the SPS Observer

Volume XLVI, Issue 4

Winter 2012-13

Women in Physics

- Unconscious Unfairness
- Questions & Answers
- Advice
- Guess Who?
- Women's Words

Pathways
Jocelyn Bell Burnell: Resolved

Awards
PhysCon Competitions
Outstanding Advisor

Elegant Connections in Physics
Diffraction, Part 1

PHYSICS STUDENTS dance at the 2012 PhysCon "Club Congress" event. Photo by Ken Cole.

Physics for All

by Toni Sauncy, SPS Director

What a fantastic time to be involved in the great science of physics! Admittedly, there probably hasn't been a time when that was not true. Those with physics backgrounds join a professional community in which opportunity abounds and graduates are sought after as valuable members of the STEM workforce. The Society of Physics Students holds high the ideals of professional development, support, and service to the growing number of physics majors. Working with undergraduates brings the privilege of witnessing fresh energy and enthusiasm, where awe and respect for their physics predecessors is mixed with bold, unapologetic curiosity about pushing limits and understanding more. This is a relatively small (approximately 14,000 undergraduate physics majors in the US), yet powerful group of young scientists who will infiltrate the world in ways that we have not yet imagined with creativity, wisdom, insight, skills, and problem-solving abilities.

One of the highest callings of SPS is inviting all kinds of people into physics, as voiced in the 2009 SPS Statement on Diversity (www.spsnational.org/governance/statements/2009diversity.htm). Diversity is beneficial to physics: people of diverse backgrounds working on the same problem will view it from different perspectives and bring their own life experiences into the project. Diversity of people adds diversity to the work.

In this issue, we take a look at the current status of one of the underrepresented groups in physics: women. As a beginning student, I was privileged to be influenced by some outstanding mentors who introduced me to the APS Committee on the Status of Women in Physics (CSWP). It was a life-changing experience to walk into the CSWP reception at my first American Physical Society (APS) March meeting and discover a room full of physicists talking about interesting science, all of whom happened to be women. I had never before been in any room where there were more women than men talking about the subject that I adored. That interaction helped me begin to be part of the conversation. CSWP has had a tremendous impact on the climate for women in physics departments. The conversation has continued. In recent years, growing numbers of students have been powerfully impacted by participation in the Conferences for Undergraduate Women in Physics, now sponsored by APS.

The less-than-desirable state of diversity among the physics community is not new. Our hope in this issue of *The SPS Observer* is to engage new voices among the communities that

continued on page 14

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Table of Contents

Volume XLVI, Issue 4 Winter 2012-13

ON THE COVER
Top: Jocelyn Bell Burnell, a longtime friend of SPS, during her college years (see the related content on pages 6, 7, and 15). Bottom: Aida Bermudez, Florida International University, presents her poster at PhysCon 2012 in Orlando, FL. Photo by Ken Cole.

Outstanding **Advisor**

MEET THE 2012 SPS OUTSTANDING CHAPTER ADVISOR

AJAY NARAYANAN teaches physics and astronomy at Green River Community College. Photo by Angela Winner.

The 2012 SPS Outstanding Chapter Advisor Award goes to Ajay Narayanan from Green River Community College in Auburn, WA. This is the highest recognition given by SPS to chapter advisors. It celebrates an individual who has made exceptional contributions toward promoting student leadership, developing a broad spectrum of activities, and inspiring enthusiastic student participation.

Says Narayanan:

> It has been my great pleasure to serve as the SPS chapter advisor at Green River Community College (GRCC) in Washington state. When we restarted the dormant chapter in 2003, four students signed up as members. Since then our membership has grown steadily. Our chapter, known as the Physics Club, has raised its profile on campus and was selected Club of the Year by the college in 2012.
>
> Our wonderful students have set up numerous outreach events for the campus community and local elementary schools. GRCC students have secured three Marsh W. White Outreach Awards, won a couple of SPS Leadership Scholarships as well as an internship, and served on the SPS National Council as associate zone councilors. I am incredibly proud of all the students have done.
>
> We chucked head-sized pumpkins a distance of 350 feet, imploded large steel drums, shot liquid nitrogen bazookas that spray columns of water three or four floors high, and participated in other mayhem that would appeal to most SPS members. The most rewarding part of our efforts has been the letters we get from the grade school students and teachers who have participated in our events.

The most rewarding part

OF OUR EFFORTS HAS BEEN THE LETTERS WE GET

> For one of our fund-raising events our chapter president dressed up in a deviled egg costume and rode a bike under an overpass while students, staff, and faculty pelted him with eggs. By charging one dollar an egg we raised over a hundred dollars. The cleanup was not fun, but the event was a success!
>
> Being part of SPS provides our students with opportunities to make science-related activities the focal point of their interactions with other students and faculty members. I believe this type of support keeps students interested in physics in ways that classroom activities cannot achieve. Being a chapter at a two-year college has its challenges, including limited funding, but over the years we have found solutions to many of these problems. What makes this possible is the tremendous support, encouragement, and participation we receive from all our faculty members and staff.

After receiving his PhD in physics from the University of Arizona in 1997, Narayanan turned his attention to full-time teaching. He served for one year as an adjunct instructor at the University of Arizona, then joined GRCC's Physics and Astronomy Department in 2000.

Narayanan has been involved with SPS since his graduate school days. Green River Community College's chapter advisor since 2003, he also served two terms as zone councilor on the SPS National Council. //

FURTHER READING

For more information about this award and how to nominate your advisor, visit www.spsnational.org/programs/awards/advisor.htm.

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PhysCon Competitions

Connecting WORLDS through science & service 2012
2012 Quadrennial Physics Congress

POSTER AND ART SESSIONS LIVELY AND INSPIRING

"If there is any take-home message from the [PhysCon] poster session, it is that students are capable of great things and should be encouraged to pursue these opportunities."
-St. Peter's College SPS chapter

Two of the most energetic and dynamic sessions during the 2012 SPS Quadrennial Physics Congress (PhysCon) were the joint poster and art sessions. Over 200 student presenters engaged with peers, science faculty, and practicing physicists, while discussing research, outreach, and artwork in more than two dozen categories. A small army of volunteer judges did a fantastic job critiquing and ranking those who participated in the poster and art competition, and several sponsors contributed funds and other prizes for the most outstanding presenters.

CONGRATULATIONS TO ALL THE WINNERS:

Outstanding Student Poster Award, sponsored by The OSA Foundation

Outstanding Posters

Michael Alemayehu, Morehouse College
Andrew Peterson is pictured accepting award on his behalf (3)
Kelsey Schafer, Ohio State University (4)
Adam Simpson, Abilene Christian University (1)
Morgan Smathers, Rhodes College (6)
Christopher Trennepohl, Davidson College (7)

Honorable Mention

Adeyemo Adetogun, North Carolina Central University (5)
Valerie Jacobson, Colorado State University (2)

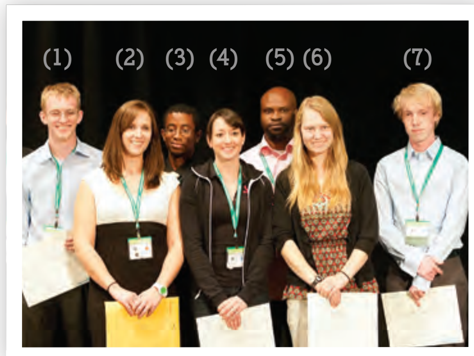


Photo by Ken Cole.

Outstanding Student Astronomy Poster Award, sponsored by the American Astronomical Society

First Prize

Mary McDaniel, University of North Alabama (1)

Second Prize

Rachel Smullen, University of Wyoming (5)

Third Prize

Jennifer Kadowaki, University of California, Los Angeles (4)

Honorable Mention

Andrew Miller, Abilene Christian University (2)
Macarena Sagredo, Florida International University (3)

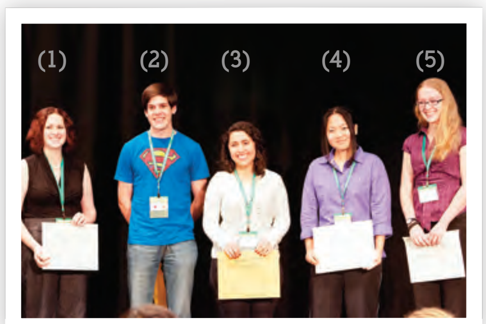


Photo by Ken Cole.

Physics and Society Student Poster Award, sponsored by The American Physical Society Forum on Physics & Society

First Prize

Allen Scheie, Grove City College (5)

Second Prize

Kofi Christie, Morehouse College (3)
Matthew Goszewski, Grove City College (4)

Honorable Mention

Jeremy Johnson, Angelo State University (1)
Yulu Liu, Southeast University, China (2)

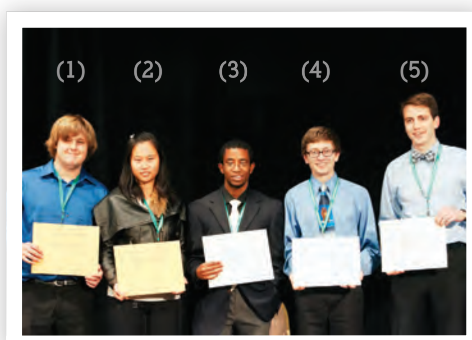


Photo by Ken Cole.

To see the abstracts of the winning posters, visit the PhysCon website at www.spscongress.org/physconprogram/posters.

PhysCon Art Contest Awards, sponsored by the American Association of Physics Teachers

Best in Show (pictured right)
Glenn Marsch, Grove City College

Artists' Choice & People's Choice
Christopher Frye, University of Central Florida

Connecting Worlds
Jordan Guzman, University of Central Florida

Space and General Science
Lauren Dallachiesa, Grove City College

Physics for Everyone
Natalia Guerrero, Massachusetts Institute of Technology

Honorable Mention
Prajwal Niraula, Saint Peter's University
Sarah Rozman, University of Central Florida
Glenn Marsch, Grove City College


Photo by Ken Cole.

To see photos of the artwork, visit the PhysCon website at www.spscongress.org.

'Future Faces' in 2013

INTRODUCING THE 2013 FUTURE FACES OF PHYSICS AWARD WINNERS

The Future Faces of Physics Awards fund SPS chapter projects that promote physics across different cultures and engage groups that are traditionally underrepresented in physics—such as African Americans, Hispanics, American Indians, females, and people with disabilities. Six chapters received the award for projects to be carried out this year:

University of Southern Mississippi

Continuing the Mentoring Program for First-Year, First-Generation Physics Students
With a 2012 Future Faces of Physics Award, the University of Southern Mississippi SPS chapter developed a mentoring program to help first-generation physics students with some of the challenges they encounter during their first year of college. This 2013 award will continue that project. Almost half of all first-generation physics majors at the University of Southern Mississippi change their field of study after their first year in the physics program.

Stephen F. Austin State University

SPS Brings Physics to the Solid Foundation
Stephen F. Austin's SPS chapter is partnering with the Solid Foundation Association to host a community lecture series once a month that will include physics demonstrations and hands-on projects. The Solid Foundation Association was developed to empower at-risk children and young learners.

