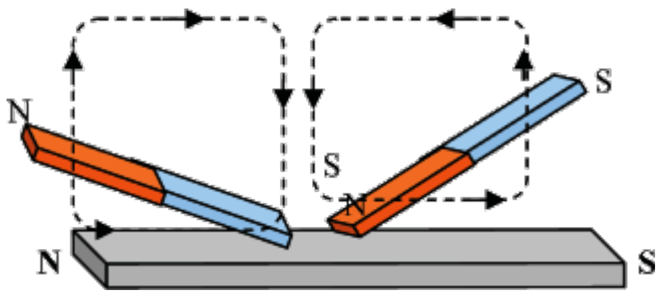


Figure 5.12 : Double touch method

Demagnetization

Making a magnet lose its magnetism is known as demagnetization. Demagnetization of a magnet can be done in one of the following ways:

1)Heating the magnet until it becomes red hot

The magnet is heated until it becomes red hot and allowed to cool pointing east-west.

2)Passing an alternating current through a coil with the magnet inside

The magnet is placed inside a coil with alternating current flowing through it. When the magnet is withdrawn from the coil in the east-west direction while the alternating current is flowing, it is discovered that it would lose its magnetism.

3)Hitting or dropping the magnet many times

Hammering the magnet many times when it is pointing approximately east west or carelessly dropping the magnet on the hard floor will make it lose its magnetism.

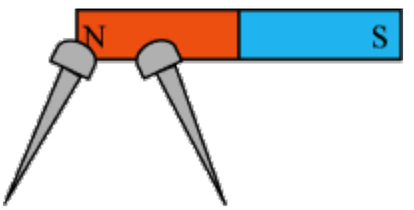
Summary

- The law of magnetic poles states that two like poles repel two unlike poles attract.
- Magnetic induction is the process of forcing or inducing magnetism in a material by bringing a magnet near to it.
- The magnetism in the iron bar during induction is temporary while the magnetism in the steel bar is permanent.
- A magnet attracts magnetic materials but it does not attract non-magnetic materials.
- Hard magnetic materials are difficult to magnetize but they retain their magnetism for a long time while soft magnetic materials are easy to magnetize but lose their magnetism once the source of magnetism is removed.
- Permanent magnets keep their magnetism long after the source of magnetism had been withdrawn but temporary magnets lose their magnetism once the source of magnetism is removed.
- Repulsion is the only sure test for a magnet.
- Domains are tiny magnets with millions of atomic magnets all aligned in one direction.
- Magnetic saturation occurs when the atomic magnets of all the domains are fully aligned in one direction.
- A magnet may be demagnetized by: heating the magnet until it becomes red hot, passing an alternating current through a coil with the magnet inside or hitting (dropping) the magnet many times.

Practice Questions 5a

1. (a) What is a magnet? (b) State four properties of a magnet.
2. (a) State the law of magnetic poles;
   (b) Illustrate the laws using a good sketch.
   (c) You are given three metal rods; one is a magnetic material, another is non-magnetic material and the third a magnet. Explain how you will identify which of the rods is a magnet, a non-magnetic material and a magnetic material.
3. Explain the term-magnetic induction. Using a well labelled diagram, describe how a soft iron can be magnetized by induction.
4. (a) What is a magnetic material? Explain the terms soft and hard magnetic materials.
   (b) How do iron and steel differ in their magnetic properties?
   (c) Explain why soft iron is used as a magnetic core of an electromagnet.

5. (a) What is magnetization? State three different ways to magnetize a steel rod.
   (b) Explain why stroking a steel rod with the S-pole of a magnet makes it a magnet.
6. (a) Explain the term demagnetization;
   (b) Explain why heating a magnet makes it to lose its magnetism.
7. (a) What is (i) dipole? (ii) a domain?
   (b) Use the domain theory of magnetism to explain why;
      (i) a non-magnetized steel is not a magnet;
      (ii) a magnetized steel rod is a magnet;
      (iii) a magnetizesteel rod becomes magnetically saturated.
8. (a) Explain the following terms:
      (i) magnetic saturation;
      (ii) magnetic induction;
      (iii) induced magnetism.
   (b) Use a diagram to describe how electricity may be used to magnetize a steel rod.
   (c) Explain how to find out the poles of the magnet produced using the direction of the current only.
9. (a) Explain why two iron nails magnetized by N-pole of a magnet are inclined as shown in the diagram below.



   (b) Draw a diagram to show how the nails will look like if different poles magnetize them.

Magnetic field of the earth

The earth is surrounded by a magnetic field the same way a magnetic field surrounds a bar magnet. The earth therefore acts like a big magnet. This explains why a magnet suspended with a string comes to rest with its N-pole pointing nearly North pole of the earth.

OBJECTIVES

At the end of the topic, students should be able to:

- locate the earthâ€™s magnetic north – south direction;
- explain the angles variation and dip and uses;
- sketch magnetic field pattern for a bar magnet with its:
    - N – Pole pointing north;

- S – Pole pointing north;

→explain and state use of the magnetic shielding or screening.

Direction of earthâ€™s magnetic field

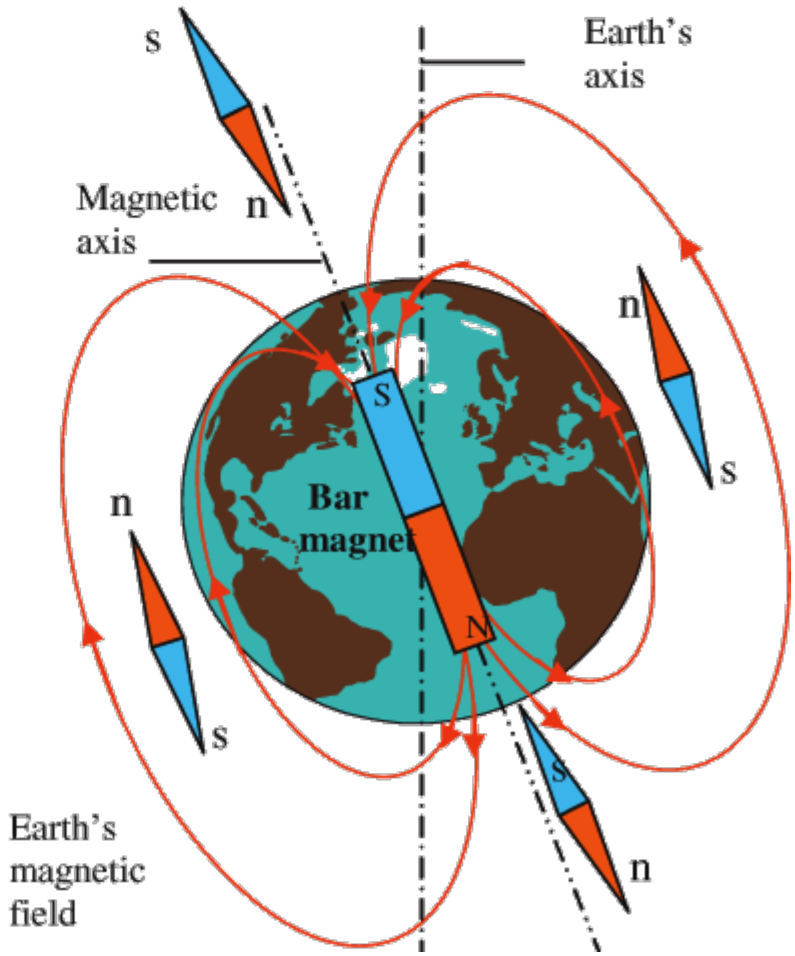


Figure 5.13 : Earthâ€™s magnetic field

The earthâ€™s magnetic field runs from the South pole towards the North pole of the earth. To explain the observed direction of earthâ€™s magnetic field, it is assumed that a big bar magnet is at the earthâ€™s core. The N – pole of the earthâ€™s magnet is pointing towards the south pole of the earth while its S – pole points towards the north pole of the earth. This is illustrated in Figure 5.13.

The source of the magnetic field around the earth is not fully understood. It is known that at the earthâ€™s core is a molten metal; the motion of this liquid metal may be responsible for the presence of magnetic field around the earth.

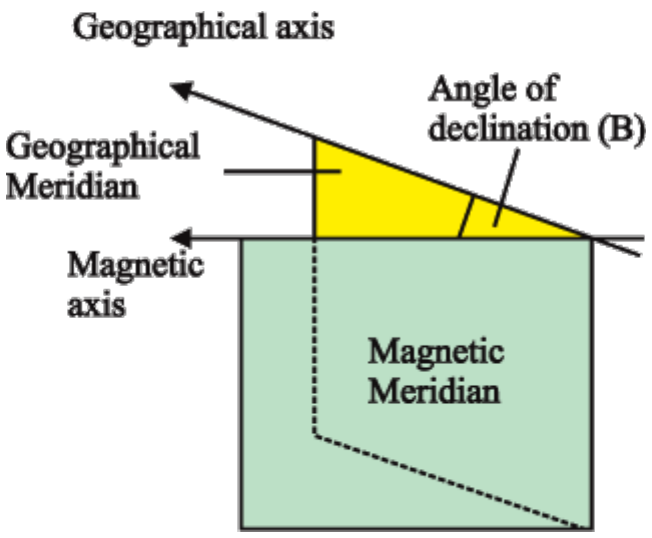


Figure 5.14 : Angle of declination

Angle of variation or declination

The earthâ€™s magnetic N – S direction can be located by suspending a bar magnet with a string and allowing it to rotate freely. When the magnet comes to rest, it points approximately north-south. The North pole of the magnet points in the direction of the North pole of the earth.

Experiments reveal that the axis of the magnet and the earthâ€™s axis do not coincide. An angle is formed between the **magnetic meridian** or the vertical plane passing through the magnetic axis and the **geographical meridian** or the plane passing through the axis of the earth. This angle is known as the angle of **variation** or **declination.**

Angle of variation or declination is the angle formed between the magnetic meridian and the geographical meridian.

Angle of declination or variation varies from place to place on the earthâ€™s surface. Places on the earthâ€™s surfaces with the same angle of declination **(Î²)** are joined by a line called **isogonal line.** Magnetic and geographic meridians coincide at places where the angle of declination is zero (0). The isogonal for places with zero declination is called **agonic line.**

Angle of dip or inclination

Dr Gilbert showed that a magnetic needle pivoted at its centre of gravity will turn in a vertical plane until it stops with its magnetic meridian inclined at an angle to the horizontal. The angle formed between the magnetic meridian and the horizontal is called the **angle of dip** or **inclination.**

Angle of dip or inclination is the angle formed between the magnetic meridian and the horizontal at a particular location on the earthâ€™s surface.

