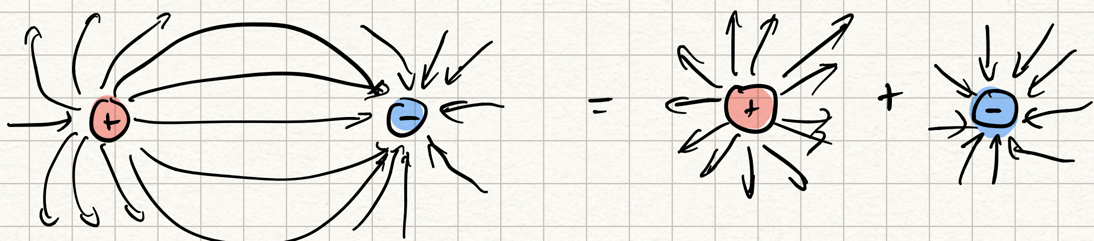
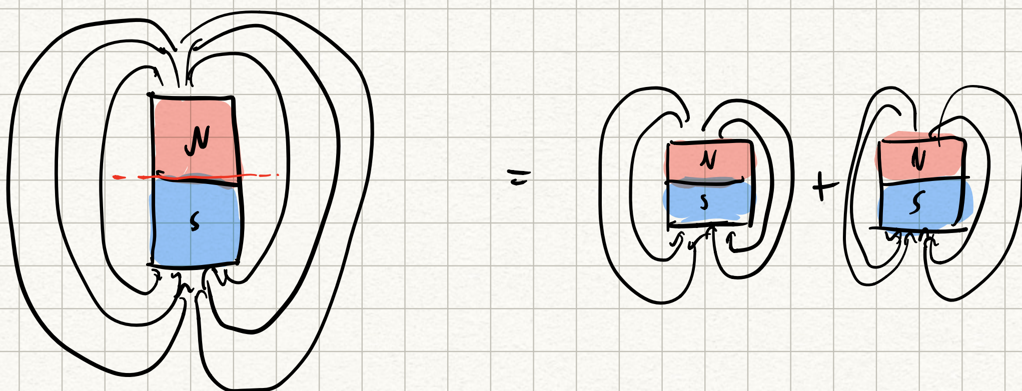
# MAGNETISM

→ Similar to electric field lines, can draw magnetic field lines
  → point from N to S

→ Magnetic fields always form closed loops

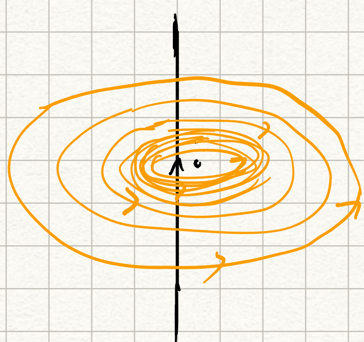



→ Can't isolate one magnetic pole

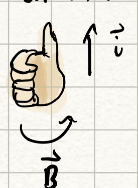
→ Measured in Teslas (T)

→ Current generates magnetic fields



Oersted's Law

- Stronger the closer to wire
- direction determined via 1st right hand rule



→ current exerts force on magnet

AND

→ magnet exerts force on current

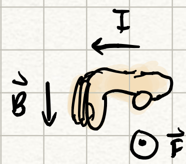
} can determine experimentally

⇒ Force is perpendicular to both current & magnetic field.

$$\boxed{F = I \ell B \sin\theta}$$

↳ length

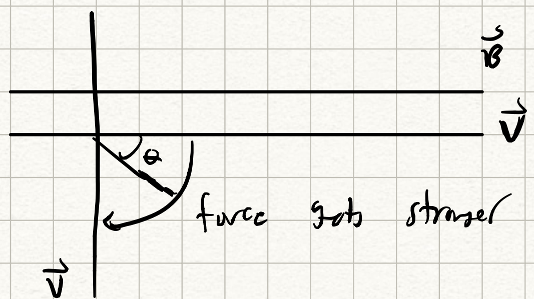
## 2nd right hand rule




↳ what about a single particle?

