APS News

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Introductory Physics Classes Can Make or Break Students' Persistence in the Field

A recent study sheds light on why undergrads pursue physics and why majors persist or leave.

BY LIZ BOATMAN

Students in a General Physics I lab at George Washington University. GWU was one of four schools that participated in a five-year longitudinal study on undergraduates in physics. Credit: Cara Taylor/GWU

While the absolute number of undergraduates majoring in physics has increased in the last decade, the data paints a complex picture of students' paths. Introductory physics classrooms are often packed, but only a fraction of those students go on to major in physics. Of those that do, many will eventually switch majors — at a higher rate than students in similar programs, like engineering or computer science.

What gives?

The American Institute of Physics (AIP) set out to understand these trends in its recent report "Attrition and Persistence in Undergraduate Physics Programs," the culmination of a five-year longitudinal study that began in 2018. The researchers surveyed more than 3,900 students in introductory physics courses at four predominately white institutions, ultimately tracking 745 students through their entire college experience. When surveyed in the first week of their first introductory physics course, those 745 students all expressed an interest in majoring in physics.

"This study addressed an important gap in our research," says Anne Marie Porter, the assistant director of statistical research at AIP and one of the report's authors. "We've done a lot of research on physics faculty members, graduate students, recent physics graduates, and majors, but intro physics students are a core group that we were missing." A college student's first physics course marks a key stage in a budding career, she says.

Porter says AIP wanted to understand how students become interested in physics as a major, why

Intro Physics continued on page 4

How the Discovery Papers on Plutonium Were Finally Published After World War II

In 1946, three physicists discussed via mail whether it was time to publish results that had been withheld during the war.

BY ROBERT GARISTO

From left to right, physicists Richard Tolman, Edward Condon, and John T. Tate Sr.
Credit: U. S. Army, NIST, AIP

In one of the back rooms of the APS Long Island editorial office, a small trove of archived documents is collecting dust. Many date back decades and aren't particularly exciting — old journal copies, APS governance documents, and the like. But occasionally, something interesting crops up.

Recently, I was rooting through these archives, looking for some old journal correspondence, when I came across a folder of letters from the 1940s. The box containing it once sat in the basement of the late Peter Adams, the former APS deputy editor in chief and longtime editor of *Physical Review B.* Peter cared deeply about the Society and had taken it upon himself to preserve the files.

In the letters, a trio of leading physicists debated when to finally publish secretive research that shaped the creation of nuclear weapons.

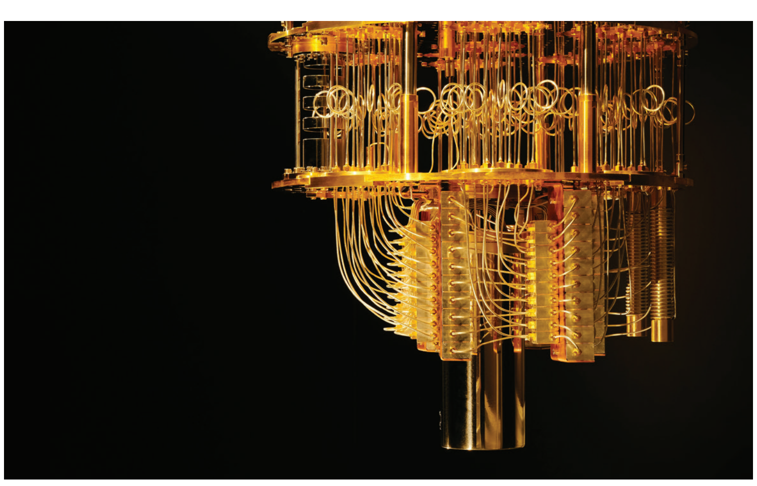
During World War II, the editors of *Physical Review* — fearing that

Plutonium continued on page 5

During its First Year, APS Unit Gives Quantum Materials Synthesis a Home

APS' newest topical group celebrates its first anniversary.

BY KENDRA REDMOND



Research on quantum materials synthesis is key to the advancement of technologies like quantum computers. Credit: IBM

It's been a big year for all things quantum: This spring, in honor of the 100th anniversary of quantum mechanics, the United Nations proclaimed 2025 the International Year of Quantum Science and Technology.

One group of physicists is celebrating another quantum science milestone this October: the first anniversary of APS's newest unit, the Topical Group on Quantum Materials Synthesis (GQMS). The unit is a gathering place for scientists who develop, synthesize, and study new quantum materials.

"So many new things can be done [with quantum materials]," says Sang-Wook Cheong, a Rutgers University physicist and founding member of GQMS. "A lot of things have never even been touched theoretically, experimentally."

Topical Group continued on page 3

Physicists Are Tackling Renewable Energy Projects to Bolster Africa's Energy Future

Scientists are working across disciplines and borders to support growth in sustainable energy.

BY RACHEL CROWELL

Many countries across Africa have an enormous need for more plentiful and reliable energy. While abundant energy potential exists on the continent, many resources remain untapped. Meanwhile, "over 650 million people across the continent still lack [electricity] access," says Rebekah Shirley, deputy director for Africa at the World Resources Institute. "The question of energy access is quickly becoming almost exclusively an African challenge."

The consequences of lagging energy access are high: Energy poverty, or a lack of access to reliable electricity, reinforces economic poverty, says Rose Mutiso, research director of the Energy for Growth Hub, a global energy think tank.

Yet renewable energy could help meet these needs — and African physicists are playing a key role, working across disciplines and borders to enable sustainable growth in energy access.

Addressing increasing challenges

Without significant progress, Africa's energy challenges are expected to persist. "The latest estimates suggest that by 2050, Africa will be the most populous continent on Earth, housing 80% of the world's poor and 90% of those without energy access," notes Shirley. That's "all while housing some of the most climate-vulnerable communities on Earth, and having contributed less than 5% of global carbon emissions."

Renewable energy could play a role in the solution. In 2020, just

The Olkaria II geothermal power plant in Kenya. Credit: Belikova Oksana/Adobe

9% of Africa's energy came from renewable sources, according to collaborative work by the World Economic Forum and *Statistica.* But one team of researchers projects that, by 2040, 76% of Africa's electricity needs could be met through renewable energy.

By conducting research on "the physics of energy fuels and technology," physicists can contribute to the future of African countries' energy, Shirley says. "Even the way that we do standardized testing for energy technologies is not necessarily adapted to Global South testing conditions or environments where technology will be operated or deployed," she notes.

Local physicists will be better able to identify current gaps and their remedies — local physicists like Diouma Kobor, director of the chemistry and physics of materials laboratory at Assane Seck University of Ziguinchor in Senegal, a West African nation of 17.3 million people.

