Quantum Computing:
From Principles to Possibilities

David McKinley
OLLI@UNT, Fall 2025

Online Resources

When I first decided to try to understand what quantum computing was all about, I came across a PDF file I could download: A text entitled, “Quantum Computing: A Gentle Introduction” by Eleanor Rieffel and Wolfgang Polak. The title sounded promising.
(https://s3.amazonaws.com/arena-attachments/1000401/c8d3f8742d163b7ffd6ae3e4e4e07bf3.pdf)

It turned out to be a book of about 400 pages, and might be complete and accurate, but “a gentle introduction” it was not. By page 33, it was introducing tensor products to explain multiple qubit systems this way:

> The *tensor product* $V \otimes W$ of two vector spaces V and W with bases
>
> $A = \{|\alpha_1\rangle, |\alpha_2\rangle, \ldots, |\alpha_n\rangle\}$ and $B = \{|\beta_1\rangle, |\beta_2\rangle, \ldots, |\beta_m\rangle\}$
>
> respectively is an nm-dimensional vector space with a basis consisting of the nm elements of the form
>
> $|\alpha_i\rangle \otimes |\beta_j\rangle$ where $\otimes$ is the tensor product, an abstract binary operator that satisfies the following relations:
>
> $$(|v_1\rangle + |v_2\rangle) \otimes |w\rangle = |v_1\rangle \otimes |w\rangle + |v_2\rangle \otimes |w\rangle$$
> $$|v\rangle \otimes (|w_1\rangle + |w_2\rangle) = |v\rangle \otimes |w_1\rangle + |v\rangle \otimes |w_2\rangle$$
> $$(a|v\rangle) \otimes |w\rangle = |v\rangle \otimes (a|w\rangle) = a(|v\rangle \otimes |w\rangle).$$

Unfortunately, as it turns out, this sort of mathematics isn’t just a confusing way to *explain* quantum computing, it really is the *essence* of quantum computing. Ultimately, “quantum computing” means taking advantage of the fact that real quantum systems behave in some specific ways that can be modeled with this sort of complex higher math. The goal of quantum computing is to find problems that can be solved efficiently by exploiting that mathematical model in some way, and then causing a real quantum system to move through a series of transformations that correspond to the process developed to solve the problem mathematically.

In other words, to *really* understand quantum computing, you need to understand this complex mathematical model.

My goal, though – personally and for the purpose of this class – was to develop some sort of intuitive feel for what quantum computing is without being bogged down in all that math. My solution was to try to introduce a bit of the mathematical underpinnings to at least provide a flavor for what quantum computing “looked like,” and then step back with the abstraction of the Bloch sphere to relate the physical elements of quantum computing to the pure mathematical nature of quantum information science in a more visual way.

I am, of course, not the only person who has been struggling to understand and then explain this interesting new science to general audiences without digging into extensive amounts of complex higher mathematics. Some of those people have recorded YouTube videos with their attempts, and with enough searching, reading a few papers and watching a lot of videos, I have begun to feel like I, at least, can understand enough of the "how it works" to be able to follow discussions about what it may or may not eventually accomplish, and what the challenges are.

So, with that introduction, here are links to some of the more useful resources I have found.

Introduction to Quantum Information Science

(https://qubit.guide/index) – This on-line text by Artur Ekert, Timothy Hosgood, Alastair Kay, and Chiara Macchiavello is a *slightly* more approachable treatment of the topic than the "Gentle Introduction" book described above. It is still filled with a lot of math, however. In fact, in the introduction it claims, "by the end of this book you will have learnt a fair bit more than what might usually be covered in a standard quantum information science course that you would find in a mathematics masters degree."

On the plus side, however, it comes with a video lecture series by Artur Ekert (https://www.youtube.com/playlist?list=PLkespgaZN4gmu0nWNmfMflVRqw0VPkCGH), which I found useful in getting that initial foothold into what it was all about. I'll admit I did not make it through either the entire text or set of video lectures, but the early chapters and lectures were enlightening.

Looking Glass Universe videos

Mithuna Yoganathan has recorded a series of YouTube videos covering various topics in quantum mechanics and quantum computing. These are definitely the most accessible that I have found. While she does delve into the math, she keeps it at a basic level, and goes slow enough that it is not hard to follow.

(https://www.youtube.com/playlist?list=PLg-OiIIbfPj1t7zYsf6aj7wrGb9fghFDk) is a playlist for a series of eight videos that make up a "Quantum Mechanics Course." With simplified math, and easy-to-understand demonstrations using laser cat-toys and polarizing filters, she introduces all the key concepts of quantum mechanics in an understandable way. In particular, I think that her explanations of superposition and how it relates to measurement bases is excellent. The last of these eight videos, "What *is* a qubit?" is particularly relevant to the topic of quantum computing.

