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Wind power

I am responding to Duane Warner's letter in the June/July issue regarding the potential effects of wind power on weather and climate.

The amount of energy consumed by windmills to generate power is extremely small compared with the total energy available in the wind currents at near ground level (NGL). Even in large arrays, windmills would have a negligible effect on the local weather immediately around the array. The main effects that have been noticed so far are increased turbulence and some acoustic problems (blade noise) downstream.

Also, numerous studies have been done to determine the wind flow effects of high-rise office buildings (of which there are literally thousands in cities such as New York, Chicago, Los Angeles, and San Francisco). Although there is an effect of increased NGL turbulence in the immediate area of the buildings, the effect in the far field is negligible.

I might add that NGL winds are a minute fraction of the wind flow throughout the entire atmosphere cross section. The troposphere (the layer of the atmosphere where dynamic weather exists) is about 50,000 feet thick, and wind patterns (the numerous jet streams) that affect global climate are actually at moderate to high altitudes in the troposphere rather than at NGL.

You can find practical information (with photos of NGL and high-altitude wind effects on storm clouds and weather dynamics) at www.chaseday.com/.

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Mr. Criswell justifies his proposed "Solar Power via the Moon" (*The Industrial Physicist*, April/May 2002, pp. 12–15) on flawed or invalid assumptions. He tells us that "using wind power would require capturing one-third of the power of the low-level winds over all continents." He also says that solar cells with 30% conversion efficiency would need to occupy the equivalent of 20% of the area of the United States in order to satisfy world electricity needs in 2050.

For me, this raises some important questions. Who has decided that the United States will supply all electricity needs for the world in 2050? Why doesn't Mr. Criswell mention conservation measures as a means of curtailing our energy demand? Earth with its atmosphere is a somewhat closed system. To imply that we can inject massive amounts of energy into this system (from the moon or satellites) without any warming effects is ludicrous if not irresponsible.

On the matter of cost, it would be cheaper to place a windmill or a solar cell on Earth than on the moon. A massive project aimed at keeping the National Aeronautics and Space Administration and peripheral industries alive does a disservice to this country in times of severe unemployment. Like almost all manned missions, it would be heavily loaded toward political interests under the guise of energy solutions or population solutions.

I find his article callous and disturbing.

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[*Author replies*: The references in the article document the estimated power needs in the 21st century and the implications of obtaining the power using wind, terrestrial solar, and 22 other options. I believe Mr. Holz will find the statements to be correct.

The United States, alone or with other space-faring nations, can expeditiously implement the space and lunar portions of the Lunar Solar Power (LPS) System. Developing nations can fabricate and implement rectennas within their own borders. Affordable power would accelerate the growth of prosperity and lower unemployment. The LSP System provides the greatest benefits for the lowest cost. These benefits become overwhelming when sufficient power is provided to underpin global prosperity.

The LSP System provides net new energy to Earth, which enables society to move beyond conservation and into virtually complete recycling of industrial products, remediation of past damage to the biosphere, nurturing of the biosphere, and decoupling of industry and services from the resources of Earth. In principle, power from rectennas can drive the "environmental impact per unit of per capita gross domestic product" to a very low level compared with today (see Graedel, T. E. "Industrial Ecology at the Crossroads," *The Industrial Physicist*, December, 1997, pp. 24–26).

Earth's disk intercepts ~176,000 TW (thermal) of solar power. Mining and then using fossil fuels to produce ~14 TW of commercial thermal power release the CO_2, methane, and other long-term greenhouse gases that restrict the flow of part of the solar power back to space. Thus, the trapping of extra solar power drives global warming. One method used to discuss this issue in the climate community is to calculate how much extra power—termed "radiation forcing" and measured in watts per square meter over the entire globe—would be required to produce the same extra warming. Some climate models predict ~4 W/m^2 of extra warming power by 2050, which corresponds to ~2,000 TW of extra power. This far exceeds the 60 to 70 TW of thermal power that would be produced by conventional power systems to enable global power prosperity.

