Physics

NTSE Foundation
Magnetism

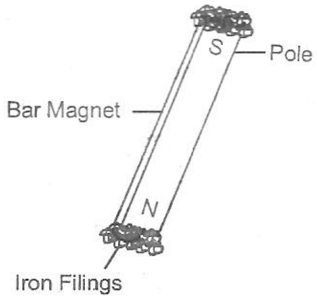
Magnetism

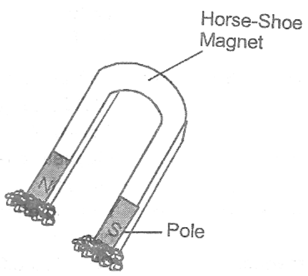
A mineral was discovered in the town of magnesia which was found to have a wondrous property. It could attract pieces of iron towards it. This mineral is called magnetite. Further it was found that thin strips of magnetite always align themselves in a particular direction when suspended freely in air. It was found that magnetite is mainly composed of oxides of iron (Fe_3O_4). Magnetite (Fe_3O_4) is the world's first magnet. It is also called natural magnet.

(a) Properties of a Bar Magnet:
(i) It attracts small pieces of iron towards itself.

Activity:
Spread out some iron fillings over a sheet of paper. Now, move a bar magnet in the fillings taking care that all parts of the magnet moves through iron fillings and observe how the iron fillings are distributed all over the magnet.

We will notice that most of the iron fillings cling near the ends of the magnet while there are a few iron fillings near the middle.





Repeat the experiment with a horseshoe magnet. This activity explains the attractive property of magnets.

(ii) the magnetic pull seems to come from two points near the ends. These preferred regions of attraction are called the magnetic poles. We will find that all magnets have maximum attractive power at their poles. Poles of a magnet remain slightly inside from the end points.

(iii) A freely suspended magnet always align itself along the north-south direction.
The end of the magnet that points towards the north is called the north pole (N-pole) end the other end of the magnet pointing towards the south is called the south-pole (D-pole).

(iv) Like poles of the magnets repel each other while unlike poles attract each other.
(v) Magnetic poles always exist in pair.
(vi) Repulsion is the surest5 test of magnetism. Since a magnet can attract magnetic substances and magnet also but it will always repel the magnet only.

(b) Types of Magnet:
(i) Natural magnet:
A magnet which occurs naturally and is not made by any artificial means is called a natural magnet.
Eg. : Magnetite, which is an ore of iron [Fe_3O_4].
(ii) Artificial magnet:
A substance to which properties of the natural magnet are imparted by artificial means is called artificial magnet.
Eg. : The magnets made from **iron, steel, cobalt and nictel.**

Need of artificial magnet:
Magnets are used in number of devices such as telephone, loudspeaker, radio, television, etc. For making these devices, we need powerful magnets.
(i) Artificial magnets can be made very powerful, which is not possible in case of natural magnets.
(ii) Artificial magnets can be made in any desired shape and size. This is not possible in case of natural magnets which bread when shaped with cutting tools.

(c) Demagnetization of Magnet:
A magnet can be made to lose its magnetism, i.e. it can be demagnetized, if the molecular magnets are disturbed so that they no longer point in the same direct5ion. This can be done by hammering the magnet. Heating the magnet above a certain temperature also demagnetizes it.

Types of Substances

(a) Magnetic Substances:
Those substances that are attracted by magnets are called magnetic substances.
Eg. : Iron, cobalt, nickel, steel etc.
(b) Non-Magnetic Substances:
Those substances that are not attracted by magnets are called non-magnetic substances.
Eg. : Plastic, rubber, glass etc.

Temporary and Permanent Magnets

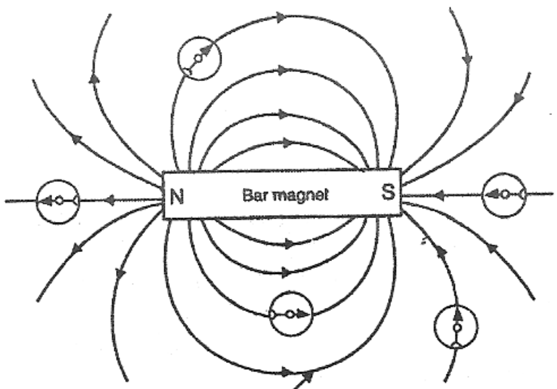
(a) Temporary magnets:
The magnets which cannot retain their magnetism for a long time are called temporary magnets. The temporary magnets are made from the soft iron.
Eg. : Electromagnet:
(b) Permanent magnets:
The magnets which retain their magnetism for a very long time are called permanent magnets. The permanent magnets are generally made from steel. More powerful permanent magnets are made from ALMICO, an alloy of aluminium, nickel and cobalt

or from ferrite. The ferrite made permanent magnets are quite strong.