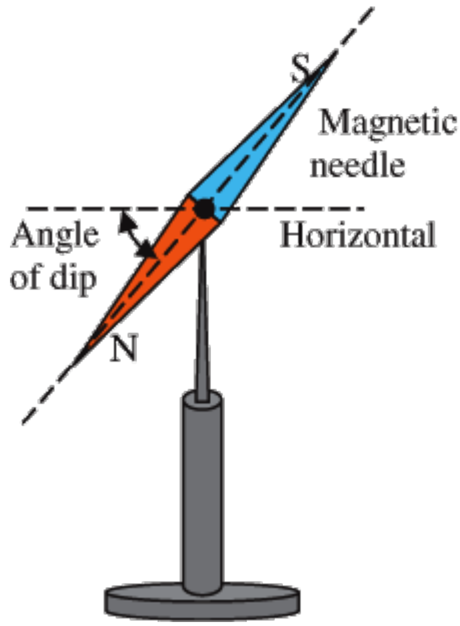


Figure 5.15 : Angle of dip

Dr Gilbertâ€™s experiment with compass needle revealed that the:

- earthâ€™s magnetic field is not always horizontal. In most places on the earthâ€™s surface, the magnetic field lines are inclined to the horizontal. The directions of a magnetic field line in any location is the direction the compass needle points.
- angle of dip varies from place to place on the earthâ€™s surface. Measurements at different locations showed that the angle of dip increases with latitude.
- angle of dip is maximum (90Â°) at the magnetic north and south poles. At the magnetic N – pole, the north pole of the compass needle points downwards. At the magnetic S – Pole, the south pole of the compass needle points downwards.
- angle of dip is zero (0) at the magnetic equator; therefore, the earthâ€™s magnetic field is horizontal or parallel to the earthâ€™s surface.

Vertical and horizontal components of earthâ€™s magnetic field

The earthâ€™s magnetic field is inclined to the horizontal. The resultant magnetic field at any location can be resolved into two perpendicular parts as shown in Figure 5.16.

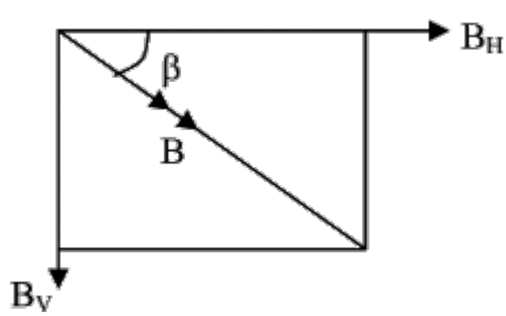


Figure 5.16: Resolving earthâ€™s magnetic field

The vertical component of the earthâ€™s magnetic field B_V = BsinÎ² and the horizontal component is B_H = BcosÎ². The dip angle (Î²) can be found if the horizontal and vertical component of the magnetic field are known.

$$\therefore\ F = m\frac{V^2}{r} = Bqv$$

Interaction of earthâ€™s magnetic field and bar magnets

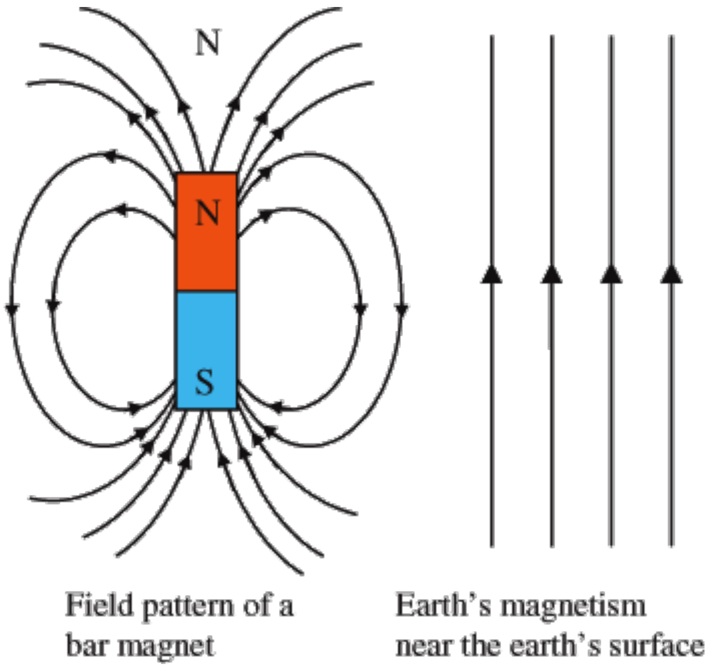


Figure 5.17 : Field patterns of a bar magnet and earthâ€™s magnetism

The earthâ€™s magnetic field near the earthâ€™s surface at any location are parallel. If a bar magnet is suspended in the earthâ€™s magnetism close to the surface of the earth, the magnetic field of earth interacts with the field of the bar magnet. The resultant field pattern formed is distorted and depends on the pole of the magnet pointing north. Figure 5.17 shows magnetic field patterns of the earth close to its surface at a given location and that of a bar magnet.

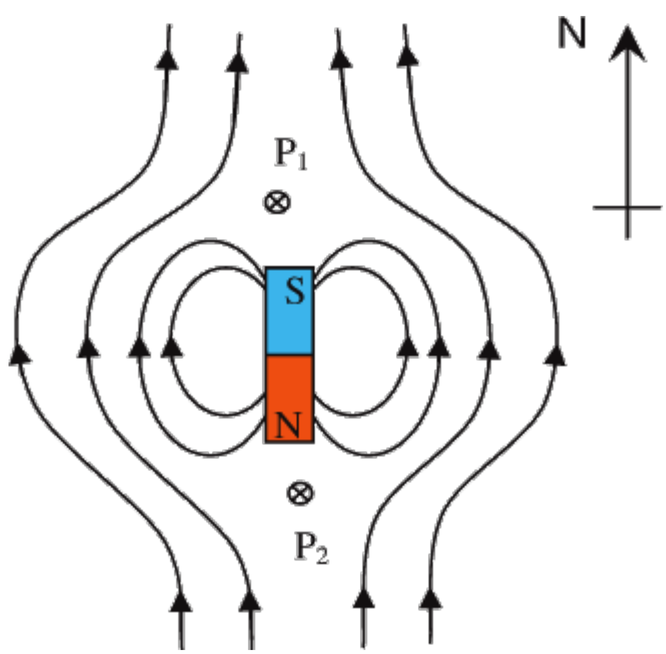


Figure 5.18 : Magnetic field pattern of a bar magnet with S – Pole pointing north

When a bar magnet is suspended in the earthâ€™s magnetic field with its S – pole pointing towards the north pole of the earth, the magnetic field pattern produced is shown in Figure 5.18. Neutral points P_1 and P_2 (point of zero magnetic field) is formed at the ends of the bar magnet. At the neutral points, the magnetic field lines are moving in the opposite directions and therefore cancel out where the opposing field lines are equal in strength.

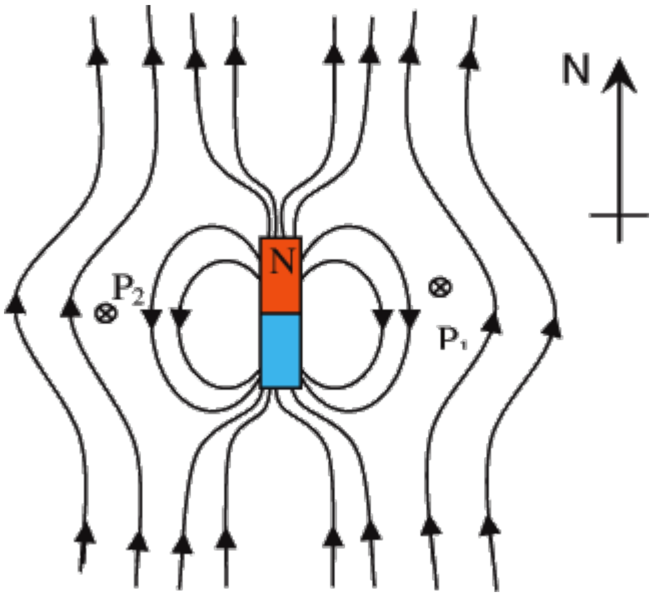


Figure 5.19: Magnetic field pattern of a bar magnet with N – Pole pointing north

A bar magnet with its N – pole pointing towards the north pole of the earth has its magnetic field pattern is shown in Figure 5.19. Neutral points $\mathbf{P_1}$ and $\mathbf{P_2}$ are formed by the sides of the bar magnet where the magnetic field lines are moving in the opposite directions.

Magnetic screening or shielding

Delicate instruments are affected by magnetic field. They are protected from the magnetic field by using a good magnetic material as shield. The magnetic shield provides an easy path or bypass for the magnetic field to move round the instrument. The instrument is now enclosed in a space with zero magnetic fields. This is called **shielding screening** or **magnetic screening.**

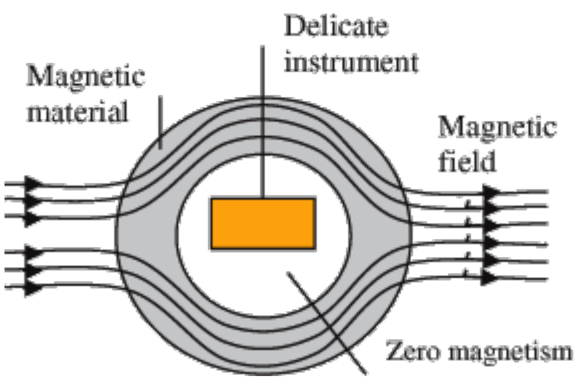


Figure 5.20 : Magnetic screening

Summary

- The earth is surrounded by a magnetic field the same way a magnetic field surrounds a bar magnet.
- The earthâ€™s magnetic field runs from the South pole towards the North pole of the earth.
- Angle of variation or declination is the angle formed between the magnetic meridian and the geographical meridian.
- Angle of dip or inclination is the angle formed between the magnetic meridian and the horizontal at a particular location on the earthâ€™s surface.
- Angle of dip varies from place to place on the earthâ€™s surface. It is maximum (90Â°) at the magnetic north and south poles and zero at the magnetic equator.

Practice Questions 5b

1. (a) What do you understand by *angle of dip and angle of declination?*

   (b) Where on the earthâ€™s surface is the *angle of dip:*

   (i) maximum (ii) zero?

2. (a) Explain what is meant by the term *â€œmagnetic fieldâ€.*

   (b) Sketch the magnetic field of the earth. Use a compass needle to indicate the directions of the magnetic field lines at the magnetic poles and equator.

3. Sketch the magnetic field pattern for a bar magnet with its:

   (i) north pole pointing north;

   (ii) south pole pointing north.

