

References

1. H. P. Noyes, D. O. McGoveran, *Phys. Essays* **2**, 76 (1989).
2. D. O. McGoveran, H. P. Noyes, *Phys. Essays* **4**, 115 (1991).
3. W. H. Zurek, K. S. Thorne, *Phys. Rev. Lett.* **54**, 2171 (1985).
4. J. A. Wheeler, in *Proc. 3rd Int. Symp. on Foundations of Quantum Mechanics, Tokyo, 1989*, S. Kobayashi, H. Ezawa, Y. Murayama, S. Nomura, eds., Phys. Soc. Japan, Tokyo (1990), p. 354; *IBM J. Res. Dev.* **32**, 4 (1988).

H. PIERRE NOYES

Stanford Linear Accelerator Center
11/91 Stanford, California

LANDAUER REPLIES: I am pleased that Pierre Noyes finds a relationship between his views and my paper. In that connection I want to point out that my own, much less specific viewpoint¹ concerning the laws of physics was first published in 1967.

The work of a number of contributors with very differing viewpoints and backgrounds has led to our understanding of reversible computation. David Wolpert sees a need for a more formal approach. I wish him luck, and hope he can generate it. Wolpert accuses us of ignoring Gibbs entropy, $-\int d\Gamma \rho \ln \rho$. But it was invoked already in my 1961 paper.² Wolpert correctly summarizes the original (but not the most definitive) argument for the energy dissipation required by noninvertible logic functions: The compression in phase space of the information-bearing degrees of freedom must be made up by an expansion in phase space of the "environment." This expansion is the dissipation, reflected as an increase in the entropy of the environment. We do not need to go beyond that, and we do not need to invoke a further net increase in phase space, as implied by Wolpert. Resetting bits, or spins, into a standardized state is, after all, the opposite of adiabatic demagnetization, and we can expect the environment to be heated as a result. Wolpert tells us that one cannot use the kind of argument we have invoked to meaningfully address the temporal inverse of a process that involves a many-to-one mapping. But I have done exactly that.³

Wolpert invokes the Gibbs entropy, which characterizes an ensemble but not a specific physical configuration such as the state of the computer at hand. Then he goes on to suggest the use of this entropy as an information-bearing variable. He has lost me at this point. From someone who likes formality, this seems a strangely vague proposal. Does he have systems in mind that carry information only

through their distinction in entropy, without a distinction in other variables used to define the ensemble?

Wolpert tells us that the literature on reversible computation contains no mathematics. That is an inaccurate characterization. The key points, as in thermodynamics, are best stated in simple terms.

Until Charles Bennett came along and expounded reversible computation,⁴ admittedly there was confusion, inconsistency and a tendency to assume that information loss was an essential ingredient in computation. Wolpert overstates the case in writing that "all researchers... were sure that reversible computation was impossible." In 1961, I had already pointed out that logically irreversible operations could be imbedded in larger reversible operations.²

Wolpert's reference to Léon Brillouin is misleading. Brillouin's analysis of Maxwell's demon assumed that the information transfer from a molecule to a register inevitably had to be accompanied by an energy dissipation of order kT because the particular method Brillouin invented for that purpose needed this dissipation. That is a far cry from the kind of reasoning used in discussions of reversible computation. A single proposal that shows how computation can be carried out with arbitrarily little dissipation per step is enough to show conclusively that there is no minimal dissipation penalty of order kT per step.

References

1. R. Landauer, *IEEE Spectrum*, September 1967, p. 105.
2. R. Landauer, *IBM J. Res. Dev.* **5**, 183 (1961).
3. R. Landauer, *Phys. Scr.* **35**, 88 (1987).
4. C. H. Bennett, *IBM J. Res. Dev.* **17**, 525 (1973).

ROLF LANDAUER

IBM Thomas J. Watson Research Center
11/91 Yorktown Heights, New York

More on Mind over Measurement

In his reply to my comments (October, page 14) on his Reference Frame column of December 1990 (page 9), Philip Anderson adds a number of new errors to his original misstatements. Most serious is his allusion, via an unidentified third body, to "discarded data" in the work of myself and my colleagues. In point of fact, every shred of data ever acquired in our laboratory has been recorded and preserved with triple redundancy, included in all appropriate analyses and published in proper course. Complete databases of every

experiment performed since the laboratory's inception in 1979 remain available to any sincere scholar who would care to sit at our computers. These data entail many "unsuccessful" experiments, and needless to say, we have learned at least as much from those experiments as from those showing anomalous yield. Any implication of data selection, however veiled, is viciously illegitimate.

As to the adequacy of our statistics, I would only note that our analyses are regularly vetted by several senior statisticians here and at other institutions, that they are refereed in due course as part of the publication process and that we have indeed examined in detail, and published, the application of Bayesian statistics to our data. We find that whenever appropriately deployed, such techniques yield essentially the same results as the more canonical methods.¹

Reference

1. L. Dobyns, *J. Sci. Exploration* **6**, 1 (1992).

ROBERT G. JAHN

Princeton University
11/91 Princeton, New Jersey

Safety Assurances for Chinese Conference

In response to a news report on page 62 of the December issue, I would like to tell everyone who is interested in participating in the 21st International Conference on Semiconductor Physics, to be held on 10-14 August 1992 in Beijing, that the Chinese Physical Society and the China International Conference Center for Science and Technology have given assurances that the policies of the International Council of Scientific Unions and the International Union of Pure and Applied Physics will be honored. The executive director of ciccst, Wu Ganmei, made the following statement in a letter to the secretary general of IUPAP, Jan S. Nilsson: "As the executive director of CAST [the China Association for Science and Technology] working with ICSU over 10 years, I would like to confirm to you that CAST and Chinese Society of Physics will fully guarantee the unions' policy on the free circulation of all scientists including the free entry and exit of Chinese students now studying and working abroad. If there is any question concerning the above matter, please contact me." The vice president of the Chinese Physical Society, Yang Guozhen, also wrote to Nilsson, "According to the policy of the Chinese government, we, on behalf of