continued from page 15
children, small animals and delicate instruments. Most experimentalists are also deeply religious ("Jesus Christ, why doesn't this goddamned thing ever work?!"). So come on, Phil, ask your colleagues next time!

PAUL KOLODNER
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ANDERSON REPLIES: Robert G. Jahn is correct that his work with his associates at Princeton was among the kinds of work I had in mind in writing the Reference Frame column he refers to. I am a theoretical physicist, not an expert on statistics or an experiment specialist, and while I have spoken to people of both those kinds who have talked with Jahn, I feel our differences would not be helped much by the pleasant collegial chat he suggests. My article was meant to explain why not.

What my piece actually said *was* within my competence as a theorist, which is to make logical connections, and the logical point I made is that physics as it is practiced, and specifically precise mensuration, is not compatible with Jahn's claims; one must choose one or the other, not both, as he also emphasizes. If the "observer effect," as he calls it—or "magic," as one might equally well characterize it—is correct, precise measurement is not possible. His ideas are as incompatible with the intellectual basis of physics as "creation science" is with that of cosmology and biology. It is for this reason that I feel measurements such as Jahn does must be tested with more rigor and more suspicion than their proponents, for some reason, are ever prepared to undergo.

I am told that people who *have* looked in detail at Jahn's protocols have found some familiar problems—discarded data, in particular. This was the substance of some of his interactions with PSICOP, in fact. Mathematical statisticians are also unhappy about some of the work. I might add as an additional point that one problem with this kind of measurement in general is that the appropriate statistical technique is not the conventional method that one uses to measure a known effect and with which most scientists are familiar. (This is the method one is usually referring to in mentioning a "so-and-so-many-σ error.") The technique Jahn uses should be closer to the modern ideas about Bayesian estimation, which is the appropriate statistical method for testing whether an extra physical parameter is needed. Physicists are, regrettably, quite unfamiliar with Bayesian methods. The Bayesian approach builds in Occam's razor—the fact that a simple theory such as physical determinism is better, in some true probabilistic sense, than a more complex one, in that the more complex theory has extra parameters to do the fitting. Bayesian statistics are the answer to the old saw that "with enough parameters, you can fit an elephant." Using Bayesian methods Jahn's numbers would be much less "favorable." (An excellent discussion of Bayesian methods by Anthony Garrett appears in *Physics World*, May 1991, page 41.)

I do not see why it is relevant whether one uses ping-pong balls or "precisely machined spheres" in these experiments. I can live with reproducible ping-pong balls.

Paul Kolodner's amusing letter does not seem to make any point that must be answered. He is not saying that well-made experimental equipment gives wrong answers, I hope, or he may have trouble with some of his colleagues who measure such quantities as e^2/h.

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Ease the Way to Hiring Foreigners

I too am worried about the decline of US science. I also worry about the decline of science worldwide.

It seems odd to me that we worry about the declining availability of good scientists when many of the best and brightest graduate students are unemployable in the United States because of their nationality. I wish I understood better how the US can be a "Mecca" for graduate research, literally attracting students from all nations, but be a "Death Valley" for employment to those same students? Cannot the large body of foreign graduate students help us (and also the world)?

The current political agreements the US has with foreign countries prevent US companies from hiring the best people for the job. I cast my vote in favor of making it easier to hire foreign scientists and engineers.

KELLY TAYLOR
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A Jump Shot at the Wigner Distribution

John Philpott (November 1990, page 123) objects to the definition of the Wigner distribution function used in the extremely well-written and informative article on squeezed and antibunched light by Malvin C. Teich and Bahaa E. A. Saleh (June 1990, page 26). In their reply to Philpott, Teich and Saleh agree to his minor criticism and concur with his modified definition. Surprisingly, neither definition is adequate.

We would like to present an intuitive, physical argument to motivate the standard definition of the Wigner phase space distribution. The central ingredient of our approach is the notion of a quantum jump.

Consider a quantum particle at position x moving in one dimension with momentum p. Here the uncertainty relation allows for a quasiprobability only. In the spirit of Heisenberg's matrix mechanics, we replace the single position x by a quantum jump from an initial position x' to a final position x''. It is reasonable to identify x with the geometric center of these two positions: $x = \tfrac{1}{2}(x' + x'')$. But how to incorporate velocity or momentum into this picture of a particle hopping by an increment $\xi \equiv x'' - x'$? The physics of de Broglie together with the mathematics of Fourier provides the immediate answer: transformation from ξ to $k = p/\hbar$. But what is the function we have to Fourier transform in this way? Heisenberg guides us in finding the answer: He represents an atomic Bohr transition—a quantum jump from an orbital of quantum number n' into one of quantum number n''—by a matrix element $A_{n''n'} = \langle n''|A|n'\rangle$. Here A stands for any dynamical variable, such as the dipole moment. Similarly we now consider the density operator $\hat{\rho} = |\psi\rangle\langle\psi|$ for a pure state $|\psi\rangle$ and its matrix element

$$\rho(x'', x') := \langle x''|\hat{\rho}|x'\rangle$$

$$= \langle x''|\psi\rangle\langle\psi|x'\rangle$$

$$= \psi(x'')\,\psi^*(x')$$

in position representation. This accounts for our quantum jump from x' to x''.

