

Forum on Education

American Physical Society

Summer 2015 Newsletter

Beth Lindsey, Editor

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Disclaimer—The articles and opinion pieces found in this issue of the APS Forum on Education Newsletter are not peer refereed and represent solely the views of the authors and not necessarily the views of the APS.

Doing Something about the Lack of Women and Underrepresented Minority Physicists

From the Chair, Randy Knight

There's good news: The number of bachelor's degrees in physics has doubled in the last 15 years, from a low of 3500 in 1999 to over 7000 this year. Unemployment of physicists is almost nonexistent, so we're far from saturating the market for physicists with bachelor's degrees.

But there's also bad news: This upsurge in the number of physics majors has largely bypassed women and minorities. The percentage of physics bachelors degrees awarded to women increased steadily for 4 decades, peaking at 23% in 2004, but has since fallen back to 20%. Women earn 40% or more of bachelor's degrees in nearly all other math and science programs.

The situation for underrepresented minorities is even worse. Over the past 20 years, the percentage of physics bachelor's degrees going to African Americans has declined from 5% to 2%. Hispanics physics majors have done a slightly better, slowly increasing to 7% of bachelor's degrees. To put this in context, underrepresented minorities make up 35% of the college-age population but earn only 9% of the bachelor's degrees in physics. One page on the APS web site refers to the statistics as "appalling" and goes on to say "Physics ranks *the lowest* [for percentage of degrees going to underrepresented minorities] at all levels of participation among science and mathematical fields."

Physics is used to being at the top of various rankings. But when it comes to women and minorities in our profession, we're at the bottom of the stack. A hard truth.

It's easy to put the blame somewhere else: Poor K-12 schools, a culture that discourages women and minorities from pursuing science, etc. But the number of girls taking high school physics has never been higher – they are now 47% of students in regular high school physics; a bit less but still a significant fraction in AP classes. And engineering, math, and the other sciences are succeeding

where we're not. The evidence is strong that there is a substantial pool of women and underrepresented minorities that is capable, well prepared, and interested in STEM fields, but they're turning away from physics.

This is not someone else's problem to deal with. As a profession, and as an educational community, it's our problem.

Fortunately, there's more good news: There are many things that physics departments can be, and should be, doing to increase the number of women and minority majors. This issue of the Forum newsletter looks at several programs that have been successful at recruiting women physics majors. Most of their actions apply equally well to recruiting underrepresented minorities. To add to their to their hands-on experience, I want to highlight a number of strategies I've learned about over the years and to point you to some resources that can help.

The APS Conference for Undergraduate Women in Physics

<http://www.aps.org/programs/women/workshops/cuwip.cfm>

CUWiP started in 2006 at the University of Southern California. It has been so successful that the next conference, in January, will be held simultaneously at 9 different sites across the country. Over 1200 students are expected to attend. *Please ensure that every woman physics major in your department has the opportunity to attend at least once during her undergraduate career.*

Site visits

<http://www.aps.org/programs/women/sitevisits/index.cfm>

The Committee on the Status of Women in Physics and the Committee on Minorities both sponsor site visits to investigate the climate for women and minorities in a department and to help shape a strategy for improving the climate. Consider requesting a site visit for your department.



APS CONFERENCES FOR Undergraduate Women in Physics (APS CUWiP)

January 15-17 2016
Applications open September 1

www.aps.org/link/cuwip

Take a hard look at your department culture

Are women and minorities *really* welcome in your department? Encouraged? What evidence can you point to? Department climate and culture, of course, are not only about student-faculty relations but about how faculty treat each other and, often overlooked, how students respond to each other. In a department where I was an external reviewer not long ago, I was perturbed in a meeting with the students when several male students kept cutting off the one female student before she could finish a thought. When I later mentioned it to the faculty, they were unaware of a hostile climate among the students. But you can be sure that potential women majors were aware of this – and were voting with their feet to choose different majors.

Provide mentoring

It's easy, if you're part of the majority, to think that mentoring is no big deal. It tends to occur fairly spontaneously. Not so if you're in the minority, aren't sure if you belong, and don't really know what your academic and career options are. Who can you talk to who has had similar experiences? Formal mentoring programs, starting with freshmen, help ensure that women majors, many of whom are still quite tentative, feel welcome and get good advice, without which they are likely to change majors. Mentoring underrepresented minorities is even more challenging due to the lack of underrepresented minorities among physics faculty. To deal with this, APS is working to establish a National Mentoring Community <http://www.aps.org/programs/minorities/mentoring/index.cfm> with skilled mentors throughout the country who can help guide underrepresented minorities through their academic career.

Actively recruit outstanding women and minority students

If you have a woman or underrepresented minority student doing well in introductory physics, why not start a conversation with her? "Hey, you're doing really well at this. Have you ever thought about majoring in physics?" For most, the answer is probably No. Maybe they're quite firm in their chosen major. Maybe they lack the confidence to consider physics. More likely, they simply have no idea what physics is or what physicists do. But if you open a door for them, a few will walk through it.

Improve your department web site!

College catalogs are long gone. Today's high school students make career choices and college choices based largely on what they find

online, especially – when application time draws near – department web sites. Does your department have a web site that is inviting and informative to all potential students, but especially to women and underrepresented minorities? Probably not. There are few excellent department web sites, but the large majority of sites I see do little to welcome potential students.

A typical department web site is so focused on research, faculty, and graduate admissions that a prospective freshman can hardly discover where to navigate to for information. If there is a page for prospective students, it's usually a dry recitation of "Physics is the foundation of all science ...", maybe a laundry list of fields of physics, a list of graduation requirements, and perhaps a sample four-year program of classes. Sorry, but in 2015 you've just lost me as a potential physics major if that's the best you can do.

Most high school seniors are not looking for the hottest research topics. They, and their parents, want to know what it's like to major in physics, what physicists do, what the career options are, and what kind of salaries physicists earn compared to other professions. And, indirectly, they want to know if they'll "fit in" to physics, if they'll find people like themselves. Who better to answer their questions than your own students and alumni?

The most effective department web sites I've seen have a highly visible Prospective Students link on the home page, and then the majority of the information is presented in vignettes and stories told by current students and recent grads. "Hi! I'm Clair, and this is what I'm doing as a physics major at State U and it's so cool and all the professors are so understanding and next quarter I'm going to start a research project on quantum widgets and I'm so excited." With lots of photos, of course. Students – especially women and minorities – want to be able to envision themselves as physics majors in your department. Help them do so, and they'll show up.

I hope you'll explore these tools and options. We have a problem. Let's fix it.

Randy Knight is Chair of the Forum on Education. He is Professor Emeritus at California Polytechnic State University, San Luis Obispo, and author of the introductory textbooks Physics for Scientists and Engineers: A Strategic Approach and (with co-authors Brian Jones and Stuart Field) College Physics.

