THREE TIMELY LOOKS AT THE FOURTH DIMENSION

The Nature of Time

Edited by Raymond Flood and Michael Lockwood
Basil Blackwell, New York, 1986. 187 pp.
$19.95 hc ISBN 0-631-14807-8

Asymmetries in Time: Problems in the Philosophy of Science

Paul Horwich
MIT P., Cambridge, Mass., 1987. 218 pp.
$22.50 hc ISBN 0-262-08164-4; $9.95 pb ISBN 0-262-58088-8

The Physics of Time Reversal

Robert G. Sachs
U. of Chicago P., Chicago, 1987. 309 pp.
$55.00 hc ISBN 0-226-73330-0; $23.00 pb ISBN 0-226-73331-9

Reviewed by Peter T. Landsberg

A colleague from the department of English asked me recently, "When you are not doing mathematical physics, what are you interested in?" Feeling a little wicked, I said, "Oh, problems of time!" This started an animated conversation in which he seemed to defend the view that this was not only a worthy subject, but a problem underlying most literature: "What else is there?" That three books on this subject, published in 1986–87, can be reviewed together is therefore no surprise. They represent, in fact, only some of the books that have been published on the topic in this period. But this does not constitute a "time boom"; it is just a continuing preoccupation.

The three books progress from one largely on physics (Sachs) through physics and philosophy (Flood and Lockwood) to philosophy (Horwich). Each contains worthwhile and thought-provoking ideas.

The Nature of Time has nine chapters by different authors. By analogy with the stock market, with such a "portfolio" of authors, one expects a "winner" or two—and that turns out to be the case in this book. You could buy it, say, for Roger Penrose's 26 pages of questioning, among other topics, whether the early universe was of high entropy because it was *hot*, or of low entropy because it was *early*. Or are we just living in a giant entropy fluctuation?

The problem is that gravity is the only one of the four basic forces that acts over long distances. Hence it can organize matter in space as time goes on. This is how stars and galaxies are produced. These would appear to be low-entropy structures. How can this be brought into line with the principle of entropy increase? One suspects that something is missing from conventional entropy calculations, namely a factor that relates entropy to the clumpiness of matter. This chapter's speculative suggestions are surely vintage Penrose.

On the other hand, if the reader already knows some thermodynamics, he can probably skip "Time and Dispersal: The Second Law" by P. W. Atkins, which is more introductory. In the philosophy section of the book I liked Michael Dummett's "Causal Loops" (although he does not mention Gödel universes). On the other hand, the Schrödinger cat paradox is discussed by at least three contributors, and inconclusively to boot, so that if one was not tired of it at the start, one surely will be at the finish. Perhaps it is naive to suggest that if one uses a probabilistic theory like quantum mechanics, it is not surprising that it cannot apply to an individual experiment. Hence in an ensemble of Schrödinger cats, the fraction of cats to be found dead will correspond to the quantum mechanical calculation and, based on the present theory, one is not entitled to expect more.

Horwich is a professor of philosophy at MIT and his is a philosopher's book. It conveys an admirable sense of modesty: "No overall 'philosophy of time' is contained in this work," he writes in one place; and elsewhere, "which cosmological conditions might account for [time] is really the business of physics. My main concern has been to examine its philosophical ramifications." He certainly does mention all conceivable asymmetries of time: one-way processes in thermodynamics, the fact that we know the past better than the future, the questions of backward causation (traveling to one's own past, tachyons) and other time travel ("auto-infanticide"), the philosophy of causation and counterfactuals. These latter are statements of what might be: If p were true, then q would be true. This sentence is false only if p is true and q is false. Such statements occur frequently in science. For example, when we describe a substance as soluble, we mean, "If it were put in such and such a liquid, it would dissolve." The philosophical problem that seems to be of considerable contemporary philosophical interest is what background set of facts goes into a counterfactual statement. Such statements are usually future-directed: "If the match had been struck, it would have lit." Of course, "If the match had lit, it would have been struck" is also possible, and is past-oriented. The discussion in the book, while no doubt excellent philosophy, may strike the physicist reader as occasionally tedious. A physicist would be inclined to reject a model once it had been shown to allow auto-infanticide. One has in physical theory a "no time travel" rule, which states that nothing can visit its own past, and most physicists would not try to discuss this rule at length.

