Introduction to quantum information processing (CMSC 858K)

Andrew Childs

Tuesday/Thursday, 12:30–1:45 pm, CSI 3120

http://ter.ps/introqip
Why quantum information?

Moore’s Law: # of transistors on a CPU doubles every two years. Feature sizes will be on the atomic scale in 15-20 years.

At this scale, quantum mechanics becomes important.

• Does QM limit our ability to compute (e.g., due to the uncertainty principle)?
• Does QM offer computational advantages?

Sources: Intel; press reports; Bob Colwell; Linley Group; IB Consulting: The Economist

*Maximum safe power consumption
Shor’s algorithm

Factoring integers is believed to be computationally difficult.

\[
\begin{align*}
3107418240490043721350750035888567930037346022842 \\
7275457201619488232064405180815045563468296717232 \\
8678243791627283803341547107310850191954852900733 \\
7724822783525742386454014691736602477652346609 \\
&= 1634733645809253848443133883865090859841783670033 \\
&\quad 092312181110852389333100104508151212118167511579 \\
&\quad \times \\
&1900871281664822113126851573935413975471896789968 \\
&\quad 51549366663859088027103802104498957191261465571
\end{align*}
\]

The security of modern electronic commerce relies on this assumption!

In 1994, Peter Shor showed that quantum computers can efficiently factor integers.

This discovery led to the extensive theory of quantum information processing and motivated efforts to build quantum information processing devices.
QIP is multidisciplinary

Quantum information processing brings together ideas from computer science, mathematics, and physics (also engineering, chemistry, philosophy, …)

Examples of impact on related fields:

• New tools for theoretical physics (from entanglement theory, computational complexity, etc.)
• Efforts to build QIP devices push the frontier of experimental physics
• Quantum computational complexity: new perspectives/tools for the theory of computation
Goals of this course

• Introduce fundamental concepts of quantum information processing

• Be accessible to students in CS, math, or physics (no prior experience with quantum mechanics required, but you should have a strong background in linear algebra)

• Prepare students for further study of quantum information processing
Main topics

• Mathematical framework of quantum mechanics/quantum information processing
• Quantum algorithms and complexity theory
• Quantum information theory
• Quantum error correction and fault tolerance
• Quantum cryptography
Evaluation

Assignments (5)  8% each

Project  30%
Expository paper on a quantum information topic of your choice

Final exam  30%
Take-home, comprehensive

CMSC 858K is a qualifying course for the Algorithms and Computation Theory area.
Quantum information at UMD

• Joint Center for Quantum Information and Computer Science (QuICs)

• Joint Quantum Institute (JQI)
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