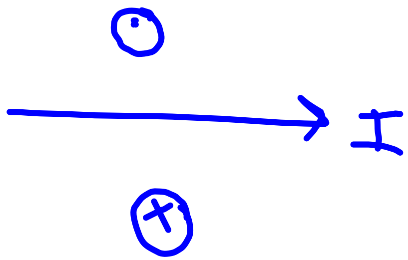
Magnetic Fields and Forces

magnetic field

symbol = "B"

unit = tesla = $\frac{1\,N}{A \cdot m}$



⊙ out of brd

⊗ into brd

Magnetic Force Law

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

The Lorentz force law

$\vec{v}$ = velocity of charged particle

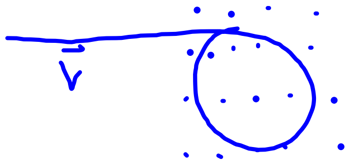
q = charge of particle

$\vec{E}$ = electric field (at location of particle)

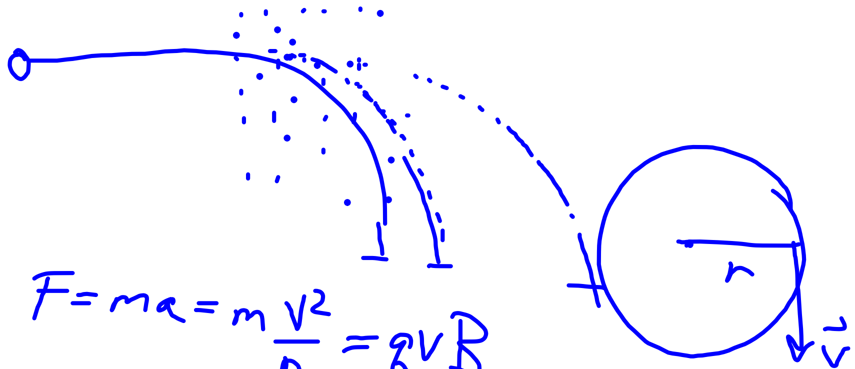
$\vec{B}$ = magnetic field (at location of particle)

$\vec{F}$ = force on particle due to $\vec{E}$ and $\vec{B}$

Magnetic force is $\perp$ to $\vec{v}$ and $\vec{B}$, so charged particle moves in circles or helix when it enters a magnetic field



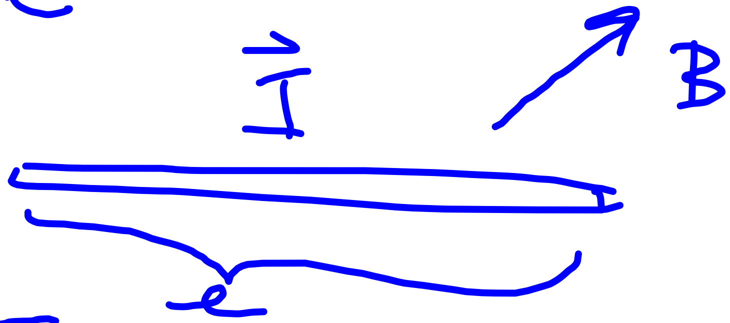
Application Mass spectrometer



$$F = ma = m\frac{v^2}{r} = qvB$$

$$\Rightarrow r = \frac{mv^2}{qvB} = m\left(\frac{v}{qB}\right)$$

Magnetic force on a current-carrying wire



$$F_m = q\vec{v}\times\vec{B}$$

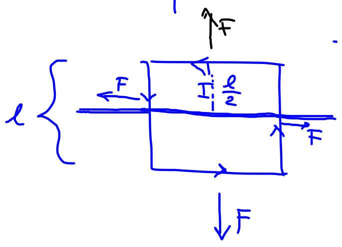
$$= (\vec{I}\Delta t)\frac{\ell}{\Delta t}\times\vec{B}$$

$$= \ell\vec{I}\times\vec{B}$$

ℓ = length of wire segment

I = current

Torque due to magnetic field on wire loop



$\vec{B}$ = points out of page

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

Loop of current align itself so that it is perpendicular to magnetic field.

Torque on loop $\vec{\tau} = \vec{r} \times \vec{F}$

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

$$\vec{\tau} = \frac{\ell}{2} \ell \vec{I} \times \vec{B}$$

$$= \frac{\ell^2}{2} \vec{I} \times \vec{B}$$

Total torque $= 2\vec{\tau} = \ell^2 \vec{I} \times \vec{B}$

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

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

$A = \ell^2$

$\vec{\mu} = A\vec{I}$

1. magnetic field exerts torque on current loop
2. Torque = ("magnetic moment" of loop) $\times$ (magnetic field)
3. (magnetic moment of loop) = (Area of loop)(Current in loop)

#2. $\equiv$ $\vec{\tau} = \vec{\mu} \times \vec{B}$

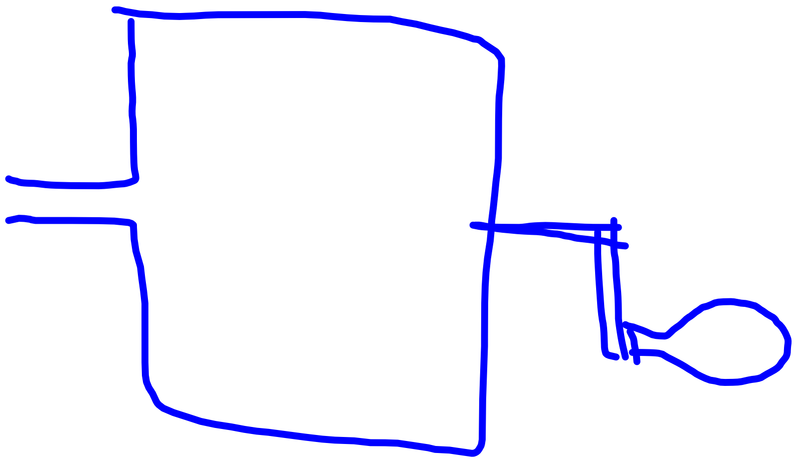
#3. $\equiv$ $\vec{\mu} = A\vec{I}$

Torque due to B-field ⟹ motor

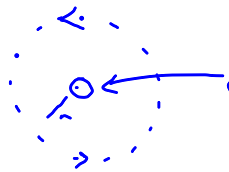
motor: current in → torque out

dynamo: torque in → current out

dynamo



Ampere's Law



$$B \cdot 2\pi r = \mu_0 I$$

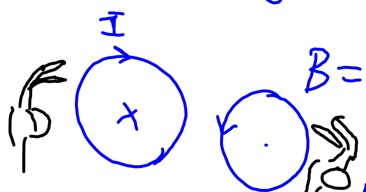
$$\mu_0 = 4\pi \times 10^{-7} \frac{T \cdot m}{A}$$

Magnetic field at a loop gives current passing through the loop.

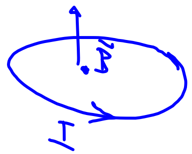
mag field due to straight wire

$$B = \frac{\mu_0 I}{2\pi r}$$

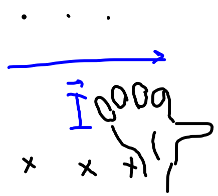
mag field at center of a loop of wire



$$B = \frac{\mu_0 I}{2R}$$



rh rule #2



rh rule #3