The 20 TWe of electric power introduced by the LSP System can be greenhouse-neutral and induce no extra "radiation forcing." Approximately 90% of the microwave power would be converted to electric power, distributed to consumers, and eventually radiated to space as infrared power. The other 10% of input power, released as heat at the rectenna, could be offset by making a part of the rectenna reflect sunlight back to space. Averaged over a year, the reflected low-quality sunlight would compensate for the waste heat of the rectenna.

The rectennas will certainly be located in industrially zoned areas with restricted access. They could also be placed in remote areas, even so-called biological deserts with few birds or insects, but then the cost would rise because of the need for long-distance transmission lines. However, that choice is available to society and must be weighed against the well-known problems of conventional power generation, which include greenhouse gas emission, health effects of pollution from the burning of fossil fuels, and nuclear-waste disposal. Rectennas are a more benign source of power.

David Criswell]

Colorless diamonds

As a former chemical vapor deposition (CVD) diamond researcher, I read with great interest the article by Eric Lerner on industrial diamonds (*The Industrial Physicist* August/September 2002, pp. 8–11). I have been following the synthetic single-crystal diamond field since I was involved in growing some of the largest (1/4 carat) CVD crystals ever produced. Although the update on the Gemesis stones is interesting, Mr. Lerner fails to mention a major development in the synthetic diamond market—the introduction of GE/POL diamonds. Tom Anthony at General Electric developed a process for removing color from Type IIa diamonds, which make up the majority of mined diamonds. The new GE high-pressure/high-temperature process can make colorless diamonds, many of which are indistinguishable from natural stones. For a discussion of the GE/POL diamonds, visit http://www.professionaljeweler.com/archives/news/2000/020900story.html

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Wave coupling

I was delighted to read the two briefs in the June/July issue titled "Raman lasing from spheres" and "Cosmology to technology." What may not be apparent is that both articles deal with a similar phenomenon—evanescent wave coupling.

The first article deals with coupling to a whispering-gallery mode pinned to the surface of the sphere. The size of the sphere is important in setting up a standing-wave resonance to both increase the power density and provide a periodicity that satifies the (*k*-space) momentum conservation requirements of Raman shifting. As the brief points out, other dimensions are also critical; for example, the waveguide diameter of the fiber must be chosen to phase-match its velocity to that of the sphere's whispering-gallery mode. Finally, the gap dimension between the sphere and fiber determines the coupling efficiency—as well as perturbations to the modes. I am concerned with the radiative losses that occur where the fiber diameter is drawn down unless the draw is done adiabatically.

In the case of the heated silicon carbide gratings, I would remind readers—as well as the researchers reporting on this interesting work—that they are seeing a case of Wood's Anomalies, reported by R. Wood about a century ago. These are surface plasmons—or surface electromagnetic waves—that are phase-matched to free space waves by the periodic structure at the surface.

I did my doctoral thesis on the prism and grating excitation of surface plasmons and surface phonons back in 1973.

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New bachelor

A bachelor's degree in industrial physics looks like a great idea to me. I would suggest some things, however, to make the curriculum look more toward the future.

Scientific computing with Fortran. Fortran is a relic of the mainframe era. Numerical Recipes for C++ has appeared. C and its extensions are more in tune with modern computer science. When I got my first PC, I bought a Fortran 77 compiler and now regret it (I don't have time to rewrite the code in C).

Limited floating-point precision is a relic of the slide rule era. Double precision (64 or even 80 bits) is not always adequate. Mathematica addresses this problem; C does not. I have read about extended precision Fortran packages but know of no supporting hardware, even among the old supercomputers. Doing it byte-by-byte is very slow! Maybe this is an opportunity for research.

Introduce the concept of linear systems. It ties together most of the traditional tool boxes of science, engineering, and economics.

Nonlinearity. Chaos has proved to be less than a "new science," but nonlinearity is the way the world works on the large scale (e.g., orbital mechanics) and maybe on the very small scale also. Quantization is some kind of nonlinear resonance. "Randomness" may be chaos sampled in some critical range of frequencies, since it cannot be defined mathematically or empirically.

Calculus (and modern algebra) should be taught from the basis of constructive analysis. As far as I know, the first introductory texts based on this new theory have yet to be written. Now is the time for your math and physics faculty to do the job.

