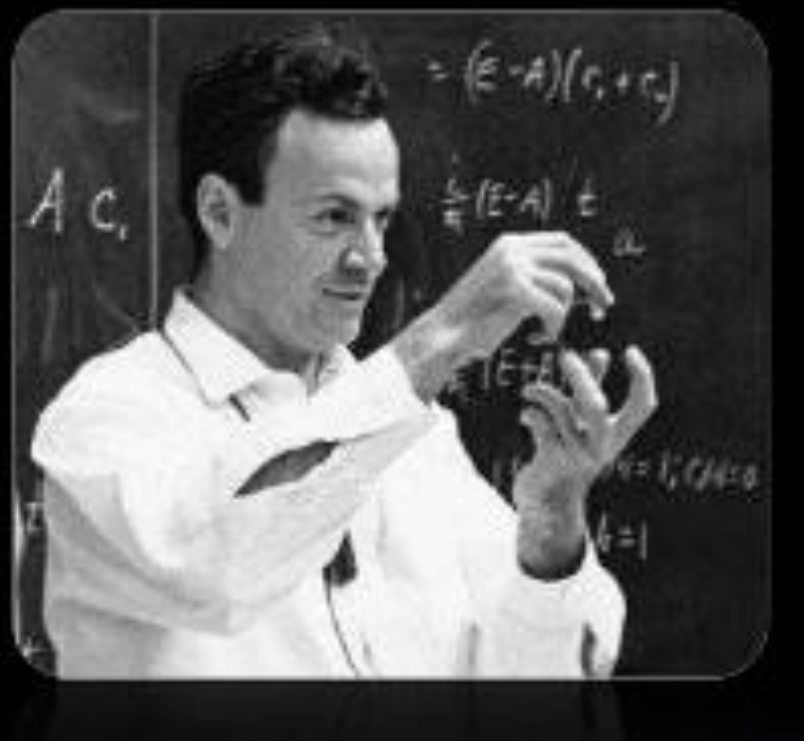
Quantum Computing

Contents

- Basic idea of a quantum computer
- Qubits and qubit operations
- Quantum logic gates and Quantum circuits

Feynman's Proposal of a Quantum Computer

1981 -Richard Feynman determines that it is impossible to efficiently simulate an evolution of a quantum system on a classical computer.



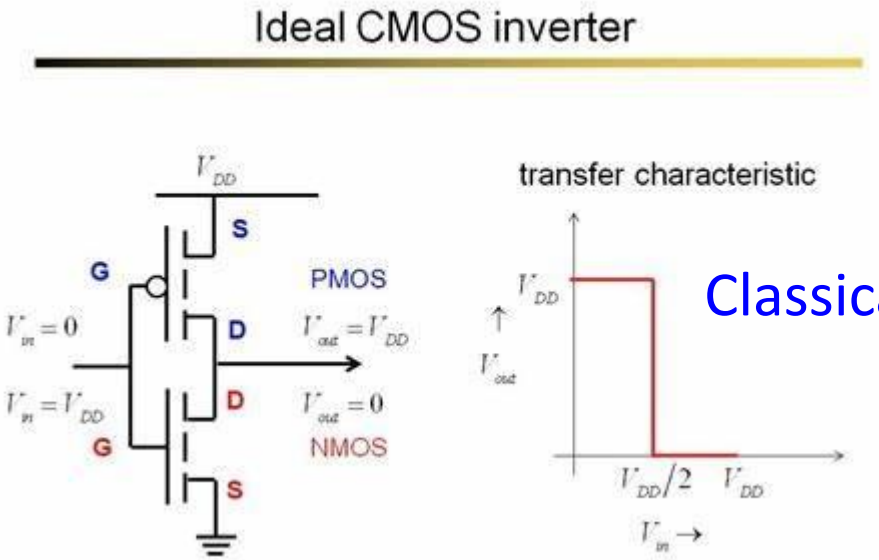
How a Quantum Computer is different?

