

# An Introduction To Quantum Computing For Non Physicists

*"Introduction to Quantum Computation" is an introduction to a new rapidly developing theory of quantum computing. The book is a comprehensive introduction to the main ideas and techniques of quantum computation. It begins with the basics of classical theory of computation: NP-complete problems, Boolean circuits, Finite state machine, Turing machine and the idea of complexity of an algorithm. The general quantum formalism (pure states, qubit, superposition, evolution of quantum system, entanglement, multi-qubit system ...) and complex algorithm examples are also presented. Matlab is a well known in engineer academia as matrix computing environment, which makes it well suited for simulating quantum algorithms. The (Quantum Computer Toolbox) QCT is written entirely in the Matlab and m-files are listed in book's sections. There are certain data types that are implicitly defined by the QCT, including data*

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types for qubit registers and transformations. The QCT contains many functions designed to mimic the actions of a quantum computer. In addition, the QCT contains several convenience functions designed to aid in the creation and modification of the data types used in algorithms. The main purposes of the QCT are for research involving Quantum Computation and as a teaching tool to aid in learning about Quantum Computing systems. The readers will learn to implement complex quantum algorithm (quantum teleportation and Deutsch, Grover, Shor algorithm) under Matlab environment (complete Matlab code examples).

Quantum mechanics, the subfield of physics that describes the behavior of very small (quantum) particles, provides the basis for a new paradigm of computing. First proposed in the 1980s as a way to improve computational modeling of quantum systems, the field of quantum computing has recently garnered significant attention due to progress in building small-scale devices. However, significant technical advances will be required before a

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large-scale, practical quantum computer can be achieved. *Quantum Computing: Progress and Prospects* provides an introduction to the field, including the unique characteristics and constraints of the technology, and assesses the feasibility and implications of creating a functional quantum computer capable of addressing real-world problems. This report considers hardware and software requirements, quantum algorithms, drivers of advances in quantum computing and quantum devices, benchmarks associated with relevant use cases, the time and resources required, and how to assess the probability of success.

A quantum computer is a computer based on a computational model which uses quantum mechanics, which is a subfield of physics to study phenomena at the micro level. There has been a growing interest on quantum computing in the 1990's and some quantum computers at the experimental level were recently implemented. Quantum computers enable super-speed computation and can solve some important problems whose solutions

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were regarded impossible or intractable with traditional computers. This book provides a quick introduction to quantum computing for readers who have no backgrounds of both theory of computation and quantum mechanics.

“Elements of Quantum Computing” presents the history, theories and engineering applications of quantum computing. The book is suitable to computer scientists, physicists and software engineers.

Mika Hirvensalo maps out the new multidisciplinary research area of quantum computing. The text contains an introduction to quantum computing as well as the most important recent results on the topic. The presentation is uniform and computer science-oriented. Thus, the book differs from most of the previous ones which are mainly physics-oriented. The special style of presentation makes the theory of quantum computing accessible to a larger audience. Many examples and exercises ease the understanding. In this second edition, a new chapter on quantum information has been added and numerous corrections, amendments, and

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*extensions have been incorporated throughout the entire text.*

*Quantum Computation and Quantum Information*

*A hands-on introduction to quantum computing and writing your own quantum programs with Python*

*Quantum Computing for Everyone*

*Quantum Computing for the Quantum Curious*

*Classical and Quantum Computation*

*Explorations in Quantum Computing*

Quantum computers are set to kick-start a second computing revolution in an exciting and intriguing way. Learning to program a Quantum Processing Unit (QPU) is not only fun and exciting, but it's a way to get your foot in the door. Like learning any kind of programming, the best way to proceed is by getting your hands dirty and diving into code. This practical book uses publicly available quantum computing engines, clever notation, and a programmer's mindset to get you started. You'll be able to build up the intuition, skills, and tools needed to start writing quantum programs and solve problems that you care about.

Quantum computing is on the horizon and you can get started today! This practical, clear-spoken guide shows you don't need a physics degree to write your first quantum software. In *Quantum Computing in Action* you will learn: An introduction to the core

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concepts of quantum computing Qubits and quantum gates Superposition, entanglement, and hybrid computing Quantum algorithms including Shor's, Deutsch-jozsa, and Grover's search Quantum Computing in Action shows you how to leverage your existing Java skills into writing your first quantum software, so you're ready for the quantum revolution. This book is focused on practical implementations of quantum computing algorithms—there's no deep math or confusing theory. Using Strange, a Java-based quantum computer simulator, you'll go hands-on with quantum computing's core components including qubits and quantum gates. About the technology Quantum computing promises unimaginably fast performance for tasks like encryption, scientific modeling, manufacturing logistics, financial modeling, and AI. Developers can explore quantum computing now using free simulators, and increasingly powerful true quantum systems are gradually becoming available for production use. This book gives you a head start on quantum computing by introducing core concepts, key algorithms, and the most beneficial use cases. About the book Quantum Computing in Action is a gentle introduction to the ideas and applications of quantum computing. After briefly reviewing the science that makes quantum tick, it guides you through practical implementations of quantum computing algorithms. You'll write your first quantum code and explore qubits and quantum

