QUANTUM MECHANICS 1

Introduction

QUANTUM MECHANICS: Describes how objects behave at a small scale

- Describes physics at the microscopic level
- Seemingly incompatible with the types of observations made in our lives
- Leads to counter-intuitive effects
- Used for describing the behavior of an atom

QM vs QC

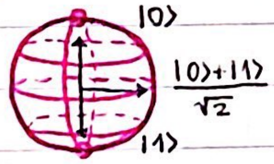
- **Quantum computing:** Uses quantum phenomena to perform computation

~ Quantum computing is an application of Quantum mechanics

superposition • entanglement • quantum interference

Enable the design of quantum algorithms which can compute in ways classical computers cannot, making quantum computers more powerful for solving certain types of problems

WHY QM?



Qubits are physical systems, and quantum mechanics describes the behavior of these systems.

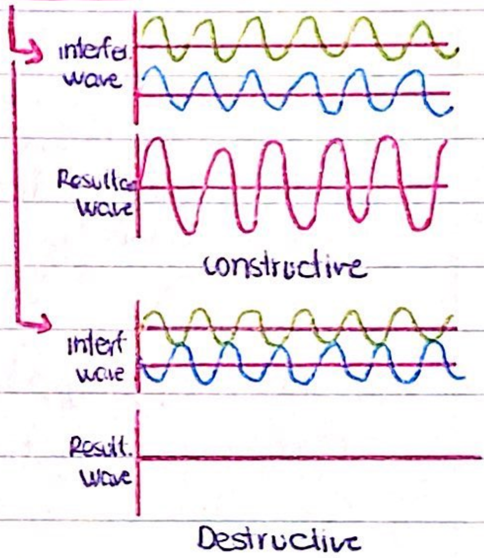
Particles and Waves

PRE-QUANTUM PARTICLES

- All particles have a well defined position
- They are discrete
- When they collide, they "bounce off" each other

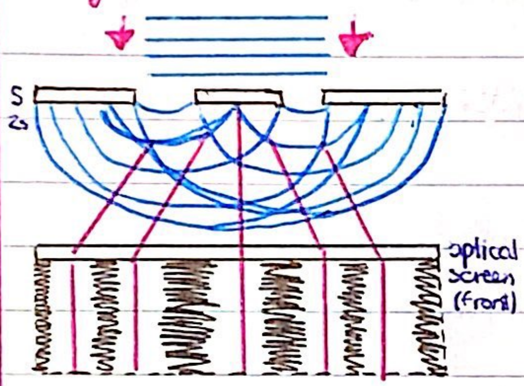
PRE-QUANTUM WAVES

- Waves don't have a well-defined position
- They are continuous
- When they collide, they will interfere



DOUBLE SLIT EXPERIMENT

light as a wave



- It forms an interference pattern!

↳ light as a particle???

~The photoelectric effect

No electrons are ejected with low-energy light -no matter how much you use
↓
Electrons are ejected with high energy light

If light is only a wave
NO SENSE
low-energy waves could eventually dislodge the e⁻

Light also made of particles :)
No matter how many "particles" of light you use, the electron is not ejected.

⇓

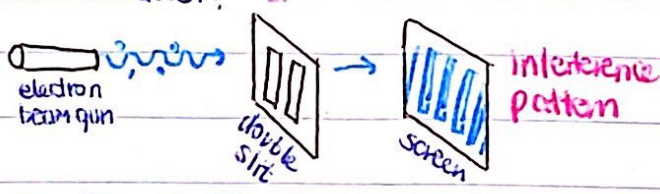
LIGHT IS A WAVE AND A PARTICLE!

WAVE-PARTICLE DUALITY

- In quantum mechanics all objects can be described as both a wave and a particle.

PARTICLES AS WAVES

Electrons exhibit wave behavior!



DE BROGLIE WAVELENGTH

- All particles have a wavelength

$$\lambda = h/p$$

lower wavelength ⟷ higher λ

More particle-like behavior — More wave-like behavior

- ★ λ : wavelength
- ★ h : Planck's constant ($6.626\ 10^{-34} m^2 Kg/s$)
- ★ P : Momentum ($M * V$) → (mass * velocity)

Wifi Wavelength : 0.125 M

X-ray Wavelength : 10^{-9} M

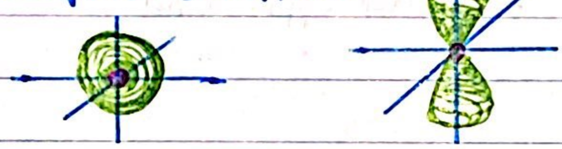
WAVEFUNCTION

- It's a probability cloud
- It shows how likely it's for a particle to be in a certain region of space at a given time

$$\Psi(x,t)$$

- ★ Ψ : psi
- ★ x : position
- ★ t : time

Example of ELECTRON



nucleus

WAVE-PARTICLE DUALITY IN QC

- Qubits behave like waves
- The superposition states of the qubit can interfere with one another
- Using Interference we can amplify the probability of the correct answer
- Quantum interference leads to a quantum speed-up

HAMILTONIAN

A quantum operator that gives us the energy of a quantum state

$$\hat{H}|\psi\rangle = E|\psi\rangle$$

form of the eq:

$$A\vec{v} = \lambda\vec{v}$$

Eigen-vectors, Eigenvalue

$$\hat{H}|\psi\rangle = E|\psi\rangle$$

Eigen states, Eigenvalue

CLASSICAL ENERGY EQ

Total Energy = Kinetic Energy (you)
+ Potential Energy (high) depends

HAMILTONIAN FORM

Total Energy = Kinetic Energy (electron)
+ Potential Energy (how far from nucl)

THE SCHRODINGER EQUATION

describes how the wavefunction changes in time based on its Hamiltonian

Describes how the quantum state changes in time based on its energy values

$$i \frac{h}{2\pi} \cdot \frac{\partial}{\partial t} |\psi\rangle = \hat{H} |\psi\rangle$$

Why this eq?

- It tells us how our quantum hardware behaves
- It tells us how to operate our quantum hardware
- It allows us to engineer and implement quantum gates
- Many more applications!