# QCI

## Day 3: Intro to Quantum Mechanics and Quantum Computing

# Intro to QM

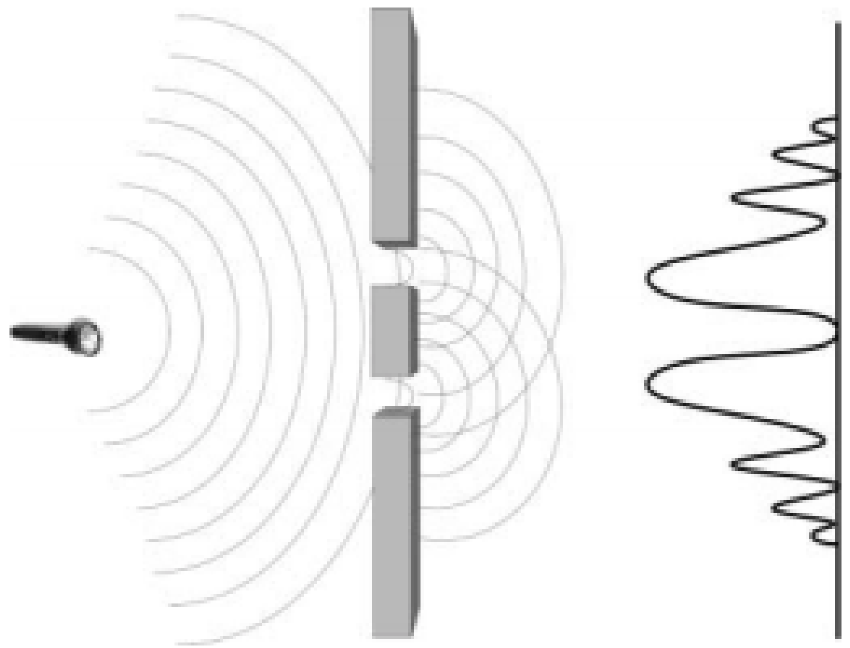


Figure 4.1. Young's double-slit experiment.

Is light a wave or a particle?

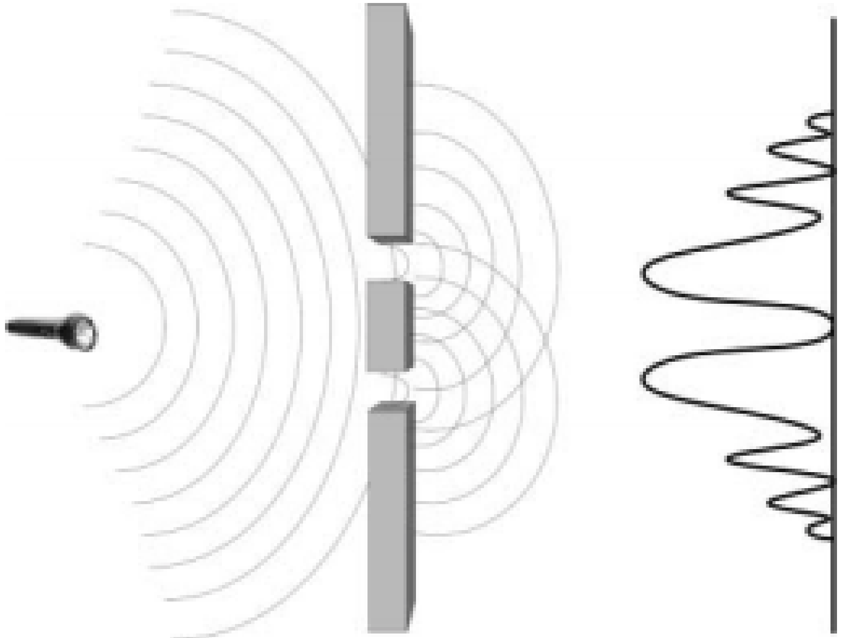


Figure 4.1. Young's double-slit experiment.

Is light a wave or a particle?

