ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

STUDY MATERIAL : 5 (Part - 1)

Subject : PHYSICS

Topic : Electromagnetism

CLASS : XII

Date : 26.06.2020

A : Short Notes
Magnetic Force

1: A charged particle having charge q will experience a force $\vec{F} = q(\vec{v} \times \vec{B})$ if it enters a magnetic field B with a velocity v.

2 : The SI unit of magnetic field is Wbm^{-2} or Tesla (T). The CGS unit is Gauss = $Maxwell/cm^2$

I Gauss = 10^{-4} T

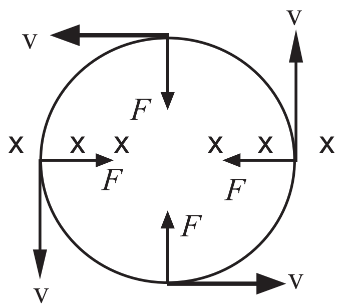
If the charged particle is subjected to both electric and magnetic fields, the net force acting on the moving charged particle is given by Lorentz force

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

3: If a charged particle always moves perpendicular to the magnetic field it will describe a circle of radius

R such that $R = \frac{mv}{qB}$

Since it is a radial force, it only changes the direction and does not do any work.



Principle of cyclotron illustration

Time period of revolution $T = \frac{2\pi R}{v} = \frac{2\pi m}{qB}$ and cyclotron frequency $f_c = \frac{1}{T} = \frac{qB}{2\pi m}$

4 : Magnetic force due to a current carrying conductor when placed in a uniform magnetic field B is

$$d\vec{F} = I\, d\vec{l} \times \vec{B}$$

The direction of magnetic force is given by Fleming's Left hand rule.

Note $\vec{F} = I\vec{l} \times \vec{B}$ if the conductor is straight. Otherwise $\vec{F} = \int I(d\vec{l} \times \vec{B})$

Torque acting on a current-carrying loop when placed in a uniform magnetic field is $\vec{7} = nI(\vec{A} \times \vec{B})$

Where n is number of turns in the coil or loop and area vector A is perpendicular to the surface.

For a rectangular coil A = lb and for a circular coil $A = \pi r^2$

We can also write

$\vec{7} = nI(\vec{A} \times \vec{B}) = \vec{M} \times \vec{B}$ where $\vec{M} = nI\vec{A}$ is magnetic dipole moment.

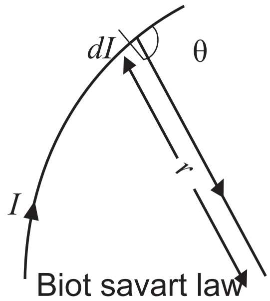
Note that the coil will be in stable equilibrium if $\theta = O$ and coil will be in unstable equilibrium if $\theta = 180^0$. Torque is maximum if $\theta = 90^0$.

5 : If the magnetic field is non uniform then coil will experience torque as well as linear motion.

6. **Biot Savart Law -** The magnetic field produced due to a current-carrying element of length *dl* at any point *P* is given

by $\vec{dB} = \mu_0 \frac{I\vec{dl} \times \vec{r}}{4\pi r^3}$

or $dB = \frac{\mu_0 I dl \sin\theta}{4\pi r^2}$



Biot savart law

where μ_0 is permeability of free space and $\mu_0 = 4\pi \times 10^{-7}$ Wb $(A\text{-}m)^{-1}$ or Henry m^{-1}.

7 : The direction of magnetic field is given by Right hand thumb rule as illustrated in Fig.

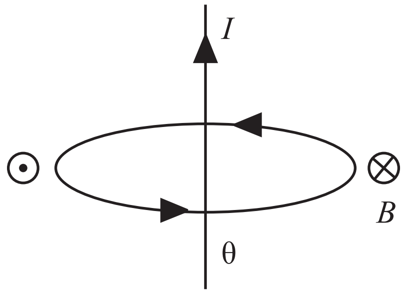
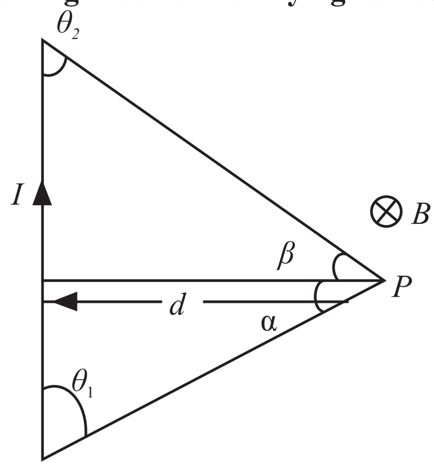