Indiana Wesleyan University

Physics Outreach to Minority and Underrepresented Middle School Kids in Rural North Central Indiana
The Indiana Wesleyan University chapter of SPS will reach out to the rural community of North Central Indiana to stimulate interest in physics-based careers among middle school students from minority and financially disadvantaged groups. The city of Marion and surrounding smaller towns belong to Grant County, an area that has suffered dramatic poverty rates due to closure of several manufacturing plants and the loss of thousands of jobs.

Morehouse College

Physics in the Phlesh: Project Ruben's Tube
The purpose of the Physics in the Phlesh community engagement initiative is working with a local youth development organization to provide individualized mentoring and exposure to young students of Atlanta's lower-income communities. The first activity will be the construction of a Ruben's tube, an apparatus that visualizes sound waves using flames.

Angelo State University

ALPHAS: Alta Loma Peers Helping the Advancement of Science
The purpose of this program is to create and maintain a partnership between the Angelo State University Society of Physics Students and Alta Loma Elementary School for the purpose of advancing science education. With some of the lowest test scores in the district, Alta Loma is the epitome of a school in need of positive reinforcement and encouragement.

Drexel University

Engaging Girls in Physics: Expanding Horizons through Outreach to All-Girls Schools
In order to encourage more women to pursue physics, Drexel University's SPS chapter will create three types of outreach events: one for middle school girls, one for high school girls, and a workshop for the 2013 Swarthmore CATALYST Conference, a conference designed to foster an appreciation for science, math, and engineering in 7th and 8th grade girls.

Resolved

NOTED SCIENTIST SHARES HER JOURNEY AS A WOMAN IN PHYSICS

by Jocelyn Bell Burnell, an astrophysicist from Northern Ireland at the University of Oxford and a former president of the Institute of Physics. During her work as a postgraduate student at the University of Cambridge she was the first person to observe pulsars. She was also a keynote speaker at the 2012 and 2004 Sigma Pi Sigma Physics Congresses.

JOCELYN BELL BURNELL delivers her plenary talk at the 2012 Sigma Pi Sigma Quadrennial Congress in Orlando, FL. Photo by Ken Cole.

As an undergraduate student at the University of Glasgow in the 1960s, I was the only woman in a class of 50. I lived with other women, but there weren't any in my physics class. Whenever any woman entered the university hall, the men in the class all banged and whistled and catcalled. They were following a university tradition, doing what the senior students had taught them was normal to do. I don't think they thought very hard about it.

I could understand those young students doing what they had been taught by the older students, but the faculty must have been aware of it, and they did nothing. That annoyed me quite a bit. It was isolating. It meant that I didn't have anyone to work with, so I had to solve all the problems myself.

Today it's still a struggle in Britain to get women into physics. An undergraduate physics course is reckoned to be doing quite well if 25 percent of the class is female.

I BELIEVE THERE IS A LOT OF
'unthinkingness'

If you go to other countries, the situation is very different. For example, I was speaking at a physics conference in Malaysia and told a woman there that I wanted to see more women in physics. She asked why. It turns out that 40 percent of the undergraduate physicists in Malaysia are men and 60 percent are women. In China you find many women scientists and engineers. Quite a lot of southeast Asia recognizes that women can do science and engineering, and women are often encouraged to do so.

There is a huge range for the number of women in my own field, astronomy. The country with the largest proportion of women professional astronomers is Argentina at 37 percent. The country with the least is Japan at 6 percent. The United States and the United Kingdom sit a little below the world average of 15 percent.

This has nothing to do with brains. It's the result of cultural differences. But making cultural changes is a long, slow process.

One of the concerning things is that the number of women is growing at the more junior levels, but the percolation through to full professor isn't always happening. The pipeline leaks. At each academic hurdle, a higher proportion of women than men quit. In the United Kingdom between two-thirds and three-fourths of female science and engineering graduates quit their fields fairly quickly after earning their degrees.

I've got some hunches as to why that is, but my hunches really need testing with proper exit interviews, which are not consistently carried out. Family issues are often cited when a woman leaves academia. I think that's an excuse. I think many women just don't enjoy the atmosphere or the ethos in some science and engineering departments, and they decide to try their luck in something else.

If a woman is in a very small minority, she simply has to behave like a man to survive. That, of course, has its cost, but I don't think you have a choice. Only when you have a critical mass in a department, I think, does it start to change character.

The subject has been male dominated for a long time. I don't believe that there is direct discrimination, but I believe there is a lot of "unthinkingness." A postgraduate I spoke with observed that new male postgraduate students at her university were allowed by their advisors to choose their topics, while the females were directed to topics. It's a lack of thought, a lack of sensitivity.

That's improving quite rapidly. Partly because the older men now in some cases have daughters going into science, engineering, and technology. These fathers are starting to see things through their daughters' eyes. Also, the younger men are spending more time sharing in the family responsibilities.

But there are still different rules for the genders. I know of a couple that has two small kids. He studies physics, and she is in theology. They decided that the optimal arrangement would be if they each worked four days. They went to the heads of their departments to ask. Her head said yes, that would be fine, which day do you want off? His head said absolutely not, don't even think about it.

New legislation that is supposed to be coming in Britain would give men more paternity leave so that young babies aren't seen as the responsibility of just the women. That would help. So would holding important meetings within what are called core hours, which correspond to school hours, so that parents can leave early to collect their kids. Flexible working conditions would help, as would having available at all levels the option of part-time work. At the moment part-time work is confined to lower pay grades and is considered inferior. Seeing part-time posts available for prestigious roles as well would be a big step forward.

Some very good programs running in Britain now accredit departments as women friendly. Athena SWAN, for instance, is an elaborate award scheme that judges how fair to everyone a department is. There's a threat that universities won't be able to apply for government research funding unless they are accredited in this way. The approach in the United States has been different. The National Science Foundation has given money for a program called ADVANCE that has made a big difference in universities that have held that funding.

Attaching financial rewards can also be very effective. Merit payment can reward the chairman of a department in which women get promoted or hired.

Hopefully things will keep improving with time. In the meantime, I encourage all women studying physics to hang in there! Female students seeking support can contact harassment officers if things get pretty serious. If an issue is within the normal course of events, quite often universities have a women's group established by a frustrated academic that sees it as the only way out. But those groups tend to be ad hoc and local. Professional bodies like the Institute of Physics quite often have local women's networks that are worth exploring, as well. //

Preventing the End of the World

by Marquette University's SPS chapter

In her light-hearted and entertaining plenary talk at the 2012 Quadrennial Physics Congress (PhysCon), Jocelyn Bell Burnell discussed several popular theories for the end of the world. Many of the theories violated the laws of physics so absurdly it was hard to believe anyone could take them to be possible.

One theory was that the magnetic poles of Earth would switch, causing the planet to come to a complete stop and reverse its rotation. Another claimed an alignment of the planets would cause a gravitational pull on Earth strong enough to rip the planet in half. "That's totally how gravity works," a student in the audience sarcastically called out. While quite amusing to a room full of up-and-coming physicists, the talk was also a clear and frightening statement about the lack of scientific understanding in our society.

Most of these ridiculous concepts are actually grounded in some scientific fact, said Bell Burnell. Her point was that purveyors of unfounded theories are trying to use science—badly misconstrued science—to understand the world. If only scientific programs put more of an effort into educating the general public, people could better discern scientific truth from fiction, mitigating beliefs in such impossible theories.

It is our duty as a scientific community to reach out and aid in providing a stronger foundation of public education. As Bell Burnell indicated, when scientific education is not encouraged in schools, we raise a scientifically illiterate population that cannot distinguish between reliable information and false premises presented under the guise of scientific fact. This in turn circles back around to hurt the scientific community. //

Listen to a complete audio recording of Dr. Bell Burnell's talk on the PhysCon website: www.spscongress.org/physconprogram/speakers/.

NO-BELL PRIZE

The 1974 Nobel Prize in Physics, which recognized the discovery of pulsars, caused a controversy. Jocelyn Bell Burnell did not share in the prize. Many people believe she should have. Her analysis of data collected by a telescope she helped to build revealed untidy fluctuations coming from a distinct source—the signature of a pulsing object. She discusses the work, the controversy, and other aspects of her life in a 2000 interview transcribed by the American Institute of Physics at www.aip.org/history/ohilist/31792.html.

CONNECTING WOMEN

Empowering women in academia and science has become an important priority for many organizations, from universities and nonprofits to scientific societies and national laboratories.

The American Association of University Women (AAUW): www.aauw.org

The Committee on the Status of Women in Physics (CSWP) @ The American Physical Society (APS): www.aps.org/programs/women/

Conferences for Undergraduate Women in Physics: www.aps.org/programs/women/workshops/cuwip.cfm

Association for Women in Science: www.awis.org

Women in Physics @ the Institute of Physics (IOP): www.iop.org/activity/groups/subject/wip/index.html

Women in Physics Resource Collection hosted by Fermilab: www.fnal.gov/diversity/women_in_physics

Athena SWAN: www.athenaswan.org.uk

NSF ADVANCE: www.nsf.gov/crssprgm/advance/index.jsp

Eggcelent Education

TREBUCHET TEAMS FACE OFF WITH PHYSICS

by Jason Stock at Idaho State University

AN ELEMENTARY SCHOOL STUDENT triggers his homemade trebuchet. Photo by Jason Stock.

COMPETITORS watch the egg they launched fly through the air. Photo by Jason Stock.

"One meter!"

As the judges call out the distance, murmurs can be heard from all directions. Those murmurs are quickly drowned out by the giddy screaming of two 5th-grade girls. The two girls are competing in the Elementary School Egg Launch, put on by Idaho State University's SPS chapter. They have just made the winning shot in the accuracy challenge with their first-ever trebuchet. An egg launched nearly 50 meters was only 1 meter off its target.

The father of one of the girls stands behind them, looking very proud of his daughter. Other parents and teachers drink hot chocolate or cider as they try to stay warm on the cold December day. None of the children seem to notice the chill. They are all very absorbed in their machines, making fine adjustments and hoping to hit their targets or maximize their distances.

The trebuchet was once a tool for destruction. It revolutionized modern warfare. The British Warwolf, one of history's most famous trebuchets, seemed unstoppable when it was built in the 13th century, a mighty machine that could tear down any fortress.

But on this day the trebuchet became a tool for education, an optimal example of classical mechanics. Each machine in the competition was an elegant system that took the potential energy of a suspended mass and used a mechanical advantage to propel a smaller mass remarkable distances.

THE TREBUCHET BECAME A
tool for education

Students from the ISU SPS chapter spent much of last year volunteering their time to help run classes in trebuchet building and to coach teams for this competition. The elementary school students learned basic physics concepts such as conservation of energy and the effects of lever arms on torque. The students were also taught how to use reference materials to develop their own designs and build the machines that finally came together for the egg launch.

Overall, the day was a fantastic success. Five teams from four schools showed up, about 30 people altogether. At the end of the day, it was clear the egg launch achieved its goal.

The event made an impact on the participants, and, even more importantly, on the Pocatello, ID, community as a whole. Teachers and parents talked about making the competition a regular event. At the end of the day, a seed had been planted in support of science education. A seed . . . or maybe an egg. //

FURTHER INFORMATION

Watch ISU's SPS chapter oxidize coffee creamer in a public demo at www.youtube.com/watch?v=Ns47Q-XrqxM&feature=related.

