Pre-Health Post-Baccalaureate Program
PHY2054 Study Guide & Practice Problems

Date:

10/19 – 10/23

Topics Covered:

Magnetic Force
Torque from Magnetic Fields

Created by Isaac Loy

The Magnetic Field

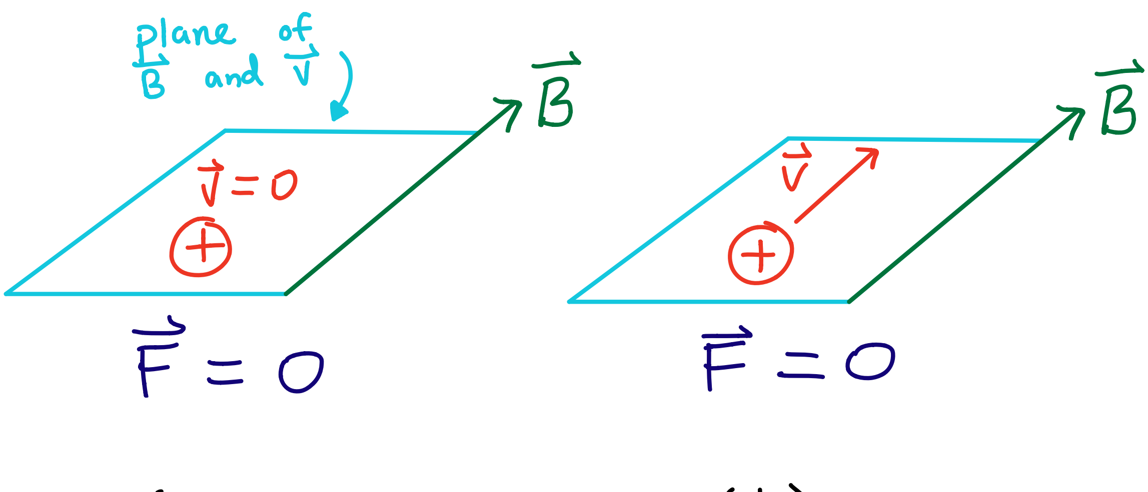
- We have previously talked about electric fields, which are environments created by surrounding stationary charged entities which have the potential to affect charged particles.

- Magnetic fields are similar, but slightly different: magnetic fields are environments created by magnetic poles which have the potential to affect currents (moving charges).

Magnetic Forces

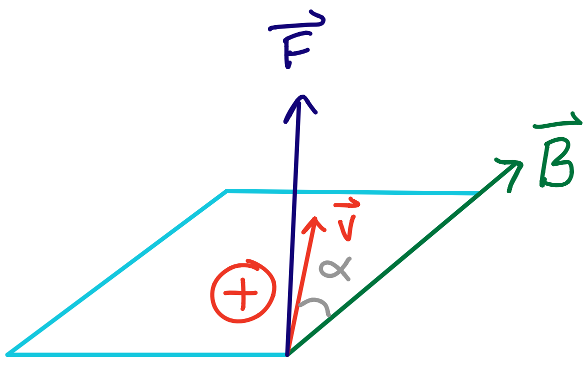
— Some basic rules

① Particles (a) at rest, or (b) having a velocity parallel to the direction of a magnetic field experience <u>NO</u> force from the magnetic field.



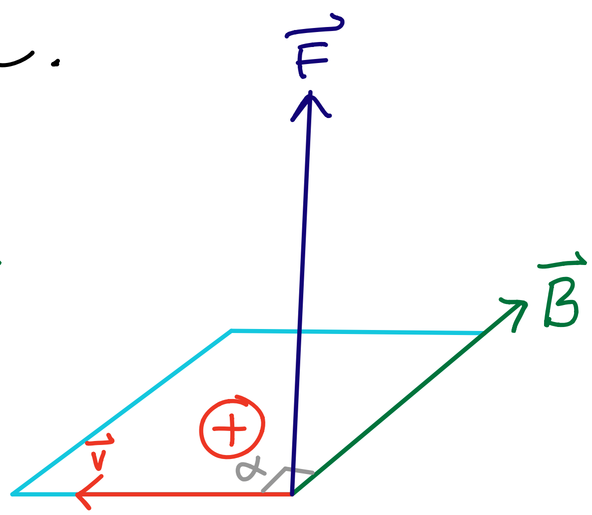
(a) (b)

② The magnitude of the magnetic force increases as the direction of the velocity (α) increases from $\alpha = 0$ (velocity parallel to magnetic field) to $\alpha = 90°$ (velocity perpendicular to magnetic field). The direction of the magnetic force points perpendicular to $\vec{B}/\vec{v}$ plane.



