LETTERS

What Wigner Meant to Signal Theory, What 'Particle' Meant to Wigner

Although I am not qualified to judge the truth of Paul Roman's remark ("Letters," June, page 11) that Eugene P. Wigner was "probably the greatest mathematical physicist in the past 70 years," I do know of a marvelous mathematical development by Wigner that seems to have escaped the notice of contemporary physicists.

His well-known dictum about the "unreasonable effectiveness of mathematics" to describe the physical world has a superb exemplar in his original joining of the Fourier integral transform and the autocorrelation function. Now called the Wigner distribution, it was used by its author to investigate "quantum thermodynamic equilibrium."[1] But what has been forgotten by physicists has been amplified by signal theorists; now the Wigner distribution is the basis of an entire discipline: time–frequency representations of wave phenomena.[2]

There is a whole class of problems involving nonstationary signals—that is, signals for which the frequency content varies with time, and vice versa. Many, if not most, signals occurring in the real world are like this: signals of "noise" from submarines; signals comprising information in human speech; signals of music in concert halls. Wigner understood that quantum statistical phenomena were best treated as such a combination; now his brilliant mathematical conflation has been generalized to signals of every sort.

Consider the continually thorny problem of music in concert halls: What is the best mathematical representation? Researchers and designers have thrashed this question about for centuries without coming to a workable result. On one hand, an analog of geometric optics would seem useful to describe the trains of reflections spreading about a large room. On the other hand, an analog of the kinetic theory of gases would seem to comprise all those reflections in an "ergodic mass" that periodically rises and falls as a "reverberant field." But both of these concepts embrace a serious fault, for they grossly oversimplify, leaving out the basic physics of the problem, which is the transmission of musical information encoded as waves. The ranges of times and frequencies in music and hearing are great, and both properties are inextricably bound, so that neither can be disentangled from the other. Both must be taken together, and the Wigner distribution does that.

Like many others, I have wrestled with the concert hall problem for years, even making some progress from time to time. Eight years ago, I learned that another worker had experimentally made Wigner distributions of several acoustically good concert halls and several bad ones. I had never heard of Wigner distributions, but those graphical presentations ordered and confirmed all the experimental evidence accumulated over many decades. The sheep clearly were distinct from the goats, and it was equally clear why sheep were sheep and goats were goats.

To understand music in concert halls or noise from submarines, one needs a mathematical construct that gets the physics right. Not any form of gibberish will do; a particular form of gibberish is required.

That is the real mystery, is it not? That some of the stuff we do actually works? I do not know if Wigner was aware of this other scientific discipline that he started, almost in an offhand manner. I think that in the long view, he well may be recognized more for mathematics of time-frequency distributions than for any of his other contributions.

In a few months the Institute of Electrical and Electronic Engineers will publish, in its proceedings, extended examples of time–frequency distributions at work. Physicists would do well to read them.

References

1. E. P. Wigner, Phys. Rev. **40**, 749 (1932).
2. L. G. Cohen, Proc. IEEE **77**, 941 (1989).

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It was a pleasure and most informative to read David Gross's article on Eugene Wigner (December 1995, page 46). However, his understanding of Wigner's position on one very important issue in physics differs from mine.

Gross states that Wigner's "analysis provided a *definition* of what we mean by an elementary particle, which according to Wigner should be identified as an irreducible representation of the Poincaré group" (Gross's emphasis). On the other hand, Wigner once told me emphatically that "a particle is a point object that moves on a world line."

At that time, I did not understand his concern about the clarification of this definition, but I now believe that he was objecting to identifying a particle with a group representation. He was very interested in the foundations of physics, and the nature of the fundamental elements of quantum mechanics was an important matter for him. Is an electron a particle or a wave? A discussion of this question requires a clear understanding of what we mean by the word "particle."

The word was originally introduced into classical mechanics, where it clearly fits the definition that Wigner gave me. The original founders of quantum mechanics depended on keeping as close to classical mechanics as possible. Consequently, attempts were made to carry over such words as "particle" into the new theory, resulting in confusion as to the definition of the word.

Wigner was aware of some of the thoughts on this question that had been expressed by a number of physicists whose work has indicated that there are no particles in a properly interpreted quantum mechanics. They have found that the appearance of particle-like phenomena, such as alpha particle tracks in a cloud chamber, is due to the interaction of the wave function with the surrounding medium.[1] If this is the case, the fundamental elements of quantum mechanics are fields, not particles.

This is a very serious problem for physicists because the word "particle" pervades many of their communications. High-energy physics is often called particle physics and yet it is surely based on quantum field theory. The introduction of the term "wave-particle duality" is often confusing to students, who find it difficult to know when an electron is a wave and when a particle. In my opinion, a real effort should be made to rid our literature of this word when quantum mechanics is used.

I cannot resist closing with an anecdote that reveals important aspects of Wigner's character. He and I were attending a civil defense conference being held at a hotel in Atlanta. As we stood at the hotel desk, a very young and neatly dressed soldier in uniform approached the desk somewhat timidly. He asked how much it would cost for a room for the night. When the clerk told him, the young soldier appeared crestfallen and turned away. Wigner quickly got the clerk's attention and said, "I will pay for half of this man's room." He knew very well that I would come up with the other half.

Eugene Wigner was a kind and patriotic man, and many of us are thankful for having had the opportunity to know him.

Reference

1. A. A. Broyles, Phys. Rev. A **48**, 1055 (1993), and references therein.

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Spacetime May Be Chief Source of Proton Spin

In his article "Where Does the Proton Really Get Its Spin?" (September 1995, page 24), Robert L. Jaffe reports that polarized scattering experiments have revealed that the quark spins contribute only 20–30% of the spin of a proton or neutron, and that the source of the rest of the spin remains unknown.

The spin of elementary particles manifests itself in several effects in fundamental interactions, such as the splitting of nuclear energy levels, the nondegeneracy of hadronic states in strong interactions and parity violations in weak states.

To answer the question of where does the proton or neutron acquire the 70–80% of the spin not supplied by quark spins, we suggest that spacetime has torsion.

It has long been recognized in gravitational theories that torsion is a manifestation of spin, and this inherent spin of spacetime has been recently studied by Venzo de Sabbata and Chidambaram Sivaran.[1] Torsion is to spin as curvature of spacetime is to mass. Gravity can be unified with the electroweak and strong interactions by an energy-dependent spin torsion coupling constant. In their book, Sabbata and Sivaran discuss in detail the idea that all interactions can be understood as originating in spin–curvature coupling.

They also show how torsion in spacetime could solve the problem of