Inside Argonne

SPS CHAPTER TOURS NEARBY NATIONAL LABORATORY

by Kevin McDermott at the University of Notre Dame

DAN WEST explains a detector component used for ATLAS, a nuclear physics accelerator that was highlighted on the Argonne tour. Photo by Kevin McDermott.

"The research being performed here can only be performed here. It's work that is one of a kind," explained Dan West, our SPS chapter's tour guide at Argonne National Laboratory just outside of Chicago, IL. West was referring to the unparalleled capabilities of the Advanced Photon Source (APS), not to be confused with the American Physical Society. Magnets in the device, spaced out along a 1,104-meter ring, accelerate electrons to an energy of 7 GeV. The electrons radiate high-energy x-rays useful for all sorts of research applications.

Created just after World War II, Argonne started off as a research facility devoted to nuclear power. Since then it has evolved into a multipurpose and multidisciplinary facility, exploring topics that range from car batteries and nuclear physics to pharmaceuticals and green energy. Public research that culminates in published academic papers can be conducted at Argonne for free. Proprietary research, typically commissioned by private companies, requires a fee.

Five members of the University of Notre Dame SPS chapter hopped on a small charter bus to Argonne one day in November. Our tour focused on the physics side of the campus. APS was the big highlight. As West explained, APS is incredibly useful for imaging various materials, including proteins. Using computers to model how proteins fold is extremely time consuming, but pulsed beams of x-rays emitted by APS can capture images of a folded protein just before the protein is destroyed by the intense energy of the x-rays.

This improvement in imaging could spur research into rare and neglected diseases, said West, who mentioned a genetic disease that he suffers from for which there is currently no cure. Advances in protein imaging could allow rare diseases like his to be researched more efficiently, making such research potentially cheaper and more profitable for drug companies.

Our visit also took us to Blue Gene/P, a supercomputer optimized for parallel processing that is used to conduct research. Large-scale lattice quantum chromodynamics computations can be performed overnight on the computer. West noted that tours of Blue Gene/P are pretty rare and usually require some pull. Our contact at Argonne, Patricia Canady, really went out of her way to set up the tour. As a small undergraduate tour group, we were pretty excited about the unusual opportunity to see one of the world's fastest computers in action.

Inside the room housing the computer, it was noticeably colder. The cooling ventilation system is optimized to allow air to flow continuously over the processors, which work nonstop on many different types of research problems. If the cooling system were to fail, the entire system would fry itself within a few minutes!

The tour provided an excellent opportunity for our SPS group to see the vast amount of research that is performed every day just an hour and a half away from our university. If you are looking to set up such a tour, the first thing to do is select a location. Do some research to see what the location has to offer and use this information to get some ideas of what you would like to see. Contact the laboratory to see what opportunities are available. Once a date has been selected, contact transportation options in the area. From there, spread the word, hop on a bus, and enjoy your tour! //

WE WERE PRETTY EXCITED ABOUT THE UNUSUAL OPPORTUNITY TO SEE
one of the world's fastest computers in action

FURTHER READING

- **Learn more about Notre Dame's SPS chapter at http://physics.nd.edu/undergraduate-program/courses/.**

Staring into the Light

NEW DEVICE WILL MEASURE LED GLOW

by Omar Hassan and Roxanne Lee at the University of Texas at Dallas

Organic light-emitting diodes (OLEDs) are much like regular LEDs, such as the green bulb next to the start-up button on any desktop computer or the red bulb that lights up on your remote control. Light in those standard LEDs comes from a piece of semiconductor within the bulb, which gives off energy when a certain voltage is applied to it. An OLED is a special kind of LED with a plastic-like semiconductor made of organic materials. In many cases, organic materials are cheaper to make than traditional semiconductors, and they have the potential to produce more efficient LEDs.

Cell phone displays made by Samsung, Motorola, and Nokia already use OLEDs, and some OLED TVs are currently on the market. OLEDs are desirable for those display applications because of their vivid colors, wide viewing angles, and low power consumptions. OLEDs can also be connected to make flexible displays (imagine an iPad that you can wrap around your wrist). Many hope to replace fluorescent and incandescent lighting with more efficient OLED lighting. But there is still work to be done to improve the efficiency and lifetime of OLEDs. Much more research and testing is needed before they become usable in lighting applications.

That's where our research advisor at the University of Texas at Dallas, Jason Slinker, comes in. He currently makes OLEDs using various organic materials and tests the lifespan of those OLEDs with an instrument that can only test one LED at a time. Each test can take weeks or even months. In addition, the instrument cannot detect OLED color changes over time, an ability that would be useful in determining the timing of particular chemical reactions within the OLED. Ultimately, what would be useful for our advisor and other researchers is an easily assembled instrument that can measure the light intensity and color of several OLEDs at a time.

With some funding from a 2012 Sigma Pi Sigma Undergraduate Research Award, we are building an instrument designed for this purpose. It contains circuitry designed to control the current through and voltage across any of eight OLEDs. But since the photodiodes used in this kind of testing only sense the intensity of the light, not the spectrum of light coming from the OLEDs, the second part of our project is an experimental instrument design that uses a different light-sensing device. Our idea was to test several different picture-taking devices, such as scanners and cameras, to see if we could get reliable light spectrum data as well as light intensity data comparable to that of the photodiodes (or even more accurate, if possible).

We started out by purchasing a regular color scanner but quickly found it to be unsuitable. It used a three-color LED to excite colors sequentially but a monochrome detector, so it was incapable of measuring the color of our LEDs. We needed a scanner with a color detector and reasoned that older models were better candidates. We found a "broken" scanner from university surplus that actually worked quite well. The light source was not functional—which was perfect, as we only wanted to measure light coming from the LED. So the scanner from the trash was better than the scanner from the store!

TEAM MEMBER OMAR HASSAN (left) prepares an OLED with Jason Slinker by pipetting a solution of organic materials to make an organic semiconductor. Photo courtesy of Jason Slinker.

The scanner was able to track the light intensity of test LEDs fairly well. However, the color spectra of the LEDs returned by the scanner were variable. Some colors were fine, while other colors were off. We reasoned that the scanner's light detector or internal processing was correcting the image based on its intended light source—possibly a fluorescent bulb with a highly nonlinear spectrum. This hypothesis gained credibility when we found another scanner of the same model with a functional light source (amazingly, also from the trash) and measured its spectrum to be that of a standard fluorescent light. We have submitted the results for publication.

The scanner takes intensity data over a decent range, and it may be useful for tracking relative changes in color. In the meantime, the first prototype that uses photodiodes for its light-sensing element is nearly complete. This instrument will be used in our advisor's lab continually after it is completed. Thus, our instrument will have immediate use in the quest to find more efficient light sources, and other LED researchers may follow our design for rapid device testing. //

RECEIVE UP TO $2,000 FOR YOUR CHAPTER RESEARCH PROJECT!

Each year Sigma Pi Sigma awards research funding of up to $2,000 to several SPS chapters for research activities. For details, see www.spsnational.org/programs/awards/research.htm.

FEATURE

Unconscious Unfairness

STUDY SHOWS BIAS AGAINST HIRING FEMALE STUDENTS

by Jude Dineley for physicsworld.com

A US study has found that researchers assessing the employability of early-career scientists subconsciously favor male students over females. The bias, which was seen to exist in both male and female physicists and was also exhibited by chemists and biologists, is thought to be a contributing factor towards the underrepresentation of women in physics.

Undertaken by psychologist Corinne Moss-Racusin and colleagues from Yale University, the study involved 127 tenured scientists across six universities in the United States being asked to provide feedback on an excerpt from a job application for a graduate-level lab-technician post at another institution. The excerpt—developed by an academic panel—was designed to be as realistic as possible and was identical, except that 64 of the scientists were told the applicant's name was Jennifer, while the other 63 were told the applicant's name was John. The scientists were told that their feedback would help the applicant's career development, unaware that both the candidate and the post were fictitious. The candidate was painted as promising but not exceptional.

The study found not only that the scientists rated the male applicant as significantly more competent and hirable than the (identical) female applicant, but also that the hirers would have given the male student a higher starting salary. "Male and female science-faculty members, including physicists, said they were more likely to hire the male student," says Moss-Racusin. "They also offered to pay him about $4,000 more per year on average and were more likely to offer him career mentoring, relative to the identical female student."

The bias shown by the potential hirers was independent of their gender, age, and seniority, indicating that even women show a subconscious bias against other women. The innate nature of the bias is thought to be evidence of the influence of a society-wide stereotype that men make more competent scientists, influencing even "very well meaning, very well trained scientists who emphasize objectivity and egalitarianism in their daily lives," according to Moss-Racusin.

Amy Graves, a physicist from Swarthmore College, near Philadelphia, who specializes in gender studies in science, says she is "saddened, but not surprised" by the findings. "This study is so well done, because they created a résumé that was good, but not amazing," says Graves. "If [the candidate] were an absolute standout, prior studies suggest that [the authors of the study] might not have seen this evidence of a genuine, unconscious bias."

According to Moss-Racusin, having structured and transparent mentoring is one solution to the problem. She recommends guidelines to help standardize support across all students and the use of secondary mentors. "One of the biggest predictors of success and retention within academia, especially for women and racial-minority students, is identifying with a role model or a good mentor."

The results [of the Yale study] are published in the October 9, 2012, *Proceedings of the National Academy of Sciences*. //

FURTHER READING

A longer version of this story originally appeared on physicsworld.com. The article is reprinted here with permission. See: **http://bit.ly/YgVrz1**

US Women in Physics: By the Numbers

To understand any problem, it is best to begin with data. Below, we present a summary of some commonly asked questions about the participation of women in physics. The questions are answered with data from the AIP Statistical Research Center (www.aip.org/statistics), courtesy of Rachel Ivie and Susan White.

Q. How has the number of women in physics changed over the course of time?

A. It increased between 1980 and 2011.

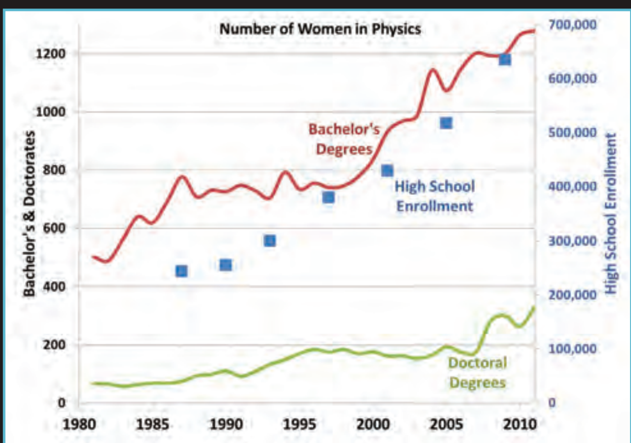


Fig. 1: Number of women in physics, by level (1980–2011). Note that high school data is not collected annually. Data is available for only the years shown.

