ADDITIONAL RESOURCES FOR LEARNING QUANTUM COMPUTING

This is a non-exhaustive list of resources for learning quantum computing compiled by members of the QxQ Academic Team and friends in the quantum community. In this fast-growing field, there are new resources every day, but this is a good place to start. Good luck on your quantum journey!

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Textbooks

Quantum Information and Quantum Computation, Nielsen and Chuang

- **URL**:
  - https://www.amazon.com/Quantum-Computation-Information-10th-Anniversary/dp/1107002176
- **Summary**:
  - A comprehensive introduction to the major tenets of quantum computing, with plenty of explanation and practice problems to guide the way.
- **Intended Audience**:
  - Advanced university undergraduate students and graduate students, with background in quantum physics and mathematics (i.e. linear algebra, probability, and some group theory).
- **Density**:
  - It is a technical book, with plenty of math and hard problems to work through. That being said, the book is written in a fairly engaging manner and can be read for leisure.
- **Reviews**:
  - "Great!" -Tim the Beaver, MIT Class of 2023, Department of Physics
  - "It's got everything! Once I had the basics down, this was my first serious step into learning quantum computing." - Corbin, Waterloo class of 2021, Engineering

Quantum Computer Science: An Introduction, Mermin

- **URL**:
  - https://www.amazon.com/Quantum-Computer-Science-David-Mermin/dp/0521876583
- **Summary**:
  - This book is a concise introduction to quantum computation, developing the basic elements of this new branch of computational theory without assuming any background in physics. It begins with an introduction to the quantum theory from a computer-science perspective. It illustrates the quantum-computational approach with several elementary examples of quantum speed-up, before moving to the major applications: Shor's factoring algorithm, Grover's search algorithm, and quantum error correction.
- **Intended Audience**:
  - The book is intended primarily for computer scientists who know nothing about quantum theory, but will also be of interest to physicists who want to learn the theory of quantum computation, and philosophers of science interested in quantum foundational issues. It evolved during six years of teaching the subject to undergraduates and graduate students in computer science, mathematics, engineering, and physics, at Cornell University.

Quantum Computing: A Gentle Introduction, Rieffel and Polak

- **URL**:

    - https://www.amazon.com/Quantum-Computing-Introduction-Engineering-Computation/dp/0262526670
- **Summary**:
    - A thorough exposition of quantum computing and the underlying concepts of quantum physics, with explanations of the relevant mathematics and numerous examples.
- **Intended Audience**:
    - The book makes quantum computing accessible to students and professionals in mathematics, computer science, and engineering. A reader with no prior knowledge of quantum physics (but with sufficient knowledge of linear algebra) will be able to gain a fluent understanding by working through the book.
- **Notes:** Also see this related paper (https://arxiv.org/abs/quant-ph/9809016) by the same authors.

An Introduction to Quantum Computing, Kaye, Laflamme, and Mosca

- **URL**:
    - https://www.amazon.com/Introduction-Quantum-Computing-Phillip-Kaye/dp/019857049X
- **Summary**:
    - A simplified version of *Quantum Information and Quantum Computation* by Nielsen and Chuang. It is still technical in nature, but it doesn't get into as many details.
- **Intended Audience**:
    - University undergraduate students comfortable with complex numbers and introductory linear algebra.
- **Density**:
    - It is a technical book based heavily on the mathematics of quantum computing.
- **Reviews**:
    - "According to one of the authors (Mosca), this book was developed over a decade by collecting notes on where undergraduate students typically struggled with Nielsen and Chuang's book. Therefore, it follows much the same format, but spends more time explaining tricky concepts and doesn't cover as much content." - Corbin, Waterloo class of 2021, Engineering

The Theory of Quantum Information, Watrous

- **URL**:
    - https://www.amazon.com/Theory-Quantum-Information-John-Watrous/dp/1107180562
- **Summary**:
    - This largely self-contained book on the theory of quantum information focuses on precise mathematical formulations and proofs of fundamental facts that form the foundation of the subject.
- **Intended Audience**:
    - Intended for graduate students and researchers in mathematics, computer science, and theoretical physics seeking to develop a thorough understanding of key results, proof techniques, and methodologies that are relevant to a wide range of research topics within the

theory of quantum information and computation. The book is accessible to readers with an understanding of basic mathematics, including linear algebra, mathematical analysis, and probability theory.

Quantum Information Theory, Wilde

- **URL**:
  - https://www.amazon.com/Quantum-Information-Theory-Mark-Wilde/dp/1107176166
- **Summary**:
  - Significant attention is given to quantum mechanics for quantum information theory, and careful studies of the important protocols of teleportation, superdense coding, and entanglement distribution are presented.
- **Intended Audience**:
  - Ideal entry point for graduate students into quantum information theory.

Classical and Quantum Computation, Kitaev, Shen, and Vyalyi

- **URL**:
  - https://www.amazon.com/Classical-Quantum-Computation-Graduate-Mathematics/dp/0821832298
- **Summary**:
  - This book is an introduction to a new rapidly developing theory of quantum computing. It begins with the basics of classical theory of computation. The second part of the book provides an exposition of quantum computation theory. In concluding sections, several related topics are discussed (parallel quantum computation, a quantum analog of NP-completeness, and quantum error-correcting codes).
- **Intended Audience**:
  - Graduate students in mathematics

Other Books

Quantum Computing Since Democritus, Aaronson

- **URL**:
  - https://www.amazon.com/Quantum-Computing-since-Democritus-Aaronson/dp/0521199565
- **Summary**:
  - This book takes readers on a tour through some of the deepest ideas of maths, computer science and physics. Full of insights, arguments and philosophical perspectives, the book covers an amazing array of topics. Beginning in antiquity with Democritus, it progresses through logic and set theory, computability and complexity theory, quantum computing, cryptography, the information content of quantum states and the interpretation of quantum mechanics.
- **Intended Audience**:
  - Aaronson's informal style makes this fascinating book accessible to readers with scientific backgrounds, as well as students and researchers working in physics, computer science, mathematics and philosophy.

Quantum Computing for Everyone, Bernhardt

- **URL**:
  - https://mitpress.mit.edu/books/quantum-computing-everyone
- **Summary**:
  - An accessible introduction to an exciting new area in computation, explaining such topics as qubits, entanglement, and quantum teleportation for the general reader.
- **Intended Audience**:
  - Accessible to anyone who is comfortable with high school mathematics

How to Teach Quantum Physics to Your Dog, Orzel

- **URL**:
  - https://www.amazon.com/How-Teach-Quantum-Physics-Your/dp/1416572295#:~:text=When%20physics%20professor%20Chad%20Orzel,treats%2C%20and%20going%20for%20walks.
- **Summary**:
  - With great humor and clarity, Chad Orzel explains to his dog, and to human readers, just what quantum mechanics is and how it works—and why, although you can't use it to catch squirrels or eat steak, it's still bizarre, amazing, and important to every dog and human.
- **Density**:
  - Highly introductory; fun and conversational tone

Technical Review Papers

A Quantum Engineer's Guide to Superconducting Qubits, Krantz et al.

- **URL**:
  - https://arxiv.org/abs/1904.06560
- **Summary**:
  - The aim of this review is to provide quantum engineers with an introductory guide to the central concepts and challenges in the rapidly accelerating field of superconducting quantum circuits. Over the past twenty years, the field has matured from a predominantly basic research endeavor to one that increasingly explores the engineering of larger-scale superconducting quantum systems. Here, we review several foundational elements -- qubit design, noise properties, qubit control, and readout techniques -- developed during this period, bridging fundamental concepts in circuit quantum electrodynamics (cQED) and contemporary, state-of-the-art applications in gate-model quantum computation.

Basic Concepts in Quantum Information, Steven Girvin

- **URL**:
  - https://arxiv.org/abs/1302.5842
- **Summary**:
  - These notes present a brief introduction to the basic theoretical concepts behind quantum information and the 'second quantum revolution.' They also provide an introduction to 'circuit QED' as an architecture for constructing quantum information processors.
- **Intended Audience**:
  - Primarily those with a physics background with experience in quantum physics / computing.
- **Density**:
  - Relatively dense and moves quickly, but covers a lot of ground!
- **Reviews**:
  - This is a great review of quantum information and cQED! Worth reading through!
    ~ Shoumik Chowdhury, Yale University (B.S. 2021, Math/Physics).
- **Notes**: See also
  - Blais, Alexandre, Steven M. Girvin, and William D. Oliver. "Quantum information processing and quantum optics with circuit quantum electrodynamics." Nature Physics (2020): 1-10. Accessible links here and in Nature.

