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PHYSICS TODAY

Readers offer their own magic moments with John Bell FREE

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Physics Today **68** (12), 11–12 (2015);
https://doi.org/10.1063/PT.3.2998

3. A. Einstein, M. Born, H. Born, *The Born–Einstein Letters: Correspondence Between Albert Einstein and Max and Hedwig Born from 1916–1955*, I. Born, trans., MacMillan (1971), p. 159.

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■ **Bertlmann replies:** I am pleased at the positive response of readers to my "Magic moments with John Bell."

I enjoyed very much the contributions of Charles Clement and Kerson Huang, who reported about their own "magic moments" with Bell. Their amusing anecdotes help complete the portrait of Bell, who was an outstanding personality indeed.

I found the comments of Nicholas Bykovetz very interesting. I remember that Bell strongly sympathized with Lorentzian relativity and Fitzgerald contraction. In my opinion, the ether-based Lorentzian view of relativity is just closer to the heart of the realist that Bell was. I think it was the acceptance of Lorentz's conception on relativity rather than Einstein's that led Bell to the correct answer that a string between two equally accelerated spaceships will break, what is known as Bell's spaceship paradox.[1] In Bell's quote "An 'ether' would be the cheapest solution. But the unobservability of this ether would be disturbing," he did not mean for the "cheapest solution" to be a derogatory phrase, but rather to mean "simple." The "unobservability of this ether" disturbed Bell, since why should the laws of physics conspire to prevent us from identifying the ether experimentally.

Regarding Robert Griffiths's arguments, I agree with some parts but strongly disagree with others. Griffiths remarks that the specific form of the expectation value used by Bell for the joint measurement of Alice and Bob in the EPR-Bohm-Bell experiment does not make sense in the context of quantum theory with noncommuting operators. That is not the point Bell wanted to make. In his formalism, the quantum states are supplemented by hidden variables, which are governed by a classical probability distribution, in order to predetermine the measurement results.

The expectation value, assigned to the local hidden-variable theory, is not applied to quantum mechanics but compared with the corresponding quantum mechanical result. Its specific form is excluded via a Bell inequality, in which a certain combination of expectation values is needed. Concentrating on the expectation value alone is not enough to distinguish local hidden variable theories from quantum mechanics; for example, the predictions of quantum mechanics can also be achieved by working with a local hidden variable theory. See reference 2 for a more explicit discussion.

Quantum mechanics as a mathematical formalism is a theory on (mathematical) Hilbert spaces, no matter whether the quantities associated with those spaces correspond to internal degrees of freedom, like spin, or external ones, like the position. In the EPR-Bohm-Bell context, the quantum formalism contains no reference to our three-dimensional space. Nevertheless, experiments are carried out in 3D space. Alice and Bob perform joint measurements of their particles at different, very remote locations. Then this nonlocal feature turns up: A measurement by Alice on the spin of her particle *does* have an effect—instantaneously—on Bob's result, in contrast to what Griffiths claims in his comments. Therefore, quantum correlations are locally inexplicable.

I sympathize with some of the comments by Michael Nauenberg, who collaborated with Bell long ago on "The

moral aspect of quantum mechanics."[3] In particular, Nauenberg's comment that "experiments have revealed that the nature of reality in the quantum world is different from our experience in the classical world" is, in my opinion, the lesson we have to learn from Bell inequalities.

I do not appreciate so much Nauenberg's example of the helium atom since it distracts from the issue of nonlocality. In fact, it is at macroscopic distances where the "puzzle" arises and not at atomic distances of separation.

I have a confession: I am not the realist one might expect after reading Bell's article "Bertlmann's socks and the nature of reality"; the world in its very foundations is much more abstract than we think with our *"anschauliche"* (intuitive) concepts, to borrow Werner Heisenberg's term. My personal feeling is that Bell's theorem, which reveals an apparent nonlocality in nature, points to a more radical conception whose onset we do not yet have.

References

1. J. S. Bell, *Speakable and Unspeakable in Quantum Mechanics*, 2nd ed., Cambridge U. Press (2004), p. 67.
2. R. A. Bertlmann, *J. Phys. A* **47**, 424007 (2014).
3. J. S. Bell, M. Nauenberg, in *Preludes in Theoretical Physics in Honor of V. F. Weisskopf*, A. De-Shalit, H. Feshbach, L. Van Hove, eds., North-Holland (1966), p. 279.

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"Salty" conversation

The "Salty solutions" Quick Study by Greg Thiel (PHYSICS TODAY, June 2015, page 66) was encouraging for the progress it described in desalinating seawater by reverse osmosis (RO). There is, however, some confusion with the thermodynamics. Thiel does recognize that not all kilowatt-hours are created equal, and the electrical energy (work) to drive the RO pump is the highest-grade energy, as compared with the low-grade heat that drives an evaporative process. He lists energies for RO in kWh_e (kilowatt-hours of electrical work) per cubic meter of fresh water and compares that with the kWh_e of heat required for thermal evaporation processes, but there is no specified conversion or equivalence factor. Is it based on the Carnot equation (for an assumed temperature difference) or on some practical thermodynamic cycle such as Rankine? A conversion factor is fundamental if the reader is to make any useful comparison.

Permit me also to raise a practical point. We generally use an engine, a water or wind turbine, or a photovoltaic array to generate electricity, whereas heat is readily available from solar thermal collectors or geothermal sources. Some may even be virtually free, such as waste heat from another process or industry. The economic choice, therefore, between RO and thermal evaporation may not always favor RO despite its numerically lower kWh_e input number. The decision would properly depend on the forms of energy available to a particular desalination plant.

In no case other than a survival emergency would it make sense for either process to run on fossil-fuel combustion, since the resulting carbon dioxide emissions would only exacerbate the climate change that is often at the root of the drought that the desalination plant is supposed to alleviate.

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■ **Gregory Thiel presents** an informative look at the technology and economics of seawater desalination through reverse osmosis. California, evidently, is