Q. How has the percentage of women in physics changed over the course of time?

A. It also increased between 1980 and 2011.

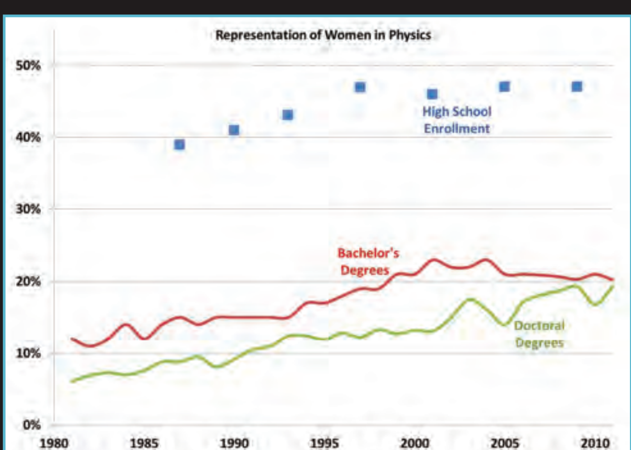


Fig. 2: Percentage of women in physics by level (1980–2011).

Q. How does the percentage of women in physics at the bachelor's level compare with that of women in other STEM fields?

A. It is significantly lower than in biology, chemistry, and math, but slightly higher than in the fields of engineering and computer science.

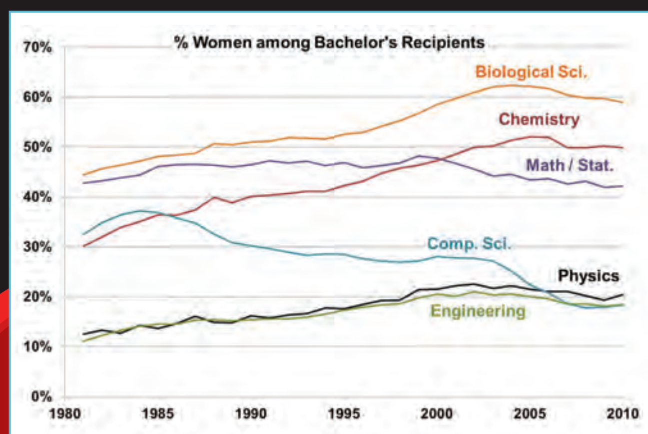


Fig. 3: Percentage of women earning degrees in STEM fields at the bachelor's level (1980–2011).

1996-97: ~50% of high school chemistry students are female

Advice

"I have seen great benefits to women in physics when the university where they are studying has a social support group for women students which meets regularly."
– Mildred Dresselhaus, Massachusetts Institute of Technology

"Expect your ability as a physicist to be questioned. Always respond by keeping the discussion professional rather than personal. Math 'em!"
– Ruth Howes, Ball State University

How is the number of women in physics related to the level of study?

Q

How is the number of women in physics related to the level of study?

A

We can look at the numbers in progressive years; however, this is not necessarily proper since not every student who earns a bachelor's degree in physics took physics in high school, and not every student who earns a doctorate in physics earned an undergraduate degree in the field. To properly examine the pipeline would require a longitudinal study with a large enough initial sample to follow progression fifteen years beyond initial enrollment in freshman physics. With that caveat, we present the following data.

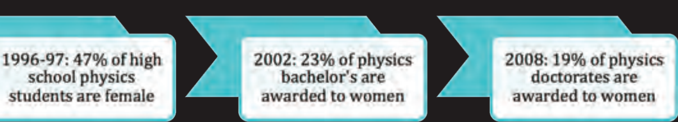


Fig. 4: Representation of women at various points in the academic progression from high school to a doctorate. The timing shown in the steps is representative. Four to five years is the typical time between earning a high school diploma and a bachelor's degree, and six years is the median time to complete a doctorate.

For comparison, consider data from biology and chemistry.

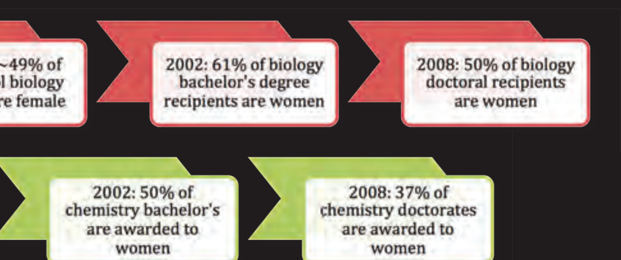


Fig. 5: Academic progression of women in STEM fields, based on representative timings for each degree from high school to doctorate.

Q

Can you say any more about the idea of the "leak" in the pipeline for women pursuing physics careers?

A

Our most recent study on this topic is from 2005. (Women in Physics and Astronomy, 2005, by Rachel Ivie and Kim Nies Ray). We examined the transition from high school to bachelor's degree to doctorate to assistant professor to associate professor and, finally, to full professor. We note that there is a "leak" in the high school to bachelor's degree transition with females representing about 47 percent of physics students in high school and about 21 percent of bachelor's degree recipients. After this initial leak, women are represented at about the levels we would expect based on degree production in the past. While it is true that the representation of women among full professors is lower than that for associate and assistant professors, it is also true that full professors earned their degrees earlier than the associate and assistant professors. Women are represented among the full professors at the rate one would expect given women's representation among degree recipients for the years during which they earned their degrees.

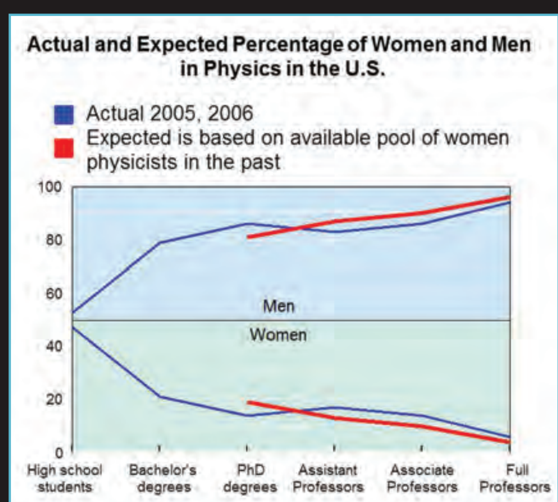


Fig. 6: Actual and expected numbers of women in physics at various levels.

Q

Are there any measurements that give concrete insight into some factors that have an effect on the participation of women in physics?

A

Until we do a longitudinal study of individuals, we will not be able to discuss factors that have an effect on the participation of women in physics. The results of the Global Survey of Physicists do draw attention to the need to focus on factors other than representation when discussing the situation of women in physics. For the first time, a multinational study was conducted with 15,000 respondents from 130 countries, showing that problems for women in physics transcend national borders. Across all countries, women have fewer resources and opportunities and are more affected by cultural expectations concerning child care. Limited resources and opportunities hurt career progress, and because women have fewer opportunities and resources, their careers progress more slowly. We also show the disproportionate effects of children on women physicists' careers when compared to male physicists' careers. Cultural expectations about home and family are difficult to change. For women to have successful outcomes and advance in physics, they must have equal access to resources and opportunities. //

References

Data for Figures 1 and 2 are from studies conducted by AIP's Statistical Research Center. All other data are taken from webcaspar (webcaspar.nsf.gov).

The time to a bachelor's degree is from the *Baccalaureate and Beyond Study* (B&B:08) conducted by the National Center for Education Statistics (nces.ed.gov/surveys/b&b). The time to doctorate is for physicists compiled by AIP's Statistical Research Center. It is not expected to be dramatically different for other science fields.

The 2005 study is *Women in Physics and Astronomy*, 2005, by Rachel Ivie and Kim Nies Ray (www.aip.org/statistics/trends/reports/women05.pdf).

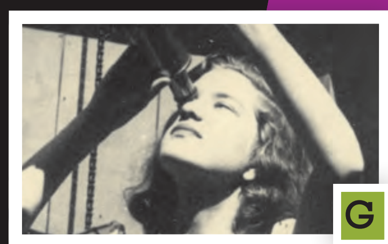
For more about the Global Survey of Physicists, see "Women in physics: A tale of limits" by Rachel Ivie and Casey Langer Tesfaye in the February 2012 issue of *Physics Today*.

For more information on the demographics of the physics community, see the AIP Statistical Research Center: www.aip.org/statistics.

Guess Who?

STUDENT SCIENTISTS FLASHBACK

These SPS-age physics students turned into some of the most influential physicists and astronomers in history. Can you match these distinguished scientists' photos from their college years with more recent photos on page 15?



PHYSICS FOR ALL

continued from page 2

we serve, to encourage dialogue in the study rooms and lounges and dorm rooms across the country, where all kinds of students struggle to define personal identities as contributors to science. We hope to be that quiet whisper that gives cause for young colleagues who come from different backgrounds, with different perspectives on science, different priorities, different cultural traditions, and maybe less importantly, with different genders—to engage in a simple conversation of inclusion and to be drawn in safely enough to wonder "why?" or "how?". Moreover, we hope to encourage everyone to become informed enough to begin to formulate a response to that question. Our aim is to have some influence in reshaping physics culture so that it naturally embraces and values inclusivity as critical to the success of the field. As all groups who have struggled in any position of "underrepresentation" know—this is a long, slow, tricky process. And, like all valid scientific processes, in order to make any progress, we must proceed by standing firmly grounded in the work of those who have come before us by studying the issue in great detail, by contributing to support networks, and by living it.

It is our responsibility to ensure that all our constituents and their friends and peers in physics are invited into the discussion that will, with the well-guided efforts of many, eventually become extinct as we all find common ground in the unity that physics is fascinating and fantastic and difficult and maddening and frustrating and sometimes even crushing and yet hauntingly inescapable — for lots of us, no matter our differences. //

Women's Words

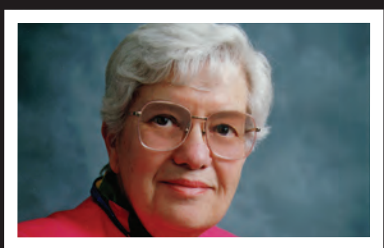
What is it like to be a woman in your physics department? We wanted to know what you think, so we compiled your answers from Facebook, Twitter, and email. The larger the word or phrase, the more common (or more liked) it was. Keep the conversation going by following us on Twitter: @SPS_physicsnews & @SPSwebster; or by liking us on Facebook: www.facebook.com/SPSNational.

Reaching for the top shelf
I love defying the odds!
Undervalued
I was doubted, then accepted
As a student, I'm outnumbered
Like being male, so far
Stressful
Humiliating
I love breaking gender roles
Swamped
Proud to be
Challenges abound, along with possibilities
Damn good
Fascinating
The few, the proud
Collaboration
Fabulous and well supported
I love it here
Gender hasn't been an issue
Physics will become more colorful
Like one of the guys
Opportunity
One of the team members
Physics is more interesting
Degrading
Completely alone, I stand out
Support and opportunity abounds
Bullied
Trivial
I'm one of many
Awesome environment for a woman
Showing the boys who's best
Sometimes empowering, others irritation inducing

01 MARIA MITCHELL (1818-1889) One of the first recognized female astronomers in the United States, she made a name for herself by discovering a comet at age 29. She spent much of her career on the faculty at Vassar College studying Jupiter and Saturn. Photo credits: page 14, US National Oceanic and Atmospheric Administration photo library; page 15, AIP Emilio Segrè Visual Archives.

