Physics 202, Lecture 12

Today's Topics

- Magnetic Forces
  - Review: magnetic force
  - Motion of charge in uniform B field:
    Applications: cyclotron, velocity selector, Hall effect

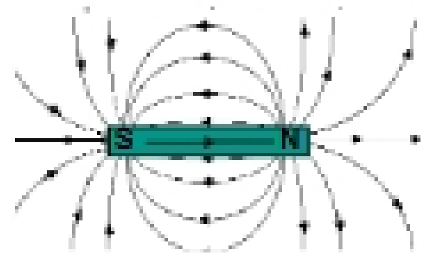
Magnetic Fields and Forces: Recap

Magnetic Force: experienced by moving charges

$$\vec{F} = q\vec{v} \times \vec{B} \qquad \vec{F} = \int I d\vec{l} \times \vec{B}$$

(point charges) (currents)

Magnetic Field B: sourced by moving charges
direction: as indicated by north pole of compass

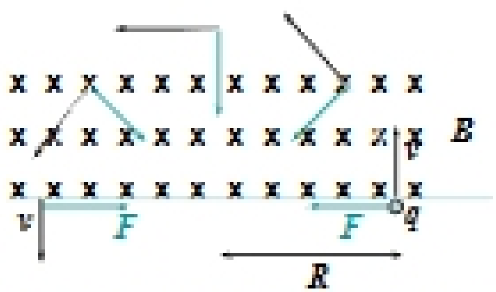


Units: 1 Tesla (T) = 1 N/(A m)

Field lines: closed loops!
Outside magnet: N to S
Inside magnet: S to N

Trajectory in Constant B Field

- Suppose charge q enters a uniform B-field with velocity v. What will be the path that q follows?

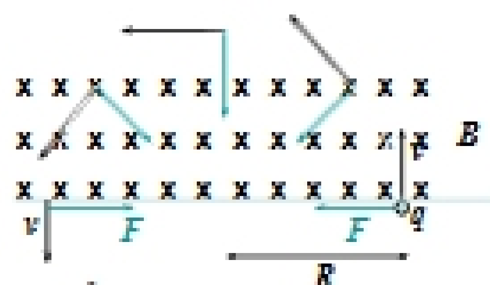


Force perpendicular to velocity: uniform circular motion

Note: magnetic force does no work on the charge!
Kinetic energy constant

Trajectory in Uniform B Field

- Force:
  $F = qvB$
- centripetal acc:
  $a = \frac{v^2}{R}$
- Newton's 2nd Law:



$$F = ma \quad \Rightarrow \quad qvB = m\frac{v^2}{R}$$

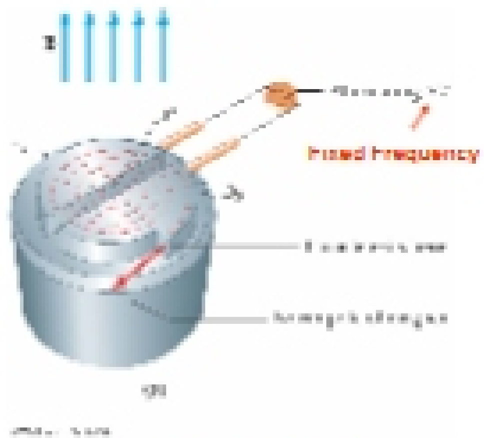
$$\Rightarrow \quad R = \frac{mv}{qB} = \frac{p}{qB}$$

(an important result, with useful experimental consequences!)

"Cyclotron" frequency: $\omega = \frac{v}{R} = \frac{qB}{m} \qquad T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$

