Lectures on Quantum Information Science

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Contents

Prerequisites

This is a *sample* book written in **Markdown**. You can use anything that Pandoc's Markdown supports, e.g., a math equation $a^2 + b^2 = c^2$.

The **bookdown** package can be installed from CRAN or Github:

```
install.packages("bookdown")
# or the development version
# devtools::install_github("rstudio/bookdown")
```

Remember each Rmd file contains one and only one chapter, and a chapter is defined by the first-level heading `#`.

To compile this example to PDF, you need XeLaTeX. You are recommended to install TinyTeX (which includes XeLaTeX): https://yihui.org/tinytex/.

Chapter 1

Quantum interference

About complex numbers, called probability amplitudes, that, unlike probabilities, can cancel each other out, leading to quantum interference and qualitatively new ways of processing information.

The classical theory of computation does not usually refer to physics. Pioneers such as Alan Turing, Alonzo Church, Emil Post and Kurt G”{o}del managed to capture the correct classical theory by intuition alone and, as a result, it is often falsely assumed that its foundations are self-evident and purely abstract. They are not![1]

The concepts of information and computation can be properly formulated only in the context of a physical theory — information is stored, transmitted and processed always by *physical* means. Computers are physical objects and computation is a physical process. Indeed, any computation, classical or quantum, can be viewed in terms of physical experiments, which produce **outputs** that depend on initial preparations called **inputs**. Once we abandon the classical view of computation as a purely logical notion independent of the laws of physics it becomes clear that whenever we improve our knowledge about physical reality, we may also gain new means of computation. Thus, from this perspective, it is not very surprising that the discovery of quantum mechanics in particular has changed our understanding of the nature of computation. In order to explain what makes quantum computers so different from their classical counterparts, we begin with the rudiments of quantum theory.

[1] Computation is a physical process. Computation is a physical process. Computation is …

1.1 Two basic rules

1.2 Quantum interference (the failure of probability theory)

1.3 Superpositions

1.4 Interferometers

1.5 Qubits, gates, and circuits

1.6 Quantum decoherence

1.7 Computation: deterministic, probabilistic, and quantum

1.8 Computational complexity

1.9 Outlook

1.10 Notes and Exercises

1.11 Supplement: Physics against logic, via beamsplitters

1.12 Supplement: Quantum interference revisited (still about beamsplitters)

Chapter 2

Qubits

Chapter 3

Measurements

Chapter 4

Quantum entanglement

Chapter 5

Quantum algorithms

Chapter 6

Bell's theorem

Chapter 7

Decoherence, and elements of quantum error correction

Chapter 8

Density matrices

Chapter 9

Quantum channels (or CP maps)

Chapter 10

Quantum error correction and fault tolerance