In Senegal, energy access varies widely. "In the urban areas, the energy access is around 80%, and in the rural areas, the percentage is low — around 60% or sometimes 50%," says Kobor, who's also the general director of Senegal's National Agency for Renewable Energy. Senegal gets about 30% of its energy from renewable sources but aims to hit 40% by 2030, Kobor says.

Kobor is one of a growing number of physicists across Africa focused on energy research. He studies photovoltaic cells, including "how to use new materials — advanced materials, like perovskites," he says. He's also experimenting with using molecules from local plants to increase the efficiency of solar cells.

Cooking fuel is another area of focus for scientists in Senegal and beyond. Lat Grand Ndiaye, a physicist also at the Assane Seck University of Ziguinchor, studies "energy polarization of biomass in solid fuels," such as briquettes — compressed blocks of combustible biomaterial. Used for cooking, heating, and elec-

Renewables continued on page 3

New Quantum Effect in Textbook Chemistry Law

The observation of quantum modifications to a well-known chemical law could lead to performance improvements for quantum information storage.

BY MICHAEL SCHIRBER

The Arrhenius law says that the rate of a chemical reaction should decrease steadily as you increase the energy barrier between initial and final states. Now researchers have found a system that obeys a quantum version of the Arrhenius law, where the rate does not drop smoothly but instead decreases in a staircase pattern. The system is a type of quantum bit (qubit) that is particularly robust against environmental disturbances. The researchers, who published the study in *Physical Review X* in September, demonstrated that they can take advantage of this quantum effect to improve the qubit's performance.

Technologies such as quantum computers and quantum cryptography use qubits to store information, and one of the continuing challenges is that uncontrolled environmental effects can change the state of a qubit. The most common solutions require large amounts of hardware, but an alternative method is to use qubits that are more error resistant, such as so-called cat qubits. The information in these qubits is stored in robust combinations of quantum states that resemble the states in Schrödinger's famous feline thought experiment.

Nicholas Frattini, Rodrigo Cortiñas, and their colleagues from Yale University previously developed a cat qubit design in which a superconducting circuit is driven by microwaves. The current in the circuit oscillates, like a ball rolling back and forth in a valley, or "potential well." For a certain driving frequency, the current can oscillate in one of two potential wells — called left and right — that are distinguished by being out of phase with each other.

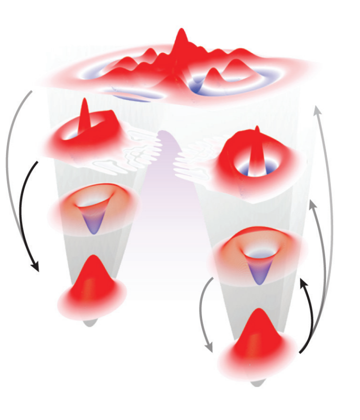
The researchers can create two cat qubit states by generating oscillations that are quantum superpositions of both wells — where there is a certain probability for the qubit to be in either the left or the right well. With this setup, the team previously demonstrated a number of quantum logic gate operations, which are the basic elements of computing. But one challenge has been "tunneling," in which an oscillation switches spontaneously from one well to the other. The possibility of tunneling affects the superposition probabilities, limiting the lifetime during which the team's qubit held information to around 100 µs.

> "Tunneling is evil," Dykman says. "This new work is a very important confirmation of the suppression of tunneling."

To reduce such tunneling, the team has now modified their system, the main change being an increase in the amplitude of one of their microwave inputs. This modification causes a rise in the energy barrier between the wells. "We can engineer a double-well system and show how the tunneling effect gets suppressed as we make the barrier higher and higher," Frattini says.

The researchers had expected the system to obey the Arrhenius law, which describes the rate at which a system makes transitions between two states separated by a barrier (usually called the activation energy). The law is modified for quantum tunneling, but the basic trend is that raising the barrier should cause a steady decrease in the tunneling rate. There was no real reason to mistrust that prediction," Cortiñas says. But instead, to the team's surprise, the tunneling rate dropped through a "staircase" of discrete steps.

The team explains this quantized Arrhenius behavior as the result of excited states in each well having a "ladder" of discrete energies. The action is dominated by the excited state with energy just at the level of the barrier. According to quantum mechanics, an oscillation in one well can climb in energy to this "barrier level" excited state and tunnel across from there. The rate of this tunneling goes down as the barrier height increases, but the situation changes when the barrier height



A cat qubit consists of a double potential well, shown here in gray. The red and blue drawings represent the quantum wave functions of different oscillation states within the wells. An oscillation that starts out at the bottom of the right well can climb up to a higher state and tunnel across the barrier into the left well. Researchers are trying to limit this well-to-well tunneling because it shortens the information-storage lifetime of the qubit. Credit: N. E. Frattini et al., *Phys. Rev. X* **14**, 031040 (2024).

Quantum continued on page 3

THIS MONTH IN PHYSICS HISTORY

Oct. 27, 1930: Birth of Gladys West, the Mathematician Who Laid the Groundwork for GPS

West's research at a naval facility in Virginia proved crucial to navigation satellite systems.

BY KENDRA REDMOND

Gladys West at Dahlgren Proving Ground, a U.S. Navy facility, where she worked for 42 years. Credit: Gladys West

Gladys West was born in Sutherland, Virginia, in the early days of the Great Depression. Her parents worked hard to make ends meet in the rural town, which afforded its Black residents few job prospects beyond farming and processing tobacco.

But while she chopped wood and fed chickens, West dreamt of more — "more books, more classrooms, more teachers, and more time to dream and imagine what life would be like if only I could fly away from the strenuous and seemingly never-ending work on our family farm," West says in her memoir *It Began with a Dream*.

West could not have imagined her eventual path: building a career as a mathematician and contributing to research that underpinned the creation of GPS.

Every day through seventh grade, West and her siblings trekked three miles to their one-room schoolhouse, which was outfitted "with rusty, decrepit furniture, sometimes leaky ceilings, and always hand-me-down books," she writes. The town's Black students went there, and they were taught by a single, overworked, underpaid teacher. "The white folks called it separate but equal, but there was nothing equal about it," she recalls.

In high school, West excelled in math and science. That's when she glimpsed a path: The top two graduates received college scholarships. West secured her place as valedictorian and became the first in her family, and second from her community, to attend college.

To West, Virginia State College — now Virginia State University, a historically Black college south of Richmond — felt like a different world, exposing her to new experiences, ideas, and career options. After graduating with a bachelor's degree in math, she became a teacher at a rural, segregated high school. A few years later, she earned a master's degree in math from Virginia State. She returned to teaching but continued applying for jobs.

Before long, West received a letter from the Naval Proving Ground (now the Naval Support Facility) in Dahlgren, Virginia. She had applied for a position as a mathematician, and they wanted her to interview.

"I wasn't sure if they were serious, and I couldn't find it on a map, so I had no idea where Dahlgren was located," West says in her memoir. Questions flooded her mind: How would I get there? Where would I live? Do they realize I'm Black? She declined the interview, hoping for an opportunity in Richmond or Washington, D.C.

