The SPS Observer

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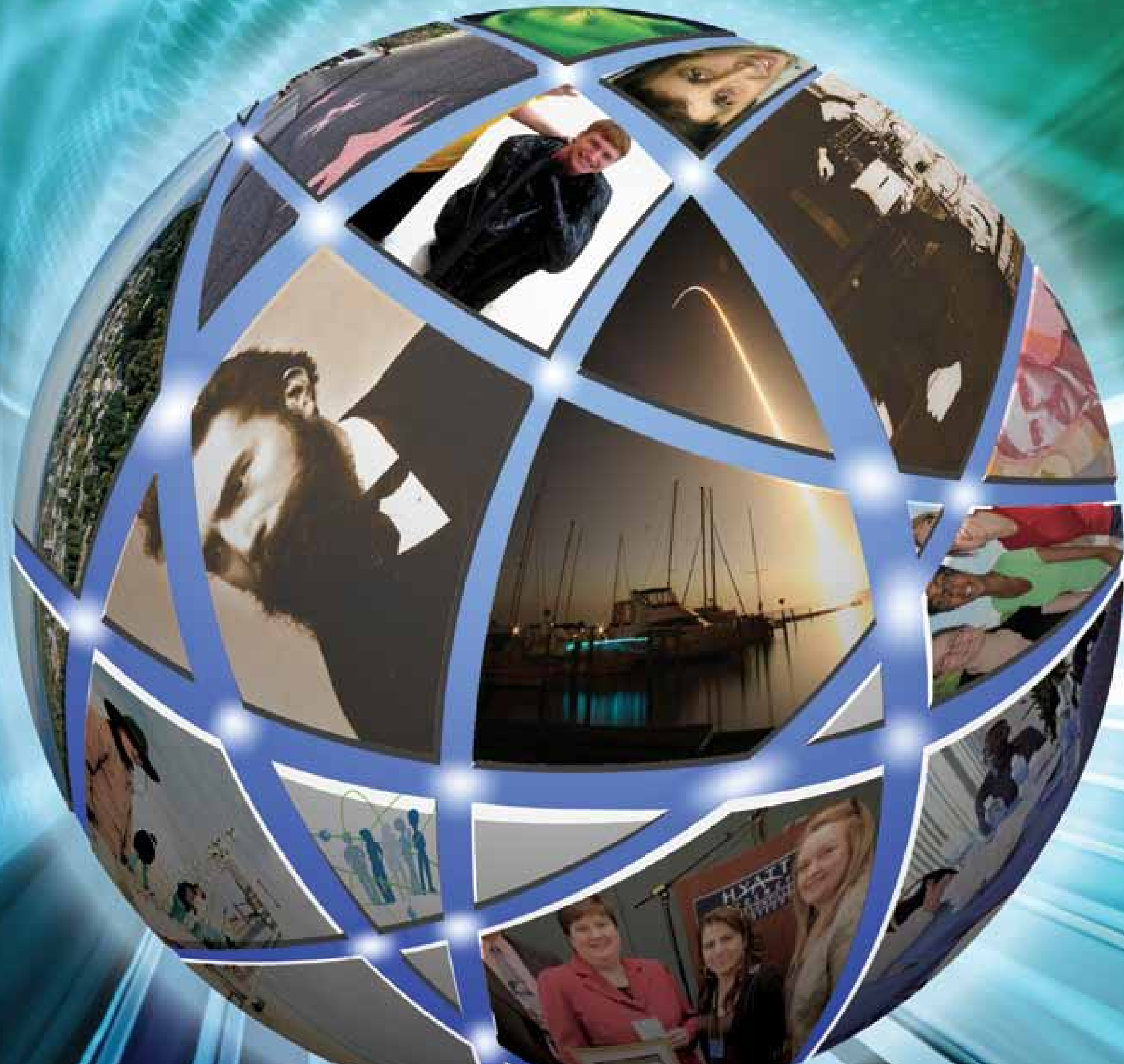
Celebrating a Century of Revolution



The **SPS Observer**

Inside This Issue

About the Cover:
Artwork by Tracy Schwab
In 1911 a loaf of bread was about 8 cents, Cal P. Rodgers made the first transcontinental airplane flight across the United States, and Ernest Rutherford proposed the existence of the atomic nucleus. This year, SPS celebrates the century of revolution that has followed, and the many people, innovations, and discoveries that have brought us to where we are.

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A Century of Revolution

By Greg Topasna and the 2011 SPS Theme Committee of the SPS National Council

This year marks the one hundredth anniversary of the discovery of the atomic nucleus by Ernest Rutherford. In a groundbreaking 1911 paper,[1] Rutherford interpreted the results of a gold foil experiment carried out by his students Hans Geiger and undergraduate Ernest Marsden in 1909. Rutherford expected only slight deflection of alpha particles fired at a thin gold foil, but what they discovered shocked and amazed him. Remarking on the alpha particles that bounced back, Rutherford said, "… it was like firing a 15 inch shell at a sheet of tissue paper and having it bounce back." He interpreted these experimental results as showing that the nucleus of the atom is concentrated in the center with the electrons "orbiting" about it.

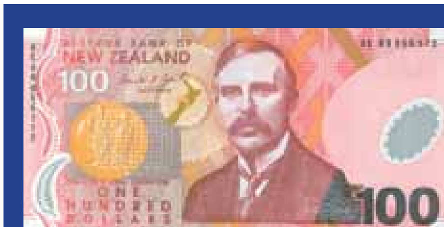
While Rutherford may have been shocked and amazed, what is truly more amazing is the revolution in innovation and discovery that nuclear science has provided since then. Through our knowledge of the nucleus and nuclear processes we have been able to understand the inner workings of stars, harness the energy of the atom to provide nuclear power, and enjoy the improvement in our lives that nuclear medicine makes possible. We are truly the beneficiaries of the work of countless numbers of women and men these past one hundred years.

In recognition of this remarkable event and the discoveries that have followed, the Society of Physics Students has selected as its 2011 theme "A Century of Revolution," to honor the one hundredth anniversary of the discovery of the atomic nucleus. Throughout the coming year, let us each explore the many remarkable and varied ways nuclear science has benefitted humankind and the possibilities the future may hold.

1 "The scattering of alpha and beta particles by matter and the structure of the atom," *Philosophical Magazine*, vol. 21, pp. 669–688 (1911).

Editor's Note:

The above statement of the 2011 SPS Theme Committee was written and approved before the recent earthquake and the tsunami devastated Japanese coastal towns and overwhelmed the Fukushima Nuclear Plants. In this issue we celebrate the discovery of the nucleus by Ernest Rutherford. A generation afterwards J. Robert Oppenheimer observed, "It is a profound and necessary truth that the deep things in science are not found because they are useful; they are found because it was possible to find them." Like all technologies, nuclear energy brings risks. The devastating tsunami and the Fukushima reactor crisis remind us—again—that we are part of nature, not detached from it. If society continues its dependence on centralized sources of electricity, in the long run nuclear power will be here to stay. As Freeman Dyson has written, "Whoever concerns himself with big technology, either to push it forward or to stop it, is gambling in human lives." Our hearts go out to the victims of the tsunami, and those accepting the risks of helping them.



Lord Rutherford

Ernest Rutherford, who became Lord Rutherford of Nelson, was born in 1871 in Nelson, New Zealand. In 1894 he went to England to do research at Trinity College, Cambridge, after finishing university in New Zealand. At Cambridge he did work with Prof. J. J. Thomson on radioactivity, which led to Rutherford's famous gold foil alpha-scattering experiments and the discovery of the nucleus of the atom. These experiments were done at Manchester University. Eventually, he succeeded J. J. Thomson as director of the Cavendish Laboratory at Cambridge in 1919. Besides Lord Rutherford, the face of the $100 note from the Reserve Bank of New Zealand has a vignette of his Nobel Prize and what appears to be a plot of his data.

—Excerpted with permission from 20th Century Physicists on Banknotes by Steve Feller (Fall 2010 issue of *Radiations* magazine)

To Err is Human (or Seeing Stars)

by Tracy Schwab, SPS Communications Coordinator

Back in the early 1970s, when I was growing up in the small and somewhat isolated ranching town of Cokeville, Wyoming, summertime usually meant a family vacation, road-trip style. My parents would pile my brother, two sisters, and me in our iconic red Volkswagen bus, and we'd hit the pavement. One of the highlights was a trip to see my Aunt Beth, who lived in Los Angeles, CA. For a mostly hick five-and-a-half-year-old country boy, the prospect of spending a week in California was wildly exciting. Disneyland, the Pacific Ocean, and the San Diego Zoo were all on the agenda—and my anticipation grew by leaps and bounds when my Aunt mentioned that she'd be sure to take us kids for a ride in her convertible to "see the stars on the sidewalks" in Hollywood once we arrived.