Application: Cyclotron

First Modern Particle Accelerator

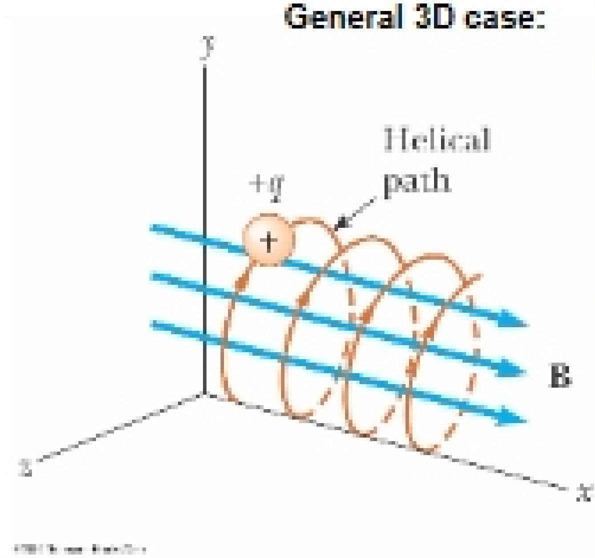


Text example: 27.66

First Cyclotron (1934)
Lawrence & Livingston

Trajectory in Uniform B Field: 3D case

General 3D case:



- In the plane perpendicular to B:

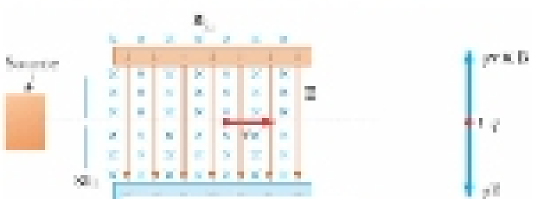
$$R = \frac{mv_\perp}{qB} \qquad T = \frac{2\pi m}{qB}$$

- Parallel to B: spacing b/w turns of helix

$$d = v_\parallel T = \frac{v_\parallel 2\pi m}{qB}$$

Application: Velocity, Mass Selectors

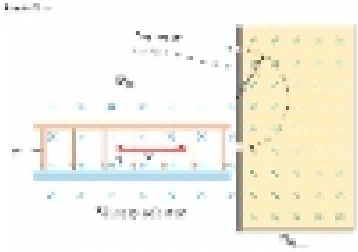
Velocity and mass selector:



Velocity Selector

speed selected:

$$v = \frac{E}{B}$$

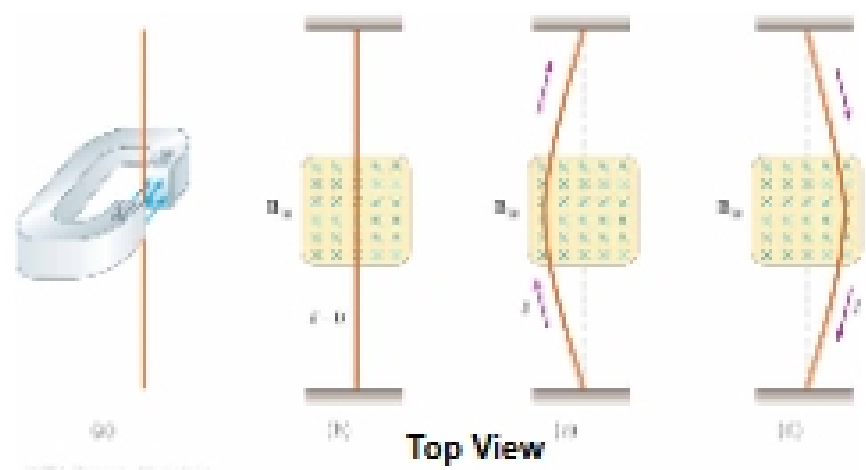


Mass Selector

mass selected:

$$\frac{m}{q} = \frac{rB_0}{v} = \frac{rB_0}{(E/B)}$$

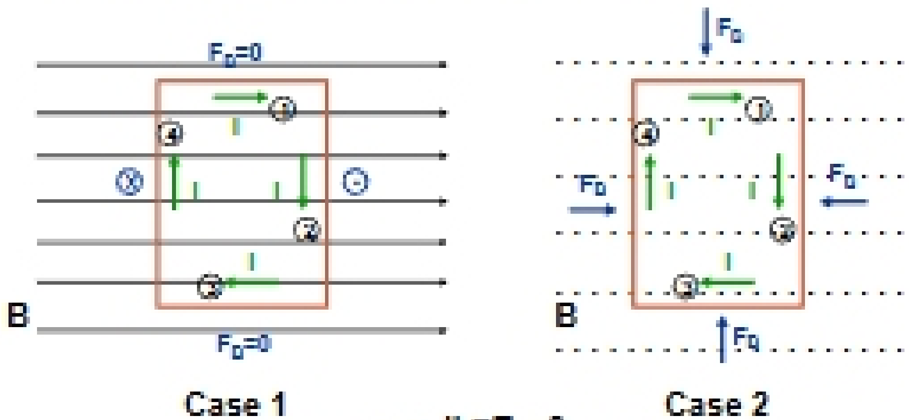
Magnetic Force On A Current Carrying Wire



