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Book review

Concepts of Simultaneity From Antiquity to Einstein and beyond
Max Jammer
2006 The John Hopkins University Press
320pp US$38.96, £22.11 (hardback)
ISBN: 978-0-8018-8422-1

Concepts of Simultaneity (henceforth: *Simultaneity*) is Jammer's historical monograph dedicated to the development of a single concept in physics. Jammer's idea to write a history of concepts of simultaneity proves to be a wonderful idea: it makes *Simultaneity* literally unique and it provides a new perspective from which to look at the historical development of concepts of time, about which much has already been written. Anyone who believes that Einstein was the first person on planet Earth to reflect on how to establish whether two distant events have occurred at the same time, i.e. simultaneously, will stop believing this after having read chapters 2 and 3 of *Simultaneity* (chapter 1 consists of terminological preliminaries), which deal with Antiquity and the Middle Ages, respectively. For example, Augustine of Hippo anticipated, in his Confessions (397 C.E.), nothing less than the method to determine the simultaneity of distant events that we associate with Einstein. Augustine set out to criticise the heresy of astrology. He considered two infants being born simultaneously in distant places. According to the doctrines of astrology they should lead very similar lives, because they are born under the same constellation of the stars. Yet one infant, Augustine imagined, is the child of a poor maid servant whereas the other is the child of a rich lady, so that they would almost certainly lead very different lives. How to know whether the infants are born simultaneously? Augustine proposed to dispatch, at the moment of birth, two messengers who run equally fast from the houses were the babies were born (whether they do run equally fast can be ascertained by using only local simultaneity judgments); the messengers should run towards each other in order to see whether they meet 'at equal distance from either house' (p.49). If so, the infants were born simultaneously. Of course, this will not be very accurate, but that is not the point. The point is that when we replace the messengers by rays of light, we obtain one of Einstein's signalling methods to synchronise distant clocks. The next two chapters (4 and 5) lead us through the rise of classical physics; the rest of the book (more than a third, 10 chapters) is devoted to the 20th Century and enacts the stage of Relativity. In the longest chapter, chapter 7, Jammer traces Einstein's thinking about simultaneity from his epoch-making paper 'Zur Elektrodynamik der bewegten Körper' (1905), which founded his Special Theory of Relativity, through all of his subsequent writings; this surprisingly reveals various subtle and important differences, such as that Einstein's method of 1911 uses no clocks at all to determine distant simultaneity but only measuring rods. Another thing we learn is that in 1917 Einstein realised that his synchronisation procedure is not an empirical determination of distant simultaneity but a stipulation, or a convention, because it assumes that the speed of light travelling in opposite directions is the same (isotropy of space), and the 'two-way velocity of light' cannot be determined empirically without presupposing that distant simultaneity has been determined antecedently. This conventionality thesis is usually ascribed to the philosopher Hans Reichenbach, who expounded it in his famous Philosophie der Raum-Zeit-Lehre (1928)—Einstein reviewed and admired this book. The conventionality thesis has proved difficult to swallow for many physicists and philosophers alike. Frequently some physicist proposes an experiment supposed to confute the conventionality thesis; but these proposals, no matter how ingenious, never survive scrutiny. Jammer devotes no less than three chapters to the enormous amount of literature on this topic. A seminal result concerning the conventionality thesis is the philosopher David Malament's proof of the theorem that the implicity definability of the simultaneity relation in terms of the structure of Minkowski space-time uniquely determines the standard convention (1977). R.I.P. conventionality thesis? The lively debate about this question is the topic of chapter 14. Finally we want to mention chapter 11, which is devoted to the question of whether the simultaneity relation is, besides trivially reflexive, symmetric and transitive too. Einstein explicitly mentioned in 1905 that he assumed this to be so, if only for the sake of expediency—it needs to be an equivalence relation in order to partition Minkowski space-time, we would say now. Should however the symmetry and transitivity of the simultaneity relation not follow from the synchronisation procedure? It turns out that for Einstein's standard procedure (equal two-way velocity of light assumed) the symmetry and in particular the transi-

