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Cl 12 Sub Physics Date 31 07 21

Unit 3 (Magnetic effect of current)

MAGNETIC EFFECTS OF CURRENT

Oersted discovered a magnetic field around a conductor carrying electric current. Other related facts are as follows:

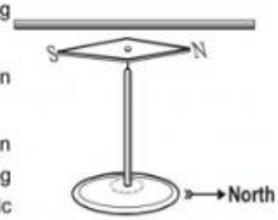
(a) A magnet at rest produces a magnetic field around it while an electric charge at rest produce an electric field around it.

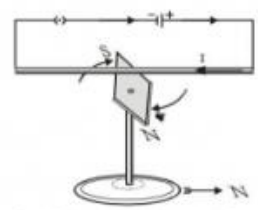
(b) A current carrying conductor has a magnetic field and not an electric field around it. On the other hand, a charge moving with a uniform velocity has an electric as well as a magnetic field around it.

(c) An electric field cannot be produced without a charge whereas a magnetic field can be produced without a magnet.

(d) No poles are produced in a coil carrying current but such a coil shows north and south polarities.

(e) All oscillating or an accelerated charge produces E.M. waves also in additions to electric and magnetic fields.





Oersted's experiment. Current in the wire deflects the compass needle.

Magnetic induction $\vec{B}$ is a vector quantity : Not uncommonly it is given by the number of lines of induction threading a unit area normal to the surface.

UNIT OF $\vec{B}$: MKS weber/metre^2, SI tesla, CGS maxwell/cm^2 or gauss.

One Tesla = one (weber/m^2) = 10^4 (maxwell/cm^2) = 10^4 gauss

Biot-Savart's law : With the help of experimental results, Biot and Savart arrived at a mathematical expression that gives the magnetic field at some point in space in terms of the current that produces the field. That expression is based on the following experimental observations for the magnetic field $\vec{dB}$ at a point P associated with a length element $\vec{d\ell}$ of a wire carrying a steady current I.

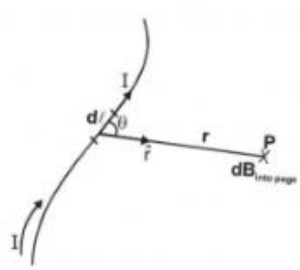
Magnitude of $\vec{dB}$ is
(a) Propotional to current I
(b) Propotional to magnitude $d\ell$ of the lenght element $\vec{d\ell}$
(c) inversely proportional to r^2, where r is the distance from $d\ell$ to P.
(d) Proportional to $\sin\theta$ where θ is the angle between $\vec{d\ell}$ and $\hat{r}$.

$dB \propto I$

$dB \propto d\ell$

$dB \propto \frac{1}{r^2}$

$dB \propto \sin\theta$



Combining all these $\quad dB \propto \frac{I\, d\ell \sin\theta}{r^2}$

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

μ_0 is called permeability of free space $\frac{\mu_0}{4\pi} = 10^{-7}$ henry/meter.

$$1(\text{H/m}) = 1\ \frac{\text{T m}}{\text{A}} = 1\ \frac{\text{Wb}}{\text{A m}} = 1\ \frac{\text{N}}{\text{A}^2} = 1\ \frac{\text{N s}^2}{\text{c}^2}$$

DIMENSIONS of $\mu_0 = [M^1L^1T^{-2}A^{-2}]$

For vaccum : $\sqrt{\frac{1}{\mu_0\varepsilon_0}} = c = 3 \times 10^8$ m/s

Biot-Savart law in vector form :

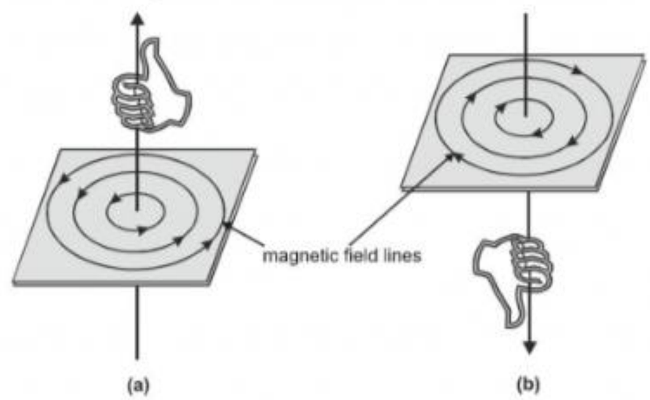
$$\vec{dB} = \frac{\mu_0 I}{4\pi} \frac{(\vec{d\ell} \times \vec{r})}{r^3}$$

Static charge is a source of electric field but not of magnetic field, whereas the moving charge is a source of electric field as well as magnetic field.

the direction of $\vec{dB}$ is perpendicular to the plane determined by $\vec{d\ell}$ and $\vec{r}$ (i.e. if $\vec{d\ell}$ and $\vec{r}$ lie in the plane of the paper then $\vec{dB}$ is $\perp$ to plane of the paper). In the figure, direction of $\vec{dB}$ is into the page. (Use right hand screw rule).

RULES TO FIND DIRECTION MAGNETIC FIELD

Right hand thumb rule. If we grasp the conductor in the palm of the right hand so that the thumb points in the direction of the flow of current, then the direction in which the fingers curl, gives the direction of magnetic field lines.



For the current flowing through the conductor in the direction shown in fig. (a) or (b), both the rules predict that magnetic field lines will be in anticlockwise direction, when seen from above.

The magnetic field produced by a current-carrying straight conductor is of circular symetry. The magnetic lines of force are concentric circles with the current carrying conductor passing through their common centre. The plane of the magnetic lines of force is perpendicular to the length of the conductor.