Intent on recruiting West, Ralph Niemann, head of the Warfare Analysis Department at Dahlgren, sent her a job offer anyway. This time, she accepted.

The Dahlgren proving ground, located in a remote area near the Potomac River 50 miles south of Washington, was established in 1918 as a testing site for naval munitions. During World War II, Dahlgren analysts determined trajectories for all the Navy's guns, unguided rockets, and bombs.

Gladys West and a colleague at Dahlgren, where West's research contributed to the creation of GPS, in 1985. Credit: U.S. Navy

"The computational requirements were staggering," wrote Raymond Hughey Jr. in an article in the *Technical Digest* of the Naval Surface Warfare Center, Dahlgren Division. "Trajectories needed to be computed for all usable conditions for each gun-projectile combination to determine the range tables."

By the time West arrived in 1956, Dahlgren was the Navy's primary computing center. Its newest acquisition, the Naval Ordnance Research Calculator, was considered the world's most powerful computer. To take full advantage, Dahlgren hired more scientists, engineers, mathematicians, and programmers. They didn't only work on trajectories; ideas and research questions were plentiful.

"The problems were already here, and the engineers and mathematicians were looking for ways to solve them faster and cheaper," Niemann said in an interview published in Kenneth McCollum's book *Dahlgren*.

West's first tasks included programming and coding algorithms to compute weapons systems range tables, a high priority given Cold War tensions between the U.S. and the Soviet Union. She also worked on orbit trajectories for the emerging U.S. satellite program, another Cold War-driven project.

The work was new in another way: While the city of Dahlgren was segregated, the base and its gated amenities, including housing, were not. For the first time, West was working and living in a racially integrated environment. Most of her colleagues were men, and almost all were white.

"When many of my white colleagues saw me in the bathroom, they would get this look on their face like they had seen a ghost or something," she recalls in her memoir. West was only the fourth Black STEM employee hired by the computing center, and she felt enormous pressure to succeed.

Gladys West continued on page 5

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Renewables continued from page 1

tricity, briquettes are an alternative energy source that "allows us to fight against deforestation by the excessive cutting of wood," Ndiaye says.

By tapping into renewable energy sources like these, African nations could reduce fuel prices for consumers, businesses, and social infrastructure. Senegal's energy costs are "very high compared to many, many countries in Africa," Kobor says.

However, there are challenges in transitioning to renewable energy, including limited financing, undeveloped infrastructure, and difficult business environments. And aging national infrastructure can impede the reliability of local energy, Kobor says. Increasing countries' reliance on renewable energy may not immediately rectify this, because sources such as wind and solar power are inherently variable.

Regulations are also often lacking. In some countries, policies aren't yet in place that would enable individuals or companies to sell renewable energy they've generated to the grid, says Robinson Musembi, a physicist at the University of Nairobi in Kenya who researches photovoltaic cells.

However, few African countries share Kenya's access to natural geothermal resources. And while some countries have natural resources conducive to renewable power, harnessing those resources is fraught with logistical and financial obstacles.

Musembi gives the example of the Democratic Republic of Congo. "It has very large rivers, but because of the dense forest and other factors, [historically], it has been impossible to develop [hydropower] infrastructure," he notes. This means that, although much of the DRC's electricity comes from hydropower, the overall supply remains limited. Musembi says efforts are underway in the DRC to develop large dams that could supply hydroelectric power, and even yield excess energy that could be exported to other countries.

Collaborating for renewable energy success

While each country's path toward energy growth may look different, collaboration across geographic borders has proven important.

For instance, Morocco aims to get more than half of its electricity from renewable energy by 2030, according to Haddou El Ghazi, a physicist at Hassan II University of Casablanca — and collaborations with other nations, organizations, and funders are a key strategy. Recent international agreements cover "training and experience sharing, cooperative program execution, technology and information transfer, and program implementation," El Ghazi wrote in the *African Physics Newsletter*.

Some Senegalese physicists are focused on research in renewable biomass-based technologies, like fuel briquettes. Credit: Bio4Africa

Harnessing unique natural resources

Each African country's renewable energy future will depend on its strengths and resources — and in many countries, physicists have helped capitalize on these resources. For instance, "Kenya's grid is almost 90 percent renewable," Mutiso says, and physicists played key roles in making the country "one of the biggest producers of geothermal energy in the world."

Kenya's success with geothermal energy "dates back decades," to the work of physicists and geophysicists "who set the basis for those early explorations and early characterization of our geothermal resource, and [who] helped build the workforce," says Mutiso.

The country's energy has also been bolstered through the Last Mile Connectivity Project, a government program funded through a World Bank grant. "Even in the villages, the availability [of electricity] is actually very good," says Musembi.

Cross-border research partnerships are also key to knowledge-sharing. Kobor and Ndiaye are involved in Bio4Africa, a collaboration between several African countries, European countries, and India. The organization is working to develop and deploy biomass-based technologies, like green biorefining, in African communities. In pilot programs in Uganda, Ghana, Senegal, and Ivory Coast, farmers and pastoralists are testing these technologies in the real world.

Partnerships can also help address energy reliability issues. For example, "cross-border trading between countries" could offset the inherent variability of solar or wind, says Shirley. Such efforts are being promoted by initiatives like the Africa Clean Energy Corridor, which involves countries in Eastern Africa and Southern Africa.

Developing the workforce

Among African students, there's high interest in research and training connected to renewable energy, according to Kobor and Ndiaye. But funding remains a challenge. As Di Caelers and Dann Okoth wrote in *Nature Africa* in December 2023, "17 years after African Union member states committed to spending 1% of their GDP on research and development, the continent's funding is at only 0.42%, in sharp contrast to the global average of 1.7%."

This can pinch researchers and students alike. For instance, Kobor and Ndiaye say that one competitive research fund through the Senegalese government offers each team a maximum amount equivalent to about €30,000 (about $32,700). "The amount is awarded to a team often belonging to more than one university," Ndiaye says.

That amount can help researchers perform some work in their labs but still leaves them without specialized instruments. Collaborations with European colleagues can help, Ndiaye adds, but there's an enormous need for local funding to support researchers in their own labs.

For the many students who are interested in establishing their own businesses, providing solar cells, biofuels, or electronic waste recycling, it's sometimes possible to secure funding by winning inter-university competitions, Kobor says. He's also working with a colleague in South Africa to start a student exchange program.

Some institutions, meanwhile, are training students for new careers in renewables. In Kenya, the University of Nairobi offers a popular program called the Solar Academy. Students, business professionals, and photovoltaic cell installation technicians receive two weeks of targeted training on solar panel installation. The Solar Academy has trained at least two cohorts per year since 2012, and other universities, both inside and outside of Kenya, offer similar programs, Musembi says.