Interference patterns

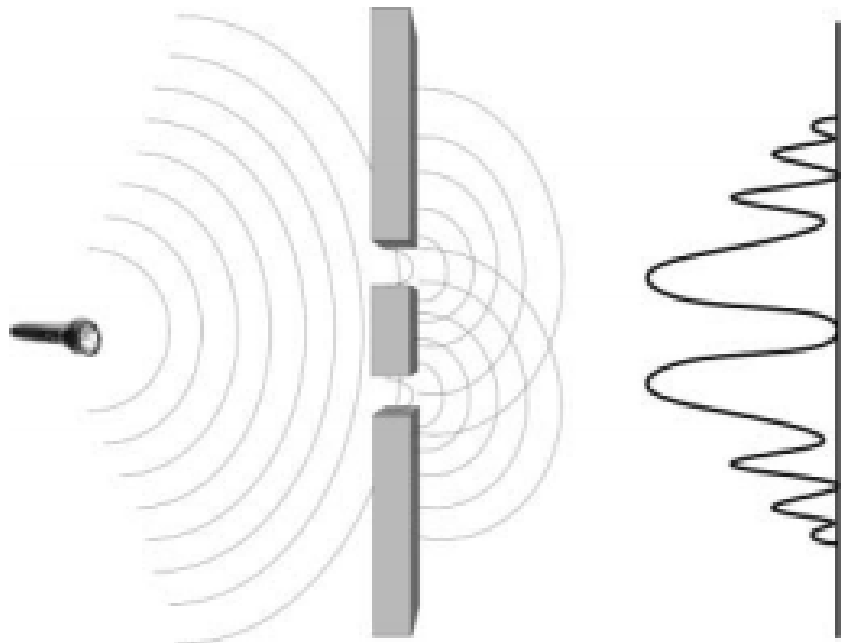


Figure 4.1. Young's double-slit experiment.

Is light a wave or a particle?