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gates with the Java-based Strange quantum simulator. You'll enjoy the interesting examples and insightful explanations as you create quantum algorithms using standard Java and your favorite IDE and build tools. What's inside An introduction to the core concepts of quantum computing Qubits and quantum gates Superposition, entanglement, and hybrid computing Quantum algorithms including Shor's, Deutsch-jozsa, and Grover's search About the reader For Java developers. No advanced math knowledge required. About the author Johan Vos is a cofounder of Gluon, a Java technology company. He is a Java Champion and holds an MSc in Mining Engineering and a PhD in Applied Physics. Table of Contents

## PART 1 QUANTUM COMPUTING

INTRODUCTION 1 Evolution, revolution, or hype? 2 "Hello World," quantum computing style 3 Qubits and quantum gates: The basic units in quantum computing PART 2 FUNDAMENTAL CONCEPTS AND HOW THEY RELATE TO CODE 4 Superposition 5 Entanglement 6 Quantum networking: The basics PART 3 QUANTUM ALGORITHMS AND CODE 7 Our HelloWorld, explained 8 Secure communication using quantum computing 9 Deutsch-Jozsa algorithm 10 Grover's search algorithm 11 Shor's algorithm

Explore the principles and practicalities of quantum computing Key Features Discover how quantum computing works and delve into the math behind it with this quantum computing textbook Learn how it may become the most important new computer

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technology of the centuryExplore the inner workings of quantum computing technology to quickly process complex cloud data and solve problemsBook Description Quantum computing is making us change the way we think about computers. Quantum bits, a.k.a. qubits, can make it possible to solve problems that would otherwise be intractable with current computing technology. Dancing with Qubits is a quantum computing textbook that starts with an overview of why quantum computing is so different from classical computing and describes several industry use cases where it can have a major impact. From there it moves on to a fuller description of classical computing and the mathematical underpinnings necessary to understand such concepts as superposition, entanglement, and interference. Next up is circuits and algorithms, both basic and more sophisticated. It then nicely moves on to provide a survey of the physics and engineering ideas behind how quantum computing hardware is built. Finally, the book looks to the future and gives you guidance on understanding how further developments will affect you. Really understanding quantum computing requires a lot of math, and this book doesn't shy away from the necessary math concepts you'll need. Each topic is introduced and explained thoroughly, in clear English with helpful examples. What you will learnSee how quantum computing works, delve into the math behind it, what makes it different, and why it is so powerful with this quantum

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computing textbook Discover the complex, mind-bending mechanics that underpin quantum systems Understand the necessary concepts behind classical and quantum computing Refresh and extend your grasp of essential mathematics, computing, and quantum theory Explore the main applications of quantum computing to the fields of scientific computing, AI, and elsewhere Examine a detailed overview of qubits, quantum circuits, and quantum algorithm Who this book is for Dancing with Qubits is a quantum computing textbook for those who want to deeply explore the inner workings of quantum computing. This entails some sophisticated mathematical exposition and is therefore best suited for those with a healthy interest in mathematics, physics, engineering, and computer science.

By the year 2020, the basic memory components of a computer will be the size of individual atoms. At such scales, the current theory of computation will become invalid. "Quantum computing" is reinventing the foundations of computer science and information theory in a way that is consistent with quantum physics - the most accurate model of reality currently known. Remarkably, this theory predicts that quantum computers can perform certain tasks breathtakingly faster than classical computers - and, better yet, can accomplish mind-boggling feats such as teleporting information, breaking supposedly "unbreakable" codes, generating true random numbers, and communicating with messages that betray the

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presence of eavesdropping. This widely anticipated second edition of *Explorations in Quantum Computing* explains these burgeoning developments in simple terms, and describes the key technological hurdles that must be overcome to make quantum computers a reality. This easy-to-read, time-tested, and comprehensive textbook provides a fresh perspective on the capabilities of quantum computers, and supplies readers with the tools necessary to make their own foray into this exciting field. Topics and features: concludes each chapter with exercises and a summary of the material covered; provides an introduction to the basic mathematical formalism of quantum computing, and the quantum effects that can be harnessed for non-classical computation; discusses the concepts of quantum gates, entangling power, quantum circuits, quantum Fourier, wavelet, and cosine transforms, and quantum universality, computability, and complexity; examines the potential applications of quantum computers in areas such as search, code-breaking, solving NP-Complete problems, quantum simulation, quantum chemistry, and mathematics; investigates the uses of quantum information, including quantum teleportation, superdense coding, quantum data compression, quantum cloning, quantum negation, and quantum cryptography; reviews the advancements made towards practical quantum computers, covering developments in quantum error correction and avoidance, and alternative models of quantum computation. This

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text/reference is ideal for anyone wishing to learn more about this incredible, perhaps "ultimate," computer revolution. Dr. Colin P. Williams is Program Manager for Advanced Computing Paradigms at the NASA Jet Propulsion Laboratory, California Institute of Technology, and CEO of Xtreme Energetics, Inc. an advanced solar energy company. Dr. Williams has taught quantum computing and quantum information theory as an acting Associate Professor of Computer Science at Stanford University. He has spent over a decade inspiring and leading high technology teams and building business relationships with and Silicon Valley companies. Today his interests include terrestrial and Space-based power generation, quantum computing, cognitive computing, computational material design, visualization, artificial intelligence, evolutionary computing, and remote olfaction. He was formerly a Research Scientist at Xerox PARC and a Research Assistant to Prof. Stephen W. Hawking, Cambridge University.

Implications to High Level Design and Validation  
A Gentle Introduction

Supervised Learning with Quantum Computers

Quantum Computing: An Applied Approach

NMR Quantum Information Processing

A Short Course from Theory to Experiment

*Combining physics, mathematics and computer science, topological quantum computation is a rapidly expanding research area focused on the exploration*

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*of quantum evolutions that are immune to errors. In this book, the author presents a variety of different topics developed together for the first time, forming an excellent introduction to topological quantum computation. The makings of anyonic systems, their properties and their computational power are presented in a pedagogical way. Relevant calculations are fully explained, and numerous worked examples and exercises support and aid understanding. Special emphasis is given to the motivation and physical intuition behind every mathematical concept. Demystifying difficult topics by using accessible language, this book has broad appeal and is ideal for graduate students and researchers from various disciplines who want to get into this new and exciting research field.*

*An Introduction to Quantum Computing Oxford University Press on Demand*

*Quantum Computation and Quantum Information (QIP) deals with the identification and use of quantum resources for information processing. This includes three main branches of investigation: quantum algorithm design, quantum simulation and quantum communication, including quantum cryptography. Along the past few years,*

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*QIP has become one of the most active area of research in both, theoretical and experimental physics, attracting students and researchers fascinated, not only by the potential practical applications of quantum computers, but also by the possibility of studying fundamental physics at the deepest level of quantum phenomena. NMR Quantum Computation and Quantum Information Processing describes the fundamentals of NMR QIP, and the main developments which can lead to a large-scale quantum processor. The text starts with a general chapter on the interesting topic of the physics of computation. The very first ideas which sparked the development of QIP came from basic considerations of the physical processes underlying computational actions. In Chapter 2 it is made an introduction to NMR, including the hardware and other experimental aspects of the technique. In Chapter 3 we revise the fundamentals of Quantum Computation and Quantum Information. The chapter is very much based on the extraordinary book of Michael A. Nielsen and Isaac L. Chuang, with an upgrade containing some of the latest developments, such as QIP in phase space, and telecloning. Chapter 4 describes how NMR generates quantum logic gates from*

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radiofrequency pulses, upon which quantum protocols are built. It also describes the important technique of Quantum State Tomography for both, quadrupole and spin  $1/2$  nuclei. Chapter 5 describes some of the main experiments of quantum algorithm implementation by NMR, quantum simulation and QIP in phase space. The important issue of entanglement in NMR QIP experiments is discussed in Chapter 6. This has been a particularly exciting topic in the literature. The chapter contains a discussion on the theoretical aspects of NMR entanglement, as well as some of the main experiments where this phenomenon is reported. Finally, Chapter 7 is an attempt to address the future of NMR QIP, based in very recent developments in nanofabrication and single-spin detection experiments. Each chapter is followed by a number of problems and solutions. \*

Presents a large number of problems with solutions, ideal for students \* Brings together topics in different areas: NMR, nanotechnology, quantum computation \*

Extensive references

This textbook aims to introduce the reader to Quantum Computing while also giving a good primer on programming Quantum Devices using Qiskit. This is aimed at complete beginners and is a good gentle

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*introduction to the field.*

*Introduction to Quantum Information Science*

*Programming Quantum Computers*

*A Short Introduction to Quantum*

*Information and Quantum Computation*

*How quantum computing works and how it can change the world*

*A hands-on approach*

*Quantum Computing Since Democritus*

Quantum machine learning investigates how quantum computers can be used for data-driven prediction and decision making. The book summarises and conceptualises ideas of this relatively young discipline for an audience of computer scientists and physicists from a graduate level upwards. It aims at providing a starting point for those new to the field, showcasing a toy example of a quantum machine learning algorithm and providing a detailed introduction of the two parent disciplines. For more advanced readers, the book discusses topics such as data encoding into quantum states, quantum algorithms and routines for inference and optimisation, as well as the construction and analysis of genuine "quantum learning models". A special focus lies on supervised learning, and applications for near-term quantum devices.

This book integrates the foundations of quantum computing with a hands-on coding approach to this emerging field; it is the first to bring these elements together in an updated manner. This work is suitable for both academic coursework and corporate technical training. The second edition includes extensive updates and revisions, both to textual content and to the code. Sections have been added on quantum machine learning, quantum error correction, Dirac notation and more.

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This new edition benefits from the input of the many faculty, students, corporate engineering teams, and independent readers who have used the first edition. This volume comprises three books under one cover: Part I outlines the necessary foundations of quantum computing and quantum circuits. Part II walks through the canon of quantum computing algorithms and provides code on a range of quantum computing methods in current use. Part III covers the mathematical toolkit required to master quantum computing. Additional resources include a table of operators and circuit elements and a companion GitHub site providing code and updates. Jack D. Hidary is a research scientist in quantum computing and in AI at Alphabet X, formerly Google X.

The authors provide an introduction to quantum computing. Aimed at advanced undergraduate and beginning graduate students in these disciplines, this text is illustrated with diagrams and exercises.

In 1994 Peter Shor [65] published a factoring algorithm for a quantum computer that finds the prime factors of a composite integer  $N$  more efficiently than is possible with the known algorithms for a classical computer. Since the difficulty of the factoring problem is crucial for the security of a public key encryption system, interest (and funding) in quantum computing and quantum computation suddenly blossomed. Quantum computing had arrived. The study of the role of quantum mechanics in the theory of computation seems to have begun in the early 1980s with the publications of Paul Benioff [6] [7] who considered a quantum mechanical model of computers and the computation process. A related question was discussed shortly thereafter by Richard Feynman [35] who began from a different perspective by asking what kind of computer should be used to simulate physics. His analysis led him to the belief that with a suitable

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class of "quantum machines" one could imitate any quantum system.

An Engineering Approach

Essential Algorithms and Code Samples

Mathematics of Quantum Computing

Quantum Information Processing and Quantum Error

Correction

Introduction to Topological Quantum Computation

Learn Quantum Computing with Python and IBM Quantum

Experience

This concise, accessible text provides a thorough introduction to quantum computing – an exciting emergent field at the interface of the computer, engineering, mathematical and physical sciences. Aimed at advanced undergraduate and beginning graduate students in these disciplines, the text is technically detailed and is clearly illustrated throughout with diagrams and exercises. Some prior knowledge of linear algebra is assumed, including vector spaces and inner products. However, prior familiarity with topics such as tensor products and spectral decomposition is not required, as the necessary material is reviewed in the text.

Quantum computing explained in terms of elementary linear algebra, emphasizing computation and algorithms and requiring no background in physics. This introduction to quantum algorithms is concise but comprehensive, covering many key algorithms. It is mathematically rigorous but requires minimal background and assumes no knowledge of quantum theory or quantum mechanics. The

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book explains quantum computation in terms of elementary linear algebra; it assumes the reader will have some familiarity with vectors, matrices, and their basic properties, but offers a review of the relevant material from linear algebra. By emphasizing computation and algorithms rather than physics, it makes quantum algorithms accessible to students and researchers in computer science who have not taken courses in quantum physics or delved into fine details of quantum effects, apparatus, circuits, or theory.

A self-contained treatment of the fundamentals of quantum computing This clear, practical book takes quantum computing out of the realm of theoretical physics and teaches the fundamentals of the field to students and professionals who have not had training in quantum computing or quantum information theory, including computer scientists, programmers, electrical engineers, mathematicians, physics students, and chemists. The author cuts through the conventions of typical jargon-laden physics books and instead presents the material through his unique "how-to" approach and friendly, conversational style. Readers will learn how to carry out calculations with explicit details and will gain a fundamental grasp of:

- \* Quantum mechanics
- \* Quantum computation
- \* Teleportation
- \* Quantum cryptography
- \* Entanglement
- \* Quantum algorithms
- \* Error correction

A number of

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worked examples are included so readers can see how quantum computing is done with their own eyes, while answers to similar end-of-chapter problems are provided for readers to check their own work as they learn to master the information. Ideal for professionals and graduate-level students alike, Quantum Computing Explained delivers the fundamentals of quantum computing readers need to be able to understand current research papers and go on to study more advanced quantum texts.