Holy cow! I was absolutely thrilled—and star-struck! I spent the next few weeks day-dreaming about who we might see once we got there: John Wayne? Carol Burnett? Burt Reynolds? Sonny and Cher? The possibilities were limitless, as was my imagination at the time. Picture my disappointment when the much-anticipated day came. We hopped in my aunt's sleek, maroon 1962 Pontiac Catalina convertible, she put on a pair enormous sunglasses and a scarf, and we drove by block after block of virtually empty sidewalks. No famous actors coming and going from the restaurants, no legends milling about, no autographs, handshakes, or "photo ops" to be had—just other tourists looking at the pink and bronze "stars" embedded in the sidewalks along Hollywood Boulevard.

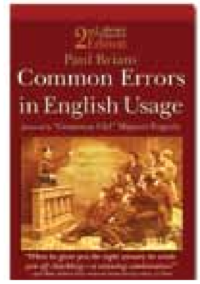
Stars on The Hollywood Walk of Fame.

It's likely that most of us have experienced a similar episode of, if you'll forgive me, "mistaken identity" at some point in life. After all, English has a lot of words. Many of them look alike, sound alike, or, worse yet, look and sound alike but have completely different meanings. Other words look and sound different but are similar in meaning, and it can be difficult to figure out which is the correct one in a given context.

In that spirit, we've secured permission to share some excerpts from Professor Paul Brians' website, *Common Errors in English Usage*, that you may run across as a student of the physical sciences, or in life in general.

Image courtesy of Beth Merritt-Zelenko

My Aunt Beth in her 1962 Pontiac Catalina (front seat) with my cousins Becky, Ari, and Josh at Venice Beach, CA.



*360 degrees/180 degrees

When you turn 360 degrees you've completed a circle and are back where you started. So if you want to describe a position that's diametrically opposed to another, the expression you want is not "360 degrees away" but "180 degrees away."

*Exited/Excited

A lot of people get so excited when they're typing that they mistakenly write they are "exited," and their spelling checkers don't tell them they've made an error because "exited" is actually a word, meaning "went out of an exit." Excitement makes you excited.

*Light-Year

"Light-year" is always a measure of distance rather than of time; in fact it is the distance that light travels in a year.

*Phenomena/Phenomenon

There are several words with Latin or Greek roots whose plural forms ending in A are constantly mistaken for singular ones. See, for instance, criteria and media and data. It's "this phenomenon," but "these phenomena."

*Rate, Speed

Lots of people like to say things like "traveling at a high rate of speed." This is a redundancy. Say instead "traveling at a high rate" or "traveling at high speed."

*Resister/Resistor

A resistor is part of an electrical circuit; a person who resists something is a "resister."

And, in light of this year's SPS theme, we throw in one of our own:

Nuclear/Nucular

Nuclear refers to something of, related to, or constituting a nucleus. Nucular is the incorrect pronunciation of nuclear that incites scientists worldwide to bang their heads against the closest wall.

*Excerpted from *Common Errors in English Usage*, by Paul Brians, Emeritus Professor of English, Washington State University, http://www.wsu.edu/~brians/errors/.

Celebrating Achievement in Physics

In the Fall 2010 issue of the SPS Observer, Editor Dwight E. Neuenschwander addressed the importance of doing physics for the love of the game:

"Prizes are nice, but they are not ends in themselves. Someone once said, 'Seek not your position; let it seek you.' The same can be said for prizes. If the Nobel Prize comes your way, that would be splendid! Use the accolades wisely and humbly, remembering the many people who helped you get there. Follow your passion, and give it your best. Physics, like sports or music, is best done for the love of the game."

In this spirit, we say "Splendid!" to Andre Geim and Konstantin Novoselov of the University of Manchester in the United Kingdom for receiving the 2010 Nobel Prize in Physics for their work on graphene. SPS has partnered with the Royal Swedish Academy of Sciences to distribute posters celebrating the 2010 Nobel Prize in Physics, so look for them in an upcoming chapter mailing.

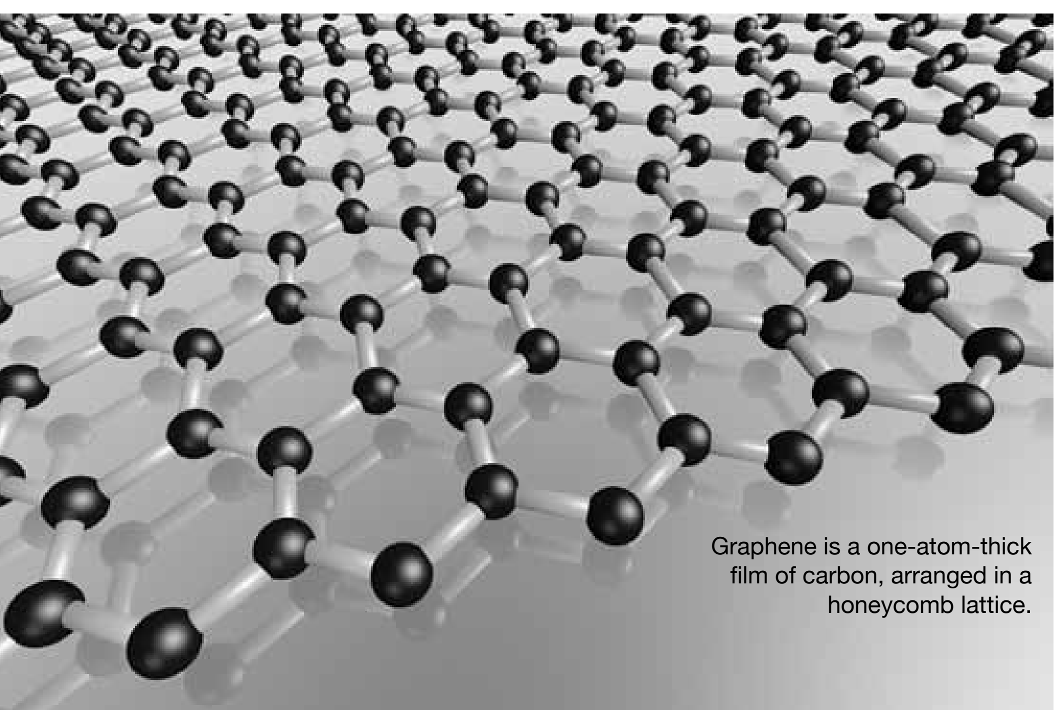
In addition, we offer many thanks to the physics and chemistry Nobel Laureates from previous years who participated in the SPS Meeting Enhancement Award. The American Institute of Physics, with the generous support of the Research Corporation, established the award in 2010 to connect Nobel Prize winners and students from Minority Serving Institutions (MSIs). The goals of the program are to enhance the presence of MSI physics students at regional physics meetings, to increase the visibility of both regional physics meetings and MSI programs, and to increase interactions among regional science departments. New applications for the program are not being accepted currently, but a few Nobel lecture sites were previously selected for 2011.

Graphene Experiments Garner Nobel Prize

The Royal Swedish Academy of Sciences awarded the 2010 Nobel Prize to Andre Geim and Konstantin Novoselov of the University of Manchester in the United Kingdom for "ground-breaking experiments" on graphene. In a paper published in *Science* in October 2004, Geim and Novoselov announced that they had been able to for the first time create a sheet of carbon atoms one atom thick.

The remarkable characteristics of graphene hold a tremendous amount of promise for future applications. It is both the thinnest material ever created while stronger than the world's strongest steel. According to the Royal Swedish Academy of Sciences, "In our 1 m^2 hammock tied between two trees you could place a weight of approximately 4 kg before it would break. It should thus be possible to make an almost invisible hammock out of graphene that could hold a cat without breaking."

Even with its strength, it is still flexible. It is as good an electrical conductor as copper and better at conducting heat than any other material. It is almost completely transparent and its hexagonal molecular structure is so



Graphene is a one-atom-thick film of carbon, arranged in a honeycomb lattice.

This article first appeared in APS News, Nov. 2010, vol. 19, no. 10. Reprinted with permission.

dense that not even helium can pass through.

It is thought that graphene could hold the key to many future technologies ranging from transparent touch screens and solar panels to strong composite materials and the hypothesized space elevator.

Scientists had been trying for years to isolate such a carbon molecule because of its amazing theorized structural and electrical properties. However all had been frustrated in their attempts. Many had given up, believing that there was no way such a thin sheet of carbon could be stable at room temperatures.

Geim and Novoselov's technique was as novel as it was simple. They stuck a piece of scotch tape on a chunk of graphite and pulled off a thin layer. After repeated attempts, they were able to isolate a flat sheet of carbon one atom thick, the long sought-after sample of graphene.

"We just try to be curious in everything and most importantly, to have fun. So Andre introduced this habit of Friday evening experiments where you just do crazy things and then some of them sometimes come out, sometimes not, and basically graphene was one of those as well," Novoselov said in a taped interview.

