10 MAGNETISM

Syllabus :

(i) Induced magnetism; Magnetic field of earth, neutral points in magnetic fields.

Scope – Magnetism : magnetism induced by bar magnets on magnetic materials; induction precedes attraction, lines of magnetic field and their properties, evidences of existence of earth's magnetic field, magnetic compass; uniform magnetic field of earth and non-uniform field of a bar magnet placed along magnetic north-south; neutral point; properties of magnetic field lines.

(ii) Introduction fo electromagnets and its uses.

(A) INDUCED MAGNETISM AND NEUTRAL POINTS

10.1 INTRODUCTION

The first known magnets were the pieces of *lodestone*, an ore of iron oxide (Fe_3O_4) found in large quantities in Magnesia, in Asia Minor. *This ore was found to possess two properties : (i) it attracts small pieces of iron, and (ii) it sets itself along a definite direction when it is suspended freely.* The Chinese, earlier than 2500 B.C., used these pieces to guide their boats. The pieces of lodestone found in nature were later on called the *natural magnets*. The word magnet has been derived from magnesia.

The natural magnets are found in quite irregular and odd shapes. They are not magnetically strong enough for use. Therefore, for different uses, artificial magnets are prepared from iron in different convenient sizes and shapes such as *bar magnet, horse shoe magnet, magnetic needle, magnetic compass, etc.*

If a magnet is suspended with a silk thread such that it is free to rotate in a horizontal plane, it *sets itself always pointing in the geographic north-south direction* as shown in Fig. 10.1. Depending on the direction in which an end of the magnet rests, its polarity is named as *north* or *south*.

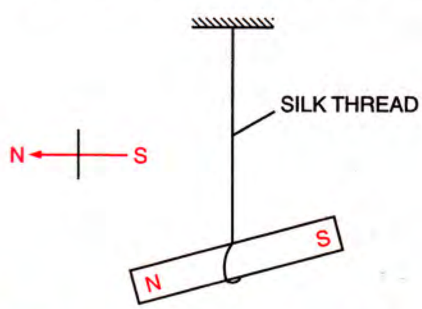


Fig. 10.1 Setting of a freely suspended magnet

Two like poles (both north poles or both south poles) repel each other, while two unlike poles (one north pole and the other south pole) attract each other.

10.2 INDUCED MAGNETISM (MAGNETISM INDUCED BY A BAR MAGNET ON THE MAGNETIC MATERIALS)

When an unmagnetised bar *AB* of a magnetic material such as soft iron or steel, is placed near or in contact with a magnet as shown in Fig 10.2 (a), the bar *AB* becomes a magnet *i.e.*, it acquires the property of attracting iron filings when they are brought near its ends. If the magnet is now removed, it is seen that nearly all the iron filings which have clung to it, fall down *i.e.*, the bar *AB* loses its magnetism [Fig. 10.2(b)]. Thus, the *bar of a magnetic material behaves like a magnet so*

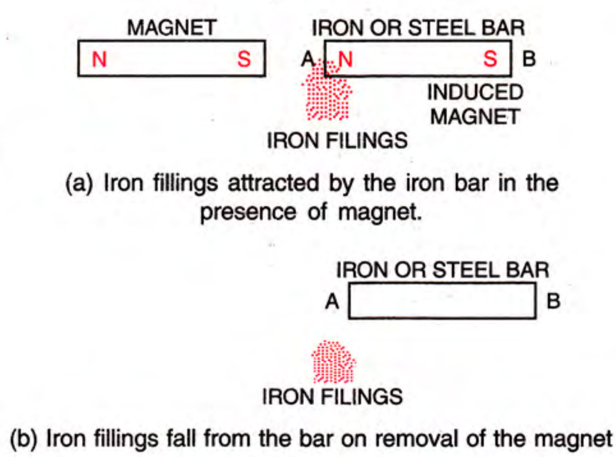


Fig. 10.2 Induced magnetism

long it is kept near or in contact with a magnet. The magnetism so produced is called *induced magnetism*. Thus

> *The temporary magnetism acquired by a magnetic material when it is kept near (or in contact with) a magnet, is called induced magnetism.*

The process in which a piece of magnetic material acquires the magnetic properties temporarily in presence of another magnet near it, is called the *magnetic induction.*

If polarity at the ends *A* and *B* of the bar *AB* is tested with a compass needle, it is found that the polarity developed at the end *A* is north (opposite to the polarity of the magnet near the end *A*) and the polarity at end *B* is south (*i.e.*, similar to the polarity at the end of the magnet near the end *A*). Thus,

> *A magnetic pole induces an opposite polarity on the near end and a similar polarity on the farther end of the iron bar.*

Induction precedes attraction

Now we can explain how an ordinary piece of iron is attracted towards a magnet. When a piece of iron is brought near one end of a magnet (or one end of a magnet is brought near the piece of iron), the nearer end of the piece acquires an opposite polarity by magnetic induction. Since unlike poles attract each other, therefore iron piece is attracted towards the end of the magnet. Thus, piece of iron first becomes a magnet by induction and then it is attracted. In other words, *induction precedes attraction.*

Induced magnetism is temporary

If one pole of a bar magnet is brought near the small iron nails, they form a chain of nails as shown in Fig. 10.3. The reason is that the bar magnet by induction magnetises an iron nail which gets attracted by the magnet and clings to it. This

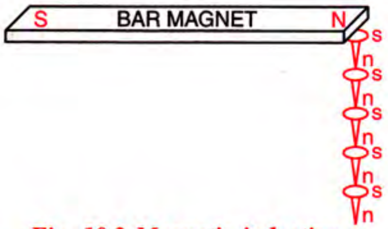


Fig. 10.3 Magnetic induction

magnetised nail magnetises the other nail near it by magnetic induction and attracts it. This process continues till force of attraction of magnet on first nail is sufficient to balance the total weight of all the nails in chain.