Letter from the Editor

Beth Lindsey, Penn State Greater Allegheny

This issue of the APS Forum on Education newsletter focuses on Women in Physics, with an emphasis on undergraduate programs. Geoff Potvin of Florida International University shares some of his research into the development of women's attitudes towards physics and their physics self-identities at the college level. He shares some practical, research-based suggestions that may help more women to consider pursuing careers in physical science. Davor Balzar of the University of Denver describes the history and some of the features of the Department of Physics and Astronomy at UD, which has historically graduated a significant fraction of women undergraduate physics majors. Finally Jyoti Katoch of The Ohio State University shares some practices and programs that the Physics department at OSU has put into place in an effort to provide a more welcoming environment to women.

In addition to the articles in this newsletter, APS provides many resources geared toward encouraging the recruitment, retention, and career development of women physicists at all levels. The Committee on the Status of Women in Physics (CSWP) has published numerous reports on "Best Practices for Recruiting and Retaining Women in Physics" at all levels, available here: <http://www.aps.org/programs/women/reports/bestpractices/index.cfm>. Together with the Committee on Minorities, the CSWP also publishes its own newsletter. (The most recent edition is available here:

<http://www.aps.org/programs/women/reports/gazette/upload/spring15.pdf>.) These resources, as well as many others, can be accessed on the APS web site: <http://www.aps.org/programs/women/index.cfm>.

On another note, I would like to take a moment to call your attention to the most recent edition of the newsletter of the PER Consortium of Graduate Students (PER-CoGS). In this newsletter, several experienced PER researchers share their personal and emotional challenges toward becoming a researcher. The results are deeply personal memoirs that may help students to recognize that the challenges they face are not unique, and that even the most accomplished of researchers have at times felt equally frustrated and overwhelmed. Although the newsletter is focused on PER researchers, I highly recommend it for graduate students of all sub-fields of physics. The newsletter can be accessed here: This special edition of the newsletter can be accessed here: <https://sites.google.com/site/pergraduatestudents/newsletters>



Call for Nominations for FED Executive Committee

John Stewart, West Virginia University

The Forum on Education (FEd) will elect three new members to its executive committee this fall: the vice chair (who, in subsequent years, becomes chair elect and then chair), a member at large, and an APS-AAPT member at large. All nominees must be members of the Forum on Education. The latter must be a member of both the FEd and American Association of Physics Teachers. The newly elected members will assume their duties in April 2016. Members at large serve three year terms, while the vice chair will serve for four years.

The executive committee plans education-related sessions at APS meetings, nominates new APS fellows, and makes prestigious FEd awards such as the Excellence in Physics Education Award or the Jonathan Reichert and Barbara Wolff-Reichert Award for Excel-

lence in Advanced Laboratory Instruction Award.

Most importantly, it is the FEd executive committee's responsibility to represent the goals and concerns of the FEd membership to the APS executive council. Serving on the FEd executive committee is an excellent way to learn about the internal function of the society and to influence science education at the national level. Please send nominations for the fall election to the address below.

Please send suggestions to:

John Stewart (jcstewart1@mail.wvu.edu)

FEd Vice Chair and Chair of the Nominating Committee
West Virginia University
Department of Physics

Call for 2016 Program Suggestions

Tim Stelzer, FEd Chair-Elect and Chair of the Program Committee

The 2016 March and April meetings are many months away, but the Program Committee is beginning its planning. The FEd sponsors or co-sponsors 4 invited sessions at the March Meeting and 5 at the April Meeting. In addition, we can sponsor contributed sessions if there is a topic of interest.

If you have a suggestion for a speaker or for a session topic, please

send that to me right away. The Program Committee has to have a fairly complete lineup by the end of July. In addition, we need volunteers to chair FEd sessions. If you know that you'll be attending next year's March or April meeting and would be willing to chair a session, please let me know via email: tstelzer@illinois.edu.

Director's Corner

Theodore Hodapp, APS Director of Education and Diversity

When many people are asked who made a big difference in their life, they often point to a teacher, a trusted friend, or another individual who was able to help them navigate a tricky situation. That sort of encouragement, mentoring of sorts, is what helps many people succeed – advice and care to help navigate difficult times and unfamiliar challenges.

Now, how do we, practicing physicists, help students who have talent, but may not have the same opportunities, advice, or encouragement that we had? To try and address this question, the APS recently launched a national effort to link mentors (like yourself) with undergraduates who can benefit from guidance to help them navigate the challenges of earning a degree in physics. The National Mentoring Community (NMC) is hoping to link a large number of underrepresented minority students with physics faculty members who are willing to spare a little of their time to help these students. The APS program is an effort to understand how to bring this experience to the students who need it, and to help

potential mentors understand how to do this effectively.

If you are interested in helping underrepresented minority students – a population where we think the need is the greatest – get this assistance, please consider signing up as a mentor with the NMC. APS will help provide some guidance on effective practices, and has travel funding to bring together a collection of mentors and their mentees this coming October. We are registering faculty members who can mentor students (and mentees if you have one), putting together a group of experts on mentoring physics students for the fall meeting, and collecting good practices to help all of us do a better job in this important service to the community. The meeting will be 9-11 October 2015 in Miami, FL, and a link for the meeting and to become a mentor can be found at www.nationalmentoringcommunity.org.

Thank you for being willing to help these students succeed.

The image is a promotional graphic for a conference. It features a light blue background with faint icons of a ladder, a gear, and a network diagram. On the left, the text reads "National Mentoring Community & Bridge Program CONFERENCE" in a mix of blue and orange fonts. On the right, there is a circular seal with a blue outer ring containing the text "Mentoring as a path to success" repeated twice. The center of the seal is orange and contains the text "October 9 - 11 2015 Miami, Florida" in white.

Impediments and Prospects for Recruiting Greater Numbers of Women to Physics

Geoff Potvin, Florida International University

Few readers of the FEd Newsletter need to be reminded that the physics community continues to suffer from a dearth of women participants. Though women enroll in high school physics in large numbers (nearly 50% overall, though lower in advanced high school physics courses), this does not continue at the college level: women receive about one in five bachelor's degrees, a proportion that has, if anything, crept slightly downwards for the past decade or more (a period in which the total number of bachelor's degrees in physics has increased substantially from a historic low point in the mid-1990s). Many efforts have been made to try to recruit women by increasing their interest in physics or physics-related careers or by facilitating young women to have meaningful and interesting physics experiences, but these efforts do not appear to have overcome this persistent problem.