It is based upon using

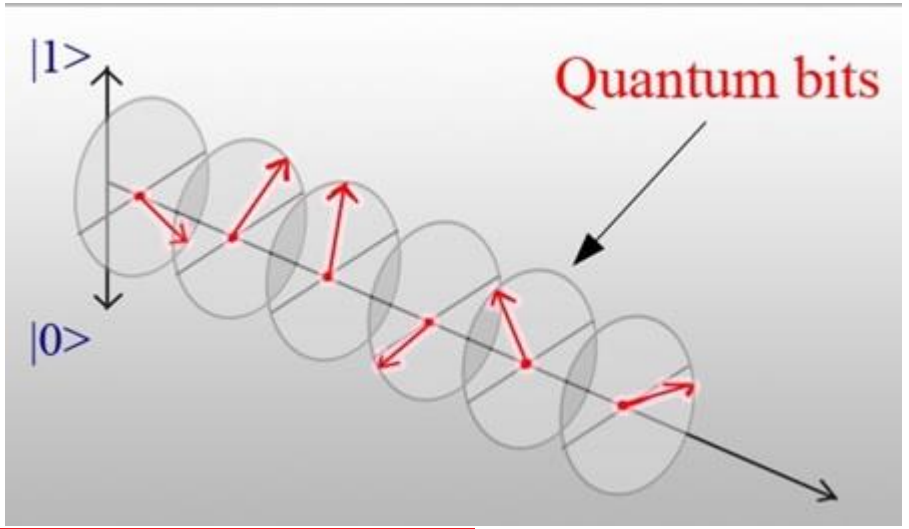
- Qubits
- Superposition/interference
- Entanglement

Superposed state is expressed as:

$|\psi\rangle = a|0\rangle + b|1\rangle$



Classical bits



Classical v/s. Quantum Computers

Classical Computer	Quantum Computer
Uses semiconductor-based CMOS logic gates	May use atomic, electronic, nuclear or photonic properties
ON/OFF state of CMOS transistor determines logic 1/0	Logic 1/0 represented by spin up/down, ground state/excited state, right/left circularly polarized light, parallel/anti-parallel magnetization etc.
Bit can be in state 1 or 0 at a given time	Bit (qubit) can be in both 1 and 0 states at a given time
Machine executes operations bit by bit	Machine executes operation on all qubits simultaneously*

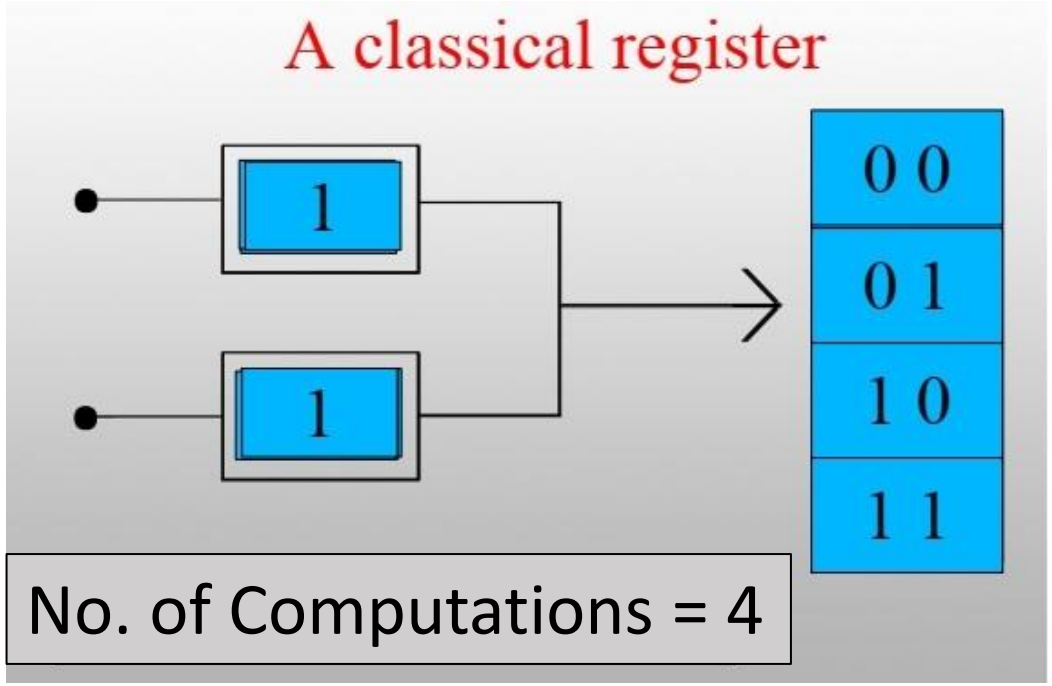
* This concept is different than parallel computing or super computing

