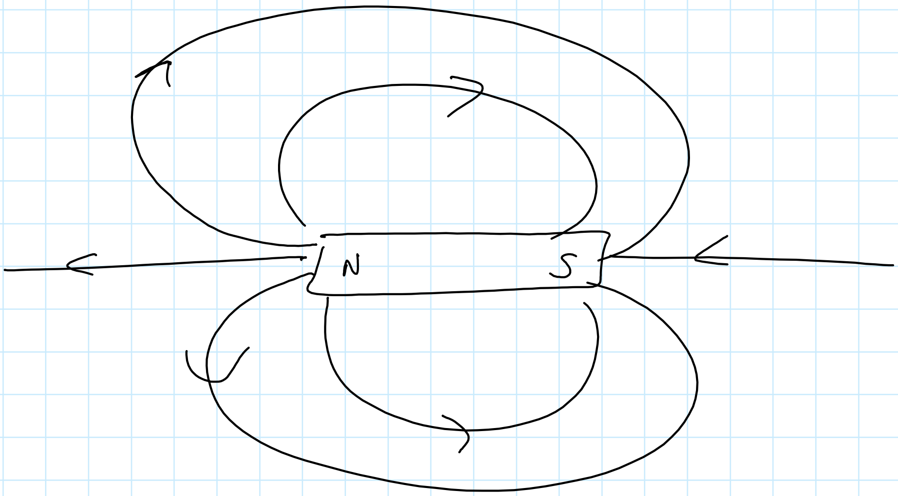
Phy 4B 5/30

Tuesday, May 30, 2017 5:27 PM

Goals for the Lecture:

1) Understand that charged particles typically move in circular paths when crossing magnetic field lines
2) Be able to solve problems involving centripetal force and circular motion in magnetic fields
3) Understand how these forces can be used in velocity selectors, mass spectrometers, and other applications
4) Understand how current carrying wires are affected by magnetic fields and be able to solve problems involving magnetic forces on current carrying wires
5) Understand current loops are affected by magnetic fields
6) Know how to calculate and solve problems involving net force on current loops in B fields
7) Know how to calculate and solve problems involving torque on current loops in B fields



$$\vec{F} = q\,\vec{v} \times \vec{B}$$

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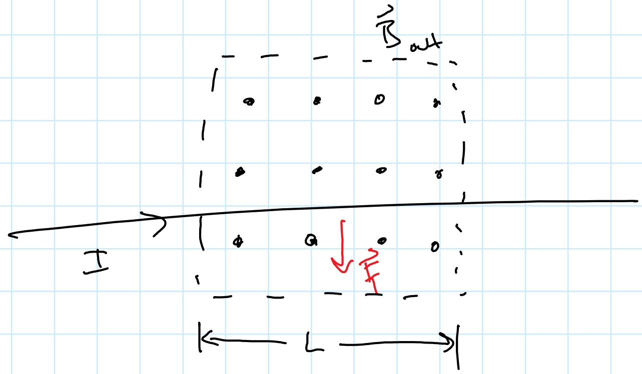
	direction of $\vec{v} \times \vec{B}$	direction of force
a)	zero	zero
b)	Into page	Into page
c)	Into page	out of page
d)	to bottom of page	to top of page
e)	zero	zero
f)	out of page	out of page

f)	out of page	out of page
g)	to top of page	to top of page
h)	to the Right	to the Left

Current carrying wire:

$\vec{F} = I \vec{L} \times \vec{B}$

↑ points in direction of I



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a) No Force

b) Into page

c) out of page

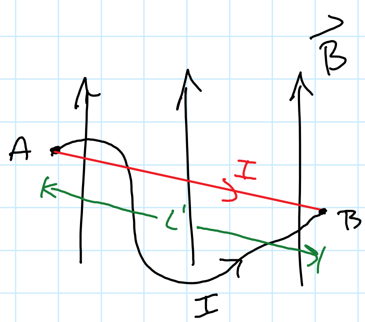
d) to bottom of page

e) to top of page

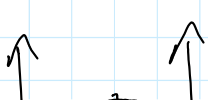
f) ↘

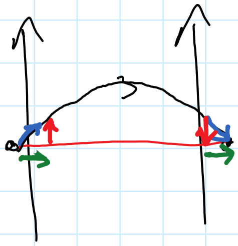
g) to top of page

h) to the Right

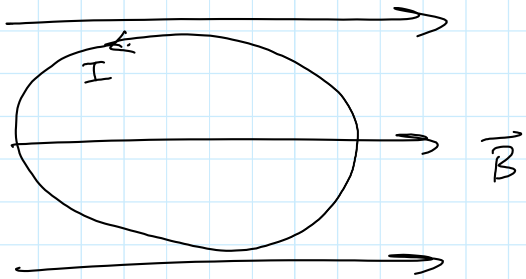


$F = I \vec{L'} \times \vec{B}$





What is the force on: current carrying wire

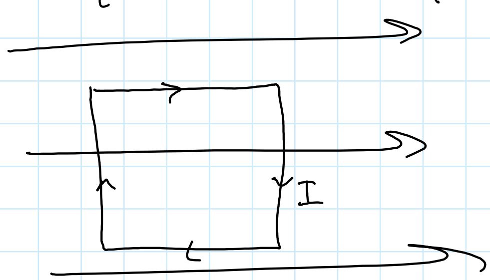


$\vec{F}_{Net} = 0$

No Net force on a closed current loop in a uniform B field

It may be easier to see like this:

square current loop



Top: $F_B = 0$

Right: F_B out of page

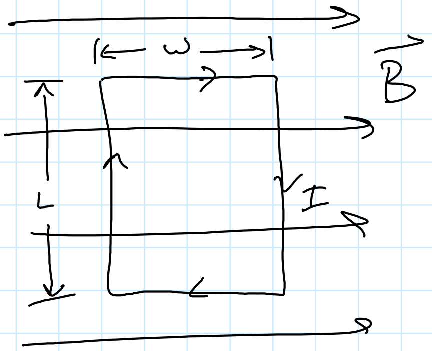
bottom: $F_B = 0$

Left: F_B into page

$F_{Net} = 0$

but there is a Net torque (It will Rotate)

Side view



Top: $F_B = 0$

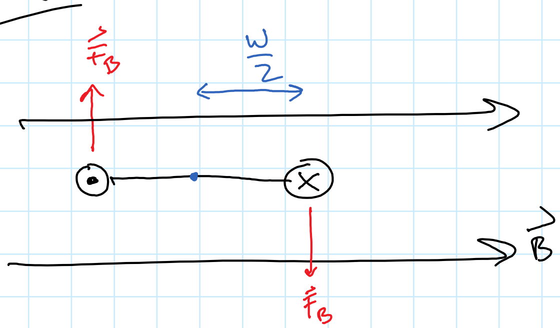
Right: $F_B = ILB$ out of page

bottom: 0

Left ILB into page

Net Force $= 0$

Top View



Torque:

$$\tau_{max} = F_B \frac{w}{2} + F_B \frac{w}{2}$$

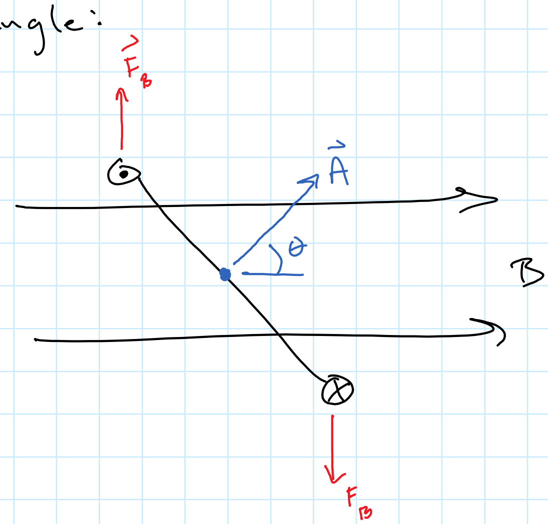
$$= ILBw$$

LW = Area of loop

$$= IBA$$

↑ area

at any angle:



$$\tau = F_B \frac{w}{2} \sin\theta + F_B \frac{w}{2} \sin\theta$$

$$= IAB \sin\theta$$

$$\vec{\tau} = I \vec{A} \times \vec{B}$$

define: $\vec{\mu} = I\vec{A}$ magnetic dipole moment

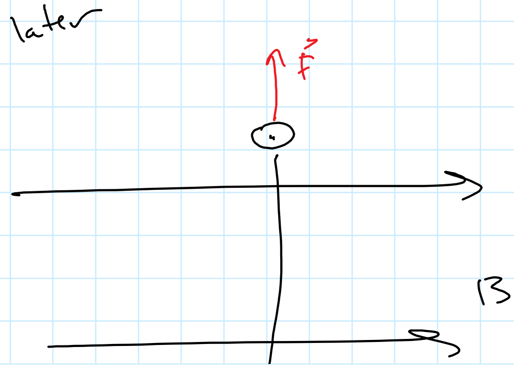
$$\vec{\tau} = \vec{\mu} \times \vec{B} \quad \text{for 1 turn}$$

For multiple turns:

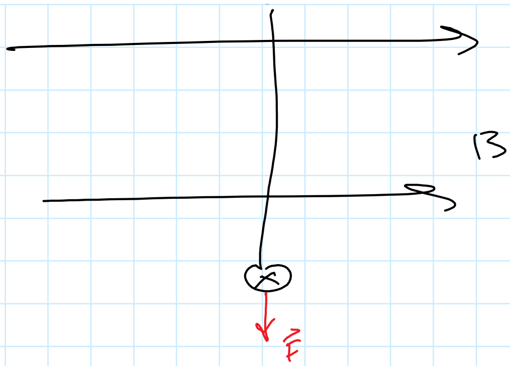
$$\tau = N \vec{\mu} \times \vec{B}$$

↖ # of turns

Some time later



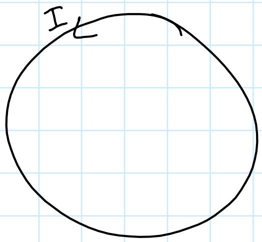
Torque is zero at this instant



τ # of turns

Torque is zero at this instant

Loop of wire



Right hand Rule gives direction of $\vec{A}$ out of page (in this case)

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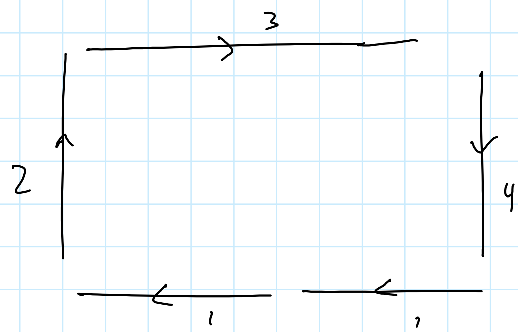

$F_1 = 0$

F_2 is into page

$F_3 = 0$

F_4 is out of page

$F_{net} = 0$

$\tau_{Net} \neq 0$

$\vec{A}$ is into page

$\vec{\tau}$ points toward bottom of page

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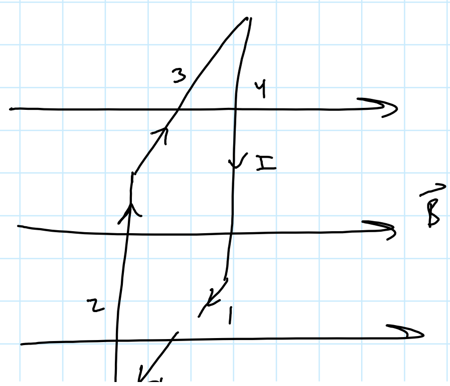
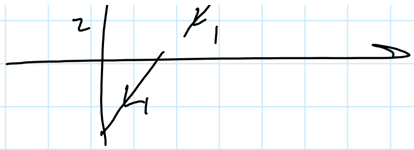


