The GE internal technical reports also provide a new perspective on the technological developments themselves. Advances in electric lighting occurred in step with the advances in basic and applied sciences during those same years. (See the article by John Anderson and John Saby, PHYSICS TODAY, October 1979, page 32.) The advances seldom occurred in isolation but rather in harmony with new products and new science developed around the world.

The record of those advances in technology in a century and more of progress has been known publicly through advertisements, product specifications, patents, academic papers, public presentations, published books, and other sources.[3,4] Access to the internal GE technical reports provides future scholars with a behind-the-scenes perspective on those advances. The documents now reside at the Hagley Museum and Library in Delaware, except for those involving glass, which are at Alfred University in New York.

We are grateful to the management team of GE Lighting, now a Savant company, who recruited us, provided logistical support in important ways, and made the preservation project possible. We hope that our experience inspires others who see history and technology moving forward and might know of artifacts worth preserving. Such items help the general public appreciate the rich history of scientific progress and enable scholars to study and interpret that history.

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LETTERS

Nineteenth-century women and physics across the pond

Joanna Behrman's article "Physics . . . is for girls?" (PHYSICS TODAY, August 2022, page 30) provides a refreshing antidote to today's stereotypes. For most of its history, Western science has been essentially a men's club, evolving in "a world without women," to borrow the title of David Noble's 1992 book that traces the male dominance of science to Christian clerical heritage.[1]

Behrman reports that in the 19th-century US, girls and young women were encouraged to study natural philosophy. But the situation at the time was quite different in Britain. Girls and women were thought incapable of "ascent up the hill of science," which Cambridge University geologist Adam Sedgwick said was "rugged and thorny, and ill-fitted for the drapery of a petticoat."[2] (Though, ironically, it is said that the cloth wrapping of the ring with which Michael Faraday discovered electromagnetic induction in 1831 was made from strips of his wife's petticoat.)

The Scottish physicist David Brewster, who worked on polarized light and invented the kaleidoscope, was explicit in his views toward women in science: "The mould in which Providence has cast the female mind, does not present to us those rough phases of masculine strength which can sound depths, and grasp syllogisms, and cross-examine nature."[3] J. J. Thomson, the Cambridge physicist who discovered the electron, expressed a similar worldview. In an 1886 letter to a family friend, he complained that a female student in one of his advanced classes did "not understand a word." He went on to state, "my theory is that she is attending my lectures on the supposition that they are on Divinity and she has not yet found out her mistake."[4]

The law of conservation of energy, established at midcentury with major contributions coming from the Englishman James Joule and the Scot William Thomson (later Lord Kelvin), was held by many to explain why women should not do science or indeed even be educated: A woman's body contained only a finite amount of energy, and trouble would befall those who channeled it away from childbirth and nurturing.[5]

In the 1800s, only a few women were accepted into Britain's scientific sphere. One of the most notable was the self-taught Mary Somerville, who wrote several treatises and translated and expanded Pierre Simon Laplace's *Mécanique céleste* (Celestial mechanics; see the article by James Secord, PHYSICS TODAY, January 2018, page 46). Fortunately, the station of women in the still predominately patriarchal social arena of science steadily improves.

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► **Behrman replies:** Robert Fleck astutely notes that despite significant cultural exchange between the US and Britain, the histories of women in physics in each country took very different paths. In her book *A Lab of One's Own*, Patricia Fara discusses the difficulty faced by British female scientists in obtaining employment and carving out spaces for themselves in science.[1] In contrast, the relative encouragement for girls to study science in the US paved the way for strong communities of female scientists at many of the country's numerous women's colleges. Miriam Levin chronicles one such

community at Mount Holyoke College in *Defining Women's Scientific Enterprise*.[2]

This is not to say that female physicists in the US didn't face plenty of barriers as well—they certainly did! Rather, it is a telling confirmation of how contextual and changeable culture is.

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Hope for CO_2 air capture

John Tanner's summary of carbon dioxide air-capture costs (Physics Today, February 2023, page 12) takes the glass-half-empty approach to an extreme. At the average US retail price for electricity (12¢/kWh), the thermodynamic energy demand of direct air capture[1] would indeed add $15 to the cost of collecting a metric ton of CO_2 from air. But large power consumers, such as aluminum smelters, get much better pricing.[2]

Moreover, removing 8 billion metric tons of CO_2 for a mere $120 billion would be a good deal. It would cancel past emissions from about 20 billion barrels of oil. The world buys that much oil every 200 days for $1.6 trillion. Prices for such a quantity have fluctuated between $200 billion and $3 trillion over the years. The implied surcharge of $6 per barrel seems cheap for fixing the climate.

Can air capture achieve such economics? The bad news is that current costs are above $500 per metric ton of CO_2. I agree with Tanner that thermodynamic limits plus unavoidable raw-material inputs set a lower bound around $10–$20 per metric ton.[3] The good news is that no physical law prevents approaching that bound through learning by doing. Betting against an order-of-magnitude cost reduction ignores the two-orders-of-magnitude reduction in wind and solar. It collides with the frequently expressed optimism that batteries will get cheaper if we produce a lot of them. Mass production has proven over and over that costs can drop 10-fold if cumulative capacity increases 1000-fold.[4] For air capture, which needs to grow more than a millionfold, that represents just the beginning of the growth curve.[5] Obviously, success is not guaranteed, but closing the door to the opportunity without trying is self-defeating.

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