LAST WEEK:

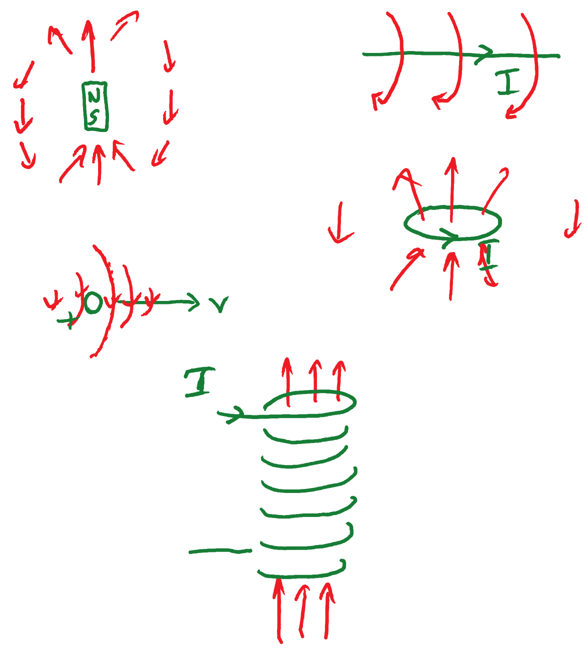
Magnets
Moving charges
Currents

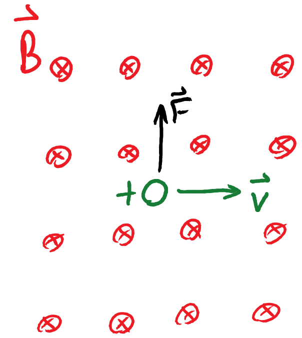
produce →

MAGNETIC FIELDS

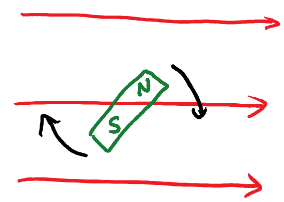
cause forces + torques on →

Magnets
Moving Charges
Currents

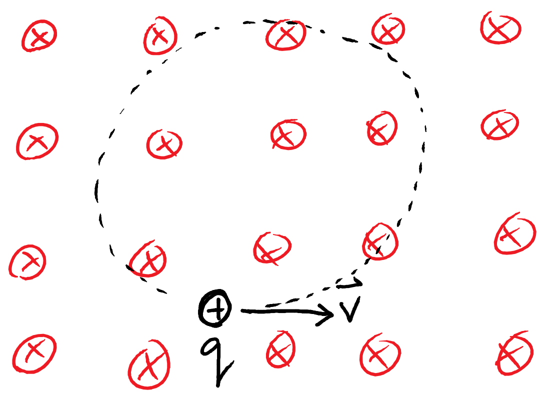




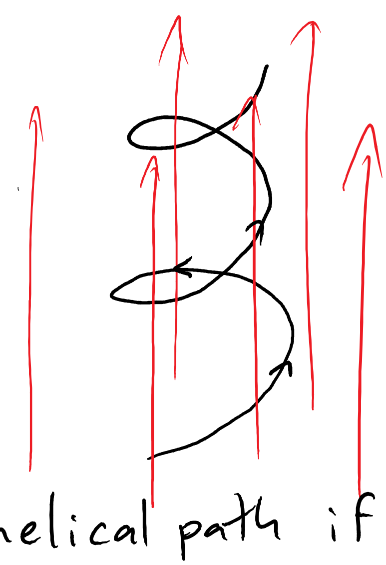
$$\vec{F} = q\vec{v} \times \vec{B}$$



e.g. charged particles in uniform $\vec{B}$ field.

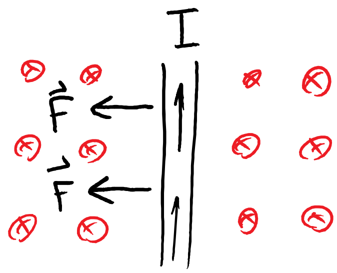


circular orbit if initially $\vec{v} \perp \vec{B}$



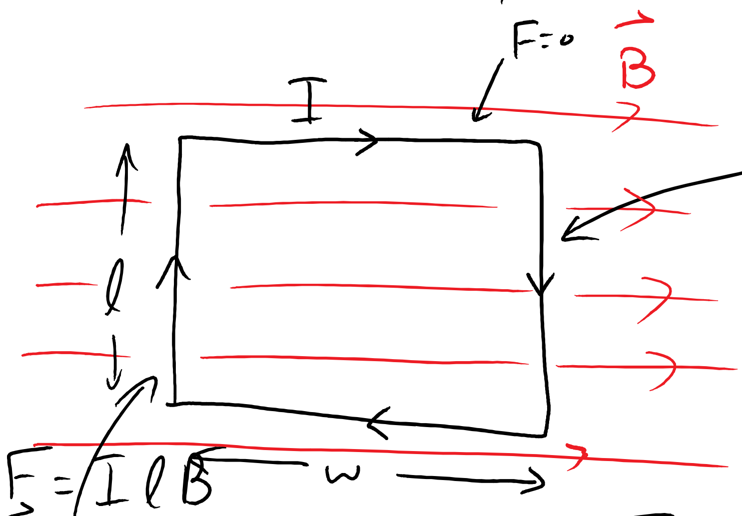
helical path if $\vec{v}$ has component along $\vec{B}$: no forces in $\hat{z}$ direction so v_z is constant.

