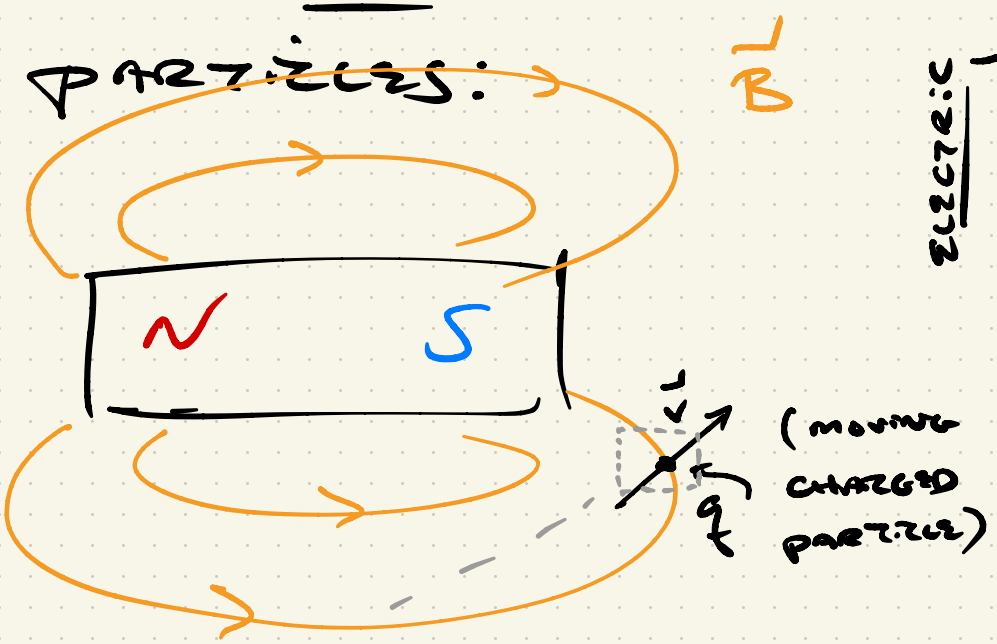
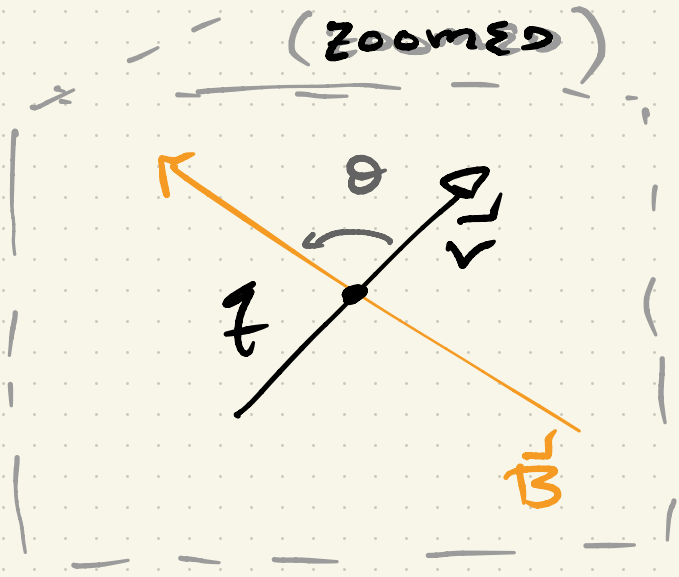
Lecture 18

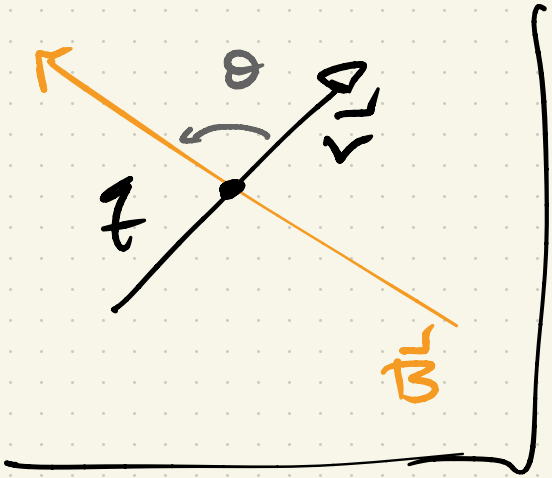
Summary

MAGNETIC FORCES ON MOVING CHARGES

- MAGNETS EXERT FORCES ON MOVING CHARGED PARTICLES:







STRENGTH OF FORCE ON CHARGED PARTICLE:

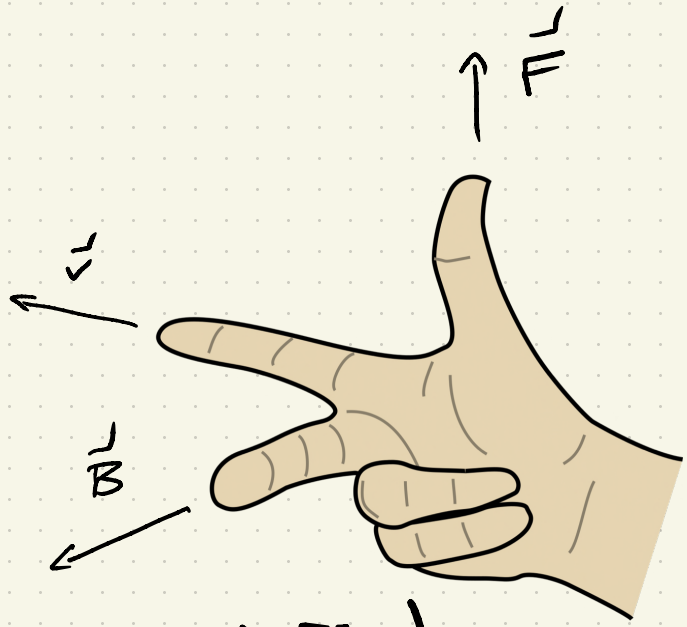
$$F = qvB\sin\theta$$

$F \equiv |\vec{F}|$,
$v \equiv |\vec{v}|$,
$B \equiv |\vec{B}|$

- FORCE STRONGEST WHEN $\vec{v}$ & $\vec{B}$ ARE PERPENDICULAR!
- FORCE WEAKEST WHEN $\vec{v}$ & $\vec{B}$ ARE PARALLEL!

DIRECTION OF FORCE:

"RIGHT HAND RULE"

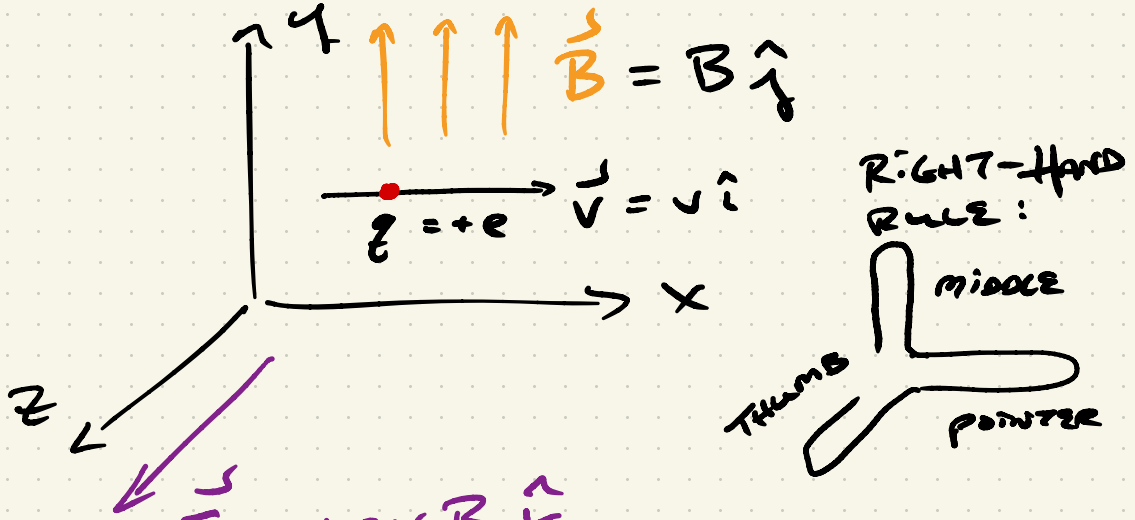


- WARNING!

IF $q < 0$ (E.G. ELECTRON), FLIP $\vec{F}$ UPSIDE DOWN ($\vec{F} \to -\vec{F}$), (OR USE "LEFT-HAND RULE").

- $\vec{F}$ PERPENDICULAR TO BOTH $\vec{v}$ & $\vec{B}$.