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I was intrigued by your article in *The Industrial Physicist* ("Introducing a Bachelor of Industrial Physics," August/September, pp. 28–29). As a Ph.D. physicist (Carnegie Mellon, 1995) who has spent the past seven years in industry, I think the shift you are making is long overdue and will likely serve your students well.

I have not used much of what I learned (and have since largely forgotten) in some of my more "classic physics" courses, including quantum mechanics and advanced mechanics, and I wish I had taken more courses on optics and circuits than I did. However, by far the most useful "field" I learned and absorbed in my undergraduate and graduate studies involved data analysis, modeling, and curve fitting—beyond what typical data analysis packages can do for you automatically. Especially important has been an understanding of how natural variability and uncertainty in the inputs to a model can impact the quality of the conclusions you can draw about the model.

In the industrial world, I also became exposed to the design-of-experiments approaches to problem solving. I noticed that this type of course is absent in your curriculum, although fundamentally it could underlie the bulk of your laboratory courses. Your students would likely be well served by acquiring a strong background in experimental design and statistics, since in industry there is a premium (dictated by cost) placed on getting as close to the right answer as possible in as few steps as possible. A deeper understanding of this issue would help your budding industrial physicists immensely and provide them with even a stronger leg up on their competition in the job market.

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[*Author replies*: If you want to insert additional topics into the curriculum, there are really only four possibilities—add a course, append the material to an existing course, replace an existing course, or replace existing material in a current course.

Choice 1 is not an option at East Stroudsburg University as the number of courses is limited by the state of Pennsylvania, and we are essentially at that limit. Choice 2 has to be carried out carefully. If none of your students can handle the workload, then the program ultimately gets canceled. So practically speaking, this is not an option. The other two options make curriculum a "zero-sum" game. For everything we add, we need to subtract something.

In response to Benjamin Frank, I think we can handle error analysis, curve fitting, and hypothesis testing in the laboratory up to the level of John Taylor's book, *An Introduction to Error Analysis*. Beyond that, I think we would need to require a good course in probability, statistics, and design of experiments. Our mathematics department teaches these subjects in a two-term sequence. If we get a large enough enrollment, perhaps we could convince the mathematics department to teach a selection of these topics in a one-term course. We would still be left with the question, what do you eliminate from the curriculum so as to fit in this new course?

In response to Foster Morrison, I have heard of many programming languages that someone thought were going to replace Fortran, including PL/1, Algol, Pascal, C, ADA, Basic (HP, Technical, Visual, etc.), C+, and now C++ (I've probably missed some). This is a debate that has been going on for at least 30 years. I bet that if and when the quantum computer becomes a reality, there will be a Fortran compiler for it! I'm not so sure about C++++. All these languages have their strengths and weaknesses (including Fortran). In fact, once you know one language, it's not that hard to learn another from this family of similar programming languages (as opposed to something like an assembly language, Lisp, APL, or SNOBOL).

I think it is more important that our students learn to use a variety of tools so they can pick the right tool for the job. Another consideration is that the language chosen be simple enough to allow us to spend more time on algorithms and physics than on programming. That said, if the computer science department decides to offer scientific programming in C++, that's what we will use. As for Mathematica or similar packages, there are problems that these packages just cannot practically solve, which is why languages like Fortran survive.

My response to the last three points (linear systems, chaos, and calculus) is that the approach of the industrial physics degree is to start with a more laboratory and practically oriented presentation and then work to the more abstract. I think these three approaches are more the reverse—start with the more abstract and then generalize to the practical. This general-to-specific approach will probably not work with our students. Much of the content of linear systems is in fact included in the traditional physics curriculum, and some of the rest will be found in the advanced electronics classes. Some nonlinear phenomena are of course in the curricula (such as the finite-amplitude pendulum). It would be an interesting challenge to see how much of an introduction to chaos and nonlinear dynamics can be given in a laboratory-based as opposed to a computer-model-based style. I'd be interested in knowing if anyone in industry would find having an undergraduate with knowledge of the subject useful, say at the level of Francis Moon's book *Chaos and Fractal Dynamics*.

As for revamping calculus, I'm not qualified to judge. My guess is that our students would find it far more abstract and much harder to learn calculus in that manner as opposed to using the traditional approach.

The one thing I am sure of is that the curriculum will change as academia and industry gain experience with this approach to undergraduate physics.

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