4. Explain how a delicate instrument can be protected from the earthâ€™s magnetic field with the aid of diagram.

5. A blacksmith used a steel bar pointing north-south as an anvil and discovered that the steel bar became a magnet after a weeks work. Explain why the steel bar became a magnet and with reasons identify the north and south poles of the magnets.

Electromagnetism

When an electric current flows through a conductor, magnetic field is produced around it. This was discovered by Ã–ersted in 1820. He also showed that the direction of current flowing through the conductor determines the direction of the magnetic field.

OBJECTIVES

At the end of the topic, students should be able to:

→plot the magnetic field around ;

- a straight conductor carrying current;
- two straight conductors carrying current;
- a solenoid carrying current;
- make an electromagnet and identify the poles using the direction of current;
- describe the working principles of an electric bell and a telephone earpiece.

Magnetic field around a straight conductor with current flowing through it

Carry out the following activities;

(i) Pass a straight conductor through a cardboard as shown in Figure 5.21 and switch on the current.

(ii) Sprinkle iron filings on the cardboard around the straight conductor. Tap the cardboard gently and observe how the iron filings arrange themselves around the straight conductor.

(iii) Place a magnetic compass at four different positions and observe the directions of the N-poles of the compasses.

Magnetic field is produced around a straight conductor-carrying current. The magnetic field lines form concentric circles around the conductor. The direction of the magnetic field lines is the direction of the N-pole of a compass needle placed in the field. If the current flowing through the wire is reversed, the magnetic field lines remain concentric but its direction is reversed. Therefore, changing the direction of the current flowing through the conductor changes the direction of the magnetic field around it. ***The direction of current determines the direction of the magnetic field.*** The magnetic field turns in an anticlockwise direction, when the current is flowing out of the paper (Figure 5.22a). If the current flows into the paper, the direction of the magnetic field is clockwise (Figure 5.22b).

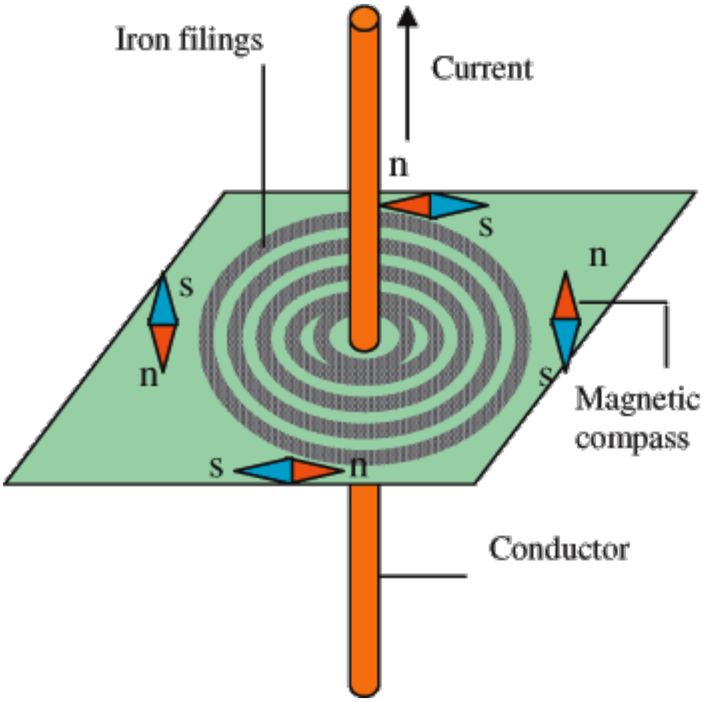


Figure 5.21 : Magnetic field around a current conductor

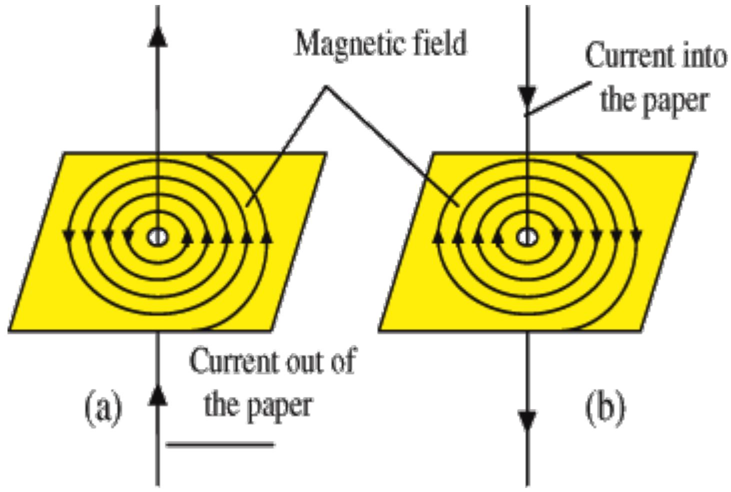


Figure 5.22: Magnetic field of a straight conductor-carrying current

Rules for finding the direction of the magnetic field around a straight conductor carrying current

The following rules are used to find the direction of the magnetic field around a straight conductor with current flowing through it.

(i)The right hand grip rule

The right hand grip rule states that if a straight conductor is held with the right hand such that the thumb points in the direction of current, the curled fingers points in the direction of the magnetic field.

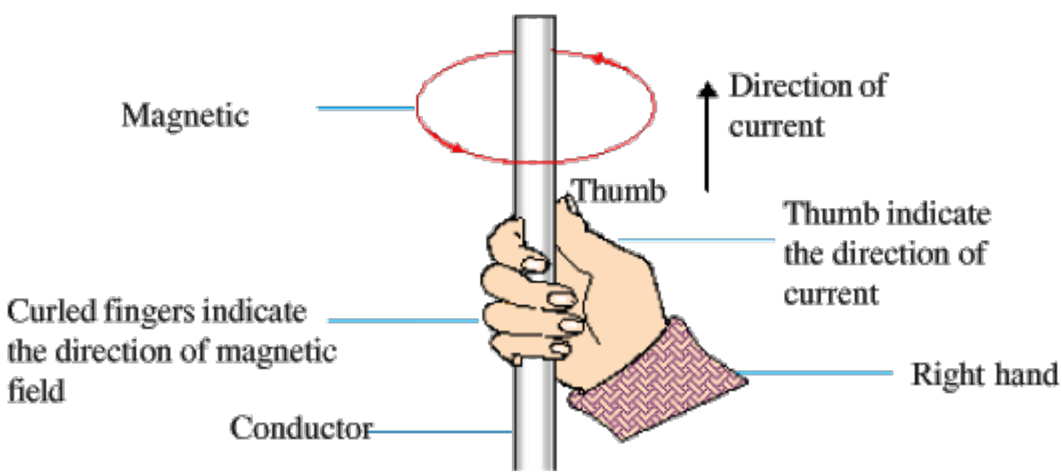


Figure 5.23a: Demonstrating right load grip circle

(ii)The Maxwellâ€™s corkscrew rule

It states that the direction of the magnetic field around a straight conductor-carrying current is the direction a right-handed corkscrew will turn in order to move the corkscrew in the direction of current.

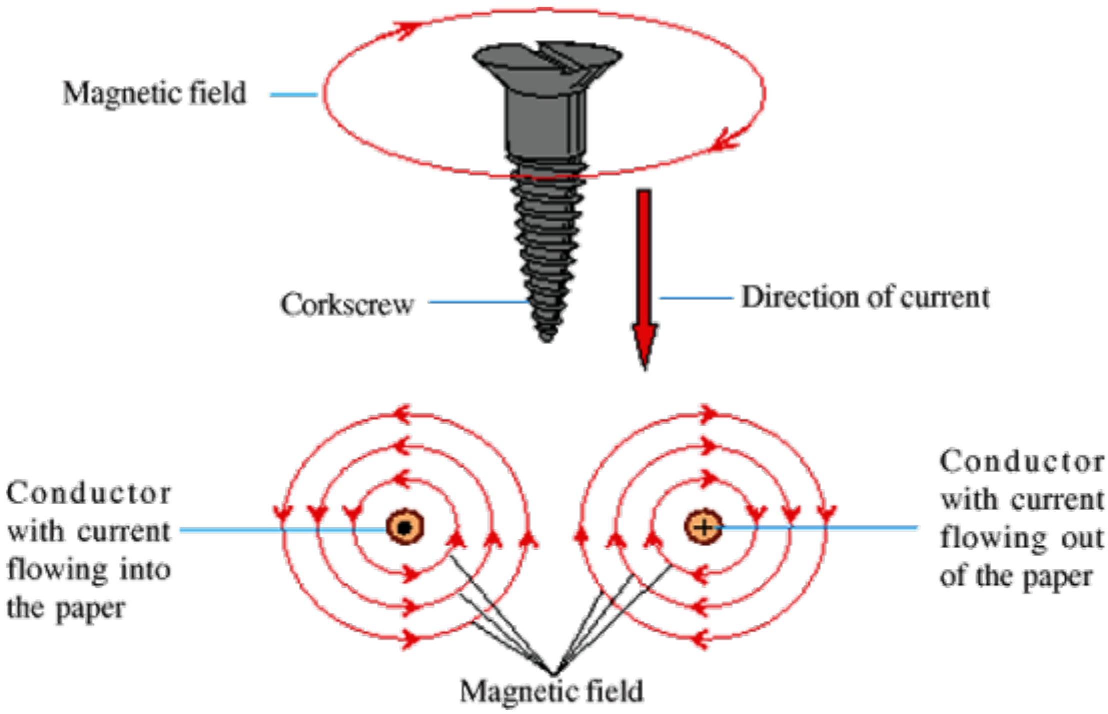


Figure 5.23b: Detecting the magnetic field around a straight current

Symbolically, we represent the conductor with a small bold printed circle and the magnetic field lines with light bigger circles. The dot (â€¢) or the tip of an arrow represents the current moving away from the paper or observer. The cross (Ã—) or the tail of the arrow represents the current flowing into the paper or towards the observer.

