BOLT MEETS QUANTUM

Raghav
my website

A BIT ABOUT ME..

QubitXQubit course,2020

Bolt IOT /ML course last month

I am Electronics and Communication Engineering undergrad at NIT , Kurukshetra. I love to learn new things

.

CONTENTS

Part1: Brief Intro to Quantum computation

1) History of Quantum Mechanics and Quantum Computation

2) Basics of Quantum Mechanics

3)Basics of Quantum computing and intro to Qiskit .

Part2: Discussion about Project

1) Hardware description

2)Code discussion

ACKNOWLEDGMENT

This presentation is result of many open and copyrighted resources. I would like to thank creators ,for such awesome resources . Many of these resources are listed in references .

I apologies if I have not listed anyone's work or not properly cited .

CONTENTS

IT’S ALL STARTED WITH LIGHT

A great puzzling question that confused physicists for centuries “Light”.

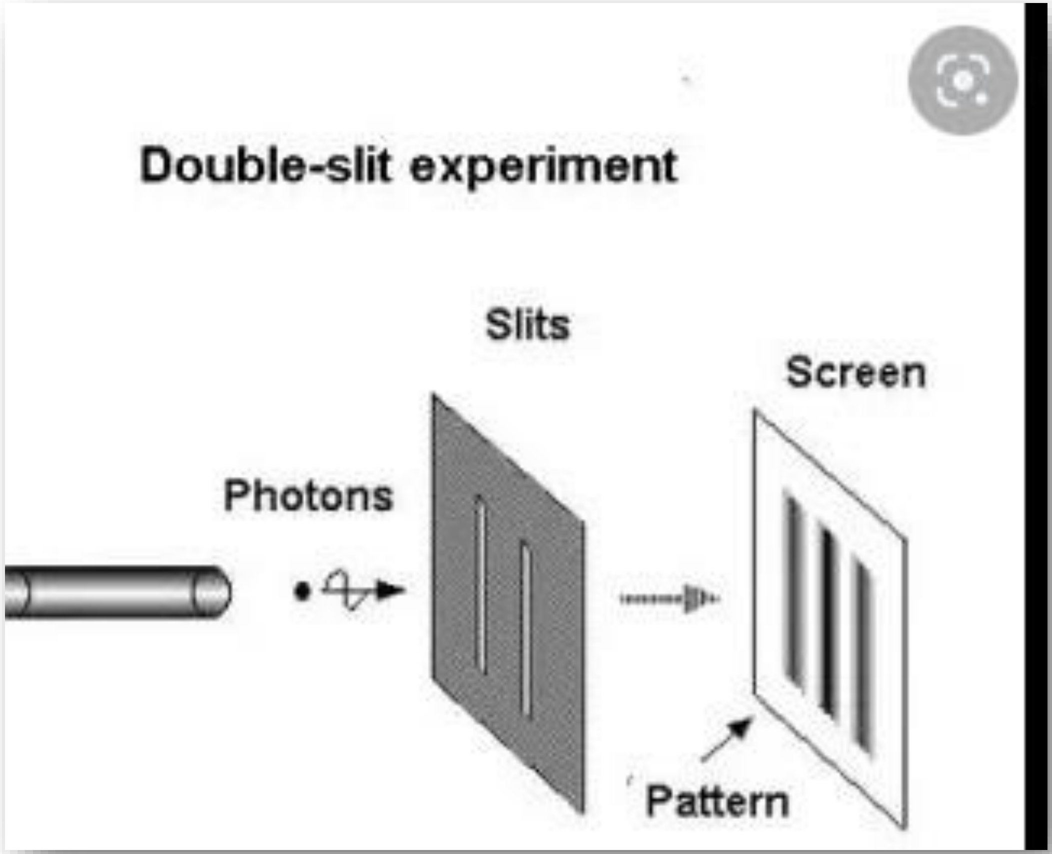
In the past there were lots of theories about light and it’s nature.

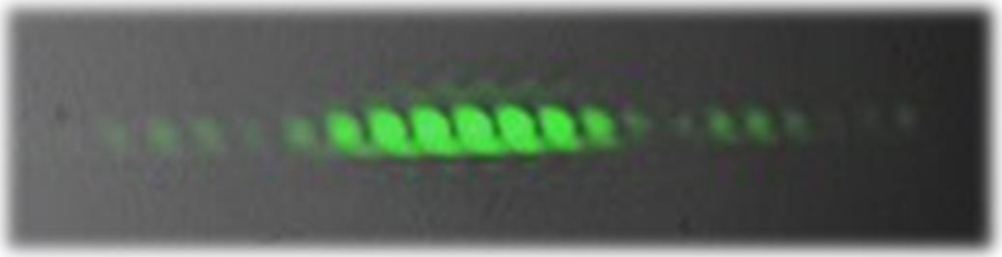
NO theory fit other theory .