Investing in this workforce could help many countries in Africa build their renewable energy futures. "The continent holds so many renewable energy resources, more than the whole world would need," Shirley says — "more than sufficient to meet the electricity needs of the continent."

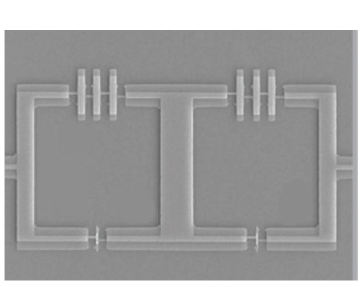
Rachel Crowell is a science journalist based in Iowa.

Quantum continued from page 2

reaches the next higher excited state, which then becomes the barrier level state, and a new step in the staircase appears.

Having identified the staircase and the role that the excited states play, the researchers showed that they could obtain lifetimes as long as 1 millisecond. Other research teams have engineered cat qubits with 1-second-long lifetimes, but their designs are not ideal for logic gates. "Our readout has much higher fidelity, and our gates are faster," Frattini says.

Mark Dykman, from Michigan State University, has worked on the theory of barrier crossing in periodically driven quantum systems. He says the Yale team has confirmed previous predictions for the behavior of such driven systems, but the team has explored a new regime where the well-switching rate displays unforeseen features of quantum fluctuations. He believes the results will have practical importance for quantum computing because a major obstacle for cat qubit designs has been unwanted tunneling. "Tunneling is evil," he says. "This new work is a very important confirmation of the suppression of tunneling."



This superconducting circuit, measuring about 10 μm vertically, allowed the team to observe the effect of barrier height on the rate of tunneling through the barrier for a double-well system. Credit: N. E. Frattini et al. (2024)

Michael Schirber is a Corresponding Editor for Physics Magazine *based in Lyon, France.*

Strength of US High-Magnetic-Field Science is Waning, Academies Report Warns

The U.S. must build new world-leading magnets to keep pace with global competition, the report urges.

BY CLARE ZHANG

The National High Magnetic Field Laboratory in Tallahassee, Florida. Credit: National MagLab

On Aug. 13, the National Academies released a consensus report that recommends federal agencies fund construction of new world-leading magnets and expand support for the development of wire technologies within the next two to three years. These steps would help the U.S. regain the lead in magnet technology over European and Asian countries, the report argues.

High magnetic fields are essential for progress in fusion science, medicine, materials science, fundamental physics, and more, according to the report. "It is hard to see how progress can be made in some of these areas without major efforts in the development of high-temperature superconducting wires and magnets," it states.

The report — the latest in a series on high-magnetic-field science — cites inadequate budgets, the lack of a national agenda, and the lack of a robust commercial industry for key resources as potential barriers to progress thus far.

Building and coordinating new magnets

The report recommends the National Science Foundation fund the construction of new magnets at the National High Magnetic Field Laboratory in Tallahassee, Florida, to surpass the lab's current records of magnetic field strength. "Moonshot" efforts like an all-superconducting 40 Tesla magnet would cement U.S. leadership in magnetic resonance, it adds.

The NHMFL remains a world-class facility, but "over the past decade, provision of similar facilities in Europe, China, and Japan has grown, often following the U.S. model, with headline capabilities

Magnetic continued on page 6

Topical Group continued from page 1

Put simply, the umbrella of quantum materials covers materials that show strong electron correlations or spin-orbit interactions, says Gang Cao, a physicist at the University of Colorado Boulder and chair of GQMS. It includes superconductors, Mott and topological insulators, quantum spin liquids, and other materials whose properties can't be well described by classical approximations.

"The science and technology of materials synthesis are at the heart of the discovery, design, and realization of novel quantum materials that underpin quantum technologies," says Cao. The reason that "realistic quantum computers are at least many decades away is because we don't have the right materials."

Historically, the physics community considered people who synthesized new materials to be technicians rather than scientists, but "in recent years, this has changed," Cao says. That is likely due, in part, to increased investments in quantum materials research, access to tools for studying materials, recognition of materials-related discoveries (like blue LEDs), and demand for materials with novel properties.

As the community has recognized the science behind synthesis and the potential of quantum materials, more physicists have joined the action.

The quantum material synthesis community is huge now, encompassing physicists, chemists, biologists, and engineers, Cao says. But they're dispersed. A few years ago, Cao, Cheong, and others attending a small-scale quantum materials synthesis conference realized that the larger community needed a place to share progress and explore common challenges. They decided to petition APS to establish the new unit. Since its founding, 270 people have joined.

Synthesizing quantum materials with desired properties can be challenging. For example, many novel quantum states predicted by theory have yet to be realized experimentally, Cao says — and not for lack of trying. "So then you wonder, 'What's wrong?'" he says. The answer might lie in the synthesis process itself.

Say theory predicts that a certain material will be superconducting, but years of synthesis efforts do not achieve that result. Maybe the theory is wrong, but maybe conventional synthesis techniques allow distortions in the materials that impede the desired property, he says. If so, new or modified synthesis methods could potentially produce the desired property.

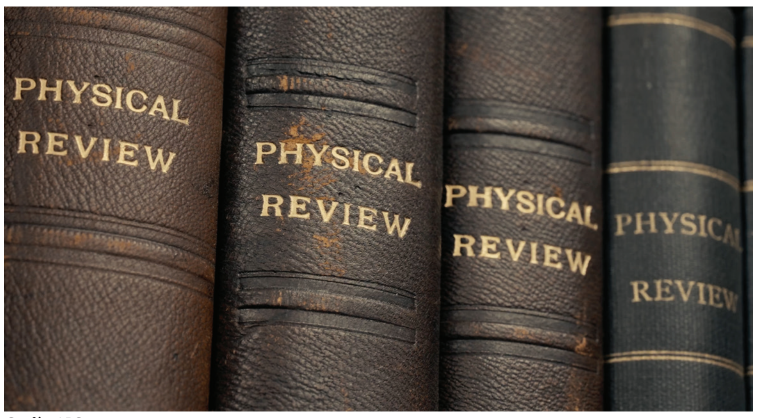
Cao hopes that discussing these questions as a community will lead to greater progress. The unit welcomes anyone working on the synthesis of bulk single crystals, thin films, 2D materials, or nanostructures, or on characterization approaches. Having those groups talk to each other could have a huge benefit, Cheong says.

Next March, during the International Year of Quantum Science and Technology, GQMS will bring these groups together at the APS Global Physics Summit — the joint March and April Meeting — where the unit is planning to organize several focus sessions and a symposium.

To learn more or join the topical group, visit engage.aps.org/gqms.

Kendra Redmond is a writer based in Minnesota.

