the use of Maxwell's equations as a mechanism for explaining the concepts, and I much enjoyed carrying out the exercise suggested in box 2. However, it occurred to me that something is missing in connection with the final result as given in equation 2c. Although it is clearly a wave equation and therefore any constraint violations may indeed "propagate away," as the authors suggest, it is also clear that the equation will accept a constant solution or even an exponentially growing one. What remains unclear is why the "propagate away" option is the one that should take precedence in actual calculations.

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■ **Baumgarte and Shapiro reply:** A good question! The solution to the wave equation depends on the adopted boundary conditions.

Imposing "outgoing" wave boundary conditions, appropriate for most of the problems of interest for us, ensures that constraint violations do indeed propagate away. For a numerical demonstration that employs such boundary conditions for the form of Maxwell's equations in box 2, see reference 1.

Reference

1. A. M. Knapp, E. J. Walker, T. W. Baumgarte, *Phys. Rev. D* **65**, 064031 (2002).

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Sexism may be in the eye of the beholder

The February 2012 issue of PHYSICS TODAY held a certain irony for me in its juxtaposition of Robert March's review of Leon Lederman and Christopher Hill's book *Quantum Physics for Poets* (page 51) with the article by Rachel Ivie and Casey Langer Tesfaye on women in physics (page 47). I had recently read Lederman and Hill's book because I sought an up-to-date and accessible text for the quantum section of my course on modern physics for nonscience students. Like the reviewer, I also found it a well-written, lively, and contemporary account of quantum physics.

Much as I liked the book, in the end I chose not to adopt it. My reason was the very example the reviewer touts as an instance of Lederman's engaging writing: the image of a reader peering in the window of Victoria's Secret while Lederman and Hill enlighten him—and it is clearly a him—about wave–particle duality. Read the cited passage in all its detail and it isn't hard to draw several conclusions about how the authors, perhaps subconsciously, view their readers as male; as drawn, in a slightly voyeuristic way, to Victoria's Secret; and as thinking highly of their own sexual allure.

How would a female student react to Lederman and Hill's example? Would it make her feel included among those interested in physics? Would it make her comfortable in the presence of male physicists or her fellow physics students? I think not. Had this example occurred just once, I might have let it go and adopted the book. But Victoria's Secret is mentioned every time the wave–particle duality comes up—which is frequently in this book on quantum physics.

If we're to remedy the underrepresentation of women in physics that Ivie and Tesfaye decry in their article, we'll need enough sensitivity to come up with more welcoming examples than that of a physics-interested male ogling the Victoria's Secret window display.

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■ **Lederman and Hill reply:** Perhaps Richard Wolfson would have viewed our work more favorably had he read our first book, *Symmetry and the Beautiful Universe* (Prometheus Books, 2004). There we championed the great mathematician Emmy Noether to the modern science lay audience. We told the story of all of physics through Noether's grand theorem and how it forms a keystone of our understanding of nature. We did so as much to honor one of the greatest intellectuals who ever lived as to show our readership that physics is not a men's club.

More to Mr. Wolfson's point, Victoria's Secret stores can be found in almost every shopping mall in the US. When we pass by, we see as many women as men looking at their windows. Both genders' thoughts may be expected to run to fantasy, yet here is a point of contact between such human experiences and physics. We are leveraging it to inspire the poetic reader to enter a world of altered reality—in this instance, to ponder the quantum world with the transmission of photons through a glass window and its inherent probabilistic nature.

We hope to invite readers deeper into the magnificent world of atoms, quarks, strings, the conduction band structure of semiconductors, Schrödinger's cat, the Dirac sea, and more. We take some risk, as we are prone to do on other topics such as politics and religion, and we have received numerous complaints concerning our belief in global warming, the creeping superstition, and anti-intellectualism that we see infecting our society today.

We are inclined to disagree, however, with Mr. Wolfson's conclusion about the effect of the Victoria's Secret windows metaphor on our female readers: We have done the experiment of taking the risk, and we have not received a single complaint thus far from anyone else that our book is sexist.

Leon Lederman
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Nature's manifest absurdity: A cautionary tale

Alan Chodos, in his commentary in the December 2011 issue of PHYSICS TODAY (page 8), summarized the OPERA experiment that supposedly found neutrinos traveling at a speed of $c + \delta c$, where c is the speed of light and $\delta c \approx 7 \times 10^5$ cm/s. He also discussed some theoretical speculations and objections, but he ended his commentary with the odd comment that "if the OPERA result fails to survive, that will not prove that neutrinos don't travel faster than light." Then he presented his own ideas of tachyonic (faster-than-light) neutrinos that would support the "apparent lack of Lorentz invariance in the neutrinos' superluminal propagation" (see the article by Olexa-Myron Bilaniuk and E. C. George Sudarshan, PHYSICS TODAY, May 1969, page 43).

