Magnetism

Lecture 5

Right Hand Rule

Msc. Ali Jaafar

2nd stage

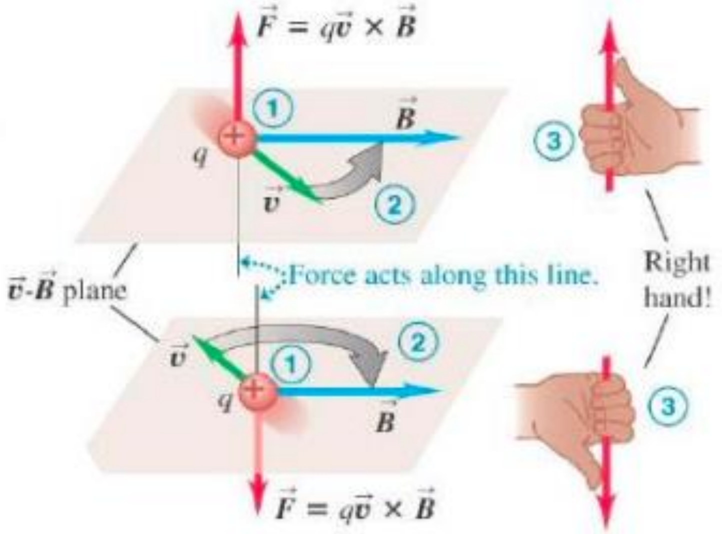
Department of medical physics Al-Mustaqbal University-College

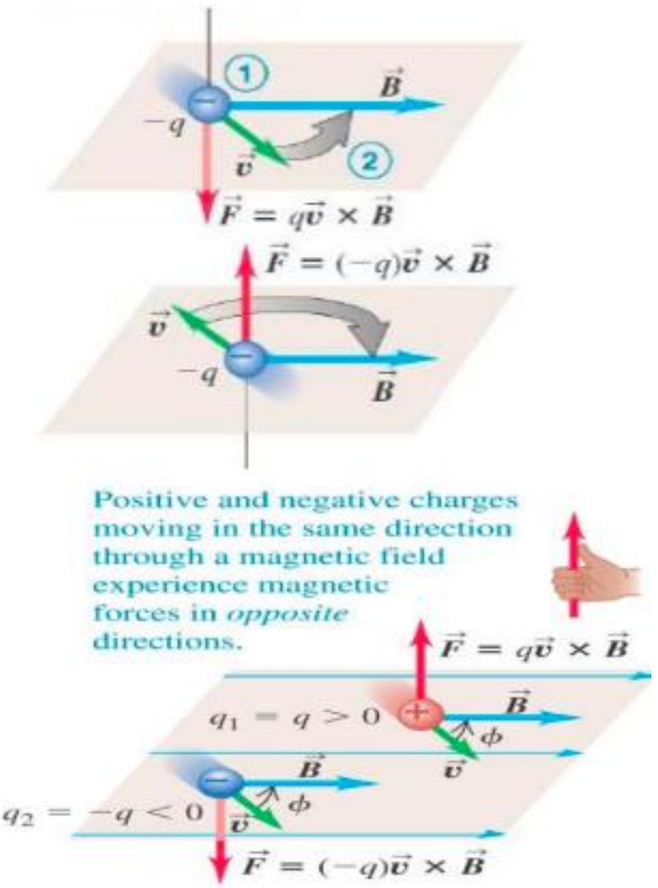
2025- 2026

Right Hand Rule

Positive charge moving in magnetic field →direction of force follows right hand rule

Negative charge → F direction contrary to right hand rule.