While there are many available textbooks on quantum information theory, most are either too technical for beginners or not complete enough. Filling this gap, Elements of Quantum Computation and Quantum Communication gives a clear, self-contained introduction to quantum computation and communication. Written primarily for undergraduate students in p Introduction to Quantum Algorithms via Linear Algebra, second edition

Elements of Quantum Computation and Quantum Communication

Reports on Leading-Edge Engineering from the 2018 Symposium

Introduction to Quantum Computers

Quantum Computing for Computer Scientists

An Introduction

***The result of a lecture series, this textbook is oriented towards students and newcomers to the field and discusses theoretical foundations as well as experimental realizations in detail. The authors are experienced teachers and have tailored this***

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*book to the needs of students. They present the basics of quantum communication and quantum information processing, leading readers to modern technical implementations. In addition, they discuss errors and decoherence as well as methods of avoiding and correcting them.*

*Quantum computing promises to solve problems which are intractable on digital computers. Highly parallel quantum algorithms can decrease the computational time for some problems by many orders of magnitude. This important book explains how quantum computers can do these amazing things. Several algorithms are illustrated: the discrete Fourier transform, Shor's algorithm for prime factorization; algorithms for quantum logic gates; physical implementations of quantum logic gates in ion traps and in spin chains; the simplest schemes for quantum error correction; correction of errors caused by imperfect resonant pulses; correction of errors caused by the nonresonant actions of a pulse; and numerical simulations of dynamical behavior of the quantum Control-Not gate. An overview of some basic elements of computer science is presented, including the Turing machine, Boolean algebra, and logic gates. The required quantum ideas are explained. Quantum information and computation is a rapidly expanding and cross-disciplinary subject. This book, first published in 2006, gives a self-contained introduction to the field for physicists, mathematicians and*

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computer scientists who want to know more about this exciting subject. After a step-by-step introduction to the quantum bit (qubit) and its main properties, the author presents the necessary background in quantum mechanics. The core of the subject, quantum computation, is illustrated by a detailed treatment of three quantum algorithms: Deutsch, Grover and Shor. The final chapters are devoted to the physical implementation of quantum computers, including the most recent aspects, such as superconducting qubits and quantum dots, and to a short account of quantum information. Written at a level suitable for undergraduates in physical sciences, no previous knowledge of quantum mechanics is assumed, and only elementary notions of physics are required. The book includes many short exercises, with solutions available to instructors through [solutions@cambridge.org](mailto:solutions@cambridge.org).

An accessible introduction to an exciting new area in computation, explaining such topics as qubits, entanglement, and quantum teleportation for the general reader. Quantum computing is a beautiful fusion of quantum physics and computer science, incorporating some of the most stunning ideas from twentieth-century physics into an entirely new way of thinking about computation. In this book, Chris Bernhardt offers an introduction to quantum computing that is accessible to anyone who is comfortable with high school mathematics. He explains qubits,

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entanglement, quantum teleportation, quantum algorithms, and other quantum-related topics as clearly as possible for the general reader. Bernhardt, a mathematician himself, simplifies the mathematics as much as he can and provides elementary examples that illustrate both how the math works and what it means. Bernhardt introduces the basic unit of quantum computing, the qubit, and explains how the qubit can be measured; discusses entanglement—which, he says, is easier to describe mathematically than verbally—and what it means when two qubits are entangled (citing Einstein's characterization of what happens when the measurement of one entangled qubit affects the second as “spooky action at a distance”); and introduces quantum cryptography. He recaps standard topics in classical computing—bits, gates, and logic—and describes Edward Fredkin's ingenious billiard ball computer. He defines quantum gates, considers the speed of quantum algorithms, and describes the building of quantum computers. By the end of the book, readers understand that quantum computing and classical computing are not two distinct disciplines, and that quantum computing is the fundamental form of computing. The basic unit of computation is the qubit, not the bit.

**Quantum Computer Science**

**Introduction to Quantum Computing with Qiskit  
History, Theories and Engineering  
Applications**

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## **Quantum Algorithms via Linear Algebra Quantum Computing**

### **Classical and Quantum Computing**

*This book presents a concise introduction to an emerging and increasingly important topic, the theory of quantum computing. The development of quantum computing exploded in 1994 with the discovery of its use in factoring large numbers--an extremely difficult and time-consuming problem when using a conventional computer. In less than 300 pages, the authors set forth a solid foundation to the theory, including results that have not appeared elsewhere and improvements on existing works. The book starts with the basics of classical theory of computation, including NP-complete problems and the idea of complexity of an algorithm. Then the authors introduce general principles of quantum computing and pass to the study of main quantum computation algorithms: Grover's algorithm, Shor's factoring algorithm, and the Abelian hidden subgroup problem. In concluding sections, several related topics are discussed (parallel quantum computation, a quantum analog of NP-completeness, and quantum error-correcting codes). This is a suitable textbook for a graduate course in quantum computing. Prerequisites are very modest and include linear algebra, elements of group theory and probability, and the notion of an algorithm (on a formal or an intuitive level). The book is complete*

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*with problems, solutions, and an appendix summarizing the necessary results from number theory.*

*The multidisciplinary field of quantum computing strives to exploit some of the uncanny aspects of quantum mechanics to expand our computational horizons. Quantum Computing for Computer Scientists takes readers on a tour of this fascinating area of cutting-edge research. Written in an accessible yet rigorous fashion, this book employs ideas and techniques familiar to every student of computer science. The reader is not expected to have any advanced mathematics or physics background. After presenting the necessary prerequisites, the material is organized to look at different aspects of quantum computing from the specific standpoint of computer science. There are chapters on computer architecture, algorithms, programming languages, theoretical computer science, cryptography, information theory, and hardware. The text has step-by-step examples, more than two hundred exercises with solutions, and programming drills that bring the ideas of quantum computing alive for today's computer science students and researchers.*

*This book presents the basics of quantum information, e.g., foundation of quantum theory, quantum algorithms, quantum entanglement, quantum entropies, quantum coding, quantum error*

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*correction and quantum cryptography. The required knowledge is only elementary calculus and linear algebra. This way the book can be understood by undergraduate students. In order to study quantum information, one usually has to study the foundation of quantum theory. This book describes it from more an operational viewpoint which is suitable for quantum information while traditional textbooks of quantum theory lack this viewpoint. The current book bases on Shor's algorithm, Grover's algorithm, Deutsch-Jozsa's algorithm as basic algorithms. To treat several topics in quantum information, this book covers several kinds of information quantities in quantum systems including von Neumann entropy. The limits of several kinds of quantum information processing are given. As important quantum protocols, this book contains quantum teleportation, quantum dense coding, quantum data compression. In particular conversion theory of entanglement via local operation and classical communication are treated too. This theory provides the quantification of entanglement, which coincides with von Neumann entropy. The next part treats the quantum hypothesis testing. The decision problem of two candidates of the unknown state are given. The asymptotic performance of this problem is characterized by information quantities. Using this result, the optimal performance of classical information transmission via noisy quantum channel is derived. Quantum*

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*information transmission via noisy quantum channel by quantum error correction are discussed too. Based on this topic, the secure quantum communication is explained. In particular, the quantification of quantum security which has not been treated in existing book is explained. This book treats quantum cryptography from a more practical viewpoint.*

*Quantum computing explained in terms of elementary linear algebra, emphasizing computation and algorithms and requiring no background in physics. This introduction to quantum algorithms is concise but comprehensive, covering many key algorithms. It is mathematically rigorous but requires minimal background and assumes no knowledge of quantum theory or quantum mechanics. The book explains quantum computation in terms of elementary linear algebra; it assumes the reader will have some familiarity with vectors, matrices, and their basic properties, but offers a review of all the relevant material from linear algebra. By emphasizing computation and algorithms rather than physics, this primer makes quantum algorithms accessible to students and researchers in computer science without the complications of quantum mechanical notation, physical concepts, and philosophical issues. After explaining the development of quantum operations and computations based on linear algebra, the book*

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*presents the major quantum algorithms, from seminal algorithms by Deutsch, Jozsa, and Simon through Shor's and Grover's algorithms to recent quantum walks. It covers quantum gates, computational complexity, and some graph theory. Mathematical proofs are generally short and straightforward; quantum circuits and gates are used to illuminate linear algebra; and the discussion of complexity is anchored in computational problems rather than machine models. Quantum Algorithms via Linear Algebra is suitable for classroom use or as a reference for computer scientists and mathematicians.*

*An Introduction to Quantum Computing Algorithms  
Quantum Computing Explained  
Elements of Quantum Computing  
A Primer*

### *Introduction to Quantum Computation*

Takes students and researchers on a tour through some of the deepest ideas of maths, computer science and physics. One of the grand challenges in the nanoscopic computing era is guarantees of robustness. Robust computing system design is confronted with quantum physical, probabilistic, and even biological phenomena, and guaranteeing high reliability is much more difficult

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than ever before. Scaling devices down to the level of single electron operation will bring forth new challenges due to probabilistic effects and uncertainty in guaranteeing 'zero-one' based computing. Minuscule devices imply billions of devices on a single chip, which may help mitigate the challenge of uncertainty by replication and redundancy. However, such device densities will create a design and validation nightmare with the sheer scale. The questions that confront computer engineers regarding the current status of nanocomputing material and the reliability of systems built from such miniscule devices, are difficult to articulate and answer. We have found a lack of resources in the confines of a single volume that at least partially attempts to answer these questions. We believe that this volume contains a large amount of research material as well as new ideas that will be very useful for some one starting research in the arena of nanocomputing, not at the device level, but the problems one would face at system level design and validation when

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nanoscopic physicality will be present at the device level.