Interference patterns

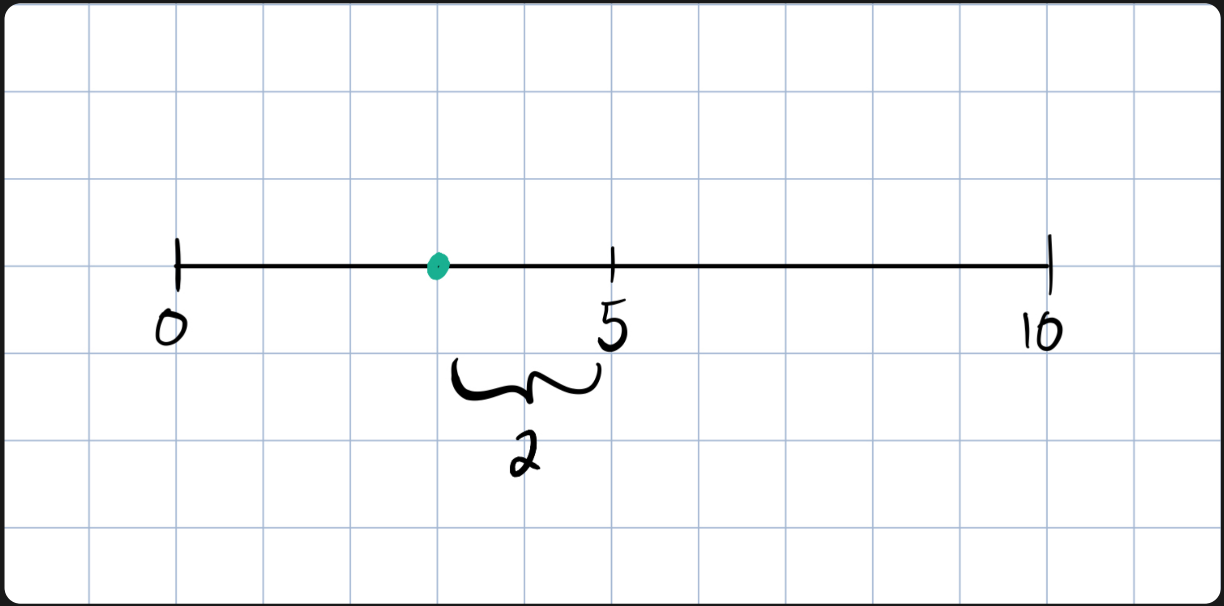
Send one photon in at a time

## Wave Equation

$$i\hbar \frac{\partial}{\partial t} |\psi(t)\rangle = \hat{H} |\psi(t)\rangle$$

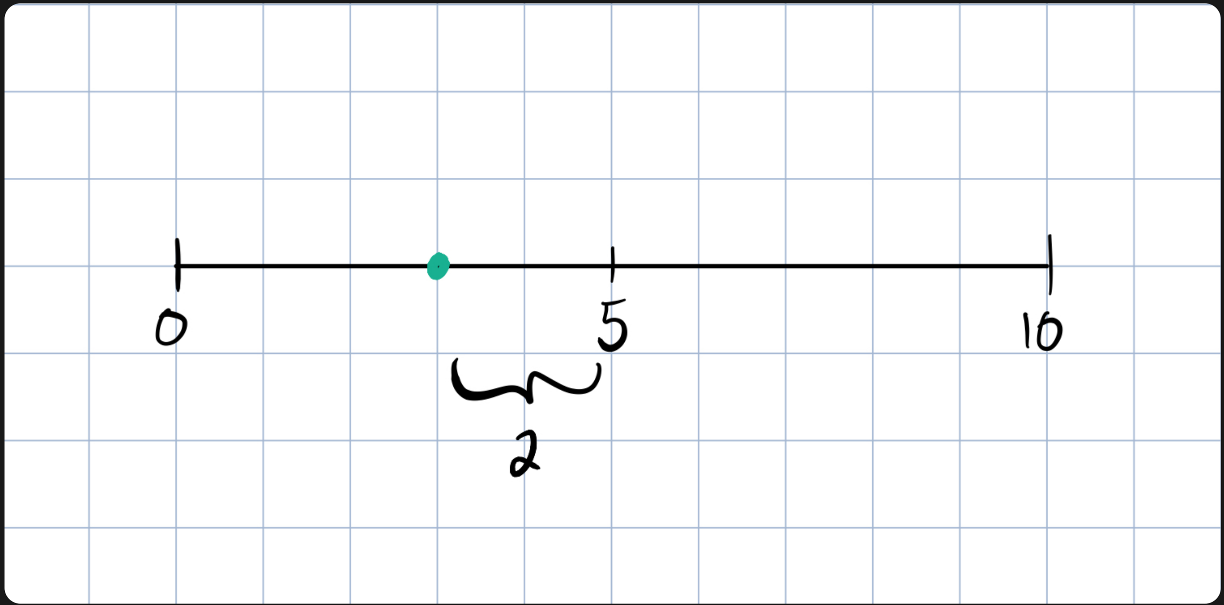
# Quantum States

# The Number Line Analogy




$$\begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ \vdots \end{pmatrix}$$

# The Number Line Analogy




$$\begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ \vdots \end{pmatrix}$$

Infinite possible positions spaced distance $dx$ apart

$$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$|1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

# Superposition

$$|\psi\rangle = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \frac{i}{\sqrt{2}} \end{pmatrix}$$

# Observer Effect

Observing a system changes its state

**Observer Effect**

Observing a system changes its state

Causes a superposition to collapse

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Observing a system changes its state

Causes a superposition to collapse

We cannot see a quantum state in superposition

## Probabilities

$$|\psi\rangle = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \frac{i}{\sqrt{2}} \end{pmatrix}$$

$$p(|x\rangle) = |\langle x|\psi\rangle|^2$$

$$p(|\psi\rangle) = 1$$

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

$$\therefore \sqrt{|\alpha|^2 + |\beta|^2} = 1$$

$$|\alpha|^2 + |\beta|^2 = 1$$

$$|\alpha|^2 + |\beta|^2 = 1$$

$$|\psi\rangle = cos(\theta/2)|0\rangle + e^{i\phi} sin(\theta/2)|1\rangle$$

$$|\alpha|^2 + |\beta|^2 = 1$$

$$|\psi\rangle = cos(\theta/2)|0\rangle + e^{i\phi} sin(\theta/2)|1\rangle$$

$\phi$ is the phase

# Understand Phase

**Understand Phase**

Comes from the wave-like nature of quantum

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Does not affect probabilities

