MAGNETIC EFFECT OF ELECTRIC CURRENT

MAGNETISM

The property due to which a substance attracts pieces of iron, nickel and cobalt towards itself, is called magnetism. A naturally occurring iron ore (black iron oxide - Fe_2O_3) having properties of attracting iron pieces, was found in Magnesia in the upper part of Greece. The name magnetism has been taken from the name of that place.

The substance having property of magnetism, is called magnetic substance and the body made up of a magnetic substance, is called a magnet.

Magnets are found in various shapes and sizes. A bar magnet is a long rectangular bar of uniform cross-section, which can attract pieces of iron, steel, cobalt and nickel. Magnet can be natural or artificial.

Poles of a magnet : When a magnet is dipped in iron filings, then maximum filings stick to its ends and almost no filings stick to its centre. It means that in magnets, centres of attraction are located near the ends only. These centres of attraction near the ends of a magnet, are called poles. Since a magnet has two poles hence it is also called magnetic dipole.

When this magnet is freely suspended, its two ends point in north south direction. The pole near the end pointing towards North (north-seeking end) is called North pole. The pole near the end pointing towards South (south-seeking end) is called South pole.

The magnetic poles exert forces on each other. Like poles repel each other, i.e., a north pole will repel another north pole or a south pole will repel another south pole. Unlike poles attract each other, i.e., a south pole will attract a north pole and vice versa.

Magnetic field of earth. Earth behaves as a huge magnet (or a giant solenoid). The source of this huge magnetism is given as the molten charged metallic fluid giving rise to a current flowing inside the core of the earth. This core has a radius of about 3500 km (Earth’s radius is 6400 km). Its strength is of the order of one gauss. Shape of the earth’s magnetic field resembles with that of a bar magnet of length one fifth of earth’s diameter buried at its centre.

Now it is believed that earth’s magnitism is due to the magnetic effect of current which is flowing in the molten core at the centre of earth. Hence, earth is a huge electromagnet.

MAGNETIC FIELD AND MAGNETIC FIELD LINES (MAGNETIC LINES OF FORCE)

MAGNETIC FIELD

It is the space around a magnetic pole or a magnet in which its effect is experienced by another magnetic pole or magnet. Magnetic field is a quantity which has both direction and magnitude.

MAGNETIC LINES OF FORCE

A magnetic line of force is a line, straight or curved, in the magnetic field tangent to which at any point gives the direction of the magnetic field at that point.

OR

A line such that the tangent at any point on it gives the direction of the magnetic field at that point is called a magnetic field or magnetic line of force.

A free unit north pole (test pole) will move along the magnetic line of force in direction of the field if it is free to do so. Direction of the magnetic line of force at any point is the direction of the force acting on unit (north) pole (unit magnetic pole) when placed at that point. Since a free unit north pole (test pole) will move away from a north (N) pole, magnetic lines of force have outward direction [Fig. (a)]. Since the free unit north pole will move towards a south (S) pole, magnetic lines of force have inward direction [Fig. (b)]. A small magnetic compass when moved along the line of force always sets itself parallel to the line of force.

Magnetic effect of current is also known as electromagnetism. Magnetic effect of current is very useful in electric motors, generators, telephone etc.

Experimental arrangement used by oersted is shown in Fig.

A straight wire AB is connected to a battery Ba and key K. The wire is held horizontally north-south over a magnetic needle. In this arrangement, when key is closed, current flows in the wire in the direction as shown in Fig. The north pole of the needle gets deflected towards west. When key is taken out and current in the wire becomes zero and the needle returns back to its initial position (S – N). This shows that a magnetic field is associated with an electric current.

When direction of current in the wire is reversed, direction of deflection of needle also gets reversed. If direction of current is kept same and the wire is put under the needle then, direction of deflection of needle again gets reversed.

Amount of deflection depends on the distance of the needle from the current carrying wire.

But we know that a magnetic needle is deflected by a magnetic field only. Hence we can conclude that current flowing in a wire gives rise to some magnetic field around it.

Position of the wire (conductor) carrying the current, direction of current and direction of deflection of the needle can be related by SNOW rule given below.

If current flows in the conductor from South towards North, with conductor kept over the needle, then North pole of the needle will be deflected towards West.