Recent Announcements From Physical Review Journals Reflect APS Commitment to Open Science



Credit: APS

APS releases new data availability policy for Physical Review journals

APS has updated its data availability policy to reflect a commitment to transparent, ethical research. All articles published in Physical Review journals will now include a statement detailing where data required to support or replicate the claims can be accessed. The policy goes into effect Sept. 4 for articles submitted to *Physical Review D* and *PRX Energy*. For all other journals, the policy will take effect by the end of the year.

Previously, APS encouraged, but did not require, authors to include statements detailing where readers could access data, code, and other source materials. Now, authors must select one of several pre-scripted data availability statements. APS still encourages public sharing of data itself, and authors who do not provide public data must explain why, and, if asked, share their data privately with referees and editors.

Data availability statements support independent verification of findings, a step that strengthens the scientific process and advances the central tenets of open science.

APS extends SCOAP³ open access agreement through 2027

APS has renewed its agreement to participate in the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP³), an international coalition of more than 3,000 libraries and institutions from over 45 participating countries to fund open access publishing in high-energy physics research.

Under the SCOAP³ model, funds contributed from participating institutions are pooled to cover open access publication charges for high-energy physics papers posted to arXiv and published in participating journals, including three journals published by APS: *Physical Review Letters*, *Physical Review C*, and *Physical Review D*.

APS has participated in SCOAP³ since January 2018. With the current phase ending at the close of 2024 and the next phase starting on Jan. 1, 2025, this renewal ensures that authors will be able to publish high-energy physics articles in participating APS publications at no cost through 2027. Anyone will be able to access these papers for free immediately after publication. All institutions and libraries that subscribe to participating journals will continue to receive reduced annual invoices to offset open access fees that APS collects from SCOAP³.

APS becomes largest society publisher to adopt research organization registry identifiers

APS has adopted the Research Organization Registry identification system, assigning persistent identifiers to authors' affiliations for every paper published in the Physical Review journals. APS is one of the first publishers to take this step.

Researchers, institutions, and libraries alike rely on high-quality, accurate metadata to monitor publication output and impact. However, institutional metadata has lacked standardization across the publishing landscape. By assigning available ROR persistent identifiers, APS aims to help authors and institutions track the scope of their work.

APS also sends ROR identifiers to Crossref, an online record for scholarly metadata. The initiative makes metadata discoverable across all search tools, with implications for funding and participation in open access models.

APS signs the United2Act consensus statement on paper mills

APS has become a signatory for the United2Act consensus statement, an agreement on key collaborative efforts to combat the persistent problem of paper mills in scholarly publishing.

United2Act — a coalition of international organizations, led by the Committee on Publication Ethics (COPE) and the International Association of Scientific, Technical and Medical Publishers (STM) — was founded in 2023 to address the persistent challenge of research paper mills.

As a signatory, APS demonstrates its dedication to advancing swift action against paper mills, including fake papers and research with fake authorship, which threaten the integrity of scientific publishing and require collective effort to counter.

Intro Physics continued from page 1

some students stick with physics until graduation while others do not, and how a student's identity shapes their experience. By focusing on students in the first week of their introductory physics course, the team could assess "what attitudes they come in with and how that affects their trajectory," says Porter.

At the beginning of the course, 19% of students reported an interest in majoring in physics. The researchers thought several factors might play a role, like high school courses, confidence in math, or parents' STEM degrees. But when the researchers compared answers from those interested in majoring and those not interested in majoring, only one factor differed in a significant way: Students interested in majoring thought they would get a higher grade than did students who were not interested.

And even though women comprised only 20% of the introductory physics students who reported an interest in majoring, the study found that the women who were interested believed they would do just as well in physics as their male counterparts.

Alexander Van der Horst, chair of the physics department at George Washington University (GWU) in Washington, D.C., one of the four schools that participated in the study, found this result intriguing. It's almost like "a self-fulfilling prophecy," he says. "If they come in with confidence, then they are more likely to actually do well."

In other words, "mindset has a really big impact."

Laura McCullough, a physics professor at the University of Wisconsin-Stout who served as one of the study's reviewers, says this finding underscores the need for more interventions in high school, to ensure more young women can see themselves as physicists.

McCullough, who authored the 2016 book *Women in Physics*, noted that the study provides "good longitudinal data to support conclusions others have put out previously." For example, the study found that over 70% of the students who opted to leave physics made that decision within the first or second year of the program — a sign that introductory physics courses play a key role in retention.

In one survey question, students could select from a list of reasons why they changed their mind about majoring. Several themes stood out in the answers, like lower self-efficacy in math skills and lower ratings of department climate. Those students were also less likely to have interacted with their physics professors outside of class.

The study also found that women and students from underrepresented racial and ethnic groups were *not* more likely to leave the major — but when they did leave, their reasons differed. Women who left the major were more likely to say they performed worse on assignments than their peers — and women, Black or African American, and Hispanic or Latino students who left were more likely to report that they encountered discrimination.

One-on-one interviews with students helped shed light on the types of discrimination students experienced. In introductory courses, those experiences tended to occur when working with peers or teaching assistants. Students reported feeling like they didn't fit in, that their ideas were ignored during discussions, or that "their peers or group members didn't see them as competent," Porter says.

"There's a lot of opportunity for intervention there," says Porter, "by paying attention to small group dynamics in physics classrooms and by being approachable and encouraging."

Van der Horst says these kinds of experiences sometimes happen in his department's introductory courses, too, and can impact any student in the classroom. "It's important for everybody," including the students who don't intend to major in physics, he says. "As a physics community, we should do more to create an environment in which everyone can thrive."

"The reason we don't have equity in physics is because of the climate and our culture," says McCullough. "People come in excited about physics from their high school ... [and] the data says that high school is getting it right and college isn't." Indeed, of the surveyed students who graduated with physics degrees, most said that high school experiences in physics sparked their interest.

> **"People come in excited about physics from their high school ... [and] the data says that high school is getting it right and college isn't," says McCullough.**

AIP found that the women who were interested in majoring in physics believed they would do just as well in physics as their male counterparts. Credit: Cara Taylor/GWU

AIP also provided each of the four schools that participated in the study their own report. Van der Horst says GWU had already made great strides toward gender parity in its undergraduate program by the time it participated in the study. His department attributes this achievement, in part, to the strong sense of community among students, and the individual report from AIP backed this up, he says.

But Van der Horst was also hoping the study would reveal more insight into the other "axes" of diversity. This is partly a numbers problem: Of the 745 students who initially reported an interest in a physics major, so few identified as members of underrepresented racial and ethnic groups that analysis was difficult, he says.

Van der Horst says this issue — that students who are members of underrepresented racial and ethnic groups are taking physics but not interested in the major — was a critical finding. It also indicates a different challenge, says Porter: how to attract these students to begin with.

There's much to do. Across all surveyed students in the introductory classes, the researchers found notable differences between the experiences of white men and the experiences of students from all underrepresented groups. Compared with white men, these students felt that their courses were less interactive, their professors were less encouraging, and their peers were more skilled than they were.

