the performance of these vehicles and now has a large fleet.

G. G. S. Engineering/Stored Energy Technology in Derby, UK, has taken the magnet-motor concept and placed it in a standard resilient wheel (for a light-rail car or streetcar), reducing weight and complexity. The concept should have even greater advantages for automobile applications.

Also in the UK, J. P. M. Parry & Associates of Cradley Heath has several low-floor, lightweight, flywheel-storage tramcars in trial operation for low-cost public transit, but has not yet used the hub- or wheel-motor concepts.

I suggest taking the hub- and wheel-motor concepts and reducing weight and complexity by replacing the rotating permanent magnets with rotating slanted copper or aluminum bars to form an inside-out hysteresis-nonsynchronous AC motor, that is, one with slanted rotating conducting bars allowing efficient operation below synchronous speed; the bars would be shaped to ensure efficient air cooling by fan action. US transit engineering expert William Vigrass has suggested possible all-wheel steering, "crab" berthing when standing, and the ability to follow a slightly modified rail right-of-way with automatic guidance and rear wheels following front wheel paths.

An experimental bus line in Trieste, Italy, designed by Breda of Italy, is all electric, using rails in the street that are powered only when the bus is over them. The bus has battery storage for limited off-rail capability, and does not require the rail for steering. Why not place power rails at specific bus stops and use battery power between? And why not extend the concept to an all-electric personal car system with the driver positioning his car on power rails at "filling stations" to charge the battery for, say, 500 km to the next charge? A similar French system is on trial on the Marseilles, France, tram line. Perhaps my "wheel motor" suggestion can make such a system even more practical for personal vehicles.

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ROSENFELD, KAARSBERG, AND ROMM REPLY: We are pleased to receive letters with excellent suggestions for more technologies that could substantially reduce carbon dioxide emissions. For the article, however, we had limited our detailed discussions to those technologies that were included in the 1997 five-labs study.

We disagree with David G. Karraker's suggestion that any single technology will be the silver bullet for the climate-change problem. Our experience from the comprehensive, multisector five-labs study, in which various technologies competed against each other, is that a broad portfolio of technologies in all sectors is needed for a credible strategy to reduce carbon dioxide emissions. In addition, we explicitly excluded the utility sector in our article, because the five-labs study on which the article was based predated the implementation of any utility deregulation plan. The report from that study also included nuclear power (extending the lives of existing plants) as an option accounting for up to 5% of the utility sector's carbon reductions.

Although we omitted discussion of the power sector because of policy uncertainties, the power sector is the single largest contributor to US CO_2 emissions. In fact, all three of us are now working on power technology issues. The electric power industry probably has the greatest efficiency backlog! Since the late 1950s, the fossil-fuel efficiency of electric utilities has been stagnant at about 30%. This lag in efficiency, however, cannot be blamed on a lack of innovation in power technologies. The regulated monopolies have had no incentive to take advantage of numerous advances in combustion, renewable, and nuclear power technologies. For example, efficiencies for natural gas-fired combustion turbines already have risen from 20% in the mid-1970s to nearly 60% for today's utility-sized (several hundred megawatt), combined-cycle units.

As for John Walmsley's criticism that we neglected the two commercial hybrid cars, that omission was unintentional. For brevity, specific vehicle names were edited out of the sentence "Technologies to double vehicle miles per gallon are available today." We are big fans of these hybrids; in fact, one of us (Kaarsberg) just bought a Prius. The vehicles were not mentioned in the Partnership for a New Generation of Vehicles box on page 33 because neither Honda nor Toyota is a member of that collaboration. We described a simplified hybrid because it was the quickest, most straightforward way to briefly highlight the energy savings. We also appreciate David Lloyd Klepper's detailed explanation of more sophisticated commercially available hybrids.

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Quantum Theory Comes in Waves and Particles

Certainly there is no unique answer to Frank Wilczek's question, "What Is Quantum Theory?" (PHYSICS TODAY, June 2000, page 11). I was not certain that a pragmatic answer, which I proposed for a course in applied quantum mechanics,[1] would be sustainable for the entire course, but it seems that it was. That answer was the assertion that everything is both a particle and a wave, and that everything else would follow from that one assertion. Planck's constant arose when the velocity of a wave (the derivative of the frequency with respect to wavenumber) was equated to the velocity of a particle (the derivative of the energy with respect to momentum), so that energy is proportional to frequency and momentum to wavenumber, with the same proportionality constant $\hbar$.

When Hamiltonian mechanics was introduced, "everything" became anything that can be described by such mechanics, or anything that satisfies a wave equation. Quantum theory does not say what nature gives, only how to predict the behavior of what is given. If nature serves up particles with half-integral angular momentum, the wavefunction that describes them must go into its negative when they are interchanged, and they therefore obey the Pauli principle.

Such principles, which historically arose as independent conjectures, now follow from the one assertion. It is a matter of seeing how this peculiar assertion can turn out to be absolutely true.

The relation between quantum theory and the physical world was seen as follows: Quantum theory tells what future scenarios are consistent with some initial information, and what the relative probability of each scenario is. Quantum theory cannot tell more than that, but neither can any other theory.