Magnetic field pattern of two straight conductors

a. Carrying current in the same direction

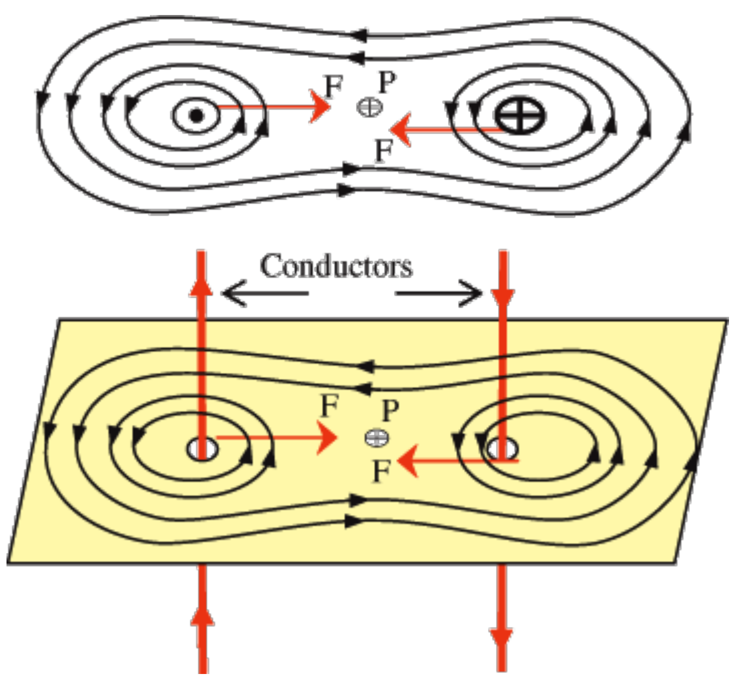


Figure 5.24 : Field patterns of two conductors carrying current in the same directions

Magnetic field is produced around each straight conductor. The field between the conductors is weak because they move in the opposite directions. The stronger fields outside the conductors push them closer; therefore, the conductors attract each other.

b. Carrying current in the opposite directions

When two straight conductors are carrying current in the opposite directions, they repel. The magnetic field between the conductors are closer and stronger than the field outside the conductors. The stronger field between the conductors push them apart; therefore, they repel.

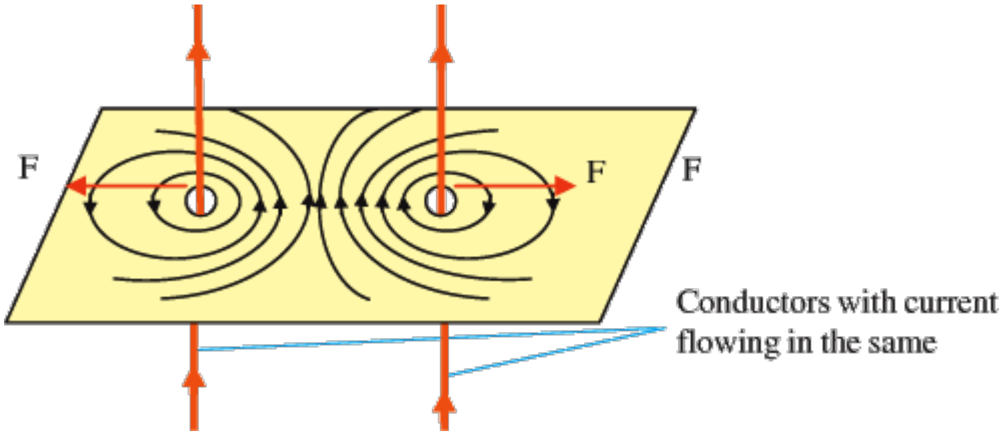


Figure 5.25 : Field patterns of two conductors carrying current in the opposite directions

c. Magnetic field pattern for a wire loop carrying current

The field pattern for a loop of wire with current passing through it is similar to that of the two straight conductor carrying current in the opposite direction. This is illustrated in Figure 5.25.

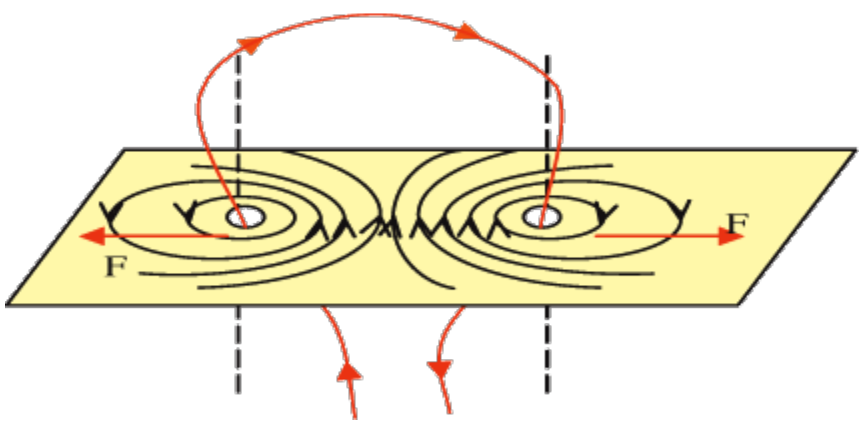


Figure 5.25 : Pattern for a current carrying wire loop

d. Magnetic field pattern for a solenoid with current flowing in it

A solenoid is a long coil of wire whose length is much greater than its diameter. The magnetic field pattern produced by a solenoid is similar to the magnetic field of a bar magnet. The pole of the magnet produced is found by using the direction of current flowing through the coil. When the current flows in the clockwise direction from one end of the coil, that end is a south pole. A north pole is formed if the current is flowing in the anticlockwise direction. The magnetic field inside the solenoid is nearly uniform.

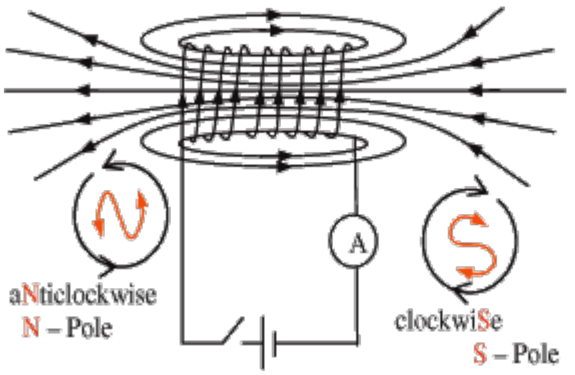


Figure 5.26 : Fieldpattern around a current carrying solemeter

The electromagnet

An electromagnet is formed when a soft iron is inserted into the solenoid and a direct current is allowed to flow through the coil. The magnetic field of the coil induces magnetism in the soft iron. The soft iron is used to make the magnetic field stronger. The strength of an electromagnet can be increased by:

- increasing the size of the current flowing through the coil.
- increasing the number of turns in the coil.
- using a high permeability magnetic core.

An electromagnet is preferred to permanent magnet because:

(i) its strength can be increased by increasing the current flowing through the coil.

(ii) it can be magnetized and demagnetized at will. The electromagnet is demagnetized if the current passing through it is switched off.

(iii) it can be used in many places where permanent magnets are not suitable (e.g. in lifting magnetic materials).

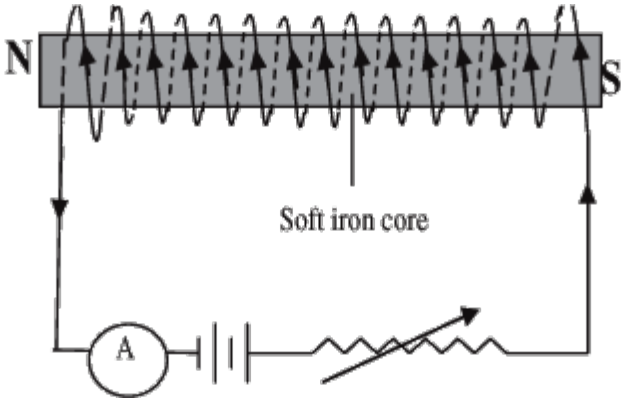


Figure 5.27 : Electromagnet

Uses of electromagnet

1.They are used in lifting heavy magnetic materials instead of cranes and hooks.

2.They are used in making electric bells, motors, generator, loudspeaker, carbon microphones, relays, etc.

3.They are used in hospitals to remove splinters of iron or steel from the eye.

Electric bell

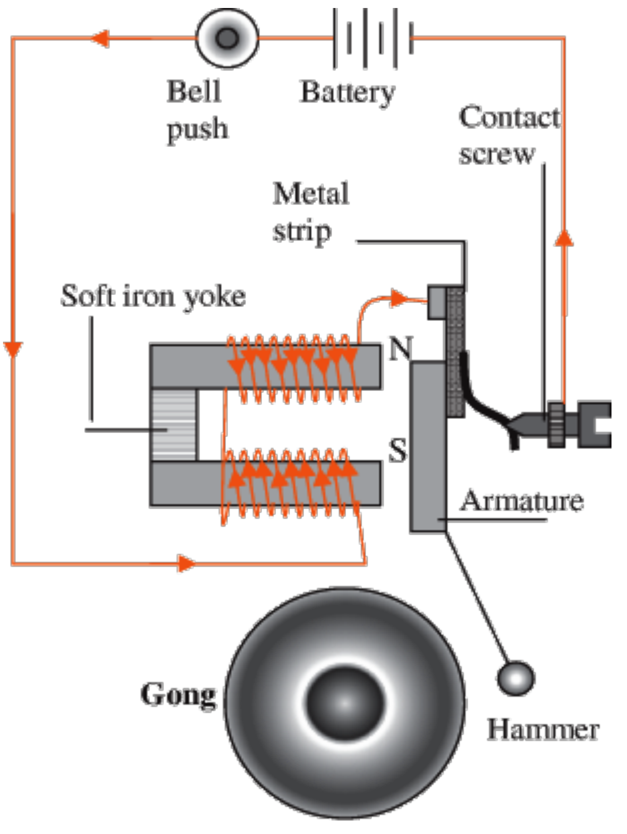


Figure 5.28 : Electric bell

An electric bell consists of two electromagnets linked by a soft iron yoke to form a U-shaped magnet. The winding of the coils of the electromagnets are in the opposite directions. This is done to make the ends of the electromagnet have opposite poles as shown in Figure 5.28.

On pressing the bell push, current flows through coil of the electromagnets. The soft iron armature is attracted by the electromagnet and the hammer attached to the armature moves with it. The hammer strikes the gong to produce a sound. The movement of the armature breaks its contact with the screw, the circuit becomes incomplete and the current flowing through the electromagnet is cut off. The electromagnet loses its magnetism and the metal strip (spring) pulls the armature back to the screw, the circuit is completed again and current flows through the electromagnet. The process is repeated until the circuit is broken finally by releasing the bell push button.

The telephone receiver

The telephone receiver is made up of the following important parts:

- A U-shaped magnet comprising two electromagnets and a permanent magnet sandwiched between the electromagnets. The electromagnets are wound in the opposite directions to make the ends of the U-shaped magnet have opposite poles.
- A magnetic diaphragm made from a magnetic alloy. The diaphragm converts the electrical signal (energy) back to sound.