Within the sciences, McCullough says there is currently "a huge push" for inclusive teaching. AIP's study underscores the need for introductory physics courses to embrace these practices.

The study's findings were new in many respects. After all, it was "the longest longitudinal study on this topic to date," according to Porter. But the report's suggestions for positive interventions are not new: Like other studies, AIP advises departments to design courses with more real-world demonstrations of physics concepts, plan smaller class sizes, encourage professors to host office hours, provide extra support in math, and promote opportunities for students to collaborate on homework and participate in social activities.

So why is it necessary to give these suggestions again — and again, and again?

"Change happens slowly," says McCullough. "We enculturate our students and then they perpetuate that culture ... If our classrooms are didactic and not welcoming, then the people who go on to do physics think the culture should be didactic and not welcoming." This issue plagues many physics programs today.

"But I don't lose hope," she says. It can feel like studies reiterate the same points, McCullough says, but the situation has "gotten better" in her 24 years as a faculty member. She credits the persistence of physics education researchers and efforts like APS's Effective Practices for Physics Programs (EP3) guide with driving that change. "We need guides like this," she says.

For Van der Horst, the drivers for change in GWU's physics program boil down to one question: "Are we serving our students in the best possible way?"

Liz Boatman is a science writer based in Minnesota.

Plutonium continued from page 1

German scientists could use American research to build an atomic bomb — decided to withhold from publication research relevant to the Manhattan Project. It wasn't until 1946, many months after the end of the war, that the withheld studies were finally published.

The archived letters — from the spring of 1946 — reveal the discussions that took place beforehand.

On March 5, 1946, the longtime editor of *Physical Review*, John T. Tate Sr., sent a letter to Edward Condon, the director of the Bureau of Standards and the APS president:

> Dear Ed:
>
> I am today forwarding...for publication...a group of Letters to the Editor and articles which had been voluntarily withheld from publication during the war...
>
> In doing this I realize that the appearance of these papers which deal with matters once regarded as classified may result in some publicity and possible criticism in certain quarters. I therefore want to give you as President of the American Physical Society whose servant I am an opportunity to stop the publication if you feel it is unwise.

Tate attached a list of 18 Letters to the Editor (precursors to the Letters of today) and articles on nuclear physics. This included two notable Letters to the Editor with, curiously, the same title — "Radioactive Element 94 from Deuterons on Uranium"— and nearly the same authors — one by Glenn Seaborg, Edwin McMillan, Joseph Kennedy, and Arthur Wahl (Phys. Rev. 69, 366) and one by Seaborg, Wahl, and Kennedy (Phys. Rev. 69, 367).

The first paper, submitted to *Physical Review* in January 1941, reported results on the "bombardment of uranium with deuterons," which turned uranium into neptunium. Some of this neptunium decayed into what the scientists suspected could be a new "element 94," later named plutonium — a finding the authors confirmed in the second paper, submitted in March. Seaborg and McMillan shared the 1951 Nobel Prize in Chemistry for this work.

Three weeks later, on March 26, Condon responded to Tate:

> ...I fully concur in your judgment that further delay serves no useful purpose, and would do actual harm in interfering with research progress unnecessarily. However, the atmosphere has been so charged with spy scare hysteria that I think we want to be in the position of having checked every possible way...

Condon suggested that Tate contact Richard Tolman, who had just stepped down as the chairman of the Committee on Declassification for the Manhattan Project. Tate obliged: On March 29, Tate sent Tolman a letter asking for his thoughts "on the propriety of publishing" the papers. Tate added:

The authors of these papers have all been consulted recently and are in favor of publishing them... Since Dr. Condon's letter was delayed three weeks, I am afraid that it will be a little late to stop publication of the Letters to the Editor. My judgment is there is nothing in them which is not already indicated...in the Smyth report...

The Smyth Report, published just days after the bombings of Hiroshima and Nagasaki, outlined the Manhattan Project and discussed plutonium in some detail.

Six days later, on April 4, Tolman sent Tate a long reply:

> It seems clear to me that such an article is the property of the author and that neither he, nor the Editor of the Physical Review, is under any legal obligation to consult with anyone as to its publication...
>
> On the other hand, from the point of view of what is prudent and in the best interests of the country, it seems to me that additional factors enter. In the first place, there is the possibility that the article might disclose something in contradiction to the provisions of the general Espionage Act...
>
> Hence as a prudent man, I should seek competent advice as editor before publishing...
>
> ...it is my guess that most if not all of the material involved would fall in the category which is now being declassified, in the case of Manhattan District reports. It would not surprise me, however, if there were a few items in them which should be eliminated before publication, in the interests of national security...

Tolman recommended that Tate consult with John R. Ruhoff, who was leading Manhattan Project declassification efforts.

Tolman also included two attachments. The first was a letter that Tolman had sent to author George Placzek with a similar message — essentially, you are not required to consult Ruhoff, but it would be prudent.

The second attachment was a five-page document dated Feb. 4, 1946, titled, in all caps, "STATEMENT OF RECOMMENDATIONS OF RELEASE OF ATOM BOMB PROJECT INFORMATION," signed by Robert Bacher, Arthur Compton, Ernest Lawrence, J. Robert Oppenheimer, Frank Spedding, Harold Urey, and Richard Tolman (quite an author list and document to hold).

The statement is a request to publish research that was withheld during World War II — a plea for transparency. "The army wishes to modify the existing secrecy restrictions which were necessitated by the War, and desires to make useful scientific and technical information generally available, where this can be done without endangering our national security," it reads.

The document does not advocate for the release of specific information but notes that "nearly everyone will agree that there is much that can be disclosed at the present time."

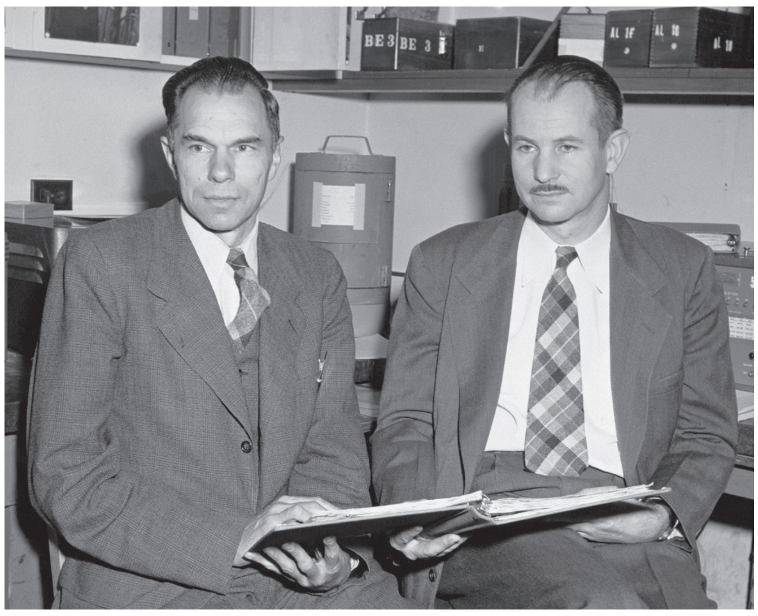
Tolman's letter to Tate was stamped "Received" at *Physical Review* on April 8. Journals were typically printed some time after the beginning of the month, so Tate may have waited for Tolman's reply before the volume was printed. There is no further correspondence in the folder.

