APS physics™

Forum on Education

American Physical Society

Summer 2017 Newsletter

Richard Steinberg, Editor

In this issue:

From the Chair

John Stewart, West Virginia University

The March and April meetings have come and gone. The Forum on Education (FEd) presented a variety of sessions from those directed toward the Physics Education Research (PER) community in the *Cutting Edge of Physics Education Research* session, co-sponsored with GPER (the Topical Group on Physics Education Research) to a highly attended session directed to graduate students called *How to Get a Job*. Sessions also discussed teaching using 21st century physics and the skills required by 21st century physics students to be competitive in the job market.

One of my favorite sessions was the contributed session at the March meeting. This session featured a broad variety of educational projects including a model for a terminal masters program, teaching sustainability, and an experiment for the advanced lab course using a parametric oscillator. I would love to see more contributed talks at all meetings and remind everyone that you can contribute BOTH a scientific talk and a Forum on Education contributed talk to the same meeting. This is a great way to disseminate the broader impacts of funded research.

For the past two years, the FEd has sponsored sessions at the DAMOP meeting. These sessions were organized by Heather Lewandowski who has since rotated off the Executive Committee (ExComm). These sessions were extremely popular. If any FEd member would be willing to continue these sessions, please contact me.

FEd membership has been falling slowly for the last few years as new forums are created. Other forums have also implemented innovative ways to increase membership. It is my hope that a dedicated committee on membership will change this trend and increase membership. While the number of members does not affect the financial resources of a forum, the structure of the APS makes it difficult for a forum to communicate with non-members; therefore, the size of the forum restricts the number of APS members who receive information about education from the FEd. Increasing membership increases the FEd's voice.

During each April meeting the APS office of Education and Diversity, the Forum on Education, the Committee on Minorities (COM), and the Committee on the Status of Women in Physics (CSWP) host the Education and Diversity Reception. Education award winners and new FEd fellows are recognized at the reception. This event gives APS members working for improved education and diversity a chance to gather and celebrate the year's successes. As a pilot project, this event will be extended at the March meeting next year. While the FEd's budget is tight, we are always looking for events that bring together APS members dedicated to advancing education.

The APS has asked all units to revisit their bylaws to ensure they conform to the new governance structure. They also suggest that an executive committee member be dedicated to unit membership and that all units have a graduate student member. It has also been suggested that the roles of members-at-large be better defined so candidates have a better idea to what they are committing. Tim Seltzer (Past Chair) began the process at the ExComm meeting in January. I will begin the discussion of changes this summer with the following proposals. Any member who has opinions about these proposals should let me know. My proposed bylaw changes:

- Revise bylaws to conform to changes in APS governance structure.
- Change the beginning of officer terms to January 1st (approved).
- Add a graduate student ExComm member to serve a 2 year term. This member would have travel funded for the ExComm meeting like any other member.
- Create a membership committee with the Forum Chair as the chair of the committee. Currently the primary role of increasing membership falls to the program chair who also has the most challenging ExComm assignment. Reversing the declining membership trends will require the creative, extended efforts of more than one person.
- Formalize Member-at-Large roles. As a starting suggestion, have Members at Large take on a sequence of roles just like ExComm members in the Chair line, but in reverse order. Members at Large would be on the awards committees their first year, the program committee the second year, and the nominating committee the third year. All would serve on the new membership committee in their second and third years. It would be difficult for the new graduate student member to contribute to the awards or nominating committees, so I suggest they be dedicated members of the membership and program committee.

Once again, these are my beginning discussion points which I expect to be substantially modified before incorporation into the bylaws. I hope we can complete the discussions this summer for a vote on updated bylaws in the fall.

Hope all had a successful semester and that we see many FEd members at the AAPT meeting this summer.

Soliciting Ideas for FEd Invited Sessions for the 2018 March and April APS Meetings

Larry Cain, FEd Chair-Elect and Program Chair, Davidson College

Each year the Chair-elect of the Forum on Education is also the chair of the FEd Program Committee. The Forum Program Committee sponsors invited sessions at the American Physical Society's March and April meetings. The Forum is allocated 4 invited sessions at the March meeting and 5 invited sessions at the April meeting based on our membership. One of the March meeting sessions is the **Jonathan Reichert and Barbara Wolff-Reichert Award for Excellence in Advanced Laboratory Instruction** session. The other three sessions at the March meeting are on education topics chosen by the Program Committee. One of the April meeting sessions is the **Excellence in Physics Education Award session.** The Program Committee works with the AAPT to sponsor two April meeting sessions and with GPER to sponsor one April meeting session. The fifth April session is an education topic chosen by the Program Committee.

We are always looking for ideas for session topics that would be interesting and beneficial to the members of the American Physical Society as we seek to promote education within the organization. If you have ideas that you think would make good invited session topics at these two meetings, please send them to Larry Cain (lacain@davidson.edu). Any ideas submitted will be considered by the Program Committee this year, and will also be passed on to future program committees for their use.

FEd also sponsors contributed sessions at both these meetings based on the number of papers that are contributed in the Physics Education sorting categories. I invite you to consider contributing an education paper to one of these two meetings.

Call for Nominations for FEd Executive Committee

Laurie McNeil, FEd Vice Chair and Chair of the Nominating Committee, University of North Carolina at Chapel Hill

It is time once again to elect new members to the Executive Committee of the Forum on Education (FEd). We have three Executive Committee positions for which to elect members: Vice Chair (who, in subsequent years, becomes Chair-Elect, Chair, and then Past Chair), Member-at-Large (3-year term), and APS/AAPT Member-at-Large (3-year term). All nominees must be members of the FEd. The APS/AAPT Member-at-Large must also be a member of AAPT.

The Executive Committee plans education-related sessions at APS meetings, nominates new APS Fellows, and presents FEd awards. They represent the goals and concerns of the FEd membership to the APS Council of Representatives. Serving as a FEd officer is also an excellent way to learn about APS and its educational missions and to influence science education at the national level.

The nominating committee will convene later in the summer to create a list of nominees for each position and assemble a ballot. New officers begin their service at the end of the Executive Committee meeting next year.

Please send suggestions nominating yourself or a colleague to:
Laurie McNeil (mcneil@physics.unc.edu)
FEd Vice Chair and Chair of the Nominating Committee
University of North Carolina at Chapel Hill Department of Physics and Astronomy

Director's Corner

Theodore Hodapp

Many have tried, but success seems to be just beyond our reach. Is this controlled fusion, or peace in the Middle East? No, but still a vexing problem, and one we all care about: the appalling lack of representation by women in physics. Simply put, we are missing out on a bunch of really smart people, and in these times of a growing tech economy and uncertain H1-B visa restrictions, we need to attract a workforce that comes from men and women. The data are pretty clear: young women are getting the message that physics and engineering are for the "boys." This is clear from numerous studies showing gender differentiation from an early age. So what can be done that will actually move the needle on this issue?