Magnetic Field and Magnetic Lines of Force

The region or space around a bar magnet where its magnetic effect can be felt is called its magnetic field.

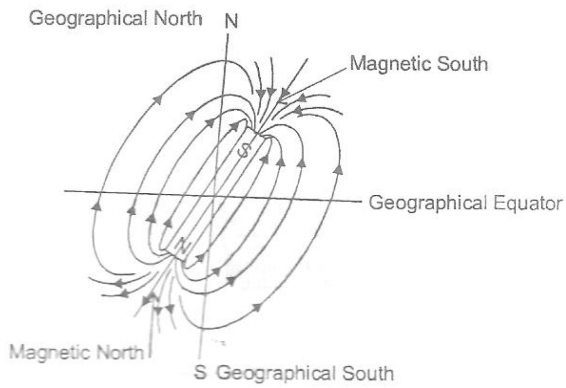
- S.I. unit of strength of magnetic field is Tesla (T).
- Its C.G.S. unit is Gauss (G). 1G = 10^{-4} T
- Magnetic material like iron fillings or a compass placed within the magnetic field of a magnet will experience a force.
- The direction of the force experienced by a freely suspended compass needle placed in a magnetic field are given by curves called magnetic lines of force.
- The direction of the magnetic lines of force is from the north pole of the magnet to the South Pole.
- A magnetic compass needle may also be used to plot the magnetic lines of force.
- The magnetic lines of force indicate the direction of the magnetic force at each point.
- The lines of force of a magnet never intersect each other. This is because at each point in the magnetic field of a magnet, the force of the magnet acts in only one unique direction.
- The direction of magnetic field at any point on the lines of force is that of the tangent drawn at that point.



Earth's Magnetism

Sir William Gilbert was the first to put forward the idea that the earth behaves like a huge magnet. The magnetic field of the earth is weak but can cause a freely suspended magnet to always point to the N-S direction.

- Towards the geographic north pole of the earth, lies the magnetic south pole of earth. Similarly, towards the geographic south pole of the earth, lies magnetic north pole of the earth.
- Human beings cannot feel the effect of the earth's magnetic field, but birds and animals can. Earth's magnetic field, also helps birds to find their way when they migrate from one place to another.



Electromagnet

When an electric current flows through a coil of wire (solenoid). The coil behaves like a magnet.

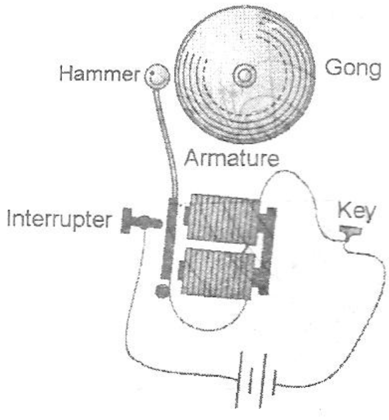
- When this current carrying coil is brought near a suspended bar magnet, one side of the coil repels the north pole of the magnet. The other side of the coil attracts the north pole of the magnet.

- A current carrying coil has both north and south poles like a magnet. Such a magnet is called electromagnet.

Uses of Electromagnet:
(i) They are used in cranes to lift heavy loads of scrap iron and iron sheets.
(ii) They are also used to separate magnetic substances, like iron, nickel and cobalt from non-magnetic substances like copper, zinc. Brass, plastic and paper.
(iii) They are used to remove foreign bodies like iron fillings from a patient's body, particularly from the eyes.
(iv) They are also used in electric bells, telegraphs, telephones, speakers, audio and video tape recorders.

Application of Electromagnet:

Electric – bell:
When the switch of an electric bell is pressed, the circuit is completed and current flows through the coils of the electromagnet. It gets magnetized and attracts the iron strip towards itself. This brings the hammer in contact with the gong and the sound of the bell is heard. Due to the displacement of the iron strip from its original position, it loses contact with the contact screw due to which the circuit of the electromagnet breaks. Current stops flowing and the electromagnet loses its magnetism. Hence, the iron strip comes back to its original position, which once again completes the circuit. The intire process is repeated as long as the switch is kept pressed. The hammer would strike the gong again and the again and the ringing of the bell would be heard.



An electric bell

Electro magnetic Induction

An electric current can be produced in a wire or in a coil by simply moving a magnet in and out of it. No battery or voltage source is needed. The same effect is observed if a part of wire loop is moved through the magnetic field of a magnet.