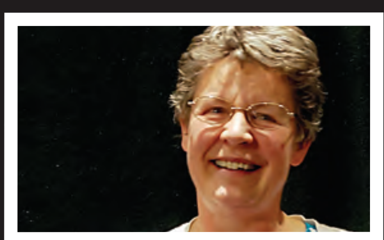
02 LISE MEITNER (1878-1968) A physicist known for her work in radioactivity and nuclear physics, she was part of the team that discovered nuclear fission. Her colleague Otto Hahn received the 1944 Nobel Prize in Chemistry for this discovery. Photo credits: page 14, US Department of Energy Public Affairs; page 15, photograph by Lotte Meitner-Graf, London, courtesy AIP Emilio Segrè Visual Archives.

03 LISA RANDALL (1962-PRESENT) The first tenured female physics professor at Princeton University, this well-cited theoretical physicist has also written popular science books on hidden dimensions and other mysteries of particle physics and cosmology. Photo credits: page 14, Society for Science & the Public; page 15, AIP Emilio Segre Visual Archives.

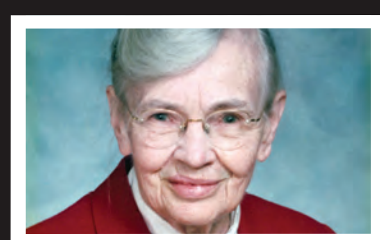


04 VERA RUBIN (1928-PRESENT) The work of this astronomer and honorary member of Sigma Pi Sigma on the orbital rates of hydrogen clouds in over 60 galaxies is often cited as the discovery that led to investigations into the existence of dark matter in the universe. Photo credits: page 14, Archives & Special Collections Library, Vassar College; page 15, AIP Emilio Segrè Visual Archives, Gallery of Member Society Presidents.

05 SAU LAN WU (1940s-PRESENT) This particle physicist played a key role in identifying the charm quark and the gluon, and more recently the Higgs particle announced in 2012. Photo credits: page 14, Archives & Special Collections Library, Vassar College; page 15, photo by Bob Palmer, courtesy of AIP Emilio Segrè Visual Archives.



06 JOCELYN BELL BURNELL (1943-PRESENT) An astrophysicist best known for her work on radio pulsars, the subject of the 1974 Nobel Prize in Physics, she is a longtime friend of SPS and Sigma Pi Sigma and has spoken at two Quadrennial Physics Congresses. Photo credits: page 14, Daily Herald Archive/ Science & Society Picture Library; page 15, photo by Ken Cole.



07 CHARLOTTE MOORE SITTERLY (1898-1990) This astronomer worked extensively on solar and atomic spectroscopy, responding to requests for data from colleagues into her eighties. Her books and tables on atomic energy levels and spectral lines are still widely used reference materials. Photo credits: pages 14 and 15, AIP Emilio Segrè Visual Archives, gift of Michael A. Duncan.

08 SHIRLEY ANN JACKSON (1946-PRESENT) This president of Rensselaer Polytechnic Institute was the first African American woman to earn a physics doctorate from MIT. She has done research at Fermilab, CERN, SLAC, and Bell Laboratories, and became the first woman and first African American to serve as chairman of the US Nuclear Regulatory Commission. Photo credits: page 14, The MIT Museum; page 15, AIP Emilio Segrè Visual Archives.

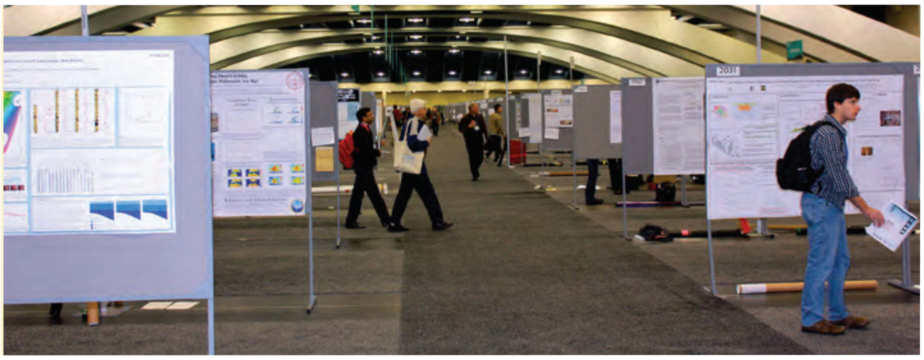
THANK YOU TO THE AIP EMILIO SEGRÈ VISUAL ARCHIVES, a part of the Niels Bohr Library & Archives of the American Institute of Physics, for helping research and compile many of these photographs. Special thanks to Lindsey Gumb. To see more photographs of your favorite physicists, visit the visual archives at http://photos.aip.org/.

KEY: 01: D 02: H 03: A 04: G 05: C 06: E 07: F 08: B

AGU: What a Week!

AMERICAN GEOPHYSICAL UNION FALL MEETING, DECEMBER 3–7, 2012, SAN FRANCISCO

by Lois Smith at the University of Colorado at Boulder



THIS SPRAWLING "SEA OF POSTERS" is a hallmark of the AGU meeting. Photo by Lois Smith.

After researching noctilucent clouds for almost two years, my advisor and I decided it was time for me to present at the American Geophysical Union (AGU) Fall Meeting, the largest geoscience conference in the world. More than 23,000 attendees from all over the world took over the Moscone Convention Center in downtown San Francisco for a week of science, collaboration, meetings, and, of course, fun!

My first "Wow, this conference is huge!" moment came on my flight to San Francisco, which had 30-plus poster tubes on board. It was clear that I was flying with others heading to the same meeting. The flight attendants debated dedicating an entire overhead bin to the poster tubes.

Once I got my bearings at this enormous meeting, I tried to focus on going to oral sessions, which feature fascinating and eye-opening presentations by well-established scientists. My first and favorite session was about using commercial space flights to launch discounted satellites for research purposes. This session inspired me, as an undergraduate on the brink of graduate school, to come up with several future projects. I took the opportunity to discuss my ideas with the presenters and other scientists afterward. If I learned anything this week, it was that collaboration is key for success!

You

SHOULD BE HERE

The AGU conference also gave me the opportunity to speak with several scientists I am interested in working with in graduate school. Walking up to someone at a conference, telling that person why you want to work with him or her, and citing some of your previous research sends a much louder message than an email with a curriculum vitae.

I received a great deal of positive feedback over the week and many exhortations to apply to various programs, some of which I had previously never considered. In fact, I was just about to rule out one program on my list when I spoke with a professor from

AAPT: The Gift of Perspective

AMERICAN ASSOCIATION OF PHYSICS TEACHERS WINTER MEETING, JANUARY 5–9, 2013, NEW ORLEANS

by Amelia Plunk at Northwestern University

When a former professor of mine reached out and asked if I would be willing to present at the American Association of Physics Teachers (AAPT) Winter Meeting, I was honored by the request. When he mentioned that I would be speaking on a panel regarding the Conference for Undergraduate Women in Physics (CUWiP), I nearly jumped out of my skin with excitement. While I was certainly pleased with the prospect of going to a conference I had never before attended, the idea of sharing with others the love I have for CUWiP was my true motivation for finding a way to get down to New Orleans.

What I was not expecting, however, was to fall in love with AAPT in a way that was completely foreign to me.

I have attended several conferences in the past, but none quite like AAPT. Where the American Physical Society March Meeting is enormous and can be intimidating, AAPT is compact and intimate. Where the Optical Society of America's Conference on Lasers and Electro-Optics (CLEO) is specific, attended by members of one small sect of physics, AAPT draws a diverse cross section of the physics community. And where CUWiP is comprised of mostly strangers, it is hard to find anyone at AAPT who does not know a handful of other attendees, if not many, many more.

While I was one of those few who arrived knowing only two others, by the time I left I had crafted several friendships I will not soon forget. I found that many other young that school who is doing the exact research I want to do. I was so impressed with his knowledge, background, and persona that the school jumped back on my list.

My poster session on Tuesday morning was quite an experience. Within a few minutes of putting up my poster, I was visited by several well-known scientists in my field, who asked many questions about my work. There was quite a bit of traffic throughout the day, and I was impressed by the feedback I received. I cannot wait to get back to my research and start working through all the ideas and possibilities people discussed with me at the AGU conference.

Overall, the conference was a terrific experience. I even met a scientist in the airport while heading back to Boulder. We spoke for more than an hour about research and life. Such connections make me a little less fearful about taking the plunge and heading off to continue my research in graduate school. //

NEXT UP

AGU's Meeting of the Americas will take place May 14–17 in Cancun. To learn more about it and other upcoming AGU meetings, visit http://sites.agu.org/meetings/.

LOIS SMITH stands atop a hill overlooking San Francisco. Photo by Anthony Rasca.

WELCOMING WOMEN

AGU "WOMEN IN SCIENCE" MIXER

by Lois Smith at the University of Colorado at Boulder

On Thursday evening more than 75 women squeezed into a room meant for 30 people to discuss, well, being a woman in science. My experiences at this event—and the rest of the conference—affirmed my belief I can do anything, regardless of my gender, and reminded me that there's an international support network of female scientists out there.

A graduate student in geophysics from the University of South Carolina gave me and an undergraduate from Columbia University terrific advice on graduate school. She spoke with us frankly, as if we were friends. In a conference as large as AGU, where you talk to complete strangers only for a few minutes, that kind of personal connection can be hard to find.

At the "Women in Science" mixer, AGU president Carol Finn and president-elect Margaret Leinen talked about how the number of women entering leadership positions in science organizations or becoming tenured faculty is on the rise. Most of AGU's council members this coming year are, in fact, female. One of my favorite conversations was one I had with Jenny Riker, the student representative on the AGU Council for the coming year. We talked about things that are not often discussed openly in many physics departments, such as when is the best time to have children in the life of a researcher.

As a young female scientist, I got the message "You should be here" at the AGU meeting. If this message can resonate throughout the rest of the science community and our school system, the future will be very bright for science. //

women attending AAPT had experienced feelings of being lost and alone at their home institutions as well as at other conferences. Renee Horton, an engineer at Samsung Rope Technology and an active

nity of students to build my horizontal network, but also to meet numerous accomplished female physicists who were more than willing to share their experiences and advice.

Previous to our meeting,

MY SIGHTS HAD BEEN SET ON A CAREER IN ACADEMIA

member of several physics communities, described during her presentation the feeling of walking into a room of physicists and "being the only" as overwhelming and terrifying. Many women have found their community and base of support at AAPT. I was blessed not only to find a commu-

The most valuable of my interactions was my introduction to Barbara Wolff-Reichert. On the second day of the conference I spotted her enthusiastically showing off her company's merchandise to curious onlookers, and I knew

continued on page 18

AMELIA PLUNK (right) poses with Barbara Wolff-Reichert in front of TeachSpin's booth at the vendor fair. Photo by Jonathan Reichert.

AAPT, *continued from page 17*

immediately that she and I would become fast friends. A graduate of Swarthmore College, she has long been an advocate for women in physics. After teaching at the high school level for many years, she joined her husband (whom she met at an AAPT meeting) in the development of TeachSpin, an advanced laboratory instrument development company. Barbara gifted me with an invitation to contact her at any time if I was in need of encouragement or advice.

Of all the trinkets and takeaways that I took home from AAPT, the most valuable gift was that of perspective. Previous to our meeting my sights had been set on a career in academia that would allow me to pass on my enthusiasm for physics to my students. I had long ago written off the idea of a career in industry as one in which I would be confined to an assembly line, trapped in a life of research and development. Barbara showed me, however, that through business one can affect the next generation of scientists in a completely different way. By making advanced laboratory equipment affordable and accessible, she is helping to open pathways to research careers that many students at smaller, less funded institutions might never have otherwise had access to.

Barbara's involvement in developing the next big names in physics is nothing short of inspirational. I hope that many more of my peers will be able to make the trip to small, intimate conferences such as AAPT, so that they may have the same opportunity to connect with pioneers in physics. //

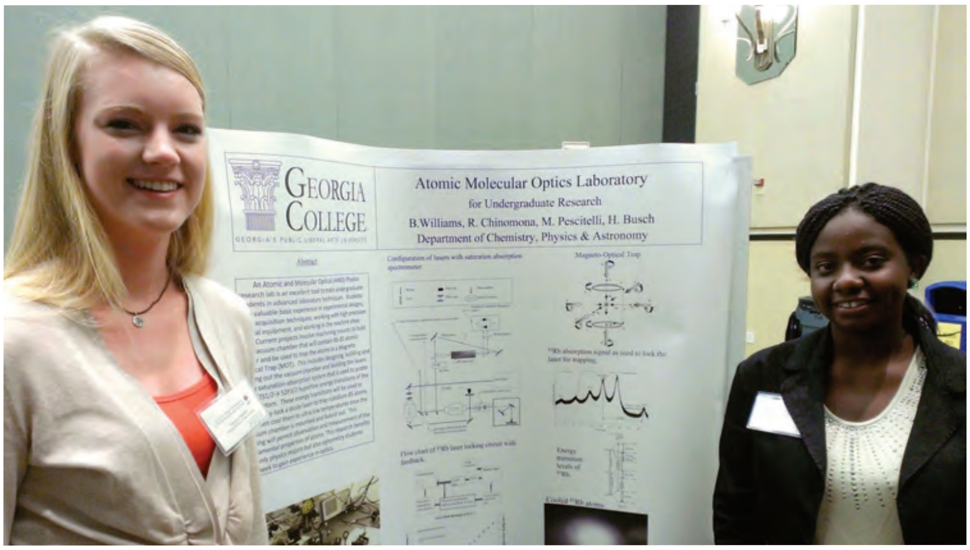
NEXT UP

The 2013 AAPT Summer Meeting will take place July 13-17 in Portland. Learn more at www.aapt.org/Conferences/sm2013/.

SCUWiP: Making Space

SOUTHEAST CONFERENCE FOR UNDERGRADUATE WOMEN IN PHYSICS, JAN. 18–20, 2013, UNIVERSITY OF CENTRAL FLORIDA

by Lily Udumukwu at the University of Miami



MONICA PESCITELLI AND RUJEKO CHINOMONA of Georgia College showcase their research during the student poster fair. Photo by Lily Udumukwu.

We all desire to be successful, so the best stories are those that celebrate success. At the Southeast Conference for Undergraduate Women in Physics (SCUWiP), where professionals from academia, industry, and government participated in a series of panel discussions, I was privy to a weekend-long banquet of telling testimonials. On the first full day, the conference commenced its schedule of events with stories of successful journeys and the obstacles encountered along the way from minorities and the minority's minority: women of color in the fields of science, technology, engineering, and mathematics (STEM). Although not all women, the panelists had all experienced what it felt like to be underrepresented in STEM.

"I remember bubbling with nervous energy when the day came for university recruits to attend the grad fair," said Peter Delfyett of the University of Central Florida. "Sweaty palms transferred my prized credentials to theirs, but all in all, I was well received." Seated before a sea of undergraduates, Delfyett and the other panelists held no reservations as they divulged personal experiences from when they were budding minorities in their fields.

After graduating from the City College of New York (CCNY), Peter Delfyett pursued

If you want it bad enough, YOU'LL MAKE IT HAPPEN

graduate studies for three years at one school before transferring back to CCNY to complete his PhD. He recalled the enthusiasm admissions personnel at that first school had displayed toward his prospective candidacy.

> I remember how enthusiastic I was, gaining acceptance into this prestigious school, and at the time of my application, it seemed like they were happy too. But it was very different once I was there; there was a moment I remember walking down the hallways of my department after studying judiciously for a test, alone. I peered through a window and could see a bunch of guys in my class engaged in a group study meeting that I wasn't invited to.

Marta McNeese of Spelman College extended those sentiments, mentioning that she is often mistaken for a custodial employee at national conferences and pestered with questions about the whereabouts of bathroom facilities. Far too often, we lose potential scientists, engineers, and pioneers in STEM fields because of biases operating at an unconscious level—petty, yet powerful predispositions.

"Throughout my studies it was like chipping away at an iceberg with a toothpick," said Cecille Labuda of the University of Mississippi. "As women we are already the minority, but as a foreign native there was additional pressure to prove myself." Born in the island nation of Dominica, Labuda reinforced the importance of perseverance, stating that if you want it bad enough, you'll make it happen and everything else, obstacles mental or otherwise, will become background noise.

"It's like *Whistling Vivaldi*," she explained. In this book, which studies the negative effects of stereotypes, especially in education, an African American whistles classical music (composed by Vivaldi) to dispel any unease his counterparts anticipated in his presence.

This portion of the Southeastern Conference for Undergraduate Women in Physics illuminated the progress women have made in the historically male-dominated fields of science, technology, engineering, and mathematics. Undergraduates were also exposed to the discouraging bias often present in the collegiate environment and the lack of diversity among women in STEM fields.

The attendees were also, and more importantly, encouraged to succeed. Despite changing schools, Delfyett holds 34 US patents, has published over 600 articles in refereed journals, and is a recipient of the National Science Foundation Presidential Faculty Fellow Early Career Award for Scientists and Engineers, awarded to the nation's top 20 scientists each year. McNeese earned her PhD at MIT and in 2000 made the decision to join the faculty at Spelman College, a historically black college. Her desire is to champion the field of physics as a viable career option for African American women. Labuda earned a bachelor's, master's, and PhD in physics, and as a professor at the University of Mississippi, her research interests are supported by the National Institutes of Health.

Whether it is by accomplishing one's studies at a more fitting institution, purposefully ignoring biased profiling, or whistling a classical tune, the underrepresented must find a means to persevere and make gains. Stereotypes are perhaps an inherent challenge of living in a diverse society, and to combat them we must stake a claim to our interests. //

BETH CUNNINGHAM, president of AAPT, chats with a student during the meeting's industry fair. Photo by Lily Udumukwu.

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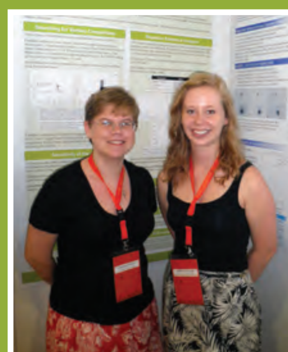

Photos by SPS reporter Stephanie Douglas, Franklin & Marshall College.

Diffraction, Part 1

HUYGENS' PRINCIPLE AND YOUNG'S EXPERIMENT

by Dwight E. Neuenschwander, Southern Nazarene University

WAVES ARE DIFFRACTED around a rocky outcrop. Photo by Wing-Chi Poon.

Like a test pilot pushing an airplane prototype to the limits of its capabilities, physics seeks Nature's fundamental limits and then pushes them as far as possible. For instance, special relativity implies that no information can travel faster than the speed of light. Quantum mechanics holds that the more precisely we know a particle's momentum, the less precisely we can know its location. The second law of thermodynamics asserts that the efficiency of any two-temperature engine cannot exceed that of the idealized Carnot engine, and the third law of thermodynamics implies that a system cannot be cooled to absolute zero in a finite number of steps. In optics, diffraction limits the maximum resolution of a telescope and the minimum size of a computer chip circuit made by mask-and-etch techniques.

Diffraction is the spreading out of a wave into regions that would otherwise be in shadow. A beam of light, even one as tightly concentrated as that emerging from a laser, spreads out as it travels, creating a sizable spot when it reaches the opposite side of a room. Such displays of diffraction offer clear evidence that light, sound, and other signals can behave as if they are waves.

Diffraction can be casually observed in water waves sweeping around a buoy, or in sound waves passing through a doorway. To observe diffraction with visible light takes more care. Ever since antiquity, people have wondered "What is light?" By the time of Robert Hooke (1635–1703), Christiaan Huygens (1629–1695), and Isaac Newton (1642–1727), responses to the question had been reduced to a binary choice: Is light a wave, or is it a beam of particles? Hooke and Huygens argued for waves, Newton for particles. Hooke pointed out that producing a specific color in thin-film interference requires choosing a specific film thickness, analogous to tuning the harmonics of an organ pipe by adjusting its length. Clearly something periodic occurs with light. Newton observed the variable thin-film interference we now call "Newton's rings."[1] However, he argued that periodicity is not *inherent* in light, but is *put into* light by its interaction with matter.

Noting the blazing speed of light, Huygens argued that, although bulk matter does not travel so fast, a wave might be able to, as illustrated with a row of marbles struck sharply at one end. The marbles do not move in bulk, but an impulse propagates swiftly down the row. Huygens developed a general model for wave propagation around a basic assumption we now call Huygens' principle. It asserts that each point on a wave front serves as the source of a subsequent wave (Fig. 1a).

Diffraction is the spreading out of a wave

INTO REGIONS THAT WOULD OTHERWISE BE IN SHADOW

The laws of geometrical optics follow from Huygens' construction. Significantly, Huygens' principle also predicted that waves necessarily diffract (Fig. 1b), as point sources on a wave front near the edge of an aperture send radiation into regions that otherwise would be in shadow.

Settling the argument in favor of waves required a demonstration of diffraction. Francesco Grimaldi (1618–1663) was evidently the first to do such a demonstration when he placed thin objects such as needles in beams of light and observed fine fringes at the edges of the objects' shadows. But the evidence was not universally convincing, especially not to Newton, whose large influence helped to advance the particle model over the wave model.

Consensus began to build in 1801 when Thomas Young (1773–1829) conducted experiments similar to Grimaldi's using a "slip of paper about one-thirtieth of an inch in breadth." Satisfied that diffraction was real, he then set out to measure the wavelength of light by allowing a beam of monochromatic light to pass through two small apertures. Upon emerging, the light from one aperture spread out by diffraction and overlapped

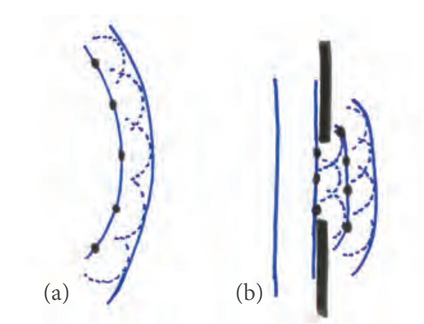

FIG. 1: (a) Huygens' principle. Note that the Huygens construction neglects the backward-propagating wave, which had to be reconciled in mathematical versions of the principle using propagator theory. (b) Huygens' principle predicts diffraction.

with the light diffracting from the other aperture. At a given point on a screen placed opposite the apertures, the total signal was a superposition of the undulating light from both apertures, which produced interference. From the intensity pattern, Young measured the wavelength of visible light. It turned out to be macroscopically tiny (400–750 nm), explaining why the diffraction of visible light is not casually obvious.