In 1672 ,Newton in his book “optiks” came with particle nature of light (corpuscles) but due to many it’s incomplete nature physicists dropped it adopted waves nature of light (Huygens principles)

WHAT DO YOU THINK ?
LIGHT IS MADE UP OF PARTICLES OR WAVE ?
LET US FIND IT OUT …

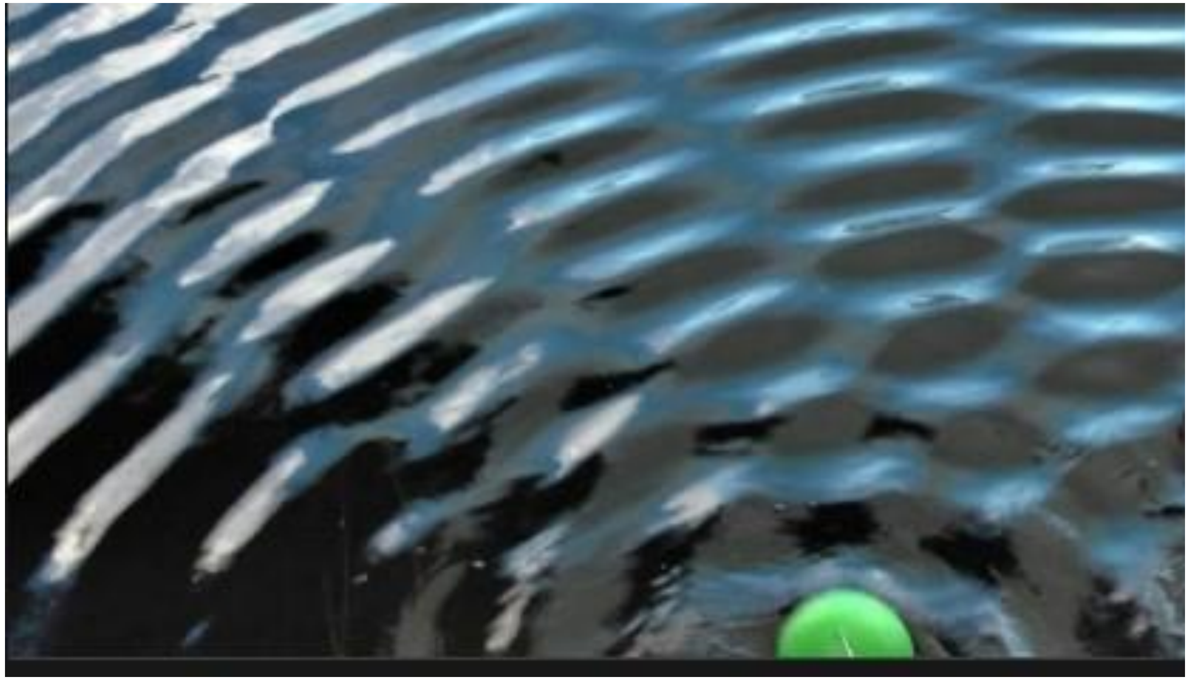
YOUNG DOUBLE SLIT EXPERIMENT



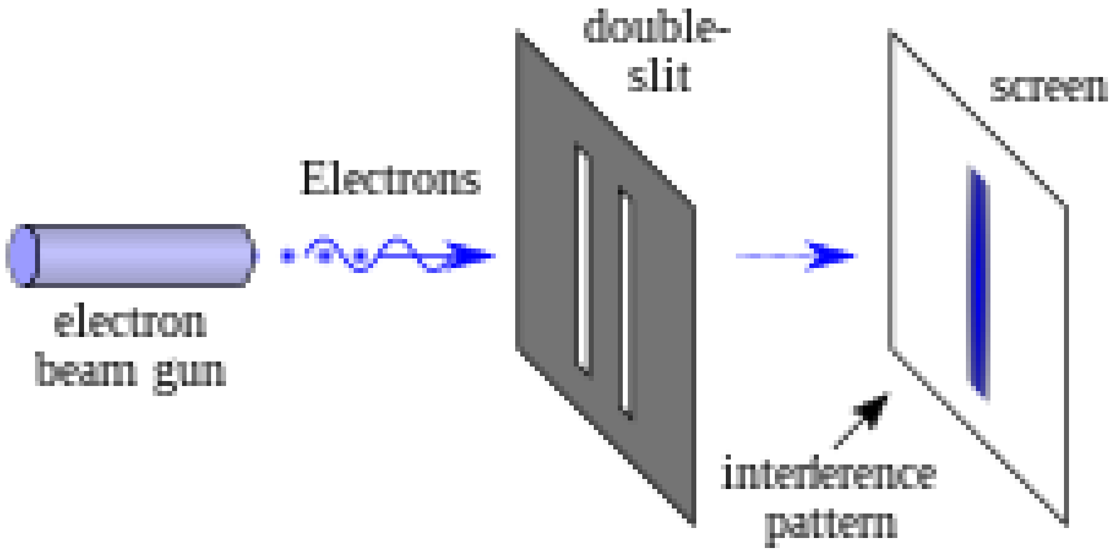


Pattern on screen

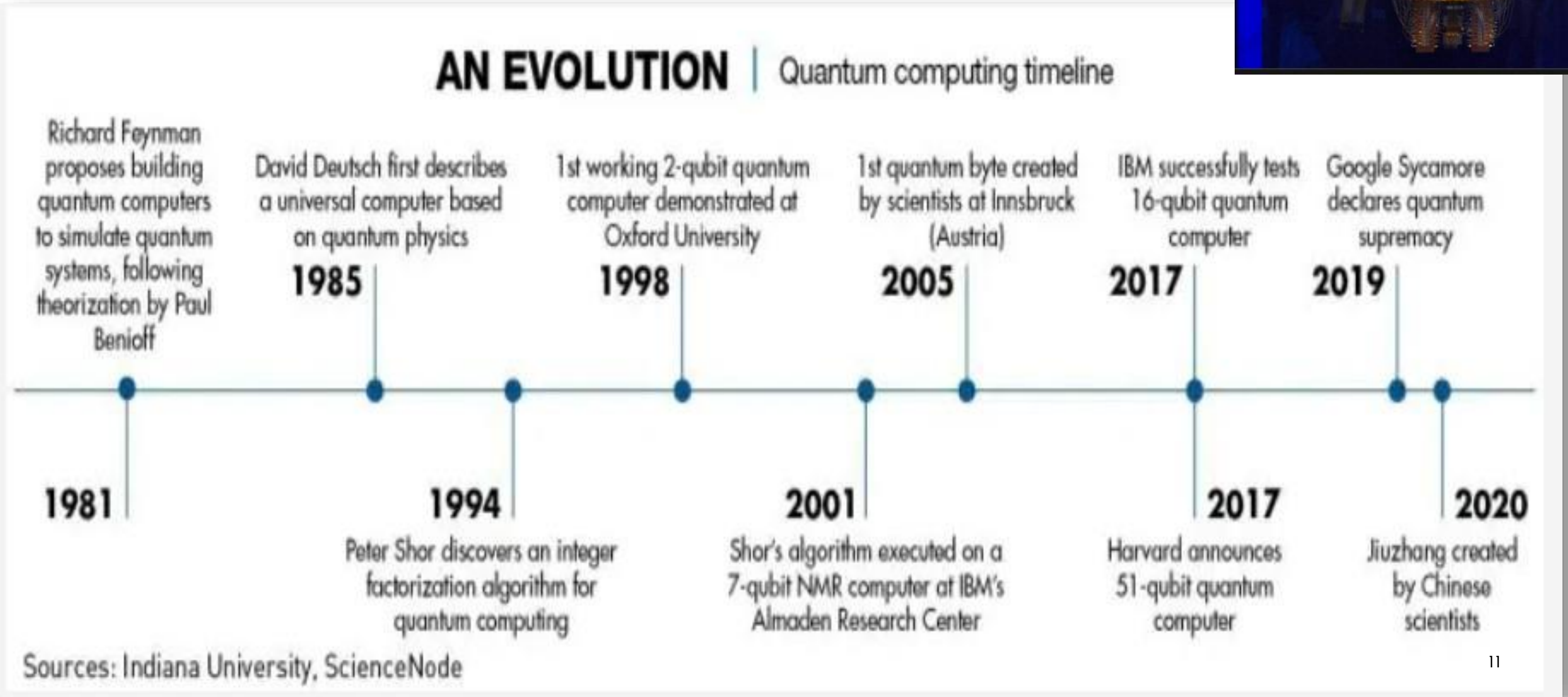
EXPERIMENT SUCCESSFUL!

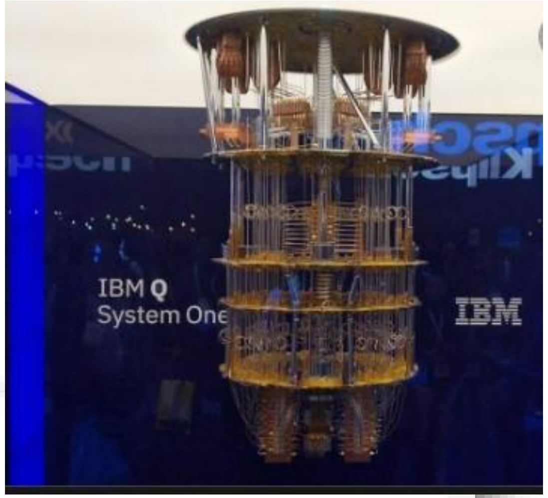


ELECTRON A WAVE ?"