F_1 to top of page

F_2 into page

F_3 to bottom of page

F_4 out of page



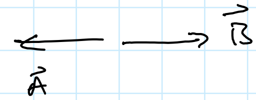
F_4 out of page

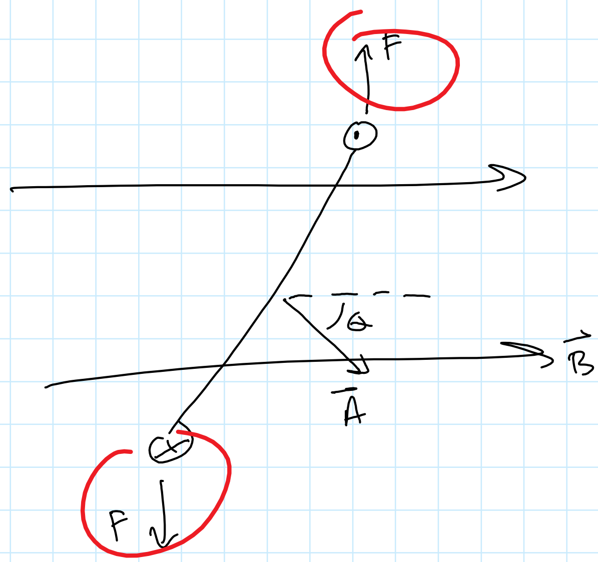
$F_{Net} = 0$

$\tau_{Net} = 0$

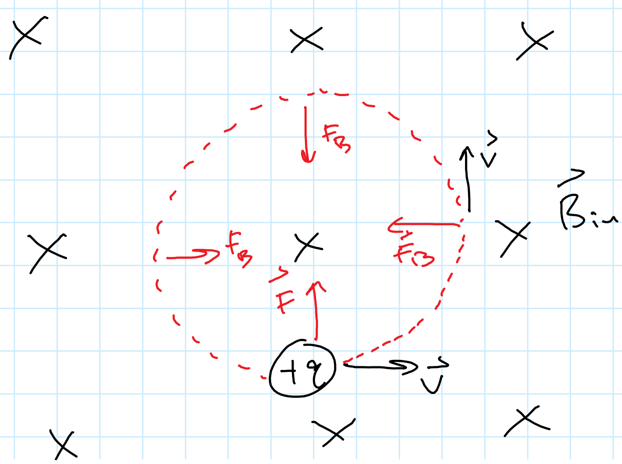
$\vec{A}$ points to Left

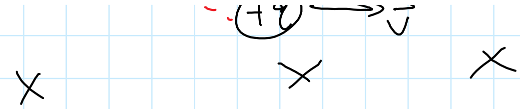
$\vec{A} \times \vec{B} = 0$





A charged particle moving in a magnetic field:





$$\Sigma F = F_c = \frac{mv^2}{R}$$

$$F_B = \frac{mv^2}{R}$$

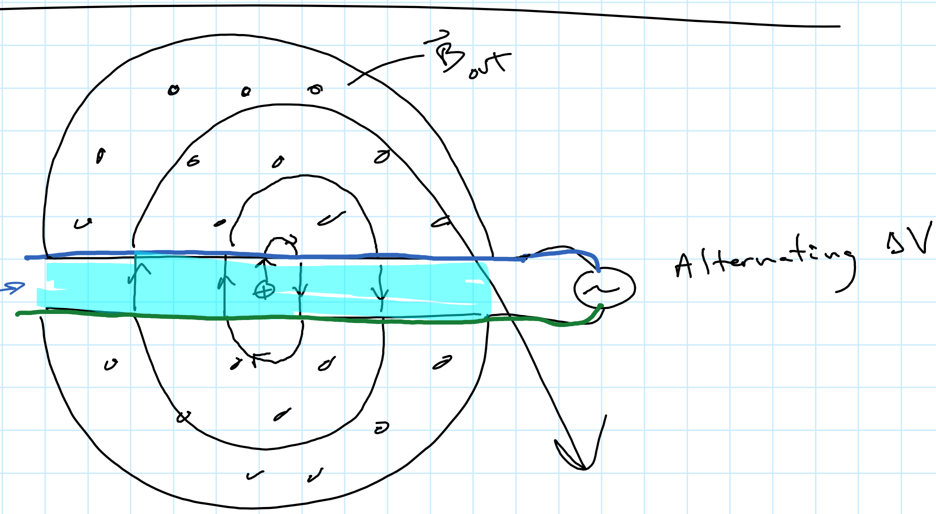
$$\vec{F}_B = q\vec{v} \times \vec{B}$$

$$qvB = \frac{mv^2}{R}$$

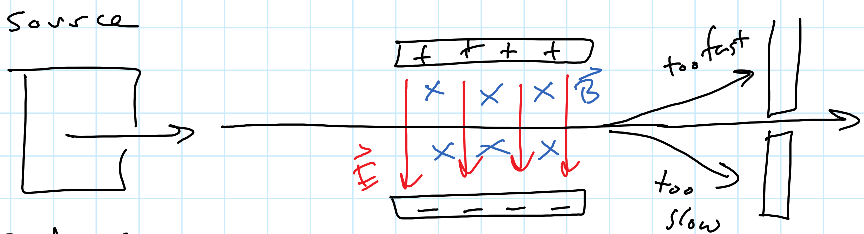
$$R = \frac{mv}{qB}$$

Applications

Cyclotron:



Velocity selector:

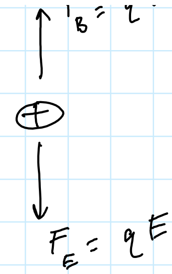


produces charged particles with different velocities

$F_B = qvB$

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

particles
with different
velocities



$\vec{F} = q\vec{E} + q\vec{v} \times B$

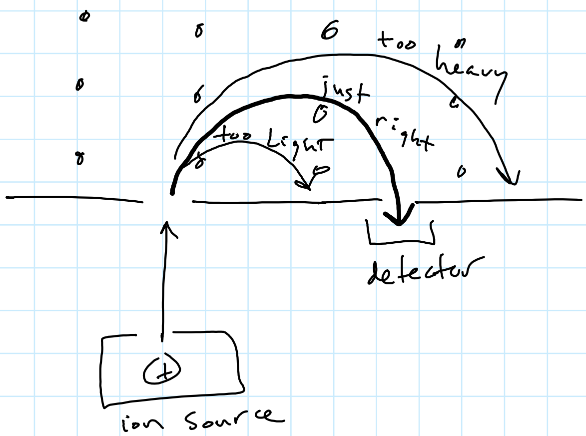
if $qE = qvB$

then particle moves in a straight line

$qE = qvB$

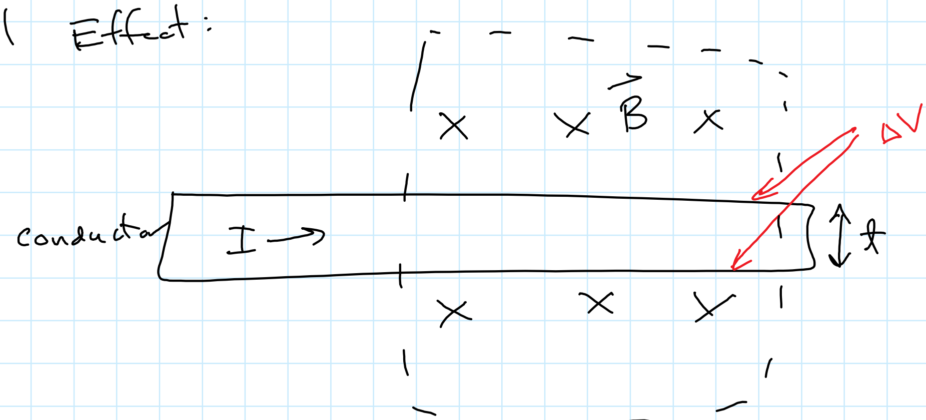
$v = \frac{E}{B}$

Mass spectrometer:



$R = \frac{mv}{qB}$

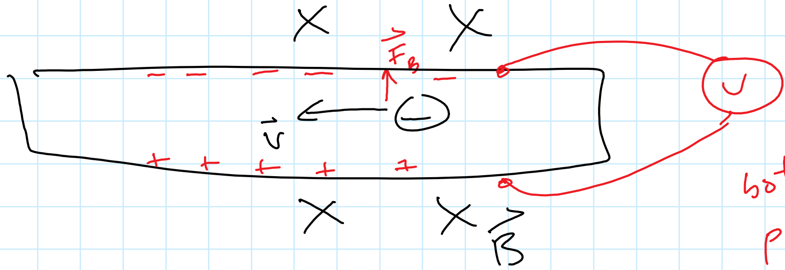
Hall Effect:



current to right
B into page

If "−" charges move:

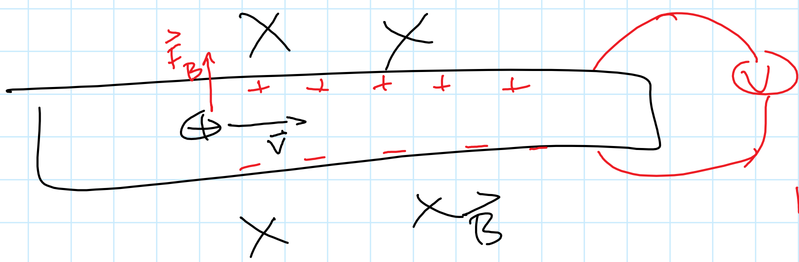
current to right means ⊖ to left



bottom higher potential than top

If "+" move:

current to right means ⊕ → to right



upper is at higher potential

$$\Delta V_H = \frac{R_H I B}{t}$$

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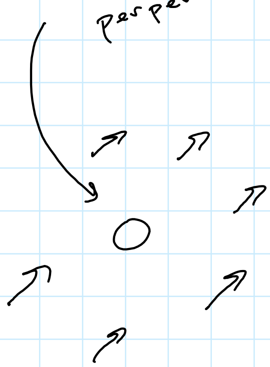
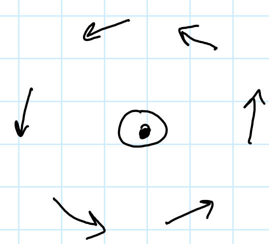
wire (no current) perpendicular to page

North

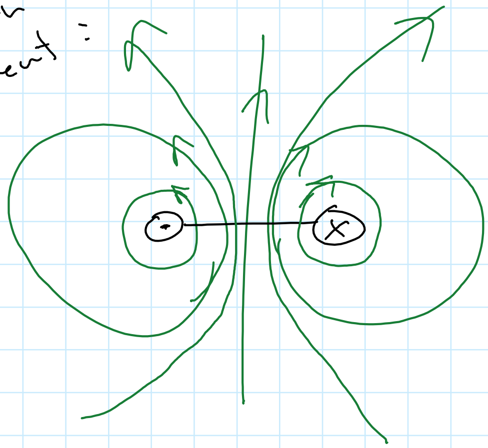


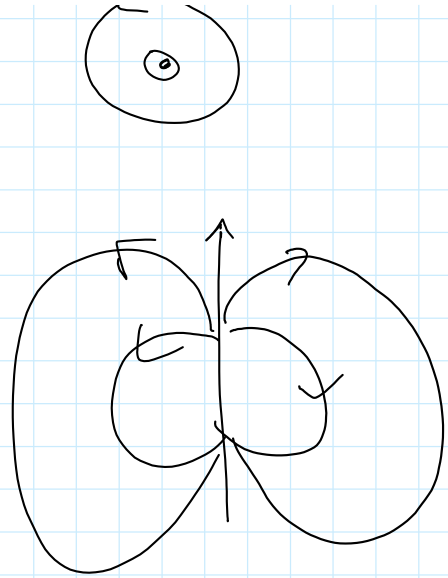
turn on current (out of page)

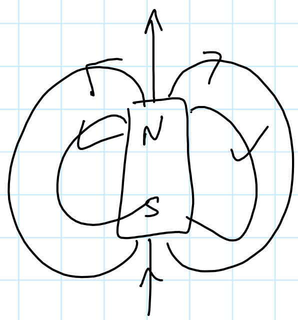


f

Small loop of a wire with current:







Two wires with currents: