

Contents at a Glance

Introduction	1
Part 1: The Power of Quantum Computing	7
CHAPTER 1: Quantum Computing Boot Camp	9
CHAPTER 2: Looking Back to Early and Classical Computing	27
CHAPTER 3: Examining the Roots of Quantum Computing	47
CHAPTER 4: Introducing Quantum Technology 1.0	69
CHAPTER 5: Unveiling Quantum Computing	83
CHAPTER 6: Quantum Computing Accelerates	99
Part 2: Quantum Computing Options	113
CHAPTER 7: Choosing Between Classical and Quantum Computing	115
CHAPTER 8: Getting Started with Quantum Computing	131
CHAPTER 9: It's All about the Stack	153
CHAPTER 10: Racing for the Perfect Qubit	173
CHAPTER 11: Choosing a Qubit Type	187
Part 3: Getting Entangled with Quantum Computing	207
CHAPTER 12: Programming a Quantum Computer	209
CHAPTER 13: Quantum Computing Applications	237
CHAPTER 14: Quantum Computing Algorithms	255
CHAPTER 15: Cloud Access Options	281
CHAPTER 16: Educational Resources	305
Part 4: The Part of Tens	327
CHAPTER 17: Ten Myths Surrounding Quantum Computing	329
CHAPTER 18: Ten Tech Questions Answered	339
CHAPTER 19: Ten Business Questions Answered	347
CHAPTER 20: Ten University Research Programs	355
Index	361

Table of Contents

INTRODUCTION	1
About This Book	1
Foolish Assumptions	3
Icons Used in This Book	3
Beyond the Book	4
Where to Go from Here	5
 PART 1: THE POWER OF QUANTUM COMPUTING	 7
CHAPTER 1: Quantum Computing Boot Camp	9
Understanding Why Quantum Computing Is So Strange	10
Grasping the Power of Quantum Computing	11
Introducing Puff, the magic — qubit?	12
Superposition, the first quantum superpower	15
Welcoming foreign entanglements	16
Enabling quantum computing with coherence	17
Doing the Math for the Power of Quantum Computing	19
Examining What Quantum Computing Will Do for People	20
Describing Different Types of Quantum Computing	22
Quantum-inspired computing	22
Quantum annealing	23
Gate-based quantum computing	23
Addressing What's Stopping Us	25
 CHAPTER 2: Looking Back to Early and Classical Computing	 27
Understanding Why Classical Computers Are Not Going Away	28
Looking Back to the Prehistory of Computers	29
Counting on the abacus, a forerunner of the classical computer	29
Unearthing the Antikythera, an early orrery	31
Calculating why the slide rule no longer rules	33
Assessing what we can learn from early computers	34
Tracking the Emergence of Classical Computing	35
Counting on the arrival of tabulating machines	35
Examining a mathematical model for classical computers	37
Commemorating the first electronic computer	41
Understanding the invention of byte-sized data	42
Tracking the rise of ICs and microprocessors	45
Joining Classical Computing and Quantum Computing	46

CHAPTER 3:	Examining the Roots of Quantum Computing	47
	Identifying the Keys to Quantum Mechanics	49
	Finding the fundamentals of fundamental particles	50
	Counting the cost of coherence	52
	Identifying the Effect of Uncertainty	53
	Summarizing the History of Quantum Mechanics	54
	Tracing the development of classical mechanics	54
	Beginning the quantum revolution	57
	Continuing the quantum revolution	61
	Laying the groundwork for quantum computing	64
	Spotting “spooky action at a distance”	65
CHAPTER 4:	Introducing Quantum Technology 1.0	69
	Finding Lasers at the Cutting Edge	70
	Studying Quantum Mechanics After 1930	71
	Speeding the Race for Solar Cells (1890s)	73
	Eyeing Electron Microscopes (1931, 1965, and 1981)	74
	Optimizing the Transistor (1947)	75
	Telling Time with Atomic Clocks (1955)	77
	Heating Up Masers and Lasers (1953 and 1960)	78
	Scanning for NMR and MRI Devices (1977)	80
	Assessing the Effects of Quantum Technology 1.0	81
CHAPTER 5:	Unveiling Quantum Computing	83
	Nailing Together a Framework for Quantum Computing	85
	Theorizing in the 1960s and 1970s	85
	Foretelling quantum computing and nanotech	86
	Keeping cool with reversibility	87
	Quantizing money — it’s a hit	87
	Cloning quantum states is a no-go no-no	88
	Regretting what you can’t have	88
	Discovering a star (in information theory)	88
	Laying the Groundwork in the 1980s	89
	Extending Turing machines to the quantum realm	89
	Speaking out on quantum computing	89
	Describing a universal quantum computer	90
	Espying the CNOT gate	90
	Modeling a real quantum computer	90
	Annealing for optimization	91
	Breaking through in the 1990s with Algorithms and Hardware	91
	Connecting with quantum communications	92
	Unveiling the first quantum-specific algorithm	92
	Shaking the multiverse with Shor’s algorithm	93