QUANTUM COMPUTATION TIMELINE





“I THINK I CAN SAFELY SAY THAT NOBODY UNDERSTANDS QUANTUM MECHANICS”-FEYNMAN

MATHS BEFORE QUANTUM MECHANICS

Vectors

Inner product

Dirac notation and qubits

Superposition

**Tensor product

**Eigen values

**Hermitian

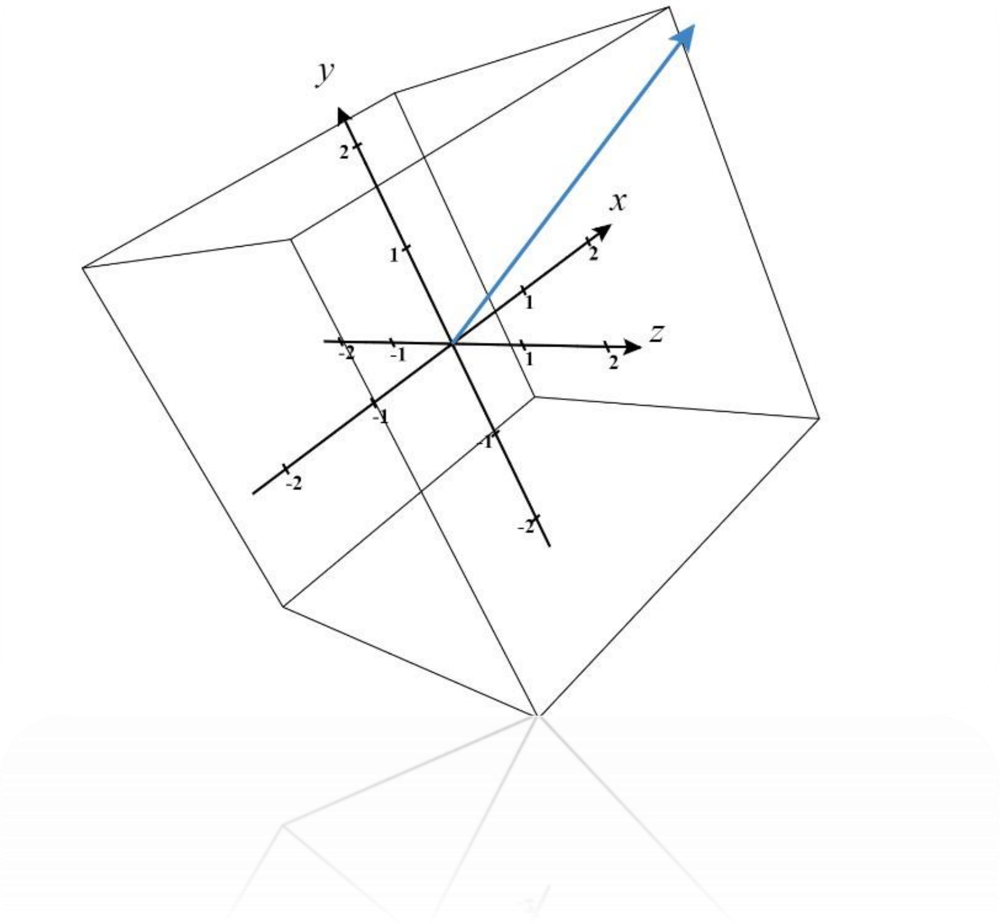
VECTORS

Vector Representation:

$$\vec{v} = \begin{pmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{pmatrix}$$

For example,
$\vec{A} = 1\hat{\imath} + 2\hat{\jmath} + 3\hat{k}$ can be represented as

$$\vec{A} = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$$



**

AV=λV

Eigen Values are all set of values ofλ.

INNER PRODUCT

The ***inner product*** is:

$$\langle \vec{v}, \vec{w} \rangle = \vec{v}\,\vec{w}^T = \sum_{i=1}^{n} v_i w_i$$

1. **vector x vector** to **scalar** mapping
2. tool for calculating vector **magnitude**
3. tool for vector **normalization**
4. tool for **geometrically comparing** vectors
5. tool for determining vector **orthogonality**

MAGNITUDE:

$$\langle \vec{v}, \vec{v} \rangle = \|\vec{v}\|^2$$

NORMALIZATION:

$$\frac{\vec{v}}{\sqrt{\langle \vec{v}, \vec{v} \rangle}} = \frac{\vec{v}}{\|\vec{v}\|}$$

GEOMETRIC COMPARISON & VECTOR ORTHOGONALITY:

$$\langle \vec{x}, \vec{y} \rangle = \|\vec{x}\|\|\vec{y}\| \cos(\theta)$$

where $\theta = \angle(\vec{x}, \vec{y})$ is the angle between $\vec{x}$ and $\vec{y}$

$$\theta = \cos^{-1}\left(\frac{\langle \vec{x}, \vec{y} \rangle}{\|\vec{x}\|\|\vec{y}\|}\right)$$

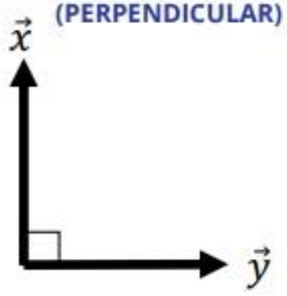
PARALLEL

$\theta = 0°$

$\langle \vec{x}, \vec{y} \rangle =$

ORTHOGONAL

(PERPENDICULAR)



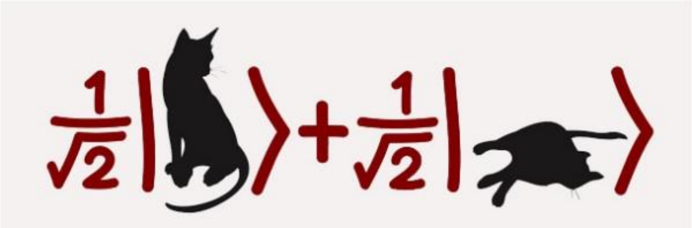
$\theta = 90°$

$\langle \vec{x}, \vec{y} \rangle =$

ANTI-PARALLEL

$\theta = 180°$

$\langle \vec{x}, \vec{y} \rangle =$



DIRAC NOTATION AND QUBITS

Quantum states:

Inputs and outputs of a quantum computer

A ***ket*** is simply a column vector!

$$|v\rangle = \begin{pmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{pmatrix}$$

A ***bra*** is the conjugate transpose of a ket (row vector)!

$$\langle v| = |v\rangle^\dagger = \begin{pmatrix} v_1 & v_2 & \cdots & v_n \end{pmatrix}$$

