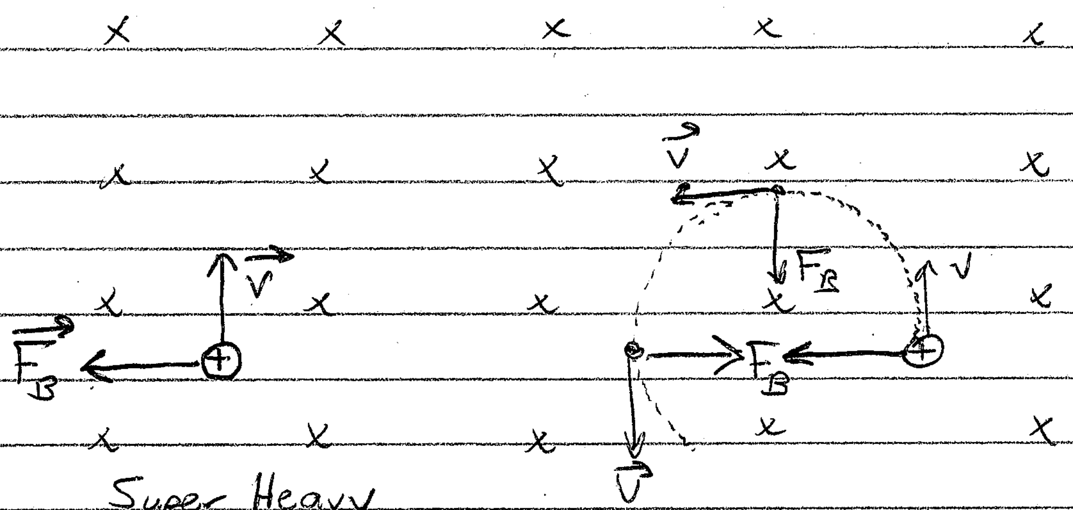
Phys 1402 2017-10-10 Lec 11

Effects of a magnetic field - Forces, Torques

$B_{in} = 5.0\ T$



Super Heavy ⊕ charge

Light, agile charge

Magnetic Force: $|F_B| = q v_\perp B$

$\hat{F_B}$ by RHR

"Hat" means Direction only

- Thumb is force (if ⊕)
- Index is $\vec{v}$
- Middle is $\vec{B}$

- For Heavy charge above, F_B is Left. Not much effect of that force.
- For Light particle

$$F_{net} = ma$$

$$q v_\perp B = \frac{m v^2}{R}$$

$$R = \frac{m v^2}{q v B} = \boxed{\frac{m v}{q B}}$$

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Force on a Current

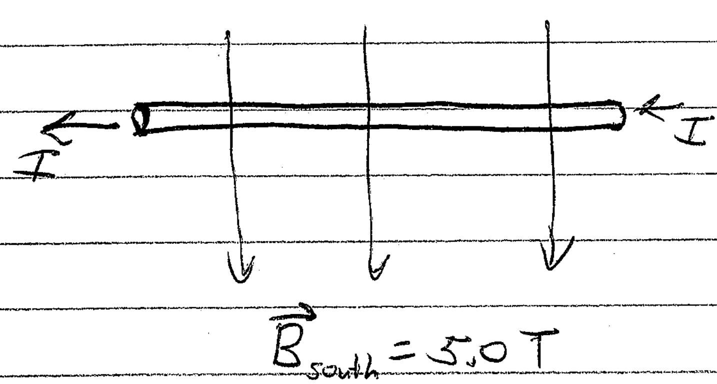
Similar rule: $|F_B| = I l_\perp B$

Ex: If $B = 5.0\ T$ and a wire has a mass of 0.05 kg/m, How much current is needed to levitate it?

$$F_g = F_B$$
$$mg = I l_\perp B$$
$$(0.05\ kg/m)\, l\, (9.8\ m/s^2) = I\, l\, (5.0\ T)$$

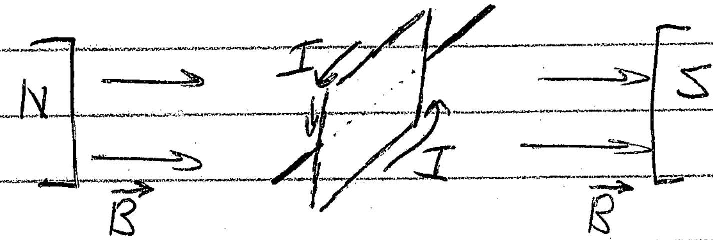
$$I = \frac{(0.05)(9.8)}{5.0} = 0.098\ A$$

What direction is the wire oriented?
Suppose $\hat{B}$ = South. Need $\hat{F}_B$ = Up



Result: $I\hat{l}$ = West

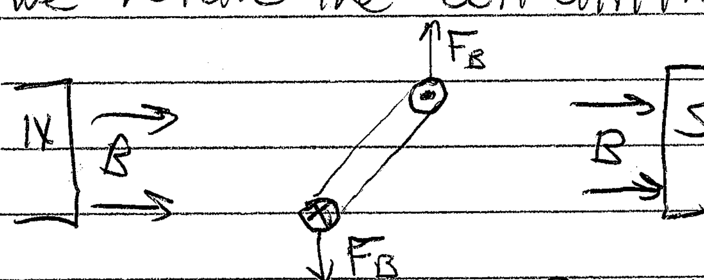
Loop in a magnetic field



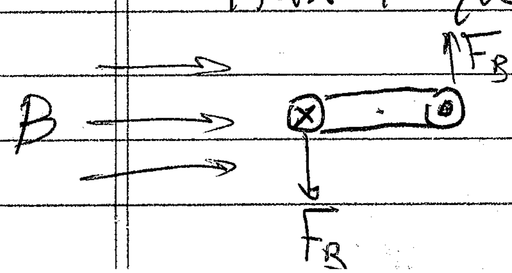
Top Segment: $\hat{I}$ = out of page $\hat{F_B}$ = Up
Front Segment: $\hat{I}$ = Down $\hat{F_B}$ = Out of Page
Bottom: $\hat{I}$ = into page $\hat{F_B}$ = Down
Back: $\hat{I}$ = Up $\hat{F_B}$ = into page.