As Young's experiment illustrates, interference occurs because diffraction spreads the two emerging beams of light into overlapping regions. But diffraction itself relies on interference between secondary waves emitted from points on the primary wave fronts, as envisioned by Huygens' principle. Interference and diffraction are not independent phenomena.

The pattern of water surface waves diffracting around a buoy carries information about the buoy's size and shape. Diffraction measurements are thus scattering experiments consisting of three components: waves, an obstacle or aperture with which the waves interact, and an image formed on a screen or film or charged-coupled device. If you know any two of these elements you can infer the third. For instance, if you have measurements of the aperture and the image (which is essentially the Fourier transform of the aperture or obstacle), you can deduce attributes of the radiation, such as the wavelength in Young's experiment. Conversely, diffraction was crucial in deducing the helical structure of DNA, as articulated in 1953 by Francis Crick and James Watson, who were guided by an X-ray photograph of the DNA (the obstacle) taken by Rosalind Franklin 1951. From the X-rays' wavelength and measurements made from the image, the double-helix structure could be inferred. That hint, and knowing the lengths of adenine-thymine bonds and guanine-cytosine bonds, allowed Crick and Watson to assemble a detailed model of DNA.

FRAUNHOFER AND FRESNEL DIFFRACTION

As a wave travels from sources to screen, how does its energy get redistributed? What we see on the screen is not the wave function itself but its intensity—the time-averaged power carried by the total wave function. Since a wave's energy is proportional to its amplitude squared, the amplitude will vary with distance. Let us see how this works.

Consider a point source emitting a wave. If no waveguides, obstacles, or apertures interact with the wave, then its rays (normal to the wave fronts) propagate radially outward in all directions from the source point. By definition, the luminosity L of that source is its time-averaged radiated power. The energy carried by the wave, emitted by the point source during an infinitesimal time interval dt, spreads out over the area of a spherical surface with a radius that grows as the wave moves outward. The intensity I of the signal is the local time-averaged power per unit area received by a detector.[2] For an observer located a distance r from an unobstructed point source, the relation between received intensity and emitted luminosity is

$$I = \frac{L}{4\pi r^2} \quad (1)$$

For light understood as a wave in an electromagnetic field, the intensity must also be related to the electric and magnetic field amplitudes. As shown in electrodynamics, the observer of an electromagnetic field receives an intensity numerically equal to the time average of the magnitude of Poynting's vector $\mathbf{S} = \mathbf{E}\times\mathbf{B}/\mu_o$, where **E** and **B** denote the electric and magnetic fields, respectively, with μ_o being the permeability of vacuum. Since waves can be written as a superposition of harmonics, one should consider a monochromatic sinusoidal wave, where **E** and **B** have amplitudes E_o and B_o. The harmonic variation in space and time enters through the factor $\cos(kr-\omega t)$, in which k is the wavenumber, ω the angular frequency, r the distance from the source, and t the time. Noting that **E** and **B** are in phase and mutually perpendicular, time-averaging $|\mathbf{S}|$ over one period yields

$$[|\mathbf{S}|] = \frac{1}{\mu_o}\int_0^T E_o B_o \cos^2(kx-\omega t)\frac{dt}{T} = \tfrac{1}{2} E_o B_o/\mu_o \quad (2)$$

The period is $T = 2\pi/\omega$, and the square brackets denote a time average. Comparing this result to Eq. (1), we see that the amplitude for spherically propagating radiation varies spatially as $1/r$.

With Euler's formula

$$e^{i\theta} = \cos\theta + i\sin\theta \quad (3)$$

where $i^2 = -1$, complex numbers can alternatively be employed to describe a harmonic wave function. $\psi_o\cos(kr-\omega t)$ gets replaced with $\psi_o e^{i(kr-\omega t)}$, with the understanding that the real part of the complex number describes the physical signal. In the language of complex variables, the result of Eq. (2) will be retained if we write

$$I = \tfrac{1}{2}|\mathbf{E}^*\times\mathbf{B}|/\mu_o = \tfrac{1}{2} E_o B_o/\mu_o \quad (4)$$

with * denoting the complex conjugate.

When the distance r in Eq. (1) is sufficiently large (the "far field"), the wave front passing over the observer is locally indistinguishable from a plane. Diffraction produced by plane waves is called Fraunhofer diffraction, named after spectroscopist Joseph Fraunhofer (1787–1826). When the spherical curvature of the wave front is taken into account (the "near field"), the ensuing diffraction is called Fresnel diffraction after Augustin Fresnel (1788–1827), who, independent of Young, extensively developed the wave model of light, beginning around 1815.

In the remainder of the present article we will examine Young's experiment. This exercise offers a prototype in terms of plane waves for procedures and ways of thinking that will be employed in this series on diffraction. In the next article, we will stay for awhile within the Fraunhofer paradigm, extend Young's experiment to multiple point sources, and let the sources blend continuously into a single slit aperture. We will derive the diffraction pattern produced by a single slit and relate it to the pattern produced by an opaque ribbon. Since Young's apparatus involved a pair of narrow slits and not point sources, we will study the diffraction pattern produced by two identical slits. The result will illustrate the elegant array theorem, which holds that the image produced by an array of N identical apertures equals the diffraction pattern of one aperture multiplied by the interference pattern of N point sources.

Then we will consider the diffraction produced by rectangular and circular apertures. The latter is important because human beings view the world through circular apertures—the pupils of our eyes—not to mention the circular apertures in cameras, telescopes, and microscopes. Before leaving Fraunhofer diffraction we will explain what it means to say that the image on the screen is the Fourier transform of the aperture.

Moving on to the complications that arise when taking into account the spherical curvature of wave fronts, we will study Fresnel diffraction. Here we will meet a classy tool for reducing complicated definite integrals to distances on a chart—the Cornu spiral.[3]

Diffraction is an old subject, now part of the furniture of physics. Still, it would be difficult to find many contemporary research topics or high-tech applications that do not depend on it in some way. We should not take for granted its elegant and useful analytic tools. Today we rely on those tools, which were mostly developed during the nineteenth century.

YOUNG'S EXPERIMENT

Between 1801 and 1803 Thomas Young, a British medical doctor, Egyptologist, and physicist (although the term "physicist" did not exist in 1800), performed a double-slit experiment repeated in introductory physics laboratories to this day. Young's experiment cleanly demonstrated the wave nature of light. That was how light was subsequently understood until Einstein's light quanta paper in 1905 presented the utility of a complementary particle model. From the wave-particle duality of quantum mechanics that matured in the 1920s, we now know that Nature does not neatly partition all of its structures and interactions into the binary categories of particle or wave. Instead of asserting that light is a wave, we now say that in some situations light behaves as if it were a wave, but in other situations it behaves is if it were a beam of particles. Particles and waves are analogies for describing light (and electrons—nature is symmetric in these matters). In discussing diffraction one operates within the wave paradigm.

Turning to the details of Young's experiment, we can conceptualize the experiment as the diffraction produced by two point sources emitting coherently, in phase, and with equal amplitude. The experimental setup is shown schematically in Fig. 2.

The two point sources are separated by distance a, with the screen located distance D away. Field points on the screen are mapped by the coordinate s, with $s = 0$ describing the point on the screen opposite the midpoint between the two sources (the sources and s axis are coplanar). To emit coherently means the phase difference between the sources upon emission remains constant, which is realized in practice by having a single beam of monochromatic light illuminate both apertures. To emit in phase means the phase difference at emission equals zero.

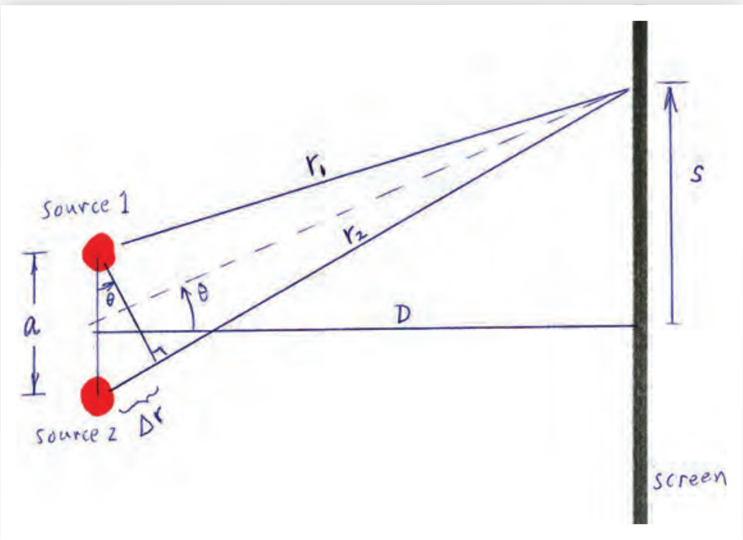

FIG. 2: Schematic of Young's experiment. In practice, $D >> a$ and s, so that $\sin\theta << 1$. Note that the lines of length r_1 and r_2 are then approximately parallel.

After leaving the apertures, the signals from both apertures spread out and add together to make a pattern on the screen. At time t some of the net signal arrives at a location on the screen having the coordinate s. The part of the total signal arriving there that came from source one traveled along a ray of length r_1, and the signal that came from source two traveled the distance $r_2 = r_1 + \Delta r$. Upon their arrival at s, the separate signals have acquired a phase difference, causing interference when they add together. Assuming equal amplitudes upon emission, by superposition the total wave function $\psi(s,t)$ (= |**E**| or |**B**|) arriving on the screen at location s at time t is

$$\psi(s,t) = \psi_o(r_1)\cos(kr_1 - \omega t) + \psi_o(r_2)\cos(kr_2 - \omega t) \quad (5)$$

with $\psi_o(r_1)$ and $\psi_o(r_2)$ denoting the amplitudes of the waves where they arrive at the screen. The amplitudes vary as $1/r$, but $(1/r_2) - (1/r_1) \sim \Delta r/r_1^2$, which is negligible. Abbreviating $kr_1 - \omega t \equiv \alpha$, Eq. (5) may be written

$$\psi(s,t) = \psi_o[\cos(\alpha) + \cos(\alpha + \delta)] \quad (6)$$

which introduces a phase shift δ. For the Young experiment δ is acquired from the path difference,

$$\delta = k\Delta r. \quad (7)$$

More generally, δ can also be caused by various other mechanisms, such as half-cycle phase shifts due to reflections or a time delay from the waves passing through different refractive media.

Our mathematical problem is to write the sum of the two cosines in a way that can be interpreted. We may choose between three equivalent methods: trigonometry identities, complex numbers, or phasor diagrams. Let us pursue all three to illustrate the diversity of techniques that will prove useful in various diffraction problems.