Electric Generators

Electric generator is a device for converting mechanical energy into electrical energy. It is also called dynamo. Generator is one of the most important application of the phenomenon of electromagnetic induction. There are two types of generators i.e. AC generator and DC generator.

❖ The device which produces alternating current is known as an AC generator or alternator. An alternating current (AC) is defined as a current which continuously changes in amnitude and periodically reverses in direction.

❖ It is a modification of an AC generator that produces a direct current (DC). A current of constant magnitude and flowing in the same direction is called direct current.

❖ **NOTE:** the word 'generator' is a misnomer. i.e. a wrong name has been given to the device, because nothing is generated by the device. It is just a converter which converts one form (mechanical energy) of energy into another (electrical energy).

❖ **Advantages of AC over DC:**
More than 90% of electric power generated in the world, is in the form of alternating current and power generated in the form of DC is less than 10%. In India AC changes its direction after every 1/100 of second i.e. the frequency of AC is 50 Hz. The advantages of AC over DC are a follows:
(i) AC can be transmitted to distant places with very small loss in AC power.
(ii) AC generator is cheaper than DC generator.
(iii) AC generators are strong and do not require much attention. The absence of commutators in AC generator avoid sparkings and increases the efficiency.
(iv) The AC voltage can be easily varied with the help of a transformer which is a device for changing alternating voltages. AC voltage can be easily stepped up or down as per requirement.
(v) AC can be easily converted into DC (if needed) by means of a rectifier.

❖ **Disadvantages of AC:**
(i) It is more dangerous to work with AC than DC.
(ii) Several chemical processes and effects such as hydrolysis, electrolysis, electroplating, electrorefining etc., are not at all possible with AC.
(iii) AC passes only through the outer layers of the conductor, unlike DC which passes through whole bulk of the conductor. Hence, several fine insulated wires (and not a single thick wire) are required for transmission of AC.

Types of Magnetic Substances

(a) Ferromagnetic Substances:
The substances which can be magnetized to greater extent are called ferromagnetic substances. A ferromagnetic substance sets parallel to the direction of magnetic field it suspended freely.

❖ **Iron, cobalt and nickel** are the examples of ferromagnetic substances.

(b) Paramagnetic Substances:
The substances which are feebly magnetized are called paramagnetic substances. A paramagnetic substance sets perpendicular to the direction of magnetic field if suspended freely.

❖ **Manganese, platinum and chromium** are examples of paramagnetic substances.

(c) Diamagnetic Substances:
The substances which are repelled by magnets are called diamagnetic substances. A diamagnetic substance wets perpendicular to the direction of magnetic field if suspended freely.

❖ **Antimony, bismuth, silver** are examples of diamagnetic substances.

Magnetic Field due to straight Current Carrying Wire

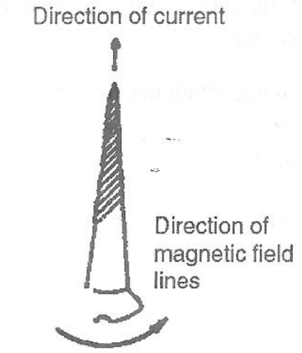
When current flows in the wire a magnetic field around the wire is created whose direction depends on the direction of current and intensity depends on the amount of the current

Magnetic field strength, $B = \frac{\mu_o I}{2\pi r}$

μ_o = Permeability of vacuum ($\mu_o = 10^{-7}$ Tm/A)
I = Current (flowing in conductor) and
R = Distance from the conductor (where magnetic field is measured).

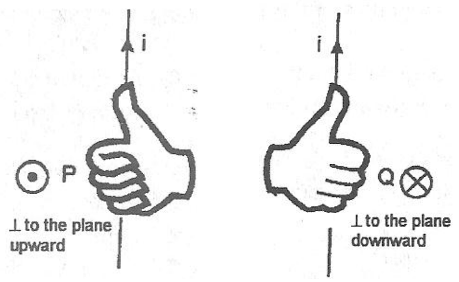
(ii) Direction of magnetic field:
The direction of magnetic field (lines of force) produced due to flow of current can be known by the following rules:

(A) Maxwell's cork screw rule:
Imaging a right handed cork screw lying with its axis coincides with the current carrying wire it is now rotated such that it advances in the direction of the current, the direction in which the screw rotates gives the direction of the magnetic lines of force.