What are the root causes of this under-representation? Women on average perform very similarly to men in high school physics courses (and other math and science courses) but have been repeatedly found to have lower interests in the physical science domain in high school (and earlier). The attention of researchers has focused on the mechanisms by which young women come to have depressed attitudes towards physics. In this light, one might worry that attitudes which marginalize women in physics contexts may primarily come from more senior members of the science community (say, teachers or professors), and that these more senior physicists impose their gender-biased views on otherwise-unbiased junior physicists/students, who then internalize or at least have to accommodate these beliefs. However, my co-authors and myself have found that students exhibit clear gender bias in physics at the **beginning** of their college careers. We examined the attitudes of new college students in a particular context: by asking them to evaluate their (previous) high school physics teachers. What we found,¹ and have now replicated independently,² is that students (men and women alike) tend to underrate their women physics teachers by about 6% of the evaluation score, on average. This gap is not explained by actual classroom practices (some of which do impact students' evaluations, as expected), student grades (also independently predictive of teacher evaluations), nor by teacher effectiveness (e.g. their effectiveness at preparing students for success and/or interest in college science). What this means is that students, **by the beginning of college at the latest** have already developed particular attitudes about the competency of women in physics-related domains to a sufficient extent that they show up in their evaluations of others. Importantly, this "evaluation bias" is present amongst both men and women evaluators, so women have internalized these beliefs in a similar way to men. Clearly, this effect is a concern for interpreting college course evaluations, but even more poignant (from the perspective of recruiting women to physics) is the concern that students are explicating these judgments with one another in a myriad of subtle (or not-so-subtle)

ways in their peer-to-peer interactions, and that women in particular have already internalized the feeling that they don't belong in physics or that they cannot perform adequately.

Another way that our research group has repeatedly explored students' self-beliefs with respect to physics is through their "physics identities", an interpretive lens that is very useful for understanding students' physics-related choices.^{3,4} Pertinent to the current discussion, it has been found that women have significantly poorer physics identities; that is, women tend to hold weaker beliefs in themselves as a "physics" type of person, which significantly impacts the likelihood that they will pursue physics-related careers in college or later. Why is this the case? Students' physics identities are, to a large extent, determined by three interrelated factors: their interests in physics as a subject, their beliefs in their ability to perform in physics contexts, and, most importantly, their beliefs in the **recognition they receive** as physics people. The latter, recognition beliefs, are the single most important predictor of an individual's physics identity. Students who receive (or at least believe they receive) recognition for their competency and/or belongingness in physics, are significantly more likely to develop a strong physics identity, an attachment to physics as a pursuit, and to choose it for their careers. This is particularly important for women, who may be receiving less physics recognition throughout their education (or even receive negative reinforcement as we have discussed above) as well as in informal contexts (e.g. media, family, peers, etc.) throughout their upbringing.

With these findings in mind, we have sought to explore ways to positively affect these attitudes such that women may begin to consider physical science careers in more appreciable numbers. Though there is much work still to be done in this space (and work that is currently in progress), there are a few classroom practices that may be helpful:

- Give all students, particularly women, multiple opportunities to be recognized as good physics students. What might these opportunities look like? One might have students take the role of "expert" in group/classroom discussions or when solving problems. Or, if you, the instructor, feel that a student has a knack for physics, or has a novel or interesting way to solve certain types of physics problems tell them so! These experiences should not be overly contrived, but it is important to keep in mind that many students, especially women, may not have an internalized assumption that they can be "good at physics", so reinforcement from an authority figure or expert could contribute to building recognition beliefs and, therefore, physics identities.
- Try to ensure that classroom and laboratory environments are safe and supportive for all students. In particular, this may

be something to pay attention to in peer-to-peer interactions, where students may consciously or unconsciously impose unfair judgments or assumptions on others. While it is not possible to monitor all peer interactions, one may try to ensure that no student get isolated or silenced in group work or labs, which are two contexts in which a solitary woman (or even a pair of women) may be marginalized simply by being outnumbered.

- Lastly, one experience that we have identified as being positively predictive of women's physical science career interests⁵ is the "discussion of underrepresentation" in the classroom. That is, we have found that women who report having been a part of a discussion of underrepresentation in their previous physics classrooms have significantly higher interest in physical science careers. We are still working to identify exactly what characteristics of this discussion are most important,⁶ but it appears that when women engage in an honest discussion that includes their peers (both men and women) to meaningfully explore why there are few women in some sciences, they may benefit by better understanding the reality of science practice and cultural expectations of scientific practitioners. That is, women may come to understand more clearly that social issues and cultural attitudes do have an impact on who chooses to participate in the scientific community and, in turn, that feelings of discomfort or disinterest in physics that they may have could be due to their tacit internalization of these issues, rather than something "inherent" to themselves. Then, these women may re-assess their physics-related choices.

There are many other things that we might do to help recruit more women to physics, but these three suggestions, based in education research, may be useful for physics instructors to think about implementing and might sometimes be overlooked. Only through concerted effort, new ideas, and further research will our community be able to finally address our underrepresentation problems.

Geoff Potvin is an assistant professor in the Department of Physics and the STEM Transformation Institute at Florida International University. He is a member of the FEd Executive Committee and conducts research in physics education that seeks to understand diversity issues in the physical sciences, retention and success in graduate education, and the culture of STEM and its connection to the recruitment of future practitioners.

(Endnotes)

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2. G. Potvin, and Z. Hazari. Student evaluations of physics teachers: On the stability and persistence of gender bias. Forthcoming, 2015.
3. G. Potvin and Z. Hazari, The development and measurement of identity across the physical sciences. *Proceedings of Physics Education Research Conference 2013*.
4. Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan. Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, 47(8):978–1003, 2010.
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Support for Female Students at the University of Denver

Davor Balzar, University of Denver

The Department of Physics and Astronomy at the University of Denver is a small program in terms of the number of students (about 65 undergraduate and 25 graduate, as of May 2015). Historically, we have had a relatively large percentage of female students at both the undergraduate and graduate levels. APS ranked the University of Denver during the period 2011-2013 (<http://www.aps.org/programs/education/statistics/topproducers.cfm>), in second place (50%) for degrees granted to undergraduate female students, and sharing third place (also 50%) for degrees granted to graduate female students.

As I reflected upon the reasons why our program ranks high in percentages of female students, I took a look back in time. Since 1991, the percentage of female bachelor and PhD degrees in our program significantly fluctuated, but was regularly above the national average and in some years reached 100%. During the period of 1991-2015, our average percentage for undergraduate degrees by female students was 42%. As our program was relatively small until about eight years ago, the large fluctuations are expected. However, when our program began to grow (the number of majors increased about ten-fold in the last eight years), the percentage of female students also increased. We cannot assign the high percentage of female students to a single factor. The fact that we have had a critical mass of female students likely plays an important role in attracting other female students, as many of them might feel intimidated to be in an almost 100% male environment. This aligns well with reports of importance of the critical mass in cohort building and retention of graduate students [Panel Session II Building Successful Graduates: Definitions, Admissions, Retention, APS Graduate Conference, February 2013] and is likely to apply to the gender factor, as well. Along those lines, active Society of Physics



Members of University of Denver Society of Physics Students after receiving University of Denver's Outstanding Student Organization Award in 2014. First from left is our SPS adviser, Professor Mark Siemens.