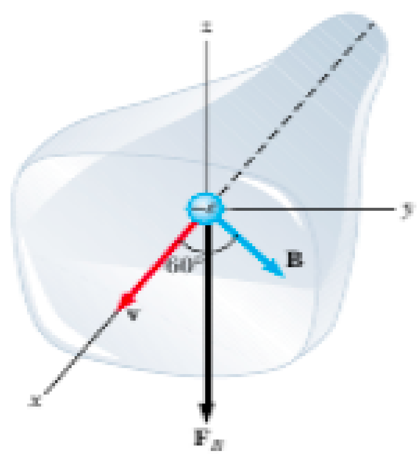




The magnitude of the magnetic force on a charged particle is: F_B | q| v B sinØ where is the smallest angle between v and B. From this expression, we see that F_B is zero when v is parallel or antiparallel to B (Ø = 0 or 180°) and maximum when v is perpendicular to B

(Ø= 90°). In the SI unit 1T= N ⁄ C.M/sec = N/Amp.m. 1Gauss = 10^{-4} T

Example1: An electron in a television picture tube moves toward the front of the tube with a speed of $8x10^6$ m/s along the x-axis show in the Figure. Surrounding the neck of the tube are coils of wire that create a magnetic field of magnitude 0.025 T, directed at an angle of 60° to the x- axis and lying in the x, y plane. Calculate the magnetic force on the electron.



Solution: F_B =| q|v .B. sin∅

$$F_B = 1.6 \times 10^{-19} C \times 8 \times 10^{6}\, m/sec \times 0.025T \times sin60°$$

$$F_B = 2.8 \times 10^{-14} N$$

Example 2: A regular magnetic field in which B = 0.12 T to the east, proton at a speed of $5x10^5$ m / Sec was thrown in the magnetic field. Find out the amount of magnetic force Attached to the proton for the following cases:

a. Towards the south? b. Westward? c-Northward? d-East? e - Towards making the corner 60 to the east ?

Solution:

The proton charge is 1.6×10^{-19} C, and the magnetic force is F_B = q .v. sin∅

a) Towards the south, then the angle between the magnetic field and the proton is 90^o

b) Westward, then the angle between the magnetic field and the proton is 180^o

$$F_B = q\ v\ B\ sin\theta$$

$= (1.6\times10^{-19}) \times (5\times10^5 m/ Sec) \times (0.12T) \times sin90$

$= 9.6 \times10^{-15}$ *nt*

b) Westward, then the angle btween the magnetic field and the proton is 180^o

$$F_B = q\ v\ B\ sin\theta$$

$= (1.6\times10^{-19}) \times (5\times10^5 m/ Sec) \times (0.12T) \times sin180$

$= 0$

C) Northward, then the angle between the magnetic field and the proton is 90^o

FB=q v B.sinθ

$= (1.6\times10^{-19}) \times (5\times10^5 m/ Sec) \times (0.12T) \times sin90 = 9.6 \times10^{-15}$ nt

c) East, then the angle btween the magnetic field and the proton is 90^o
θ = $(1.6\times10^{-19}) \times (5\times105 m/ Sec) \times (0.12T) \times sin180 = 0$

d) e) Towards making the corner 60 to the east?

e) $\theta = (1.6\times10^{-19}) \times (5\times10^{5}\text{m/Sec}) \times (0.12\text{T}) \times \sin60 \quad = 8.31\times10\text{-}15$ nt

H.W. Find the magnetic force for an electron moving with velocity 6×107m/Sec. In the same regular magnetic field?

Magnetic Flux and Gauss's Law for Magnetism

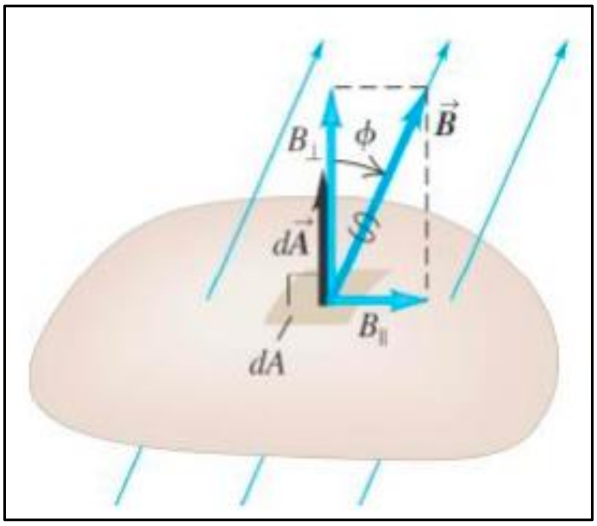
$$\Phi_B = \int B_\perp\, dA = \int B\cos\emptyset . dA = \int \vec{B} . d\vec{A}$$

Magnetic flux is a scalar quantity.