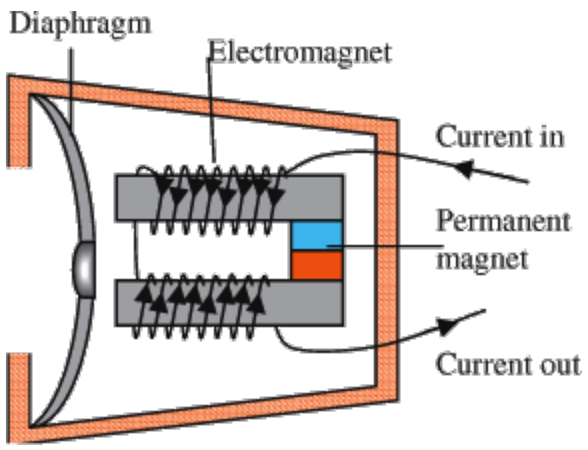


Figure 5.29 : Telephone receiver

How the telephone receiver works

At the other end of the telephone, the microphone converts the sound energy to electrical signal. The electric current produced by the microphone flows through the voice coil (the coil of the electromagnet) in the receiver. A changing magnetic field is produced by the electromagnets because of changing current from the microphone. This changing magnetic field of the electromagnets combines with the magnetic field of the permanent magnet to produce a distorted magnetic field pattern. A changing force is exerted on the magnetic diaphragm making it to vibrate. The vibration of the diaphragm is converted to sound waves giving the exact copy of sound, which enters the microphone.

Summary

- Magnetic field is set up around a straight conductor carrying current. The magnetic field lines form concentric circles around the conductor.
- *The direction of current determines the direction of the magnetic field.* A current flowing out of the paper produces an anticlockwise magnetic field round the conductor. A current flowing into the paper produces a clockwise magnetic field.
- Two straight conductors carrying current in the same direction attract each other.
- Two straight conductors carrying current in the opposite directions repel each other.
- An electromagnet is temporary magnet produced when a direct current flows through a solenoid. The strength of an electromagnet can be varied.

Practice Questions 5c

1. (a) What is a magnetic field?

   (b) Describe an experiment to show that magnetic field is produced around a straight wire in which an electric current is flowing.

   (c) Sketch the pattern of the magnetic field produced showing the direction of current and the magnetic field.

   (d) State one rule that will help you find the direction of the magnetic field if the direction of current is known.

2. (a) Sketch the magnetic field pattern of two straight conductors with current flowing in the:

   (i) same direction;

   (ii) opposite directions.

   (b) Explain why a force acts between the conductors in (a) (i) and (ii).

3. (a) Sketch the magnetic field pattern for a solenoid in which an electric current is flowing.

   (b) Explain how to find the poles of the magnet as result of the current flowing in the coil.

4. (a) Draw a well-labelled diagram of an electromagnet.

   (b) State **two:**

   (i) ways to increase the strength of an electromagnet.

   (ii) advantages of an electromagnet over a permanent magnet.

   (iii) uses of an electromagnet.

5. (a) Draw a labelled diagram of an electric bell and use it to describe and explain how it works.

   (b) State the energy conservation which takes place during the operation of the electric bell.

6. (a) Describe and explain how a telephone receiver works.

   (b) State two similarities and two differences between an electric bell and a telephone receiver

7. (a) Describe an electromagnet and explain how changing the size of current passing through it affects its strength.

   (b) Describe how an electromagnet is used in the construction of an electric bell.

THE MOTOR EFFECT OF ELECTRIC CURRENT

A current carrying–conductor, when placed in a magnetic field experiences a force. The force acting on the conductor causes it to move in the magnetic field if it is free to move. *The movement of the conductor in the magnetic field when a current flows through it is called the motor effect of electric current.* Electric current is the flow of charge (electrons), therefore, force acts on a charge moving in a magnetic field.

OBJECTIVES

At the end of the topic, students should be able to:

→explain the magnetic force on a moving charge;

→state the relation between magnetic force and the motion of a charge in a magnetic field;

→identify the directions of current, magnetic field and force in an electromagnetic field;

→explain the action of a loop of wire carrying current in a magnetic field;
→explain the basic working principle of the galvanometer and the electric motor.

Force on a charge moving in a magnetic field

When a charge is placed in a magnetic field and allowed to move, a force acts on it. The size of the force is proportional to the product of the charge (q) and the velocity (v) if the charge is allowed to move in uniform magnetic field. The size of the force (F) is mathematically given by:

F = Bqv sinÎ±

F = force acting on the charge moving in a magnetic field
B = magnetic flux density measured in Tesla
q = charge on the particle
v = velocity of the particle in the magnetic field
Î± = the angle between v and B
The equation of the force on a charge above is shortened as:

$$\mathbf{F} = q\,(\mathbf{B} \times \mathbf{v})$$

This is the vector form of the force acting on a charged particle. **B** Ã— **v** is called the cross product of vectors **B** and **v** and is defined by;

$$\mathbf{B} \times \mathbf{v} = Bv\sin\alpha.$$

When the magnetic field density **B** is at right angle with the velocity **v** of the charge (i.e. Î± = 90Â°), the force **F** acting on the charge is at its maximum. The maximum force is given by **F** = **B**q**v.** The force **F** is zero if the velocity of the particle is parallel to the magnetic field density **B** (i.e. Î± = 0).

The direction of the force

A charge moves in a magnetic field in a way that the force **F** acting on it is perpendicular to the velocity **v** and the magnetic field density **B.** The angle (Î±) formed between **v** and **B** varies between 0Â° and 90Â°.

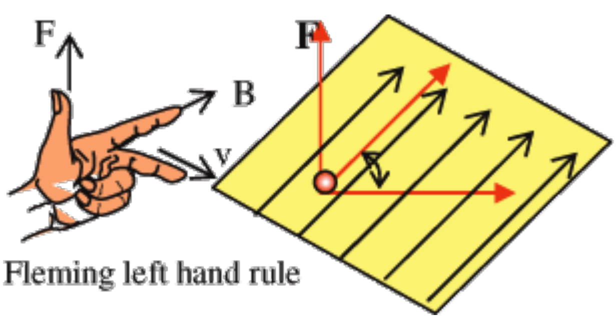


Figure 5.30: Using Flemingâ€™s left hand rule to detect the direction of charge

The direction of the force acting on the charge can be found by Flemingâ€™s left hand rule.

Motion of charge in a magnetic field

A charge (q) moving in a magnetic field of uniform flux density **(B)** is deflected by the magnetic force acting on it. The deflecting force makes the charge to move in a curved path. If the charge moves at right angle to the magnetic field, the maximum force of F = Bqv acts on it to make it move in a circular path of radius r (uniform circular motion). The centripetal force keeping the charge moving in a circle is the same as the magnetic force the field exerts on the charge.

$$\therefore\ F = m\frac{V^2}{r} = Bqv$$

The radius of the circular path along which the charge moves is given by:

$$r = \frac{mv}{Bq}$$

r = radius of the circle along which the charge moves
v = velocity of the charge round the circle
m = mass of charge
B = magnetic field intensity or flux density
q = electronic charge of the particle

Worked examples

1.An electron of charge 1.6 Ã— 10^{-19}C moves perpendicularly to the magnetic field of intensity 5.0 Ã— 10^{-6} T with a speed of 1.2 Ã— 10^{8} ms^{-1}. Calculate the force acting on the charge.

Solution

F = Bqv = 5.0 Ã— 10^{-6} Ã— 1.6 Ã— 10^{-19} Ã— 1.2 Ã— 10^{8}
F = 9.6 Ã— 10^{-17} N

2.An electron of charge 1.6 Ã— 10^{-19}C moves perpendicularly to the magnetic field o f intensity 2.0 Ã— 10^{-3} T. The speed of the electron as it moves through the field is about 7.8 Ã— 10^{7} ms^{-1}. Calculate the radius of the circular path in which the electron is moving.

Solution

$$\mathrm{r} = \frac{\mathrm{mv}}{\mathrm{Bq}}$$

$$= \frac{9.0 \times 10^{-31} \times 7.8 \times 10^{7}}{2.0 \times 10^{-3} \times 1.6 \times 10^{-19}} = 2.2 \times 10^{-1}\ m$$

Force on a straight conductor carry current in a magnetic field

A thin strip is held in the gap between the poles of a powerful magnet. On closing the key k, current flows through the metal strip, causing it to move upward as shown in Figure 5.31.

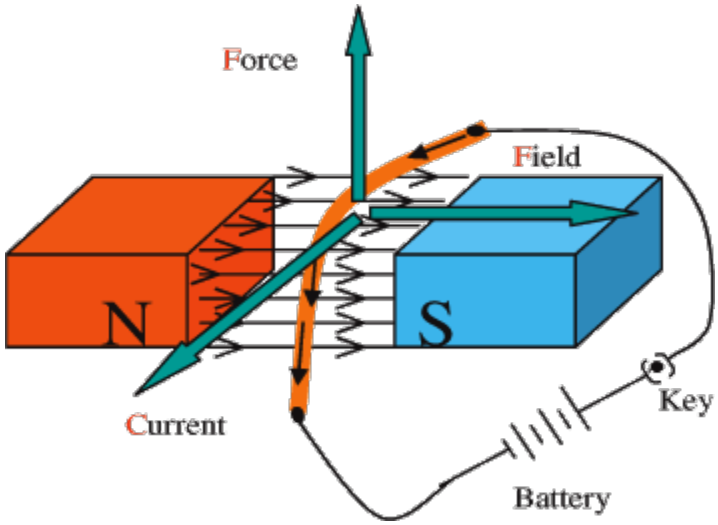


Figure : 5.30

The direction of force acting on the conductor depends on direction of the:

Â· magnetic field (F)

Â· current (I)

If the direction of the magnetic field is changed by interchanging the poles of the magnet, the metal strip is pushed downward. When the direction of current is reversed, the direction of the force is also reversed. Experiments reveal that reversing the direction of current and the magnetic field at the same time does not change the direction of force.

Direction of force or motion

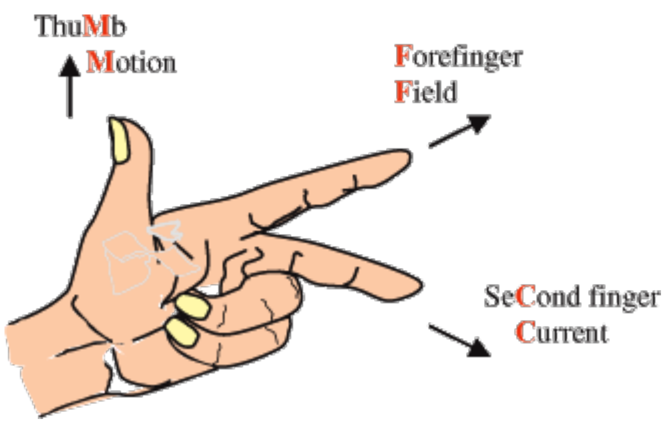


Figure 5.32 : Flemingâ€™s left hand rule

Flemingâ€™s left hand rule is used to find the direction of the force or motion of a current-carrying conductor in a magnetic field. It states that:

If the left hand is held so that the first three fingers are mutually at right angles to each other, the Forefinger points in the direction of the magnetic Field, the secCond finger in the direction of Current, then the thuMb points in the direction of Motion (force) of the conductor.