MAGNETIC FIELD DUE TO CURRENT CARRYING STRAIGHT CONDUCTOR (WIRE) AND CURRENT CARRYING CIRCULAR COIL

When Current carrying conductor is Straight, Magnetic Field is Circula

It means that when the current flows in a straight wire, the magnetic field produced has circular lines of force surrounding the wire, having their centres at the wire as shown in Fig. This can be shown by sprinkling iron filings on the cardboard C. When current flows through the conductor, iron filings get magnetised and now if the cardboard C is tapped gently iron filings arrange themselves in the circles around the wire.

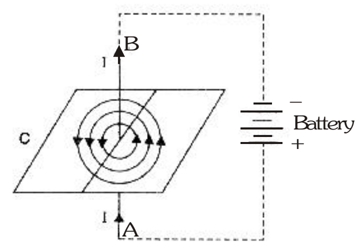

Fig.Current straight, magnetic field circular

Hence we can say that magnetic lines of force around a straight current carrying conductor are circular. The plane of circular lines is perpendicular to the length of the wire. Their direction is marked by arrows. When current I flows through a straight wire, the magnetic field strength (B) at a small distance r from it is given by

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

From the above expression we see that magnitude of magnetic field produced by a straight current carrying wire at a given point is :

(i) directly proportional to the quantity of current flowing through the wire.

(ii) inversely proportional to the distance of that point from the wire. Thus, if current is more, magnetic field will be stronger and vice versa.

EXERCISE

Q.1 The fact that magnetic field is produced around a wire carrying a current, was discovered by
(A) Faraday (B) Oersted
(C) Maxwell (D) Joule

Q.2 When the current is passing through the straight wire then, the associated magnetic field is
(A) Straight (B) Elliptical
(C) Circular (D) Parabolic

Q.3 When current is circular, the associated magnetic field is
(A) Straight (B) Elliptical
(C) Circular (D) Parabolic

Q.4 When current flows clockwise in a loop, the polarity of its face is
(A) East (B) South (C) West (D) North

Q.5 When current flows anticlockwise in a loop the magnetic polarity of the face is
(A) East (B) South (C) West (D) North

Q.6 For a solenoid carrying a current I and having n turns per unit length, wrapped on a core of permeability μ, the correct expression for magnetic field intensity (B) is

(A) $B = \frac{\mu_0}{\mu} nI$ (B) $B = \frac{\mu_0 \mu I}{n}$

(C) $B = \mu_0 \mu nI$ (D) $B = \frac{\mu_0 \mu n}{I}$

Q.7 Which of the following statements is incorrect regarding magnetic field lines :
(A) The direction of magnetic field at a point is taken to be the direction in which the north pole of a magnetic compass needle points
(B) Magnetic field lines are closed curves
(C) If magnetic field lines are parallel and equidistant, they represent zero field strength
(D) Relative strength of magnetic field is shown by the degree of closeness of the field lines

Q.8 Magnetic field lines determine :
(A) The shape of the magnetic field
(B) Only the direction of the magnetic field
(C) Only the relative strength of the magnetic field
(D) Both the direction and the relative strength of the magnetic field

Q.9 The magnetic field near a long straight wire is described by :
(A) Straight fieldlines parallel to the wire
(B) Straight field lines perpendicular to the wire
(C) Concentric circles centred on the wire
(D) Radial field lines starting from the wire

Q.10 When an electric current flows through a long solenoid, magnetic field is set up in and around the solenoid :
(A) Magnetic field inside the solenoid is non-uniform and weak
(B) Magnetic field outside the solenoid is uniform and strong
(C) Magnetic field inside the solenoid increases as we move towards the ends of the solenoid
(D) Magnetic field of solenoid resembles the magnetic field of the bar magnet.

Q.11 Magnetic field produced at the centre of a current carrying circular wire is :
(A) Directly proportional to the square of the radius of the circular wire
(B) Directly proportional to the radius of the circular wire
(C) Inversely proportional to the square of the radius of the circular wire
(D) Inversely proportional to the radius of the circular wire.

Q.12 The direction of the magnetic field at a point P above the current carrying wire is
(A) Down the page (B) Up the page
(C) Into the page (D) Out of the page.

Q.13 Which of the following properties of a proton can change while it moves freely in a magnetic field ?
(A) Mass (B) Speed
(C) Velocity (D) Momentum

Q.14 A positively charged particle say an alpha particle projected towards west is deflected towards north by a magnetic field. The direction of the magnetic field is :
(A) Upward (B) Downward
(C) Towards south (D) Towards east