If $\vec{B}$ is uniform:

$$\Phi_B = B_\perp A = B\,A\cos\emptyset \quad ....(7)$$

1 Weber (1 Wb = 1 T.m^2 = 1 N .m / A)



- Difference with respect to electric flux ⇒ the total magnetic flux through a closed surface is always zero. This is because there is no isolated magnetic charge ("monopole") that can be enclosed by the Gaussian surface.

$$\Phi_B = \int \vec{B} . d\vec{A} = 0 ....(8)$$

$$B = \frac{d\Phi_B}{dA_\perp} \quad ....(9)$$

- The magnetic field is equal to the flux per unit area across an area at right angles to the magnetic field = magnetic flux density.

Motion of Charged Particles in a Magnetic Field

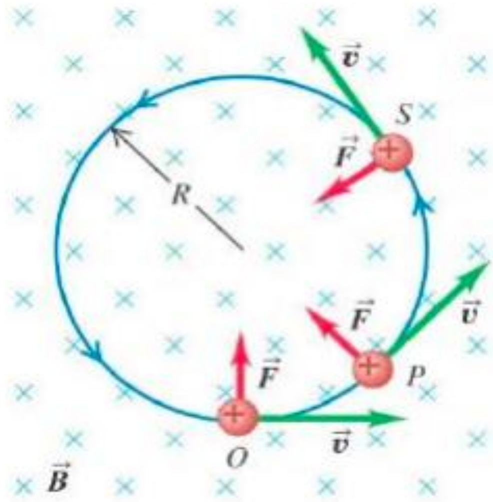
- Magnetic force perpendicular to $\vec{}$ It cannot change the magnitude of the velocity, only its direction.

$$\vec{F}_m = q\,\vec{v} \times \vec{B}$$

-F⃗ does not have a component parallel to particle's motion ⇒ cannot do work.

- Magnitudes of F and v are constant (v perp. B) ⇒ uniform circular motion.

$$\vec{F}_m = |q|.v.B = m\frac{v^2}{R} \quad ....(10)$$



Radius of circular orbit in magnetic field:

$$R = \frac{mv}{|q|B}$$

+ particle ⇒ counter-clockwise rotation.
- particle ⇒ clockwise rotation.

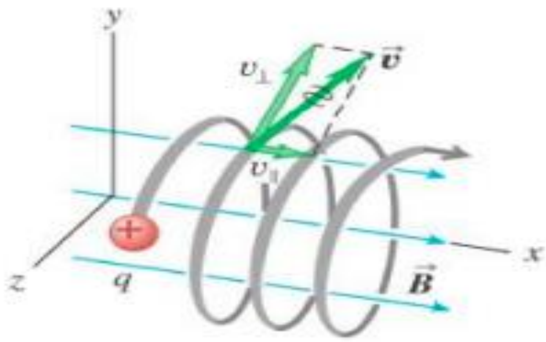
Angular speed:

$$\omega = \frac{v}{R} = v\frac{|q|B}{mv}$$

-If v is not perpendicular to B → v parallel to B constant because F = 0 particle moves in a helix. (R same as before, with $v = v_{\perp}$).

A charged particle will move in a plane perpendicular to the magnetic field.

This particle's motion has components both parallel ($v_{\parallel}$) and perpendicular ($v_{\perp}$) to the magnetic field, so it moves in a helical path.



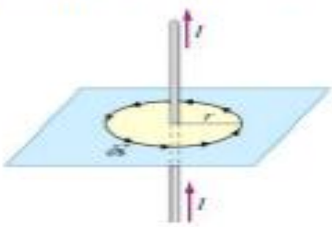
1-7 Ampere' Law: states that the line integral of B and dl over a closed path is μ_o times the current enclosed in that loop:

$$\oint \vec{B}\,.\,\vec{dl} = \mu_o.i_{enclosed} \quad ....(11)$$

$\mu_o = 4\pi \times 10^{-7} T.m/A$ is the magnetic permeability of free space.

Example: Using Ampère's law to find the field around a long straight wire:

Sol:



$$\oint \vec{B}\,.\,\vec{ds} = \mu_o.i_{enclosed}$$

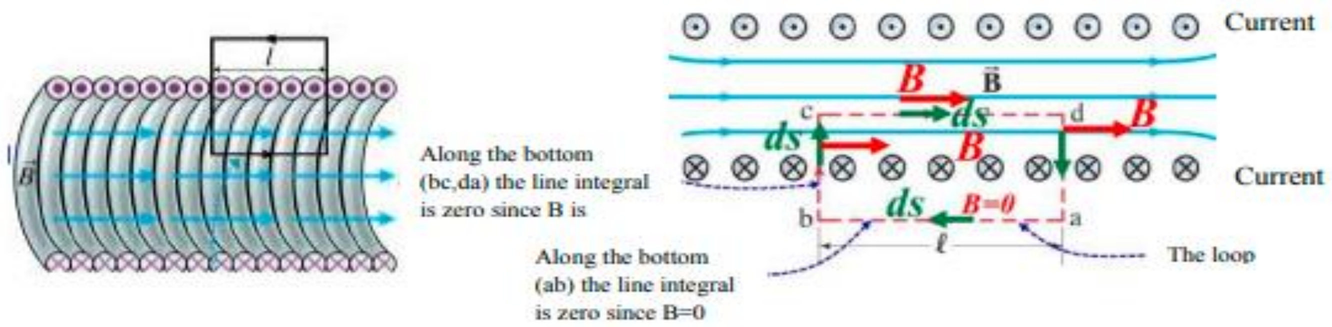
$$\oint \vec{ds} = 2\pi r \quad the\ circumference\ of\ the\ loop$$

$$B.2\pi r = \mu_o.i_{enclosed}$$

$$B = \frac{\mu_o.i_{enclosed}}{2\pi r} \quad ....(12)$$

Solenoid

A solenoid is a helical coil of wire with the same current I passing through each loop in the coil. A uniform magnetic field can be generated with a solenoid



$$\oint \vec{B}\,.\,\vec{ds} = \mu_o.\,I \text{ ....(13)}$$

$$\oint_{abcda} \vec{B}\cdot d\vec{s} = \int_a^b \vec{B}\cdot d\vec{s} + \int_b^c \vec{B}\cdot d\vec{s} + \int_c^d \vec{B}\cdot d\vec{s} + \int_d^a \vec{B}\cdot d\vec{s} = \mu_0 I_{in}$$

$\vec{B} = 0$; $\vec{B} \perp d\vec{s}$; $\vec{B} \parallel d\vec{s}$, $\vec{B} = const$; $\vec{B} \perp d\vec{s}$

There are N loops with current I enclosed by an Amperian loop, so

$$I_{in} = N.\,I \text{ ....(13)}$$

$$B\int_c^d ds = \mu_o.\,N.\,I \text{ ....(14)}$$

$$Bl = \mu_o.\,N.\,I \Rightarrow B = \frac{\mu_o.\,N.\,I}{l} \qquad \text{where } n = \frac{N}{l}$$

n is the number of turns per unit length.

$$B_{solenoid} = \mu_o.\,n.\,I \text{ ....(15)}$$

Example2: What current is required in the windings of a long solenoid that has 1000 turns uniformly distributed over a length of 0.4m, to produce at the center of the solenoid a magnetic field of magnitude 1x10^{-4} T?

Solution:

$$B = \frac{\mu_o.\,N.\,I}{l}$$

$$I = \frac{B.\,l}{\mu_o.\,N.}$$

$$I = \frac{(1 \times 10^{-4}T) \times 0.4m}{\left(4\pi \times 10^{-7}\,\frac{T.\,m}{Amp}\right) \times 1000} = 31.8 \text{ mA}$$