Students (SPS) or other student organizations may play an important role. Our SPS chapter recently won the 2015 Blake Lilly Prize for physics outreach and the University of Denver's Outstanding Student Organization in 2014 (see photo above). It is interesting to note that our chapter has had a high percentage of female students (68% among regularly active members) with female students regularly elected as our SPS officers (currently, eight out of nine members of the executive committee are women) and have frequently led different initiatives, such as Physics Night at Elych's amusement park and physics demonstrations for K-12 students from the Denver area (see photo on left).

Another factor that I believe positively impacted our female student enrollments was the rejuvenation of our department that occurred over the last nine years, during which we replaced eight out of ten tenure-track positions. In particular, the fact that three out of eight of our new hires were women, was certainly extremely important for attracting and retaining female students, as it is well known that role models have a positive impact on the retention of female students [Best practices for female graduate students, <http://www.aps.org/programs/women/reports/bestpractices/graduate-students.cfm>].

Lastly, from both my own and my colleagues' anecdotal experience, which is based on feedback received from departing seniors over the years, there is an overwhelming impression that it might be easier for women to thrive in smaller academic programs. A hallmark of all departments with a small number of majors is their ability to offer more substantial support, both in and out of the classroom. As much as this is helpful to both men and women, female students might appreciate this environment more as they are frequently more likely to become victims of old "sciences are



Members of University of Denver Society of Physics Students (SPS) at the Elych's amusement park (Denver, May 7, 2015). First row, first from left is our SPS adviser, Professor Mark Siemens.

not for women” labels and, hence, are less likely to change majors if they receive constant support and encouragement. This might explain the fact that we have consistently had a relatively high percentage of female students for at least 25 years.

In summary, it would be an oversimplification to assign a single reason to a high percentage of female majors. However, our own experience has shown that a strong extracurricular effort, such as an active Society of Physics Students chapter, may play an important role in building a cohort and letting female students express their leadership potential. Furthermore, female faculty members are extremely helpful in supporting and guiding female students by example. Finally, smaller programs may be in a better position

to support female students, and once their numbers reach critical mass, it might be easier to attract additional female majors, as well as to increase their retention.

Davor Balzar has been chair of the Department of Physics and Astronomy at the University of Denver since 2006. He received the University of Denver's Faculty Service Award in 2010 for his efforts to rejuvenate the department. His research is in studies of crystalline defects and disorder by diffraction methods in ferro-electrics, photovoltaics, and oxides. He was elected a Fellow of the International Centre for Diffraction Data (ICDD) in 2006 and currently serves as Vice-Chairman of the ICDD Board of Directors. He can be reached at balzar@du.edu.

Welcoming Climate for Women at The Ohio State University

Jyoti Katoch, The Ohio State University

In this document we highlight the steps the Ohio State University Physics Department continuously has taken to develop a community that encourages, nurtures and supports female physicists. The department participates in several programs and activities that provide a welcoming and conducive environment for women and underrepresented minorities to flourish and become successful scientists. In addition, the faculty and staff in the physics department make a concerted effort to understand and be sensitive to the challenges faced by the women in STEM (science, technology, engineering and mathematics) fields. There are many successful women faculty members in the department who are excellent mentors for younger women. In this article we share the actions taken by our department to make the environment welcoming to women.

Female Faculty: In recent years, there has been a concerted effort to hire new women faculty in the department. Today, about 10% of our physics faculty is female, which is comparable to the national average number of 12%, according to the information available from American Institute of Physics (AIP) Statistical Research Center in 2010. To ensure the success of our new faculty, we have a mentoring program in place that advises them about the tenure process. The senior male/female faculty members informally and formally participate in this mentoring program, which has strongly benefited new female faculty.

Graduate admission: One of the first barriers to having a strong female presence in STEM fields is removing any bias in the admissions process itself. A growing volume of scholarly work suggests that graduate admissions based only on traditional standardized tests cannot predict future success in graduate school, and can lead to reduced diversity in graduate physical science programs. This is due to the fact that women score significantly lower on standardized tests, which can put them at a disadvantage during the initial screening of applications and frequently results in rejection. To

combat this, Ohio State's Physics Department progressively implemented a more “holistic” approach to attract promising women to our PhD program, particularly female students who had low GRE physics scores, but had done outstanding research. This means that our Graduate Admissions Committee puts less emphasis on traditional so-called “cognitive” metrics of student ability and potential, such as general GRE scores, Physics Subject GRE scores, and GPA, and puts more emphasis on “non-cognitive” factors, such as research experience, letters of reference and evidence of “grit” – the drive and persistence to overcome significant obstacles and succeed. Recently, the Department of Physics offered fellowships to a group of women who had very similar and low Physics GRE scores, but had good grades and extremely strong research experience and letters. Three of these students came to Ohio State, two went on to win NSF Graduate Research Fellowships while at Ohio State, and all three were extremely successful and have graduated. With this experience in mind, we now consider all aspects of graduate student applications, and never use a GRE “cutoff” to screen applications. We have found that this has led to a strong increase in the number of offers we make to women and students from other groups that have traditionally been underrepresented in physics graduate programs. These efforts have helped to increase the number of applicants and matriculated students from underrepresented groups into our PhD program, as well as into our Bridge Program.

The Society of Women in Physics (SWiP): With a growing population of women and underrepresented groups in the department, it is important that support systems exist to ensure their continued success. The department encourages many activities that help women to network, grow and reach their full potential. The physics department provides monetary as well as administrative support for smooth and effective functioning of The Society of Women in Physics (SWiP), an academic organization of undergraduate and graduate students. This group provides a platform for women

undergraduate, graduate, postdoctoral and faculty in the department to interact, socialize and connect one-to-one with each other. SWiP engages in various activities aimed at professional development and the social and emotional well-being of its members. This includes inviting female speakers from many disciplines to give talks, creating workshops for coping with conflicts common in academia, and hosting social events that increase the communication between women at all stages in their career. Recently SWiP organized a “microaggressions” panel and an “imposter syndrome” workshop. Both these events were also well attended by male members of the department and led to positive discussions. Additionally, the SWiP Mentoring program connects undergraduates with graduate student mentors; several undergraduates who previously participated in this program went on to graduate school and careers in industry.

Girls Reaching to Achieve in Sports and Physics (GRASP): Every year during summer, physics department faculty, staff and students organize a five-day camp for middle school girls to inspire and encourage scientific thinking. Each day, the participants take part in an interactive physics demonstration and then follow it by physical activity that helps in understanding physics phenomenon in everyday life. Such scientific activities are important to attract women to STEM fields in higher education. It is noteworthy that this program was conceived and initiated by a few of our undergraduate women in physics about five years ago.

Behavioral coaching: With increasing numbers of women in the undergraduate and graduate program, there is a greater need to coach male members in the department about professional language and behavior. In 2013, our physics department discovered a concern about the unprofessional behavior by undergraduate men towards undergraduate women in the student lounge. The department took very swift action to curb such unacceptable behavior through discussions within the department and invited an external review committee site visit. The external review site visit was sponsored by the Committee on the Status of Women in Physics (CSWP) of the American Physical Society (APS). The committee (four member team) acknowledged the significant steps taken by the department to improve the climate for women in the department and at the end recommended certain areas for improvement. The review process was very informative and positive, and helps us to further work towards improving diversity in the department.

