Improving undergraduate labs FREE

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ence consultant for blockbuster Hollywood movies, in his new book, *The Dialogues: Conversations About the Nature of the Universe* (2017), a graphic novel that he also illustrated.

Scientists thinking about authorship should have a clear idea why they want to write a book before making the commitment. It's true that writing a book can be time consuming. But for those who commit to the task for reasons that resonate with their core values and goals, the rewards can be immeasurable.

And for scientists who are almost ready to make the commitment, theoretical physicist and prolific author Steven Weinberg offers additional purpose. In his 3 April 2015 *Guardian* article "The 13 best science books for the general reader," Weinberg extolls the virtues of authors who "have done much to make science what some scientists have always hoped it would be: a part of the culture of our times."

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LETTERS

Improving undergraduate labs

Toni Feder's news story "Undergraduate labs lag in science and technology" (PHYSICS TODAY, April 2017, page 26) is a welcome analysis of the challenges facing advanced undergraduate physics laboratories and current efforts to provide effective solutions for undergraduate physics programs at US colleges and universities.

The Advanced Laboratory Physics Association (ALPhA) sponsors a laboratory immersion program in which physics faculty receive three days of dedicated instruction and hands-on experience with modern advanced undergraduate physics experiments. The goal is to provide enough training so that participants can implement the experiments at their own institutions.

Since the inception of the program, I have participated in nine immersions. Each was excellent, and I have implemented at least one experiment—and in one case, five—from each immersion I attended. The topics have been fascinating, and they included single-photon tests of quantum mechanics, external-cavity diode lasers, laser-induced fluorescence, Compton scattering, precision laser interferometry, Fourier methods, and saturated absorption spectroscopy.

At my small undergraduate institution—10 physics majors per year on average—the primary obstacle I faced in implementing those experiments was locating funds to purchase the equipment. Fortunately, the Jonathan F. Reichert Foundation started the ALPhA immersions equipment grant program, which has been a godsend to me and my students. Its support has allowed me to acquire a Leybold x-ray diffraction apparatus, a TeachSpin diode laser spectroscopy instrument, a Stanford Research lock-in amplifier, and a TeachSpin Fourier Methods system.

As a direct result of the efforts of ALPhA and the Reichert Foundation, I have implemented 13 advanced undergraduate physics experiments at my institution. Additionally, I proposed a new course, Advanced Laboratory in Physics, which was offered for the first time in the fall of 2017.

Some friends and colleagues suggest that after 30 years of professorial experience I should be thinking about retiring. I disagree. I am more excited now than ever, because I see my students' enthusiasm as they perform the new experiments. I look forward to many more years in the best job on the planet.

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The April 2017 issue of PHYSICS TODAY included a report by Toni Feder on the current poor state of student advanced physics labs and efforts by the Advanced Laboratory Physics Association to improve the situation. But a few aspects need discussion to complete our understanding of the situation.

Some colleges advertise that all their undergraduates have the opportunity to participate in faculty research projects. I wonder whether such arrangements are an attempt to compensate for poor or nonexistent advanced labs.

As the US population ages, an increasing share of federal revenue will go for Social Security and health care benefits. Less money will be available for discretionary federal spending, such as for student lab equipment, so petitioning NSF for funds is not promising. Physics teachers should be petitioning their own universities to make some tuition money available for that purpose.

The typical department budget for lab equipment and supplies is approximately $1000, according to the report. If the college charges $30 000 annual tuition, why not use $1000 of that to upgrade lab equipment? If 20 students took the lab each year, that lab would receive $20 000, which should be enough to pay for one new or refurbished experiment set-up. If we assume student pairs rotated through 10 experiments and that each required only one apparatus set, after 10 years all experiments would be upgraded or refurbished!