Zahra Hazari, one of the top researchers in gender and physics, is leading a newly funded effort that includes Florida International University, Texas A&M Commerce, AAPT, and the APS. We are working collectively to design, test, and disseminate a portion of high school curriculum that integrates with teachers' lesson plans to recognize and compliment young women in the classroom, discuss critical representation issues with students, and individually encourage them to study physics. If we get just one more woman to major in physics each year from every 10th high school classroom in the country, we fix the problem.

We will be working with master teachers from across the country to develop our research-based strategies. The critical pieces of this will be working with teachers at local and national scales to understand how to get the information to them and then helping them implement it. We are going to mobilize as many resources as we can find including APS Conferences for Undergraduate Women in Physics, teachers who use the widely implemented modeling curriculum, members of AAPT, and our large network of schools in the PhysTEC program. If you have other ideas, please contact me (hodapp@aps.org). This will be a big effort over the next five years, but it is the first one I have seen that I think has a real chance to impact this problem.

PHYS21: Preparing Physics Students for 21st Century Careers

Laurie McNeil, University of North Carolina at Chapel Hill
Paula Heron, University of Washington

If you are a physics professor, you probably followed the traditional path to get where you are: undergraduate and graduate degrees in physics, one or more postdoctoral positions, and then a faculty position. Perhaps you think that most of the physics majors you now teach will follow in your footsteps, and that you will best serve them by preparing them to become physics professors like you. If so, you are mistaken. According to data from the American Institute of Physics' (AIP) Statistical Research Center, about 5% of U.S. physics bachelor's graduates end up employed as physics professors (though some may pursue academic careers in other fields, such as engineering). The overwhelming majority of people who receive a bachelor's degree in physics are employed outside academia for all or part of their careers, and are engaged in a wide variety of work, about half of which is in the private sector. (See the article by Susan White and Patrick Mulvey later in this issue.) This is equally true for recipients of Ph.D. degrees in physics, almost half of whom occupy positions outside academia one year after receiving their degrees, and more of whom move to private-sector or government positions after completing a postdoc. Physics graduates working in the private sector report that they regularly need to use skills that go beyond their knowledge of physics, such as working in teams, technical writing, programming, applying physics to solve interdisciplinary problems, designing and developing products, managing complex projects, and working with clients. Yet for most physicists the development of the skills necessary to succeed at these tasks formed a small part of what they experienced in their undergraduate (and graduate) programs, if it was addressed at all. While physics graduates are largely remarkably successful in the career paths they choose, if these skills were more explicitly emphasized in undergraduate physics programs, we could better prepare physics graduates for all of the career paths available to them.

The Joint Task Force on Undergraduate Physics Programs (J-TUPP) was convened by the American Physical Society (APS) and the American Association of Physics Teachers (AAPT) in 2014 to answer this question: *What skills and knowledge should the next generation of undergraduate physics degree holders possess to be well prepared for a diverse set of careers?* The report of the Task Force, entitled *Phys21: Preparing Physics Students for 21st Century Careers*, is available for download at http://www.compadre.org/JTUPP. Through our study of a wide range of reports and interviews we developed a clear picture of the knowledge and skills that ideally a physics graduate should have in order to be successful in a wide range of careers. We also commissioned a set of case studies of departments that have modified their programs to enhance graduates' career readiness, to find examples of strategies that other departments could adopt. (See the article by Paul Cottle later in this issue to learn about Florida State University.)

We concluded that physics graduates are prepared to pursue a wide range of careers, and are sought for their flexibility, problem solving skills, and exposure to a wide range of technologies. However, graduates would benefit from a wider and deeper knowledge of computational analysis tools, particularly industry-standard packages, and a broader set of experiences that engage them with industry-type work, such as internships and applied research projects. Graduates would also be more successful in the workplace if opportunities to develop professional skills such as teamwork, communications, and basic business understanding were added to the undergraduate physics program. (See the article by Walter Buell later in this issue for a view from industry.) We formulated our findings into a set of learning goals to assist physics faculty in identifying explicitly what specific knowledge and skills they want to help students acquire and in developing ways to verify that their program is providing the necessary opportunities. We organized these goals into four categories: physics-specific knowledge, scientific and technical skills, communication skills, and professional and workplace skills.

When a physics graduate enters the workplace (or, for that matter, when she undertakes a dissertation project), she is likely to face the challenge of solving complex, ambiguous problems in real-world contexts. She will need to define and formulate the problem, perform literature studies (print and online) to determine what is known about the problem and its context and manage scientific and engineering information so that it is actionable. Based on that information, she will need to identify appropriate approaches, such as performing an experiment, performing a simulation, or developing an analytical model; and develop one or more strategies to solve the problem and iteratively refine the approach. To carry out the strategy she will need to identify resource needs and make decisions or recommendations for beginning or continuing a project based on the balance between opportunity cost and progress made, determine follow-on investigations, and place the results in a larger perspective. It is likely that she will have had little or no experience in most of these actions unless her undergraduate program has provided her with specific opportunities to develop such skills.

Beyond this wide range of skills and knowledge that are often not explicitly fostered, most physics programs short-change their students in another way: they rarely help their students learn about career opportunities in physics, how to find a job (e.g., by developing résumé writing and interview skills), and how to assess one's skill set and its relevance to a job. This can make physics graduates' transitions to the workforce more challenging than is necessary. The fact that many physics faculty members are only vaguely aware of careers outside academia makes this doubly challenging.

This long list of skills and knowledge that physics graduates need may seem daunting to both students and faculty members. How can a program provide a student with all that career preparation and still make sure she can solve Schrödinger's equation? Fortunately most of the learning goals can be pursued through more than one channel, and there are examples of different kinds of institutions that have found creative and effective ways to address the challenges. Depending on the local conditions, the resources available, the size and aspirations of the student body, industries in the region, and other factors, departments can choose different strategies. They may be ready to redesign their programs entirely, or choose to infuse the development of new skills into their current course offerings or rely primarily on enhanced co-curricular activities. In our report we provide many examples of different approaches that have been adopted by physics departments.

We urge all physics faculty members to read the *Phys21* report and discuss ways of implementing its recommendations in their own programs. We further urge physicists outside academia to find ways to assist physics departments as they seek to prepare 21st-century graduates as effectively as possible for the diverse careers that they can be expected to have. If enough physicists make this choice, we are confident that our discipline will continue in robust health through this century and beyond.

Laurie McNeil and Paula Heron are the co-Chairs of the APS/AAPT Joint Task Force on Undergraduate Physics Programs

Where Do They Go? Career Trajectories of Physics Majors

Patrick Mulvey and Susan White, Statistical Research Center, American Institute of Physics

There is no such thing as a typical physics major. Although physics majors share a common interest in physics subject matter, they come from a variety of backgrounds and have diverse academic and career aspirations. With record numbers of physics bachelor's degrees being conferred in recent years (8,431 in the class of 2016), it is important that both future and current physics students understand the variety of potential career paths that lie before them.