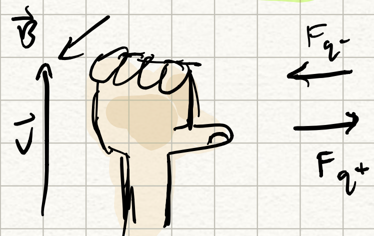
$$F = \left(\frac{Q}{t}\right)(vt)(B\sin\theta)$$

$$\boxed{F = qv \times B}$$




force gets stronger as $\theta \to \frac{\pi}{2}$

## 3rd right hand rule



# MAGNETIC FIELD/FLUX

→ Magnetic field lines are NOT lines of force

- $F = qv \times B$

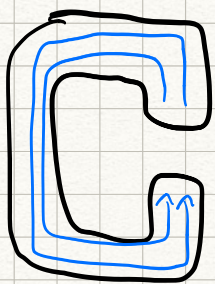
→ Field lines point in the direction a compass needle will point

→ Field lines have no ends

- whereas electric field lines start/end on point charges, magnetic field lines continue inside the magnet to form a closed loop.

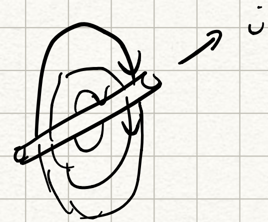
ex.

a)

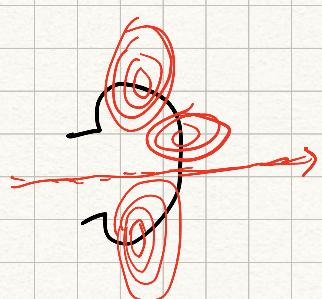


C-shaped magnet,
between flat, parallel plates,
field is uniform

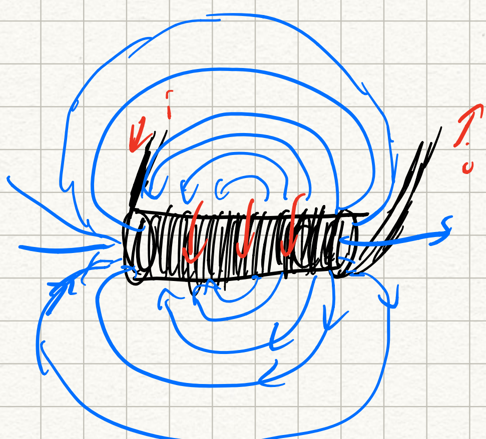
b)



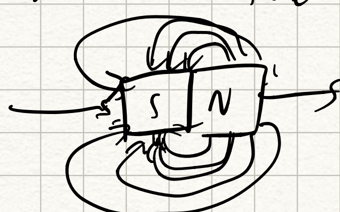

$\vec{B}$ of current carrying wire



Current-carrying loop

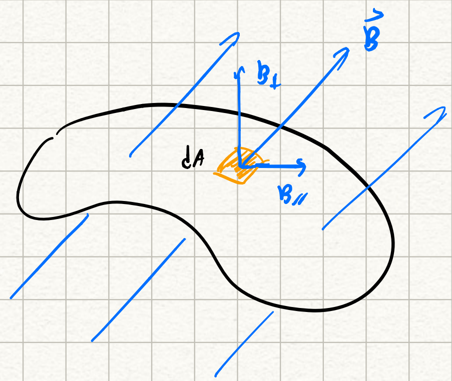



→ looks like field from bar magnet



# GAUSS'S LAW (MAGNETISM)

$$\Phi_B = \int B\cos\phi \, dA = \int B_\perp \, dA = \int \vec{B}\cdot d\vec{A}$$




→ Measured in Webers (W)

$$1\ Wb = 1\ T\cdot m^2 = 1\ \frac{N\cdot m}{A}$$

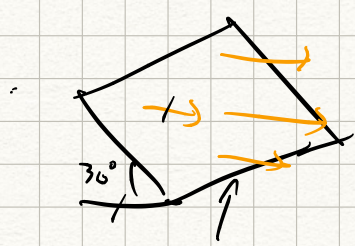
→ For all closed surfaces, there is no enclosed magnetic charge (monopole).