Illustration of direction of magnetic field

8. **Magnetic field strength due to straight current-carrying conductor at a point *P***



Magnetic field due to finite straight conductor
from fig. magnetic field strength at *P* is

$$B = \frac{\mu_0 I}{4\pi d}(\cos\theta_1 - \cos\theta_2)$$

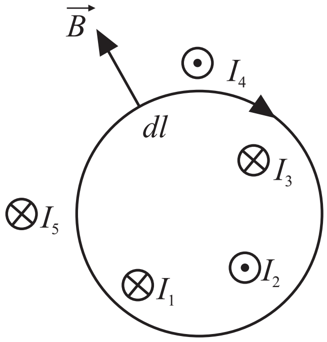
The direction of magnetic field is given by Right hand thumb rule. From Fig. it is clear that magnetic field at P is perpendicular inwards the plane of paper .

9: Magnetic field strength at point p due to a long current-carrying conductor is $B = \frac{\mu_0 I}{2\pi d}$
Magnetic field strength at the center of a circular loop carrying current *I*

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

Ampere's Circuital law

10 : $\oint \vec{B}.\vec{dl} = \mu_0 I$



Ampere circuital law illustration

if I_1 and I_3 are taken as positive and I_2 as negative then $I = (I_1 + I_3 - I_2)$ and then

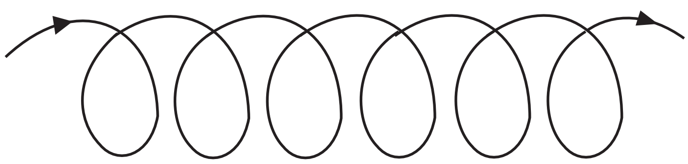
$$\oint \vec{B}.\vec{dl} = \mu_0 (I_1 + I_3 - I_2)$$

Note that any current outside the loop is not included in the right hand side in the current.

Note that $\oint \vec{B}.\, \vec{dl} = \mu_0 I$ can be applied even to a long conductor.

11: **Magnetic field due to a long solenoid at the axis of the solenoid**

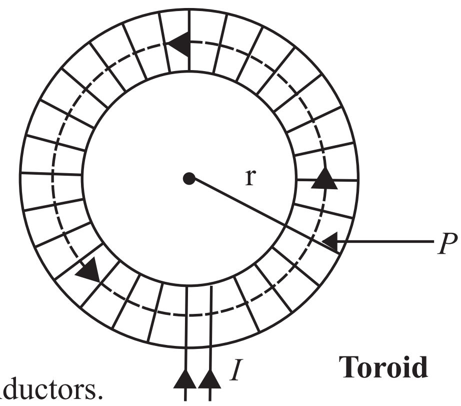
$B = n\mu_0 I$ where n is number of turns per unit length



Solenoid

Magnetic field outside the coil is zero.

12 : **Magnetic field at any point P (acting tangentially) on a toroid.**



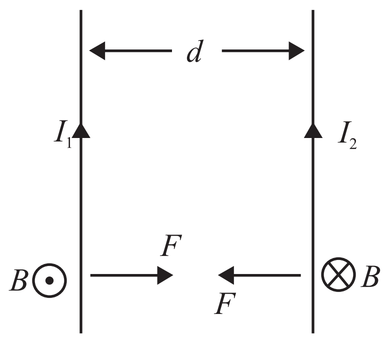
Toroid

$$\text{From Fig. } B = \frac{\mu_0 N I}{2\pi r}$$

where N is total number of turns.

Magnetic force between two long, parallel current-carrying conductors.

If d is the separation between two long current-carrying conductors carrying currents I_1 and I_2 as shown in



Force between two long current-carrying conductors

$$\text{Then } \frac{dF}{dl} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Note that the force is attractive if the conductors carry current in the same direction. Force will be repulsive if they carry current in opposite directions.

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