"My work is my hobby. So some people would call me a workaholic; I don't consider it this. I just love my work so much so it's my real hobby," Geim said in a taped interview.

In the six years since the team published their paper, graphene has become one of the hottest research areas in condensed matter. It's estimated that over 2500 scientific papers were published in 2010 on graphene. Last year at the APS March Meeting, hundreds of abstracts on the subject were submitted and nineteen special focus sessions on graphene were held.

Geim was born in Sochi Russia in 1958. He received his PhD in 1987 from the Institute of Solid State Physics at the Russian Academy of Sciences. Novoselov was born in Nizhny Tagil Russia in 1974. He received his PhD from Radboud University Nijmegen in the Netherlands.

Geim's award also marks the first time that an individual has won both an Ig Nobel prize as well as a Nobel Prize. The Annals of Improbable Research awards Ig Nobel prizes to goofy but legitimate scientific research. Geim won an Ig Nobel in physics in 2000 for work on diamagnetic levitation where he suspended frogs in air using magnetic fields. Placing the frog in the magnetic field was another Friday evening experiment.

SPS Chapters Host Nobel Laureates

Through the SPS Meeting Enhancement Award, in 2010 seven physics and chemistry Nobel Laureates traveled to schools and regional meetings to encourage and inspire physics students. Most of the visits included a public lecture, a question and answer session with students, shared meals, and science talks. Three additional visits are scheduled for 2011.

Spring 2010

Nobel Laureate: Wolfgang Ketterle
Massachusetts Institute of Technology
Meeting Host: Elon University
Ketterle received the 2001 Nobel Prize in Physics jointly with Carl Wieman and Eric Cornell from the University of Colorado "for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates."

Nobel Laureate: Martin Chalfie
Columbia University
Meeting Host: Claflin University
Chalfie received the 2008 Nobel Prize in Chemistry jointly with Osamu Shimomura from the Marine Biological Laboratory and Boston University Medical School, and Roger Y. Tsien from the University of California, San Diego, and Howard Hughes Medical School, "for the discovery and development of the green fluorescent protein, GFP."

Fall 2010

Nobel Laureate: Sidney Altman
Yale University
Meeting Host: Hampton University
Altman received the 1989 Nobel Prize in Chemistry jointly with Thomas R. Cech from University of Colorado, Boulder, "for their discovery of catalytic properties of RNA."

Nobel Laureate: Eric Cornell
University of Colorado & the National Institute of Standards and Technology
Meeting Host: The University of Southern Mississippi
Cornell shared the 2001 Nobel Prize in Physics with Carl Wieman, also of the University of Colorado, Boulder, and Wolfgang Ketterle of the Massachusetts Institute of Technology "for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates."

Nobel Laureate: Robert Curl, Jr.
Rice University
Meeting Host: Spelman College
Curl received the 1996 Nobel Prize in Chemistry jointly with Sir Harold W. Kroto from the University of Sussex and Richard E. Smalley, also from Rice University, "for their discovery of fullerenes."

Nobel Laureate: Sir Anthony J. Leggett
University of Illinois
Meeting Host: Delaware State University
Leggett received the 2003 Nobel Prize in Physics jointly with Alexei A. Abrikosov from P.N. Lebedev Physical Institute and Vitaly L. Ginzburg from Argonne National Laboratory "for pioneering contributions to the theory of superconductors and superfluids."

Nobel Laureate: Douglas Osheroff
Stanford University
Meeting 1 Host: Howard University
Meeting 2 Host: The University of Texas at El Paso
Osheroff received the 1996 Nobel Prize in Physics jointly with David M. Lee and Robert C. Richardson from Cornell University "for their discovery of superfluidity in helium-3."

Spring 2011

Nobel Laureate: William Phillips
National Institute of Standards and Technology & University of Maryland
Meeting Host: Morehouse College
Phillips received the 1997 Nobel Prize in Physics jointly with Steven Chu from Stanford University and Claude Cohen-Tannoudji from Collège de France and École Normale Supérieure, "for development of methods to cool and trap atoms with laser light."

Nobel Laureate: John Hall
University of Colorado & National Institute of Standards and Technology
Meeting 1 Host: Florida A&M University
Meeting 2 Host: University of Arkansas Pine Bluff
Hall received one half of the 2005 Nobel Prize in Physics jointly with Theodor W. Hänsch from the Max-Planck-Institut für Quantenoptik and Ludwig-Maximilians-Universität, "for their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique." The other half went to Roy J. Glauber from Harvard University "for his contribution to the quantum theory of optical coherence."

Highlights from Eric Cornell's visit to the University of Southern Mississippi

Excerpts from reports by Amanda Palchak, Kileigh Peturis, and Xandria McWaters, University of Southern Mississippi, and Ronald Stubblefield and De'Andre Cherry, Morehouse College

- The scene at the reception was unlike any we've seen before. University professors looked more like excited children, all waiting in line with nervous grins to get the opportunity to shake this man's hand. Students huddled around him, packed as closely together as possible, just to catch a few words of wisdom. Kileigh Peturis, a physics graduate student, remembers, "I myself waited for ten minutes to finally be introduced, but was so nervous that by the time I made it to him, I could not think of one intelligent thing to say!"

- Three hundred seats were full of excited spectators, and people had begun to line the sides of the room, willing to stand for the entire lecture time! They would soon find out that it was worth it to stand. Dr. Cornell gave a brilliant talk about his research on the Bose-Einstein condensate. His presentation was full of funny hand-drawn pictures and hilarious analogies to everyday life. Everyone in the room was stunned at this physicist's charm and quick wit...When the night ended, over three hundred people left campus with an entirely new appreciation for science and for the people who do science.

- On the second day of his visit, members of the Society of Physics Students went for a morning run with Dr. Cornell. SPS member Charles Young said, "It feels good to be able to tell friends and family that I got to go on a casual run with a physics Nobel Prize winner. That's not something most people can say."

Photo courtesy of Morehouse College Physics Department

Dr. Eric Cornell (front row, center) alongside colleagues and their students from Jackson State, the University of Southern Mississippi, and Morehouse College.

- Without hesitation, Dr. Cornell shared maybe the most important information he could impart to a student. "In undergrad, I struggled through thermodynamics, not understanding anything about topics such as entropy, but the American education system is repetitive, so undergrad shows you THAT something works while graduate school explains HOW and WHY something works."

Photo by Gary White

Howard students and faculty discuss physics, life, and long-term prospects for US helium supplies with Douglas Osheroff after lunch (clockwise from left: Osheroff, physics lecturer Dr. Kayode Ogungbemi, graduate students Daniel Casimir, Julius Grant, and Philip Kurian).

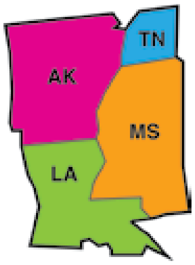
Photo courtesy of Delaware State University Physics Department

Nobel Laureate Anthony J. Leggett (red jacket) with students and faculty at Delaware State.

Zone 10 Declares Physics Outreach Week

POW!

SPS Zone 10



Zone 10 joined forces for the first-ever Physics Outreach Week (POW) during November 1–7, 2010. Initiated by Zone Councilor Alina Gearba and Associate Zone Councilors Josh Fuchs (2009-10) and Kayli Birdsong (2010-11), POW aims to promote an attitude of service among SPS chapters toward fellow students, colleagues, and the public, and to encourage interest in physics.

Photo courtesy of the Univ. of Southern Mississippi SPS chapter.

The University of Southern Mississippi's SPS President Xandria McWaters, Secretary Amanda Palchak, and Advisor Dr. Alina Gearba led an outreach event at Gulfport High School focused on celebrating Laserfest, teaching about low-temperature physics, and discussing the many fields of physics.

The students were extremely excited to learn about the many different functions of lasers and low-temperature physics, as well as the many applications the subjects have to offer. After discussing the physics behind the topics, the laser and liquid nitrogen demonstrations began and the students became very engaged in the presentation. Overall, the trip to Gulfport High School was quite a success and fulfilled our goal of getting high school students excited about all that physics and SPS has to offer.

On Tuesday, November 2, the Rhodes College SPS chapter launched a three-week series of school outreach sessions to Memphis city schools. Several SPS members participated in these outreach events, which were focused on teaching elementary and middle school students about force and motion.

The first school at which we presented and which coincided with POW was Idlewild Elementary School. Two students gave the physics presentation to about sixty kids. The kids were very enthusiastic and inquisitive about the demonstrations. Other schools we visited during our three-week outreach program were White Station Middle School and Springdale Elementary School.

Photo courtesy of the Louisiana State University SPS Chapter

To celebrate POW, the Louisiana State University (LSU) chapter held a physics demonstration event for the public. The event took place during the school wide *LSU Day* and featured a Van de Graaff generator, pressure vacuum, tesla coils, a mobile planetarium, nanotechnology demonstrations and more.

POW motivated us to reach out to people with science. People realized how fun science is.