- all field lines that enter, leave

⇒ $\oint \vec{B}\cdot d\vec{A} = 0$ for any closed surface

$$B = \frac{d\Phi_B}{dA_\perp}$$ → since this is flux / Area, B is sometimes called magnetic flux density

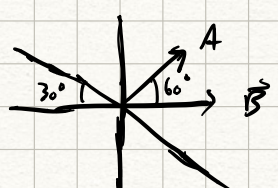
ex.




$A = 3\ cm^2$

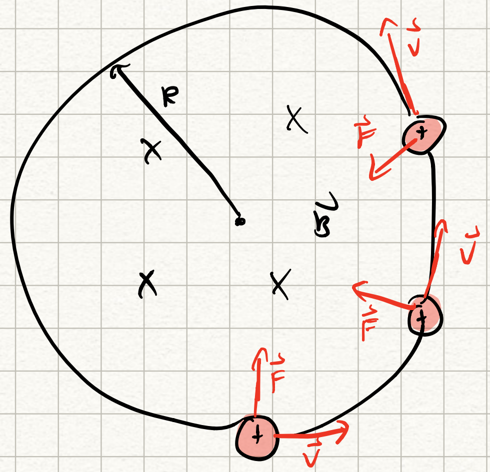
$\Phi_B = 0.90\ mWb$, find magnitude of B and dir. of A.

$$B = \frac{0.90}{3\cos 60°} \times \frac{1\ Wb}{1000\ mWb} = 6.0\ T$$



# CHARGED PARTICLES IN FIELDS

consider




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

since $\vec{F}$ always $\perp$ to $\vec{v}$, it can't change magnitude, only direction

→ never has component // to $\vec{v}$, so no work is done.

→ true even if $\vec{B}$ not uniform

motion of charged particle in magnetic field alone is always constant speed.

thus,

$$\boxed{F = |q| vB = m\frac{v^2}{R} \qquad R = \frac{mv^2}{|q|vB}}$$

if initial velocity $\perp$ B

→ if q is negative, it moves clockwise.

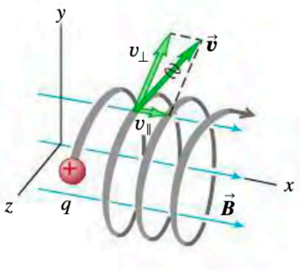
$$\boxed{\omega = \frac{v}{R} = v\frac{|q|B}{mv} = \frac{|q|B}{m}}$$

if $v_i$ not $\perp$ B, it moves in a helix shape.

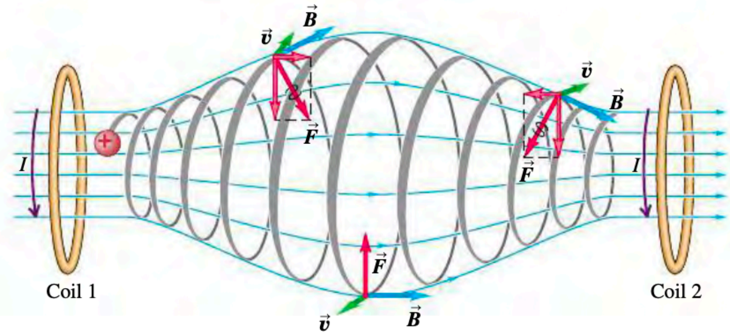
→ $v_\perp$ determines radius of orbit
→ $v_{//}$ determines lateral speed

**27.18** The general case of a charged particle moving in a uniform magnetic field $\vec{B}$. The magnetic field does no work on the particle, so its speed and kinetic energy remain constant.

This particle's motion has components both parallel ($v_{\parallel}$) and perpendicular ($v_{\perp}$) to the magnetic field, so it moves in a helical path.




**27.19** A magnetic bottle. Particles near either end of the region experience a magnetic force toward the center of the region. This is one way of containing an ionized gas that has a temperature of the order of $10^6$ K, which would vaporize any material container.




↳ particles oscillate between the two coils, trapping them

→ this creates Aurora Borealis

**27.20** **(a)** The Van Allen radiation belts around the earth. Near the poles, charged particles from these belts can enter the atmosphere, producing the aurora borealis ("northern lights") and aurora australis ("southern lights"). **(b)** A photograph of the aurora borealis.

(a) (b)