Now holding the uppermost nail in position by fingers, if magnet is removed, we find that all nails fall down. The reason is that on removing the magnet, the uppermost nail loses its magnetism, so all other nails also lose their magnetism, they get separated from each other and they all fall down due to force of gravity. This shows that *the magnetism acquired by induction is purely temporary.* It lasts so long as the magnet causing induction remains in its vicinity.

10.3 LINES OF MAGNETIC FIELD

If a magnetic compass is placed on a table, it is found that its needle rests in geographic north-south direction*. But when it is placed near a magnet, the needle swings and then rests in some other direction. As the compass is placed at different positions around a magnet, the direction in which the needle rests, changes such that its one end always points towards the nearer pole of the magnet. This behaviour of needle is due to the influence of the magnet near it. The region in which the compass gets influenced is called the *magnetic field* of the magnet.

> *The space around a magnet in which the needle of a compass rests in a direction other than the geographic north-south direction, is called magnetic field of the magnet.*

As the distance of point from the magnet increases, the effect of its magnetic field dicreases.

Magnetic field is a ***vector*** *quantity*. The magnitude of magnetic field at a point is measured by the force which a magnetic pole placed at that point, experiences, while the direction of magnetic field is the direction in which the needle of compass rests when it is placed at that point.

If we place a magnet below a sheet of stiff paper (or a glass plate) and spread some iron filings uniformly over the glass plate, then on tapping the glass plate gently, the iron filings arrange themselves along the curved lines as

* Due to the earth's magnetic field.

shown in Fig. 10.4. The reason is that due to magnet, each piece of iron filing gets magnetised by magnetic induction and experiences a force due to the magnet and arrange itself along the curved line. These curved lines are called the *magnetic field lines*.

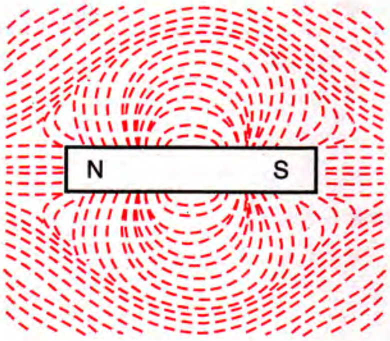


Fig. 10.4 Arrangement of iron filings over a magnet showing the magnetic field of the bar magnet

When a compass needle is placed at any point in a magnetic field, its needle rests along the magnetic field line. An arrow is marked on the magnetic field line from south pole of the needle to its north pole. The arrow indicates the direction of magnetic field at that point. Thus

A magnetic field line is a continuous curve in a magnetic field such that tangent at any point of it gives the direction of the magnetic field at that point.

10.4 PROPERTIES OF MAGNETIC FIELD LINES

The magnetic field lines have following properties :

(1) They are closed and continuous curves.

(2) Outside the magnet, they are directed from the *north* pole towards the *south* pole of the magnet*.

(3) The tangent at any point on a field line gives the direction of magnetic field at that point.

(4) They never intersect one another. If two field lines intersect, there would be two directions of the magnetic field at that point which is not possible. Fig 10.5 shows two magnetic field lines *PQ* and *PR* intersecting each other at a point *P*. It would mean that if a compass needle is placed at the point *P*, north pole of its needle will point in two directions *PQ* and *PR* simultaneously which is not possible.

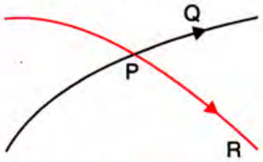


Fig. 10.5 A compass needle placed at the point P cannot show the two directions PQ and PR simultaneously

(5) They are crowded near the poles of the magnet where the magnetic field is strong and are far separated near the middle of the magnet and far from the magnet, where the magnetic field is weak.

(6) Parallel and equi-distant field lines represent a *uniform* magnetic field. The earth's magnetic field in a limited space is uniform.

(7) They behave like the stretched elastic rubber strings.

10.5 MAGNETIC FIELD OF EARTH (Evidences of existence of earth's magnetic field)

Our earth itself has a magnetic field and it behaves like a magnet. The existence of earth's magnetic field is based on the following facts :

(i) A freely suspended magnetic needle always rests in geographic north-south direction.

(ii) An iron rod buried inside the earth along north-south direction becomes a magnet.

(iii) Neutral points are obtained on plotting the field lines of a magnet where the net magnetic field in zero.

(iv) A magnetic needle rests with its geometric axis making different angles with horizontal when suspended at different places on the earth.

(i) A freely suspended magnetic needle always rests in geographic north-south direction — When a magnetic needle (or a magnet) is suspended such that it is free to rotate in a horizontal plane, it always rests indicating the geographic north-south direction. But the north pole of a magnet will point towards the geographic

* Inside the magnet, the magnetic field lines are directed from *south* pole towards the *north* pole and thus a closed and contineous curve is formed.

north only when there is a magnetic south pole attracting it. Similarly the south pole of the magnet will point towards the geographic south when there is a magnetic north pole attracting it. Therefore we can assume a magnet inside the earth which must have its south pole in the geographic north and north pole in the geographic south.

