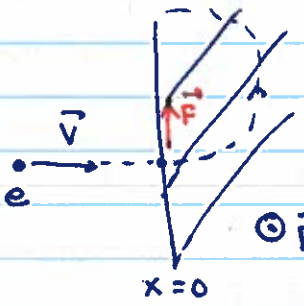
# Quantum way of thinking

Classical physics → all properties of a system are preset, and can be measured without affecting the state of a system.
Observer → "fly on a wall"
We often use the measurable properties to describe the system.

Example: an electron with charge $(-e)$ and mass $m_e$ enters the region of magnetic field $\vec{B} = (B_x, 0, 0)$ moving with $\vec{v} = (0, 0, v)$.
Find its trajectory




$\vec{F} = (0, F_y, 0)$ $\quad F_y = e \cdot v \cdot B = m_e \frac{v^2}{R}$

$\vec{F} = (-e) \cdot \vec{v} \times \vec{B}$

$R = \frac{m_e v}{e \cdot B}$

Moves along the circle of radius R

Quantum physics → the system is in a particular state (which can be known) but its properties can only be revealed through a measurements. The act of a measurement itself usually changes the state of the system.

Notation: quantum state description
wave-function $\psi(x)$
ket vector $|\{\text{state label}\}\rangle$

For example: an electron moving with speed $\vec{v}$ → $|\vec{v}\rangle$
an atom with energy $E_n$ → $|n\rangle$

Example – energy states of a hydrogen atom

$|n\rangle \Leftrightarrow E_n$

$n=3 \longrightarrow |3\rangle$

$n=2 \longrightarrow |2\rangle$

$n=1 \longrightarrow |1\rangle$

If an energy of an atom in state $|n\rangle$ is measured, the outcome is $E_n$

If an atom is in some unknown state

$|?\rangle \rightarrow$ Energy measured $\rightarrow |1\rangle$ with $P_1$, $\rightarrow |2\rangle$ with $P_2$, $\rightarrow |5\rangle$ with $P_5$

different possible outcomes

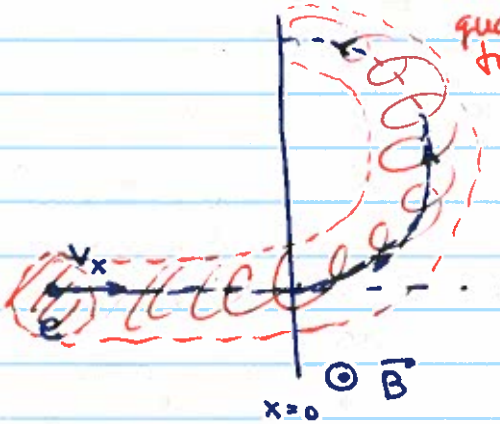
If the experiment repeated many times we can recreate probability distribution of different outcomes

Another important feature: many parameters cannot be measured together!

Uncertainty principle

$|$moving electron$\rangle$ → measure velocity → $|\vec{v}\rangle$ or → measure position → $|x\rangle$

Example: electron in a magnetic field




Classical trajectory → semi-circle

$\vec{F} = (-e)\,\vec{v} \times \vec{B}$ ; $F = eVB = \frac{mv^2}{R}$

Radius $R = \frac{mv}{eB}$

Quantum → velocity and position are not completely known