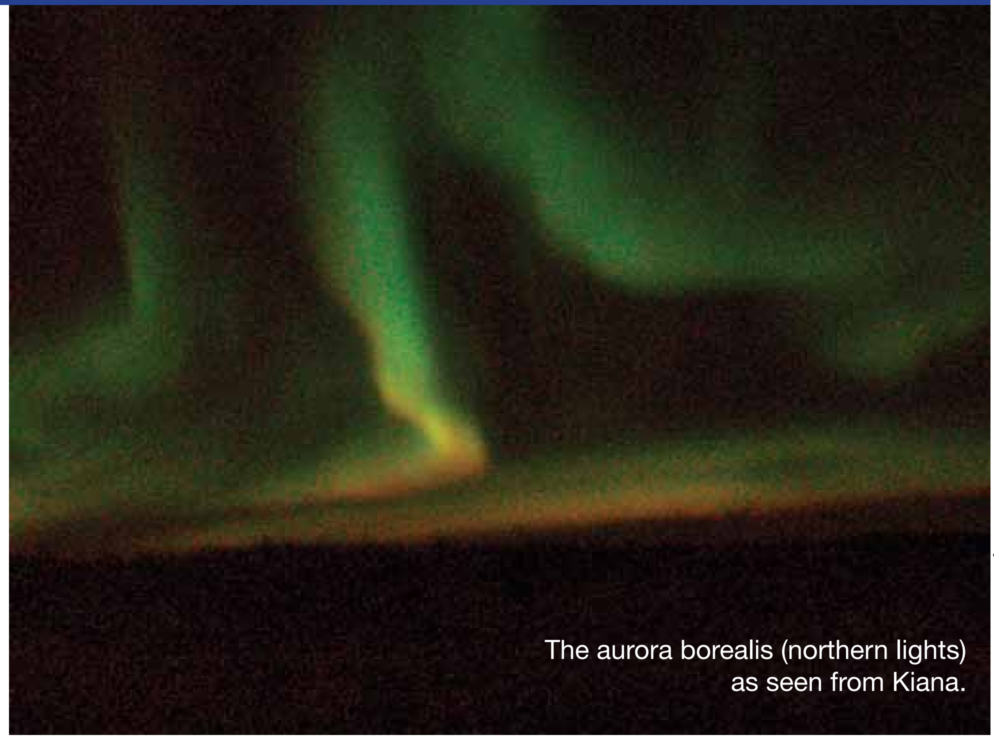
Photo courtesy of Henderson State Univ. Chapter

For POW, the Henderson State University chapter of SPS offered free physics tutoring for one hour every day, which included cookies! They also held the first Physics Circus practice of the semester, for which they earned a 2010 Marsh White Award.

Physics Circus is a hokey skit that incorporates fun physics demos; five actors performed it last year in front of an audience of elementary school students. One of our actors graduated, and three of them will be graduating soon; however, we have just recruited five new actors! So, this practice involved reading through the script and learning about some of the demos used in the skit.

Outreach to (Nearly) the North Pole, Part 2

By Dwight E. Neuenschwander



The aurora borealis (northern lights) as seen from Kiana.

Photo by Zonda and Scott Martin

In the last issue of the *Observer* (Fall 2010, p. 10) we introduced you to Scott and Zonda Martin, science teachers who went from teaching science in the Oklahoma public schools to teaching in Kiana, Alaska, a village of some four hundred people located about 43 miles north of the Arctic Circle. The largest structure in Kiana is the K-12 school. Since the SPS routinely engages in science outreach to K-12, we are keeping in touch with the Martins.

Getting to Kiana is not easy. In the old days you went by ship to the Alaskan coast, then hiked inland or went by dog sled. Today, from Oklahoma you fly a commercial airliner to Seattle, and then transfer to a flight for Anchorage. There you board a smaller plane that carries you across Alaska and sets you down in Kotzebue, near the Bering Strait. Kiana is 57 miles east of Kotzebue by air. When you fly between Kotzebue and Kiana, you board a nine-passenger aircraft. On winter flights everyone wears winter gear so they won't quickly freeze to death should the plane make an emergency landing on the tundra. Upon finally arriving in Kiana, you notice the airstrip is longer than the village.

Kiana means "a place where three rivers meet." The village lies at the confluence of the Kobuk and Squirrel Rivers. There are few roads, but the road that runs along the riverbank has optimistically been named "Beach Road." When the February wind blows sharp and cold across the Oklahoma prairie, we joke that there's nothing between us and the North Pole but a barbed wire fence. In Kiana, they don't even have the barbed wire fence. Their genuine, intense cold of deep wintertime is no joke. A few days ago (in late January) the temperature was -48 F, with a wind chill of -62 F. A few days later, however, it was a balmy +10 F. If a foot of snow falls in Oklahoma, the schools close. The Kiana school closes only if the temperature drops below -35 F.

Travelling between villages presents a task not to be taken for granted. Scenes from Jack London's short story "To Build a Fire" come to mind. To avoid such scenes, when the Kiana basketball team plays an "away" game, the team and supporters travel together in a snowmobile convoy to the other village. The snowmobilers carry sleeping bags, not only for safety should they get stranded, but also because they will camp in the host school's facilities before returning home.

The Martins and their students are part of Project THEMIS (Time History of Events and Macroscale Interactions during Substorms), which is run by the University of California–Berkeley. The project studies the dynamics of the Earth's magnetosphere, whose effects include the northern lights. The Project explains, "THEMIS answers longstanding fundamental questions concerning the nature of the substorm instabilities that abruptly and explosively release solar wind energy stored within the Earth's magnetotail" (http://themis.ssl.berkeley.edu/overview.shtml). These tasks are accomplished through five spacecraft. Three inner satellites orbiting at 10 Earth radii monitor the onset of current disruption. The other two orbiters, at 20 and 30 Earth radii, monitor plasma acceleration due to flux lobe dissipation. All five spacecraft orbits have apogees that line up every four days over a dedicated array of ground observatories located in Canada and the northern US, including Kiana. The mission's objectives include determining how substorms power the aurora, and how local current disruption mechanisms couple to global substorm phenomena.

Modern society makes it oh so easy to buy into the false notion that human beings are detached from nature

The Martins' adventure is taking place in an extreme environment, with its special challenges for education to both students and teachers. But their adventure and the lives of their students also offer some educational opportunities for the rest of us, if we care to be receptive to them. We want to be receptive. Modern society makes it oh so easy to buy into the false notion that human beings are detached from nature. Such illusions vanish when you trudge to school and it's -34 F. We would like to learn whatever we can from the Martins' students and all the residents of Kiana. We would like to visit them ourselves but will have to be content with a glimpse, through the Martins' eyes, of what life is like near the top of the globe. In return we offer the students, their community, and Zonda and Scott Martin our interest and support.

The 2010 Outstanding SPS Advisor

While there are many truly excellent SPS advisors, this past year's top awardee, the 2010 SPS Outstanding Chapter Advisor winner, is Dr. DJ Wagner of Grove City College of Pennsylvania. In her nomination letter her students wrote extensively about her exceptional leadership, which is now in its tenth year. Here is just one example: "Having twenty-five students travel to Fermilab for the SPS Congress at minimal cost, and pulling off a multizone meeting with over one hundred attendees, were both huge learning experiences for us, and definitely would not have happened without her guidance and encouragement. She is always excited about physics and her enthusiasm is contagious." Dr. Wagner is a familiar face at SPS events, conducts physics education research with the help of several undergraduate research assistants, and is an enthusiastic hand bell ringer.

Photo by Karen Matsler

DJ Wagner, the 2010 SPS Outstanding Chapter Advisor, displays her certificate. SPS President Toni Sauncy (far right) presented the award at the recent Jacksonville AAPT meeting; also shown are SPS staff members Gary White and Lydia Quijada.

SPS President Dr. Toni Sauncy presented Dr. Wagner the award at the American Association of Physics Teachers (AAPT) winter meeting in Jacksonville, FL, January 8–12, 2011. While at the meeting, Dr. Wagner and her students, Adam Moyer and Sam Cohen, joined AAPT faculty and SPS members from Angelo State University, Jamestown Community College, and the University of Illinois in presenting physics activities to seventy-five children from Eugene J. Butler Middle School in Jacksonville. Named in honor of recently deceased AAPT icon Betty Preese, this Science and Engineering Experiences for Students (SEES) event is a tradition that SPS has supported for about a decade by hosting activity stations, thanks to great advisors like DJ Wagner, Toni Sauncy, and their students.

Photo by Matthew Payne, AAPT

SPS Program Coordinator Kendra Redmond and students from Eugene Butler Middle School explore the science of rolling at one of the SEES physics stations.

Photo by Matthew Payne, AAPT

Eugene Butler Middle School Assistant Principal Andrea Talley looks on as her students explore the vibrant colors produced by the interactions of polarizing filters and transparent adhesive tape at another physics station developed by the SPS chapter at Angelo State University.