(ii) An iron rod buried inside the earth along north-south direction becomes a magnet — If an iron rod is buried few metres inside the earth keeping it along north-south direction, after some days it is found that the rod becomes a weak magnet. It is possible only if the earth itself behaves like a magnet.

(iii) Neutral points are obtained on plotting the field lines of a magnet — If a magnet is placed in a horizontal plane with its north pole facing towards the geographic north and the magnetic field lines are plotted, we obtain *two* neutral points, one on either side of the magnet, on its broad side-on position. Similarly, if the magnet is placed in a horizontal plane with its north pole facing towards the geographic south and the magnetic field lines are plotted, we obtain *two* neutral points, one on either side of the magnet on its end-on position. At each neutral point, the resultant magnetic field is zero *i.e.*, if a compass needle is placed at a neutral point, it rests in any direction. The reason for zero resultant magnetic field at the neutral point is that the magnetic field produced by the magnet is neutralised by some other equal and opposite magnetic field. This other magnetic field is actually the horizontal component of the earth's magnetic field.

(iv) A magnetic needle rests making different angles with horizontal when suspended at different places of the earth — If a magnetic needle is suspended such that it is free to rotate in a vertical plane and it is taken around the earth through its geographic poles, we find that at *two* places, magnetic needle becomes normal to the earth surface *i.e.*, it becomes vertical. These points are called the *earth's magnetic poles*. At *two* places it becomes parallel to the earth surface *i.e.*, it becomes horizontal. These points lie on *earth's magnetic equator*. At other places, it rests making different angles with the horizontal as shown in Fig. 10.6. It implies that the earth itself has a magnetic field.

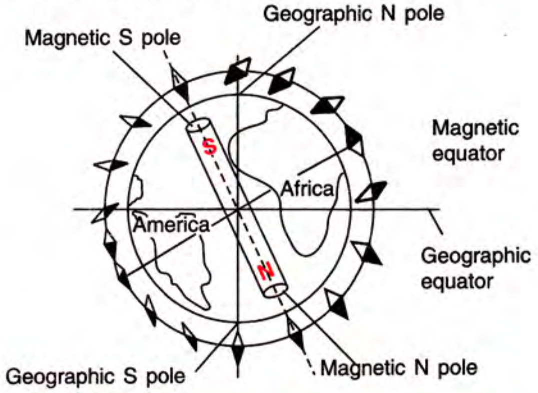


Fig. 10.6 The magnetic needle at different places on earth

> *Two places where the magnetic needle becomes vertical are called the magnetic poles.*
>
> *The line joining the places where the magnetic needle becomes horizontal, is called the magnetic equator.*

Conclusion : On the basis of above facts, it can be concluded that the earth behaves as if a huge bar magnet is present at its centre with its magnetic south pole in the geographic north and the magnetic north pole in the geographic south. Actually, the geographic poles do not coincide with the earth's magnetic poles, but they are somewhat displaced. The magnetic axis of the earth makes an angle of 17° with the axis of rotation of the earth. The magnetic south pole of earth is in Canada at a distance nearly 2240 km from the geographic north pole at 70·75° north latitude and 96° west longitude, while the earth's magnetic north pole is at a distance nearly 2240 km from the geographic south pole at 73° south latitude and 155° east longitude. It has been experimentally observed that the positions of these poles are not stationary, but they gradually change over a long period of time.

Magnetic Field Lines of Earth

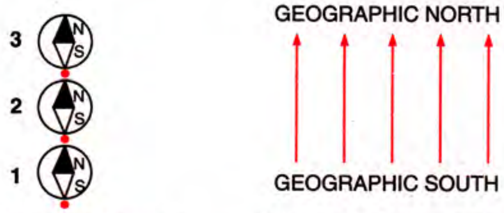
In a limited space, the magnetic field lines of earth are parallel and equidistant to each other as shown in Fig. 10.7(b). They are always directed from the geographic south to the geographic north. They are horizontal at the magnetic equator and vertical at the magnetic poles, but at any other point, they are inclined to the horizontal.

The magnetic field lines of the earth are normal to earth surface near the magnetic poles and parallel to earth surface near the magnetic equator.

10.6 PLOTTING OF UNIFORM MAGNETIC FIELD LINES OF EARTH

Earth's magnetic field is uniform in a limited space. Experimentally we can plot uniform magnetic field lines of earth as follows.

Experiment : Fix a sheet of paper on a drawing board (or a table top) by means of *brass pins*. Place a small compass needle at position 1 [Fig. 10.7 (a)] and looking from top of the needle, mark *two* pencil dots exactly in front of two ends of the needle. Then move the compass needle to position 2 in such a way that one end of the needle coincides with the second pencil dot. Mark the position of the other end of needle with a dot. Repeat the process of moving the compass needle to position 3, 4, ... to obtain several dots. On joining the different dots, you will get a straight line. Thus one magnetic field line of earth is traced.



(a) Plotting a field line with a compass needle

(b) Lines of uniform magnetic field of earth

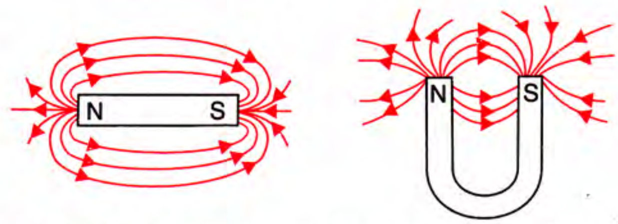
Fig. 10.7 Magnetic field lines of earth

Repeat the process starting from a different point and trace out another magnetic field line. In this manner, draw several magnetic field lines starting from the different points. Label each line with an arrow from the south pole of needle towards the north pole to indicate the direction of the magnetic field. Fig. 10.7 (b) shows several magnetic field lines so obtained.

