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MAGNETISM AND MAGNETIC EFFECT OF ELECTRIC CURRENT

MAGNETS AND THEIR PROPERTIES

The pieces of naturally occurring magnetite are called natural magnets.

Natural magnets are weak, but materials like iron, nickel, cobalt may be converted into strong permanent magnets. All magnets–natural or artificial – have same properties.

Directive Property:

A small bar magnet, when suspended freely on its center of mass so as to rotate about a vertical axis, always stays in approximately geographical north-south direction.

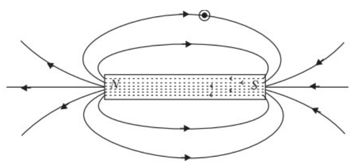
Attractive Property:

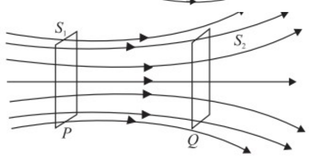
- A magnet attracts small pieces of magnetic materials like iron, nickel and cobalt.
- The force of attraction is maximum at points near the ends of the magnet.
- These points are called poles of the magnet
- The pole which points towards the geographical north is called is north pole and
- The one which points towards the geographical south is called south pole

Magnetic Field Lines

- Interactions between magnets or a magnet and a piece of iron essentially representation at a distance. This can be understood in terms of magnetic field

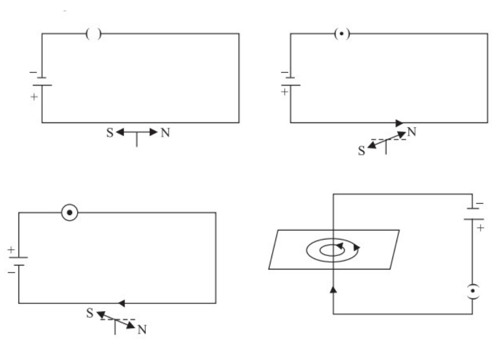
- The direction of magnetic field vector B at any point is given by the tangent to the field line at that point.
- The number of field lines that pass through unit area of a surface held perpendicular to the lines is proportional to the strength of magnetic field in that region. Thus, the magnetic field B is large where the field lines are closer together and smaller where they are far apart
- Outside the magnet, the field lines run from north pole to south pole and inside it, these run from south pole to north pole forming closed curves .
- Two magnetic field lines can never cross each other





ELECTRICITY AND MAGNETISM: BASIC CONCEPTS

Magnetic Field around an Electric Current



BIOT-SAVART'S LAW

Experiments show that the field B due to an element Δl depends on – current flowing through the conductor, I;

– length of the element Δl ;

– inversely proportional to the square of the distance of observation point P from the element Δl ; and

– the angle between the element and the line joing the element to the observation point.

$$|\Delta B_0| \propto \frac{I\,\Delta\ell\,\sin\theta}{r^2}$$

$$= \frac{\mu_0}{4\pi}\,\frac{I\,d\ell\,\sin\theta}{r^2}$$

Applications of Biot-Savart's Law

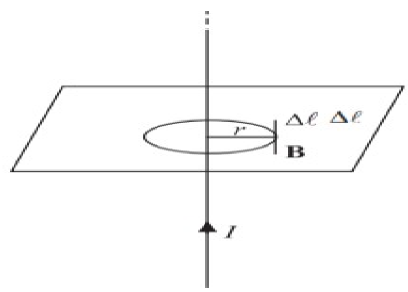
Magnetic field at the centre of a circular coil carrying current

$$|\mathbf{B}| = \frac{\mu_0\,nI}{2r}$$

where n is number of turns

AMPERE'S CIRCUITAL LAW

Ampere's circuital law states that the line integral of the magnetic field B around a closed loop isμ_0 times the total current, I.