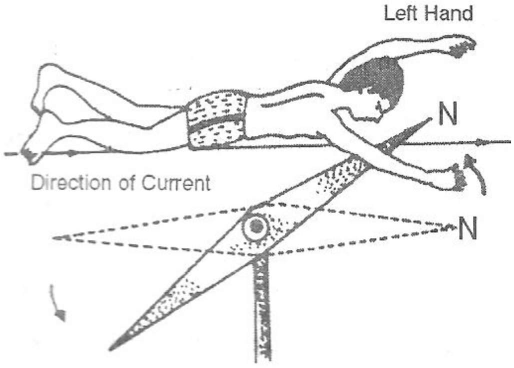


Maxwell's cork screw rule

(B) Right hand thumb rule:
The direction of the magnetic field at a point P due to a straight wire can be found by a slight variation in the right hand thumb rule. If we stretch the thumb of the right hand along the current and curl our fingers to pass through the point P, the direction of the fingers at P gives the direction of the magnetic field there.



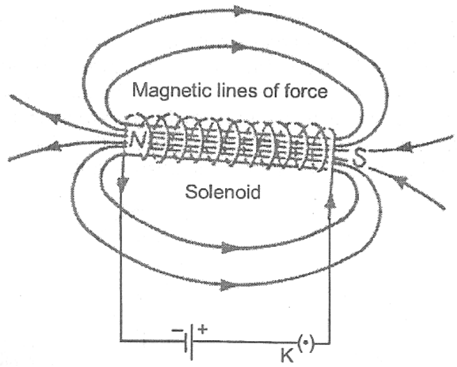
(C) Ampere's swimming rule:
Imagine a man swimming along the wire in the direction of current (such that the current enters at his feet and leaves him at his head) facing towards a magnetic needle kept undemeath the wire, then the magnetic field produced is such that the north pole of the needle will be deflected towards his left hand.



Ampere's Swimming Rule

Magnetic Field due to a Solenoid Carrying Current

If a conducting wire is wounded in the form of a cylindrical coil whose diameter is less in comparison to the length, then this coil is called a solenoid (it looks like a helical spring).
The magnetic field lines in a solenoid, through which current is passed, are as shown in figure.



The magnetic field, thus produced, is very much similar to that of a bar magnet and one end of the coil acts like a magnetic north pole, while the other acts like a south pole.

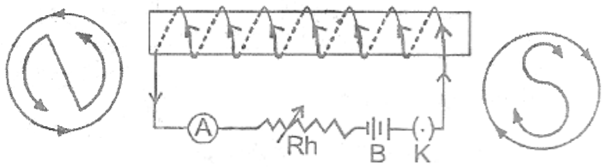
❖ The lines of force inside the solenoid are nearly straight and parallel to the axis of the solenoid.

❖ A strong magnetic field can be obtained by increasing the current strength.

❖ The magnetic field is increased if the number of turns in the solenoid of given length is increased.

❖ The magnetic field is also increased if a soft iron core is kept along the axis of the solenoid.

❖ Thus a current carrying solenoid behaves like a bar magnet with fixed polarities at its ends.



The strength of magnetic field produced by a current carrying solenoid depends upon :

(i) The number of turns per unit length in the solenoid:
Larger the current passed through solenoid, greater will be the magnetic field produced.

(ii) The strength of current in the solenoid:
Larger the current passed through solenoid, stronger will be the magnetic field produced.

(iii) The nature of "core material" used in making solenoid:

The use of soft iron rod as core in a solenoid produces the strongest magnet.

Magnetic field inside the solenoid is :

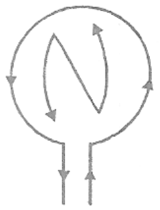
$B = \mu_o n I$

[Here n is number of turns per unit length]

At the ends of the solenoid the magnetic field:

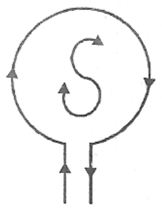
$$B_{end} = \frac{1}{2}\mu_o nI$$

The polarity of the faces of the coil depends on the direction of current and is determined by the clock rule. Looking at the face of the coil, if the current around that face is in an anticlockwise direction, the face has north polarity, while if the current at that face is in the clockwise direction, the face has south polarity. This can be tested by using a compass needle.



Anticlockwise Current

(a)



Clockwise Current

(b)

EXERCISE

1. The magnetic lines of force:
(A) intersect at the neutral point
(B) intersect near north and south poles.
(C) cannot intersect at all
(D) depend upon the position of the magnet

2. In an electric bell when iron strip displaces from its original position, then :
(A) current will stop flowing
(B) electromagnet looses its magnetism
(C) both A and B
(D) none of these

3. Magnetic field is a :
(A) vector quantity
(B) scalar quantity
(C) scalar as well as vector quantity
(D) neither vector nor scalar

4. Magnetic lines of force determines:
(A) the shape of the magnetic field
(B) only the direction the magnetic field
(C) only the relative strength of the magnetic field
(D) both the direction and the relative strength of the magnetic field