The career paths of physics bachelors start developing while they are still students. Undergraduates may pursue a particular track or concentration of study within a department's degree program. These tracks help shape and influence their future career trajectory. About a quarter of physics bachelors receive a physics bachelor's degree that has a specific focus such as applied physics, biophysics, or high school teaching. Additionally, two thirds of physics bachelors graduate with a double major or minor, providing students with exposure to a broader range of disciplines.[1]

A student's post-degree career trajectory may also be influenced by his or her involvement in an undergraduate research project. Such experiences could include a thesis project or an NSF-funded research experience. Typically about three-quarters of physics bachelors have had at least one undergraduate research experience by the time they graduate.[2] These experiences help inform students about whether they may want to pursue graduate study or immediately enter the workforce. Physics bachelors frequently comment about the importance of their research experiences. Many cite that it provided them with relevant work experience and valuable references, both of which help with applying to graduate programs or securing employment.

The initial divergence in the career trajectory physics bachelors pursue happens after graduation. About half of physics bachelor's degree recipients enter the workforce. An additional third pursue graduate-level studies in physics, and the remaining fifth pursue graduate studies in other fields. (See Figure 1.)

Figure 1: Status of Physics Bachelors One Year After Degree, Classes of 2013 & 2014 Combined

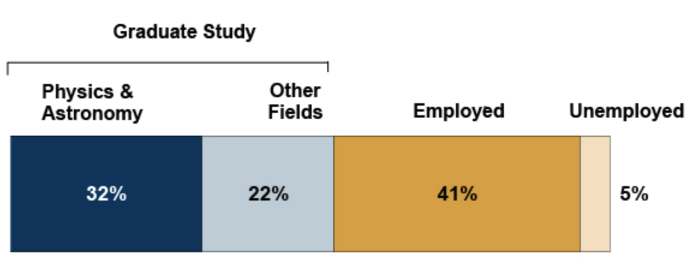
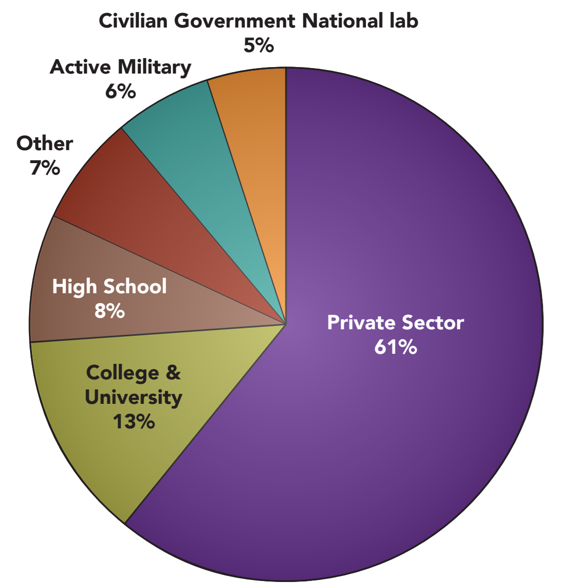


Figure 2: Initial Employment Sectors of Physics Bachelors, Classes of 2013 & 2014 Combined



*Data do not include degree recipients from the three military academies (US Naval Academy, US Military Academy, US Air Force Academy).

** Data include two- and four-year colleges, universities, and university affiliated research institutes.

www.aip.org/statistics

Those who choose to purse graduate studies in a PhD program, regardless of field, are typically well supported. Almost all of these students secure teaching assistantships, research assistantships, or fellowships. Physics bachelors enrolling in a master's programs are not as well supported as those enrolled in PhD programs with 43% relying on their own funds.[3]

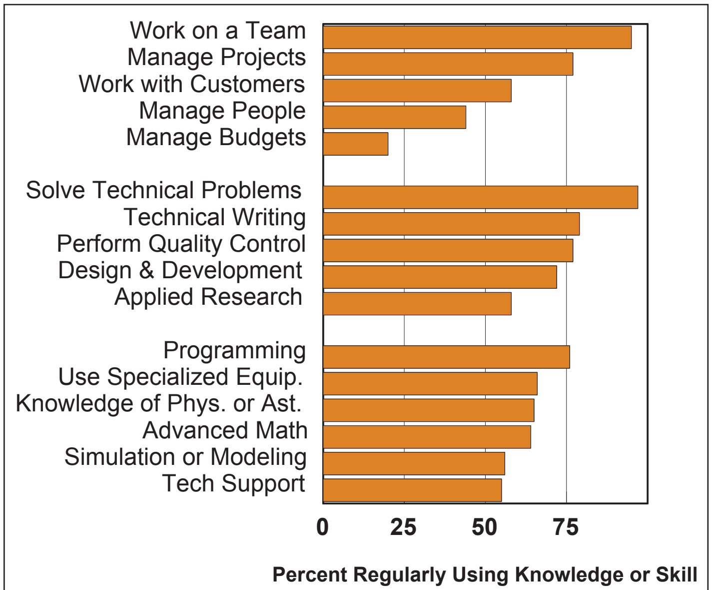
Physics bachelors who enter the workforce pursue employment opportunities in a diverse range of fields and sectors. The private sector is the largest employer of new physics bachelors, hiring almost two-thirds of the new bachelors in the classes of 2013 and 2014. Academia hired about a fifth of the new graduates with a similar proportion taking positions as high school teachers or at a college or university. (See Figure 2.) It is not uncommon for a physics bachelor to enroll in a graduate program after having been in the workforce for a year or two. About a third of employed bachelors indicated that they have plans to enroll in a graduate program in the future.

The fields of "computer or information systems" and "engineering" comprise the majority (59%) of the STEM positions new physics bachelors working in the private sector accept.[4] A quarter of the physics bachelors employed in the private sector indicated they were working in a non-STEM field. The types of non-STEM jobs bachelors accept span a wide range from banking and finance to management positions in the food service industry. Only a small fraction (~5%), of the new physics bachelors who secured employment in the private sector indicate they are working in the field of physics. New physics bachelors that work for the civilian government were more likely to be working in the field of physics, with about a quarter indicating that it was their primary field of employment.

To get a better understanding of the variety of employers that hire new physics bachelors, students can visit the SRC resource Who's Hiring Physics Bachelors? where they will find the names of employers that have hired new physics bachelors in the past to fill science and engineering positions. The page also has a link to the common job tiles of new bachelors and links to other career resources.

A major part of what makes a physics degree marketable to such a wide variety of employers are the skills that undergraduates gain while earning their degree. (See Figure 3.) These skills are transferrable to both technical and non-technical positions. Some of the skills that physics bachelors acquire (e.g. advanced math, physics knowledge, use of specialized equipment, modeling) are a core part of any physics curriculum. Other important and marketable skills students develop are frequently acquired as a byproduct of studying physics and include problem solving, team work, project management, programming, and technical writing. These life skills are equally, and in some cases more important to an employer than those explicitly taught by a department. Programming skills are

Figure 3: Skills Used Regularly by New Physics Bachelors Employed in STEM Fields



Note: Percentages represent the physics bachelors from the classes of 2013 & 2014 combined who chose "daily," "weekly," or "monthly" on a four point scale that also included "never or rarely." STEM refers to positions in natural science, technology, engineering, and math.