To bring out the structure of this jump we express the function ρ in terms of the mean position x and the increment ξ, which leads to

$$\sigma(x,\xi) \equiv \psi(x + \xi/2)\,\psi^*(x - \xi/2)$$

This is the quantity we want to Fourier transform with respect to the jump increment ξ. Thus we arrive at

$$P_{\mathrm{W}}(x,p) = (2\pi\hbar)^{-1}\int_{-\infty}^{\infty} \sigma(x,\xi) \times \exp(-\mathrm{i}\xi p/\hbar)\,\mathrm{d}\xi$$

$$= (2\pi\hbar)^{-1}\int_{-\infty}^{\infty} \psi(x+\xi/2)\,\psi^*(x-\xi/2) \times \exp(-\mathrm{i}\xi p/\hbar)\,\mathrm{d}\xi$$

With the integration variable $y \equiv -\xi/2$ this expression becomes identical with the standard definition of the Wigner quasidistribution,[1] which is a real-valued function that may take on negative values. Finally we compute

$$P(x) := \int_{-\infty}^{\infty} P_{\mathrm{W}}(x,p)\,\mathrm{d}p$$

and

$$\tilde{P}(p) := \int_{-\infty}^{\infty} P_{\mathrm{W}}(x,p)\,\mathrm{d}x$$

The results, $P(x) = |\psi(x)|^2$ and $\tilde{P}(p) = |\tilde{\psi}(p)|^2$, with

$$\tilde{\psi}(p) = (2\pi\hbar)^{-1/2}\int_{-\infty}^{\infty} \psi(x) \times \exp(-\mathrm{i}px/\hbar)\,\mathrm{d}x$$

are indeed the genuine probability distributions, thus verifying the proper normalization and scaling of the standard P_{W}.

Reference

1. M. Hillery, R. F. O'Connell, M. O. Scully, E. P. Wigner, Phys. Rep. **106**, 121 (1984).

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12/90

Philpott replies: My comment on the article by Malvin C. Teich and Bahaa E. A. Saleh was simply that the expression they used for the Wigner distribution function is inconsistent with the commutation rule $[x,p] = \mathrm{i}/2$, which they adopted in their paper. Wolfgang P. Schleich and Georg Süssmann do not address this point.

John Philpott
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2/91

Teich and Saleh reply: The standard definition of the Wigner distribution function can indeed be written as

$$W(x,p) = \frac{1}{2\pi\hbar}\int_{-\infty}^{\infty} \psi\left(x+\frac{\xi}{2}\right) \times \psi^*\left(x-\frac{\xi}{2}\right)\exp\left(-\mathrm{i}\xi\frac{p}{\hbar}\right)\mathrm{d}\xi \qquad (1)$$

$$= \frac{1}{\pi\hbar}\int_{-\infty}^{\infty} \psi(x-y)\,\psi^*(x+y) \times \exp\left(\mathrm{i}2y\frac{p}{\hbar}\right)\mathrm{d}y \qquad (2)$$

as Wolfgang Schleich and Georg Süssmann point out. In our article we had intended to take $\hbar = 1$ and obtain

$$W(x,p) = \frac{1}{\pi}\int_{-\infty}^{\infty} \psi(x-y)\,\psi^*(x+y) \times \exp(\mathrm{i}2yp)\,\mathrm{d}y \qquad (3)$$

Unfortunately, a factor of 2 in the exponent of equation 3 was missing, and the normalization factor $1/\pi$ was ignored. The results presented in the article are not affected by these errors, however.

If, instead, we substitute $\hbar = \frac{1}{2}$ in equation 1 we obtain

$$W(x,p) = \frac{1}{\pi}\int_{-\infty}^{\infty} \psi\left(x+\frac{\xi}{2}\right)\psi^*\left(x-\frac{\xi}{2}\right) \times \exp(-\mathrm{i}2\xi p)\,\mathrm{d}\xi \qquad (4)$$

This is equivalent to the definition suggested by John Philpott. Thus equations 3 and 4 are special cases of the definition (equation 1) advocated by Schleich and Süssmann, with the units defined such that $\hbar = 1$ and $\frac{1}{2}$, respectively. It is unfortunate that our missing factor has stirred a discussion on a subject where no real differences exist.

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5/91

The Meter's Origins: A Clockwork Conspiracy?

Why, in SI units, is $g \cong \pi^2$? Coincidences are only occasionally accidental. I wish to suggest that this one is evidence for a conspiracy to obscure the origins of the metric unit of length.

The lore is that the meter was originally defined in 1791 as one ten-millionth of the distance from the North Pole to the equator.[1] It is