**Physics 202, Lecture 12**

**Today’s Topics**

- Magnetic Forces (Ch. 29)
- Review: magnetic force
- Motion of charge in uniform B field:
  - Applications: cyclotron, velocity selector, Hall effect

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**Magnetic Fields and Forces: Recap**

**Magnetic Force:** experienced by moving charges

\[ \vec{F} = q\vec{v} \times \vec{B} \quad \vec{F} = \int I dq \times \vec{B} \]

(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

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**Trajectory in Constant B Field**

- Suppose charge \( q \) enters a uniform B-field with velocity \( \vec{v} \). 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

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**Trajectory in Uniform B Field**

- **Force:**
  \[ \vec{F} = q\vec{v}B \]

- **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:**

\[ \omega = \frac{v}{R} = \frac{qB}{m} \quad T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB} \]
**Application: Cyclotron**

First Modern Particle Accelerator

First Cyclotron (1934)
Lawrence & Livingston

**Trajectory in Uniform B Field: 3D case**

General 3D case:
- In the plane perpendicular to B:
  \[ R = \frac{mv}{qB} \quad T = \frac{2\pi m}{qB} \]
- Parallel to B: spacing b/w turns of helix
  \[ d = vT = \frac{v}{qB} \]

**Application: Velocity, Mass Selectors**

Velocity and mass selector:

**Magnetic Force On Current Carrying Wire (1)**

For a uniform magnetic field:

To get the sum of a number of vectors - put them all head to tail and connect the initial (a) and final point (b):

\[ \int_{a}^{b} d\vec{l} = \vec{L}_{ba} \]

If the initial and final points are the same, the integral is zero!

There is no net magnetic force on a closed current loop in a uniform magnetic field.
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?

**Case 1**
- \( F_B = 0 \)

**Case 2**
- \( F_B \neq 0 \)

Torque on a Current Loop

\[ \mathbf{F} = NLI \]

\( (\mathbf{I} \text{ to coil face}) \)

The Galvanometer

- The galvanometer measures the current using the torque generated by the magnetic field and the current.
The Hall Effect

Potential difference on current-carrying conductor in B field:

Equilibrium between electrostatic & magnetic forces:

\[ F_{up} = q v_d B \quad F_{down} = q E_{ind} = q \frac{V_H}{W} \quad V_H = v_d B w = "Hall Voltage" \]

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