5470 Project

***Due**: Tuesday, December 9th, 2025 @ 5:00PM*

CPSC 4470/5470 Introduction to Quantum Computing (Fall 2025)

1 Introduction

Quantum computing is more than a new technology. It represents a new way of thinking about information and computation. In this project, you will explore one quantum idea in depth and then bring it to life for a non-expert audience. You will first learn the underlying science rigorously and then communicate it in a way that is accurate, intuitive, and creative. It is important to note that, as with most concepts in quantum mechanics/computing, some everyday analogies could be misleading. By the end, you should understand not only at a mathematical level, but also know how to translate your understanding into refined intuitions for communicating with people outside the field.

2 Project Overview

You will begin by selecting one person outside this class (e.g., a friend, roommate, or family member) who is curious but not trained in quantum computing. Show them the menu of questions in Section 3 and ask which one intrigues them the most. Their choice will define your topic.

In Week 1, you will interview your chosen person and record their thoughts, curiosities, and confusions. In Week 2, you will research the topic and write a concise, expert-facing technical note that could serve as a reference for scientists or engineers. In Week 3, you will design a personalized explainer for your interviewee, written or visual, that clearly communicates the core idea in accessible language. Finally, in Week 4, you will reflect on what you learned about both quantum science and the art of explanation, incorporating feedback from your interviewee about what surprised them and what remains puzzling.

If you use any generative AI tools for writing or code, maintain a transparent `AI-use.log` file recording prompts, edits, and your final decisions. All submissions should be compiled into a single folder or GitHub repository.

Submission.

Once you have completed the project and are ready to submit, upload **one PDF file** to Gradescope: `project.pdf` (including all required sections). If your project involves programming, webpages, or videos, please include references to your source (e.g., with a GitHub link, stable URL, or YouTube link) in the PDF file.

3 Menu of Topics

Show these questions to your interview partner and let them pick the one that sparks the most curiosity or confusion. Each is deliberately open-ended and meant to invite wonder rather than a single correct answer.

1. How Does Nature Hide and Reveal Information?

Quantum systems store information in delicate waves of possibility (called superpositions) that seem to exist in many states at once. If information is hidden in these waves, how can we ever read it out without disturbing it? Explore why encoding and retrieving data from qubits is so difficult and what this reveals about how the universe handles knowledge itself.

2. How Do I Program a Quantum Computer?

Every quantum program is written using a small set of basic instructions called *quantum gates*. Somehow, these few discrete, primitive moves (like the Hadamard, T, and CNOT gates) can reproduce every transformation allowed by quantum mechanics. How can something so limited generate infinite variety? Investigate the logic behind *universal quantum computation* and illustrate, with an example or visualization, how these elementary gates combine into limitless possibilities.

3. What Does a Quantum Computer Look Like Inside?

A classical computer has neat layers: processors, memory, caches, and storage. Does a quantum computer need the same organization, or something entirely different? What would "quantum memory" or "quantum cache" even mean, when copying data is forbidden by physics? Consider how information must be moved and stored in a machine where observation itself can change the outcome.

4. Why Could Quantum Computing Break the Internet?

Modern encryption relies on problems that are easy to check but nearly impossible to solve, at least for classical computers. Quantum algorithms threaten that balance by revealing hidden periodic patterns in numbers. How does a quantum computer use interference and phase estimation to uncover those patterns, and what would that mean for the security of online communication?

5. How Could a Quantum Computer Search for a "Needle in a Haystack" Faster?

Grover's algorithm can find one marked item in a large, unstructured collection faster than any classical search. But why exactly does it gain a $\sqrt{N}$ speedup, and why can't quantum mechanics do even better? Use this question to explore how amplitude amplification redirects probability, and what this reveals about the limits of quantum speedups.

4 Timeline and Deliverables

The final submission document should contain four main sections: **The Conversation**, **The Technical Note**, **The Personal Explainer**, and **Reflection and Feedback**. To stay organized, it is strongly recommended that you follow the suggested weekly timeline, completing roughly one section per week. This suggested timeline ensures that your final submission reflects both scientific depth and authentic engagement with your chosen audience.

Week 1: The Conversation

Interview your chosen partner. Ask what they have heard about quantum computing, what excites or confuses them, and why they chose their question. Capture at least three direct quotes. Write a one-page summary identifying your interviewee, their chosen topic, and the key questions, ideas or misconceptions that emerged.

Week 2: The Technical Note

Write a comprehensive technical note explaining the chosen concept in precise, expert-facing language. This note should serve as a scientific reference for everything discussed later in your explainer. Begin with an **executive summary** (one-half to one page) that clearly articulates the key claims or takeaways relevant to the chosen topic, written at the level of a technical abstract. Follow this with a concise statement of the theoretical principles, a worked derivation or small simulation, and at least one figure or diagram that you create. Cite primary sources such as textbooks, research papers, or lecture notes. An **unlimited appendix** can be provided at the end of the submission for mathematical derivations, empirical evidence, or computational results that substantiate each claim made in the executive summary. Figures or simulations should be clearly labeled and reproducible. All equations, results, and references must be scientifically sound and properly cited.

Week 3: The Personal Explainer

Create a public-facing explainer aimed specifically at your interviewee. Address their questions or misconceptions directly. You may choose any form, such as an essay, illustrated story, video, or interactive page, but the explanation must include at least one original analogy or visual element. Your goal is not to oversimplify, but to convey real understanding in accessible form. Create an accessible but accurate explanation aimed at your interviewee. Every time a non-trivial idea or technical claim appears, the explainer should explicitly reference the corresponding section of the Technical Note, e.g., "(see Technical Note, Appendix A)." Some useful resources for visualization:

- Bloch sphere using QuTiP library: `https://qutip.org/docs/4.0.2/guide/guide-bloch.html`
- Quantum circuit and Feynman-path diagrams using QSL tool: `https://www.yongshanding.com/viz/`

Week 4: Reflection and Feedback

Share the Explainer to your interviewee and write a one-page reflection that integrates both your own learning and your interviewee's reaction. Ask your interviewee to respond to several short questions:

- What concept surprised you the most?
- What part still feels puzzling or mysterious?
- Did this change how you think about computing?
- What explanation or analogy helped you the most?

Summarize their feedback and reflect on what you learned about communicating quantum ideas, what misconceptions you discovered, and what still feels unresolved.

5 Grading Rubric

Component	**Weight**	**Description**
Interview Summary	10 pts	Authentic conversation; thoughtful topic selection; clear quotes and insight.
Technical Note	30 pts	Scientifically rigorous and well-structured; includes derivation or simulation; technically accurate and well-cited.
Personal Explainer	30 pts	Accessible and engaging; clearly tied to the interviewee's perspective; includes original visual or analogy.
Reflection & Feedback	20 pts	Integrates interviewee's responses with your own insights; shows genuine engagement with both science and communication.
Integrity & Craft	10 pts	Clean presentation, proper citations, full AI-use transparency, and timely submission.