This is a self-contained, systematic and comprehensive introduction to all the subjects and techniques important in scientific computing. The style and presentation are readily accessible to undergraduates and graduates. A large number of examples, accompanied by complete C++ and Java code wherever possible, cover every topic.

Quantum Information Processing and Quantum Error Correction is a self-contained, tutorial-based introduction to quantum information, quantum computation, and quantum error-correction. Assuming no knowledge of quantum mechanics and written at an intuitive level suitable for the engineer, the book gives all the essential principles needed to design and implement quantum electronic and photonic circuits. Numerous examples from a wide area of application are given to show how the principles can be implemented in practice. This book is ideal for the electronics, photonics and computer engineer who requires an easy- to-understand foundation on the

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principles of quantum information processing and quantum error correction, together with insight into how to develop quantum electronic and photonic circuits. Readers of this book will be ready for further study in this area, and will be prepared to perform independent research. The reader completed the book will be able design the information processing circuits, stabilizer codes, Calderbank-Shor-Steane (CSS) codes, subsystem codes, topological codes and entanglement-assisted quantum error correction codes; and propose corresponding physical implementation. The reader completed the book will be proficient in quantum fault-tolerant design as well. Unique Features Unique in covering both quantum information processing and quantum error correction - everything in one book that an engineer needs to understand and implement quantum-level circuits. Gives an intuitive understanding by not assuming knowledge of quantum mechanics, thereby avoiding heavy mathematics. In-depth coverage of the design and implementation of quantum

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information processing and quantum error correction circuits. Provides the right balance among the quantum mechanics, quantum error correction, quantum computing and quantum communication. Dr. Djordjevic is an Assistant Professor in the Department of Electrical and Computer Engineering of College of Engineering, University of Arizona, with a joint appointment in the College of Optical Sciences. Prior to this appointment in August 2006, he was with University of Arizona, Tucson, USA (as a Research Assistant Professor); University of the West of England, Bristol, UK; University of Bristol, Bristol, UK; Tyco Telecommunications, Eatontown, USA; and National Technical University of Athens, Athens, Greece. His current research interests include optical networks, error control coding, constrained coding, coded modulation, turbo equalization, OFDM applications, and quantum error correction. He presently directs the Optical Communications Systems Laboratory (OCSL) within the ECE Department at the University of Arizona. Provides

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everything an engineer needs in one tutorial-based introduction to understand and implement quantum-level circuits Avoids the heavy use of mathematics by not assuming the previous knowledge of quantum mechanics Provides in-depth coverage of the design and implementation of quantum information processing and quantum error correction circuits

Nano, Quantum and Molecular Computing Progress and Prospects

Dancing with Qubits

with C++ and Java Simulations

An Introduction to Quantum Computing

Frontiers of Engineering

***This textbook presents the elementary aspects of quantum computing in a mathematical form. It is intended as core or supplementary reading for physicists, mathematicians, and computer scientists taking a first course on quantum computing. It starts by introducing the basic mathematics required for quantum mechanics, and then goes on to present, in detail, the notions of quantum mechanics, entanglement, quantum gates, and quantum algorithms, of which Shor's***

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*factorisation and Grover's search algorithm are discussed extensively. In addition, the algorithms for the Abelian Hidden Subgroup and Discrete Logarithm problems are presented and the latter is used to show how the Bitcoin digital signature may be compromised. It also addresses the problem of error correction as well as giving a detailed exposition of adiabatic quantum computing. The book contains around 140 exercises for the student, covering all of the topics treated, together with an appendix of solutions.*

*In the 1990's it was realized that quantum physics has some spectacular applications in computer science. 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*

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*applications: Shor's factoring algorithm, Grover's search algorithm, and quantum error correction. 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.*

*This volume presents papers on the topics covered at the National Academy of Engineering's 2018 US Frontiers of Engineering Symposium. Every year the symposium brings together 100 outstanding young leaders in engineering to share their cutting-edge research and innovations in selected areas. The 2018 symposium was held September 5-7 and hosted by MIT Lincoln Laboratory in Lexington, Massachusetts. The intent of this book is to convey the excitement of this unique meeting*