$90° > \alpha > 0°$

$\vec{F} > 0$



$\alpha = 90°$

$\vec{F} >>> 0$

Determining the magnitude and direction of the magnetic force

- Magnitude – use the magnetic force equation:

$$\boxed{F = |q| v B \sin\alpha}$$

where:

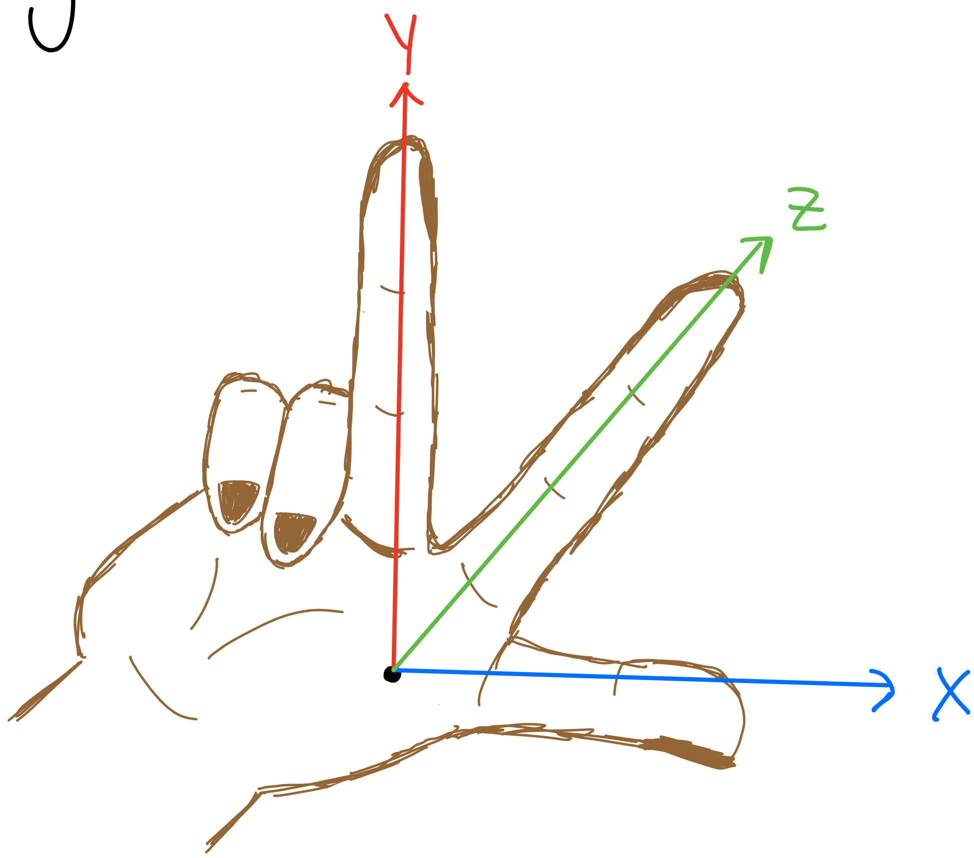
q = charge of particle (C)