Calling quantum for the defense	94
Initiating quantum error correction	94
Finding a groove with Grover's algorithm	95
Manifesting a working quantum computer	96
Hitting seven lucky qubits in hardware	97
Starting Today's Quantum Computing Race	98
CHAPTER 6: Quantum Computing Accelerates	99
Pushing Technical Progress Forward, 2000–2010	100
Seeing Shor's algorithm executed (Shor unharmed)	100
Making a quantum leap in education	101
Experiencing spooky action at astronomical distances	102
Moving toward a fully implemented computer	104
Investing More Resources from 2010–2015	105
Shipping a working annealer from D-Wave	105
Adding software to the incorporation party	105
Causing a quantum panic with Edward Snowden	106
Putting down (square?) roots in quantum computing with Google	106
Bending the Arc of Progress Upward, 2016 to Today	107
Offering quantum computing through the cloud	107
Ruling that there ought to be a law	108
Going universal with IBM	108
Claiming quantum supremacy with Google and others	109
Getting entangled in a Nobel effort	109
Asserting quantum utility with IBM	110
Finding Out What's Still Needed for Quantum Computing	111
PART 2: QUANTUM COMPUTING OPTIONS	113
CHAPTER 7: Choosing Between Classical and Quantum Computing	115
Identifying Limitations in Classical Computing	116
Watching the sun go down on Moore	116
Suffering exponential growing pains	120
Fighting fixed ways of thinking	123
The bottom line	124
Finding What's Right with Quantum Computing	125
Highlighting where quantum computing is better	125
Querying quantum's status today	128
Looking for early access	128
Needing what quantum computing offers	130

CHAPTER 8:	Getting Started with Quantum Computing	131
	Identifying Five Classes of Solutions	132
	Dancing to That Algorithm	136
	Deciding Whether to Start Now	138
	Getting Your Organization Involved	140
	Putting together a project team	143
	Involving an executive sponsor	145
	Depending on algorithm experts	146
	Setting goals	148
	Considering Quantum-Inspired Solutions	148
	Using CPUs and GPUs	149
	Using special-purpose hardware	149
	Including quantum-inspired solutions	150
CHAPTER 9:	It's All about the Stack	153
	Analyzing the Stack	153
	Examining how classical computers stack up	154
	Comparing the stack for quantum computers	155
	Considering the Annealing Alternative	161
	Annealing in the medieval mode	164
	Identifying the problem annealing solves	165
	Moving on to quantum annealing	167
	Choosing a Type of Quantum Computer	169
CHAPTER 10:	Racing for the Perfect Qubit	173
	Identifying Three Levels of Qubit Achievement	176
	Winning the Race for Focused Quantum Advantage	177
	Visiting the Qubit Zoo	179
	Deconstructing qubits	179
	Defining quantum computing modalities	182
	Mapping Out the Modalities Landscape	184
	Figuring Out What's Next	186
CHAPTER 11:	Choosing a Qubit Type	187
	Telling the Players Apart with a Scorecard	188
	Trapped ion qubits	191
	Superconducting qubits	193
	Photonic qubits	197
	The best of the rest	199
	Choosing a Strategy for Quantum Computing	202
	Taking advantage of the cloud	203
	Sharing a quiet word about companies	205

PART 3: GETTING ENTANGLED WITH QUANTUM COMPUTING	207
CHAPTER 12: Programming a Quantum Computer	209
Figuring Out What We Are Doing	211
Figuring Out How to Do It	213
Getting Down to the BASICS	216
Writing the Requirements for a Quantum Program	217
Components of a quantum programming environment	218
Components of a quantum program	219
Thinking Like a Developer	221
Tips for becoming an awesome software developer	221
Setting Up a Development Environment	223
Finding Where to Get Your Quantum On	224
Getting started with the Strangeworks Python SDK	225
Let's optimize something	226
Singing QAOA-ooooo	228
Getting started with QAOA	229
Breaking Down a Quantum Algorithm	234
Asking Where Do We Go Now?	235
CHAPTER 13: Quantum Computing Applications	237
Thinking in Triplicate	237
Cracking Cryptography with Quantum	239
Finding Waldo in a Sea of Striped Hats	243
Grabbing That Cash	244
Insuring That Quantum Makes Its Mark	245
Making the World Go Round with Logistics	246
Dreaming of Machines Learning	248
Searching for the New Oil in Quantum	249
Making Materialism Matter	250
Simulating Our Way to Better Health	251
Finding New Pharmaceuticals	252
Forecasting Future Fog	253
CHAPTER 14: Quantum Computing Algorithms	255
Mapping Quantum Computing Algorithms to Applications	256
Understanding the Basics of Quantum Algorithms	258
Mapping algorithms to use cases	258
Investing in research	259
Visiting the Quantum Zoo	261
Finding New Kinds of Time	261
Starting with the Deutsch-Jozsa Algorithm	265

Making Shor Quantum Computing Will Be Big	266
Searching with Grover	267
Using the Quantum Phase Estimation Algorithm.....	268
Applying Simon's Algorithm	270
Implementing the Quantum Fourier Transform (QFT) Algorithm	271
Stepping into Vaidman's Quantum Zeno Effect	273
Getting Linear with the HHL Algorithm	274
Solving and Simulating with QAOA.....	275
Getting Grounded with VQE.....	276
Assessing Additional Algorithms.....	277
Identifying What's Ahead	278
CHAPTER 15: Cloud Access Options	281
Exploring the Major Types of Options	282
Grouping public cloud providers.....	282
Examining quantum computer manufacturers	283
Looking at access providers.....	286
Noting the Importance of Amazon Braket.....	287
Counting on Azure Quantum.....	290
Investigating Google Quantum AI	292
Opening Quantum Computer Vendor's Portals	294
Unlocking Quantum Potential with Strangeworks.....	297
Perusing a classical catalog of quantum technologies	299
Exploring compute providers	300
Understanding managed applications.....	302
CHAPTER 16: Educational Resources.....	305
Connecting with Online Classes	305
MIT Quantum Information Sciences.....	306
Quantum Cryptography	308
The Quantum Internet and Quantum Computers: How Will They Change the World?	308
Understanding Quantum Computers	309
Quantum Quest.....	309
Quantum Machine Learning	310
Quantum Computing: Less Formulas — More Understanding.....	310
Black Opal.....	311

Trying Tutorials and Documentation	311
Nielsen and Chuang	311
Documentation for Forest and pyQuil	312
Documentation for Ocean	312
Documentation for Xanadu's Strawberry Fields	312
IBM Q Full User Guide	314
John Preskill's Notes on Quantum Computation	314
Qiskit Tutorials	315
The Quantum Algorithm Zoo	316
Quantum Computing Playground	317
Quantum Katas	318
Quantum Machine Learning for Data Scientists	318
Skipping through Unstructured Study	319
Blogs	319
Papers	321
Getting into Interaction and Fun	323
Communities	323
Interactive Learning Tools	324
Videos	326

PART 4: THE PART OF TENS.....327

CHAPTER 17: Ten Myths Surrounding

Quantum Computing	329
Myth 1: Quantum Computing Won't Be Commercially Available for 10–15 Years	330
Myth 2: A Qubit Can Be a 0 and a 1 at the Same Time	331
Myth 3: Quantum Computers Will Replace Classical Computers	332
Myth 4: Only a Physicist Can Program Quantum Computers	333
Myth 5: Quantum Computers Will Soon Solve All Classical Computer Problems	334
Myth 6: We Should All “Shut Up and Calculate”	334
Myth 7: Soon There Will Be Only a Small Number of Quantum Hardware Companies	335
Myth 8: Quantum Companies Have All the Talent They Need to Grow the Industry	336

Myth 9: Quantum Computing Will Destroy Data Encryption	336
Myth 10: Quantum-Safe Cryptography Provides Complete Data Security	337
CHAPTER 18: Ten Tech Questions Answered	339
Will Quantum Technology Find Its Way into a Consumer Product?	339
Is the Quantum Realm Real? Will Ant-Man Save Our World?	340
How Do You Explain Quantum Computing to a Dummy?	341
Where Is the Quantum Computing Field Going?	341
When Will Quantum Computing Become Commercially Practical?	342
What Is the Coolest Application of Quantum Computing?	343
Where Will Quantum Computing Be the Most Disruptive?	343
How Long Until Shor's Algorithm Breaks RSA?	344
How Can You Use Quantum Computing in Manufacturing?	344
Where Is the Overlap Between Quantum Computing and AI/ML?	344
CHAPTER 19: Ten Business Questions Answered	347
How Can I Evaluate the Market for a New Company, Product, or Service?	347
How Do I Evaluate My Employer's Need to Be an Early Adopter (or Not)?	348
What Roles and Jobs Are Needed in the Current Stage of Development?	349
What Background Is Needed to Learn Quantum Computer Coding?	350
What Advice Can You Give to First-Timers?	350
What University Programs Would You Recommend?	351
Who Is the Current Leading Developer of Quantum Computing?	351
What Should I Do if I Have an Idea for a Startup?	352
What Habits Have Helped You in Your Career?	353
What Are Your Biggest Lessons Learned?	353

CHAPTER 20: Ten University Research Programs	355
University of Oxford, UK	356
University of California, Berkeley	356
Stanford University	357
Cal Tech	357
Massachusetts Institute of Technology	357
Harvard University	358
University of Chicago	358
University of Maryland	359
University of Waterloo	359
University of New South Wales, Sydney	359
INDEX	361