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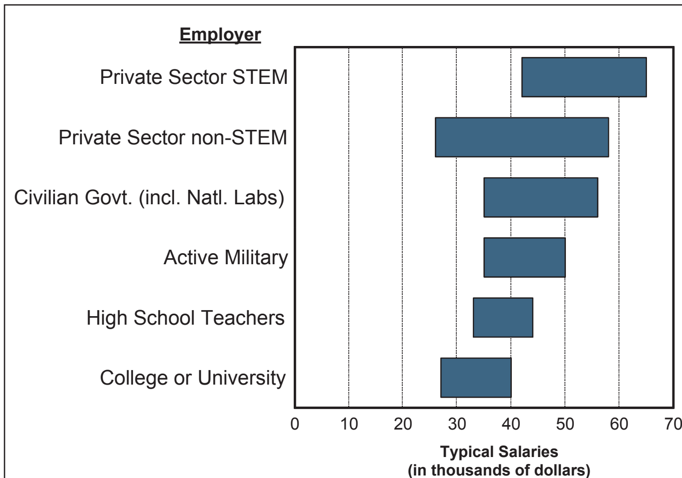
Figure 4: Typical Starting Salaries for Physics Bachelors, Classes of 2013 & 2014 Combined



This figure includes only bachelors in full-time, newly accepted positions. Typical salaries are the middle 50% i.e. between the 25th and 75th percentiles. STEM refers to positions in natural science, technology, engineering, and math.

www.aip.org/statistics

regularly used by the majority of employed physics bachelors in STEM positions and new graduates frequently indicate they wish they had stronger programming skills.

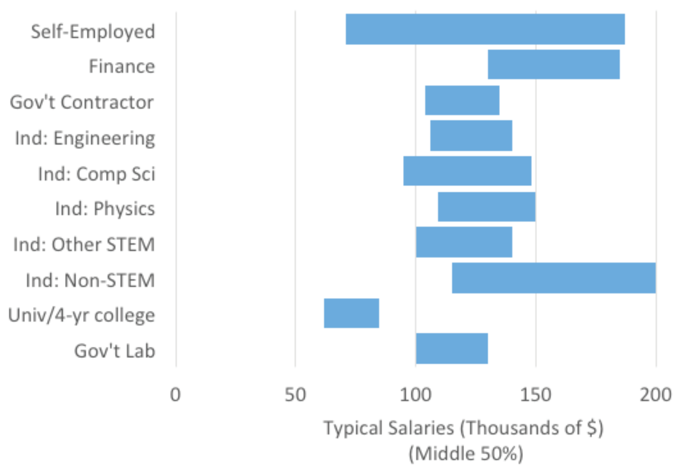
Among new physics bachelors, those accepting private sector positions in STEM fields (science, technology, engineering, mathematics) had the highest starting salary range, with a median of $55,000. (See Figure 4.) The salary range for bachelors accepting private sector non-STEM positions is much wider, reflecting the variety of positions included in the category. According to the National Association of Colleges and Employers, physics bachelors in the class of 2016 are expected to receive the highest starting salaries among all math and science majors.[5]

As mentioned earlier, about half of the students who earn a bachelor's degree in physics go on to graduate school – some in physics and some in other disciplines. The focus so far has been on what bachelor's degree recipients do immediately after graduation and especially about the types of positions they secured. Now we will shift to what students who earn PhDs in physics do after earning their degrees.

Since physics students are taught by PhD physicists, one might assume that all PhD physicists work in academics. In fact, just over one-third of PhD physicists are employed in higher education. *Half* of the people who earn PhDs in physics are employed in the private sector – either with a for-profit firm, a non-profit firm, or self-employed. Most of the rest work for the federal government with a few working in state or local governments.[6]

In 2011, we surveyed people who had earned a PhD in physics from a U.S. institution in 1996, 1997, 2000, or 2001 (we call this our PhD+10 study). We received responses from 1,544 PhD

Figure 5: 2011 Salaries by Career Type for Mid-Career PhD Physicists



www.aip.org/statistics/phd-plus-10

physicists who were working in the US in 2011. We found PhD physicists working in a variety of fields. Some respondents were industrial physicists; others were employed in engineering, computer science, and other STEM fields. Some worked for government contractors, and others worked in non-STEM disciplines. A non-trivial portion worked in finance – mostly doing advanced computer modeling. Some were self-employed, and some worked for government labs. Some had earned law degrees and were practicing attorneys. Of course, some worked at universities and four-year colleges. Typical salaries earned by respondents to our study are shown in Figure 5. In addition to these salaries, some respondents reported earning significant commissions and bonuses.

As was true for the physics bachelors, PhD+10 respondents working in the private sector told us that their jobs typically involved solving complex problems, managing projects, and writing for a technical audience. Most work with people; virtually all respondents were members of teams with people from diverse professional backgrounds. They replied that they found their jobs intellectually stimulating and challenging and that they enjoyed regularly working with smart and interesting people.

One in five (20%) of the respondents working in higher education were *not* in physics or astronomy departments. They were in math departments, computer science departments, materials science departments, engineering, and more. The university salaries in Figure 5 are lower as most of these positions are for nine or ten months. The 20% of physicists working outside physics and astronomy departments typically had higher salaries than those in physics and astronomy departments.

We found very little movement from one employment sector to another. That is, most respondents whose first job was in industry were still employed in industry ten to fifteen years later. The same is true for those whose first job was in higher education and those whose first job was in the government sector. This does not mean they had not changed jobs; most had. However, very few left a job in one sector for a job in another. One year after they graduated, we asked our PhD+10 respondents where they hoped to be working in ten years. About 70% were working in the sector they hoped to be working in industry, government, or higher education. Even those who were not working in their desired sector still found rewarding aspects in their current jobs.

Susan White is the Assistant Director and Patrick Mulvey is the Senior Survey Scientist of the Statistical Research Center at the American Institute of Physics

(Endnotes)

1. P. J. Mulvey and S. Nicholson, "focus on: Physics Bachelor's Degrees", 2015, Table 2, https://www.aip.org/statistics/reports/physics-bachelors-degrees

2. Physics Trends, Fall 2009, https://www.aip.org/statistics/physics-trends/research-experiences-physics-undergraduates

3. J. Pold and P. J. Mulvey, "focus on: One Year After Degree" (2016), Figures 5 & 6, https://www.aip.org/statistics/reports/physics-bachelorsone-year-after-degree

4. P. J. Mulvey and J. Pold, "focus on: Physics Bachelors Initial Employment" (2017), Figure 4, https://www.aip.org/statistics/reports/physics-bachelors-initial-employment2014

5. National Association of Colleges and Employers (April, 20, 2016) https://www.naceweb.org/job-market/compensation/physics-projected-as-top-paid-class-of-2016-math-and-sciences-major/

6. Survey of Doctorate Recipients 2013, National Science Foundation, Table 12, https://ncsesdata.nsf.gov/doctoratework/2013/html/SDR2013_DST12.html, last accessed May 11, 2017.