Superposition: $|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$

Overlap between two quantum states:

braket (bra+ket): $\langle\psi|\phi\rangle$

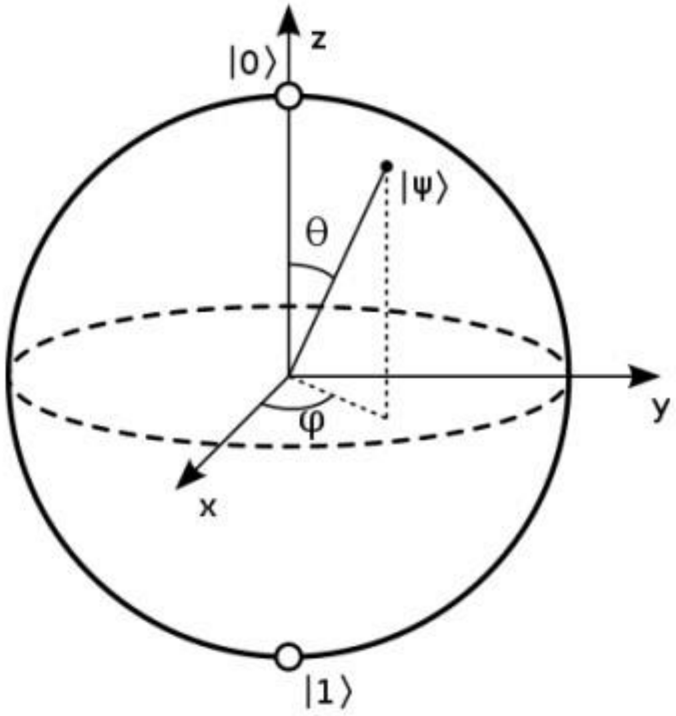
Expectation of quantum operation $\boldsymbol{A}$ with respect to state $|\psi\rangle$:

$$\langle\psi|\,\boldsymbol{A}\,|\psi\rangle$$

States $|\psi\rangle$ and $|\phi\rangle$ are **orthogonal** if: $\langle\psi|\phi\rangle =$

State $|\psi\rangle$ is **normal** if: $\langle\psi|\psi\rangle =$

IT'S HOW WE REPRESENT QUBITS..

