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Book Review: *Path Integrals from meV to MeV*

Path Integrals from meV to MeV. M. C. Gutzwiller, A. Inomata, J. R. Klauder, and L. Streit, eds. World Scientific, Singapore and Philadelphia, 1986, XI + 453 pp.

This volume contains the papers from a symposium held at the Bielefeld Center for Interdisciplinary Research in August 1985. That conference (which was preceded in 1983 by a similar one in Albany) gave an overview of the present work on and with path integrals. The applications cover a wide range of physics, from fairly low-temperature phenomena (1 meV $\approx k_B T$ for $T \approx 10$K) through all of physical chemistry and condensed matter physics to nuclear physics (1 MeV is about the "hot" end of nuclear physics). As the applications of path integrals keep proliferating, a regular series of conferences devoted to this topic, as well as publication of their proceedings, is of great help to the scientific community in order to digest and consolidate what has been done.

I shall not review each one of the 29 contributions to this volume separately, but rather point out some general trends that might be interesting to a readership of statistical physicists.

One of the most notable recent results is the exact calculation of various highly nontrivial path integrals with sophisticated space-time transformations. For example, the path integral for the hydrogen atom can be calculated explicitly, using the Kustaanheimo–Stiefel transformation for the intermediate space coordinates and a position-dependent transformation for the intermediate time coordinates. These transformation techniques are adding a new dimension to path integration, but it is still not understood when they can be expected to work. This point is discussed by Inomata; the application to polar coordinates is discussed by Steiner, and that to the Hartmann potential by Carpio and Inomata.

Various other contributions are devoted to the explicit calculation of path integrals with other, less general means. For example, Castrigiano and Kokiantonis calculate the partition function of a quantum oscillator coupled to a radiation field, Khandekar, Lawande, and Bhagwat give explicit expressions for the propagator for a general two-time quadratic

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action, Schulman discusses the propagator for the delta function potential, and Junker and Inomata study the Rosen–Morse oscillator.

Another general trend is the increasing sophistication of the saddle point method, the main approximation technique for path integrals that cannot be calculated exactly. For example, the usual difficulties near caustics can be avoided by using a coherent-state path integral (Klauder). Also, there are indications that the approximation is useful even for certain chaotic quantum systems (Gutzwiller, Reinhardt, and Gillilan). Voros actually suggests that this approximation method can be pushed to give the full solution of the Feynman path integral. Hunt, Hunt, and Ross show that it leads to accurate results in some nonlinear cases of nonequilibrium thermodynamics, and Patton uses it to discuss ocean acoustics.

Numerical simulations of path integrals are reviewed by Negele, who stresses that one needs to know the essential physics of the system (tunneling, spontaneous fission) to find an efficient algorithm. Here the situation is analogous to the Monte Carlo simulation of polymer configurations (the Wiener path integral!), where there is an ongoing discussion of the proper algorithm [cf. M. D. Frank-Kamenetskii and A. V. Vologodskii, *Sov. Phys. Usp.* **24**:679 (1981)].

There is much more of interest in this volume. For example, recent progress in polaron theory with the use of variational methods is reviewed by Devreese. Quantum electrodynamics and quantum field theory form the subjects of papers by Barut, by Kleinert, and by Duru and Unal (here one slips out of the MeV to MeV range, but this is quite commendable, as it helps to close the gap between the statistical physics and high-energy physics literatures).

There are also several contributions by mathematical physicists, mainly trying to provide a firm foundation for the Feynman path integral. As this work is outside the competence of the reviewer, he will only note the general impression that this problem is indeed slowly collapsing under the weight of modern mathematics.

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Book Review: *Entropy in Relation to Incomplete Knowledge*

Entropy in Relation to Incomplete Knowledge. K. G. Denbigh and J. S. Denbigh. Cambridge University Press, 1985.

If you liked undergraduate thermodynamics, you'll really like this book. All those worries and uncertainties that you had when you tried to get an intuitive idea about "that entropy thing" (as one of my classmates called it) have been turned into a book to be read with pleasure whether or not you ever thought you understood entropy, whether or not you're a student on your first round, or whether or not you agree with the authors' verdict (and maybe even whether or not you have ended up an officer on a nuclear submarine as my classmate did).

As we all know, the trouble is the apparent conflict between entropy as disorder/ignorance, known only subjectively, depending on how many measurements we can make, and entropy as a function needing to be invented to predict the quantity of usable work, i.e., the thermodynamic definition of the Carnot cycle and all that. The authors come down solid for the objective definition. As the world discovered molecules, and then formulated Information Theory, there emerged too much of a temptation to equate the information that we learn about a system with the decrease in the system entropy seen as a quantity of disorder or ignorance. The extra information one gains from molecular measurement indeed reduces our ignorance, but it leaves the system's entropy unaffected.

(No? Imagine that you knew the location and momenta of all particles to within uncertainty limits. So you have the entropy near zero? Now cool the system. You haven't left room for the entropy to decrease.)

After going through it all—and the authors make sure there is enough "all" in Appendices aimed to bring everyone back up to speed on thermodynamics, statistical mechanics, and quantum statistics—the issue seems to fall back to a question of language. It was wrong to use "entropy" for information. The linguistic culprits are some pretty big names and some fine physicists.

Shannon was reportedly persuaded by von Neumann to call his infor-

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mational uncertainty function "entropy": "It's already in use under that name, and besides it will give you a great edge in debates because nobody really knows what entropy is anyway" (p. 104).

What with people being able to use lasers to bring small numbers of particles to a near standstill, we might be seeing a continuum of possibilities between mechanics (quantum or classical) and statistical mechanics. We will have enough information to bring system uncertainties near zero and even call it "entropy" to make ourselves feel warm or intellectual or whatever. But maybe a different word would save a lot of trouble.

In any case, read the book.

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