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BOOK REVIEW

on

The Physics of Quantum Information: Quantum Cryptography, Quantum Teleportation, Quantum Computation

edited by Dik Bouwmeester, Artur Ekert and Anton Zeilinger
Springer Verlag, 2000
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It is an obvious but profound observation that information and communication require a physical medium for support. If asked to point to information we inevitably point to some physical object, be it ink on paper, the magnetic orientations of metallic grains on a hard disk, or tiny pulses of light coursing through an optical fiber. Yet information lies in a conceptual category once removed from physical objects because it does not matter much what physical objects we chose to represent it.

Probability is a concept that bears a similar relationship to matter. If we toss a coin we can talk about the probability to obtain a head or a tail. In quantum mechanics we can calculate the probability to obtain particular measurement outcomes for some physical quantity. However, no one has seen a 'probability' in the same way we see a coin land heads up or a pointer deflection on an instrument. Yet we can talk and reason about probability without referring to anything in particular. In a similar way, we can only point to specific physical examples of information, but reason about the properties of information in the abstract. In the last decade a revolution has taken place in our understanding of the physical world precisely because we have learned to take this more abstract view of quantum theory. By considering the quantum mechanics of those physical systems that execute communication or computational tasks we have discovered the new science of quantum information with profound implications for physics and technology.

A great textbook can define a field for a generation. Meisner, Thorne and Wheeler's *Gravitation* comes to mind. The field of quantum information science is as yet too young for us to expect such a text, although Nielsen and Chuang's lucid and coherent presentation (*Quantum Information and Computation*, reviewed in QIC Vol.1, No.2, September 2001) comes close. For some time to come the best resource for the beginner will remain the primary literature, as published in print or on the Los Alamos archive, supplemented by multi-author works just beginning to appear. Of the latter the best of these so far is *The Physics of Quantum Information* edited by Dik Bouwmeester, Artur Ekert and Anton Zeilinger and published by Springer Verlag. It is too much to expect that a multi-author book would present a coherent vision of a subject as young as this. The editors however have done an excellent job of stitching together a rewarding tapestry of the field as it stands today.

The subtitle of the book is *Quantum Cryptography, Quantum Teleportation, Quantum Computation*, but it could well have been *Quantum Information Science: The View from Europe*, as the book provides a snapshot of the very best of European research in this field. The book is roughly divided into two parts: one dealing with the more established aspects of quantum communication and the elementary aspects of quantum computation; and the second dealing with more advanced topics such as quantum networks, decoherence and entanglement manipulation. A special feature of the book is the mix of theoretical and experimental topics. Given the immature state of experimental quantum information science this is not an easy balance to strike.

The book as a whole has a distinctly quantum optics flavor. This is not due to a bias on the part of the editors. The fact is that the best experiments in quantum information have been in the general field of atomic, molecular and optical (AMO) physics. The book does not contain a discussion of quantum information science in the context of condensed matter physics. Admittedly, experiments on solid state implementations of quantum computing are just getting under way, but a chapter on quantum information in the context of condensed matter physics would have made the book more accessible to the large condensed matter physics community. At the very least a discussion of superconducting schemes for quantum computation could have been included.

The chapters in the book that deal with quantum communication are particularly successful. The discussion includes such topics as quantum cryptography, teleportation, dense coding and quantum networks. The discussion on cavity QED, ion trapping and NMR experiments provide an excellent introduction to these fields. The treatment of quantum computation is less successful. To be fair this may be a reflection of the current state of our understanding. There is no consensus view on why quantum mechanics offers a bonus, if any, in computational efficiency. The allusions to the many-worlds-interpretation of quantum mechanics in the chapter introducing quantum computation, provide an indication of how desperate the situation is. The many-worlds-interpretation provides most certainly not a consensus view of quantum mechanics and, while seductive, it seems to me little more than the last desperate refuge of the classically minded. As far as I am aware photons do not interact with each other in this universe, let alone with photons in other putative universes. I expect that our understanding of quantum computation would increase considerably if we had a few more algorithms like Shor's factoring algorithm. Alas, there is no algorithm for finding algorithms, and future progress will require hard work, inspiration and a good dose of serendipity. The discussion of quantum algorithms in this book is excellent and would be useful to a beginner, despite being needlessly technical at some points. Anyone with an ambition to find the next stunning quantum algorithm would do well to begin with this chapter.

This book does not provide a comprehensive introduction to this exciting field. For that a beginner should look to the book of Nielsen and Chuang. Nonetheless *The Physics of Quantum Information* is essential reading for anyone new to the field, particularly if they enter from the direction of quantum optics and atomic physics.

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