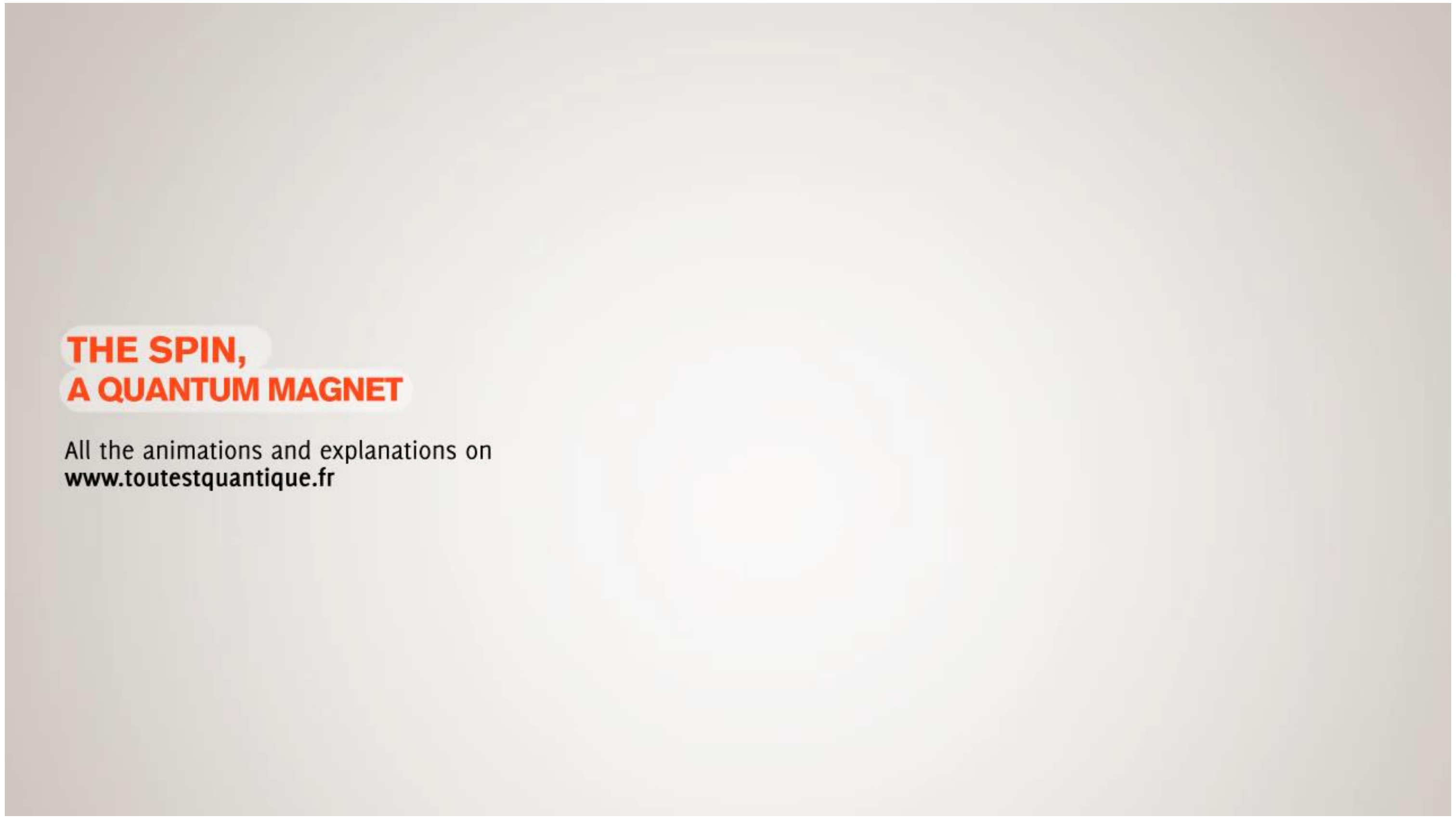


Bloch Sphere

**OTHER NOTATIONS

Notation	Meaning
$A \otimes B$ (Kronecker Product)	Tensor product : It is special type of product unlike our algebraic product it is not commutative.
$\dagger$ (Dagger)	Hermitian : It is complex conjugate transpose of any matrix
$\lvert\psi\rangle\langle\phi\rvert$ $\langle\psi\vert\phi\rangle$ $\lvert\psi\phi\rangle$	Outer product :Unlike inner product outer product is an operator. Inner Product : as discussed .. Kronecker product of $\lvert\phi\rangle$, $\lvert\psi\rangle$

STERN-GERLACH EXPERIMENT



Wikipedia

PRINCIPLES QUANTUM MECHANICS

1)All observable or measurable quantities are represented by linear operators.

2)Possible results of measurements of any quantum states are it's eigen values.

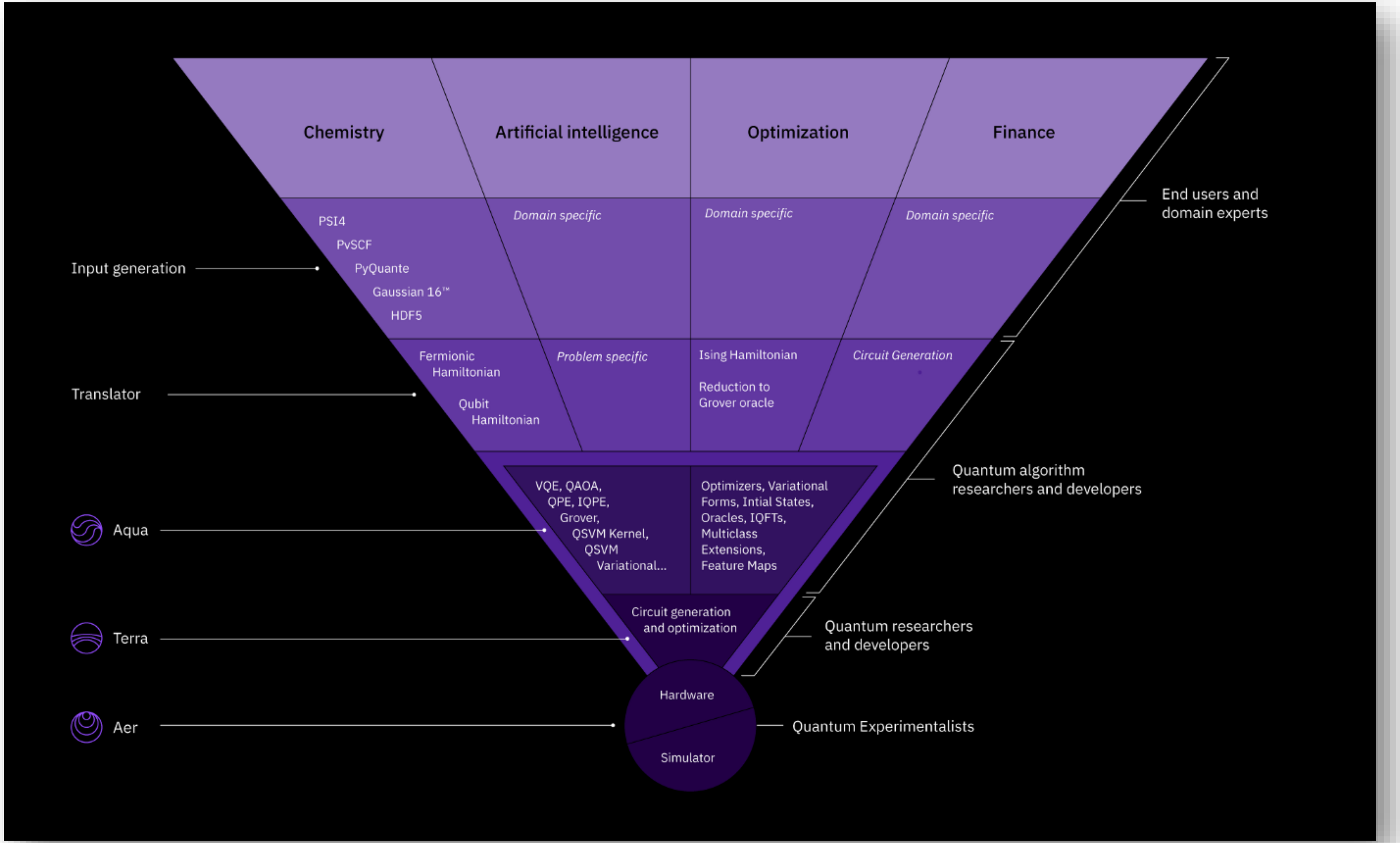
3)Unambiguously distinguishable states are represented by orthogonal vectors