Wellness Room: In order to accommodate the specific needs of

women in the department, the physics department, in partnership with the SWiP, constructed, furnished and maintains a wellness room. This room provides a clean, private environment to breast-feeding mothers or individuals who need it for physical and mental well-being. It is equipped with refrigerator, sink, microwave, chair and a phone. This room is a tangible example of how the faculty and staff are supportive of women and their family responsibilities. It is also open for men who might need such private space.

Conference for Undergraduate Women in Physics (CUWiP):

We also are very concerned with extending this support to as many females in STEM fields as possible. In January 2010, the department hosted the 3rd Annual Midwest Conference for Undergraduate Women in Physics, attended by 150 undergraduate women in physics. In our continued commitment to support women in physics, the department has once again pledged to host the conference for undergraduate women in physics (CUWiP) in January 2016. The conference will attract undergraduate women in physics from Ohio and five neighboring states: Wisconsin, Illinois, Michigan, Indiana and Kentucky. It provides a unique opportunity to encourage, motivate and guide undergraduate women in physics. It is a great platform for all attendees to interact with each other and provide them with tools to have a successful career and life balance. The conference helps us attract more women to our PhD program, which in turn helps to improve the diversity of our department. It also allows us to engage with female students, staff and faculty to learn and understand the evolving challenges faced by women in the sciences.

In summary, the active steps taken by the physics department have enhanced the department’s atmosphere. By continuous vigilance, engagement and openness to new ideas, we can ensure an environment where women in STEM fields will succeed.

Jyoti Katoch is a post-doctoral researcher at The Ohio State University. She received her PhD in 2014 from the University of Central Florida, where she founded and served as president of the Physics Women Society. While at UCF, she was the recipient of the Provost’s Graduate Fellowship for two consecutive years. Her research focus is on electronic and spintronic properties of 2D materials. She co-wrote the proposal to host Conference for Undergraduate Women in Physics (CUWiP) at The Ohio State University in January 2016.



Section on Teacher Preparation

Teacher Preparation Section

Alma Robinson, Virginia Tech

At the 2015 PhysTEC conference in February, I had the wonderful pleasure of meeting Kristine Callan from the Colorado School of Mines (CSM) and Wendy Adams from the University of Northern Colorado (UNC). During introductions, they spoke of their unique STEM Teacher Preparation Program where students at CSM, a highly selective, small public research university devoted to engineering and applied science, can pursue teaching licensure with an option for a master's degree through UNC, Colorado's premier teacher preparation institution.

At the next meeting break, conference attendees swarmed Kristine and Wendy and inundated them with questions about their program. It was clear that many institutions see great potential in recruiting and training engineering students as physics teachers and were very interested in learning how these partnerships can be created.

For this edition of the Teacher Preparation Section, three institutions that are making inroads in graduating physics teachers who have engineering backgrounds will be highlighted. First, Kristine Callan and Wendy Adams outline their aforementioned program,

PhysTEC's first multi-institution comprehensive site.

Kathy Koenig explains how the University of Cincinnati has created a streamlined pathway for engineering students to earn both an engineering degree and a Master's in Curriculum and Instruction in five years. By taking advantage of the university's existing 5-year master's degree program that includes multiple co-operative work experiences, students can now earn their teaching licensure while fulfilling some of their required co-operative experience through student teaching.

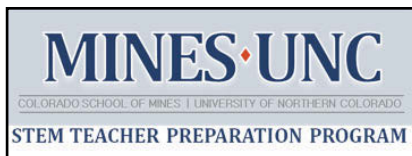
Finally, John Simonetti, Brenda Brand, and George Glasson explain how the partnerships between the Department of Physics, School of Education, and College of Engineering at Virginia Tech have played key roles in the success of their physics teacher preparation program. Engineering students are encouraged to participate in courses that offer early teaching experiences, and pre-service physics teachers are invited to enroll in a Mechanical Engineering Robotics elective where college students mentor high school students in building a robot for the FIRST Robotics competition.

A Symbiotic Physics Teacher Preparation Partnership

Kristine Callan, Department of Physics, Colorado School of Mines

Wendy Adams, Science Education and Department of Physics and Astronomy, University of Northern Colorado

To help battle the shortage of highly qualified physics teachers, Colorado School of Mines (CSM) and University of Northern Colorado (UNC) have recently created a unique partnership that plays on each institution's strengths to produce highly qualified STEM teachers: One is a highly-selective, public applied sciences and engineering research university and the other is the state's premier teacher preparation institution. Together, we hope to produce teachers with both strong content and pedagogical knowledge from a previously untapped pool of potential educators.



The Partnership

Many students enter CSM interested in a career in engineering due to their passion for math and science, but without a clear understanding of what it actually means to be an engineer. Over time, some of these students realize that they do not want to be engineers and change to a major in the basic sciences or math, while others leave CSM entirely. Dean Kevin Moore has thought for years that a sizeable fraction of these students might be interested in persisting at CSM if they could see a viable non-engineering career path, such as secondary teaching. This would also provide an additional avenue for recruitment of new students. In 2006, a survey of 1,015 CSM students supported this idea, showing that 46.5% would be interested in pursuing a teaching minor, if one were offered. CSM had preliminary discussions with a couple of Colorado institutions, but these did not move forward.

In the Fall of 2013, independent of the above, Eugene Sheehan, the Dean of Education and Behavioral Sciences at UNC, suggested that a viable approach to addressing the needs in STEM teaching could be a partnership whereby UNC provides professional teacher training to CSM students. Faculty at UNC reached out to colleagues at CSM and initial discussions found a strong synergy

between the two institutions' goals.

By March of 2014 we had completed an MOU committing to building a teacher preparation program for CSM students. In 2014 this partnership was awarded an NSF Noyce Capacity Building Grant and in 2015, it became both a PhysTEC Comprehensive site and a 100Kin10 Partner.

While program development has progressed reasonably smoothly, our biggest challenges have been communicating effectively to all players and determining who to bring to the table and when. The design team consists of faculty from multiple colleges in both institutions (the UNC College of Education, UNC Secondary Science and Math content faculty, and the Mines content faculty) as well as their respective Deans; however, we did not anticipate the range of administrators from the two different institutions that needed to be involved. As expected, faculty, deans, and provosts were required to form the institutional agreement; however, registrars, financial aid directors, bursars, and UNC's Extended Campus and Graduate School also had to be at the table. This program is not business as usual for any of these folks.

The Students

As part of the design process, we have collected evidence that CSM students have a very strong content preparation. Nationally, average composite SAT/ACT scores of those who enter teaching are far below those who go into engineering, research, science and other related fields¹. CSM students sit in the top 5% of students nationwide with an average ACT score of 30. The CSM students who have expressed interest in this program have a slightly higher average GPA than the CSM student body. Additionally we have administered the General Science PRAXIS exam to CSM student volunteers with majors in Physics, Mechanical Engineering, Chemistry, Petroleum Engineering, Biochemistry and Applied Math. Without extra study or preparation, all students passed with scores well above the national average.