It is noticed that these *lines do not intersect each other*. They are parallel and equidistant. They are directed from geographic south to geographic north (*i.e.*, the direction in which a magnetic needle, suspended freely in a horizontal plane, rests).

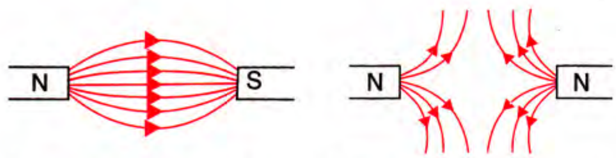
10.7 PLOTTING OF NON UNIFORM MAGNETIC FIELD OF A STRONG BAR MAGNET AND NEUTRAL POINTS

The magnetic field around a bar magnet (or a horse shoe magnet) is non-uniform. The magnetic field lines in a non-uniform magnetic field are not equispaced and parallel, but they are curved (either converging or diverging). The closely spaced magnetic field lines at a place represent a strong magnetic field at that place, while the widely spaced magnetic field lines at a place represent a weak magnetic field at that place. Fig. 10.8 shows the non-uniform magnetic field lines due to (a) a bar magnet, (b) a horse shoe magnet, (c) two unlike poles facing each other and (d) two like poles facing each other.



(a) Magnetic field lines due to a bar magnet

(b) Magnetic field lines due to a horse shoe magnet



(c) Magnetic field lines due to two unlike poles facing each other

(d) Magnetic field lines due to two like poles facing each other

Fig. 10.8 Non-uniform magnetic field lines

We shall now plot the non-uniform magnetic field lines of a bar magnet placed in the magnetic meridian (*i.e.*, along the direction in which a freely suspended magnet rests) in the following *two* positions :

(1) When the magnet is placed with its north pole pointing towards north.

(2) When the magnet is placed with its south pole pointing towards north.

(1) *When the magnet is placed with its north pole pointing towards north*

Fix a sheet of white paper on a drawing board with the help of *brass pins*. Mark north-south direction in the middle of the paper by keeping a compass needle on it. Draw a line along this direction and place a bar magnet on the paper along this line with its *north pole pointing towards north*. Mark its outline with a fine pencil. Now place the compass needle close to the *north* pole of the magnet and looking from above, mark *two* pencil dots exactly in front of two ends of the needle. Then move the compass needle in such a way that one end of the needle coincides with the second pencil dot. Mark position of the other end of the needle with a dot. Repeat the process of moving the compass needle till other end of the bar magnet is reached. Join different dots to get a continuous smooth curve. Thus, one magnetic field line is traced.

Repeat the process from the same pole of the magnet, but starting from a different point and trace out another magnetic field line. In this manner, draw several magnetic field lines starting from the different points near the same pole of the magnet. Label each line with an arrow from the north pole towards the south pole of the magnet (or from south pole of compass needle to its north pole) to indicate the direction of magnetic field at that place.

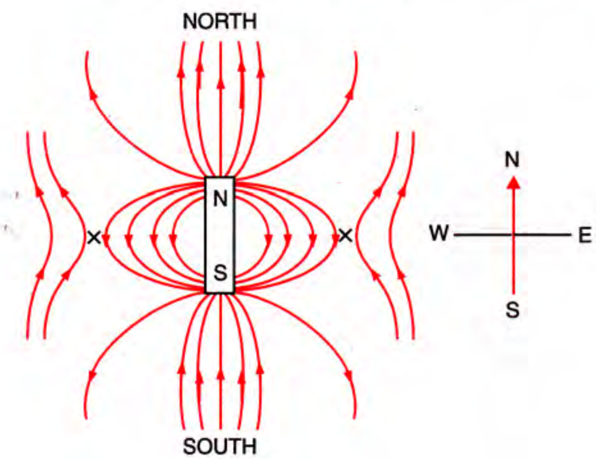


Fig. 10.9 Magnetic field lines of a bar magnet when its north pole N faces geographic north

The magnetic field lines obtained are shown in Fig. 10.9. These are due to the combined effect of (i) the magnetic field of magnet and (ii) the earth's magnetic field.

From Fig. 10.9, it is noted that

(i) The magnetic field lines are curved in the vicinity of magnet. They are mainly due to the magnetic field of magnet which is stronger than the magnetic field of the earth. As the distance from the magnet increases, the strength of the magnetic field due to the magnet decreases and at distant points, it becomes weaker than the earth's magnetic field. The magnetic field lines are therefore parallel to each other at distant points. Here they are mainly due to the earth's magnetic field.

(ii) There are *two* points equidistant from the centre of the magnet marked as × in Fig. 10.9 in *east and west directions* where the magnetic field of the magnet and the horizontal component of the earth's magnetic field are equal in magnitude and they are in opposite directions such that they neutralise each other. These are the *neutral points*. A compass needle when placed at these points, remains unaffected and the needle rests in any direction.

(2) *When the magnet is placed with its south pole pointing towards north*

In this case, the bar magnet is placed on the paper along the magnetic meridian with its *south pole pointing towards north* and lines of magnetic field are traced following the same method as described above. Fig. 10.10 shows the magnetic field lines due to the combined effect of (i) the magnetic field of the magnet and (ii) the earth's magnetic field.