Websites

Quantum Country, Michael Nielson

- **URL**:
  - https://quantum.country/
  - Read: "Quantum Computing for the Very Curious" https://quantum.country/qcvc
- **Summary**:
  - A free introduction to quantum computing and quantum mechanics. To maximize retention, it is written in a mnemonic medium and offers short conceptual reviews of the material. It covers the basic principles of quantum computing and quantum mechanics, as well as two applications: Grover's Search algorithm and quantum teleportation.
- **Intended Audience**:
  - This series of essays assumes only knowledge of complex numbers and basic linear algebra.

Shtetl-Optimized, Aaronson

- **URL**:
  - https://www.scottaaronson.com/blog/
- **Summary**:
  - Scott Aaronson's blog
- **Reviews**:
  - "I learned Shor's algorithm for the first time from this website. Very engaging and visual content!" - Corbin, Waterloo class of 2021, Engineering

The Quantum Atlas

- **URL**:
  - https://quantumatlas.umd.edu/
- **Summary**:
  - An NSF-funded project to demystify quantum physics. Lots of illustrations and animations to help you understand *weird* phenomena.
- **Reviews**:
  - "As someone who is new to learning quantum physics, the creativity of this website has helped me wrap my mind around the counter-intuitive nature of quantum." -Rachel, QxQ Program Director

Coding Resources

Qiskit Textbook: Learn Quantum Computation Using Qiskit, IBM Quantum

- **URL**:
  - https://qiskit.org/textbook/preface.html
- **Summary**:
  - This textbook is a university quantum algorithms/computation course supplement based on Qiskit to help learn: 1) The mathematics behind quantum algorithms 2) Details about today's non-fault-tolerant quantum devices 3) Writing code in Qiskit to implement quantum algorithms on IBM's cloud quantum systems
- **Intended Audience:**
  - University-level students

Other Resources

Quantum Computers Explained – Limits of Human Technology (video), Kurzgesagt – In a Nutshell

- **URL**:
  - https://www.youtube.com/watch?v=JhHMJCUmq28
- **Summary**:
  - Where are the limits of human technology? And can we somehow avoid them? This is where quantum computers become very interesting.
- **Density**:
  - Brief introductory video.

Quantum Computing for the determined (video playlist), Michael Nielson

- **URL**:
  - https://www.youtube.com/playlist?list=PL1826E60FD05B44E4
- **Summary**:
  - 22 video series about quantum computing (10-15 minutes each)
- **Intended Audience**:
  - Introductory

Introduction to Quantum Information (video lectures), John Preskill

- **URL**:
  - Part 1: https://www.youtube.com/watch?v=Q4xBlSi_fOs
  - Part 2: https://www.youtube.com/watch?v=PJ6HbxBKZ68

- **Summary**:
    - An introduction to quantum information that covers big pictures questions about the field. It talks about why to study quantum, the basics of quantum information processing, qubits, the notion of entanglement, quantum algorithms, and quantum error correction.
- **Intended Audience**:
    - This lecture (split into two parts) is a high-level talk intended for people working in the field of quantum information. However, it is easily accessible to a non-technical audience as well!
- **Density**:
    - Roughly 2 hours of lecture, but has a good mix between high-level overview and details.
- **Reviews**:
    - John Preskill is a great speaker and is really able to convey an overview of the big picture ideas in the field of quantum information. Prof. Preskill is able to easily convey complex topics in quantum information using helpful analogies, but also explains the underlying math as well. This talk is also helpful for understanding current problems and research areas in the field.

      ~ Shoumik Chowdhury, Yale University (B.S. 2021, Math/Physics).