The size or magnitude of the force

The size or magnitude of force acting on the conductor is given by:

$$F = BIlsin\hat{I}\pm$$

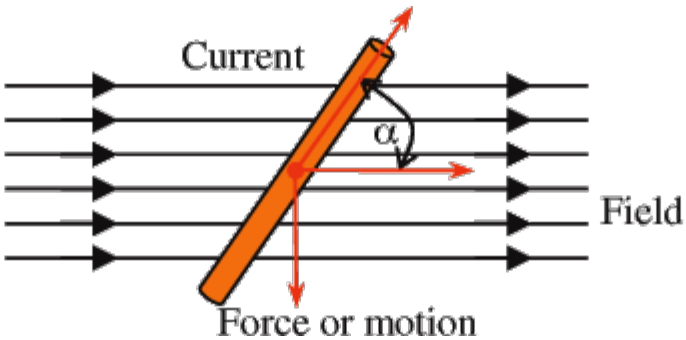
The force F acting on the conductor can increase by increasing the:

(i) strength or the intensity of the magnetic field (B) (magnetic flux density).This is done by using a powerful magnet;

(ii) current (I) flowing through the conductor;

(iii) length *(l)*of the conductor;

(iv) angle (a) the conductor makes with the magnetic field.



Maximum force F = *BIl* acts on the conductor when it is perpendicular to the magnetic field (Î± = 90Â°). The force on the conductor is zero when the conductor is parallel to the magnetic field (Î± = 0Â°).

Interaction of the two fields

A magnetic field surrounds a conductor carrying electric current as in Figure 5.33(a). When it is placed in a magnetic field Figure 5.33(b), the two fields combine to produce a distorted field pattern Figure shown in 5.33 (c). A stronger field is formed to the left of the conductor where the two magnetic fields are moving in the same direction. A weaker field is produced on the right of the conductor because the two fields are moving in the opposite directions. The conductor is forced to move from the strong side of the field to the weak side of the field as indicated in Figure 5.33(c).

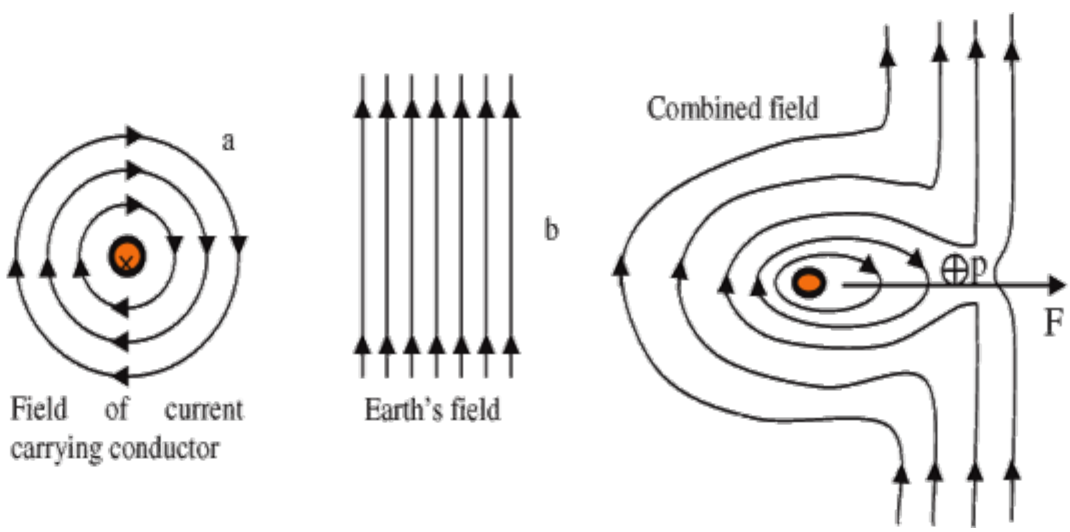


Figure 5.33 Combined field

Force on a rectangular coil

When current flows through a rectangular coil placed in a magnetic field produced by a strong magnet, equal and opposite forces are exerted on the sides of the coil to cause it turn or rotate. The direction the coil turns is found by applying Flemingâ€™s left hand rule.

Forces act on the arms of the coil in the opposite directions as shown in Figure 5.34. Two equal and opposite forces form a couple and the effect of the couple is to turn the coil in the clockwise direction. If the current in the coil is reversed, it turns in the opposite direction. The force or torque making the coil to turn can be increased by:

- increasing the current in the coil;
- using a stronger magnet;
- increasing the number of turns of the wire on the coil;
- shaping the poles of the magnet spherically to make the magnetic fields radial;
- increasing the area of the coil.

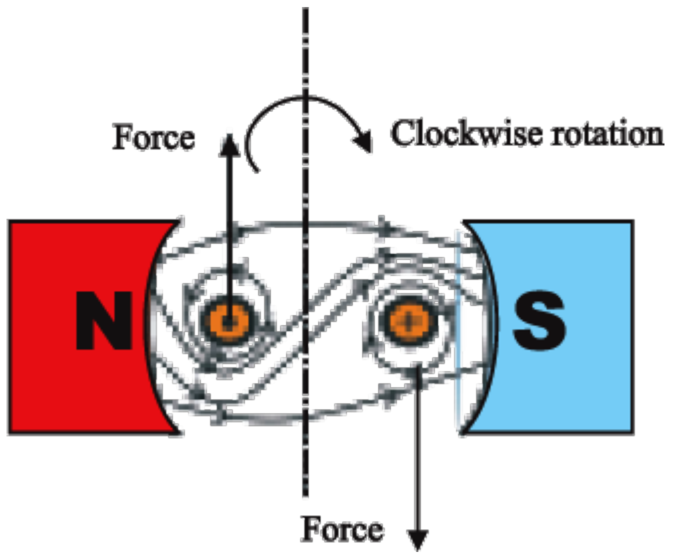


Figure 5.34 : Force on a current carrying rectangular coil

Worked example

1.A straight conductor of length 0.45m moves in a magnetic field of flux density 1.2 T when a current of 10 A flows through it.

(a)Calculate the force moving the conductor when it is inclined at an angle of 60Â° to the magnetic field.

(b)What is the maximum force acting on the conductor in same magnetic field?

Solution

(a) F = BI*l*sina

= 1.2 Ã— 10 Ã— 0.45 Ã— sin 60Â° = 4.68N.

(b) Maximum force F = *BIl*

F= 1.2 Ã— 10 Ã— 0.45 = 5.4N.

2. A force 12.5N acts on a straight conductor 0.5m long placed perpendicularly in a magnetic when a current of 24A flows through it. Calculate the magnetic field density of the field.

Solution

$$B = \frac{F}{I \times l} = \frac{12.5}{24 \times 0.5} = 1.042\ T$$

Application of motor effect of current

The force exerted on a conductor or coil when an electric current flows through it is used in the construction of:

- moving coil meters (galvanometer, ammeter and voltmeter);
- electric motors;
- loudspeakers and
- relays.

The moving coil meter

The moving coil meter works on the principle that a coil carrying current will rotate or turn if it is placed in a magnetic field.

All moving coil meters have the following useful parts:

- A powerful horseshoe magnet to produce strong magnetic field. The poles of the magnet are curved as in the diagram above to make the magnetic field radial. The radial magnetic field ensures that a maximum force acts on the coil in any position.
- A rectangular coil which is free to turn in the narrow gap between the poles of the horseshoe magnet.
- Two hair springs. Electric current enters and coil leaves the coil through the hairsprings. The hairspring also controls the movement of the pointer brings it back to zero position when the current is switched off.
- the soft iron drum is used to concentrate the magnetic field around the rectangular coil; making the magnetic field around the coil uniform.
- a pointer which moves over a uniform scale.

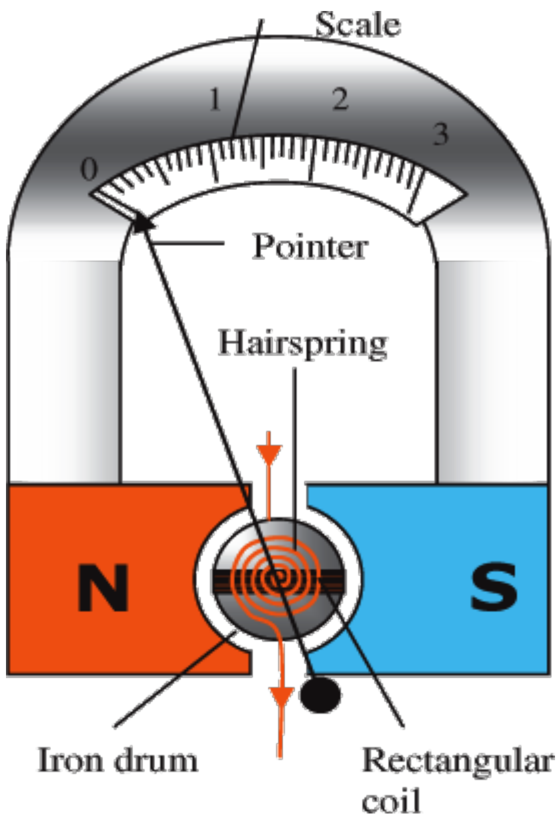


Figure 5.35 : Moving coil meter

The working of a moving coil meter

As the current flows through the coil, magnetic field is produced around it. This interacts with the magnetic field of the horseshoe magnet to produce two equal and opposite forces on the coil. The coil turns around the iron drum in the narrow gap between the poles of the horseshoe magnet. The radial and uniform magnetic field produced around the coil makes its deflection proportional to current. This is the reason the scale of moving coil meter is linear or uniform.

Sensitivity of moving coil meter

A sensitivity moving coil meter is able to detect small currents or voltages. Such meters give large deflection when a small current flows through it. Sensitivity of a moving coil meter is defined as:

Deflection (angle turned) per unit current or voltage.

The sensitivity of a moving coil meter is increased by using a:

a.stronger magnet.

b.weaker hair spring (spring with small force constant).

c.coil with large area with more turns of wire on it.

d.beam of light reflected from a mirror attached to the coil as a pointer.

Moving coil instruments are suitable for the measurement of direct currents and voltages only. It can be modified to measure alternating current by using diodes as rectifiers. A galvanometer is a very sensitive moving coil meter; it can be converted to ammeter by connecting a shunt. A galvanometer is converted to a voltmeter by connecting a high resistance in series to it.