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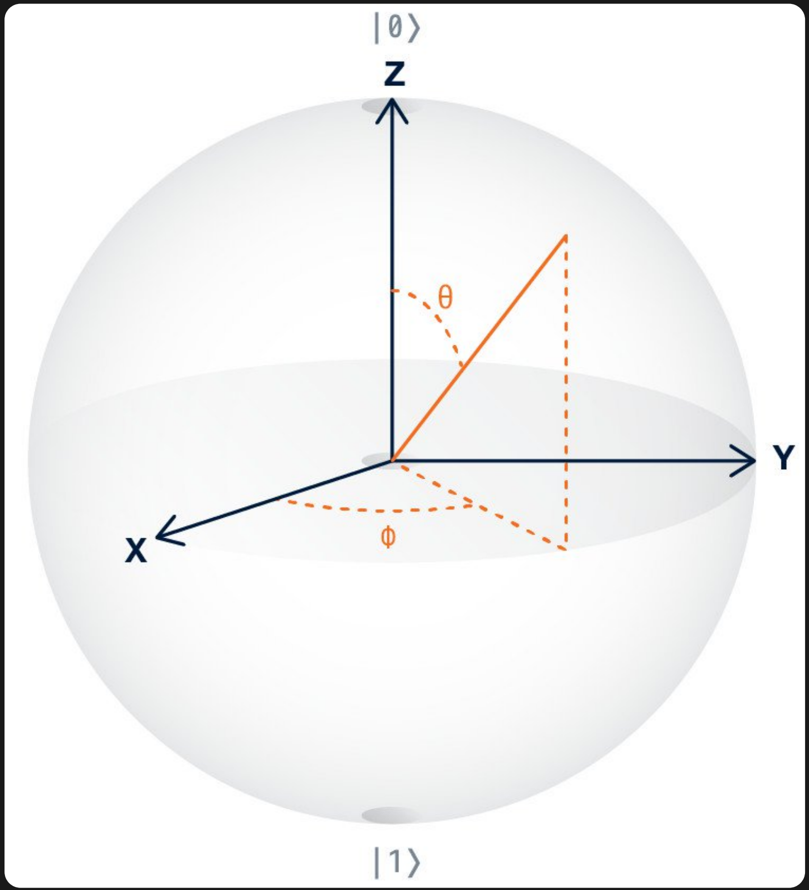
Comes from the wave-like nature of quantum

