MAGNETIC FIELDS

- Magnetic Fields can be produced (or exist) in two ways - Permanent Magnets
  - Due to current in a wire

- Units of Magnetic Field (Symbol generally used is 'B') - Tesla—Fauss/Oe

$$1 \text{ Tesla} = \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{C} \cdot \text{m/s}} = \frac{1 \text{ kg}}{\text{C} \cdot \text{S}} = 10^4 \text{ g}$$

- Ranges of Magnetic Fields found around us and in nature

Space	**10^{-10} T**	
Earth	**10^{-4} T**	**1 G**
Refrig. Magnet	**10^{-2} T**	**100 Gauss**
Largest Man Made		
Steady Magnet	**33 T**	
Pulsed Magnet	**1000 T**	
Surface of Nucleus	**10^{12} T**	
Surface of Magnetic Disk	**10^{-2} T**	**100 Gauss**

- Notation used in illustrations to represent magnetic field:

  $\otimes$ used when the field is into paper

  $\odot$ used when the field is out of paper.

The symbolism here is that the first symbol represents the rear (feathers) of an arrow going in and the in the second symbol the dot represents the tip of the arrow.

- What if both $\vec{E}$ & $\vec{B}$ fields coexist? A charge q in such a situation experiences a force $\vec{F}_e = q\vec{E}$ due to the E field and there will also be a force due to the B-field given by $\vec{F}_B = q(\vec{V} \times \vec{B}) = qVB \ \text{Sin}\vartheta = qV_\perp B$. Note that this force is active only if the charge is moving and one uses the right hand rule to figure out which way the force acts.

Both these types of forces will of course add vectorially i.e. the superposition principle applies. Thus $F = q(\vec{E} + \vec{V} \times \vec{B})$ $\rightarrow$ Lorentz Force Equation

Applications: Motion of Charges Under Different Conditions

Case (a) : Constant Magnetic Field only : (E = 0)

-- only component of velocity $\perp^2$ B-field yields a force

-- || component of velocity is unaffected

-- also since F is $\perp$ to $V_\perp$ $\Rightarrow$ acceleration produced is $\perp^\gamma$ to B (plane $\perp^\gamma$ to B)

What is the magnitude of this in plane force?

$F = qVB$ for $B \perp V$

But acceleration is $\perp$ to V $\Rightarrow$ $a = \frac{\upsilon^2}{R}$

$$\therefore \; m \frac{v^2}{R} = qVB$$

or $$R = \frac{mv}{qB} \propto \text{momentum} \propto \frac{1}{B} \; .$$

Thus we can conclude:

Large v produces large orbits and small B also produces large orbits.
Small v produces small orbits and large B also produces small orbits.

The period of the circular motion in these orbits of the charge can be worked out from the readius: $R = \frac{\frac{md\ell}{dt}}{qB} = \frac{qB}{2\pi m} = \text{frequency} = f$

Where f is called cyclotron frequency—independent of <u>speed</u>

In general when magnetic field is not perpendicular to v:

$R = \frac{mV\perp}{qB}$; $V_{\parallel}$ is unaffected

What about the kinetic energy of the particle?

$K-E = \frac{1}{2} mv^2$; since magnitude of V does not change kinetic energy does not change.
$V_{\perp}$ changes direction & V unaffected.