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tivity cannot be demonstrated without making additional assumptions. Jammer provides a piercing discussion of all sorts of fascinating schemas to demonstrate the symmetry and transitivity. What can be established without additional assumptions is that non-standard simultaneity relations are neither symmetric nor transitive. The chapter ends with a conventionality thesis of transitivity! All in all, in spite of the deplorable fact that *Simultaneity* does not have a list of references (which means annoying footnote back tracking), every serious physics and philosophy library should have it on its shelves. Everyone who is teaching a course in the Special Theory of Relativity will do well to spend an afternoon browsing *Simultaneity* and to studying chapters 7, 9, 11, 13 and 14. Recommendations to even bachelor-level students are appropriate, because *Simultaneity* is a monograph that is accessible, revealing and engaging.

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The Quantum Hall Effect: Poincaré Seminar (Progress in Mathematical Physics)
B Doucot, B Duplantier, V Pasquier and B Rivasseau (Editors)
2005 Birkhauser Verlag AG
197pp EUR69.90, £54.00 (hardback)
ISBN 978-3-7643-7300-9

The *Séminaire Poincaré* provides hopefully accessible, accurate and up-to-date reviews of important topics in physics. The seminar usually invites people from both experiment and theory to discuss aspects of the topic. Recent topics, including Entropy (2003), Einstein (2005), and Quantum Decoherence (2005), demonstrate a determination on the part of the organisers to keep the seminar attractive to almost anyone active in physics and to avoid becoming too focused on a specialist area of research.

A seminar on the quantum Hall effect (QHE) was held in 2004. There were presentations by Klaus von Klitzing (historical overview), Benoit Doucot Vincent Pasquier (introductory theory), Blaise Jeanneret and Beat Jeckelman (QHE as an electrical resistance standard), Steven Girvin (introduction to the fractional QHE) and by Christian Glattli (tunnelling in the FQHE regime). This book is the collection of their contributions.

The QHE as a field is already well-served by a small number of excellent books containing original articles by collections of authors and by a reprint volume, so it was not at all clear what a new volume could contribute. Well, this seminar has found something. It concentrates on experimental aspects not so often reviewed and keeps the theory as non-technical as possible. The introductory notes on the theory of electrons in a strong magnetic field give a beautiful explanation of the background theory. In the rush to get onto the technically challenging theory, this material is often assumed part of everyone's background knowledge or it is oversimplified. At the level of a first year graduate student/final year masters student, the chapter takes the reader carefully through projection onto a Landau level, Laughlin's original argument for the quantization of the Hall effect and the link to a topological invariant. Steve Girvin's chapter is at approximately the same level. It covers introductory material on the Laughlin wavefunction and its neutral and charge excitations.

The chapter on metrology is a stand-alone article about the use of the QHE in defining absolute standards of measurement. The authors have given an interesting account of how the small deviations from an absolute standard or resistance depend on aspects of the samples, the current distribution, the temperature, edge states as well as contacts. They also explain how the QHE is now used by most metrology institutes to provide a dc reference for the Ohm.

The final chapter on tunnelling in FQHE systems looks at conductance and shot noise measurements (many of which were made by collaborations including the author). Backscattering in the FQHE by constrictions lead to a non-linear conductance in which the exponent varies as a power of voltage, which (according to theory) is quantized, and in which the shot noise directly measures the charge of the elementary excitation. This chapter is very welcome. It manages to explain what is actually measured and how to think about the implications without including technical theory.

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Principles of Quantum Computation and Information Volume II
G Benenti, G Casati, and G Strini
2007 World Scientific Press
444pp US$38, £22 (paperback)
ISBN 978-981-256-528-0

Any new textbook in quantum information has some pretty strong competition to contend with.

Not only is there the classic text by Nielsen and Chuang from 2000 [1], but also John Preskill's lecture notes, available for free online [2]. Nevertheless, a proper textbook seems more enduring than online notes, and the field has progressed considerably in the seven years since Nielsen and Chuang was published. A new textbook is a great opportunity to give a snapshot of our current state of knowledge in quantum information.