Does not affect probabilities

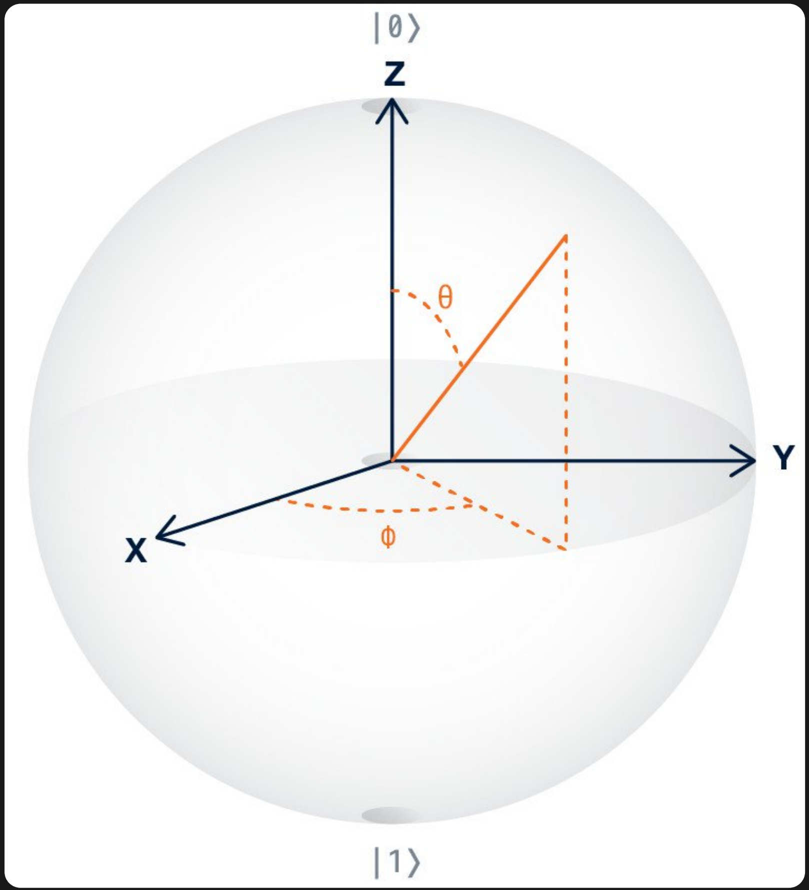
Can be used to cancel things out

# Bloch Sphere and Phase




Phase on y-axis

# Bloch Sphere and Phase




Phase on y-axis

Probabilities depend only on $\theta$

# Qiskit Exercise

# Multi-Qubit States

$$\begin{pmatrix} 1 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$$

Entangled States

$$\begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

Entangled States

$$\begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

Cannot be factored!

# Intro to Dynamics

## Reversible Operations

Given a function and an output, you can find the input

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Given a function and an output, you can find the input

Quantum operators are their own inverses

## Questions

Is $f(x) = 3x$ reversible? How about $f(x) = x^2$?

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Which of our single-bit operations are reversible?

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Is $f(x) = 3x$ reversible? How about $f(x) = x^2$?

Which of our single-bit operations are reversible?

Is negation a valid quantum operator?

Quick Math!

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} |0\rangle$$

Quick Math!

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} |0\rangle$$

$$= |1\rangle$$

# Quantum Computing: An Overview

# Qubits: Quantum Bits

## Qubits: Quantum Bits

Obeys quantum principles

**Qubits: Quantum Bits**

Obeys quantum principles

Special quantum logic gates

**Qubits: Quantum Bits**

Obeys quantum principles

Special quantum logic gates

Represented by superconducting chips

**Qubits: Quantum Bits**

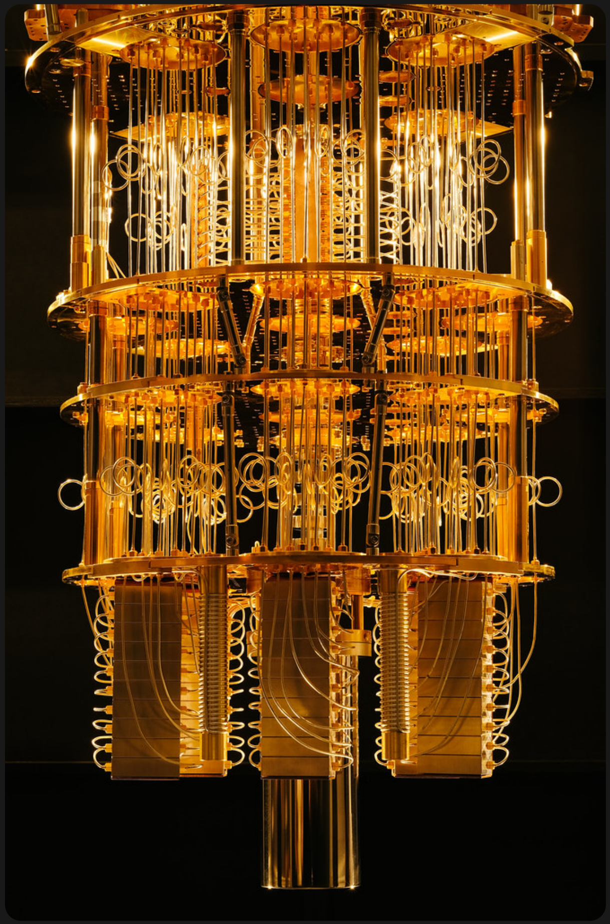
Obeys quantum principles

Special quantum logic gates

Represented by superconducting chips

Manipulated by microwave pulses

# The Quantum Computer



## Why Quantum?

Superposition

**Why Quantum?**

Superposition

Entanglement

# Applications of QC

Simulations

**Applications of QC**

Simulations

Computer security

# Applications of QC

Simulations

Computer security

Computer science

# References


- *Yanofsky, Mannucci. Quantum Computing for Computer Scientists*
- Wikipedia. Schrodinger Equation
- Qiskit Textbook. Representing Qubit States
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- Towards Data Science. The Qubit Phase