Championing Improvements to Prepare Students for Diverse Careers

Paul Cottle, Florida State University

A champion who is passionate about undergraduate education can make an enormous impact in the quality of a bachelor's degree program in physics. At Florida State University, the excellence of our undergraduate physics program – which was recently recognized as a case study in the *Phys21* report – has been driven by our champion, Professor Susan Blessing.

In 2001, Dr. Blessing established a one credit hour course called *Discovering Physics* for first-semester physics majors so that they could become excited about the research taking place in the department. Prior to that (and in most physics departments) physics majors spent their first semester learning about topics like inclined planes and springs, which are a far cry from the topics like astrophysics, elementary particles and superconductivity that students find most attractive about our field. *Discovering Physics* put students in touch with the research and the researchers – and in doing so made it more likely that physics majors would persevere through the challenges ahead of them.

In recent years, *Discovering Physics* has also been used to acquaint students with careers that might be considered "non-traditional" for physics graduates like medical imaging, video game design, financial services and information technology. Speakers from outside fields are brought in either in person or via skype to talk with students.

Several years later, the Physics Department's Undergraduate Affairs Committee took a hard look at the introductory-level courses that its majors took while preparing for the upper division physics major courses that begin in the spring of a student's second year. Too many students who appeared to succeed in the three semester introductory lecture sequence – taken with students majoring in engineering and other physical sciences – were hitting a wall in their first upper-division classes. Part of the department's response was to establish a SCALE-UP option for introductory courses, which provided an opportunity for faculty members to keep a personal eye on the development of the physics majors and make sure they were developing the foundational skills required to be successful at higher levels.

We recognized that there was a sizable gap between the level at which introductory courses are taught and the upper level mechanics and mathematical methods classes that physics majors faced in the spring semester of their second year. To bridge that gap, we established a course titled *Physics Problem Solving* that physics majors take in the fall of their second year. The course mostly focuses on improving the skills of applying calculus to physics problems and solving more difficult problems in which the steps are not given. A formal group problem-solving structure is built into *Physics Problem Solving* to both reinforce the message that students learn more deeply in groups and fortify the interpersonal relationships among physics majors that make persistence in the discipline more likely. *Physics Problem Solving* began as an elective course. Several years later, when it became clear that the course was useful, it was made a required course for physics majors. Once there were enough data to show a strong positive correlation between student grades in *Physics Problem Solving* and in the subsequent courses the new course was made a pre-requisite for the upper level classes.

We have also established a lounge and study area for physics majors. The furniture provides study spaces for individuals and groups of students, and a microwave and refrigerator are available as well. Once again, the goal was to provide an opportunity to strengthen the interpersonal relationships among the majors. Dr. Blessing, now Director of the Physics Department's undergraduate program, visits the lounge regularly and uses those opportunities to get to know individual students better and to root out problems they face.

Research is an important component of a bachelor's degree program in physics. However, it can be surprisingly difficult to get students involved, even in a department like FSU's that has more than forty faculty members, nearly all of whom are active in research areas including condensed matter, high energy, nuclear, and astrophysics. We start telling students about the importance of research even before they arrive on campus for their first day of college. The message about the importance of research is first delivered during recruiting via brochures and in person, for those students who make personal visits. Students hear about the importance of research again during orientation. Students in the *Discovering Physics* course described above not only listen to talks about the department's research areas but are also required to interview a professor about her or his research.

Those students who participate in research in the department are invited to take part in a departmental student research poster session in the spring. A private donor provides prize funds to reward the top three undergraduate posters in the session. The prizes are substantial - \$750 for first place, \$500 for second, and \$250 for third. The awards serve not just to reward the strongest undergraduate research projects, but also to make it clear to the entire department – both faculty and students – that research is of great importance to the undergraduate program. Students are also encouraged to explore summer research opportunities at other institutions through the NSF's Research Experiences for Undergraduates program. These opportunities are often used by students to scope out possible graduate programs.

The recent growth in the number of bachelors' degrees demonstrates the impact of these innovations. In the four academic years before 2011, the department graduated 52 bachelor's degree recipients. For the next four academic years, that number rose to 85. The department has supported these efforts with staff and other resources, but none of the improvements would have occurred without Dr. Blessing taking on the role of champion.

Paul Cottle is Professor of Physics at Florida State University.

Hiring Physicists in Industry

Walter F. Buell, The Aerospace Corporation

As Principal Director of a medium-sized laboratory organization in the aerospace industry, recruiting and retaining top quality scientists is probably the single most important part of my job - certainly the most enduring. As a physicist myself, I quickly came to recognize the value of physics-trained employees in my organization (I was an easy sell), and my engineering colleagues recognize the value brought by physicists as team members as well. Roughly one third of my technical staff have degrees in physics (BS, MS or PhD), and I rely on them for their deep technical knowledge, problem-solving prowess and creativity.

So why are non-academic R&D laboratory directors like myself so keen on hiring physicists? Certainly one key reason is the depth and breadth of physics knowledge that form the core of a physics education. Beyond being "conversant in the canon," however, employees with a physics background bring a habit of deep pursuit of the underlying mechanisms (The Physics) of a given problem - this is key in pursuit of root cause of a failure or ideating a novel solution and understanding the range of applicability of the new technology. Physicists also tend to be intellectually flexible "quick studies" who can make substantive progress in a new field in a relatively short time. This ability (if I can discern it in an interview) makes me much more comfortable hiring the best and brightest even if their specific skill set is not a match for my short-term needs. The physics training of reasoning by analogy and making connections is also a powerful skill when one is just not sure where the solution lies — physicists often are good at "getting traction" in ill-defined and multidisciplinary projects. It is important that physics majors entering the workforce are able to articulate and capitalize on these skills to prospective employers.

To gain an appreciation for the kinds of scientific research conducted in industry, it is instructive to cite some examples of physics and astronomy research that is conducted by my colleagues at The Aerospace Corporation.

- In pursuit of improved and more reliable atomic clocks for satellite applications such as GPS, we have been engaged in over three decades of basic research in atomic physics and precision timekeeping, resulting in more than 40 refereed publications in the last 15 years. For example, studies of the energy dependence of collisional interactions led to the invention of the isoclinic point thermometer, key to improving the long term stability of atomic clocks, and research into multiphoton transitions in a colored vacuum led to an improved understanding of the interplay of the AC Stark Shift, spontaneous emission and the Lamb shift in atomic clock frequency shifts.
- To advance our understanding of the space and ionospheric environment, we have launched over 300 space payloads on over 160 spacecraft and sounding rocket launches. Recent results include discovery of a new high-energy electron radiation belt occurring after strong geomagnetic storms, using two of our instruments on the NASA Van Allen Probes, and results from our Fly's Eye Electron Proton Spectrometers on board the NASA MSS mission are providing new insights on magnetic reconnection in the Earth's magnetosphere.
- In pursuit of the most cutting edge nanoelectronic devices, we have been engaged in research into devices such a FET based on a single carbon nanotube and demonstrated the world's smallest acoustic transducer.