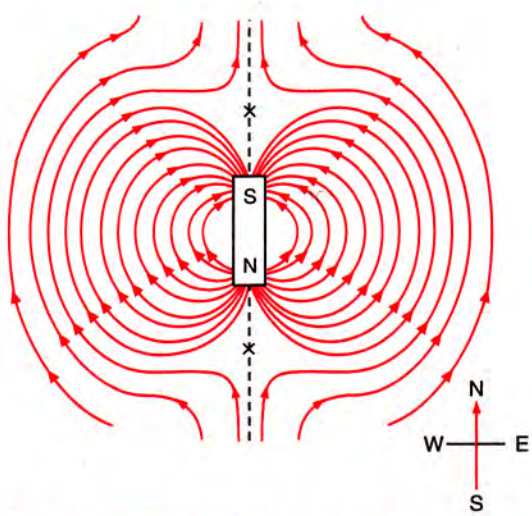


Fig. 10.10 Magnetic field lines of a bar magnet when its north pole N faces geographic south

From Fig. 10.10, we notice that

(i) The magnetic field lines are curved in the vicinity of the magnet and they are mainly due to the magnetic field of the magnet which is much stronger than the earth's magnetic field. As the distance from the magnet increases, the strength of the magnetic field due to the magnet decreases and at distant points, it becomes weaker than the earth's magnetic field. The magnetic field lines *are nearly parallel straight lines from south to north,* at the distant points from the magnet. They are mainly due to the earth's magnetic field.

(ii) There are *two* points equidistant from the centre of the magnet marked as × in Fig. 10.10 *in the north and south directions* where the magnetic field of the magnet and the horizontal component of the earth's magnetic field are equal in magnitude and they are in opposite directions such that the two fields neutralise each other. At these points, the compass needle remains unaffected and the needle comes to rest pointing in any direction. These points are the *neutral points.*

10.8 NEUTRAL POINTS

Neutral points are the points where the magnetic field of magnet is equal in magnitude to the earth's horizontal magnetic field, but it is in opposite direction. Thus the resultant (or net) magnetic field at the neutral points is zero.

The neutral points are situated symmetrically on either side of a magnet at equal distances from the centre in east-west direction, if the north pole of the magnet faces towards geographic north. But the neutral points are on either side of the magnet at equal distances from the centre in north-south directions, if south pole of the magnet faces towards geographic north. If a compass needle is placed at the neutral points, it remains unaffected (*i.e.*, it comes to rest pointing in any direction) because the net magnetic field at these points is zero.

EXAMPLES

1. A horse shoe magnet has two iron needles attached at its ends. Show on a diagram the positions occupied by the needles and name the phenomenon which comes into play.

Fig. 10.11 shows the iron needles attached at the ends of a horse shoe magnet. The lower ends of both the needles get attracted towards each other, since they have opposite polarities. The upper ends touching the poles of the magnet, have polarities opposite to that of the magnet. This phenomenon is called **magnetic induction.**

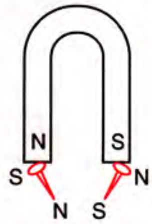


Fig. 10.11

2. You are given two identical bars, one of which is magnetised. How will you select the magnetised bar ?

The two bars are suspended by a silk thread one by one, so as to swing freely in a horizontal plane. The bar which rests in the north-south direction will be the magnetised bar.

3. You are given a magnetised bar and a compass needle. How will you mark polartiy at the ends of bar ?

The two ends of bar are brought near the north pole of the compass needle one by one. The end of bar which repels the north pole of the compass needle will be the *north pole,* while the end of the bar which attracts the north pole of the compass needle will be the *south pole.*

EXERCISE 10 (A)

1. What is a lodestone ?
2. What is a natural magnet ? State *two* limitations of a natural magnet.
3. What is an artificial magnet ? State *two* reasons why do we need the artificial magnets.
4. How will you test whether a given rod is made of iron or copper ?

   [**Hint :** Iron rod gets magnetised when placed near a bar magnet by magnetic induction, while copper rod does not get magnetised]
5. You are provided with *two* similar bars, one is a magnet and the other is a soft iron bar. How will you distinguish between them without the use of any other magnet or bar ?

   [**Hint :** A magnet when suspended freely will rest only in the north-south direction, but the soft iron bar will rest in any direction]

6. Fill in the blanks to complete the sentences :
   (a) The two ends of a magnet are called ....
   (b) Unlike poles of a magnet .... each other.
   (c) Like poles of a magnet .... each other.
   (d) A freely suspended magnet rests in the geographic .... direction.