4)Probability of any quantum state is square of amplitude of it's **wavefunction**

PRINCIPLE OF UNITARY

$UU^{\dagger}=\mathrm{I}$

QISKIT A BRIEF



QUANTUM GATES

Quantum operations:

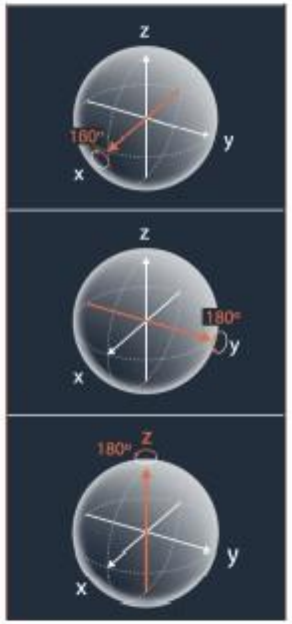
Perform the computation in a quantum computer

Pauli operators:

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$ Pauli-X

$$\sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$ Pauli-Y

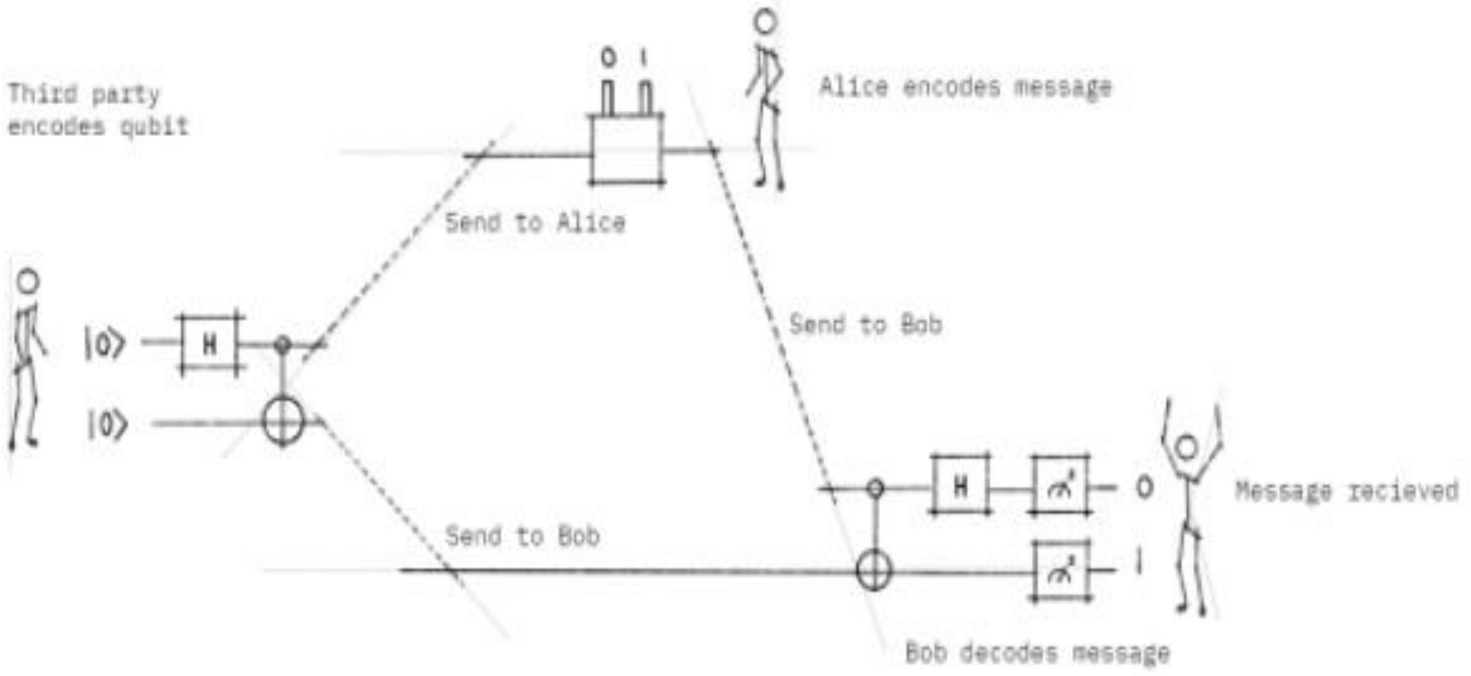
$$\sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$ Pauli-Z



Operator	Gate(s)	Matrix
Pauli-X (X)	X	$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$
Pauli-Y (Y)	Y	$\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$
Pauli-Z (Z)	Z	$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$
Hadamard (H)	H	$\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
Phase (S, P)	S	$\begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$
$\pi/8$ (T)	T	$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi/4} \end{bmatrix}$
Controlled Not (CNOT, CX)		$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$
Controlled Z (CZ)	Z	$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$
SWAP		$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
Toffoli (CCNOT, CCX, TOFF)		$\begin{bmatrix} 1&0&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&0&0&1&0&0&0 \\ 0&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&0&1 \\ 0&0&0&0&0&0&1&0 \end{bmatrix}$

SUPERDENSE CODING

Superdense coding involves two parties, conventionally known as ‘Alice’ and ‘Bob’, who are a long way away from one another. Their goal is to transmit some classical information from Alice to Bob. Suppose Alice is in possession of two classical bits of information which she wishes to send Bob, but is only allowed to send a single qubit to Bob. Can she achieve her goal?