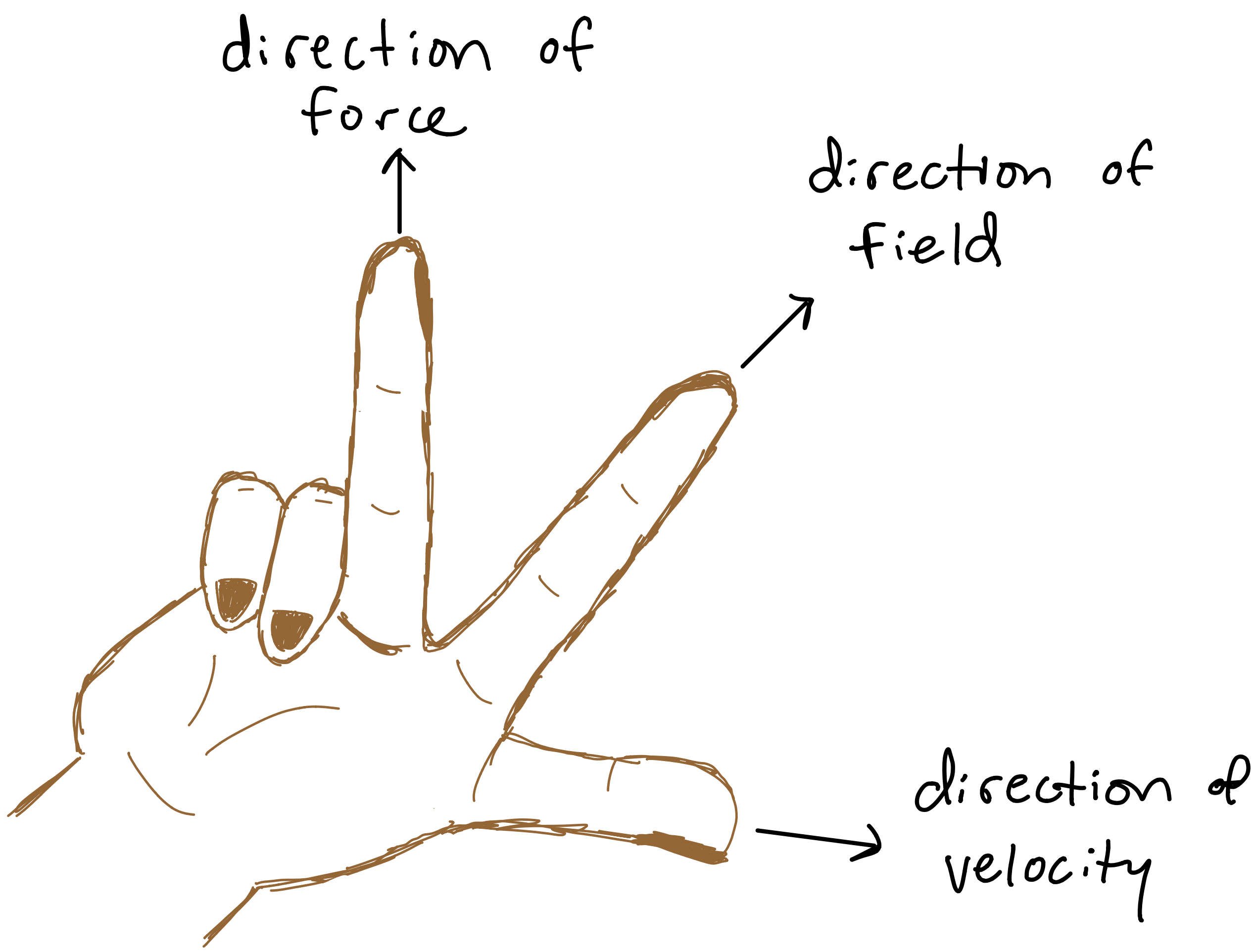
v = velocity of particle (m/s)

B = magnetic field strength (T)

α = angle between $\vec{V}$ and $\vec{B}$

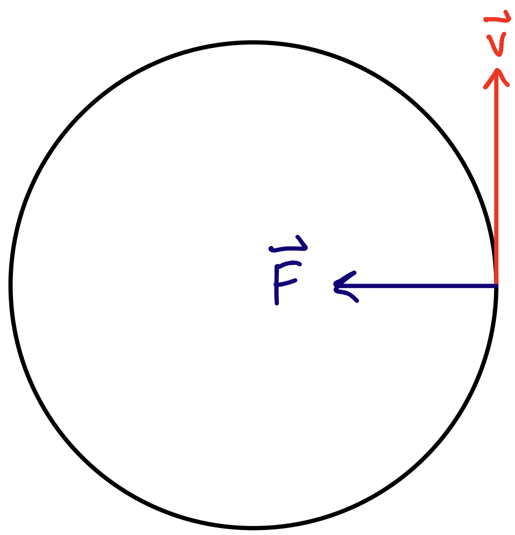
– Direction – use the right hand rule:





Charged Particles in circular motion being affected by magnetic fields

- Recall from last semester that an entity in circular motion has a force pointing towards the center of the circle



- The magnitude of that force is given by:

$$\boxed{F = \frac{mv^2}{r}}$$

- Therefore, if we have a particle in a magnetic field with this motion, we set the centripetal force equal to the magnetic force:

$$F_c = F_B$$

$$\boxed{\begin{aligned} \frac{mv^2}{r} &= |q|vB \\ \frac{mv}{r} &= |q|B \end{aligned}}$$

Currents in wires and magnetic fields

- Let's look at units to derive another equation:

$$F = |q| v B$$

$$[N] = [C]\left[\frac{m}{s}\right][T]$$

- Recall that the unit for current, the ampere, equals one coulomb per second:

$$1\,A = \frac{1\,C}{1\,s}$$

meaning that one coulomb equals one ampere · second:

$$1\,C = 1\,A \cdot 1\,s$$

- Next, substitute:

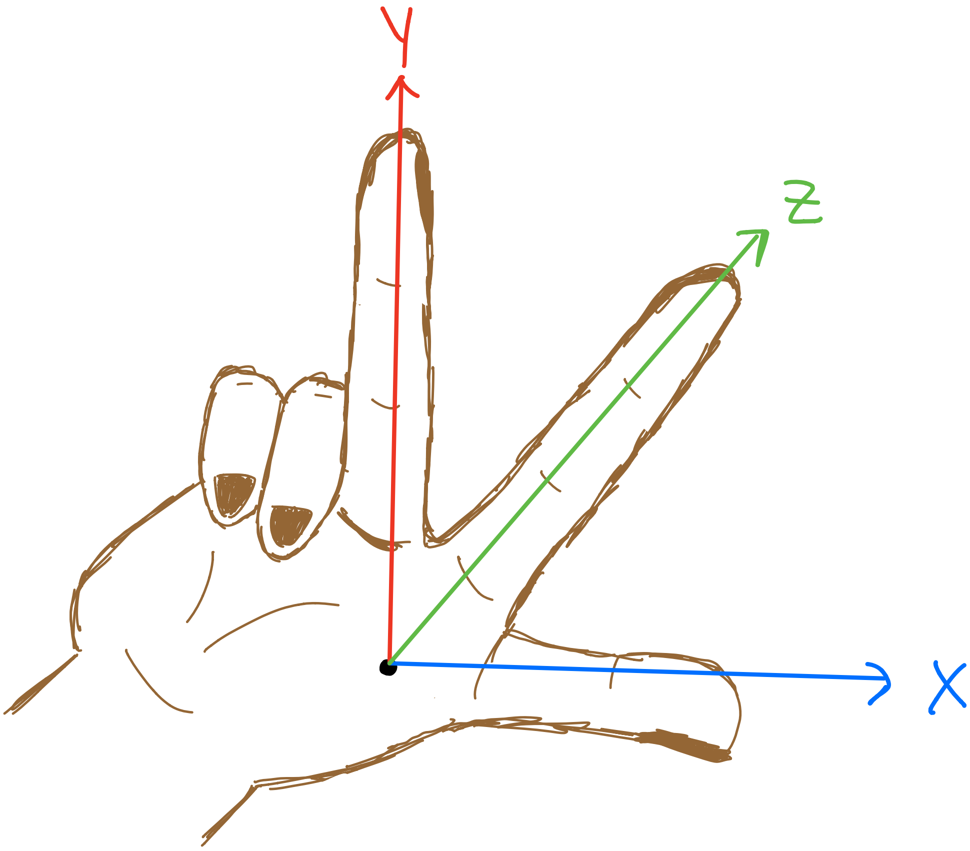
$$[N] = [A \cdot \cancel{s}]\left[\frac{m}{\cancel{s}}\right][T]$$

$$\therefore \underbrace{[N]}_{\text{Force}} = \overbrace{[A]}^{\text{current}}\underbrace{[m]}_{\text{length}}\overbrace{[T]}^{\text{magnetic field}}$$