Among my minor criticisms is that Horwich should have pointed out that

Peter T. Landsberg is a professor at the University of Southampton, UK, and the University of Florida, Gainesville. His research interests include thermodynamics, statistical mechanics and semiconductors. He is the editor of *The Enigma of Time* (Adam Hilger, Bristol, UK, 1982).

a tachyon detector becomes a tachyon emitter in some frames of reference and therefore one must discuss measurements with some care. Also, he might have modified his remark that statistical mechanics cannot explain an entropy increase if he had considered coarse-graining. What I found most surprising is that Horwich envisages repeatedly that "time itself" is temporally asymmetric without ever explaining what this might mean.

However, this is indeed as wide-ranging a book on the purely philosophical problems of time as one is likely to find. I am happy to agree with physicist Arthur Fine (quoted on the book's jacket) that the chapter on Gödelian universes is good fun. The discussion is also "unified" by the repeated use of certain flow charts—but real unification of such diverse discussions is not really possible.

Sachs is the author of the well-known *Nuclear Theory* (Addison–Wesley, Reading, Mass., 1953), and in his new book he gives a workmanlike introduction to all important aspects of the time-reversal transformation, T. After short chapters on time reversal in classical mechanics and in quantum mechanics he takes us through the physics of decay processes to T invariance in classical and quantum field theories. This thorough and pedagogical treatment arrives at the CPT theorem in the second half of the book, where the connection with experiment (K mesons, for example) and unified field theories is carefully explored.

Here C stands for the operation of charge conjugation, whereby the field operator associated with a particle is replaced by the analogous one for the antiparticle; P stands for parity, or roughly the operation of spatial inversion $\mathbf{r} \to -\mathbf{r}$; and T stands for the operation of time reversal $t \to -t$. Separate C and P invariance of the fundamental physical interactions was replaced by the idea of their invariance under the joint action of C and P in view of studies on neutral K mesons. This led to the idea of the CP mirror, which (in common with normal mirrors) converts a right-handed coordinate system to a left-handed one, and which in addition converts every particle to its antiparticle. The discovery that the weak interactions violate even CP invariance then led via the assumed CPT invariance also to violation of T invariance. Sachs exposes the subtleties of this well-known story, which lead one to ask for even more searching experimental tests of CPT invariance and for deeper analyses of the foundations of the proofs of the CPT theorem. A tabular summary of key features of the theory and history of these problems would have helped.

This is a book for theoretical physicists, and it is unique in the depth of its treatment of the quantum mechanical aspects of time reversal. I highly recommend it.

Science, Computers and People (From the Tree of Mathematics)

Stanislaw Ulam
Birkhäuser, Boston, 1986. 264 pp. $39.00 hc
ISBN 0-8176-3276-X

Although trained formally as a pure mathematician, Stanislaw Ulam truly flowered intellectually when he arrived at Los Alamos in 1944. There he entered a period of remarkable developments in applied mathematics and particularly the application of mathematics in novel ways to somewhat unconventional fields. And with tutelage from such greats as J. Robert Oppenheimer, Enrico Fermi, John von Neumann and others, he built up a penetrating physical insight. This he applied in many areas, including hydrodynamics, nonlinear mechanics and statistical mechanics. Perhaps most remarkable of all is that he is credited, along with Edward Teller, with inventing a method for igniting thermonuclear reactions, which made possible the construction of thermonuclear bombs (certainly far afield for a mathematician!). For another 40 years Ulam remained a catalyst for an amazing variety of brilliant intellectual advances at Los Alamos.

The present book is a posthumous collection of about two dozen short essays by Ulam on the topics specified by the title: science, computers and people. Those on people are easiest to characterize. We are presented with seven descriptions, some serving as obituaries, of people like von Neumann, George Gamow and Stefan Banach. They are delightful. Each contains factual material and personal observations and inferences blended in an informative and entertaining way. The editors have done us a great service by gathering this material from diverse and sometimes obscure sources into one convenient volume.

The essays on science and computing are less straightforward. First, it is hard to say for whom some of the articles are written. They would be extremely elementary for the average physicist, yet for the lay reader they often use too many technical terms