Advantage of a Quantum Computer

A classical computer

- Each register has unique input

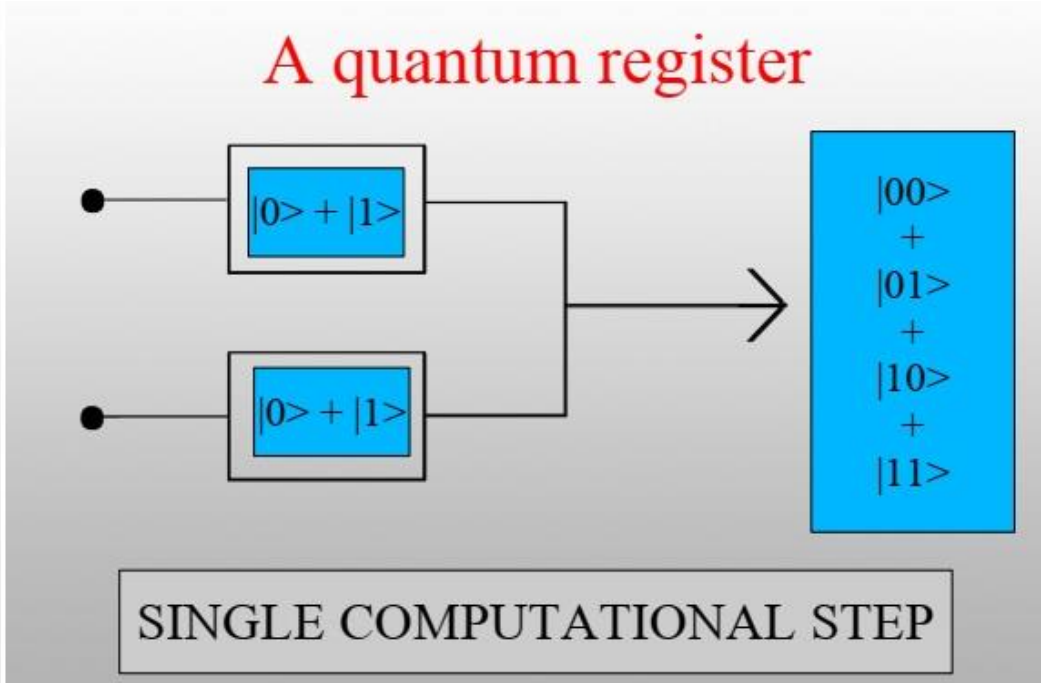
  Executes one operation at a time



A quantum computer

- Each register has both inputs

  Executes all operations in one go

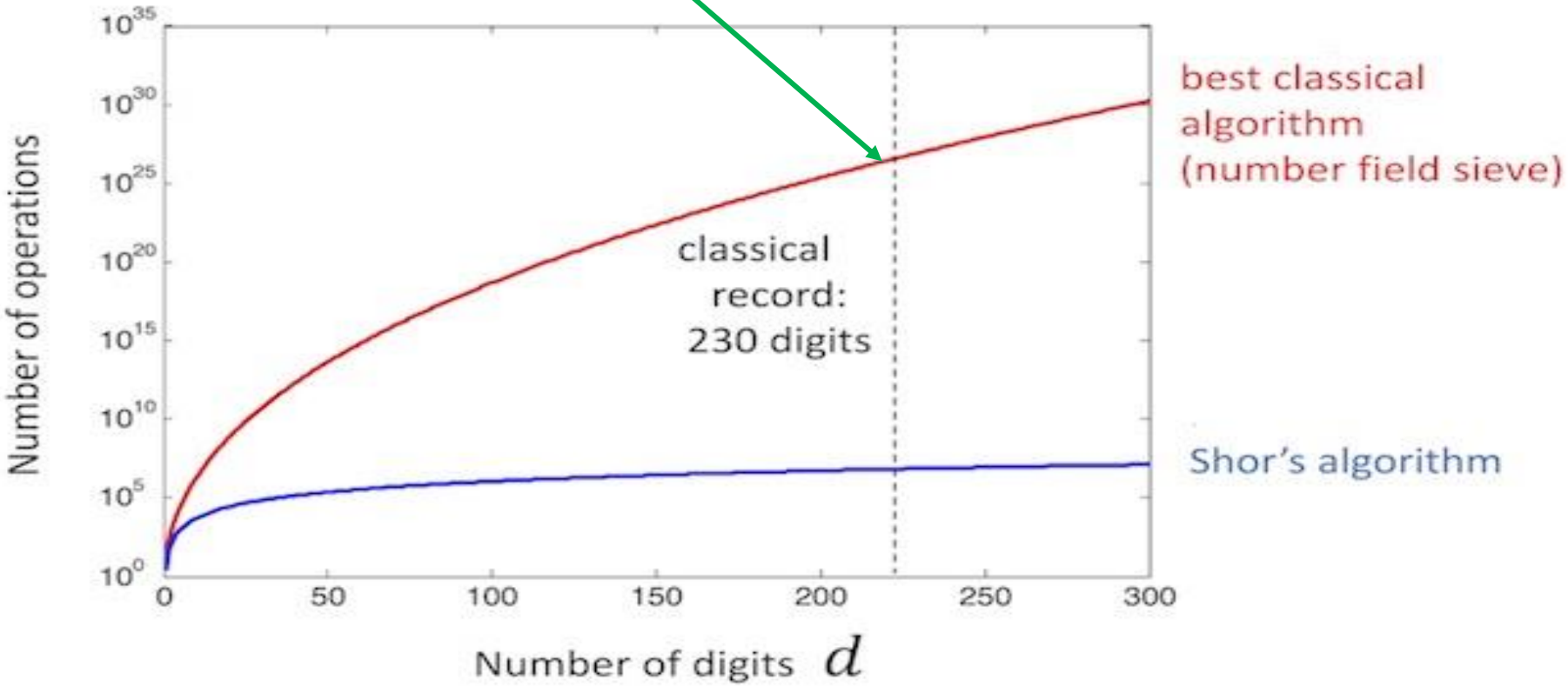


Quantum Algorithms

- Programs that would run on a quantum machine
- Currently, there are no genuine quantum algorithms
- We have Algorithms running on virtual machines that mimic quantum effects
- All use cloud based computing e.g. IBM's Qiskit

Advantage of Quantum Algorithm

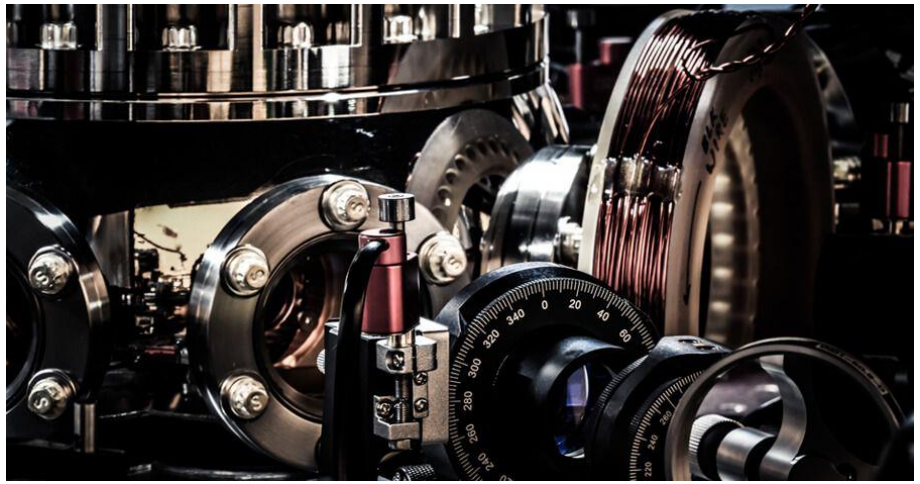
Took ≈ 2000 CPU years (OR 2000 parallel processors x 1 year)



Graph credit: IBM Quantum Computing

Quantum Hardware

- Ion trap – uses atomic energy levels
- SQUIDs – uses magnetisation
- NMR – uses nuclear spin
- QD/SET – uses electron energy states



Examples:

- Honeywell using Ion trap
- D-wave Technologies using SQUID
- IBM using NMR
- Google using superconductors

Quantum Computing

- Using Quantum Mechanical effects for solving computing problems
- Particularly useful for problems involving operations on massive data:

1. Cryptography/Cybersecurity
2. Accurate weather forecasting
3. Traffic optimisation
4. Financial models
5. Drug development
6. Astronomical data analysis