A Primer in Quantum Computing

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Course Description:

Ready to delve in the math and physics required for understanding quantum algorithms? Looking to gain valuable experience simulating quantum systems? Or just wanna know what the hype is all about? If so, this might be the class for you!

We'll start by laying a strong foundation in probability, linear algebra, complex numbers, quantum measurement, etc. From there, we'll apply what we've learned through Python simulations written using the QuTiP library.

By the end of the class, we will have enough tools under our belt to simulate quantum algorithms, including ones that have motivated the push for quantum computing and the pursuit of *quantum supremacy*.

Motivation:

Quantum computing is a relatively new way of thinking about computation, and for certain applications, may push the boundaries of what's currently possible.

This is especially interesting to scientists and engineers as the growth in computing power of classical computers, like your phone or laptop, tapers off in the coming decades.

Though there are many ways to *do* quantum computing, such as computing on trapped ions, superconducting circuits, etc; each promises (with differing pros and cons) efficient ways to factor large numbers, simulate quantum systems, and search databases, among other things.

Schedule:

Though we'll adapt based on the pace of the class, below is a tentative schedule for the five weeks we'll spend together.

Week	Topics	Goal / Takeaway	Python Lab
3/02	Intro to linear algebra, working with Dirac notation, superposition	Understand arbitrary single-qubit state superposition.	Google CoLab setup, bras and kets in QuTiP
3/09	Probability and	Quantum measurement	Measurement in QuTiP,

	quantum measurement, post-measurement state	is probabilistic and destructive. Describe the collapse of a single qubit in terms of probabilities.	generating statistics
3/23	Single-qubit gates, Deutsch algorithm	Understand the historical significance of Deutsch's algorithm. Describe the resulting outcomes using probability. Implement it yourself using QuTiP.	Deutsch algorithm
3/30	Tensor product and multi-qubit states, gates, and measurement	Extend gates and measurement theory to arbitrarily many qubits.	Multi-qubit systems in QuTiP
4/06	Deutsch-Jozsa algorithm, conclusion and outlook	Extend Deutsch algorithm from earlier to handle arbitrarily many qubits (Deutsch Jozsa)	Deutsch Jozsa algorithm

Labs:

Each class will be divided into a lecture/seminar style portion, followed by a lab where you'll get a chance to apply what you've learned.

We'll be using QuTiP (Quantum Toolbox in Python) and Google CoLab to transfer the math and algorithms we learn into code. These tools are ubiquitous in quantum computing research/development, so hopefully you'll find gaining experience in these to be valuable!

Prerequisites:

- No knowledge of quantum physics or Python programming is required nor expected.
- Studying quantum computing involves a solid understanding of basic linear algebra, specifically vector-vector, vector-matrix operations. If these words are completely foreign to you, don't worry! We'll spend the first lecture going over what we'll need for the class; these are skills we'll be strengthening along the way.

- Please bring a laptop with access to a Google account for our labs. If this is an issue in any way, please contact me or the HSSP coordinators and we’ll figure something out.