$$\oint \mathbf{B}\cdot d\mathbf{l} = \mu_0 I$$

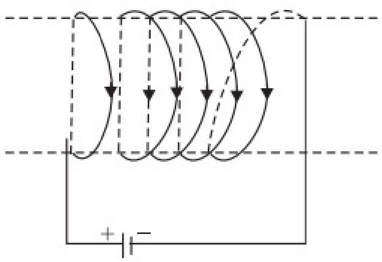
Applications of Ampere's Circuital Law

- Magnetic field due to an infinitely long current carrying conductor

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

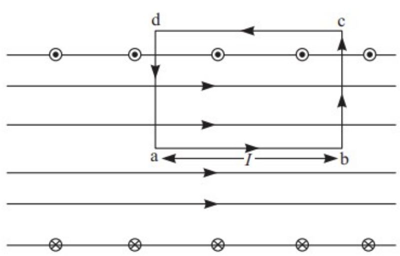
- Magnetic field due to a solenoid

$$|\mathbf{B}| = \frac{\mu_0 n I}{2}$$



Application of Ampere's Circuital Law Magnetism

Magnetic Field due to a Straight Solenoid



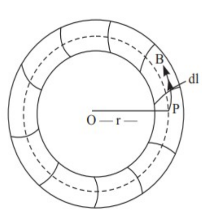
$$\sum \mathbf{B} \cdot d\ell = \mu_0 (nli)$$

$$B\ell = \mu_0 nli$$

$$B = \mu_0 ni$$

Magnetic field due to a toroid

A toroid is basically an endless solenoid which may be formed by bending a straight solenoid so as to give it a circular shape



$$\sum \mathbf{B} \cdot d\ell = \mu_0 Ni$$

$$2\pi r B = \mu_0 Ni$$

$$B = \frac{\mu_0 Ni}{2\pi r}$$

Electromagnets and Factors Affecting their Strength

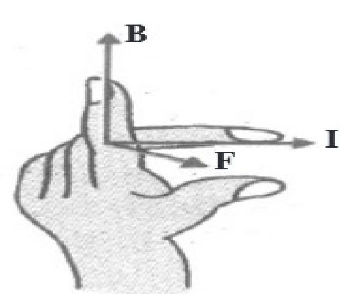
Its strength depends on :

(i) Number of turns per unit length of the solenoid, and (ii) The current flowing through it.

Concept of Displacement Current

FORCE ON A MOVING CHARGE IN A MAGNETIC FIELD

Fleming's left hand rule states that if we stretch the fore finger, the central finger and the thumb of our left hand at right angles to each other and hold them in such a way that the fore finger points in the direction of magnetic field and the central finger points in the direction of motion of positively charged particle, then the thumb will point in the direction of the Lorentz force



$$\mathbf{F} = q\,(\boldsymbol{v} \times \mathbf{B})$$
$$|\mathbf{F}| = q\,v\,B\sin\theta$$

Force on a Current Carrying Conductor in a Uniform Magnetic Field

Force Between two Parallel Wires Carrying Current

Motion of a Charged Particle in uniform Electric Field and Magnetic Field (a) Motion in **Electric Field**

F=am, a=$\frac{F}{m} = \frac{qE}{m}$

v=u+$\frac{qE}{m} \times t$, s = ut+$\frac{1}{2}\left(\frac{qE}{m}\right)t^2$

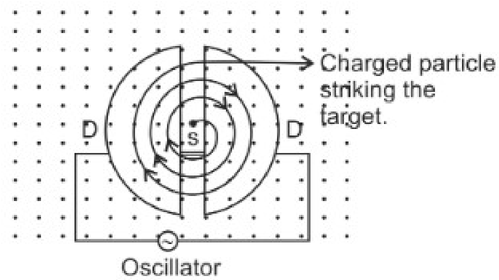
Motion in magnetic field

F=qBvsin θ

- If θ = 0, F = 0 and charged particle will move along a straight line with constant speed.
- If θ = 90°, F will be maximum and its direction, according to Fleming's left hand rule, will be perpendicular to the plane of v and B and the charged particle will move along a circular path with a constant speed and frequency.
- If θ ≠ 0° ≠ 90°, then the velocity of the charged particle will be vsinθ perpendicular to the field and vcosθ parallel to the field. The particle, therefore, moves along a helical path.