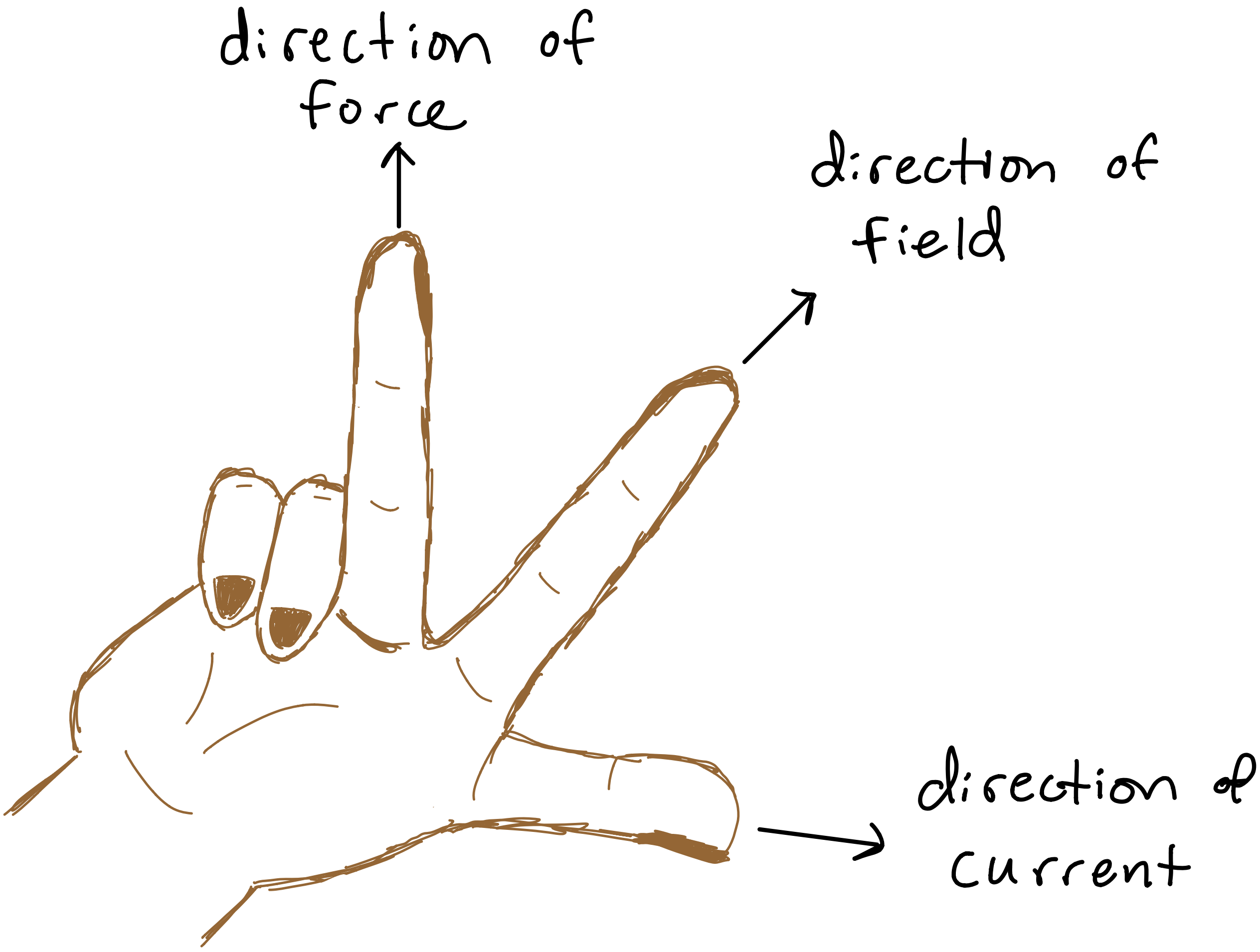
- From this analysis, we can relate the magnetic force to the current (movement of charge) through a wire:

$$\boxed{F = I L B}$$

- The right hand rule still applies, however, we will now point our thumb in the direction of the current instead of velocity:



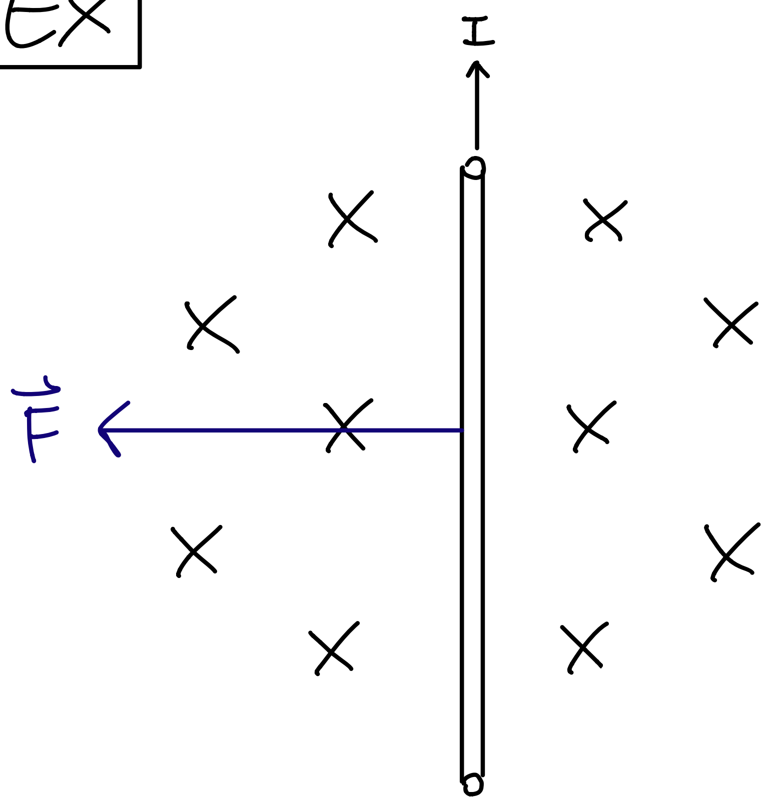
Y
Z
X



direction of force
direction of field
direction of current

- Diagrams commonly use × to show a current into the page and • to show a current out of the page

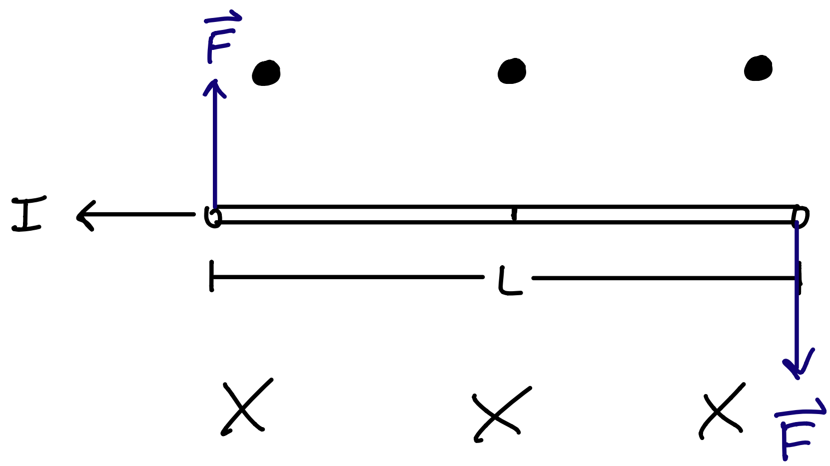
$\boxed{\text{Ex}}$



Magnetic torques

- Recall the basic equation for torque:

$$\boxed{\tau = rF\sin\theta}$$



- Substituting in our newest force equation, we can determine the torque produced from a magnetic field:

$$\tau_{total} = \tau_{Left} + \tau_{right}$$

$$\tau = rF\sin\theta + rF\sin\theta$$

$$\tau = \left(\frac{L}{2}\right)(ILB)(\sin\theta) + \left(\frac{L}{2}\right)(ILB)(\sin\theta)$$

$$\tau = IL^2 B\sin\theta$$

$$\tau = IAB\sin\theta$$

Take-aways

- Most of this isn't new (forces, circular motion, torque, currents, etc.), it's just presented in a new way.

- Make sure you're doing the right hand rule with your <u>RIGHT</u> hand – it won't work with your left.

- Don't feel foolish for using the right hand rule – you'll need it!