Quantum Computation

Tutorial

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A Quantum Computer uses qubits and the principles of quantum theory, such as superposition of states, in place of regular digital bits to do computations. The result is a computer that produces non-deterministic computational output, where there is a finite probability that you have arrived at your desired correct answer. But it also allows for the simultaneous computation of all possible branches for a given number of qubits. This enables certain problems that are nearly impossible on conventional computers to become tractable on a quantum computer, as well as improve the performance of certain problems such as the Deutsch oracle problem.

Problem 1

Describe and illustrate the form of the wavefunction in quantum theory. Discuss its properties and how it explains most of the major principles of quantum theory.

[Hint: See Lecture 1 and 2 of the Quantum Computation module]

c(x)

|c(x)|^2 = c(x)*c(x) = p(x)--(probability density function)

wave functions magnitude squared is equal to the probability Density function. So you can go between wave function and probabilities. And the reason why you have absolute value now is because you a function can have negative values but negative probabilities don't really make any sense at all.

key thing to remember is that your particles, unlike regular physics like standard naive interpretation of physics where things have a particular fixed date, like a particle is in one place. It is that your pen is on your desk, for example.

In the quantum mechanical interpretation of things which is correct. Every thing in the universe is in like a superposition of states and that superposition of states and he collapses. If something interacts with it.

Problem 2

Describe how qubits are constructed, including the principles used in its construction with the appropriate mathematical expressions, comparisons to a classical bit with the same notation, as well as the advantages that are offered by it with respect to computation.

[Hint: See Lecture 3 of the Quantum Computation module, (Moore and Mertens, 2011) section 15.2.2 and the Microsoft Quantum Computing for CS Video]

|0> = (1, 0) |1> = (0, 1)   (dirac vector notation)

A qbit is represented by $\binom{a}{b}$ where a and b are Complex numbers and $\|a\|^2 + \|b\|^2 = 1$

Superposition means the qbit is both 0 and 1 and the same time

When we **measure** the qbit, it **collapses** to an actual value of 0 or 1

- We usually do this at the end of a quantum computation to get the result

If a qbit has value $\binom{a}{b}$ then it collapses to 0 with probability $\|a\|^2$ and 1 with probability $\|b\|^2$

|q> = (u, v) : |u|^2 + |v|^2 = 1

quantum bit: we're no longer in a state 01 just like for a wave functions, a particle is no longer at a particular position, it's in a superposition of old positions with some probability for each position. so our qubit is a superposition of the zero and one state.

e.g. (1/sqrt(2), 1/sqrt(2)) --qubit

SUMMARY: any physical object which exists in the superposition of two states can be qubit (photon, electron)

|qr> = (u_1, v_1) ox (u_2, v_2) = (u_1*u_2, u_1*v_2, v_1*u_2, v_1*v_2)

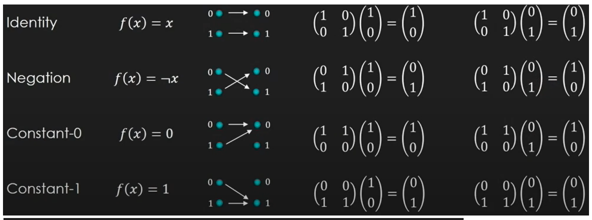
It's in superposition of states which |00>, |10>, |01>, |11>

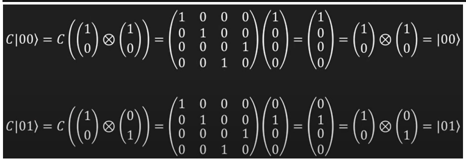
adv:

- parallel computing
- represent different parts the computation as I checks shake notes harmonics of your computational wave function, (reduce computation time)

Problem 3

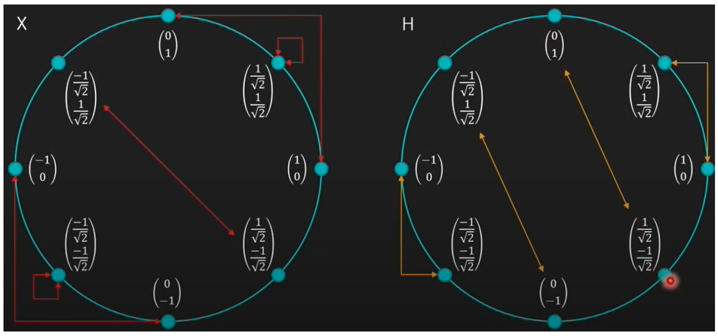
Draw the quantum circuits for the four main types of operations of a two qubit system including the conditional NOT gate and verify each operation using matrix multiplication on appropriate example quantum states.
[Hint: See Lecture 3 and 4 of the Quantum Computation module, (Moore and Mertens, 2011) section 15.2.7 and the Microsoft Quantum Computing for CS Video]