Fig. 1: CSM Physics students, Libby Booton (left) and Spencer Fretwell (right), fire a vortex cannon during a Society of Physics Students Future Faces of Physics event at Berry Creek Middle School. Outreach activities, such as this one, are able to give CSM students a taste of teaching, and those who become "hooked" can now pursue a teaching license via our program. Photo credit: Taylor Smith, CSM Engineering Physics student.

There has been a healthy response from students who are interested in the program, as well as from local schools, which are excited to have these high quality teacher candidates in their classrooms during early field experiences, student teaching, and ultimately as new teachers.

Through a new student poll in core classes and emails to select major lists, we have identified roughly 180 current CSM students who indicated that they are “interested” or “very interested” in this new program with UNC. Of these students, roughly one third are either physics majors, physics minors, or have equivalent coursework.

The Program

Just shy of two years after the initial discussions, the first cohort of students will begin this summer. The current plan is to have the first cohort of students begin their teacher preparation course work either over the summer or in the fall 2015 semester. Many of these classes can count toward the student’s CSM degree, and since they will either be delivered on the CSM campus (by a UNC faculty member) or online, the student will retain their identity as a CSM student. Each student will also have the option to 1) pursue teaching licensure only, which will require them to enroll at UNC for only one additional semester after graduating from CSM, or 2) pursue teaching licensure with a master’s degree that will include a research component, which will require them to enroll at UNC for a full year after graduating from CSM.

We are excited about the potential of this unique new program to produce a healthy stream of STEM teachers with strong physics and engineering content knowledge and a balanced preparation in educational theory and practice from a previously untapped pool of students. Additionally, this partnership serves as a model for how an education focused entity can recruit and train students from an engineering institution or department to become teachers.

The CSM PhysTEC team includes Vince Kuo and Kristine Callan from the Department of Physics, and Steven DeCaluwe from the Department of Mechanical Engineering. The UNC PhysTEC team members are Wendy Adams, Physics and Astronomy, who also serves as the Director of UNC’s Science Education Programs and Christy Moroye, Foundations and Curriculum Studies, who coordinates UNC’s Secondary Post Baccalaureate and K-12 licensure programs.

(Endnotes)

1. National Science Board, *Science and Engineering Indicators 2006* National Science Foundation, Arlington, VA, 2006, Vol. 1, NSB 06-01; Vol.2, NSB 06-01A



Fig. 2: Prospective physics teacher, Jordan Diemer, teaches Berry Creek Middle School students about the wonders of circular motion with a simple demonstration. He plans to pursue a teaching license while earning his degree in Engineering Physics from CSM. Photo credit: Taylor Smith, CSM Engineering Physics student.



Fig. 3: CSM Engineering Physics students, David Grisham (left) and Libby Booton (right), practice a fascinating bead chain demonstration that always leaves students in awe. Photo credit: Taylor Smith, CSM Engineering Physics student.

Creating Pathways into Teaching through Engineering Programs

Kathy Koenig, Associate Professor, Joint Appt Physics & STEM Education, University of Cincinnati

Recruiting students into high school physics teaching is a challenge. As a result of our efforts under PhysTEC, we reflected on the pathways that students might take through our physics licensure program. Although earning a BA or BS in physics might seem to be the most logical pathway, the reality is that our physics department graduates a dozen or less majors per year, which is a small pool from which to recruit future physics teachers. On the other hand, our college of engineering graduates well over 600 majors each year. These students are strong in math and science, and although they have high interest in these subjects, some learn through the program's coursework and mandatory co-operative (co-op) work experiences that a future career in engineering is not what they wish to do upon graduation. It is these students who are targeted as future high school teachers through University of Cincinnati's ACCEND™ (Accelerated Engineering Degree) program.

ACCEND™, a 5-year program through the College of Engineering and Applied Science, allows students to earn an undergraduate degree in engineering along with a master's degree while still enjoying the benefits of the university's top ranked cooperative education program. Under the original ACCEND™ program, master's degree options included engineering, science, and business. In 2013, a Master's in Curriculum & Instruction with a high school teaching license was added to the list of possibilities, which enabled us to expand our recruitment efforts.

In order to complete the curriculum in the prescribed 5-year timeframe, many of the students who consider the ACCEND tracks already have a semester or more of credits completed in high school through either AP or dual enrollment. Students without these incoming credits may catch up by taking additional courses during their co-op experience. This is becoming easier as more and more of our courses are being offered online. To ensure that the students have enough time to complete the various degree and licensure requirements, it is essential that they are recruited into the program after their freshmen or sophomore year. Much of our recruitment efforts occur through our learning assistant program, academic advisors, and scheduled program information sessions.

The majority of the coursework for the engineering degree and teaching license is completed in the first four years of the program with only a few graduate courses completed prior to the fifth and final year. One of the essential elements of the program that adds to its success is flexibility. Through careful planning, students may take as many as six of the thirteen classes required for high school licensure prior to entering the teaching cohort during their fourth year. Some of these are offered as online courses, which students may take during co-op. Four of these courses also count as required Breadth of Knowledge (general education) courses, which further increases the program's accessibility. In addition, under ACCEND™, students complete only four of the five semesters of



Blake Baldwin, an engineering major, serving as a Learning Assistant in a physics class

mandatory co-op, providing one additional semester for necessary academic coursework. For those seeking high school licensure, the final co-op experience is replaced by student teaching. Currently, funding through a Math and Science Partnership (MSP) grant pays for a student's tuition during the semester of student teaching, and Noyce funding is also available.

Due to the complexity of the program, student advising is critical, and students often have multiple advisors including someone from the College of Engineering as well as someone from the College of Education, Criminal Justice and Human Services. Students must meet all requirements of the undergraduate program to earn their undergraduate degree and fulfill all requirements of the graduate and licensure program to earn their graduate degree with teaching license. Additionally, the same course cannot count towards both an undergraduate and graduate requirement, and ACCEND students must also maintain a 3.0 or higher GPA to stay in the program.

While an undergraduate, students in the ACCEND program are permitted to take as many graduate courses as appropriate for credit toward the Master's in Curriculum & Instruction. Once students have completed at least 90% of the undergraduate credit require-

ments, they complete a “Transition to Graduate Status” form rather than complete and submit a full graduate school application, which further simplifies the process.

This program has many benefits for recruiting more high school physics teachers. One of the major advantages is that the program was designed to include only those courses found within existing programs, so that new courses did not need to be created and staffed. It also attracts some of our brightest and most energetic students into teaching, and it does so after the students have had some teaching experience in college, including serving as a learn-

ing assistant. And finally, because these students are earning an engineering degree along with their teaching license, they are highly marketable when they enter the workplace.