Advantages of moving coil meter

(i) They are very sensitive to small changes in currents and voltages.

(ii) Deflection of moving coil meters is proportional to current; therefore, they have a uniform or a linear scale.

(iii) They can be upgraded to measure higher currents or voltages.

Disadvantages of moving coil meter

(i) They can measure only direct current.

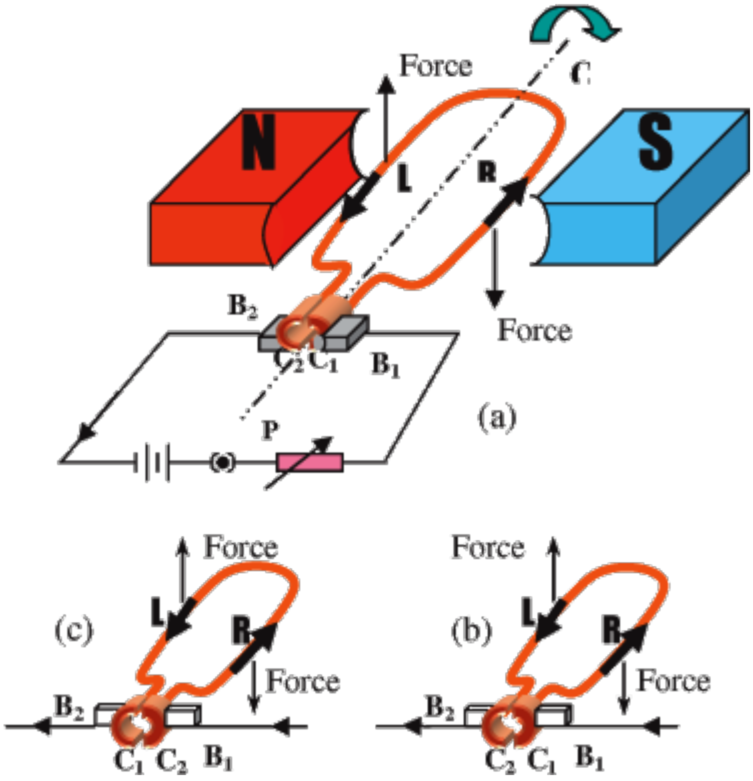
(ii) The internal resistance of moving coil meters affects the current or the voltage being measured.

The electric motor

The working of an electric motor is based on the force exerted on a current carrying coil or loop of wire in a magnetic field. The energy conversion in an electric motor is for electrical to mechanical. Direct current (d.c.) motors have the following essential parts:

- strong magnet (permanent or electro-magnet) to produce strong magnetic field (B). The magnets are designed to produce radial magnetic field so that a maximum force is exerted on the loop of wire or coil.
- a laminated soft iron drum with many coils of fine wires wound on it. This is called the armature. It is used to concentrate the magnetic field on the coil and make the magnetic field radial. It also gives the coil the required momentum to keep turning.
- split-ring commutators C_1 and C_2 to reverse the direction of current in the coil every half turn or cycle. This ensures that the coil keeps turning in the same direction.
- two carbon brushes B_1 and B_2 to allow current to enter and leave the coils.

The working of direct current (d.c.) motor



The brushes and the commutators swerve position; current flows from B_1 to C_2 into the coil

Current flows from B_1 to C_1 into the coil

Figure 5.36 : Electric motor

When current flows through the coil in the direction indicated in Figure 5.36, that is, current enters the coil from brush B_1 through the commutator C_1 and leaves the coil through commutator C_2 and brush B_2.The left side of the coil L is forced upward while the right side of the coil R is pushed downward. The couple makes the coil to turn in the clockwise direction about the axis PQ. The coil continues to turn until the side L and R are vertical (the sides of the coil are parallel to the magnetic field). In this position, the brushes are not in contact with the commutators; current is cut off from the coil but the momentum of the coil keeps it moving in the same direction. The coil will continue to turn in the same direction after half a turn or cycle if the current flowing in it is reversed. This happens when the commutators C_1 and C_2 and the brushes B_1 and B_2 swerve position. The brush B_1 initially on C_2 moves to C_2 and the brush B_2 initially on C_2 moves to C_1; current now flows in the opposite direction from side R to side L of the coil. The coil continues to turn in the clockwise direction.

Practical d.c. motors

The power or efficiency of a d.c. motor is increased if:

(i) the armature has more loops of wire on a laminated soft iron drum.

(ii) each loop of wire is connected to a split-ring commutator segment to improve its efficiency and to make the motor run smoothly.

(iii) an electromagnet is used instead of permanent magnet to produce a stronger magnetic field in which the coil turns.

(iv) the current flowing through the coil is increased.

The moving-coil loudspeaker

The moving-coil loudspeaker consists of a:

- disc-permanent magnet. The disc magnet produces a radial magnetic field.
- speech or voice coil. This is coiled on a cylindrical frame and placed between the poles of the disc magnet. The disc is free to move to and fro when the current in it varies.
- paper cone or magnetic diaphragm which moves with the voice coil.

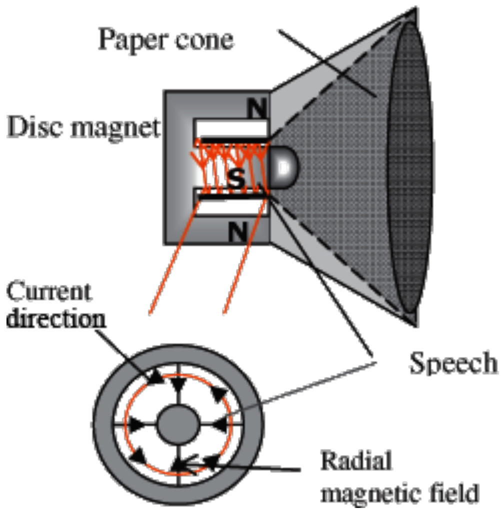


Figure 5.37: Moving-coil loudspeaker

How the moving-coil loudspeaker works

The electrical signal from a CD player a tape recorder or a radio enters the speech coil of the speaker as an alternating current. The interaction between the changing magnetic field of the speech coil and the field of disc magnet makes the coil vibrate. When the current flows through the coil in an anticlockwise direction, the coil is pushed out of the paper (Figure 5.37a). It is pulled in (into the paper) if the direction of current is reversed. The vibration of the speech coil causes the paper cone (magnetic diaphragm) attached to it to vibrate. Air molecules near the paper cone are forced to vibrate at the frequency of the incoming electrical signal from the CD player or microphone. The loudspeaker therefore, converts electrical energy (signal) to sound energy.

Summary

- A force acts on a charge moving in a magnetic field. The size of the force is given by

  F = BqvsinÎ±

- The maximum force acting on the charge is given by **F** = **B**qv**.** This occurs when the I charge moves perpendicular to the field (Î± =90Â°). The force **F** is zero if the velocity of the particle is parallel to the magnetic field density **B** (i.e. Î± = 0).
- A charge moving at right angle to the magnetic field is deflected by maximum force and forced to move in a circular path of radius r.
- A force acts on any conductor carrying current in a magnetic field. Maximum force

on the conductor is given by $F = BIl$.

- The direction of the force is given by Flemingâ€™s left hand rule. It states that: if the left is held so that the first three fingers are mutually at right angles to each other, the Forefinger points in the direction of the magnetic Field, the seCond finger in the direction of Current then the thuMb points in the direction of Motion (force) of the conductor.
- The force exerted on a conductor or a coil when an electric current flows through it is used in the construction of:
  - â€¢moving coil meters (galvanometer, ammeter and voltmeter)
  - â€¢electric motors
  - â€¢loudspeakers
  - â€¢relays
- Moving coil meters, electric motors and loudspeakers work on the principle that a coil carrying current will rotate or turn if it is placed in magnetic field. Sensitivity of a moving coil meter is defined as the deflection (angle turned) per unit of current or voltage.
- Electric motors are used in appliances like CD player, tape recorder, blender, washing machine, vacuum cleaner, etc.

Practice questions 5d

1. (a) State what happens to a charge moving perpendicularly to the magnetic field.

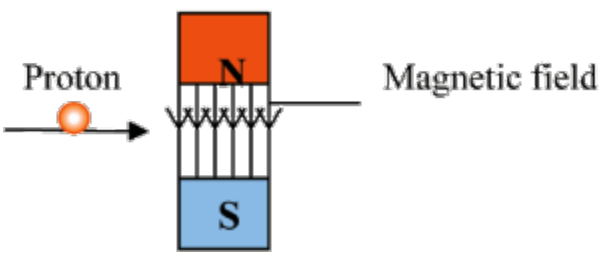
   (b) The force acting on a charge in a magnetic field is given by *F = BqvsinÎ±*.

   (i) What do the symbols B, q, v, and Î± represent in the equation?

   (ii) What is the force acting on the charge when its velocity is perpendicular to the magnetic field?

   (c) A particle of charge 2.0 Ã— 10^{-8} C moves with a velocity of 4.0 Ã— 10^{-6} m s^{-1} through a magnetic field of flux density 0.74 T. Calculate the force exerted on the charge if it moves at an angle of (i) 60Â° (ii) 90Â° to magnetic field.

2. (a) The diagram below shows a proton passing perpendicularly in a magnetic field.



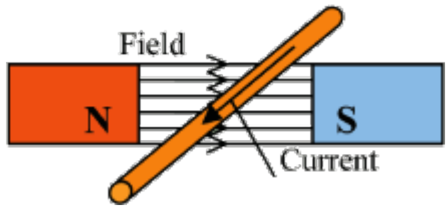
   (i) Draw a vector diagram showing how the force on the proton, magnetic field and the velocity are related.

   (ii) Explain why the proton will move in a circular path.

(iii) How will the radius of the circular path be affected if the speed of the proton is doubled?

(b) A proton of charge 1.6 Ã— 10^{-19} C and mass 1.67 Ã— 10^{-27}kg moves at right angles in a magnetic field of flux density 2.2 T. Calculate the speed of the proton if the radius of the circular path is 0.5 m.

3. (a) A conductor with current flowing in it is placed in a magnetic field as shown below; the direction magnetic field and current are shown:



(i) Copy the diagram and indicate on it the direction of the force acting on the conductor.

(ii) State rule you used to find the direction of force on the conductor.

4. (a) Describe an experiment to show that a force acts on a straight conductor carrying current in a magnetic field.

(b) State the factors that determine the size of the force exerted on the conductor.

(c) A straight conductor of length 30 cm is placed in a magnetic field of intensity 0.4 T. Calculate the force exerted on the conductor:

(i) when it is inclined at 30Â° to the magnetic field and a current of 5 A flows through it;

(ii) when it is perpendicular to the magnetic field.

