ridiculed. He installed solar collectors on the White House roof, but Ronald Reagan had them ripped out.

Even some members of the technical community have tried to discredit solar energy by making claims that, among other things, solar installations are visually polluting. See, for example, the letters and comments in the October–November 2002 issue of *The Industrial Physicist* (page 12).

Six years ago, for about $1200, I built and retrofitted from secondhand components a solar space-heating system for our residence, which was built in 1916. In those days, circulating hot-water heating systems were common. They are uniquely suited to conversion to solar heat because the interior heat-transfer arrangement is already in place. All that is needed is to connect solar collectors to the existing system.

A neat feature of the conversion is that the solar heating supplements rather than supplants the gas heating system. On very cold days, we fire up the natural gas and have gas and solar systems working together, with the benefit that free solar heat tempers the cost of the metered gas heat. If the weather is really bad and the sun isn't shining, we leave the circulating pump from the collectors turned off and rely exclusively on gas heat. Our heating bill has been cut in half.

Our system is sort of a hybrid, like the hybrid autos that when outfitted with plug-in capability will go a long way toward solving that aspect of the energy problem. But that's another story.

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Physics and information

A pivotal question among today's science educators is, How can the teaching of physics be improved in this information age? The topic has recently been discussed in several publications. We propose a direct answer: Formally introduce the concept of information, in its various quantitative forms, into introductory physics coursework. That is, augment the "physicalist" viewpoint of today's physics curriculum with the knowledge-acquisition viewpoint of information theory. But is that heresy?

Physics is ultimately based on observation, and observation entails a flow of information from source to observer. Furthermore, each such flow of information can be analyzed to derive the source law of physics that gave rise to it.[1] Thus, teaching physics from both physicalist and informational viewpoints is both logical and supported by good evidence. One of us (Frieden) taught such a survey course for many years and found that the resulting unified view reaps great benefits in excitement and comprehension, for both the students and the instructor.

Thermodynamics, with its emphasis on measurable extrinsic parameters—and with the implication that our knowledge of them is incomplete[2]—is an obvious starting point for such a program. The lack of complete knowledge underlies, as well, all information theory and provides an entry point for its mathematical analysis.[1] Does that imply use of a particular information concept in the program?

There are many candidates. One, the Shannon–Jaynes information concept, is an outgrowth of the concept of Boltzmann entropy, a linchpin of thermodynamic theory. A second form of information, an outgrowth of the density matrix of quantum statistical mechanics,[1] is Fisher information, in both its classical and quantum[3] varieties. Many of the concepts of thermodynamics and statistical mechanics can be derived by either maximizing Shannon–Jaynes entropy or minimizing Fisher information.[1,2] In addition, Shannon's information theory has been extended to the quantum regime, where it opens up a fascinating world full of surprises[3] and the potential for radical new technology. These surprises center on the concept of entanglement and include quantum computation, quantum cryptography, and quantum teleportation. The basic questions concern how to effectively code,[4] store, process, and transmit information. Many physicists have realized that quantum theory is basically a theory of information, of observing and processing data. Hence, the valuable connections to information should be taught early on.

As a final example, the TCV tokamak at CERN currently uses principles of both maximum entropy and minimum Fisher information to reconstruct laser spot profiles during the implosion process.[5] The international collaboration is using the information concept to help solve one of humanity's most important problems—how to control fusion, with its promise of unlimited energy.

We urge physics educators to join us in looking toward information theory for new approaches to making physics more useful, understandable, and enjoyable.

References

1. B. R. Frieden, B. H. Soffer, *Phys. Rev. E* **52**, 2274 (1995). See also B. R. Frieden, *Science from Fisher Information: A Unification*, Cambridge U. Press, New York (2004).
2. A. Plastino, A. R. Plastino, M. Casas, in *Variational and Extremum Principles in Macroscopic Systems*, vol. 2, S. Sieniutycz, H. Farkas, eds., Elsevier, San Diego, CA (2005), p. 379.
3. M. A. Nielsen, I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge U. Press, New York (2000).
4. R. C. Venkatesan, in *Exploratory Data Analysis Using Fisher Information*, B. R. Frieden, R. A. Gatenby, eds., Springer, London (2007), p. 181.
5. M. Anton et al., *Plasma Phys. Control. Fusion* **38**, 1849 (1996).

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Justifying the funding of basic science

Despite the role it has played in the evolution of humans, science has often been considered a dangerous and profane activity or, at best, an obscure practice whose validity resides mainly in the possible usefulness of its objectives. The need to justify science through its applications dates back to the dawn of the scientific enterprise, as shown by the following dialog from Plato's *The Republic*, circa 360 BCE.

> GLAUCON: To know something about the seasons, the months, and the years is of use for military purposes, as well as for agriculture and for navigation.
>
> SOCRATES: It amuses me to see how afraid you are, lest the common herd of people should accuse you of recommending useless studies.

Things have not changed. A crucial point of any research project is the ability to demonstrate the usefulness of the proposed investigation for practical purposes.

Science does not escape cost–benefit analysis. Since its main product, knowledge, is not easy to evaluate, allocation of resources is based mainly on derived results, in the form of technology and commercial applications. When those cannot be foreseen within reasonable