Ans. (a) poles, (b) attract, (c) repel, (d) north-south

7. A small magnet is suspended by a silk thread from a rigid support such that the magnet can freely swing. How will it rest ? Draw a diagram to show it.
   Ans. It will rest in the geographic north-south direction with north pole towards the geographic north, making some angle with the horizontal as shown in Fig. 10.1.
8. Explain the meaning of the term induced magnetism.
9. Explain what do you understand by magnetic induction. What role does it play in attraction of a piece of iron by a magnet ?
10. Explain the mechanism of attraction of iron nails by a magnet when brought near them.
11. Explain the following :
    (a) When two pins are hung by their heads from the same pole of a magnet, their pointed ends move apart.
    (b) Several soft iron pins can cling, one below the other, from the pole of a magnet.
    (c) The north end of a freely suspended magnetic needle gets attracted towards a piece of soft iron placed a little distance away from the needle.
12. A small iron bar is kept near the north pole of a bar magnet. How does the iron bar acquire magnetism ? Draw a diagram to show the polarity on the iron bar. What will happen if the magnet is removed ?
13. 'Induced magnetism is temporary'. Comment on this statement.
14. 'Induction precedes the attraction'. Explain the statement.
15. What do you understand by the term magnetic field lines ?
16. State *four* properties of the magnetic field lines.
17. Explain why iron filings which are sprinkled on a sheet of cardboard over a bar magnet, take up a definite pattern when cardboard is slightly tapped.
18. Explain the method of plotting the magnetic field lines by using a small compass needle.
19. Can *two* magnetic field lines intersect each other ? Give reason to your answer.
20. In Fig. 10.12, draw at least *two* magnetic field lines between the two magnets.

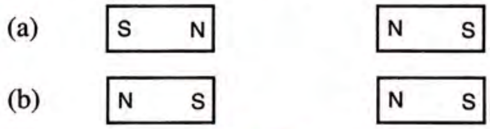


Fig. 10.12

21. State *two* evidences of the existence of earth's magnetic field.
22. Sketch *four* magnetic field lines as obtained in a limited space on a horizontal plane in the earth's magnetic field alone.
23. (a) Draw the pattern of magnetic field lines near a bar magnet placed with its north pole pointing towards the geographic north. Indicate the position of neutral points by marking ×.
    (b) State whether the magnetic field lines in part (a) represent a uniform magnetic field or non-uniform magnetic field ?
24. Fig. 10.13 shows a bar magnet placed on the table top with its north pole pointing towards south. The arrow shows the north-south direction. There are no other magnets or magnetic materials nearby.

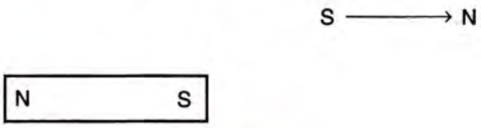


Fig. 10.13

    (a) Insert *two* magnetic field lines on either side of the magnet using arrow head to show the direction of each field line.
    (b) Indicate by crosses, the likely positions of the neutral points.
    (c) What is the magnitude of the magnetic field at each neutral point ? Give a reason for your answer.
25. What conclusion is drawn regarding the magnetic field at a point if a compass needle at that point rests in any direction ? Give reason for your answer.
    Ans. Magnetic field is zero. **Reason :** The earth's magnetic field at that point is neutralised by the magnetic field of some other magnetised material.

26. What is a neutral point ? How is the position of neutral point located with the use of a compass needle ?

27. State the positions of neutral points when a magnet is placed with its axis in the magnetic meridian and with its north pole (i) pointing towards the geographic north, (ii) pointing towards the geographic south.
Ans. (i) in east-west direction
(ii) in north-south direction.

28. Complete the following sentences :
(a) If the field lines in a magnetic field are parallel and equidistant, the magnetic field is ....
(b) At a neutral point, the resultant magnetic field is ....
(c) The neutral points of a bar magnet kept with its north pole pointing towards geographic north are located ....
Ans. (a) uniform, (b) zero, (c) on either side of the magnet in east and west.

Multiple choice type :

1. Two like magnetic poles :
(a) repel each other
(b) attract each other
(c) first attract each other, then repel
(d) neither attract nor repel.
Ans. (a) repel each other

2. In a uniform magnetic field, the field lines are :
(a) curved
(b) parallel and equidistant straight lines
(c) parallel, but non-equispaced straight lines
(d) nothing can be said.
Ans. (b) parallel and equidistant straight lines

(B) ELECTROMAGNET AND ITS USES

10.9 ELECTROMAGNET

An electromagnet is a temporary strong magnet made from a piece of soft iron when current flows in the coil wound around it. It is an artificial magnet.

An electromagnet can be made in any shape, but usually the following *two* shapes of electromagnet are in use :

(a) I–shape (or bar) magnet, and
(b) U-shape (or horse-shoe) magnet.

(a) Construction of the I-shaped (or bar) electromagnet

To construct an I-shaped electromagnet, a thin insulated copper wire is wound in form of a solenoid around a straight soft iron bar *PQ*. The ends of the wire are connected to a battery *B* through an ammeter *A*, a rheostat *Rh* and a key *K* as shown in Fig 10.14.

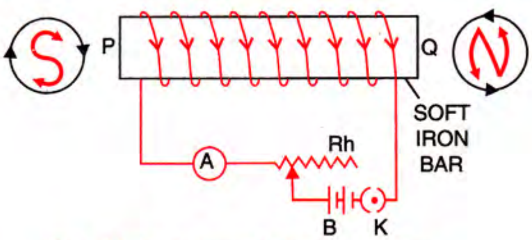


Fig. 10.14 I-shaped electromagnet

When current is passed through the winding of solenoid by closing the key *K*, the end *P* of the bar becomes the *south pole* (*S*) since current at this face is clockwise, while the end *Q* at which the current is anticlockwise, becomes the *north pole* (*N*). Thus the bar becomes a magnet. The bar shows the magnetic properties only when an electric current flows through the solenoid and it loses the magnetic properties as soon as the current is switched off (since soft iron has a low retentivity), thus it is a temporary magnet. Such arrangement is commonly used in a relay.*

(b) Construction of the U-shaped (or horse-shoe) electromagnet

To construct a horse-shoe electromagnet, a thin insulated copper wire is spirally wound on the arms of a U-shaped soft iron core, such that the winding on the two arms as seen from the ends, is in *opposite sense*. In Fig. 10.15, winding on the arm *P* starts from the front and it is in the clockwise direction (when viewed from the bottom). On reaching the upper end of the arm *P*, winding starts from the back at the top of the arm *Q* and it is in anticlockwise direction.