5. (a) Draw a labelled diagram of a moving coil meter and explain how it works.

(b) State the functions of the following parts of a moving-coil meter:

(i) soft iron drum

(ii) rectangular coil

(iii) hair spring

(c) Explain how a moving coil galvanometer can be converted to an

(i) ammeter (ii) voltmeter.

6. (a) Describe the structure of a moving coil galvanometer.

(b) How can the moving coil galvanometer be made more sensitive?

(c) Explain why the deflection of moving coil galvanometer is proportional to current.

(d) A galvanometer of internal resistance 50 Î© gives a full scale deflection current of 10 mA. Calculate the value of resistance required to:

(i) convert it to an ammeter reading up to 5 A.

(ii) convert it to a voltmeter reading up to 3 V.

7. (a) What do you understand by sensitivity of moving coil meters?

(b) State the factors that will increase the sensitivity of a moving coil meters.

(c) State **two** disadvantages and **two** advantages of moving-coil meters.

(d) A milliammeter gives a full scale deflection of 1 mA. When a resistance of 0.005 Î© is connected in parallel to it, the milliammeter can measure up to 2 A. What is the internal resistance of the milliammeter?

8. (a) State the principle on which the working of an electric motor is based.

(b) How will you find the direction of force acting on the conductor in a magnetic field?

(c) State the functions of the following parts of a d.c. motor:

(i) Armature (ii) Split-ring commutator.

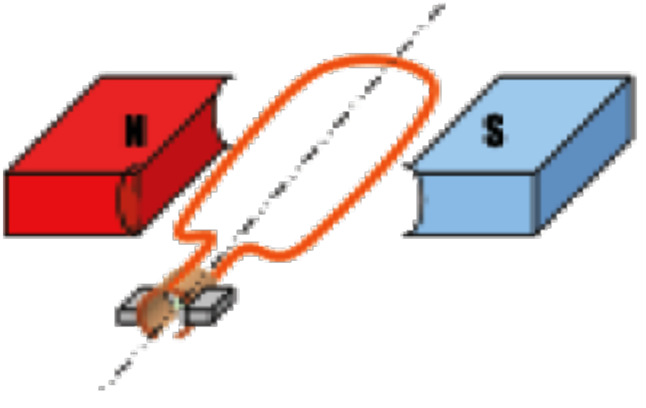
9. (a) Using a well drawn and labelled diagram describe an electric motor and explain how it works.

(b) Explain why the efficiency of an electric motor cannot be 100%.

(c) State **two** ways to increase the force on the armature and **two** uses of an electric motor.

10. (a). State Flemingâ€™s rule for electric motors.

(b) The diagram below shows an electric motor.



(i) On the diagram, show the directions of current, magnetic field and the force acting on the loop of wire. Indicate also the direction the loop will turn if it is free to rotate.

(ii) Explain what happens when the sides of the loop are parallel to the field.

11. (a) Describe the structure of a moving coil loudspeaker and explain how it works.

(b) Explain how the speaker can be made to produce louder sound.

Past Questions

1. A rectangular coil of wire can rotate in a magnetic field. The ends of the coil are soldered to two halves of a split ring. Two carbon brushes are to press lightly against the split ring and when these are connected in circuit with a battery and rheostat, the coil rotates. This is a description of

   A. a suspended coil galvanometer.

   B. a moving coil ammeter.

   C. a d.c. generator.

   D. an electric motor.

   E. an induction coil.

WAEC

2. A particle of charge **q** and mass **m** moving with a velocity **v** enters a uniform magnetic field **B** in the direction of the field. The force on the particle is

   A. qvB

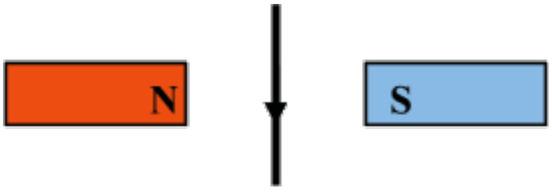
   B. mqvB

   C. $\frac{qvB}{m}$

   D. $\frac{mvB}{q}$

   E. 0

WAEC

3. 

   The diagram above shows a current-carrying wire between the poles of a magnet. In which direction will the wire tend to move?

   A. Into the paper.

   B. Out of the paper.

   C. Towards the N-pole of the magnet.

   D. Towards the S-pole of the magnet.

   E. Towards the top of the paper.

WAEC

4. A particle of charge 5 C moves perpendicularly to a magnetic field of magnitude 0.01 Tesla. If the velocity of the charge is 1.5 m s^{-1}, calculate the magnitude force exerted on the particle.

A. 0.050 N

B. 0.075 N

C. 0.300 N

D. 3.300 N

E. 0.000 N

WAEC

5. Electric motor primarily converts

A. electrical energy into chemical energy.

B. electrical energy into heat energy.

C. kinetic energy into potential energy.

D. electrical energy into mechanical energy.

E. mechanical energy into light energy.

WAEC

6. Which of the following statements are not true of moving coil milliammeter?

I. It can be used to measure alternating current.

II. It has a linear scale.

III. It can be adapted to measure higher values of current.

IV. A resistor connected in parallel with the milliammeter would convert it to a voltmeter.

A. I and IV only.

B. II and III only.

C. III and IV only.

D. I, II, and III only.

E. I, III and IV only.

WAEC

7.

A magnet is placed successively near rings made of the materials indicated in the diagrams above. The polarity of the magnet in each case is also indicated. Inside which of the rings will a magnetic field be observed?

A. I only.

B. III only.

C. I and III only.

D. II and III only.

E. I, II and III.

8. Which of the following is not a component of a d.c. motor?

   A. Commutator.

   B. Field magnet.

   C. Slip rings.

   D. Armature.

   E. Carbon brushes.

WAEC

9. The diagram below illustrates the conversion of a galvanometer of resistance 2 Î© to an ammeter. The galvanometer gives a full scale for a current of 10 mA. Calculate the value of R.

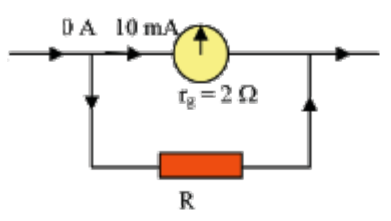
   A. 2.0 Ã— 10^3 Î©

   B. 2.0 Ã— 10^2 Î©

   C. 2.0 Ã— 10^{-1} Î©

   D. 2.0 Ã— 10^{-2} Î©

   E. 2.0 Ã— 10^{-3} Î©



WAEC

10. The relationship between the directions of the magnetic field, the current and the motion of a current carrying wire in the magnetic field is easily remembered using

    A. Octet rule.

    B. Right-hand grip rule.

    C. Maxwellâ€™s screw rule.

    D. Ampereâ€™s swimming rule.

    E. Flemingâ€™s left-hand rule.

WAEC

11. A freely suspended compass needle on the Earthâ€™s surface will come to rest in a plane called

    A. geographical equator.

    B. geographical meridian.

    C. magnetic equator.

    D. magnetic meridian.

WASSCE

12. The angle of dip at the magnetic poles is

A. 90Â°.

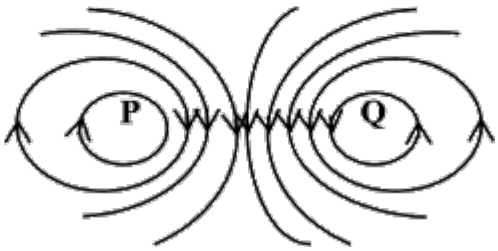
B. 60Â°.

C. 45Â°.

D. 0Â°.

WASSCE

13.



The diagram above illustrates the resultant magnetic field pattern due to a circular coil carrying current. The points P and Q are two arms of the coil. Which of the following statements is correct? The current is directed

A. out of the plane of the paper through P and into it through Q.

B. out of the plane of the paper through P and Q.

C. into the plane of the paper through P and out through Q.

D. such that the wires attract each other.

WASSCE

14. The Earthâ€™s magnetic equator passes through Jos in Nigeria. At Jos, the

A. angle of variation is zero.

B. magnetic declination is 90Â°.

C. angle of dip is 0Â°.

D. horizontal component of the Earthâ€™s magnetic field is zero.

WASSCE

15. In order to make a moving electron follow a circular path

A. a magnetic field is applied perpendicular to its path.

B. a magnetic field is applied parallel to its path.

C. An electric field is applied parallel to its path.

D. an electric field is applied perpendicular to its path.

WASSCE

16. The main function of the commutator in a simple d.c. motor is to

A. enable the armature to rotate freely.

B. increase the flux linking the armature windings

C. maintain a direct current in the armature.

D. provide uniform magnetic field around the armature.

E. reverse the direction of the current in the armature.

NECO

17. (a)

(i) What is meant by a neutral point in a magnetic field?

(ii) Draw and label a diagram to show the pattern and direction of the magnetic field produced around a straight current carrying-wire.(b) When is an ammeter said to be

(b) (i) sensitive; (ii) accurate.

(c) (i) Explain, using a labelled diagram, how a delicate magnetic material could be protected from the Earthâ€™s magnetic field.

(ii) A charge 1.6 Ã— 10^{-19} C enters a magnetic field of flux density 2.0 T with a velocity of 2.5 Ã— 10^{7} m s^{-1} at an angle 30owith the field.

Calculate the magnitude of the force exerted on the charge by the field.

WASSCE

18. (a) Sketch the form of the flux pattern due to a current flowing

(i) in a long solenoid;

(ii) through two long parallel wires when the directions current are opposite. [Neglect the earthâ€™s magnetic field]

(b) Draw a labelled diagram of an electric bell and explain how it works.

WAEC

19. Explain the term *angle of dip,* and describe how it varies over the earth.

WAEC

20. Distinguish between the *magnetic meridian* and the *geographical meridian.* What is the name given to the angle between these two meridians? Mention one important fact about this angle.

WAEC

21 (a) Explain what is meant by a magnetic field.

(b) (i) Describe an experiment to show that a magnetic field exists around a straight wire carrying-current.

(ii) Draw a label diagram to showing the pattern and direction of the magnetic field produced around the wire. [Neglect the earthâ€™s magnetic field]

(c) Sketch the form of the flux pattern due to two straight parallel wires carrying current in the same direction. Indicate the neutral point in the field.

(d) Explain, with the aid of a labelled diagram, how a delicate magnetic material could be protected from the earthâ€™s magnetic field.

WAEC

22 (i) Draw a labelled diagram of a simple d.c. electric motor and explain how it works.

(ii) State two reasons why the efficiency of an electric motor is less than 100%.

WAEC