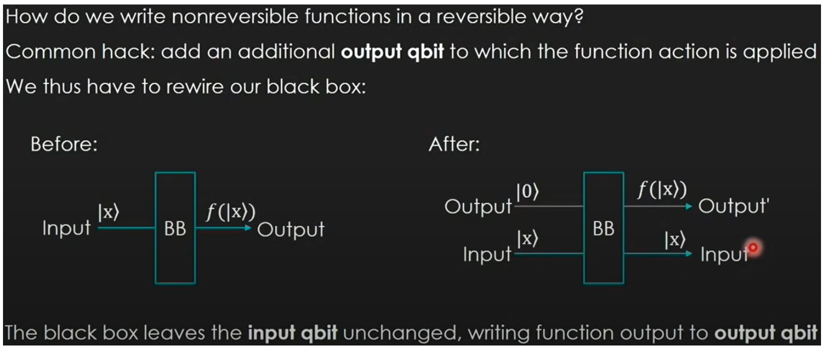
bit flip

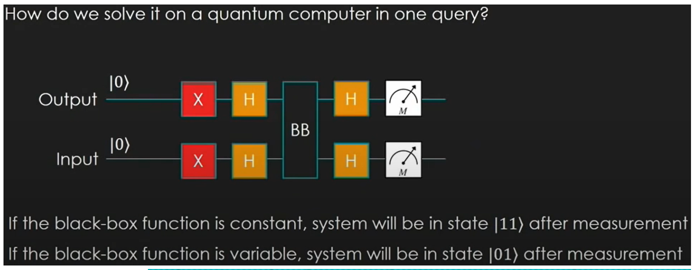
hadamard gate



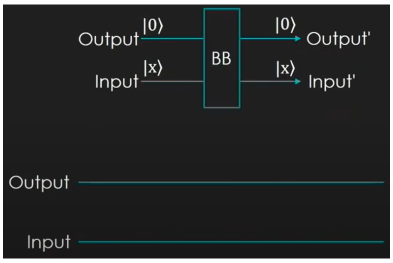
Problem 4

Describe why a quantum computer is well suited and offers advantages over conventional computers for the Deutsch problem.
[Hint: See Lecture 4 and 5 of the Quantum Computation module, (Moore and Mertens, 2011) section 15.4.1 and the Microsoft Quantum Computing for CS Video]

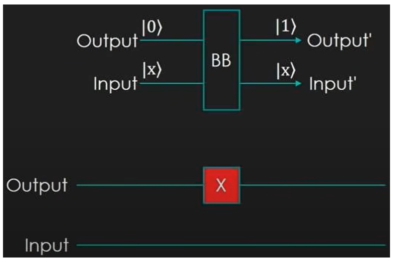


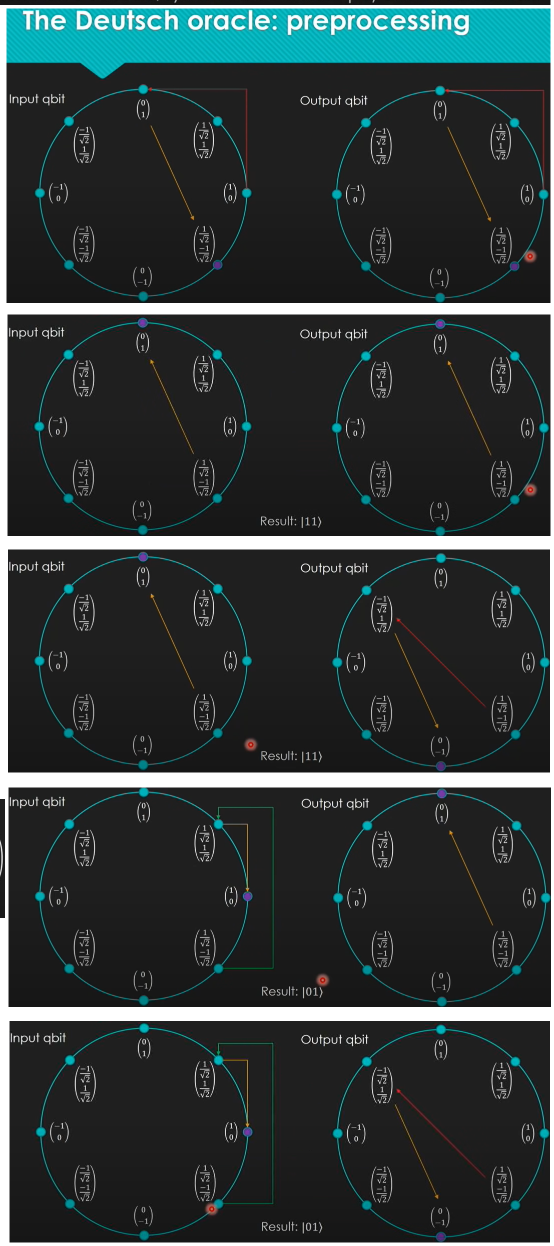


constant-0

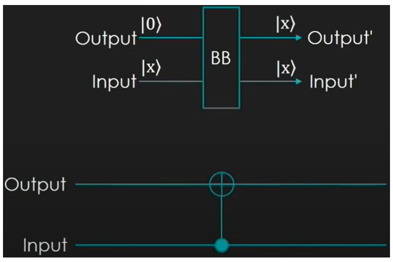


constant-1

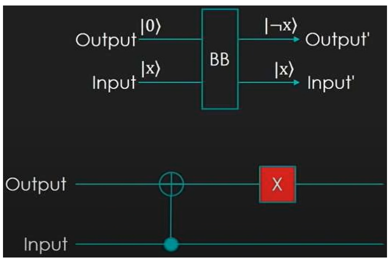


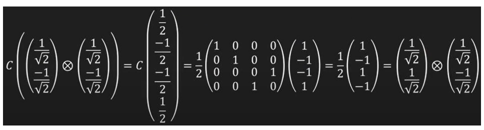


identity



negation





The intuition here is you are moving into a superposition of state. So, you have another degree of freedom, you're feeding through possibilities of ones and zeros, rather than just a one or just a zero and that gives you additional information.