EXAMPLE: PROTON



$$\vec{F} = +evB\hat{k}$$

($\sin\theta = 1$ since $\vec{v}$ perp. to $\vec{B}$)

- MAGNETIC FIELD PUSHES PROTON IN $+z$ DIRECTION. ($\cdot$)
- ELECTRON TRAVELING IN SAME DIRECTION AS PROTON PUSHED IN $-z$ DIRECTION, i.e. $\vec{F} = -evB\hat{k}$ $(q = -e)$

MAGNETIC FIELD UNITS

- FROM $F = qvB\sin\theta$, WE GET MAGNETIC FIELD $\vec{B}$ EQUAL TO A:
  - **FORCE / CHARGE × VELOCITY**
- THE SI UNIT OF MAGNETIC FIELD IS THE TESLA (T) WHERE

$$1\,T = 1\,\frac{N \cdot s}{C \cdot m}$$

- I.E. "A MAGNETIC FIELD OF 1 T WILL EXERT A FORCE OF 1 N ON A PARTICLE OF CHARGE 1 C TRAVELING $1\ m/s$ @ A RIGHT ANGLE TO THE FIELD."

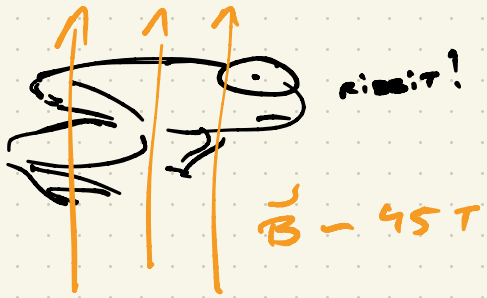
$\vec{B}$ FIELD UNITS CONT.

EXAMPLES:

- FRIDGE MAGNET: $< .01$ T
- EARTH'S $\vec{B}$ FIELD: $\approx 5 \times 10^{-5}$ T
- MRI MACHINE: ≈ 1 T
- STRONGEST MAN-MADE (CONTINUOUS): 45 T

LEVITATES A FROG!

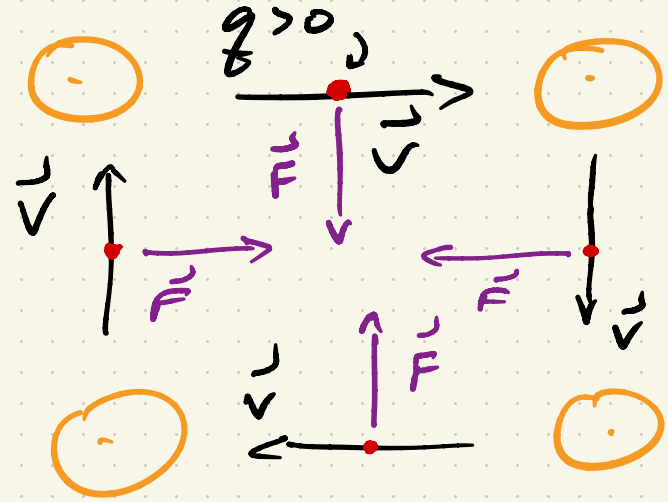
SEE Y.T. VIDEO



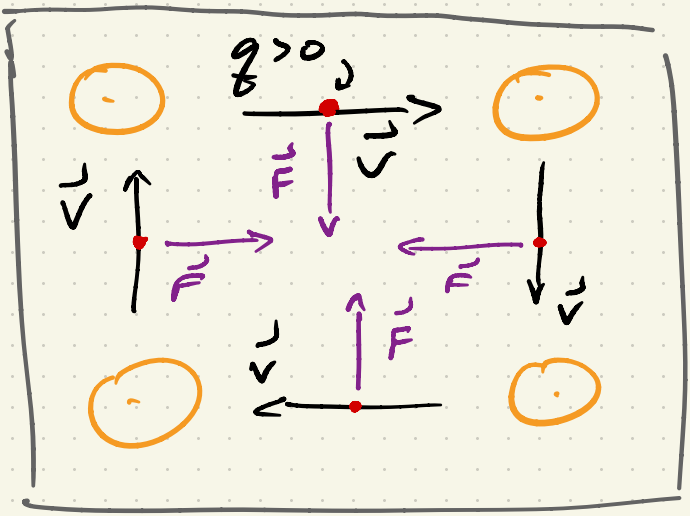
MOTION OF CHARGED PARTICLE IN CONSTANT MAGNETIC FIELD:

- CHARGED PARTICLE MOVING PERPENDICULAR TO $\vec{B}$ FIELD MOVES IN CIRCULAR TRAJECTORY!

