We appreciate Robert Schumacher's clarification on the design of violins. Despite this oversight in our explanation, the example still serves to demonstrate that when the answer is not obvious or intuitive to students, only a small percentage of them will learn from careful explanations alone.

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Women gain ground in academia; science mentors needed

Many of us in academia may feel discouraged by the persistence of gender discrimination in science and math after reading Toni Feder's reports "Why Women Leave Academic Physics" (PHYSICS TODAY, May 2005, page 32) and "No Leaky Pipeline for Women in Physics, but Discrimination Persists" (PHYSICS TODAY, April 2005, page 28). However, professors and students of science around the globe—both male and female—should be pleased that Susan Hockfield took the helm of MIT, a world-renowned physical-sciences authority. Working in a research group supervised by a female leader, I was excited to learn that two women were promoted to head the University of Toronto's prestigious faculties of law and medicine.

Although men have historically dominated the upper echelons of academia, the fact that more and more women are taking on high-powered positions in top-tier academic institutions not only inspires hope that the traditionally male-dominated field of science is undergoing a radical shift toward gender equality, but also suggests that women are not, as has been suggested by some, less capable than men, either biologically or psychologically.

Former Harvard University president Lawrence Summers was forced to resign after stating that the innate genetic differences between men and women account for the preponderance of men in math- and science-related careers. While it is undeniable that science is a male-dominated field and that there are indeed genetic differences between men and women, the latter does not explain the former. To the contrary, it has been established that women excel at a variety of tasks that relate to language and articulation.[1] In addition, females tend to outperform males at fine-motor activities, particularly those involving rapid, repetitive temporal sequencing,[2] making them more efficient at mastering laboratory skills.

What, then, is holding women back?

Although the answer to that question is highly complex and deeply rooted in societal expectations, it is important to consider whether an ideal leader possesses qualities that more closely resemble the attributes intrinsic to men or to women. The answer, I believe, is that the ideal leader possesses both. If one believes that a fully functional family requires equal contributions from a father and a mother, the same should hold true for larger institutions, from a university to an entire country.

References

1. R. Joseph, *Arch. Sex. Behav.* **29**, 35 (2000).
2. E. Hampson, D. Kimura, in *Behavioral Endocrinology*, J. B. Becker et al., eds., MIT Press, Cambridge, MA (1992), p. 357.

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If a pipeline is losing most of its product between the source and the first metering station, that isn't considered a leak? I don't know any industrial scientist who would even try to sell that idea to the plant manager. Similarly, the fact that talented, hard-working women with interests in physics, science, and engineering are leaving the system between high school and a bachelor's degree really is a problem that needs to be addressed. As the parent of a female undergraduate physics student contemplating advanced degrees in this field, I know how important it is for these high-school students to find science or engineering mentors who can take students into the labs and involve them in the excitement of scientific discovery that lies beyond the grind of getting the tough homework done—and maybe give help and encouragement with that homework too. My daughter was lucky enough to find such a mentor, but most students are not.

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Tough questions about wind energy

In suggesting that the US should turn to wind-generated electric power (see PHYSICS TODAY, July 2005, page 34), Cristina Archer and Mark Jacobson fail to discuss the visual impact of wind farms.

Individual wind turbines range in

See www.pt.ims.ca/9467-7

height from 10 meters to 10 building stories and appear to average about 50 meters.[1] The generation of significant amounts of electrical power requires multiple turbines arranged in wind farms. These farms are sited along seacoasts, atop ridge lines, and in flat, desert areas subject to strong seasonal winds.

Where wind farms exist, their turbines visually dominate the landscape. To wind-power enthusiasts the turbines are apparently a thing of beauty, symbols of "free" energy and progress. Readers should study enlargements of the photographs of wind farms (see, for example, http://windeis.anl.gov/guide/photos) and decide for themselves whether the sight is an acceptable substitute for nature's beauty.

The Bureau of Land Management is currently preparing environmental impact statements before permitting wind farms on government land throughout western states. Detailed state wind power classification maps[2] show where future wind farms are likely to be sited and provide power classification, resource potential, wind power density, and wind speed at 50 meters above ground.

After studying the photographs and reference 2, interested readers should be able to supply their own answer to Archer's rhetorical question "why not?"

References

1. US Bureau of Land Management, Wind Energy Development Programmatic Environmental Impact Statement FAQs, http://windeis.anl.gov/faq.
2. US Department of Energy, Wind and Hydropower Technologies Program, State Wind Resource Maps, http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp.