* A relay is a switching device.

The ends of the wire are connected to a battery through an ammeter, rheostat and a key.

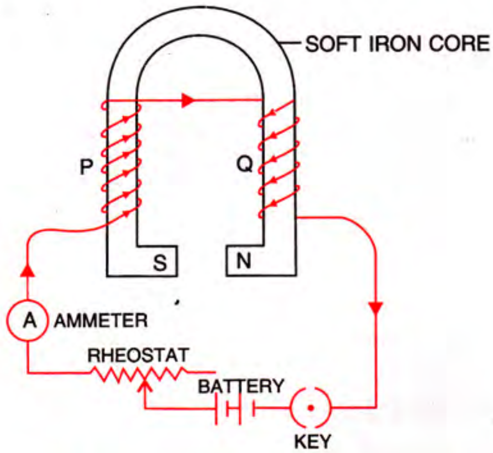


Fig. 10.15 Horse-shoe electro-magnet

When current is passed through the winding by closing the key, the end of the arm *P* becomes the *south pole S* (current at this face is clockwise) and the end of the arm *Q* becomes the *north pole N* (current at this face is anti-clockwise). Thus we get a very strong magnetic field in the gap between the two poles. The magnetic field in the gap vanishes as soon as the current in the circuit is switched off. Thus it is a temporary magnet. Such magnets are used in d.c. motor, a.c. generator, etc.

Note : For sending current in the coil, the source must be the d.c. source (*i.e.*, battery). With an a.c. source of frequency 50 Hz, although the soft iron core gets magnetised as long the current is passed, but its polarity magnetics as long to current is passed, but its polarity at the ends changes 50 times in each second.

Ways of increasing the magnetic field of an electromagnet

The magnetic field of an electromagnet (I or U-shaped) can be increased by the following *two* ways :

(i) by increasing the number of turns of winding in the solenoid, and

(ii) by increasing the current through the solenoid.

10.10 PERMANENT MAGNET

A permanent magnet is a naturally occuring magnet. Since it is not strong enough and of required shape for many purposes, so a strong permanent magnet is made like an electromagnet using steel instead of soft iron. A coil of insulated copper wire is wound around the steel piece and then current is passed in the coil. Once magnetised, it does not lose its magnetism easily (since steel has more retentivity than soft iron) so it becomes a permanent magnet. The permanent magnets are used in electric meters (*e.g.*, galvanometer, ammeter, voltmeter) and in magnetic compass, etc.

10.11 COMPARISON OF AN ELECTROMAGNET WITH A PERMANENT MAGNET

Electromagnet	Permanent magnet
1. It is made of soft iron.	1. It is made of steel.
2. It produces the magnetic field so long as current flows in its coil. *i.e.*, it produces the temporary magnetic field.	2. It produces a permanent magnetic field.
3. The magnetic field strength can be changed.	3. The magnetic field strength cannot be changed.
4. The magnetic field of an electromagnet can be very strong.	4. The magnetic field of a permanent magnet is not so strong.
5. The polarity of an electromagnet can be reversed.	5. The polarity of a permanent magnet can not be reversed.
6. It can easily be demagnetised by switching off the current.	6. It can not be easily demagnetised.

10.12 ADVANTAGES OF AN ELECTROMAGNET OVER A PERMANENT MAGNET

An electromagnet has the following advantages over a permanent magnet :

(i) An electromagnet can produce a strong magnetic field.

(ii) The strength of the magnetic field of an electromagnet can easily be changed by changing the current (or the number of turns) in its solenoid.

(iii) The polarity of the electromagnet can be reversed by reversing the direction of current in its solenoid.

10.13 USES OF ELECTROMAGNETS

Electromagnets are mainly used for the following purposes :

(i) For lifting and transporting heavy iron scrap, girders, plates, etc. particularly when it is not convenient to take the help of human labour. Electromagnets are used to lift as much as 20,000 kg of iron in a single lift. To unload the iron objects at the desired place, the current in the electromagnet is switched off so that the iron objects get detached.

(ii) For loading the furnaces with iron.

(iii) For separating the iron pieces from debris and ores, where iron exists as impurities (e.g., for separating iron from the crushed copper ore in copper mines).

(iv) For removing pieces of iron from wounds.

(v) In scientific research, to study the magnetic properties of a substance in a magnetic field.

(vi) In several electrical devices such as electric bell, telegraph, electric tram, electric motor, relay, microphone, loud speaker, etc.

Use of electromagnet in an electric bell

An electric bell is one of the most commonly used application of an electromagnet.

Construction and wiring : An electric bell is shown in Fig. 10.16.