E.G.

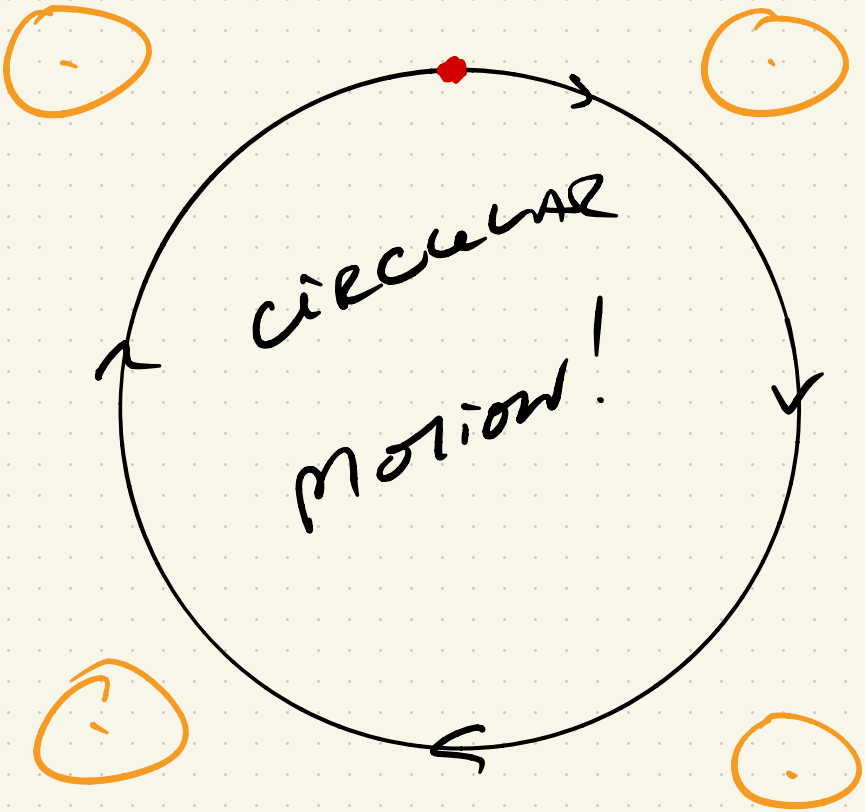


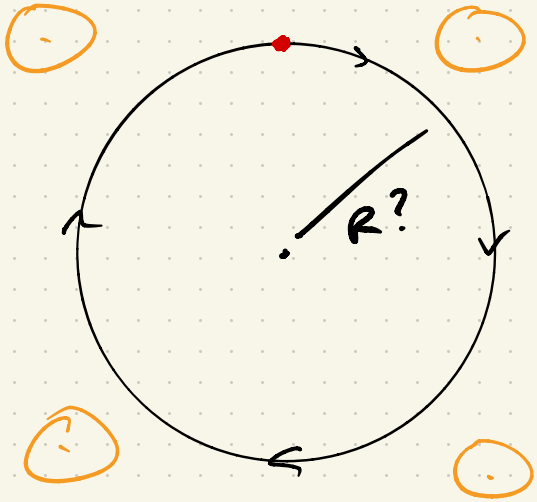
$\vec{B}$ FIELD POINTING OUT OF THE PAGE (INTO THE PAGE IS DENOTED BY ⊗)



CENTRIPETAL FORCE!

B





$$F = mv^2/R \quad \text{(CENTRIPETAL FORCE)}$$

$$= qvB \quad \text{(MAGNETIC FORCE)}$$

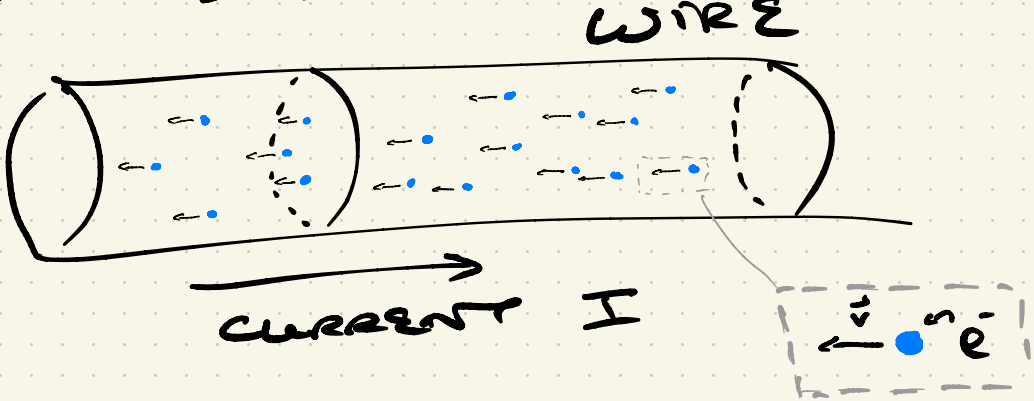
$$\xrightarrow{\text{(ALGEBRA)}} R = mv/qB$$