As an editor, I know that one must make important decisions with incomplete information. It is possible that Tate, as editor, called Ruhoff — or he may have been confident in his own assessment.

Regardless of how and when Tate made the final decision to let the issue proceed, many of the papers, including those outlining the discovery of plutonium, were published in the April 1946 issue of *Physical Review*.

These letters highlight *Physical Review*'s role not only as a journal, but as a strategic mediator of research with profound relevance for the war. The letters make clear, too, the extent to which leading physicists wrestled — with themselves and with one another — over the role and timing of scholarly publishing, and of the tension between open science and national security that World War II laid bare.

Robert Garisto is the chief editor of Physical Review Letters.



Glenn Seaborg and Edwin McMillan were awarded the 1951 Nobel Prize in Chemistry for their work on the discovery of plutonium. Credit: National Archives/photograph by Donald Cooksey (1951)

"The atmosphere has been so charged with spy scare hysteria that I think we want to be in the position of having checked every possible way." — Edward Condon, 1946

APS Looks to the Future with Refreshed Mission, Vision, and Core Values

To celebrate the Society's 125th anniversary and plan for its bright future, APS has unveiled its new vision, mission, and core values, which form a central part of APS' new strategic framework. This framework serves as a roadmap, guiding the Society's work to advance physics and serve the global physics community.

The refreshed vision, mission, and core values are outlined below.

Vision: APS envisions a world inspired, enriched, and sustained by a thriving physics enterprise.

Mission: APS advances physics by fostering a vibrant, inclusive, and global community dedicated to science and society.

Core values: Our core values serve as guiding principles for the way we do our work and engage with each other to advance physics.

Scientific method: We rely on scientific methods as the foundation for physics and its applications; we recognize the evolution of scientific inquiry.

Trust, integrity, and ethical conduct: We act honestly and ethically to ensure integrity in physics and across our community.

Equity, diversity, and respect: We champion a culture of mutual respect, inclusion, access, and belonging; we embrace diversity in physics.

Collaboration: We engage in open and respectful exchange to accelerate scientific discoveries and solve global challenges; partnerships and collaborations make us stronger.

Education and learning: We promote education that nurtures curiosity, sparks innovation, and supports lifelong learning and discovery.

Speaking out: We listen, promote our core values, and speak out on issues where scientific evidence or expertise can inform the public or benefit society.

Gladys West continued from page 2

One of her Black colleagues was Ira West, a mathematician. They became friends, eventually marrying and raising three children.

In the 1960s, against the backdrop of the Civil Rights movement, West's projects shifted from weapons systems to the fundamental nature of orbits, gravity, and Earth's shape. Much of the work was top secret: The Department of Defense wanted an accurate, stable satellite navigation system, and the Navy was developing key pieces of a framework for the Global Positioning System, or GPS.

"One of my duties was to calculate the geoid, the hypothetical shape of the Earth, coinciding with mean sea level and its imagined extension under, or over land areas," West wrote. She had the added challenge of working mostly with satellite data collected over water, which required factoring in the tides and other forces.

In addition to the geoid model, her work improved the reference ellipsoid model of Earth and models of satellite orbit trajectories. This work laid the foundation for GPS. "Without these three key elements, using satellites to determine a position on Earth would not be possible," she wrote. "The better these elements are defined and continually refined, the better the resulting position."

West spent the next few decades improving these results, completing a master's in public administration along the way. She led data analysis projects for two NASA satellite missions that further advanced the models, and published several GPS-related papers. Still, West was often passed over for career advancement opportunities that were awarded to white male colleagues.

By the 1990s, when her children were grown and her husband retired, West was ready for more. While still working full-time at Dahlgren, she tackled the coursework and exams for a Ph.D. in public administration and public affairs.

West retired from Dahlgren in 1998 after 42 years. "The highlight," she said in an email, "was when I was able to understand the software system well enough to determine problems."

In 2000, after recovering from two strokes, West completed her thesis and graduated with her Ph.D. In her memoir, she calls it "the most amazing accomplishment of my life."

West's contributions were largely overlooked until the 2010s, when she gained recognition for her career. In 2018, West was inducted into the U.S. Air Force Space and Missile Pioneers Hall of Fame.

Today, West — now 94 years old — is still thinking about "more." She'd like to see more fun methods of teaching math, more youth pursuing STEM classes, and more girls and women confident in science. "Keep learning," she says. "Follow your dream."

Kendra Redmond is a writer based in Minnesota.

In 2018, West was inducted into the U.S. Air Force Space and Missile Pioneers Hall of Fame. Credit: Adrian Cadiz/Air Force

BACK PAGE

Why Do So Many Physics Students Want to Work in Academia?

Professors' "academia or bust" attitudes sway students — and hurt their careers.

BY CARA GIOVANETTI

During a break at a workshop on dark matter I attended this summer, a senior researcher asked me, "Why do you think so many students want jobs in academia?" She was right to ask the question: 30% of new physics bachelor's degree-earners want to be employed by a college or university, and yet only 5% will end up in tenure-track faculty positions.

I'm a job-seeker this cycle, among the even higher percentage of graduate students seeking faculty careers, and this question has been lurking around the edges of my attention ever since it was asked of me. I'd originally responded by repeating a gripe I'd heard from senior physicists: I pointed the finger at students' tunnel vision and, perhaps, lack of creativity.

But the more I've styled my CV, the more I've realized how surgical my preparation has been for a postdoctoral position. This question exposes a deep insufficiency in academia: Academics must do more to prepare their students for future careers, and undertake the personal work of driving cultural shifts in our physics community to realize this goal.

So, why do so many students want jobs in academia? If all physics undergraduates and graduate students in the U.S. were surveyed on the issue, I'd expect to see several major themes emerge.

The first is perhaps the most intuitive: selection bias. Students complete physics degrees because they like the work related to a physics degree, and students who like this work want to continue it. But this is exacerbated by curricula that favor future professors, often at both the undergraduate and graduate levels. We teach to students who excel in a broad, historical, largely theoretical curriculum, which favors retention of students who seek similar work. Students without interest in, say, Quantum Mechanics II have fewer pathways to success, and may elect to continue their studies in a department that emphasizes domain knowledge relevant to a broader set of careers.