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As a free-standing, reliable, and stable source of energy, wind power is totally inadequate; even as a secondary, supportive source, it has serious limitations. Due to the character of wind, power is not produced in a steady stream over a long period but in a succession of spikes between zero and full power. The fluctuation makes reliable management of the power grid very risky. Moreover, wind power generation delivers only a modest fraction (20% to 25%) of the installed power capacity. For example, a 150-MW wind farm planned for the Gulf of Mexico outside Galveston, Texas, at a cost of $310 million would realistically deliver at an average rate of 30 MW. This will provide power for less than one extra minute per day for the state. To keep up with a 1.5% annual increase in electrical usage in Texas, one would have to build about 25 of these wind farms every year. So one 150-MW wind farm is small potatoes for Texas's electrical supply.

Germany is half the size of Texas but has more than twice the installed wind power capacity of the entire US, namely 16 400 MW, producing 4.9% of Germany's electricity (1.25% of its total energy). The problems created by the large investment Germany has made in wind power are discussed in the *Wind Report 2005*[1] from E.ON Netz, Germany's second largest electrical utility. The report concluded that the possibility of wind energy replacing conventional energy sources is quite limited. For instance, the country's 16 400 MW wind-energy system can actually only contribute 8% of its output capacity (1312 MW) as secure power production. So an extra, conventional generating capacity of about 90% of the wind capacity has to be added to the grid as backup, which would require an enormous additional investment.

The report also stated that the feed-in capacity for wind energy can change often and dramatically. "On Christmas Eve 2004, wind production in Germany fell 4000 MW in 10 hours, representing the capacity of eight 500 MW coal-fired power plants! This created an enormous challenge for the operators of the grid and it could easily have led to a vast blackout in central Europe."

For people thinking "the more wind energy the better," *Wind Report 2005* should be required reading.

Reference

1. E.ON Netz GmbH, *Wind Report 2005*, English translation available at http://www.eon-netz.com/EONNETZ_eng.jsp.

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Cristina Archer is quoted in the PHYSICS TODAY story as saying of wind energy, "We should really try to switch to wind power as much as possible. . . . It's an amazing source of energy—it's free, there's no fossil fuel involved, why not?" The story also notes that seven times as much energy is available as is currently consumed, from which I infer that the "possible" may include complete conversion to wind energy.

How much of this energy can be diverted without affecting climate and weather? Bird kills by wind turbines are dismissed as currently being less than 0.1% of wild bird deaths due to human causes, but the possibility that increasing use of wind energy could increase that rate by a factor of thousands is not considered. I'm sure other concerns—such as the effects of globally diminished wind speeds on ocean waves and currents—will arise when the matter is considered carefully.

Archer and Mark Jacobson are to be commended for their efforts in acquiring interesting and valuable information regarding wind speeds and distributions. However, I remain dismayed by the continuing efforts over the last three decades to identify desirable sources of energy without lucid analyses of the undesirable feedback and side effects they all must generate when scaled up from their experimental and marginal initial development.

Hints have appeared recently that even hard-core environmentalists are beginning to recognize that only nuclear energy can easily fulfill a major portion of current and projected energy needs, and that it would do so with the least amount of negative impacts—except for the criminally irresponsibly designed Soviet reactors—of all current energy sources. As Edward R. Murrow said, "The obscure we see eventually; the completely apparent takes longer."

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Archer and Jacobson comment: Kenneth Perry suggests that wind turbines interfere with nature's beauty. We believe, though, that the correct comparison is not with nature's beauty but with the visual, health, and climate impacts of coal, natural gas, and nuclear power plants (see, for example, http://www.fotosearch.com/photos-images/coal-burning-plant.html), which is what wind turbines would be replacing. No one wants to add a new facility of any type to the landscape, but so long as society demands energy, it must come from somewhere. Coal, natural gas, and nuclear power all have visual and health-risk externalities that we believe exceed those of wind power.

Frits de Wette contends that the intermittency of wind makes power management of a wind-energy-dominated grid risky. This is true when wind farms are not linked together in an organized manner through the transmission grid, but not true if they are. We have shown in a new study that interconnecting up to 19 wind farms several hundred kilometers apart converts an intermittent wind resource to one that produces about one-third of its electric power at the same reliability as the average US coal-fired power plant—which has a 12.5% outage rate. Remaining electricity can be firmed with hydroelectric, geothermal, solar, or other power. The website for Red Eléctrica, which operates Spain's electric power system (http://www.ree.es/ingles/i-index_de.html), further shows, as an example, that linking most of Spain's wind farms through a common grid would eliminate minute-by-minute fluctuations that occur at a single wind farm.

Whereas older wind turbines produce capacity factors of 20% to 25%, modern turbines (for example, producing 1500 kW, with 77-meter blades and 80-meter hub height) placed where mean annual wind speeds exceed 6.9 m/s at hub height have capacity factors greater than 35%. The Galveston project will generate approximately 40% of 150 MW, or 60 MW of electric power. California's electric power from fossil-fuel sources could be replaced by 6280 5-MW turbines offshore or onshore in wind speeds greater than 8.5 m/s. This is only 3.3 times the current number of smaller turbines in California. We believe wind can provide a large portion of electric power and energy if wind