Quantum Computing Expert Explains One Concept in 5 Levels of Difficulty (WIRED video)

- **URL**:
    - https://www.youtube.com/watch?v=OWJCfOvochA
- **Summary**:
    - IBM's Dr. Talia Gershon (Senior Manager, Quantum Research) explains quantum computing to 5 different people; a child, teen, a college student, a grad student and a professional. Part of WIRED Magazine's "5 Levels of Difficulty" series.
- **Intended Audience**:
    - Anyone! This is a non-technical and fun-to-watch video! The level of explanation gradually gets more difficult — and the final level with Prof. Steven Girvin (Yale University) is fairly in depth.
- **Density**:
    - 19 minute video. Very easy to watch and understand!
- **Reviews**:
    - This is a fun video and cool to see Dr. Gershon explaining complicated ideas in an intuitive way. For more technical watchers, it can also help you reflect about how to better explain your own work/research in quantum computing.

      ~ Shoumik Chowdhury, Yale University (B.S. 2021, Math/Physics).

How Does a Quantum Computer Work? Veritasium Video

- **URL**:
    - https://www.youtube.com/watch?v=g_IaVepNDT4
- **Intended Audience**:
    - Anyone interested in Science.

- **Density**:
    - Pleasure video
- **Summary:** Explains basics of quantum computing in easy to understand manner

How to Make a Quantum Bit? Veritasium Video

- **URL**:
    - https://www.youtube.com/watch?v=zNzzGgr2mhk
- **Intended Audience**:
    - Anyone interested in Science, but high school preferable.
- **Density**:
    - Pleasure video
- **Summary:** Explains qubit and shows the lab for a spin-qubit

Quantum Entanglement & Spooky Action at a Distance, Veritasium Video

- **URL**:
    - https://www.youtube.com/watch?v=ZuvK-od647c
- **Intended Audience**:
    - Anyone interested in Science.
- **Density**:
    - Pleasure video
- **Summary:** Explains important concepts like superposition and entanglement involved in quantum mechanics and quantum computation.

Quantum Entanglement Animated, PhD Comics + John Preskill

- **URL**:
    - https://www.youtube.com/watch?v=1zD1U1sIPQ4
- **Intended Audience**:
    - Anyone interested in science, but high school preferable.
- **Density**:
    - Pleasure video
- **Summary:**
    - Explains quantum computation, superposition and entanglement in an accurate manner with simple analogies.

Essence of Linear Algebra: A Video Playlist by 3Blue1Brown

- **URL**:
    - https://www.youtube.com/watch?v=fNk_zzaMoSs&list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab

- **Intended Audience**:

    - Anyone interested in science, but high school preferable.
- **Density**:
    - Pleasure video
- **Summary:**
    - Explains all important concepts in linear algebra visually in a geometric way. Very highly recommended!
- **Reviews:**
    - "This is the intro to linear algebra every high school student entering university needs. It makes all the core concepts visual and easy to understand, which makes the mathematical formalisms more palatable. I honestly wish this was the first few weeks of my first-year linear algebra course." - Corbin, Waterloo class of 2021, Engineering

Lockdown Math: A Video Playlist by 3Blue1Brown

- **URL**:
    - https://www.youtube.com/playlist?list=PLZHQObOWTQDP5CVelJJ1bNDouqrAhVPev
- **Intended Audience**:
    - High school+
- **Density**:
    - Pleasure video
- **Summary:**
    - Important math concepts presented in a visual manner. Multiple episodes on complex numbers which are very highly recommended!

Nonlocal: A Quantum Computing Podcast

- **URL**:
    - https://nonlocal.libsyn.com
- **Intended Audience**:
    - It tries to "recreate the feeling of being at a bar after a quantum computing conference". So I guess anyone who would be interested in being in that bar!
- **Summary:**
    - A podcast that takes you behind the scenes in quantum computing research. Hosted by Vincent Russo, William Slofstra, and Henry Yuen.

The Potential Impact of Quantum Computers on Society, de Wolf

- **URL**:
    - https://arxiv.org/abs/1712.05380
- **Intended Audience**:
    - Anyone interested in quantum computing and its implications.
- **Density**:

    - It does not go into any math, it just talks about overarching concepts.
- **Summary:**
    - It discusses three main applications of quantum computers (cryptography, search and organization, and simulation of quantum systems), and discusses the ethics involved for each application.
- **Reviews:**
    - "This article not only provided a brief explanation of the applications of quantum computing, it also gave insight into how the world might be impacted by these advances - both the positive and negative potential outcomes." Sarah Goodman, MIT PhD 2020