These are just a few of the exciting and intellectually rewarding physics research areas to be found in the setting of "industrial and applied physics".

Despite the great value of recent physics graduates to my organization - both because of their direct technical skills and because of physicists' ability to rapidly grasp the fundamentals of new, disparate and multidisciplinary problems - there are still some critical skills that their education did little to prepare them for. These include working in diverse and interdisciplinary teams, project management, written and oral communication with diverse non-technical audiences and entrepreneurial pursuit of new projects. These skills are absolutely critical for success in the non-academic workforce and physics institutions would better serve their students by devoting some portion of the physics education experience to such topics. Just as it is key for physics majors to understand the value of their technical training, they must also be able to articulate these important "non-textbook" skills to prospective employers. Of course these very skills are every bit as crucial for research physics professors, so adding these dimensions to physics education will prepare students for academic as well as non-academic careers.

Our staff with physics bachelor's degrees have been quite successful; about 80% of our staff who came in with physics BS degrees have been promoted to positions of increasing responsibility (and remuneration), and over half have reached the highest-level technical non-management position in the company. To quote a former Executive Vice President from my company, "Years ago, approaching my BS degree in Engineering Physics, I was told that this degree would open many doors for me. More than 50 years later, the data I have suggest that statement is still true."

While many of the physicists in my organization continue in a physicist role throughout their career, others find success in management or related roles through the most senior executive levels. Of course the ways of thinking and approaching complex problems serves these individuals well throughout diverse career paths, but those that do have **also** mastered the extended set of skills that the *Phys21* report recommends. While these successful individuals have typically developed these skills through the necessity of "on-the-job training" supplemented with company-provided training courses, the benefits of arriving on Day One with exposure to those skills is clear. Such new employees can immediately have greater impact and demonstrate both their immediate value and long term potential.

I will continue to hire physicists, along with chemists, engineers and other science and technology professionals, but will also place a premium on candidates with the extended skill set advocated by the *Phys21* report. I am confident that students so prepared will both rack up successes in the workplace more quickly and have the opportunity for a more diverse and rewarding career in the long run.

Walter F. Buell is Principal Director of the Electronics and Photonics Laboratory at The Aerospace Corporation.

Physics Teacher Education Coalition

Section on Teacher Preparation

Teacher Preparation Section

Alma Robinson, Virginia Tech

During the 2016-2017 academic year, the Teacher Preparation Section has featured articles presenting programs and activities that have been successful in recruiting and training pre-service physics teachers without the assistance of PhysTEC funding. We conclude this theme with two final articles in this issue from Stony Brook University and Ithaca College.

In the United States, most institutions graduate less than two physics teachers a year,[1] so PhysTEC recognizes the achievements of institutions that graduate five or more physics teachers in one year with the 5+ Club Award.[2] Keith Sheppard, Robert McCarthy, Angela Kelly, and Axel Drees explain how Stony Brook University's 6 'C' Model (Content Rich, Clinically Rich, Context Rich, Continually Rich, Champion Rich, and Capacity Rich) for physics teacher preparation has been integral in their winning a PhysTEC 5+ Club Award for the past three years.

Michael "Bodhi" Rogers describes how Ithaca College's science teacher certification program has grown substantially with the development of their Master of Arts in Teaching (M.A.T.) program and Robert Noyce Teaching Scholarship grant. In parallel with this growth, Ithaca has created new science education graduate courses, employed retired teachers in residence, and collaborated with regional institutions that do not offer a graduate teaching certification.

(Endnotes)

1. David E. Meltzer, Monica Plisch, and Stamatis Vokos, editors, *Transforming the Preparation of Physics Teachers: A Call to Action*. A Report by the Task Force on Teacher Education in Physics (T-TEP)(American Physical Society, College Park, MD, 2012).

2. http://www.phystec.org/the5plus/

Stony Brook University Physics Teacher Preparation Program – The 6 ‘C’ s

Keith Sheppard, Robert McCarthy, Angela Kelly, and Axel Drees, Stony Brook University

Physics Teacher preparation is thriving on Long Island. Stony Brook University (SBU) has been awarded a PhysTEC 5+ award for the last three years and is on course to graduate at least six physics teachers with majors in physics in 2016 -17. SBU is unusual in that it does not have a Department of Education, and teacher preparation for all of the sciences is distributed across the various scientific departments in collaboration with the Institute for STEM Education (I-STEM). The university has enjoyed a strong partnership among the Physics department, the Institute for STEM Education (I-STEM), and regional K-12 schools for many years, and that has been integral in its success in producing physics teachers.

The SBU Physics Teacher preparation program has a long rich history, with Clifford Swartz, a faculty member of the Physics Department and for 30 years an editor of “The Physics Teacher,” being integral in its establishment and development. Cliff was legendary for his innovative lectures and dedication to physics teacher education, and he helped to train several generations of Long Island physics teachers. Since 1994, when record keeping began, the university has produced 85 certified physics teachers (60 majors and 25 minors).

The Physics Teacher preparation programs at SBU are characterized by what we describe as the “6 C Model.” Most importantly the programs are Content Rich. Prospective physics teachers can follow one of three pathways to New York (NY) state certification – an undergraduate route, a graduate MAT route, and a combined BS/MAT route. The undergraduate route requires completion of a BS degree in Physics. The graduate and combined routes require the completion of a BS degree in physics plus 15 graduate credits in physics. With New York State requiring teachers to complete a master’s degree for the award of a professional license, the vast majority of our Physics teachers complete the graduate or combined pathway options. All of the physics courses are taught through the Physics department.

In addition, our programs are **Clinically Rich**. All program graduates have been exposed to extensive school-based experiences

Students at school-based field experiences

before student teaching. Methods courses are taught by highly experienced former teachers. There are two tenured faculty members who hold physics certification and have extensive experience teaching high school physics: one teaches undergraduate physics courses, and the other directs the science teacher education programs. This clinical richness is enhanced by the demographic factors of the Long Island region. The region (Nassau and Suffolk counties) is a ‘hotbed’ for physics teaching, with over 250 NY certified physics teachers teaching in the region’s 108 high schools; this includes more than 110 teachers who teach AP Physics. For the majority of physics teachers in the region, physics teaching is their only assignment, and the vast majority of the schools have more than one physics teacher. In addition to Nassau and Suffolk county schools, the Queens and Brooklyn boroughs of New York are on Long Island and employ an additional 150 physics teachers.

Teslamania: Long Island Physics Teacher Demonstration Competition (http://teslamaniacompetition.org/)

This environment leads to the programs being **Context Rich**, with extensive professional physics teacher support in the region. The Long Island Physics Teacher Association (LIPTA) is large and very active. The New York State Master Teacher Program (NYSMTP) for Long Island also has a large and active Physics Teacher section that is involved in numerous professional development activities for teachers. The region holds its own annual, well-attended physics teacher demonstration competition, *Teslamania*, which is organized and run by physics teachers from Long Island. The rich environment provides a cadre of highly qualified, experienced physics teachers who are able to act as cooperating teachers for student teachers in physics.