A truly successful SPS chapter requires leadership, organization, a broad spectrum of activities, and enthusiastic student participation. In determining the recipient of the award, the Award Committee considers the leadership, student leadership development, support, and encouragement provided by the chapter advisor to create and sustain a successful program. The award consists of a plaque and an honorarium totaling $5000, with $3000 going to the chapter advisor, $1000 to the chapter, and $1000 to the recipient's physics department.

All SPS chapter advisors are eligible for nomination for the award, provided that within the preceding two years, and during their tenure as advisor, the chapter has received an Outstanding Chapter Award. In order to be considered for an Outstanding Chapter Award, a chapter must have submitted an annual report.

Congratulations 2009-2010 Outstanding SPS Chapters!

Jordan Keough, SPS President at Idaho State University (ISU), Erik, William, and SPS Advisor Steve Shropshire prepare for a launch at the First Annual ISU Pumpkin Chuck.

Image courtesy of the ISU SPS Chapter

Outstanding Chapters from Western Zones include:

California State University, Sacramento
California State University, Chico
Green River Community College
Central Washington University
University of California, Davis
Northern Arizona University
Colorado School of Mines
Portland State University
Idaho State University
Utah State University

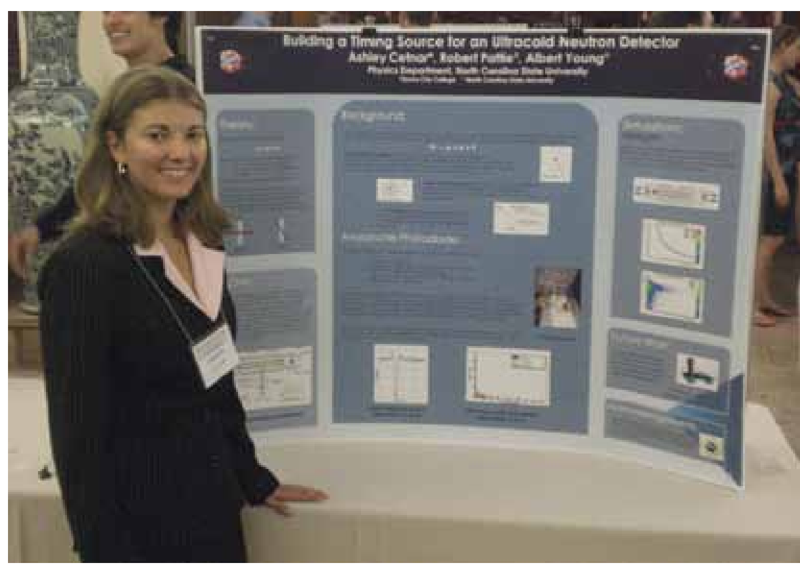
▲Rhodes College hosted a zone meeting in 2009 that included a tower building competition.

Outstanding Chapters from North and Central Zones include:

Michigan Technological University
University of Louisville
Indiana University
Coe College
Grove City College
Augsburg College
University of Wisconsin-Platteville
University of Wisconsin-River Falls
Eastern Michigan University
Cleveland State University
Augustana College
Millikin University

Photo by Steve Feller

Coe College students enjoyed an outing on Lake McBride during a summer research course.



Ashley Cetnar from Grove City College presenting her research at the Division of Nuclear Physics Conference.

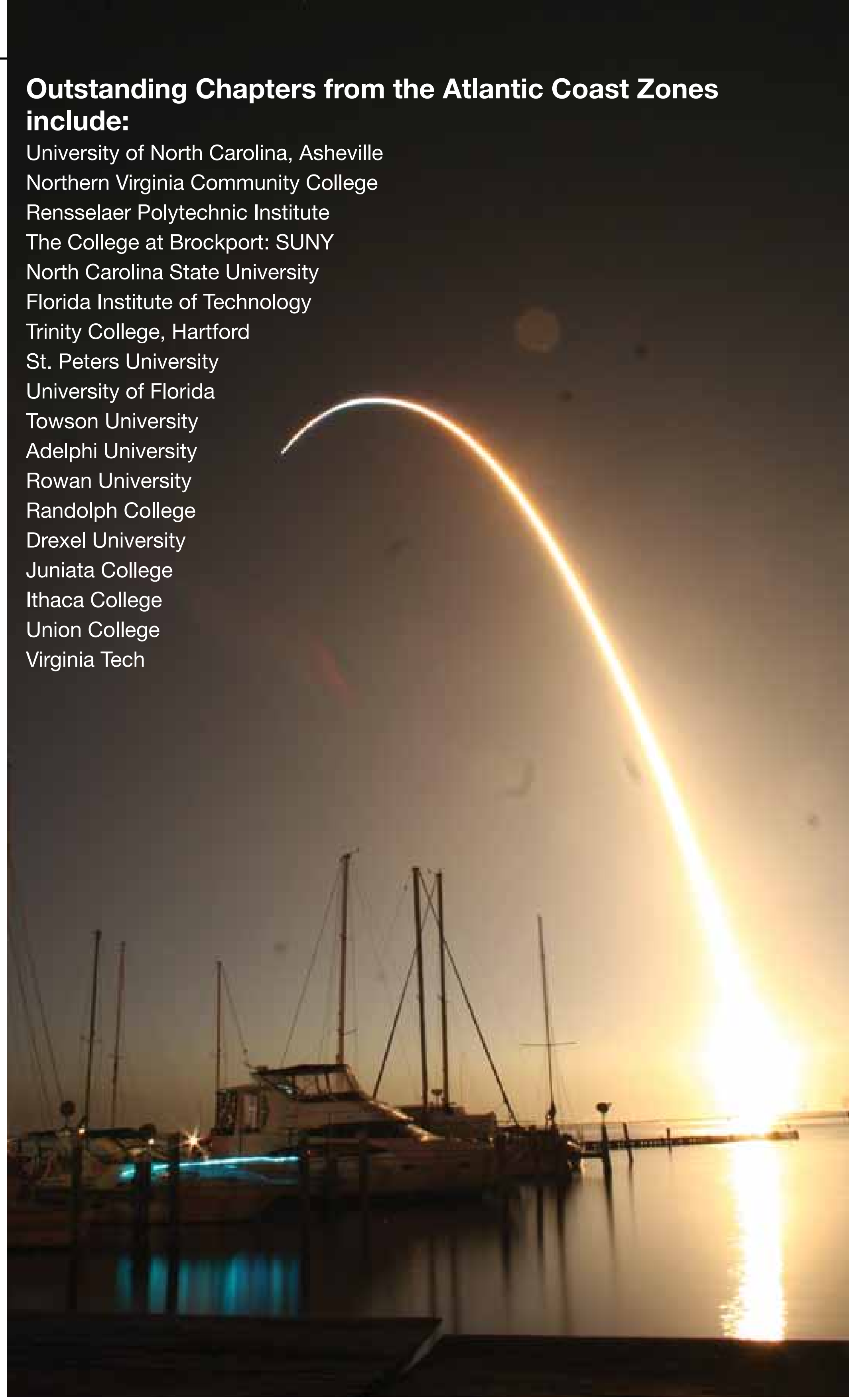
University of Florida SPS member Stefan O'Dougherty took the time-lapse photo at right of the space shuttle *Discovery* taking off on STS-131 during a joint trip with the Undergraduate Astrophysics Society to Titusville, FL, just one of the many activities in which this group engaged. UF SPS members presented research at several professional meetings and hosted several speakers, including alumni and recruiters. Other events kept them busy, such as a twist on the old liquid nitrogen ice cream by making Dippin' Dots, weekly Coffee Time, and hosting a Department of Energy Regional Science Bowl for area high schools.

Image courtesy of Rhodes College SPS

Image courtesy of the Florida Inst. of Tech. SPS Chapter

Florida Institute of Technology SPS members attempted to determine the correct wire to cut (foreground) and tried to pick locks (background) at their MacGyver Competition. They also hosted other creative physics ventures such as the Incredible Edible Race and Fun with Microwaves, and community events like the Relay for Life.

Image courtesy of Ashley Cetnar



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University of North Carolina, Asheville
Northern Virginia Community College
Rensselaer Polytechnic Institute
The College at Brockport: SUNY
North Carolina State University
Florida Institute of Technology
Trinity College, Hartford
St. Peters University
University of Florida
Towson University
Adelphi University
Rowan University
Randolph College
Drexel University
Juniata College
Ithaca College
Union College
Virginia Tech

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Southwest Texas Junior College
Southwestern Oklahoma State
Abilene Christian University
Henderson State University
Angelo State University
East Central University
William Jewell College
Texas Tech University
Rhodes College

Elegant Connections in Physics

The Discovery of the Nucleus, Part 1: The Atom is not Indivisible

Dwight E. Neuenschwander

The discovery of the atomic nucleus was announced a century ago, in 1911. How does one "discover" a nucleus?[1] Its existence and properties must be inferred. Before we can entertain the notion of an atomic nucleus, we need the atom. Part 1 of this two-part series discusses how it was realized that the atom is not indivisible. Part 2 will describe the scattering experiment whereby Ernest Rutherford, with a student and an assistant, discovered the nucleus and estimated its size. This story features physics students as much as it does the nucleus.