5. The S.I. unit of magnetic field intensity is :
(A) Weber (B) Tesla
(C) Oersted (D) none of these

6. C.G.S. unit of magnetic field intensity is :
(A) Tesla (B) Gauss
(C) Weber (D) none of these

7. Alnico is a material which is used to make :
(A) temporary magnet (B) permanent magnet
(C) both (A) and (B) (D) none of these

8. The chemical formula of magnetite (natural magnet) is:
(A) Fe_2O_3 (B) Fe_3O_4
(C) ReO (D) ReO_2

9. The south pole of the earth's magnetic field points to the:
(A) geographic North (B) geographic South
(C) both (A) and (B) are correct
(D) none of these

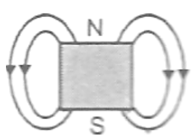
10. When current is flowing in straight conductor, the associated magnetic lines of force are :
(A) straight (B) elliptical
(C) circular (D) parabolic

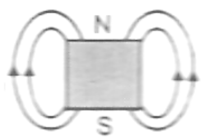
11. A magnetic field can be produced by:
(A) a moving charge
(B) A changing electric field
(C) Both (A) and (B) (D) None of these

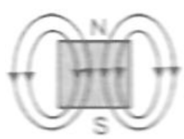
12. Which one of these is temporary magnet?
(A) Bar magnet (B) Electromagnet
(C) U shaped magnet (D) Horse-shoe magnet

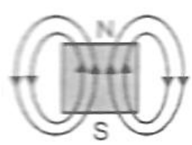
13. A generator or dynamo works on the principle of:
(A) magnetic effect of electric current
(B) electromagnetic induction
(C) chemical effect of electric current
(D) heating effect of electric current

14. The magnetic field lines due to a bar magnet are correctly shown in :

(A)


(B)


(C)


(D)


15. Magnetic effect of current was discovered by:
(A) Faraday (B) Oersted
(C) Ampere (D) Bohr

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

17. The vertical plane which passes through the magnetic axis of a freely suspended magnet is :
(A) Magnetic meridian
(B) Geographical meridian
(C) North meridian
(D) South meridian

18. The similar magnets of steel are …………than the magnets of soft iron.
(A) stronger (B) of equal strength
(C) weaker (D) none of these

19. the magnetism in a magnet is mainly due to :
(A) The orbital motion of the electrons
(B) The spin motion of the electrons
(C) The nuclear charge
(D) None of these

20. A magnet can be demagnetized by :
(A) Hammering the magnet
(B) By heating the magnet
(C) Without use of keepers
(D) All of these

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

22. Magnetic field lines outside the magnet start :
(A) from N-poles
(B) from S-poles
(C) from current-carrying wires
(D) none of these

23. A transformer used to reduce the alternating voltage is :
(A) Step-up transformer
(B) Step-down transformer
(C) both (A) and (B)
(D) none of these

24. If a bar magnet is cut lengthwise into 3 parts, the total number of poles will be :
(A) 2 (B) 6
(C) 3 (D) 4

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

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

27. The permanent magnet are kept with soft iron pieces at ends an keepers :
(A) to magnetise the soft iron pieces
(B) to increase the strength of the magnetic
(C) to avoid self demagnetization
(D) for physical safety of the magnets

28. Value of tesla in gauss is :
(A) 10^3 (B) 10^6
(C) 10^4 (D) 10^2

29. The earth's magnetic field is maximum:
(A) at poles of the earth
(B) at centre of the earth
(C) at outer surface of the earth
(D) none of these

30. The magnetic south pole of the earth is near to:
(A) geographical north pole
(B) geographical south pole
(C) east
(D) west

31. What happens when a bar-magnet is broken into two pieces?
(A) The magnetism is destroyed
(B) Each piece becomes a magnet
(C) One piece becomes a north-pole and the other becomes a south-pole
(D) One piece remains a magnet and the other becomes an ordinary bar

32. Which of the following statements is true?
(A) An electromagnet does not attract a piece of iron.
(B) An electric current flowing in a circuit deflects a magnetic needle
(C) An electric bell has a permanent magnet
(D) An electromagnet can be used to separate plastic bags from a garbage heap.

ANSWER – KEY

MAGNETISM

Q.	1	2	3	4	5	6	7	8	9	10
A.	C	C	A	D	B	B	B	B	A	C
Q.	11	12	13	14	15	16	17	18	19	20
A.	C	B	B	D	B	B	A	C	B	D
Q.	21	22	23	24	25	26	27	28	29	30
A.	B	A	B	B	C	A	C	C	A	A
Q.	31	32								
A.	B	B								