The need for physics teachers in the region is considerable, which has given rise to a relatively stable population of physics teachers. The SBU physics teacher program has an 86% five-year retention rate, i.e., 86% of the physics teacher graduates are teaching high school physics five years after graduating. We describe this as being **Continuity Rich**, and many of our graduates are now our program's cooperating teachers. A factor contributing to physics teacher retention are the salaries offered in the area. Starting salaries for Physics teachers with an MAT degree are approximately $60,000, and the majority of physics teachers in Nassau County earn in excess of $100,000, though it should be noted that the region has a very high cost of living.

In common with many programs that produce multiple physics teachers, the SBU physics teacher program is **Champion Rich** – with, as previously described, strong advocates in multiple areas — the Physics Department, I-STEM, and the region's K-12 school community. These champions have allowed us to actively recruit undergraduate students (SBU has a relatively large UG physics population), and funding from the NSF Noyce Program and Petrie Foundation has allowed us to financially support students as they complete the teacher preparation program. And the final C is **Capacity Rich**. SBU has the capacity to double or even triple its production of physics teachers.

We would like to acknowledge the NSF Noyce Program and Carroll and Milton Petrie Foundation, for their financial support of Physics pre-service students. Their funding has allowed Stony Brook to move from producing 3-4 physics teachers per year to 5-6 teachers per year.

Keith Sheppard directs the science teacher preparation programs and has taught high school physics in England, Tanzania and the USA, before moving into higher education.

Robert McCarthy is a professor of Physics, the Undergraduate Physics program director and the Physics Education program advisor.

Angela Kelly taught high school physics in New Jersey and now teaches undergraduate physics courses.

Axel Drees is the Chair of the Physics Department and an ardent supporter of Physics Teacher Preparation Programs.

Ithaca College Physics/Science Teacher Certification Program

Michael "Bodhi" Rogers, Ithaca College

The Ithaca College Master of Art in Teaching (MAT) program is a 13-month-long, 36-credit pathway to New York State (NYS) teaching certification in agricultural science, biology, chemistry, earth science, English, French, mathematics, physics, or Spanish. Prior to enrollment in our MAT program, teacher candidates complete an undergraduate degree in their certification area, a year of a foreign language, educational psychology, social and cultural foundations of education, and an early field experience that includes 50 hours of fieldwork in a classroom setting. All of our ~20 MAT candidates are enrolled together in courses covering educational technology, foundations of literacy, inclusive teaching practices, language acquisition, and general pedagogy and practices. Each disciplinary area has an additional pedagogy and practices course (all of our science students are grouped together in the same course). Our biology, chemistry, earth science, and physics candidates also take courses on inquiry and the nature of science, science topics every science teacher should know, and research for the science teacher. Similarly, our agriculture science candidates take additional courses on educational programs in agricultural science, youth leadership and organizations, and advanced concepts in agricultural education.

While we do offer undergraduate pathways for our students to become certified in four years (which require 120+ mostly proscribed credits), only one biology student has opted to pursue the undergraduate certification option. Through active advising we encourage our freshman science majors interested in becoming teachers to focus on their discipline area, minor in education, and then enter our MAT program. (There is evidence that extended programs result in better prepared teachers as compared to traditional 4-year-long certification programs.[1]) The Undergraduate Degree + MAT is also a viable pathway for science students who discover their passion for teaching later in their undergraduate careers. This most commonly happens through our undergraduate teaching assistant program.[2]

Our science teaching program has experienced a series of internal and external changes since adding the MAT option in 2007. During the summer of 2011, Ithaca College was awarded a National Science Foundation Robert Noyce Teaching Scholarship Program grant to support the recruitment and retention of high quality and diverse physics and mathematics teaching candidates, which we later expanded to include all science disciplines and STEM-fo-

A Noyce Scholar, farthest left, during student teaching. This scholar was an Ithaca College undergraduate chemistry major who entered into our MAT program.

cused childhood teaching candidates. From 2013 to 2014 Ithaca College went through its first national accreditation (NCATE / CAEP[3]) of its teacher certification programs, and we also responded to NYS's requirement of edTPA[4] assessment as part of certification. In 2013 Ithaca College, Cornell University, and the NYS Education Department worked together to create an agricultural certification program that is housed at Ithaca College but is also in collaboration with Cornell's excellent agricultural program. In 2015 we formally added an MAT in Agricultural Teaching along with a new MAT pathway in earth science.

To facilitate entry into our MAT program, we formed an articulation agreement with Cornell that streamlines the admissions process when certain metrics are met. We have now expanded our articulation agreements to include Rochester Institute of Technology and the State University of New York (SUNY) at Cobleskill, and additional agreements are in the works with regional institutions that do not offer graduate certification programs.

The confluence of the NSF Noyce grant and our national accreditation provided us an opportunity to rethink the structure of our science teaching program. National accreditation required the restructuring of our curriculum to meet new standards, and the Noyce grant provided the financial means to try new ideas. We created three new graduate courses already mentioned: Inquiry and the Nature of Science, Science Topics every Science Teacher Should Know, and Research for the Science Teacher; as well as an undergraduate seminar: Linking Science Learning to Science Teaching, which is a review of the science education research literature with a focus on pedagogical content knowledge.[5] Each fall the science teaching cohort attends the Science Teachers Association of NYS meeting; and during our teacher programs' annual urban education field experience in NYC, the science candidates visit the American Museum of Natural History to explore the role museums play in education. In a model similar to PhysTEC,[6,7] we now have retired-teachers-in-residence who assist with teaching courses, running Skype professional learning community[8] meetings every other week for our pre-and in-service teachers, and accompanying Noyce scholars to professional conferences. Table 1 outlines how our science teaching program has grown from being a biology-focused program averaging one to two teaching candidates per year to a program that has teaching candidates in all of the science disciplines and averages two physics candidates per year.

Our graduate science teaching program has grown to be a robust program that creates a tight cohort of highly prepared science educators. Only one science candidate did not pass edTPA on the first try, and 53% achieve a score of mastery. All of our candidates who actively seek employment (some take a gap year) are teaching in the fall following their completion of our program. 70% of our students who became certified from 2005-2016 are still actively teaching, and 95% of our physics teachers are actively teaching (a 2016 graduate took a gap year and is now actively seeking employment).

With our 13-month-long teacher certification program having a track record of success, we are now looking at what elements of our program develop persistence in our candidates. Once our teaching

Table 1: Growth of the Science Teaching Program at Ithaca College

Certification Year	Ag	Bio	Chem	Earth Sci	Phys	Total	Comment
2005		1				1	
2006		2				2	
2007		1				1	First Year of MAT
2008		1	1			2	
2009		1	1		2	4	
2010		3	1		1	5	
2011		1			1	2	Awarded NSF Noyce Grant
2012		1			2	3	
2013		1				1	
2014		2	1		2	5	
2015			2			2	
2016		1	1		2	4	
2017	4	2	1		2	9	First Ag. Science Candidates
2018 Anticipated	4	4	1	1	4	14	First Earth Science Candidate

candidates graduate, we have no control over their school district's professional development and retention programs. Developing persistence in our candidates can help them succeed as teachers regardless of their school district's retention programs. To support our in-service teachers, our Noyce grant provides resources for project staff to visit our in-service teachers' classrooms to better understand what support they need, as well as resources for our in-service teachers to continue attending professional conferences and to participate in a summer teaching workshop held at Ithaca College.