With trig identities, one uses the clever trick of adding and subtracting ½δ in the first term,

$$\cos(\alpha) + \cos(\alpha + \delta) = \cos[\alpha + \tfrac{1}{2}\delta - \tfrac{1}{2}\delta] + \cos[\alpha + \tfrac{1}{2}\delta + \tfrac{1}{2}\delta] \quad (8)$$

then abbreviates $\alpha + \tfrac{1}{2}\delta \equiv \varphi$. By the trig identities for the cosine of a sum or a difference, this becomes

$$\psi(y,t) = 2\psi_o \cos(\tfrac{1}{2}\delta)\cos(\varphi + \tfrac{1}{2}\delta). \quad (9)$$

Using complex numbers Eq. (6) gets replaced with

$$\psi_o[e^{i\alpha} + e^{i(\alpha+\delta)}] = \psi_o e^{i(\alpha+\delta/2)}[e^{-i\delta/2} + e^{i\delta/2}]$$
$$= 2\psi_o e^{i(\alpha+\delta/2)}\cos(\tfrac{1}{2}\delta).$$

The real part corresponds to the physical signal:

$$\psi(s,t) = 2\psi_o \cos(\tfrac{1}{2}\delta)\cos(\varphi + \tfrac{1}{2}\delta). \quad (10)$$

For the phasor diagram approach, pretend the cosine terms in Eq. (6) are x components of vectors. Vectors that represent such signals are called phasors.[3] One adds the phasors via usual vector addition and finds the x component of the resultant to get the total wave function (see Fig. 3).

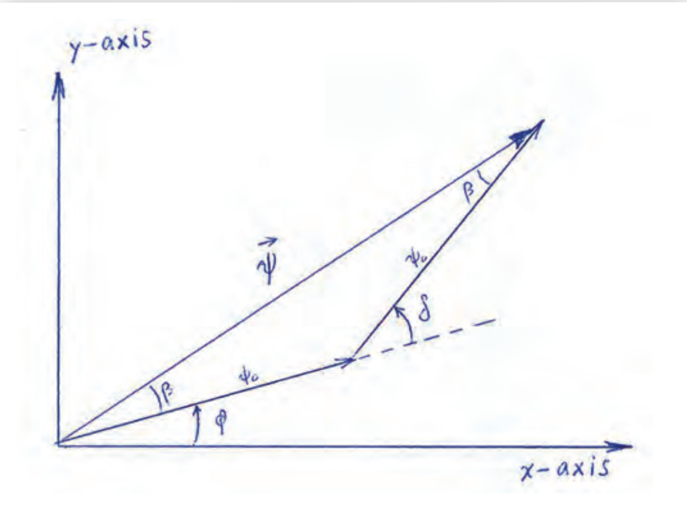

FIG. 3: Phasor diagram construction. Equation (6) is considered the *x* component of this vector sum.

Apply the law of cosines to $\psi = \psi_1 + \psi_2$:

$$|\psi|^2 = \psi_o^2 + \psi_o^2 - 2\psi_o^2 \cos(\pi - \delta)$$

$$= 2\psi_o^2 (1 + \cos \delta). \qquad (11)$$

The trig identity $1+\cos \delta = 2\cos^2(½\delta)$ yields $|\psi|^2 = 4\psi_o^2 \cos^2(½\delta)$. The *x* component of the resultant, the physical total wave function, becomes

$$|\psi_x| = 2\psi_o \cos(½\delta) \cos(\beta + \varphi). \qquad (12)$$

The triangle formed by ψ_1, ψ_2, and ψ shows that $2\beta + (\pi - \delta) = \pi$, and thus

$$\psi(s,t) = 2\, \psi_o \cos(½\delta) \cos(\varphi + ½\delta)\,. \qquad (13)$$

All three approaches give the same answer, as they must, since they are different ways of doing the same thing. However you compute it, the total wave function arriving at *s* oscillates harmonically in time, weighted by the effective amplitude:

$$\psi_{o(\text{eff})} = 2\, \psi_o \cos(½\delta). \qquad (14)$$

By virtue of Eq. (2), the intensity is (see Fig. 4)

$$I(s) = 4\, I(0) \cos^2(½\delta). \qquad (15)$$

Intensity maxima, $I(s) = 4I(0)$, occur where $\cos(½\delta) = \pm 1$ so that $½\delta = \pi n$, with $n = 0,1,2,\ldots$. Intensity minima, $I(s) = 0$, occur where $\cos(½\delta) = 0$ and thus $½\delta = (2n' + 1)\pi/2$ with $n' = 0,1,2,3,\ldots$. For δ due to a path difference, recalling that $k = 2\pi/\lambda$ with λ the wavelength, those results give $\Delta r = n\lambda$ for maxima and $\Delta r = (n' + ½)\lambda$ for minima. In practice Δr is too small to measure directly with a meter stick. But since $\theta << 1$, Δr may be written, using the similar triangles in Fig. 2, in terms of easily measurable parameters:

$$\Delta r = a \sin \theta \approx a \tan \theta = a\, s/D. \qquad (16)$$

With this method, Young's experiment facilitates measuring the wavelength of light.

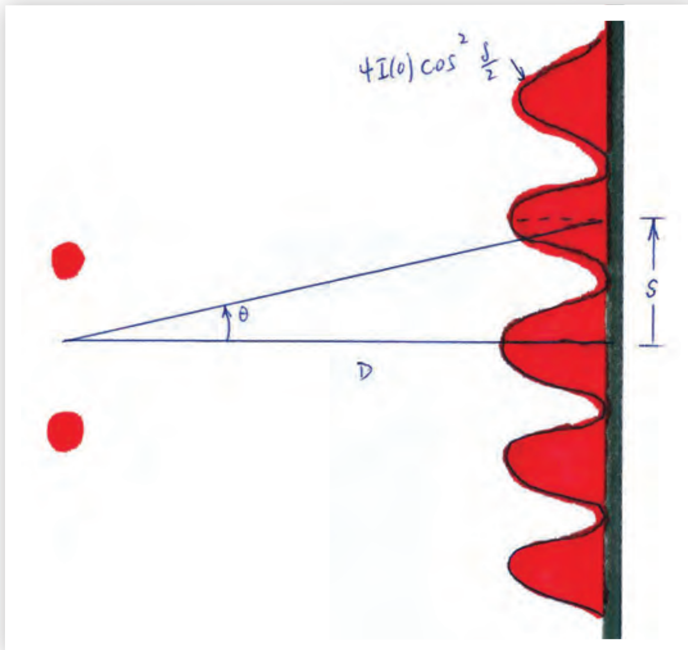

FIG. 4: The intensity pattern in Young's experiment.

The radiation has so far been assumed to be coherent, which means that δ remains constant in time. If the sources emit radiation incoherently (i.e., random emission at the sources), then δ varies randomly with time, so $\cos^2(½\delta)$ varies randomly between 0 and 1 and averages to ½. Now Eq. (15) reduces to the uniform illumination $I(s) = 2I(0)$. Two identical candles emitting radiation incoherently merely double the intensity of one, and no interference patterns appear.

In the next installment we will recall that the sources in Young's experiment are not really point sources but have finite sizes. Thus to examine a double slit we must first study in detail diffraction from a single slit. Guided by Huygens' principle, our first intermediate step will be to generalize the interference from two point sources to that of multiple point sources. The Huygens wave front coming through the slit can then be considered the limit of an infinite number of infinitesimally small sources. //

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[1] Place a spherical lens on flat glass and shine monochromatic light on it from above. The rings of maxima and minima you see in the curved wedge of air between the lens and the glass sheet are Newton's rings.
[2] Some authors call *I* the irradiance because it is the average power per area being absorbed, the opposite of radiance. This term can, however, be confusing. "Irrational" implies "not rational," possibly leading one to ask how irradiance could measure the brightness of a light source.
[3] The Cornu spiral is an elaborate phasor diagram.

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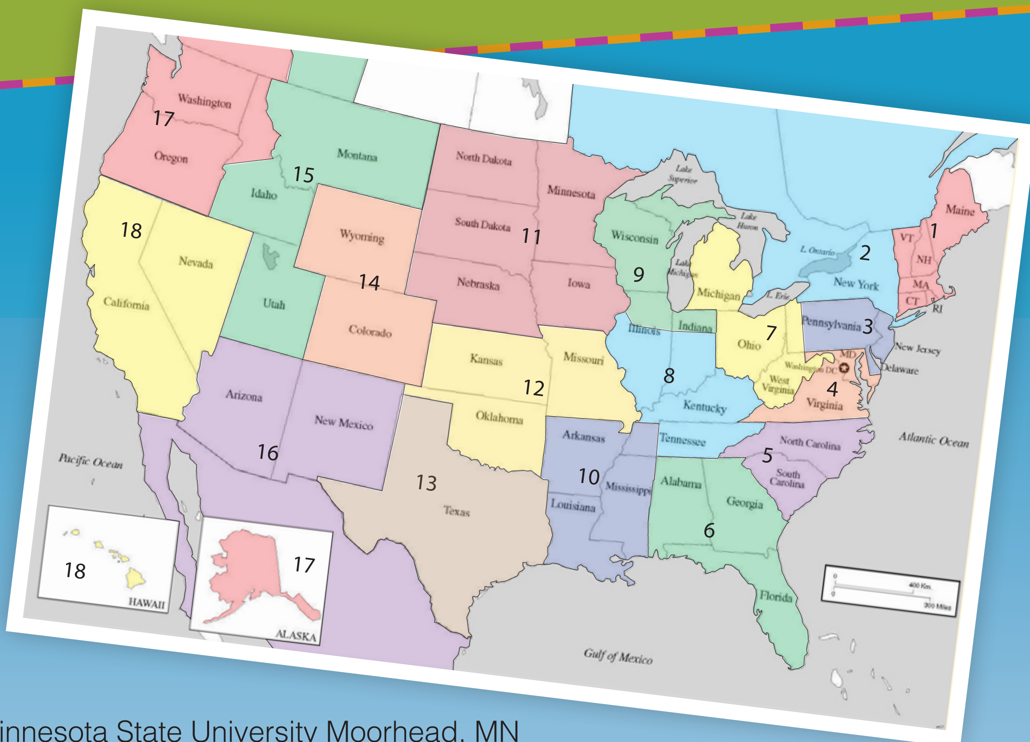

ZONE 11: March 1-2 at Minnesota State University Moorhead, MN
ZONE 15: March 15-16 at Utah Valley University in Orem, UT
ZONE 7: March 15-16 at Eastern Michigan University in Ypsilanti, MI
ZONE 13: April 4-6 at Tarleton State University, Stephenville, TX
ZONE 10: April 5-6 at the University of Mississippi in Oxford, MS
ZONE 12: April 5-6 at the University of Missouri in Kansas City, MO
ZONE 17: April 5-6 at Washington State University, Pullman, WA
ZONE 2: April 6 at the University of Rochester in Rochester, NY
ZONE 14: April 12-13 at Auraria Campus in Denver, CO
ZONE 6: April 12-14 at the University of Central Florida in Orlando, FL
ZONE 8: April 12-14 at the University of Tennessee, Knoxville, TN
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