Therein also lies a problem: The field has expanded so much that it is impossible to cover everything at the undergraduate level. Quantum information theory is relevant to an extremely large portion of physics, from solid state and condensed matter physics to particle physics. Every discipline that has some relation to quantum mechanics is affected by our understanding of quantum information theory. Those who wish to write a book on quantum information therefore have to make some profound choices: Do you keep the ultimate aim of a quantum computer in mind, or do you focus on quantum communication and precision measurements as well? Do you describe how to build a quantum computer with all possible physical systems or do you present only the underlying principles? Do you include only the tried and tested ideas, or will you also explore more speculative directions? You don't have to take a black-or-white stance on these questions, but how you approach them will profoundly determine the character of your book.

The authors of *Principles of Quantum Computation and Information (Volume II: Basic Tools and Special Topics)* have chosen to focus on the construction of quantum computers, but restrict themselves mainly to general techniques. Only in the last chapter do they explicitly address the issues that arise in the different implementations. The book is the second volume in a series, and consists of four chapters (labelled 5 to 8) called 'Quantum Information Theory', 'Decoherence', 'Quantum Error Correction', and 'First Experimental Implementations'. The first volume covers the basics of classical computation, quantum mechanics, quantum computation, and quantum communication.

Chapter five starts with the density matrix formalism, and proceeds with the development of the Kraus representation, POVMs, von Neuman entropy, quantum data compression, the Holevo bound, the partial transpose criterion, and it ends with a very nice section on the various entropies that play a role in modern physics. This includes not only the thermodynamical and statistical entropy, but also the dynamical Kolmogorov–Sinai entropy, which is used in quantum chaos in chapter 6. On the whole, I think that this is a really clear and well-presented chapter. A minor drawback is that the concept of CP maps is not explained as well as it could have been, for example by relating it to the partial transpose criterion.

Chapter six continues with the high standard set in chapter five, and presents a very thorough exposition of decoherence in general. It introduces the different decoherence channels, and gives truly excellent explanations of the master equation (tied in with the Kraus representation), quantum jumps, and the quantum trajectory formalism. It also has an elegant explanation for the sensitivity of Schrödinger cats to decoherence. I do miss a proper section on the fidelity of a quantum state, though. The chapter ends with two sections on quantum chaos. Since the authors are experts in this fascinating area, this is a welcome addition to the canon of topics typically covered in quantum information. Unfortunately, the section is quite hard to follow, and as a result it is a bit of a missed opportunity. There is a section on chaos in the first volume of this series, and this may provide the required background. However, for readers who posess only volume II this is of little use.

Chapter seven on quantum error correction is disappointing, and I have the feeling that the authors went through the motions without a real passion for the subject matter. The chapter describes various error correction codes, including Hamming codes and CSS codes, but it is virtually silent on fault tolerance; it does not give examples of universal sets of fault tolerant gates, and it does not mention the Solovay–Kitaev theorem. Also, it does not present the stabilizer formalism. All of these are serious omissions in a textbook on quantum information theory.

Chapter eight gives a rough sketch of the early simulations and implementations of quantum gates. The readers of this journal will have no trouble following this chapter, but the undergraduate in computer science or mathematics will be completely lost. Most (but not all) physics terms do get a brief explanation, but I doubt whether that is enough to keep non-physicists on board. The chapter covers NMR, cavity QED, ion traps, solid state qubits, and optical implementations of quantum communication.

I would have liked to see a more bold choice for the topics covered in the last chapter. For example, whereas liquid-state NMR was an important step in the development of quantum technologies, and many current techniques were invented for it, it does no longer play a role in the design of quantum computers. It would have been better to introduce these techniques in a section on condensed matter systems. Also, as a snapshot of our current state of knowledge in quantum information, I really miss extensive sections on the one-way model of quantum computing [3] and topological quantum computing [4].

In conclusion, the second volume of *Principles of Quantum Computation and Information* is a partial success. The first two chapters are very good, and I would happily pay £22 for these two chapters alone. However, for a text on quantum error correction the reader is better off with Nielsen and Chuang or Preskill's lecture notes. If the reader wants an overview of quantum information in specific physical systems, there are a host of review articles to choose from, which give more details and are generally more accessible.

References

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