Kathy Koenig received her PhD in Physics Education in 2004 after serving as a high school physics teacher for 6 years. She is currently an Associate Professor of STEM Education with a joint appointment in Physics. Her research interests include developing curriculum to improve student acquisition of scientific reasoning abilities as well as improving student success and retention in introductory STEM courses.

PhysTEC at Virginia Tech: The Importance of Engineering

John H. Simonetti, Department of Physics, Virginia Tech

Brenda Brand, School of Education, Virginia Tech

George Glasson, School of Education, Virginia Tech

The PhysTEC program at Virginia Tech (VT) involves a variety of collaborations between the Department of Physics, the College of Engineering, and the School of Education. These collaborations provide undergraduate physics and engineering students with multiple pre-service teaching experiences that increase the probability that they will find teaching to be a viable and interesting career choice. At Virginia Tech, our pre-service physics teachers complete an undergraduate degree in physics or engineering and then obtain a Master of Arts in Education (MAEd) from the School of Education. Throughout their undergraduate and graduate education, students benefit from these partnerships in ways uncommon to other PhysTEC programs. Perhaps seeking similar collaborations at your institution could prove beneficial.

Potential PhysTEC students at VT often start out pursuing a standard physics or engineering degree. Many of them do not start their formal education courses or pursuit of licensure until they have nearly completed their bachelor’s degree in physics or engineering and enter the graduate program in the School of Education. This leaves us with two hurdles to overcome in our recruitment and education of future secondary school physics teachers: (1) How do we spark the interest of undergraduate physics or engineering students in teaching before they obtain their undergraduate degree? And, (2) How do we alleviate the worry that students (and parents) may have about paying tuition for additional years of education beyond their undergraduate degree?

Perhaps surprisingly, at least some of the answers to these questions come from the presence of a large and successful College of Engineering (COE) at Virginia Tech. Undergraduate COE students account for about 30% of the undergraduate student body at VT. All General Engineering students — students entering the COE — must take two semesters of introductory physics starting in the spring of their freshman year. In the Spring 2015 semester, the Physics Department taught over 1800 engineering students, in



A competition robot made by local high school students with the help of college student mentors.

total, across both parts of the two-semester introductory physics sequence. As a result, the Physics Department obtains a large number of Graduate Teaching Assistantships (GTAs) from the university — partly funded by the COE — for use in conducting recitation and laboratory sections for these students.



Matt Libuit (left), physics teacher with a degree in Engineering Science and Mechanics, assists classmates with design activity

Because we are allocated more GTA positions than we have physics graduate students who need them, we can award some of these GTAs to our PhysTEC MAEd students. Thus, we offer complete tuition coverage plus a monthly stipend to our PhysTEC students during their post-bachelorette academic year while they pursue their MAEd and licensure. Having this GTA award removes the financial burden of obtaining a graduate degree.

We realize that you may not have a large school of engineering your institution, however, so our GTA solution to alleviating the financial burden of pursuing a master's degree may not be viable for you or your students. But there are other ways in which the presence of the COE helps with our recruitment and overall program. Further, these ways fall more into the realm of direct collaboration. First, the sheer number of undergraduate engineering students taking physics helps with recruitment. Our Undergraduate Advising Coordinator spreads the word about our PhysTEC activities, through personal contact, with the advisers in the College of Engineering. When engineering students express interest in becoming physics teachers, our Teacher in Residence (TIR), Alma Robinson, meets with them to discuss our PhysTEC program and helps them navigate through all the required coursework needed to enter the MAEd program.

Our TIR also created the Enriched Physics Outreach course (now in the course catalog), in which undergraduate students work with K-12 science and physics teachers to construct and carry out lesson plans in science classes. The Enriched Physics Outreach course is an extension of our Physics Outreach course, and both attract

physics students into PhysTEC. The Enriched Physics Outreach course is counted by the COE as fulfilling a “technical elective” requirement for COE students, and we have had success in recruiting engineering students into the MAEd program through this course. The Physics Learning Assistant (LA) program is also open to engineering students. In fact, one of our engineering LAs has just obtained his MAEd. As a result of all these efforts, we have had a small but steady increase in the number of engineering students participating in PhysTEC activities over the past few years. And, some of these students have enrolled in the MAEd program — with the support of a GTA from the Physics Department.

With the focus of the Next Generation Science Standards (NGSS) on the intersection between science and engineering, future physics teachers are being prepared in the MAEd program to teach engineering design lessons in the K-12 schools. In the science methods class, taught by one of the authors (Glasson), pre-service science and mathematics teachers are collaborating to develop Science-Technology-Engineering-Mathematics (STEM) lesson plans that are inclusive of both physics and engineering design principles. The pre-service physics teachers who either have an engineering background or who participated in the FIRST Robotics program take a leadership role in class by assisting other students in developing lessons that engage K-12 students in problem-solving design activities.

Finally, the “crown jewel” in our collaborative efforts with Engineering is the Robotics Program. This program is a senior-level Mechanical Engineering technical elective course, in which engineering students utilize their training in the engineering design process to work with high school students to design and build a robot for competition in the national First Robotics program. Through the efforts of one of the authors (Brand), Engineering has accepted Physics majors into this course. And those students have been quite enthusiastic about their experience! Of course, this experience can help to cement a student's interest in working with high school students. Thus, this course acts as another recruitment tool into PhysTEC from the pool of physics majors. One recent graduate from the MAEd program has started a First Robotics program at the high school where he now teaches. Interestingly, when his parents saw him interacting with his team of high school students at a regional First Robotics competition, they said they were now completely convinced that their son's pursuit of a teaching career was a great choice.

John Simonetti is a Professor and the Associate Chair in the Department of Physics at Virginia Tech. He is the site leader for the VT PhysTEC project. Brenda Brand is an Associate Professor in Science Education at Virginia Tech. She is the coordinator of the MCPS/VT Robotics Collaborative. George Glasson is Professor and Program Leader of the MAED Secondary Science Licensure Program in the School of Education at Virginia Tech. He is a Co-PI on the VT PhysTEC project.