The article reports complaints about century-old lab experiments. Yet there is nothing wrong with letting students perform a few classic experiments such as the Millikan oil drop, the Michelson interferometer, or the Franck–Hertz tube. Recent PHYSICS TODAY pieces (July 2016, pages 8 and 38; March 2017, page 11) have suggested that students should learn the history of physics. Doing classic experiments allows students to experience using simpler equipment and getting meaningful results without using computerized black boxes. I never appreciated how hard it is to measure the universal constant of gravitation *G* until I used a Cavendish balance.

Feder reports that new professors are reluctant to get involved with maintaining student lab equipment because such activity does not contribute to obtaining tenure. Perhaps we need a reform of the tenure process so that ratings include those activities that directly help undergraduate students. For their tuition dollars, students should be getting good laboratory training.

In a separate editorial (PHYSICS TODAY, June 2016, page 8), Charles Day commented that the student labs he took did not inspire him to become an experimental physicist. I think his complaint is invalid. Student labs are not recruiting events for the field but training sessions that should

- Teach some laboratory techniques and practices.
- Give experience in analyzing real-world data whose error distribution does not follow a Gaussian distribution.
- Observe physics phenomena firsthand.
- Verify firsthand that some textbook theory is borne out by experiment.
- Allow one to learn some physics topics not covered in other courses.

As demonstrated by the effort required to become proficient at playing a musical instrument, learning a craft is hard work, and not all of it is inspiring.

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[Editors' note: Some of the issues Victor Slabinski mentions are also discussed in the feature article "Introductory physics labs: We can do better" by Natasha Holmes and Carl Wieman on page 38 of this issue.]

Funding concerns for big telescopes

The news story "Fates of two big radio dishes hang in the balance" (PHYSICS TODAY, February 2017, page 26) toes the official line of the NSF astronomical sciences division (AST) with regard to the Arecibo Observatory and the Robert C. Byrd Green Bank Telescope. It implies that the AST conducted a complete and reasonable evaluation of its commitment to these observatories. I do not agree.

On 27 April the AST published a letter, "MPS-AST Facility Divestment Activity," that provided "a top-level summary of the current status of NSF actions regarding facility divestment recommendations made in 2012." The story mentions the recommendations, commonly called the 2012 portfolio review. One recommendation is that "AST should reevaluate its participation in Arecibo . . . later in the decade in light of the science opportunities and budget forecasts at that time." A follow-up assessment in 2016 considered the budget but not the science, and included serious errors and omissions. Arecibo and Green Bank science is unique and cutting edge, with significant discoveries and developments since the 2012 review.

As one example, the North American Nanohertz Observatory for Gravitational Waves (NANOGrav), which uses both Arecibo and Green Bank, is precisely in line with the national priority of multimessenger astrophysics—the combined use of photons, cosmic rays, neutrinos, and gravitational waves—outlined by NSF director France Córdova in her May 2016 speech to the National Science Board. NANOGrav is our nation's second gravitational-wave observatory, sensitive to a different frequency range and far cheaper — the combined total annual operating costs for Arecibo and Green Bank are less than for LIGO, about $24 million versus $30 million, and without the $1.5 billion price tag for LIGO development, construction, and support, as Córdova reported to Congress on 7 June.

The Arecibo and Green Bank contribution to gravitational-wave astrophysics was touched on in "Pulsar timing arrays are poised to reveal gravitational waves" (PHYSICS TODAY, July 2017, page 26), which quotes Xavier Siemens of NANOGrav as saying, "We want to buy all the available time at Arecibo and Green Bank. . . . It would save both telescopes." Córdova discussed building additional detectors "to observe other parts of the frequency spectrum," but did not mention that such a detector already exists in the US and is in jeopardy of losing necessary NSF-sponsored facilities.

I wondered whether NSF is interested in providing that funding. My emails to the NSF physics division on that subject received a reply from the program director for gravitational physics suggesting that I contact the AST.

NANOGrav has not yet made a detection, but since sensitivity improves with the time spanned by the measurements, that day is rapidly approaching. When the LIGO detection was announced, several other nations quickly funded gravitational-wave detectors. Why is NSF fighting to close one of the two US gravitational-wave observatories?