Force on a wire:



$$|\vec{F}| = I \cdot L \cdot B$$

e.g. current loop



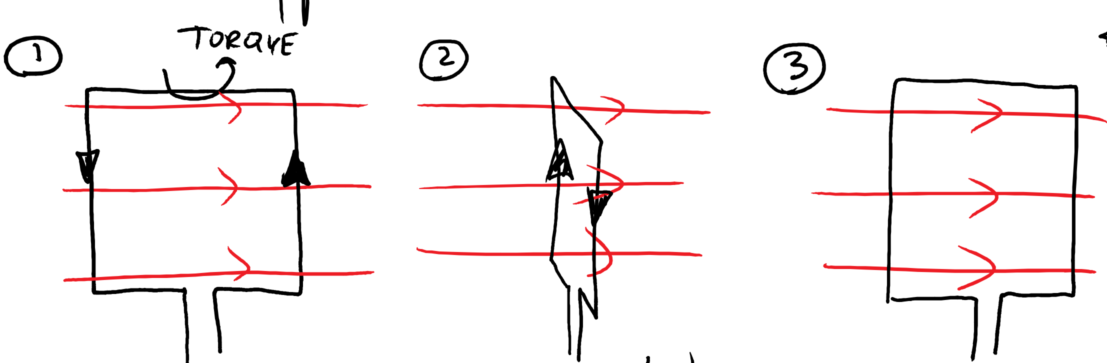
$\vec{F} = I\ell B$ (out of page)

(into page)

☆ No net force ☆

$$\text{Torque} = I\ell B \cdot \frac{w}{2} + I\ell B \cdot \frac{w}{2}$$
$$= I\,(\ell \cdot w)\,B$$
$$= (I \cdot \text{Area}) \cdot B$$

Practical application: electric motor



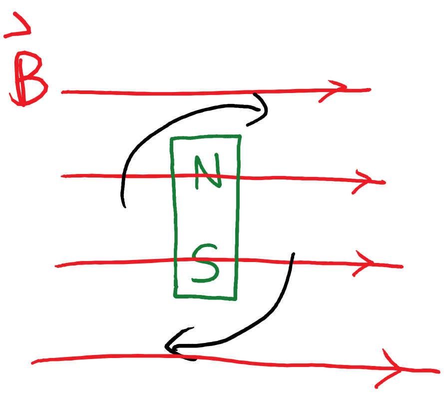
No torque, but keeps rotating due to ang. mom. conservation

☆ Torque would switch direction + cause loop to rotate back ∴ NEED to stop current or switch direction of current until back in original position ☆

Q: How can we quantify the strength of a magnet?

A1: Stronger magnet feels more torque in constant magnetic field

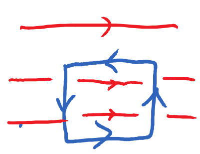
Define MAGNETIC MOMENT $\vec{\mu}$: vector in direction from south pole to north pole



Torque : proportional to B

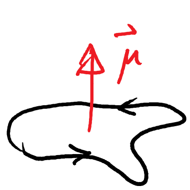
$$\frac{|\tau|}{|B|} = \mu$$ ← constant : larger for stronger magnet.

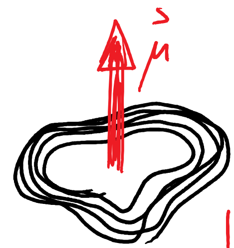
Generally: $$\boxed{\vec{\tau} = \vec{\mu} \times \vec{B}}$$

e.g. 

$\tau = (I \cdot \text{Area}) \cdot B$ for current loop

$|\vec{\mu}| = I \cdot \text{Area}$ for any planar current loop





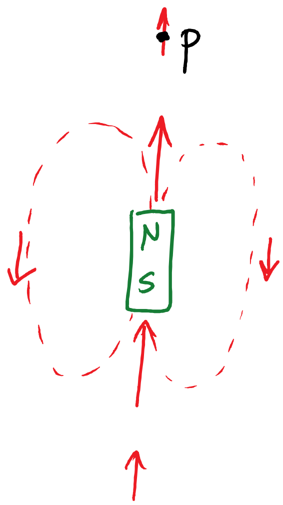
N turns: $|\vec{\mu}| = N \cdot I \cdot \text{Area}$

$|\vec{\mu}| = N \cdot I \cdot \text{Area}$

application: electric motor.

A2 (another answer for how to quantify magnet strength):

★ stronger magnet makes stronger field



field at point p along axis:

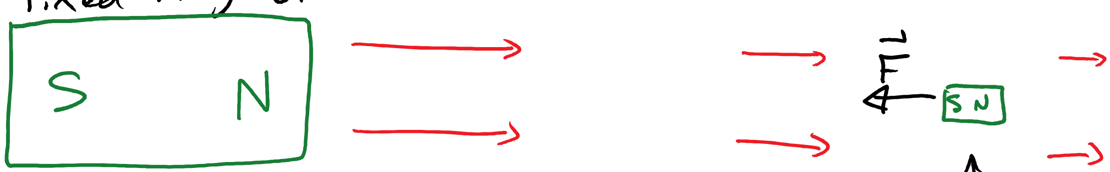
$$B = \frac{\mu_0}{4\pi} \frac{2\mu}{z^3}$$

Larger B for larger μ

assuming $z \gg$ size of magnet

A3: stronger magnet attracted more by other magnet.

fixed magnet



magnet we are testing

Force: arises because field from big magnet is decreasing in magnitude as we move to the right

$$|\vec{F}| = |\vec{\mu}| \left| \frac{d\vec{B}}{dx} \right|$$

for setup shown.

more force for larger μ.