Dr. Yoganathan has also recorded a number of other videos on similar topics, any of which I would recommend. Three which are particularly relevant to quantum computing are:

I made a (useless) quantum computer at home. (https://www.youtube.com/watch?v=muoIG732fQA), which concludes with her thinking that perhaps her homemade quantum computer isn't useless after all. This leads to another video,
What can my homemade quantum computer do? (https://www.youtube.com/watch?v=tHfGucHtLqo)
Another interesting video she made is,
Why I Left Quantum Computing Research. (https://www.youtube.com/watch?v=pDj1QhPOVBo)

Scott Aaronson videos

Mentioned in the lecture, Scott Aaronson is a quantum computing researcher at the University of Texas at Austin, and has made a number of videos and appeared in others being interviewed about quantum computing, it's hype, and reality. Searching for his name on YouTube will turn up a number of interesting videos. One that I enjoyed is:

Straight Talk on Quantum Computing (https://www.youtube.com/watch?v=AVYRW9Qdp7Q)
This is a 98 minute interview by another knowledgeable scientist that is fascinating, very accessible, and covers some interesting information on AI topics, as a bonus.

"The Talk" (https://www.smbc-comics.com/comic/the-talk-3)
Just for fun, this is a comic strip that Scott Aaronson co-authored on the topic of teaching your children about … ahem ... the secrets of quantum computing.

Bell's Inequality

One fascinating topic that I only touched on in the lecture is Bell's Inequality, and the experimental evidence that demonstrates that quantum entanglement really behaves as described in theory, although that violates "common sense" principles of locality and realism. Several videos take on this complex topic – some going into more detail about how the experiment itself works, and others more into what it means.

Bells Theorem: The Quantum Venn Diagram Paradox
(https://www.youtube.com/watch?v=zcqZHYo7ONs)
This video is a collaboration between 3Blue1Brown (Grant Sanderson, of whom I am a great fan) and MinutePhysics, (Henry Reich) leaning more into the "what does it mean" treatment.

Some light quantum mechanics
(https://www.youtube.com/watch?v=MzRCDLre1b4) A companion video by the same collaborating producers on the more general topic of quantum mechanics and the math behind it.

The EPR Paradox & Bell's inequality explained simply
(https://www.youtube.com/watch?v=f72whGQ31Wg) Another attempt to explain Bell's experiment – pretty much in the middle between how it works and why it matters.

Bell's Inequality
(https://www.youtube.com/watch?v=qd-tKr0LJTM) This video goes into even more detail of an example of a Bell's inequality experiment using polarized light. His final conclusion that the entangled particles are "in constant instantaneous communication" is probably not how most physicists would put it.

Quantum Mechanics – Bell's Inequality I & II
(https://www.youtube.com/watch?v=sAXxSKifgtU) and
(https://www.youtube.com/watch?v=8UxYKN1q5sI)
Two-part video (about 30 minutes total) that explains Bell's inequality thoroughly, but is a bit harder to actually follow. Yet, if you've made it through the others, and still don't feel like you quite "get it," this is a good follow-up to try to complete your understanding.

Euler's Formula

Another interesting topic I touched on only lightly in the lecture was Euler's Formula:

$$e^{i\theta}=\cos(\theta)+i\sin(\theta)$$

This turns out to be a critical mathematical foundation for understanding much of quantum mechanics, and other things as well. It is also fascinating on its own. What can it even mean to raise a number to an imaginary power? And why is it related to angles and sines and cosines?

It certainly bothered me that I didn't really "get" this when trying to learn about quantum mechanics and quantum computers, so I dug into it as well, and found these videos that I thought did a nice job of explaining why it is (a) true, and (b) significant.

The most beautiful equation in math, explained visually [Euler's Formula]
(https://www.youtube.com/watch?v=f8CXG7dS-D0) A nice history of Euler's Formula and a basic explanation about it – if you are comfortable dealing with exponents and logarithms. It gets a bit harder to follow later on, as he really works on deriving the formula visually rather than algebraically.

What is Euler's formula actually saying?
(https://www.youtube.com/watch?v=ZxYOEwM6Wbk) 3Blue1Brown (Grant Sanderson) almost hour-long lesson about Euler's formula. This is a bit of a different style of video, much more like a teacher/student lecture, but with some interesting things to say about what an exponential function really means – defined as an infinite series.

Complex Numbers 3: The Magic of Euler's Formula
(https://www.youtube.com/watch?v=iULcFfYnEGU) An elegant explanation of Euler's formula, including showing how it can be derived using the Taylor series for e^x, cos(x) and sin(x). Two little things about this video, though. Throughout, he uses "j" instead of "i" to represent the base imaginary number (square root of -1). This is because it is part of a series about electrical engineering, and that's the convention in that particular discipline. Second, he does not explain *why* those Taylor series are valid for e^x, cos(x) and sin(x). He just shows that given those series, you can derive Euler's formula.

Why do trig functions appear in Euler's formula?
(https://www.youtube.com/watch?v=TLgZit1HTxA) This video is somewhat harder to follow, in my opinion, but I include it here because it is similar to the previous video showing how to derive Euler's formula from the corresponding Taylor series, but in addition, it shows *why* those are the Taylor series for e^x, cos(x) and sin(x) – though you need to be comfortable with derivative calculus to follow that explanation.