Top View

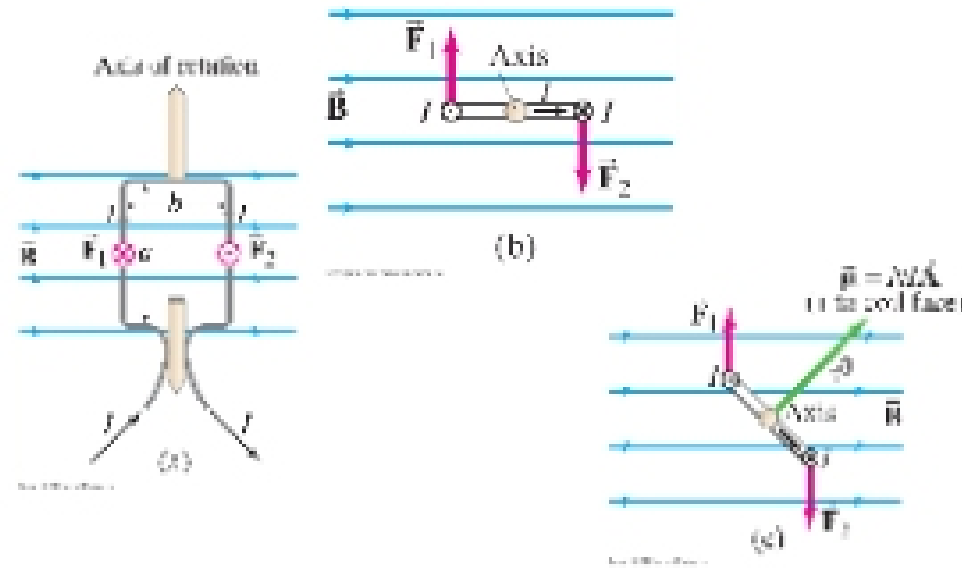
Forces on a Current Loop

For current loops in a uniform magnetic field as shown, what is the direction of the force on each side?

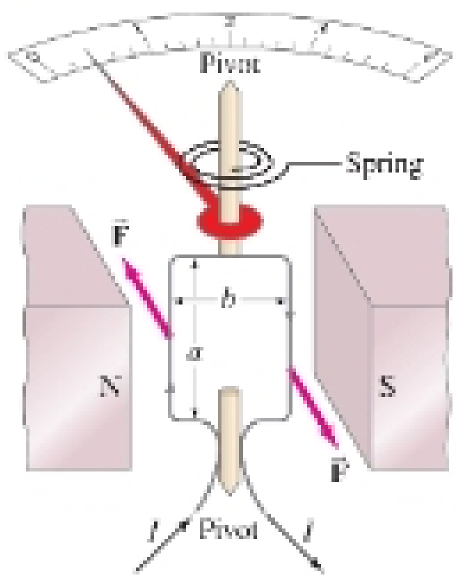


recall: $\Sigma F_B=0$

Torque on a Current Loop



The Galvanometer



The Hall Effect

Potential difference on current-carrying conductor in B field:

positive charges moving counterclockwise: upward force, upper plate at higher potential

negative charges moving clockwise: upward force Upper plate at lower potential

Equilibrium between electrostatic & magnetic forces:

$$F_{mag} = qv_d B \qquad F_{elec} = qE_{ind} = q\frac{V_H}{w} \qquad V_H = v_d Bw = \text{"Hall Voltage"}$$

(first evidence that electrons are charge carriers in most metals)