The ancient Greeks faced the philosophical question of what would happen if a piece of matter were cut into smaller and smaller pieces. Those who argued that one would eventually encounter an indivisible bit were called "atomists" because the term "atom" denoted an indivisible, basic unit. The Greeks also tried to identify the fundamental "elements." Candidates for these included air and fire.

By the Middle Ages we find achemists trying to transmute the elements, such as lead into gold. In Victor Hugo's 1831 novel *The Hunchback of Notre Dame*, whose action begins in Paris in 1482, we see Claude Frollo muttering to himself as he practices alchemy:

"Fire is the soul of the universe. Its elementary atoms are diffused and in constant flux throughout the world, by an infinite number of currents. At points where these currents meet in the heavens, they produce light; at their intersecting points on the earth, they produce gold. Light, gold, the same thing…"

After the Enlightenment, fire started being seen as a process, rather than a substance, and with it in 1774 Joseph Priestly in England discovered oxygen as a component of air, and corresponded with Benjamin Franklin about it. In one instance he wrote, 'Hitherto only two mice and myself have had the privilege of breathing it."[2] Using oxygen and fire, Antoine Lavoisier in France repeated Priestly's experiments, then showed that chemical reactions take matter apart and put it back together again, in reversible experiments that heated mercury oxide and separated it into liquid metal and oxygen. By running the reaction both directions Lavoisier quantified the components by their weight.

This hot chemistry of mercury and fire then moved to the damp chilly airs of Manchester, England, where in 1805 John Dalton published the first notion of atomic theory. He measured the minimum amounts of carbon that could be combined with oxygen to give the fizzy gas, familiar to brewers, that we now call carbon dioxide. He found the ratio of oxygen to carbon weight to be about 8 to 3. He did the same experiment with hydrogen and oxygen to make water, and found the oxygen to hydrogen ratio to be 8 to 1. In the double swap of combining carbon with hydrogen to make methane, by dividing out the oxygen numbers from his first two experiments, Dalton predicted the ratio of carbon to hydrogen to be 3 to 1, which agreed with the actual experiment. One might say the modern notion of the atom was, loosely speaking, launched among the vapors of the damp glens of Manchester.

Throughout the 19th century much of the scientific community took the existence of atoms as a working hypothesis, but the evidence of the atom's objective reality was not universally convincing. While it was widely recognized that the atomic concept was useful for balancing chemical equations, many eminent scientists thought this usefulness to be analogous to that of complex numbers—mere tools for calculations; one need not admit their physical existence in the real world. One of the major goals of the atomic proponents was the measurement of Amedeo Avogadro's number. Once the relative weights of Dalton's atoms were worked out, it was realized that 12 grams of carbon, 16 grams of oxygen, or 1 gram of hydrogen would contain the same number of their respective atoms. One of the achievements of 19th century chemistry and physics was to measure that number, which we know today as 6.02×10^{23}. If you have "one dozen" eggs that means you have 12 eggs, but if you have Avogadro's number of eggs, or one "mole," then you have 602 billion trillion of them!

As the 19th century turned into the 20th, the evidence for the reality of atoms was making its case.[2] The question moved on to atomic structure.

Nothing in the story that follows would have been possible without previous advances in technology, such as photography, vacuum pumps, and the Crookes tube and its derivatives—a glass enclosure with leads from an induction coil passing through the glass to terminate on a cathode and an anode. The Crookes tube's operation depends on low-pressure air ($<10^{-6}$ atm) inside, so that a high voltage accelerates cathode rays from the cathode to the anode.[3] These rays were seen as a fine green streak reaching across the chamber. The Crookes tube, in turn, could not have worked but for nascent vacuum technology. Vacuum pumps as we know them did not yet exist. In the early days you made do with a mercury drip apparatus that pulled air out one bubble at at time. William Crookes developed a hand pump in 1859 that made the Crookes tube possible.

X-Rays and Radioactivity

With such apparatus Wilhelm Röntgen (Fig. 1a) accidentally discovered X-rays (his name; X for "unknown")[4] while working late one evening in November 1895 at the University of Würzburg. With his Crookes tube running at a high voltage, Röntgen was amazed to see the soft glow of fluorescence on photographic paper (coated with barium platinocyanide) located some two meters across the lab. Its fluorescence ceased when the Crookes tube was turned off. The astonishing fact was the that Crookes tube was enclosed in a thick black carton to prevent the passage of light! That these mysterious rays could actually pass through matter became clear when Röntgen made the first X-ray photographs, including a ghostly picture of the bones inside his own hand. These photos compelled the science community to take his mysterious rays seriously (Fig.

1b), and of course medical applications were appreciated at once. Röntgen was instantly famous. Besides honorary doctorates and awards, including the first Nobel Prize in Physics in 1901, streets

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Fig. 1. (a) Wilhelm Röntgen. (b) Probably the first X-Ray photo taken in the United States, this picture of his own hand, taken by E.R. Wolcott at the University of Wisconsin, was made just after Röntgen announced the discovery of X-rays.

were named after him. Through it all he remained modest and reticent.

Henri Becquerel (Fig. 2), at the École Polytechnique in Paris, had been studying phosphorescent crystals. When illuminated by light, and the light source is removed, such crystals continue glowing. Following up on Röntgen's discovery that X-rays caused fluorescence, Becquerel wondered whether phosphorescence could include the emission of X-rays. He began to work through his collection of minerals, exposing them to sunlight for several hours and then removing them to a darkroom to see if they had exposed a photographic plate. By February 1896 Becquerel announced that some of his minerals could produce X-rays. Wanting to be sure, he planned to repeat the experiments. But the weather turned cloudy, so he stored his wrapped unexposed film, along with some uranium samples, in the same drawer.

A week or so later, he took the supposedly unexposed film from the drawer and developed it. Now it was Becquerel's turn to be astonished: the image showed the silhouette of the uranium sample. The rays seemed to come from the uranium but, unlike

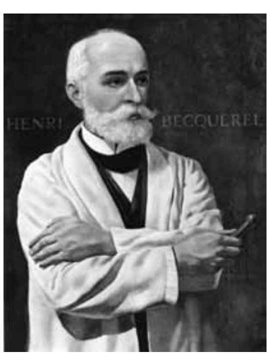

Fig. 2. (a) Henri Becquerel.
Credit: AIP Emilio Segrè Visual Archives, William G. Myers Collection

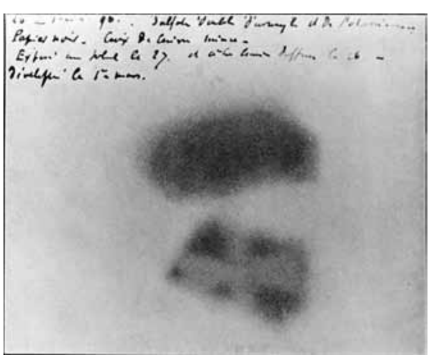

Fig. 2. (b) First evidence of radioactivity with Becquerel's notes.
Credit: AIP Emilio Segrè Visual Archives, William G. Myers Collection.

X-rays, without any external source of energy. Was energy not conserved? This was just outrageous!

These rays also carried an electric charge, as shown by collecting them on a foil electroscope. Becquerel may have talked the problem over with his colleague at the Polytechnique, Pierre Curie, who was well known for his study of piezoelectric crystals. In the presence of an electric field, these materials undergo mechanical stress (and conversely), leading to the design of an electroscope far more sensitive than the venerable foil instrument. Pierre's young wife, Marie Sklodowska from Poland, had recently completed her undergraduate studies, with distinction, at the

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Fig. 3. Marie and Pierre Curie in 1896.

prestigious Sorbonne in Paris and was ready to start her PhD research at the Polytechnique (Fig. 3).

Following up on Becquerel's discovery, she looked into his mysterious "uranium rays," but Marie had Pierre's piezoelectric crystals at her disposal. After confirming Becquerel's results with relatively pure uranium and thorium compounds, she turned to the uranium ore called pitchblende, which also contains some thorium, and measured far more outgoing rays than could be accounted for by the uranium and thorium. Assays of pitchblende had uncertainties at the time of about 1%. Thus other active elements must be hiding there. Since the ore was about three times more active than pure uranium, these hidden elements must be at least three hundred times as active! With little encouragement from the scientific establishment, Marie Curie started looking for the mysterious source of the anomalous activity, a substantial risk into the unknown for her doctoral dissertation. She slogged through the colossal task of identifying the various elements, first by melting the pitchblende and separating its many components by chemistry, then testing each sample for the ray-emitting activity, which she named "radioactivity." With endless patience, Curie discovered a radioactive element that was chemically similar to bismuth, which she named polonium, in honor of Poland, her homeland. Yet there remained more radioactivity in the remnant material than could be accounted for by uranium, thorium, and polonium. With further exhaustive work Curie discovered and named this radioactive barium-like element "radium." Present in parts per million in pitchblende, radium was not a few hundred, but millions of times more radioactive than uranium.