BREAK 10 MIN

Read the Post

Install qiskit and BOLT IOT library on your local machine.

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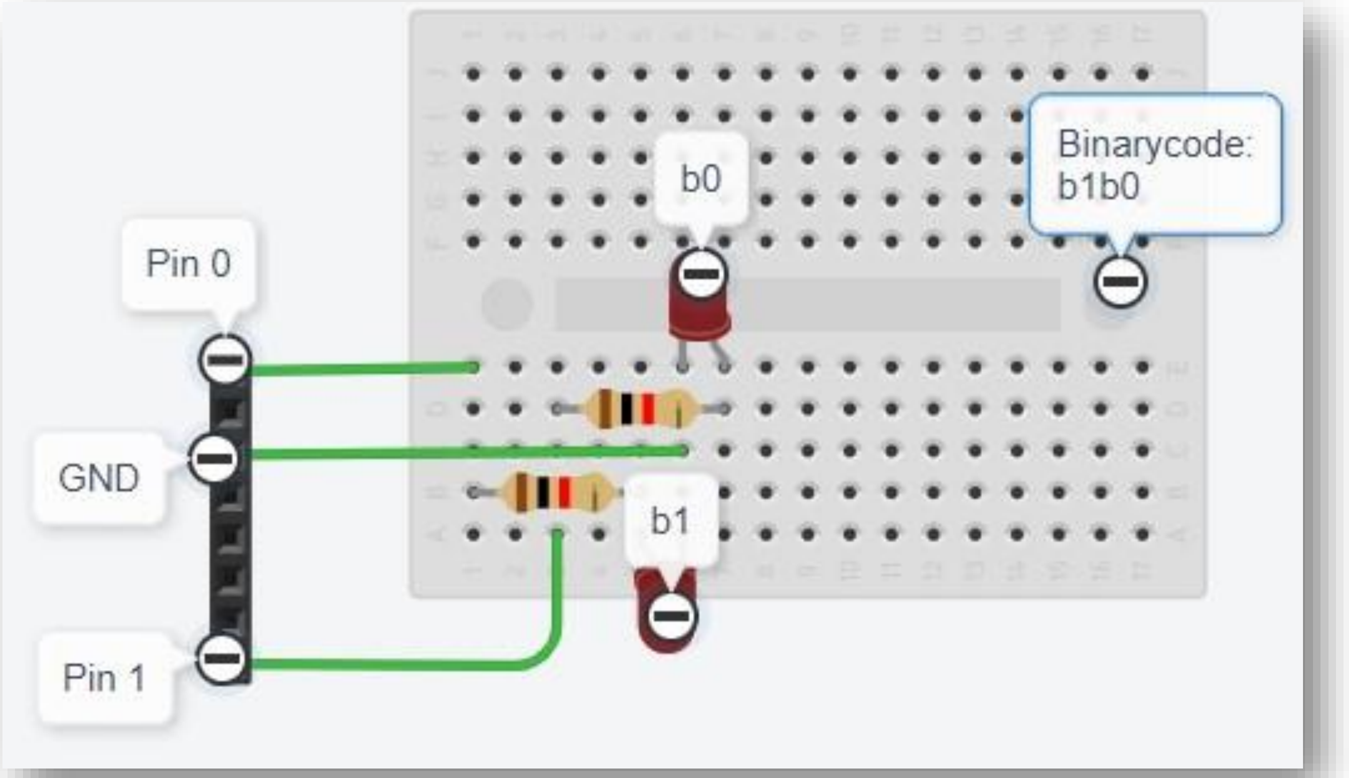
HARDWARE DESCRIPTION

<u>Components:</u>

1)2XLEDS
2)2X330Ω resistors
3)Breadboard
4) 3 X Male-Male jumpers
5)BOLT IOT module



tinkercad

SOFTWARE DESCRIPTION

GitHub link

Post

TEST IT YOURSELF..

Use 2 Bolt modules

Use real Quantum hardware

CONCLUSION

1. During the talk various important concept of Quantum Mechanics ,Dirac notation, Unitary ,and about cats,😄
2. We learnt about current state of art of Quantum Computation ,where it is and how can we involve in that.
3. Most important one , we used Classical devices (Bolt Iot module) , classical protocols (MQTT,HTTP etc)to simulate Quantum Protocols (Superdense coding).

* HINT FOR DO IT YOURSELF

NOTE: You need IBMQ account to run this script

```
provider= IBMQ.get_provider('ibm-q')

qcomp=provider.get_backend('ibmq_16_melbourne')
job = execute(circuit, backend=qcomp)
from qiskit.tools.monitor import job_monitor
job_monitor(job)
result=job.result()
plot_histogram(result.get_counts(circuit))
```

REFERENCES

Big Bang video

Quantum Computers Explained – Limits of Human Technology

Quantum Computation And Quantum Information by Nielson and Chuang

Quantum Mechanics: The Theoretical Minimum by Leonard Susskind

Qubit X Qubit website

Qiskit Textbook

IBM Quantum Experience