Cyclotron

It is used foraccelerating charged particles (such as protons, deutron or α–particles) to highvelocities.



The frequency of revolution of the charged particle is given by

$$\nu = \frac{1}{T} = \frac{v}{2\pi R} = \frac{Bq}{2\pi m}$$

Current Loop as A Dipole

A current carrying coil behaves like a magnetic dipole having north and south poles. One face of the loop behaves as north pole while the other behaves as south pole

$$B = \frac{\mu_0\,2I\,.\,\pi r^2}{4\pi r^3} = \frac{\mu_0\,2\,I\,A}{4\pi r^3} = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$$

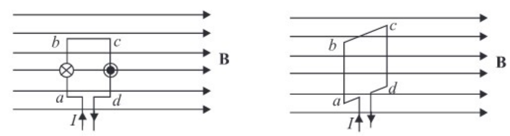
A current loop behaves as a magnetic dipole with magnetic moment M= NIA

Like the poles of a magnetic dipole, the two faces of a current loop are in separable

A magnetic dipole in a uniform magnetic field behaves the same way as an electric dipole in a uniform electric field.

A magnetic dipole also has a magnetic field around it similar to the electric Field around an electric dipole

Torque on a Current Loop



Torque= force × perpendicular distance between the force=

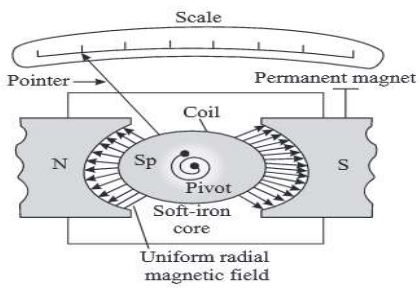
B I l. b sin θ

Galvanometer

Galvanometer is used to detect electric current in a circuit

Principle of Galvanometer :

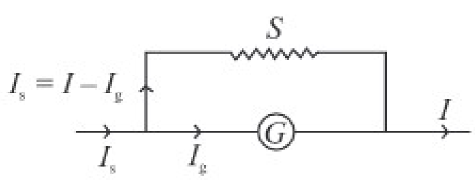
A current carrying coil, when placed in a magnetic field, experiences a torque



An Ammeter and a Voltmeter

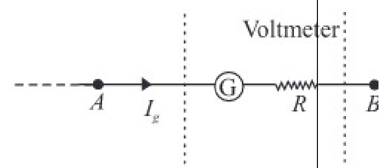
Ammeter

To convert a galvanometer into an ammeter, a low resistance wire is connected in parallel with the galvanometer. The resistance of the shunt depends on the range of the ammeter



Voltmeter

Convert a galvanometer into a voltmeter by connecting a high resistance in series with the galvanometer coil



Check Yourself

1. A magnetic field can be produced by
   (a) A moving charge
   (b) A changing electric field
   (c) None of these
   (d) Both of these
2. Field inside a solenoid is
   (a) Directly proportional to its length
   (b) Directly proportional to current
   (c) Inversely proportional to total number of turns
   (d) Inversely proportional to current
3. The magnetic field near a current carrying conductor is given by
   (a) Coulomb's law
   (b) Lenz' law
   (c) Biot-savart's law
   (d) Kirchoff's law
4. The Biot-savart's law is a general modification of
   a) Kirchhoff's law
   b) Lenz's law
   c) Ampere's law
   d) Faraday's laws
5.

Stretch Yourself

1. A long straight wire carries a current of 10 amperes. Calculate the intensity of the magnetic field at a distance of 40 cm from it.

2. An electron is moving in a circular orbit of radius 5 × 10–11 m at the rate of7.0 × 1015 revolutions per second. Calculate the magnetic field B at the centre of the orbit.
3. A force acts upon a charged particle moving in a magnetic field, but this force does not change the speed of the particle, Why ?
4. The magnetic field at the centre of a 50cm long solenoid is 4.0 × 10–2 NA–1m–1 when a current of 8.0A flows through it, calculate the number of turns in the solenoid.

Hint to check yourself

1 D 2 B 3 C 4 C