My pragmatic approach may not satisfy everyone's philosophical needs. But the aim of an applied quantum course is to see how to use the theory and to introduce the many approximations that have made the theory accessible to physicists and engineers. If some basic consequences are difficult to accept, the problem must lie with the initial assertion from which the consequences follow.

Reference

1. W. A. Harrison, *Applied Quantum Mechanics*, World Scientific, River Edge, N.J. (2000).

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ENIAC or ABC?

The review by J. Ross Macdonald and Harvey G. Cragon (Physics Today, July 2000, page 58) of *ENIAC: The Triumphs and Tragedies of the World's First Computer* seems to be an able assessment of the book and its content. However, perhaps due to misstatements in the book, the review fails to reflect adequately the place of the Atanasoff–Berry Computer (ABC) relative to the Eckert–Mauchly ENIAC in the lineage of the electronic digital computer. (See Alfred E. Brenner's article, "The Computing Revolution and the Physics Community," Physics Today, October 1996, page 24.)

Work on the ABC design by John V. Atanasoff (a University of Wisconsin PhD physics graduate whose adviser was John Van Vleck) began in 1937 at Iowa State University (ISU). It is well established that a breadboard mock-up was completed in 1939 and that a full-scale prototype was being tested by early 1942. The review correctly indicates that, years later, Honeywell initiated a lawsuit claiming that ENIAC patents applied for by Presper Eckert and John Mauchly in 1947, though not issued until 1964 to Sperry Rand, were invalid.

On 19 October 1973, the trial judge entered his opinion, stating that "Eckert and Mauchly did not themselves invent the automatic digital computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff."[1] Behind that terse statement is a trial record that exhaustively examines the "prior art" embodied in the ABC and the adoption in either ENIAC or the later EDVAC of many concepts first introduced in the ABC, such as regenerative memory, base-2 calculating, modular construction, and fully electronic computation.[2,3] (See also Alan R. Mackintosh's article "The First Electronic Computer," Physics Today, March 1987, page 25.)

Evidence introduced at the trial showed that, starting in December 1940, Atanasoff met with Mauchly, briefed him on the ABC design, invited him to Iowa to see the full scale machine under construction (he stayed at Atanasoff's home) and provided him with free and open access to detailed design features that later appeared in the ENIAC or the EDVAC. Nevertheless, many supporters of ENIAC's historical primacy still claimed that the court decision was flawed, that the ABC could never operate, and that the ENIAC did not, in fact, depend on the ABC design.

After 1973, Atanasoff began receiving widespread recognition for his accomplishment, including major awards from the Institute of Electrical and Electronics Engineers (IEEE) and the Navy, several honorary doctorates, and, in 1990, the National Medal of Technology presented by President George H. W. Bush.

In 1994, senior engineers at the Department of Energy's Ames Laboratory put forward the idea that the availability of ABC documentation and old parts could make it possible for them to build a full-scale replica of the ABC that might refute the charge that the ABC could never have operated successfully. A small group of ISU officials, of which I was one, then took on the challenges of project oversight and fundraising.

In late November 1996, the completed (but not yet operational) replica was unveiled in Pittsburgh, Pennsylvania, at "Supercomputing '96," an annual joint meeting of the IEEE and the Association for Computing Machinery. The ABC anchored an extensive display of historic supercomputer artifacts in celebration of 50 years of computer development.

By October 1997, all systems were fully operating and the machine was brought to Washington, DC. At the National Press Club, the ABC carried out its first public calculations before computer experts, ISU alumni, and the press. For the next eight months, the ABC toured Iowa, promoting ISU eminence in developing advanced technology. Along the way, some computing runs were videotaped, preserving a visible place in history for Atanasoff's dream. Ironically, the unattributed adoption of some of the ABC's concepts apparently provided the only means by which they were incorporated into the mainstream of computer development.

References

1. Section 3 of Judge Earl R. Larson's opinion in *Honeywell Inc. vs. Sperry Rand Corp. et. al.*, 19 October 1973.
2. C. R. Mollenhoff, *Atanasoff: Forgotten Father of the Computer*, Iowa State U. Press, Ames (1988).
3. For an informative technical discussion of the ABC and the trial, see A. R. Burks and A. W. Burks, *The First Electronic Computer: The Atanasoff Story*, U. of Michigan Press, Ann Arbor (1989).

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In SOA, S Is for Semiconductor

I read with great interest the article on optical communications by Gordon A. Thomas, David A. Ackerman, Paul R. Prucnal, and S. Lance Cooper (Physics Today, September 2000, page 30). A good portion of the text describes the nonlinear optical loop mirror (TOAD) device, a critical component for very high bit-rate modulation. The nonlinear element in the optical loop is a semiconductor optical amplifier (SOA). However, throughout the article and the figure captions, the authors refer to the SOA as a "silicon optical amplifier." This error is not just a matter of words. SOAs, for fundamental physical considerations based on conservation of energy and momentum, cannot be made from silicon. Furthermore, even if silicon could be used to make an SOA, it would operate in a wavelength range of little interest for optical communications.

Semiconductor optical amplifiers for optical fiber communications are made from gallium indium arsenide phosphide. This material is chosen