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*and to highlight innovative developments in engineering research and technical work.*

*A step-by-step guide to learning the implementation and associated methodologies in quantum computing with the help of the IBM Quantum Experience, Qiskit, and Python that will have you up and running and productive in no time*

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- Determine the difference between classical computers and quantum computers*
- Understand the quantum computational principles such as superposition and entanglement and how they are leveraged on IBM Quantum Experience systems*
- Run your own quantum experiments and applications by integrating with Qiskit*

*Book Description*

*IBM Quantum Experience is a platform that enables developers to learn the basics of quantum computing by allowing them to run experiments on a quantum computing simulator and a real quantum computer. This book will explain the basic principles of quantum mechanics, the principles involved in quantum computing, and the implementation of quantum algorithms and experiments on IBM's quantum processors. You will*

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start working with simple programs that illustrate quantum computing principles and slowly work your way up to more complex programs and algorithms that leverage quantum computing. As you build on your knowledge, you'll understand the functionality of IBM Quantum Experience and the various resources it offers. Furthermore, you'll not only learn the differences between the various quantum computers but also the various simulators available. Later, you'll explore the basics of quantum computing, quantum volume, and a few basic algorithms, all while optimally using the resources available on IBM Quantum Experience. By the end of this book, you'll learn how to build quantum programs on your own and have gained practical quantum computing skills that you can apply to your business. What you will learn

Explore quantum computational principles such as superposition and quantum entanglement  
Become familiar with the contents and layout of the IBM Quantum Experience  
Understand quantum gates and how they operate on qubits  
Discover the quantum information

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*science kit and its elements such as Terra and AerGet to grips with quantum algorithms such as Bell State, Deutsch-Jozsa, Grover's algorithm, and Shor's algorithm*  
*How to create and visualize a quantum circuit*  
*Who this book is for*  
*This book is for Python developers who are looking to learn quantum computing and put their knowledge to use in practical situations with the help of IBM Quantum Experience. Some background in computer science and high-school-level physics and math is required.*

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mechanics of quantum computers  
Simulating qubits in Python Exploring  
quantum algorithms with Q# Applying  
quantum computing to chemistry,  
arithmetic, and data About the reader  
For software developers. No prior  
experience with quantum computing  
required. About the author Dr. Sarah  
Kaiser works at the Unitary Fund, a non-  
profit organization supporting the  
quantum open-source ecosystem, and is  
an expert in building quantum tech in  
the lab. Dr. Christopher Granade works  
in the Quantum Systems group at  
Microsoft, and is an expert in  
characterizing quantum devices. Table  
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QUANTUM COMPUTING 10 Solving chemistry problems with quantum computers 11

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Arithmetic with quantum computers

A thorough exposition of quantum computing and the underlying concepts of quantum physics, with explanations of the relevant mathematics and numerous examples. The combination of two of the twentieth century's most influential and revolutionary scientific theories, information theory and quantum mechanics, gave rise to a radically new view of computing and information. Quantum information processing explores the implications of using quantum mechanics instead of classical mechanics to model information and its processing. Quantum computing is not about changing the physical substrate on which computation is done from classical to quantum but about changing the notion of computation itself, at the most basic level. The fundamental unit of computation is no longer the bit but the quantum bit or qubit. This comprehensive introduction to the field offers a thorough exposition of quantum

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computing and the underlying concepts of quantum physics, explaining all the relevant mathematics and offering numerous examples. With its careful development of concepts and thorough explanations, 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.

This open access book makes quantum computing more accessible than ever before. A fast-growing field at the intersection of physics and computer science, quantum computing promises to have revolutionary capabilities far surpassing “classical” computation. Getting a grip on the science behind the hype can be tough: at its heart lies quantum mechanics, whose enigmatic concepts can be imposing for the novice. This classroom-tested textbook uses simple language, minimal math, and plenty of examples to explain the three key principles behind quantum

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computers: superposition, quantum measurement, and entanglement. It then goes on to explain how this quantum world opens up a whole new paradigm of computing. The book bridges the gap between popular science articles and advanced textbooks by making key ideas accessible with just high school physics as a prerequisite. Each unit is broken down into sections labelled by difficulty level, allowing the course to be tailored to the student's experience of math and abstract reasoning. Problem sets and simulation-based labs of various levels reinforce the concepts described in the text and give the reader hands-on experience running quantum programs. This book can thus be used at the high school level after the AP or IB exams, in an extracurricular club, or as an independent project resource to give students a taste of what quantum computing is really about. At the college level, it can be used as a supplementary text to enhance a variety of courses in science and computing, or as a self-study guide for students who want to get ahead. Additionally,

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readers in business, finance, or industry will find it a quick and useful primer on the science behind computing's future.