Browsing the Journals

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

- There are five platonic solids. If we draw a straight line passing through any vertex of such a solid and the geometric center of the solid, that line will intersect another vertex of the solid in 4 out of these 5 solids. Which is the exception and what does that have to do with the challenge question related to the cover picture of the February 2015 issue of *The Physics Teacher* (<http://scitation.aip.org/content/aapt/journal/tpt>)? Also be sure to check out the incredible photograph of a balanced tower of rocks on the back page of the March issue!
- An article on page 110 of the February 2015 issue of the *American Journal of Physics* (<http://scitation.aip.org/content/aapt/journal/ajp>) considers a remarkable variation on Newton's cradle. Suppose a traditional cradle has 3 equal-mass balls. If ball 1 is pulled aside and released, ball 3 will come off the end of the chain with the incident velocity of ball 1. That happens because ball 1 makes 1 elastic collision with ball 2 transferring all its momentum to it, and likewise ball 2 makes 1 collision with ball 3. One can instead reduce the mass of ball 2 to $\sqrt{5} - 2 = 23.6\%$ of balls 1 and 3. The cradle will now function as before. This time it happens because ball 1 makes two elastic collisions with ball 2, to end up at rest, and likewise ball 2 makes two collisions with ball 3. The paper similarly finds the "magic mass ratio" of 11.0% for Newton's cradle to operate where ball 2 makes three elastic collisions with each of balls 1 and 3. A general formula is found for any integer number of collisions with each end ball. See a quicktime movie linked to Fig. 6 of the paper at <http://scitation.aip.org/docserver/fulltext/aapt/journal/ajp/83/2/1.4897162.mm.v1.mov?expires=1422924519&id=id&accname=2120645&checksum=17D804DA91518CD31D4A08496E313AED>. Next, Bertrand's theorem states that only forces that vary linearly or with the inverse square of the distance from a point can yield closed orbits. Proofs of this theorem are generally not simple. However, an elementary derivation is provided on page 320 of the April issue. Incidentally, the book review of "A Student's Guide to Entropy" on page 383 of the same issue motivated me to buy that well-written text. Finally, Craig Bohren's article on page 443 of the May issue makes it clear that the difference in thermal conductivities is not the *only* reason that aluminum feels colder to the touch than does paper in the Veritasium video at <https://www.youtube.com/watch?v=vqDbMEdLiCs>.
- Page 329 of the May 2015 issue of *Physics Education* has a detailed study of the sliding motion of a ladder leaning against a wall, where friction with both the floor and wall is considered. Video analysis is used to compare the theory with experiment, including the loss of contact between the ladder and wall at a sufficiently small angle of inclination. Also be sure to read about David Featonby's surprising experiment showing the difference in behavior of a spinning top on an inclined plane coated with sandpaper depending on whether the base of the top is rounded or pointed on page 391 of the same issue. Turning to the *European Journal of Physics*, article 028001 in the March 2015 issue calculates the length of a heavy cable spanning two fixed points that minimizes the tension at the highest end. Article 035027 in the May issue uses high-speed cameras to investigate the flickering of incandescent and fluorescent lamps. Both journals are accessible at <http://iopscience.iop.org/journals>.
- Page 643 of the April 2015 issue of the *Journal of Chemical Education* at <http://pubs.acs.org/toc/jceda8/92/4> asks what produces the thick white fog seen when dry ice is dropped into water? The answer is *not* condensation of atmospheric water vapor onto the cold CO₂ gas subliming away.
- Article 010101 in *Physical Review Special Topics—Physics Education Research* at <http://journals.aps.org/prstper/abstract/10.1103/PhysRevSTPER.11.010101> compares student performance in adding and subtracting vectors graphically versus algebraically. The authors conclude that optimal learning occurs if students are introduced to both methods concurrently and that it is important for students to practice the graphical approach for arrows drawn in a variety of different orientations.



Web Watch

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



- Science Friday at <http://www.sciencefriday.com/> is the website of a public radio program but is neatly organized into materials you can listen to, watch, read, or use in class.
- The University of Nebraska at Lincoln has lots of stuff related to astronomy education at <http://astro.unl.edu/>.
- A helpful tutorial on Fourier Transforms using cooking analogies and interactive animations can be found online at <http://betterexplained.com/articles/an-interactive-guide-to-the-fourier-transform/>. Then you can learn about the Fast Fourier Transform at <http://nonagon.org/ExLibris/gauss-fast-fourier-transform>; be sure not to miss the MIT video near the bottom of the page!
- Brookhaven has a website called Physics of the Universe at <http://www.bnl.gov/science/physics.php>.
- The concept of relativistic mass, if treated with care, can be useful at times. Read a defense of this idea at <http://math.ucr.edu/home/baez/physics/Relativity/SR/mass.html>.
- A free introductory physics textbook, so far covering Mechanics and Thermodynamics but projected to cover E&M, Optics, and Modern Physics as well, can be downloaded at <http://bluephysics.org/>.
- AAPT has a policy statement about the goals of the introductory physics laboratory at <http://www.aapt.org/Resources/policy/goaloflabs.cfm>.
- The White House has put together a history of women in STEM at <https://www.whitehouse.gov/women-in-stem>, intended to encourage young women to pursue such careers. For contemporary examples, go to <http://www.womeninscience.org/>.
- BBC has prepared a colorful poster about the temperature limits of the universe from coldest to hottest at <http://www.bbc.com/future/story/20131218-absolute-zero-to-absolute-hot>.
- A series of vignettes about optics with links to related *Physical Review* articles for the International Year of Light has been put together by APS at <http://physics.aps.org/IYL>.
- Quizlets are study tools such as flashcards and games that can be used in and out of the classroom at <https://quizlet.com/>.
- Science magazine has annotated some of its research articles for teaching purposes at <http://www.scienceintheclassroom.org/>.
- Let's Talk Science is a Canadian charitable organization dedicated to education and outreach with a website at <http://www.letstalkscience.ca/>.
- It's fun to play with the simulated tearable cloth mesh at <http://codepen.io/dissimulate/full/KrAwX> and there's physics behind its realistic motion.
- I'm sure you've seen strange appearing videos of propellers or guitar strings using rolling shutters. A brief explanation is at <http://www.diyphotography.net/everything-you-wanted-to-know-about-rolling-shutter/>.
- Another recent controversy has been about underinflated footballs. Physicists have chimed in on the issue, as blogged for example at <http://blogs.mprnews.org/newscut/2015/01/it-took-football-to-get-people-interested-in-physics/>.
- Lots of pictures, videos, and news stories about asteroids have been collected together at <http://www.huffingtonpost.com/news/asteroid/>.
- Does cold glass ever stop flowing? Bristol researchers have written a paper supporting a yes answer. See the blurb at <http://www.bristol.ac.uk/news/2015/january/glass-a-true-solid.html>.

- A set of YouTube videos called The Quantum Around You can be accessed from <https://www.youtube.com/playlist?list=PLHSIfioizVW1sXAJY3aYCugtKDFPTNztl>. NSF also has a diverse set of videos at <https://www.youtube.com/channel/UCRuCgmzhczsm89jzPtN2Wuw>.
- Fiat Physica (<http://www.fiatphysica.com/>) uses crowdsourcing to fund physics education.
- *Wired* magazine has put together a science website at <http://www.wired.com/category/science/>.
- Check out the World Science Festival online at <http://www.worldsciencefestival.com/>.
- Engineering: Go For It at <http://www.egfi-k12.org/>. Also check out MakerSpace at <http://makerspace.nysci.org/> and Engineer Your Life at <http://www.engineeryourlife.org/>.
- Finally, the middle schoolers at Colonial Academy asked me to tell you about the resources related to simple machines at http://www.partsgeek.com/mmparts/physics_for_kids_simple_machines_in_automobiles.html.

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Upcoming newsletter deadlines:

Fall 2015: October 1st, 2015
Spring 2016: January 11th, 2016
Summer 2016: June 1st, 2016