"LARMOR RADIUS"

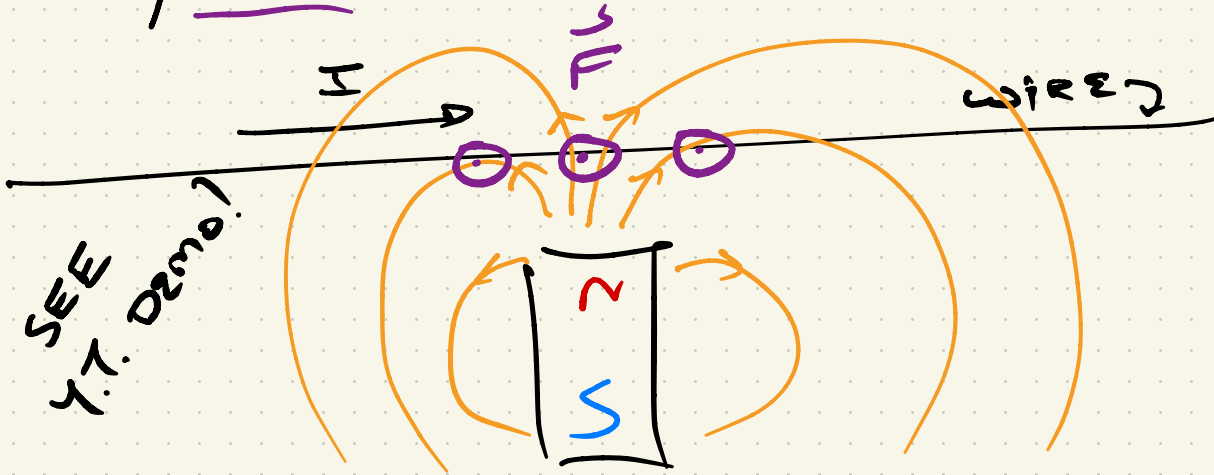
- SEE Y.T. VIDEO ON BETA SPECTROSCOPY & Y.T. DEMO OF CIRCULAR TRAJECTORIES.

FORCES ON CURRENT-CARRYING WIRES:

- ELECTRIC CURRENT: MANY CHARGED PARTICLES MOVING IN SAME DIRECTION:

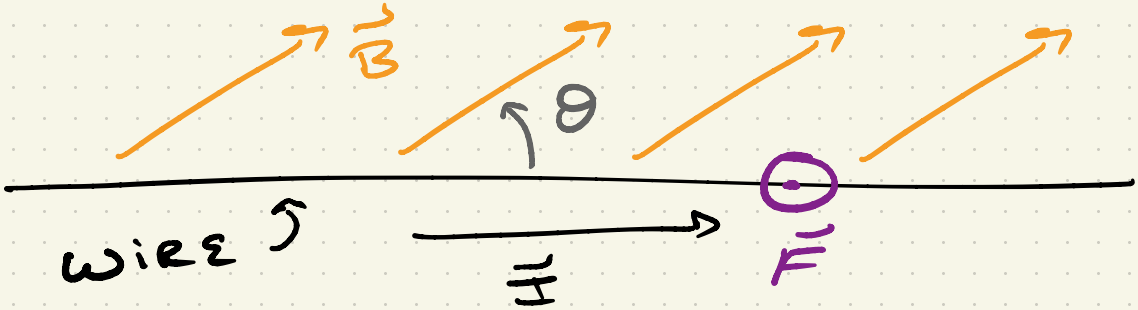


- MAGNETIC FIELD EXERTS FORCE ON WIRE!



SEE 1.7. DEMO!

FORMULA:



$$F = IBl\sin\theta$$

[l : LENGTH OF WIRE]

DIRECTION OF FORCE: RIGHT HAND RULE