Chodos didn't mention that regardless of neutrino properties, the most serious problem with the OPERA result is that it entails a failure of *causality*. Since the clocks in the rest frame of the experiment are synchronized by GPS in accordance with special relativity, which is accepted as valid, consider the corresponding observations with clocks synchronized in a frame of reference moving with velocity $c - \delta c'$

along the CERN beam direction, where $0 < \delta c' < \delta c$. In that frame, one would find that each signal at the CERN graphite target detector occurs after a corresponding signal at the Gran Sasso neutrino detector, which would be manifestly absurd.[1,2] Recently it has been found that OPERA's faster-than-light result was an error due to "a faulty cable connection."[3] Moreover, an independent research group, ICARUS, has announced that neutrinos obey nature's speed limit.[4]

References

1. R. C. Tolman, *The Theory of the Relativity of Motion*, U. California Press, Berkeley (1917), p. 54.
2. G. A. Benford, D. L. Book, W. A. Newcomb, *Phys. Rev. D* **2**, 263 (1970).
3. G. Brumfiel, *Nature* (16 March 2012), http://www.nature.com/news/neutrinos-not-faster-than-light-1.10249.
4. M. Antonello et al., http://arxiv.org/abs/1203.3433.

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■ **Chodos replies:** One must be careful. The history of science is littered with examples of ideas that people dismissed as manifestly absurd, only to find in due course that Nature disagreed. Whether neutrinos travel faster than light is an experimental question. If the OPERA result is wrong, as it now appears to be, neutrinos may still be superluminal, just not at as high a level as the parts per 10^{-5} that OPERA claimed. That is the meaning of my "odd comment" to which Nauenberg refers.

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A note on rocky planet formation

Bernard Wood presents a nice overview in his article, "The formation and differentiation of Earth" (Physics Today, December 2011, page 40). For many years the prevailing model has been that rocky planets formed in our solar system as a consequence of a succession of impacts of large objects during the first 100 million years or so following the Sun's formation. That picture is the outcome of theoretical considerations combined with the study of asteroids, meteorites, and the rocky planets—Mercury, Venus, Earth, and Mars. Only recently has it become possible to confirm or deny by observation whether the rocky-planet formation time scale of 100 million years generally applies for Sun-like stars.

A collision of large, rocky-planet embryos that orbit young stars would typically eject a mélange of rocky debris, as illustrated in Wood's figure 1. Abundant dusty debris has now been observed in orbit around a handful of young, nearby stars with ages between 30 million and 100 million years.[1] The dust temperature, generally somewhat greater than the temperature of Earth, suggests that the colliding objects typically orbit at a distance from their stars similar to the distance from our sun to Venus. By contrast, there are no known examples of stars between, say, 100 million and 1000 million years old that have large quantities of orbiting warm dust particles. The most straightforward interpretation of those observations is that rocky planet formation around solar-mass stars is pretty much complete by the time the stars are 100 million years old, which agrees with what theory would have predicted.

The same study indicates that rocky planet formation, in a zone analogous to the region of the rocky planets in the solar system, is common and perhaps nearly ubiquitous around Sun-like stars.[1]

Reference

1. C. Melis, B. Zuckerman, J. H. Rhee, I. Song, *Astrophys. J. Lett.* **717**, L57 (2010).

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Coherence and precision in classical systems

The Quick Study "Collaboration and precision in quantum measurement" (Physics Today, December 2011, page 72) by Rob Sewell and Morgan Mitchell points out that some quantum mechanical coherence, "quantum collaboration" in their language, allows for the magnetization of a gas to be measured with a precision of $1/N$, where N is the number of photons. For large N, $1/N$ is smaller than $1/\sqrt{N}$, so improves upon the usual $1/\sqrt{N}$ measurement limit; the authors comment that for noninteracting particles, the central limit theorem precludes better classical measurements.

However, coherence is not merely a quantum mechanical effect; many classical systems exhibit similar behavior. For example, one can search for ultra-high-energy neutrino interactions in Antarctic ice by observing the coherent radio pulses emitted by the resulting particle showers. The observed electric field strength of the pulse scales as the square of the number of particles in the shower (reference 1; see also the article I wrote with Francis Halzen, Physics Today, May 2008, page 29), so for a given uncertainty in field-strength measurement, the uncertainty in the number of shower particles scales as $1/N$. That is purely classical electromagnetism.

There are also examples of $1/N$ scaling without coherence. Consider a system consisting of a noninteracting gas in a reservoir at pressure P, and a small valve that controls access to a gas sensor. The best measurement of the valve's opening time comes from the first gas molecule observed by the sensor. As one increases the pressure (number of probe molecules N), the time delay between the gate opening and the sensor decreases in a $1/N$ fashion. For large N, that is more accurate than finding the mean arrival time of the molecules, with an accuracy of $1/\sqrt{N}$, and trying to correct for the average delay time.

These comments are not to take anything away from the nice study by Sewell and Mitchell. However, measurements that exhibit $1/N$ scaling are not limited to quantum systems, and are more common than one might imagine.

Reference

1. P. W. Gorham et al., *Phys. Rev. D* **72**, 023002 (2005).

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■ **Sewell and Mitchell reply:** Spencer Klein's insightful comments wonderfully illustrate the connections between seemingly disparate areas of research. His May 2008 article with Francis Halzen is indeed well worth going back for if you missed it the first time around.

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Correction

April 2012, page 22—The Update item titled "Gravity waves and heat in Mars's atmosphere" should give wind speeds on Mars as up to 400 km/h, not 400 km/s. ■