The chemists would not be convinced until they had a pure sample, which meant that Marie would have to melt literally tons of pitchblende to extract a few grams of radium. Realizing the importance and the difficulty of Marie's task, in 1898 Pierre postponed his other research in order to assist Marie. Together Marie and Pierre melted cartloads of pitchblende over vats stirred with an iron rod, under abominable conditions inside a decrepit old shed, carrying out the painstaking separations and quantitative analyses. Finally, one night they saw a few grams of radium salt glowing in its beaker by the light of its own radioactivity. In 1903 Marie Curie

Fig. 4. Marie Sklodowska Curie in 1903.
The Musée Cuire Association of Curie & Joliet-Curie Collection and the AIP Emilio Segrè Visual Archives. Musée Curie (coll. ACJC) have the originals.

became Dr. Curie, and that same year she and Pierre shared the Nobel Prize in Physics with Henri Becquerel (see Fig. 4).[5]

The enormous energies liberated by radioactivity remained a mystery. For example, alpha particles could have energies up to about 10 MeV, a million times larger, atom for atom, than typical energy exchanges in common chemical reactions. Only after Albert Einstein derived $E = mc^2$ in 1905 would the energy budget in radioactivity have a plausible explanation. If in the radioactive reaction a tiny amount of mass was converted into energy, the macroscopic weights would be hardly affected but the radiation's energy source would be explained. Einstein closed that paper by saying that "It is not impossible that with bodies whose energy-content is variable to a high degree (e.g. with radium salts) the theory may be successfully put to the test."[6]

Alpha Rays and Transmutation

Meanwhile, over at the Cavendish Lab in Cambridge, England, Joseph J. Thomson (Fig. 5) was placing cathode rays in crossed electric and magnetic fields to measure their velocity, and in magnetic fields to measure their charge to mass ratio. His ratio of 1897 for cathode rays was close enough to that of bound electrons, as described in the electron theory of H.A. Lorentz, based on the Zeeman effect of the mid-1890s, to suggest that bound electrons and cathode rays are the same particle.

In 1895 Ernest Rutherford, from Nelson, New Zealand, finished his undergraduate education and, thanks to a fellowship, set off for Cavendish to earn his PhD under Thomson. Rutherford began with magnetism and the detection of radio signals. With Röntgen's discovery of X-rays, he turned to the ionization they produced in air. The year after Becquerel's discovery of "uranium rays," Rutherford applied his techniques to their ionization abilities.

Fig. 5. J.J. Thomson at home in his study in 1899. He is sitting in a chair that had belonged to James Clerk Maxwell.
Sir George Thomson, courtesy AIP Emilio Segrè Visual Archives.

He quickly realized that two kinds of rays were emitted by uranium. In 1899 he called these "alpha" and "beta."[7] Becquerel and the Curies also studied these rays. The beta rays were energetic and quite penetrating, and Becquerel showed them to be Thomson's electrons. The identity of the alpha rays remained puzzling. Meanwhile, having finished his PhD, Rutherford accepted a position at McGill University in Montreal. There he procured some radioactive sources and resumed work. Rutherford, Becquerel, and the Curies eventually agreed that their data showed a beam of alphas were deflected, though only slightly, in a magnetic field: alphas were charged but relatively heavy.

In 1900 William Crookes found that when the products of uranium's radioactive decay were separated from a sample, the same species of decay product continued being produced back in the original uranium. Looking into the rates of such reactions, or equivalently, the time dependence of the abundance of reactants and products, Rutherford and McGill's newly hired chemist, Frederick Soddy, worked on this problem from 1900 to 1903. Sometime around 1903 or 1904, Rutherford started to suspect that alphas are identical to ionized helium—even though they came from uranium. If that were so, it would be a revolutionary demonstration of the alchemist's age-old dream of transmuting the elements.

Let me present a simplified version of the data analysis that supported the notion of radioactive decay as transmutation. Suppose radioactive element A decays to relatively stable element B, with specific rate constant k. The rate of decay of A and the rate of production of B are proportional to the abundance of yet-undecayed A atoms, so that we may write the rate equations $dA/dt = -kA$ and $dB/dt = kA$. For the abundances at time t these integrate to

$$A(t) = A(0)e^{-kt} \qquad (1)$$

and

$$B(t) = A(0)\,[1 - e^{-kt}\,] \qquad (2)$$

assuming $B(0) = 0$. A plot of these solutions shows descending and ascending exponential curves, with $A(t)+B(t) = A(0)$ for any $t \geq 0$ (Fig. 6a).

Rutherford and Soddy had demonstrated the transmutation of the elements! This discovery made Rutherford famous. In 1908 he was awarded the Nobel Prize in Chemistry. In his Nobel Lecture entitled "The Chemical Nature of the Alpha Particles from Radioactive Substances," he wryly remarked that the fastest transformation of all was his transformation for the occasion from a physicist into a chemist. Intersecting exponential curves were used in the design of Lord Rutherford's escutcheon when he was knighted in 1914 (Fig. 6b).

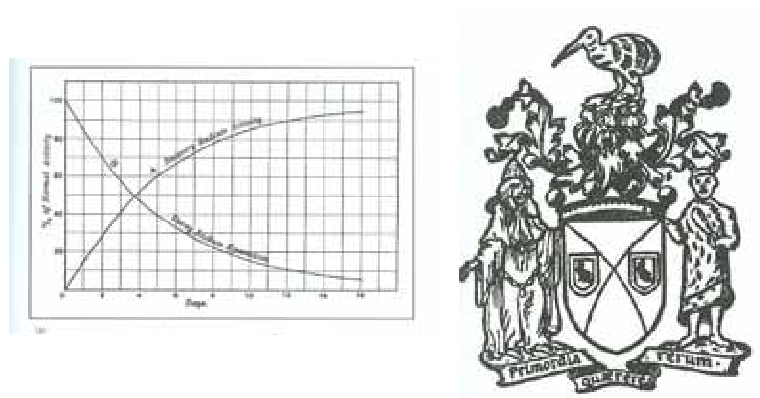


Fig. 6. (a) Rutherford's intersecting exponential curves describing transmutation. (b) The curves appear (along with a New Zealand kiwi and a Maori warrior) in Rutherford's escutcheon when he was knighted in 1914. From A.S. Eve, *Rutherford* (Cambridge Univ. Pr., 1939).

Radioactive transmutation as an energy source solved a serious problem in reconciling physics to biology and geology. Lord Kelvin had shown in 1862 that an initially molten earth would cool and solidify on a timescale many orders of magnitude shorter than the time implied by geological processes and required by biological evolution through natural selection. How then could the Earth still have a hot molten interior, as shown by its volcanism?[8] But if the Earth contains a source of heat in the form of radioactive elements, the apparent conflict vanishes. Rutherford described giving a talk when Kelvin, then elderly, was in the audience:

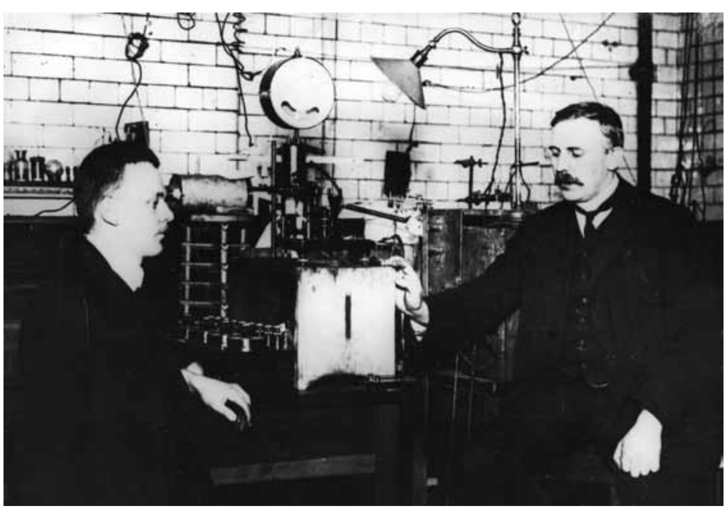
"I came into the room, which was half -dark, and presently spotted Lord Kelvin in the audience and realized that I was in trouble at the last part of my speech dealing with the age of the earth, where my views conflicted with his. To my relief, Kelvin fell fast asleep, but as I came to the important point, I saw the old bird sit up, open an eye and cock a baleful glance at me! Then a sudden inspiration came, and I said Lord Kelvin had limited the age of the earth, provided no new source [of heat] was discovered. That prophetic utterance refers to what we are now considering tonight, radium! Behold! The old boy beamed upon me."[9]

In 1907 Rutherford moved again, this time returning to England to chair the physics department at the University of Manchester, where John Dalton a century before had proposed the existence of atoms. Despite the atom's name, at Manchester Rutherford and his students were going to find out what was deep inside the atom.