Advocates have clearly been pushing for a stronger approach to career preparation for physics students for some time. Why do so few departments seem to be listening?

This narrow and often inflexible curriculum produces graduates who are underprepared for work outside of academic physics, and the skills we teach to complement this curriculum intensify these outcomes. We prioritize quantitative reasoning — inarguably valuable — but in our quest to craft the perfect problem-solver, we miss out on other important skills. A report published by the American Institute of Physics in 2019 found that 27% of Ph.D. physicists employed in the private sector reported skill and ability barriers in their work experience, like insufficient programming skills, poor preparation for hands-on experimental work, or low public speaking proficiency. In my experience, there has been progress here: Presentations help students practice communication skills, and active learning methods (though their rollout has been slow and uneven) encourage teamwork and peer education. Yet this hasn't been enough for physics students to see themselves as broadly employable. At a conference this year, an undergraduate told me her friends teased her by asking, "What're you gonna do with a *physics* degree?" She wasn't sure how to respond.

After earning physics degrees, enterprising students ready to enter the non-academic workforce are left with their work cut out for them. But their climb is steeper than squeezing in preparation for non-academic jobs around the periphery of a packed curriculum. They also shoulder the burden of determining what that preparation looks like. In some sectors, staying on track for jobs and internships require that students make decisions about their careers years in advance — a reality to which I was oblivious as an undergraduate (instead I was told I could waltz into a finance job after graduation, which I now know is witheringly false).

I'm not alone in this, as research in the past decade has found that students tend to delay career exploration until near or after graduation. This leaves students too little time to prepare, which suggests to me that some students may prolong their stay in academia because the alternative is building a portfolio for another career after the time to do so has already passed.

The issues outlined above — curricula that retain academic hopefuls, preparation too narrow for work outside of academia, and a lack of scaffolding for students who want to break out of these molds — have concrete solutions, which don't require us to completely abandon our theory-forward curricula in favor of applied physics (there's something to be said for learning this material just because it's enriching). Recent research has compiled laundry lists of recommendations for departments seeking to better prepare students for their careers without curriculum overhaul, ranging from teaching computational-analysis tools to encouraging internships to incorporating basic business concepts like teamwork and communication into existing coursework. One 2015 study on "developmental networks" — the people (or person) who provide developmental assistance that furthers a student's career — "challenges the taken-for-granted notion that doctoral advisors are, and should be, students' most important source of career development," and instead finds "that students need a wide range of networks, beyond peer and advisory relationships." APS has also assembled recommendations, and, crucially, success stories of departments whose interventions work for their faculty and their students.

Advocates have clearly been pushing for a stronger approach to career preparation for physics students for some time. Why do so few departments seem to be listening?

I argue these first three issues, and a reluctance to address them, stem from a root cause. It is less straightforward to address, and yet I think students in my hypothetical "why do so many students want academic careers" survey would have no trouble identifying it.

It is not a secret that there is an insidious attitude permeating academia that says an academic job in physics is a badge of competence and intellect, and any other job — regardless of the stability, financial security, balance, or fulfillment it might bring — is an indication of a shortcoming in academic ability. Students pick up on this quickly, or are instructed in it; research has revealed that, across the board in the sciences, graduate advisors strongly encourage careers in academic research while deemphasizing other career options. As an extreme example, I have heard faculty describe doctorate-holders who pursued non-academic work as "failures." The intense competition for academic positions only enhances their prestige.

I don't argue that there's malice here. I don't think that most faculty are making a conscious decision to neglect the needs of students with different career aspirations. But the fact that these students are still being left behind, despite decades of research about how to support them, indicates a little too much complacency with the status quo.

As an aspiring academic — entranced by the intellectual freedom my career could afford me, and maybe a beneficiary of selection bias at work — I find myself wondering what I could do to challenge this culture.

I think the first step is to see my future students as future members of the workforce. My goal as an educator and advisor should not be to usher them through the finish line of graduation, but to provide a springboard for a career. Instead of asking an incoming student what classes they've signed up for, I might ask, "What kind of work would you be excited to do after graduation?" — a signal to the student that a career is worth thinking about early in their studies.

As a student, I never received much information about careers; I'd get handed data on where physics degree-earners end up after their studies and then never hear follow-up. As an advisor, I could improve on this. Instead of referring to the monolith of "industry," I could specify those real roles — at startups, at technology companies, in government — that real physicists are doing, as well as their starting salaries and many perks.

Better still, I could build my own network that includes physicists outside of academia, so that I can provide a starting point for students' developmental networks. I can list former students' non-academic careers on my research group's homepage. I can keep in touch with those alumni, and solicit their advice for current students on how to prepare for similar outcomes. I can talk to my colleagues in computer science and engineering to learn when and how students should apply for summer internships.

Systemic, department-level change will be crucial in our field's work to prepare students for diverse roles and workplaces. But we as individuals can help, too. I — and I hope my future colleagues — can carve out just a bit of extra time to invest in students' careers. I think I'll find it's worth it, to share in the successes of more than 5% of our field.

Cara Giovanetti is a graduate student in physics at New York University.

Magnetic continued from page 3

that now match that of the United States," the report notes, adding that the U.S. would need around 12 high-field nuclear magnetic resonance (NMR) instruments to match European levels.

And though U.S. facilities like the NHMFL are well-funded, the country has many "decentralized" facilities that depend on user fees, limiting researcher access. The report recommends creating a consortium of high-field NMR instrument sites across the U.S., funded and partially coordinated by NSF, the National Institutes of Health, and the Department of Energy, "similar to what the worldwide competition has established."

Ramping up support for wire innovation

The report recommends NSF and DOE "double" their support for developing high-temperature superconducting wires, as the high-temperature superconductor wire that would enable future technologies like muon particle colliders does not have a large-scale commercial source in the U.S. Additionally, certain superconductor materials, including the optimal wire for high-field pulsed magnets, are largely sourced from China or Russia.

The report acknowledges that the fusion industry is driving some development of high-temperature superconductor materials. However, it recommends that NSF, DOE, and NIH create collaborative programs for magnet and wire development to ensure applications for other fields, such as particle physics and condensed matter physics.

Addressing helium shortages for researchers

The report emphasizes that liquid helium has "no substitute" for maintaining low temperatures in condensed matter physics research, including superconducting magnets. However, supply of liquid helium has been limited by high demand across many industries, the sale of the U.S. Helium Reserve, and geopolitical instability. This has led superconducting magnets across the U.S. to be decommissioned, and some university administrators have expressed reluctance to hire researchers in areas requiring helium.

Accordingly, the report recommends giving researchers preferred access to helium extracted from federal lands. It also proposes the U.S. establish a new helium reserve for emergency use, classify helium as a critical material, further fund helium recycling systems, and research materials and designs that reduce or avoid helium use.

Clare Zhang is a science policy reporter at FYI, published by the American Institute of Physics.

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