Simulation of Quantum Computing Models

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Purpose:

This paper was done to familiarize myself with some of the basic concepts of Quantum Computing. It was a learning experience for me. This work provides **Quantitative Solutions and Simulations** for Quantum Computing (QC) models and examples. This material has been gathered from a number of QC books and papers. A list of some the books and papers used in this analysis are given at the end of this work. This is not original work. It is a compendium of various books and research papers.The goal is to capture basic Quantum Computing Concepts and Models using the mathematical tools Python/Spyder, ChatGPT, Formula Editor. We use this methodology to Simulate various Quantum Mechanical and Quantum Computing Phenomena.

Perspective:

When I took courses in Quantum Mechanics (QM) many years ago, the concepts and operations involved in QM seemed very foreign and abstract. The availability of Programming Languages that can capture the mathematics symbolically, has now made it possible to easily do mathematical operations and explore QM models, simulations, solutions, and plots of abstract math. The capability for these manipulations was unimaginable when I first studied QM. Being able to reproduce the original numerical results, and in particular, being able to run simulations and make the results visible with 2-D and 3-D graphics, which can be tilted, rotated, contrasted, thus being able to examine geometric details in phase space, has in some sense, mastered and made explicit many of the complexities of this subject. This work has been great fun.

Simulation Methodology

Simulation of quantum computers generally involves representing quantum states and operators in linear algebra and applying transformations in accordance with quantum mechanics. This is usually done in languages like Python, which have libraries like Qiskit, Cirq, and Pennylane specifically built for quantum computing.

However, theoretically, it is possible to simulate simple quantum systems using Vector Math because at its core, quantum mechanics relies heavily on Linear Algebra, Matrix Mechanics, Vector Tensor Products, and solutions of Eigenvalue Equations, all of which, for example, Mathcad, can easily accommodate. For example, we will represent qubits (quantum bits) as vectors and quantum gates as matrices and perform matrix multiplication to simulate the application of quantum gates to qubits. Note: The | and > symbols needed to define the names for the states of Dirac Notation, e.g. |Ψ> are only available in Symbol font. The results of these operations can be calculated using Mathcad operators and functions, but **the Dirac Notation symbols cannot be used as the Names** for the associated variables or functions. We will use the words bra and ket for the symbols <Ψ| and |Ψ>, respectively.

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