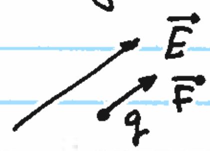
Magnetic force and magnetic field

Magnetic force acts only on moving charges (free particles or electric currents)

Electric field → any charged object (moving or stationary)

Electic force is straight forward

$$\vec{F}_{\vec{E}} = q \cdot \vec{E}$$

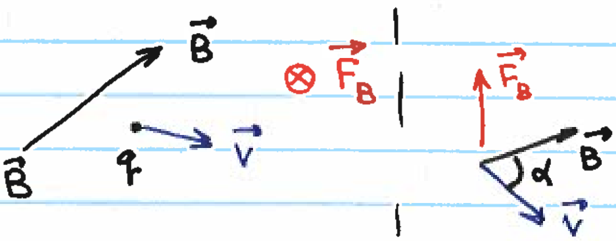


Magnetic field → only moving object

Magnetic force is round about

$$\vec{F}_{\vec{B}} = q \; \vec{V} \times \vec{B}$$

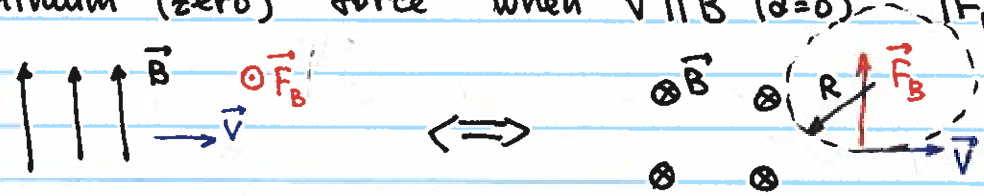
The magnetic field is perpendicular to both $\vec{V}$ and $\vec{B}$



$$|\vec{F}_{\vec{B}}| = q \cdot v \cdot B \cdot \sin \alpha$$

Maximum force when $\vec{V} \perp \vec{B}$ $\quad |\vec{F}_B| = q v \cdot B$

Minimum (zero) force when $\vec{V} \parallel \vec{B}$ $(\alpha = 0)$ $\quad |\vec{F}_B| = 0$



Acceleration due to magnetic force is perpendicular to the velocity → it only changes its direction, not magnitude!

$$\vec{a}_B = \frac{\vec{F}_B}{m}$$ – centripital acceleration circular motion

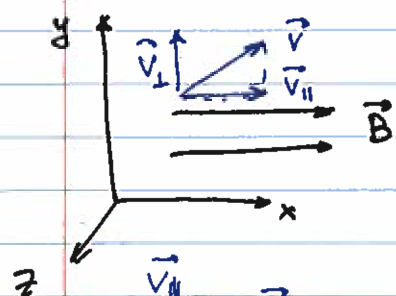
$$\frac{v^2}{R} = a_B = \frac{q \cdot v \cdot B}{m} \Rightarrow R = \frac{mv}{qB}$$

If a particle circulates in a constant orthogonal magnetic field, its period

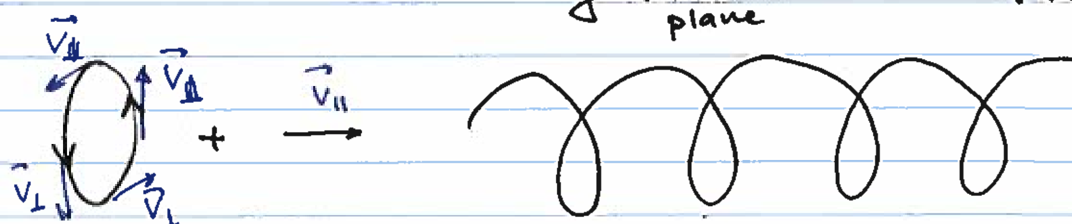
$$T = \frac{2\pi R}{v} = 2\pi \frac{m}{qB}$$, it depends on its mass, but not velocity

$$\omega = \frac{2\pi}{T} = \frac{qB}{m}$$ cyclotrone frequency

What if velocity is not perpendicular to $\vec{B}$



no acceleration in x direction
→ moving with constant speed
centripital acceleration in
y-z ~~direction~~ plane → circular motion

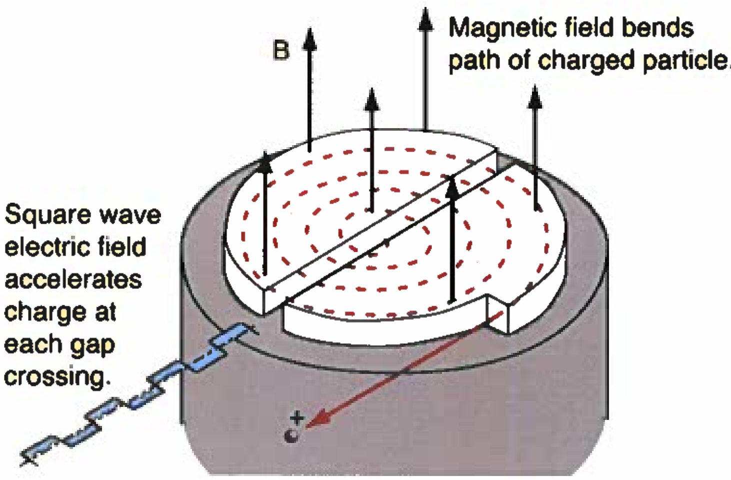


spiraling

What if both magnetic and electric fields are present?

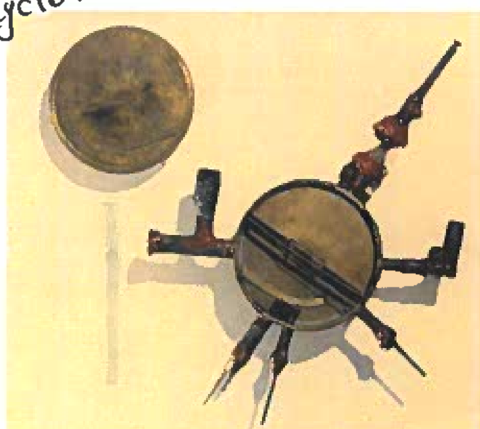
Lorentz force $\vec{F}_L = q \cdot \vec{E} + q \vec{v} \times \vec{B}$

Applications: mass spectrometers
isotope separation
cyclotrone accelerators
Hall effect



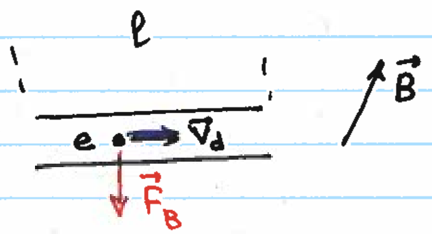
Flips at the cyclotrone frequency

It always takes the same time for a particle to return to the gap, so it is always gaining energy



Magnetic force on a current-carrying conductor

Since electric current is a stream of moving charges, and magnetic field exerts a force on each, there will be a total force on the whole wire



$$\vec{F}_{total} = N_{charges} \cdot e\,\vec{v}_d \times \vec{B}$$

$$N_{charges} = n \cdot A \cdot \ell$$

ℓ ← length of the wire; A ↑ area of the wire; n ↑ charge density

$$\vec{F} = n A \ell \cdot e \vec{v}_d \times \vec{B} = I\,\vec{\ell} \times \vec{B}$$

($nAe\vec{v}_d = I$)

$\vec{\ell}$ – vector length of the current-carrying wire, direction is along the current