The main parts of the bell are :

(i) a horse-shoe electromagnet *M*, having a soft iron core,

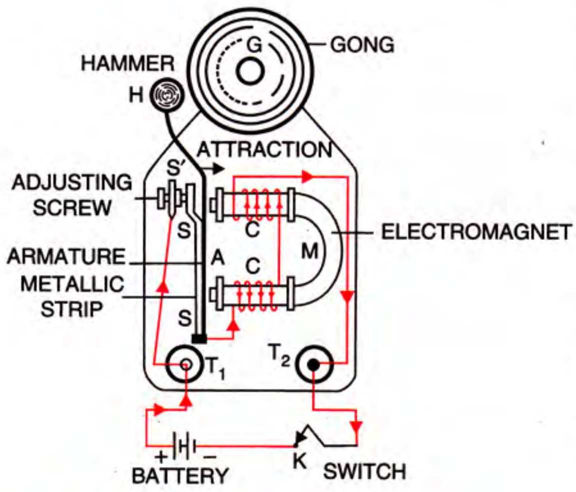


Fig. 10.16 Electric bell and its wiring

(ii) a soft iron armature *A*,

(iii) a hammer *H*,

(iv) a gong *G*,

(v) a metallic spring strip *SS*,

(vi) an adjusting screw *S′*,

(vii) a switch (or bell-push) *K*, and

(viii) a battery.

The armature *A* is fixed to the spring strip *SS*. The hammer *H* is attached at the upper end of the armature *A*. When the switch *K* is not pressed, the strip *SS* makes contact with the adjusting screw *S′* and there is a gap between the armature *A* and the poles of the electromagnet.

The coil *CC* is wound on the two arms of the electromagnet in the *opposite direction* as shown in Fig. 10.16. One end of the coil is connected to the terminal T_1 through the strip *SS* and the screw *S′*, while the other end is connected to the terminal T_2. A battery is provided in series with the switch *K* across the terminals T_1 and T_2.

Working and function of each part : When the electric circuit is closed by pressing the switch *K*, the current flows through the coil *CC* and the core of the electromagnet gets magnetised and therefore it attracts the armature *A* as shown by an arrow in Fig. 10.16. Due to movement of the armature *A*, the hammer *H* strikes the gong *G* and the bell rings.

At the moment, when the armature *A*, due to magnetic attraction, moves towards the electromagnet, the connection between the strip *SS* and the screw *S′* breaks due to which the flow of current in the coil stops. Consequently, the electromagnet loses magnetism (*i.e.*, it gets demagnetised) and the armature *A* flies back to its original position due to the spring effect of the strip *SS*. Now the armature *A* again touches the screw *S′*, resulting in the flow of current in the coil. The electromagnet regains its magnetism and the armature *A* is again attracted, so the hammer *H* again strikes the gong *G*. This process continues.

This process of make and break of the circuit goes on and the hammer strikes the gong repeatedly so the bell rings as long as the switch *K* is kept pressed.

Note : If an a.c. source is used in place of battery, the core of electromagnet will get magnetised, but the polarity at its ends will change. Since attraction of armature does not depend on the polarity of electromagnet, so the bell will still ring on pressing the switch *K*.

EXAMPLE

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

The labelled diagram is shown in Fig. 10.17. The polarity at the **end** ***A*** where the current is clockwise, is **south (*S*)**, while at the **end** ***B*** where the current is anticlockwise, is **north (*N*)**.

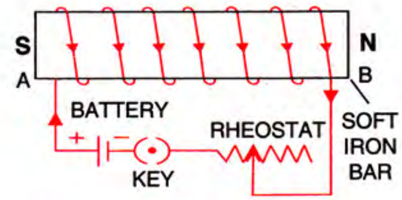


Fig. 10.17

EXERCISE 10 (B)

1. What is an electromagnet ?
2. Name the material used for preparing an electromagnet.
3. How is an electromagnet made ? Name *two* factors on which the strength of magnetic field of the electromagnet depends.
4. You are required to make an electromagnet from a soft iron bar by using a cell, an insulated coil of copper wire and a switch. (a) Draw a circuit diagram to represent the process. (b) Label the poles of the electromagnet.
5. Fig. 10.18 shows a coil wound around a soft iron bar *XY*. (a) State the polarity at the ends *X* and *Y* as the switch is pressed. (b) Suggest *one* way of increasing the strength of electromagnet so formed.

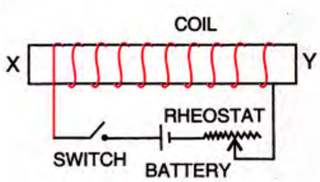


Fig. 10.18

Ans. (a) *X*-north pole, *Y*-south pole.
(b) By increasing the current in the coil.

6. A coil of insulated copper wire is wound around a piece of soft iron and current is passed in the coil from a battery. What name is given to the device so obtained ? Give *one* use of the device mentioned by you.
Ans. Electromagnet, electric relay.
7. Show with the aid of a diagram how a wire is wound on a U-shaped piece of soft iron in order to make it an electromagnet. Complete the circuit diagram and label the poles of the electromagnet.
8. State *two* ways through which the strength of an electromagnet can be increased.
9. Name *one* device that uses an electromagnet.
Ans. Electric bell.
10. State *two* advantages of an electromagnet over a permanent magnet.
11. State *two* differences between an electromagnet and a permanent magnet.
12. Why is soft iron used as the core of the electromagnet in an electric bell ?
13. How is the working of an electric bell affected, if alternating current be used instead of direct current ?
14. Name the material used for making the armature of an electric bell. Give a reason for your answer.

Multiple Choice Type

1. Electromangets are made up of :
(a) steel (b) copper
(c) soft iron (d) aluminium
Ans. (c) soft iron
2. The strength of the electromegnet can be increased by
(a) reversing the directions of current
(b) using alternating current of hight frequency
(c) increasing the current in the coil
(d) decreasing the number of turns of coil.
Ans. (c) increasing the current in the coil