



FIREPLACE IN JONES HALL at Princeton University. Albert Einstein had an office there in the 1930s. (Photo by Robert Fleck.)

Magritte's art and Einstein's science are striking and help to situate the painting in the broader intellectual and cultural compass of its transfixed time.

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Repulsive Casimir forces

The article "Science and technology of the Casimir effect" by Alex Stange, David Campbell, and David Bishop

(*PHYSICS TODAY*, January 2021, page 42) presents data from a 2009 experiment by Jeremy Munday and coworkers¹ that shows that Casimir forces can be repulsive. Sixteen years earlier we published similar results.²

As Stange and coauthors point out, the Casimir force is emerging as a technological tool to manipulate matter at small scales. Our earlier effort to create repulsive and nearly neutral Casimir and van der Waals interactions was motivated by an attempt to improve the imaging resolution of contact-mode atomic force microscopy (AFM). The idea was to eliminate the jump-to-contact instability associated with attractive Casimir interactions, which elastically deforms the AFM tip, sets a lower limit on its effective size, and reduces imaging resolution. Imaging with special fluids works to eliminate that instability, but the fluids we had to use, bromo- and methylnaphthalene, were not compatible with biological materials. Since our hope was to image molecules such as DNA, we did not pursue further the manipulation of Casimir forces.

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Icebreakers and Arctic ice melt

Saara Matala's article "Finnish-Soviet nuclear icebreakers" (*PHYSICS TODAY*, September 2020, page 38) gives an account of how the small Western country of Finland managed to maintain its neutrality and start a commercial collaboration with the Soviet Union based on icebreakers. What struck me most in the article was figure 1, which depicts the routes around the Arctic Ocean: the Northern Sea Route along Siberia and the Northwest Passage along Canada.

Almost every article I have read regarding the early and accelerating melting of the Arctic ice stresses the importance of the albedo difference between intact ice and free ocean water (see, for example, "The thinning of Arctic sea ice," by Ron Kwok and Norbert Untersteiner, *PHYSICS TODAY*, April 2011, page 36).

When I read that Finland's "five *Moskva*-class polar icebreakers" were "designed to cut through multiyear Arctic sea ice," my mind linked icebreakers with the premature Arctic melt. Icebreakers keep the routes in figure 1 open most of the year—if not year-round—for commercial shipping. Thus they initiate or at least aggravate the melting of multiyear sea ice: Breaking the ice allows the open waters to warm with respect to the surrounding ice due to the albedo difference, with probably a very small addition from the heat generated by the ships themselves. I therefore find it hard to believe that a *PHYSICS TODAY* news story (September 2017, page 24), for example, advocates the use of new icebreakers "to gauge global effects of the polar region's diminishing ice cover." I have to wonder if the models regarding Arctic warming have taken the effect of icebreakers into consideration.

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► **Matala replies:** The question Peter Steur asks, whether it is reasonable to advocate the use of icebreakers "to gauge global effects of the polar region's diminishing ice cover," would be better answered by a climate change expert.

As a historian of technology, not a trained climate scientist, I consider what information the contemporary actors had. The Helsinki shipyard contracted for the first *Moskva*-class polar icebreakers in the mid 1950s, before climate change was seriously considered in ship design.

My article emphasized the ability of polar icebreakers to "cut through multiyear Arctic sea ice" because length constraints restricted discussion of other features that differentiated the polar icebreakers from the previous Finnish design. Getting through multiyear ice is a heavy task even for modern icebreakers. Most of the shipping activities in the Northern Sea Route take place during the summer season when sea-ice cover is lower.



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Polar icebreakers also make the Arctic Sea accessible for research vessels gathering information essential to improving climate models. As historian Melvin Kranzberg famously put it, "Technology is neither good nor bad; nor is it neutral."

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Nine reactors beat ZEEP into service

David Kramer's article on nuclear developments in my native Canada (PHYSICS TODAY, January 2021, page 23) was an enjoyable read. However, his assertion that the Zero Energy Experimental Pile (ZEEP) was the world's second operating nuclear reactor after Enrico Fermi's Chicago Pile-1 (CP-1) is erroneous; at least nine other stateside piles achieved criticality before ZEEP did so in September 1945.

Those nine US piles were CP-2 and CP-3 at Argonne National Laboratory (March 1943 and May 1944; CP-3 was the first heavy-water pile); the X-10 pilot-scale pile at Oak Ridge National Laboratory (November 1943); the 305 fuel-testing pile and the B, D, and F plutonium production piles at the Hanford Site (1944 to early 1945); and two small aqueous enriched-uranium devices, LOPO and HYPO, at Los Alamos National Laboratory (1944). ZEEP was the first pile outside the US to achieve criticality.

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"But what is physics?"

I took my first physics class ever at Stanford University in January 1960. The professor was Leonard Schiff, then also the chairman of the physics department. The lecture hall was full of mostly freshmen, some excited and some terrified at the thought of calculus-based physics taught by one of the most distinguished members of the department.

Leonard began by talking about the difference between basic and applied research, perhaps not a topic calculated to excite the group. But one guy (not I, let me assure you) raised his hand to stop the lecturer for a question: "Yes, but what is *physics*?" Leonard stopped in his tracks. I doubt he had ever been asked that question that way.

After thinking for a few moments, he responded, "Why, physics is whatever physicists do." In the 61 years of my career as a physicist, I've never heard a definition I liked better. Physics isn't the manipulation of mass and energy and the measurement of ever-more-precise quantities. Instead, it's whatever the people trained in those arts decide to do.

That's a definition I've used more than once as I've wandered from MeV- to GeV-range nuclear and particle physics, to planetary orbital mechanics, to strategic arms control, and to diplomacy with Chinese and Soviet colleagues. As long as I'm using the mental attitudes of a physicist, I'm doing physics and need not apologize for my changing interests and skills.

And so, my thanks for the February 2021 issue, which demonstrates and encourages the enormous range of activities that we can collectively call "physics": from neutrinos to rare-earth magnets, lunar exploration, tech transfer, and measurable differences between whisky and whiskey. I think Leonard would have been charmed and delighted. I wish I had a hundred copies to give to high school seniors, mid-degree undergraduate physics majors, grad students, and physicists who have left the lab for other careers.

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Corrections

February 2021, page 23—The article erroneously reported a \$1.8 million grant in 2020 to Ucore Rare Metals Inc from the US Army Research Laboratory. In fact, grants totaling \$1.8 million were awarded in 2014–16 to Innovation Metals Corp to help fund development of its proprietary rare-earth separation technology. IMC was acquired by Ucore in 2020.

February 2021, page 27—The device in the photo is incorrectly identified as "the inside of an acoustic cytometer." It is actually a close-up image of a DNA fragment-sizing flow cytometer. PT