This work was supported by the National Science Foundation DUE Award - 1136320.

Michael "Bodhi" Rogers is a professor in the Department of Physics & Astronomy. He is currently the coordinator of the science teaching program at Ithaca College. Along with being a physicist he is a registered professional archaeologist who specializes in geophysical archaeology and the use of laser scanning for historic preservation.

(Endnotes)

1. Linda Darling-Hammond, "How teacher education matters." *Journal of Teacher Education* 51.3 (2000): 166-173.

2. University of Colorado Learning Assistant Program - https://laprogram.colorado.edu

3. Council for the Accreditation of Educator Preparation (CAEP) - http://caepnet.org

4. edTPA - http://www.edtpa.com

5. Lee S. Shulman, "Those who understand: Knowledge growth in teaching." *Educational Researcher* 15.2 (1986): 4-14.

6. Rachel E. Scherr, Monica Plisch, and Renee Michelle Goertzen, "Sustaining programs in physics teacher education: A study of PhysTEC supported sites." (2014).

7. Mistilina Sato, "What is the underlying conception of teaching of the edTPA?." *Journal of Teacher Education* 65.5 (2014): 421-434.

8. Eugenia Etkina, "Pedagogical content knowledge and preparation of high school physics teachers." *Physical Review Special Topics-Physics Education Research* 6.2 (2010): 020110.

Browsing the Journals

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- The January 2017 issue of *The Physics Teacher* (http://aapt.scitation.org/journal/pte) has articles on page 6 about how to construct an acoustic levitation apparatus and on page 8 about what a dolphin would see when it looks up toward the surface of its tank. Page 83 of the February issue uses a cell phone to measure the electromagnetic skin depth of salt water. A brief article on page 236 of the April issue shows that Newton's third law can be "derived" from the second law by assuming that the mass of a composite system equals the sum of the masses of its component objects. Finally, a fascinating study on page 268 of the May issue explores whether the Hindenburg disaster is mostly due to an explosion of the hydrogen gas in the dirigible or to the flammability of the coating applied to the airship's fabric.
- Page 98 of the February 2017 issue of the *American Journal of Physics* (http://aapt.scitation.org/journal/ajp) compares theory and experiment for the weight of an hourglass containing flowing sand. Another article on page 124 of the same issue shows experimentally that for the familiar problem of a ball starting on top of a hemisphere and rolling down it, the ball begins to slip before it loses contact with the surface. An interesting note on page 228 of the March issue proposes using a gyroscope mounted on a boat in a small pool to demonstrate how a gyrocompass works.
- Article 035006 in the May 2017 issue of *Physics Education* quantifies experimentally the force required to pull apart two interleaved books as a function of number of pages and distance of page overlap. Article 025204 in the March 2017 issue of *European Journal of Physics* catalogs the general motions of a charged particle moving in crossed uniform electric and magnetic fields. Both journals can be found online starting at http://iopscience.iop.org/journalList.
- Interesting articles in the January and February 2017 issues of *Resonance* include "Endangered Elements of the Periodic Table" and the two-part "How Do Wings Generate Lift?" These articles can be freely accessed at http://www.ias.ac.in/listing/issues/reso.
- Atomic weights are not constants of nature for reasons discussed on page 311 of the March 2017 issue of the *Journal of Chemical Education*. Page 320 of the same issue discusses the first manmade element, technetium, in terms of the nuclear shell model. The journal archives are at http://pubs.acs.org/loi/jceda8.
- Article 010110 in *Physical Review Physics Education Research* at https://journals.aps.org/prper/pdf/10.1103/PhysRevPhysEducRes.13.010110 investigates the question of whether including diagrams in problem statements on tests improves student performance and learning? The answer is often no.

Web Watch

Carl Mungan, United States Naval Academy, <mungan@usna.edu>

- Starts with a Bang! is a website at https://medium.com/starts-with-a-bang presenting science stories.
- Some tips for getting girls involved in STEM are online at http://ithare.com/tips-for-getting-girls-involved-in-stem/.
- Kyle Forinash has an inexpensive iBook that includes 33 interactive simulations involving sound waves available at https://itunes.apple.com/us/book/sound/id1194175298.
- A web calculator to solve a system of linear equations using several different input options can be accessed at http://wims.unice.fr/wims/en_tool~linear~linsolver.en.html.
- NIST has a simulation of a drumhead they have constructed on a microchip to measure zero-point fluctuations at https://www.nist.gov/news-events/news/2015/06/vacuum-fluctuations-measuring-unreal.
- A lovely interactive global map of wind, weather, and ocean currents is online at https://earth.nullschool.net/.
- The first direct observation of crystallization at the molecular level is discussed at http://wis-wander.weizmann.ac.il/chemistry/crystallization-made-crystal-clear.
- Funsize Physics at https://funsizephysics.com/ discusses current research in materials science.
- Did you know that Winston Churchill penned an essay about the likelihood of extraterrestial life? Read the Nature commentary at http://www.nature.com/news/winston-churchill-s-essay-on-alien-life-found-1.21467.
- The debate about the conditions under which warm water can freeze faster than cold water continues to stir interest at http://www.chemistryviews.org/details/ezine/10245331/Why_Warm_Water_Freeze_Faster_Than_Cold_Water.html.
- A nifty astronomomy video showing four planets orbiting a star 130 light years away can be viewed at https://apod.nasa.gov/apod/ap170201.html.
- A science alert at http://www.sciencealert.com/hydrogen-has-been-turned-into-a-metal-for-the-first-time-ever reports the metallization of hydrogen.
- The US Navy's plans for a 150 kW laser weapon aboard a ship is discussed at http://www.nextbigfuture.com/2017/01/us-navy-will-fire-150-kilowatt-laser-on.html. Also read about UK's plans at http://optics.org/news/8/1/11.
- Tell your class about an atmospheric radiative cooler that operates without electrical input at http://physicsworld.com/cws/article/news/2017/feb/13/new-metamaterial-enhances-natural-cooling-without-power-input.
- Watch this video of Feynman explaining how a train stays on its tracks at https://www.wimp.com/feynman-explains-how-trains-stay-on-train-tracks/.
- Recently I have become interested in optical computing. One small firm working to bring this idea to reality reviews progress in the field at http://www.optalysys.com/technology/optical-processing-timeline/.
- A classic article on the mechanics of effective scientific writing has been reprinted online at http://www.americanscientist.org/issues/pub/the-science-of-scientific-writing.
- A learning space for science education can be found at http://www.visionlearning.com/en.

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