Each Segment is being pushed "outward".
No net force, no torque.

What if we rotate the coil a little:



Front & Back: no change from before.
Top Feels F_B = Up
Bottom Feels F_B = Down
Net Force = 0 Now there is torque.
Max torque when F_B perpendicular to loop.



Max τ = NBA I

Area of loop

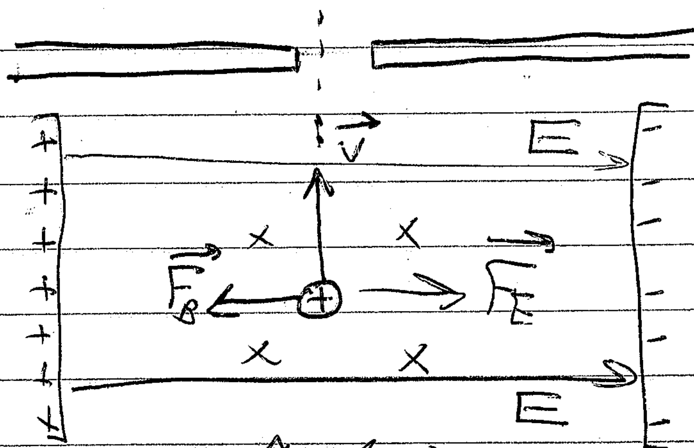
Can magnetic and electric forces cancel?

Yes, if the $\vec{B}$, $\vec{E}$, and $\vec{v}$ are pointing the right ways

Require:

$\vec{F_B}$ opposite $\vec{F_E} = q\vec{E}$

RHR $\quad \vec{E}$



$\hat{B} = $ (in)

$\vec{v} = $ (up)

$\vec{F_B} = $ (left)

$\vec{F_E} = $ (right)

$\vec{E} = $ (right)

Build a capacitor!

Magnitudes:

$F_E = F_B$

$\not{q}E = \not{q}vB$

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

If $v = \frac{E}{B}$, net force = 0.

If too slow F_B = weaker, F_E wins.
Deflected rightward.

If too fast F_B = stronger, F_B wins.
Deflected leftward.

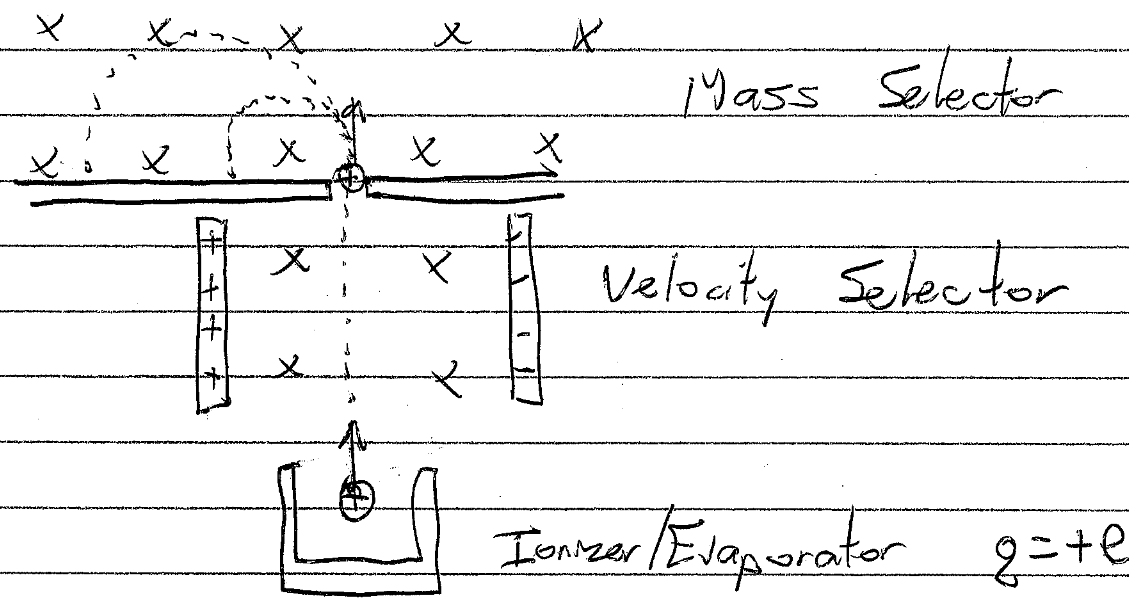
<u>Velocity Selector</u>

Mass Spectrometer

Evaporator Ionizer → Velocity Selector → Mass Select

$V = \frac{E}{B}$ in velocity selector

$r = \frac{mV}{qB}$ in mass selector



Last Effect : Forces on magnets