Alpha Scattering

When Rutherford arrived in Manchester he made a list of promising research programs. One of the items on the list was checking his suspicion that alpha particles were ionized helium. Rutherford's predecessor at Manchester, Sir Arthur Schuster, had an assistant in the person of Hans Geiger, who stayed on after Rutherford arrived (Fig. 7). With another assistant T. Royds, by allowing the alpha particles to pick up electrons from surrounding matter and then checking the spectrum, they were able to confirm that alpha particles are doubly ionized helium.

Seventh on Rutherford's list was the "scattering of alpha rays." With his keen intuition, Rutherford recognized alpha particles could be an effective probe of the atom's structure. Before the electron was discovered the prevailing view had been that the atom was a kind of microscopic billiard ball. But doubts had grown. In 1903 the German physicist Philipp Lenard scattered cathode rays from various elements, arguing that atoms were mostly empty space. About 1904 W.H. Bragg and R.D. Kleeman showed that alpha particles with a given kinetic energy can penetrate matter a definite distance, measured by adding layers of thin-film targets until no more alphas come through. The alpha lost kinetic energy by ionization, stripping electrons from atoms as it passed by.[10] Rutherford set out to study these phenomena, with the help of Hans Geiger and various students.



AIP Emilio Segrè Visual Archives, Physics Today collection.

Fig. 7. Rutherford (right) with Hans Geiger who invented, between 1908 and 1913, a simple device for counting alpha particles one by one. Photo 1908 in Schuster Laboratory.

One of those students was Ernest Marsden, who like Rutherford had come from New Zealand. In 1909, at age 18, he found himself in Rutherford's lab. At some point he and Geiger were studying alphas passing through metal foils. Most of the alphas went through with less than 2 degrees of deviation, but there were some troubling stray alphas that came out at wider angles. Rutherford told Marsden, "See if you can get some effect of alpha particles directly reflected from a metal surface," expecting a negative result. After Marsden had been hard at it for awhile, he came to his mentor with a puzzling observation: While most of the alphas passed straight through a thin absorbing film as expected, some were deflected at large angles, and a few even bounced almost backwards off the target! This was a startling result. This being an undergraduate research project, the surprised Rutherford made Marsden repeat the experiment, but the occasional violent deflections persisted. Rutherford famously recalled that it was as astonishing as if one had fired a 15-inch artillery shell at a sheet of tissue paper and it bounced back!

Perhaps this result was baffling because of a contemporary model of the atom. Ever since J.J. Thomson had showed that electrons can be stripped from atoms, several models were proposed for atomic structure, trying to envision how the positive charge, which carried most of the mass, was distributed. The dominant model at the time seems to have been a "plum pudding model" suggested by Thomson. Plum pudding is the British term for what others might call "fruit-cake." For the Brits it is sometimes baked into a sphere like a cannonball, with small chunks of fruit or raisins distributed throughout its savory volume. In the analogy to the atom, the raisins are electrons and the cake is the uniformly distributed positive charge.[11]

Some weeks passed after Marsden's observations; meanwhile Rutherford, Geiger, and Marsden published some data showing alpha deflections of 90 degrees or more. After much work with calculations and large-scale models using repulsive electromagnets for visualization, on March 7, 1911, in a meeting of the Manchester Literary and Philosophical Society, Rutherford announced that he knew why some of the alpha "bullets" bounced off at wide angles. The data from alpha scattering experiments demonstrated the existence of a tiny, massive, positively-charged nucleus, and implied an upper limit on its size. In Part 2 we shall examine the scattering experiment that Rutherford designed, and which he and his assistant Hans Geiger, and his student Ernest Marsden, carried out to discover the nucleus.

AIP's Center for the History of Physics will open a web exhibit titled "Rutherford's Nuclear World" later this spring, at www.aip.org/history.

Acknowledgment
I thank Thomas Olsen for critiquing a draft of this manuscript.

Bibliography
Jacob Bronowski, *The Ascent of Man* (Little, Brown, & Co., 1973); J.C. Crowther, "Marie Curie" in *Six Great Scientists* (Barnes & Noble Books, 1995); Eva Curie, *Marie Curie* (Heinemann, 1938); Vivian Grey, "Mysterious Rays: The Discovery of Nuclear Energy (Basic Books, 1966); Richard Rhodes, *The Making of the Atomic Bomb* (Simon & Schuster, 1986); John Ridgen, Ed., *Macmillan Encyclopedia of Physics,* Vol. 4 (Macmillan, 1996); Emilio Segrè , *From X-Rays to Quarks* (Freeman, 1980).

[1] The distinction between "observing" and "detecting" something not directly accessible to the senses, like the atomic nucleus, forms a genuine problem in the philosophy of science.

[2] An important part of answering the "how we know" question about the atom's reality include Brownian motion and its interpretation by Albert Einstein who in 1905 suggested an *rms* distance measurement vs. time that was carried out by Jean Perrin about 1909. See "Einstein on Atoms, Fluctuations, and Brownian Motion," *SPS Observer*, Fall 2006, pp. 10-15.

[3] As in the formation of lightning, cathode rays begin with the strong electric field accelerating ions, whose collisions release the "cathode rays," the electrons. The cathode ray tube was an ancestor of the television picture tube.

[4] Sixteen years later Max Von Laue showed by diffraction in crystals that X-rays are very short-wavelength electromagnetic waves. Röntgen was observing *bremsstrahlung* radiation. Upon colliding with the glass and being so suddenly stopped, the electrons shook off their kinetic energy as light.

[5] Marie Curie received a second Nobel Prize, in chemistry, in 1911. Pierre Curie was tragically killed in an accident in 1906.

[6] A. Einstein, "Does the Inertia of a Body Depend on its Energy Content?" *Ann. Phys.* **18**, 639-641 (1905), translations in W. Perrett and G.B. Jefferey, *The Principle of Relativity* (Methuen, 1923; Dover reprint, 1952); J. Stachel (Ed.) and R. Penrose, *Einstein's Miraculous Year: Five Papers that Changed the Face of Physics* (Princeton Univ. Press, 1998); annotated in a series on Einstein's 1905 papers in the *SPS Observer* **37** (4, Winter 2005), 10-20.

[7] In 1900 P.V. Villard in France found a third (gamma) radiation emitted by radium.

[8]In 1868 Kelvin also showed that known mechanisms of energy production, such as gravitational collapse, fell ridiculously short of powering the Sun's luminosity for geological timescales. That problem, of course, was also solved by nuclear physics. See "Charles Darwin, Lord Kelvin, and the Age of the Earth," *Radiations* **12** (2, Fall 2006), 19-20.

[9] Quoted from A.S. Eve, *Rutherford* (Cambridge Univ. Press, 1939) by Segrè, p. 59.

[10] These studies led to the "Bragg peak" for *dE/dx,* where most of the ionization energy occurs the last few millimeters as the alpha particle slows to a stop. An important application is proton beam therapy for treating some cancers.

[11] In *A Christmas Carol* (1843) Charles Dickens deliciously describes, with great warmth, the Cratchit family's Christmas plum pudding. In the lab, people probably wondered, if the plum pudding model was right, what keeps the positively charged cake from exploding under its own electric repulsion? That question persisted with the nucleus until the neutron was discovered in 1932 by one of Rutherford's former students, James Chadwick, at the Cavendish Laboratory, where Rutherford was then director.

Grandma's Plum Pudding Recipe

4 slices bread, torn up
1 cup milk

2 eggs, slightly beaten
1 cup light brown sugar
1/4 cup orange juice
6 oz finely chopped suet
1 tsp. vanilla

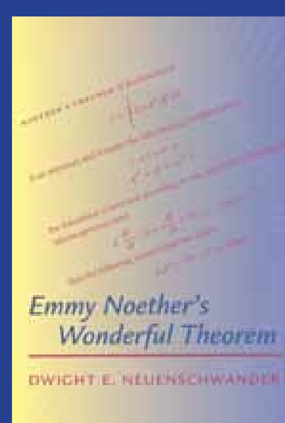
1 cup flour, sifted
2 tsp. ground cinnamon
1 tsp. ground cloves
1 tsp. ground mace
1 tsp. baking soda
1/2 tsp. salt

2 cups raisins
1 cup dates, pitted & chopped
1/2 cup mixed candied fruit & peels, chopped
1/2 cup broken walnuts

Soak bread in milk; beat. Stir in next five ingredients. Sift together dry ingredients; add fruits and nuts; mix well. Stir in bread mixture. Pour into well-greased mold (2-quart); cover with foil & tie with string. Place on rack in a very deep baking pan (like a Dutch oven); add boiling water to 1inch deep. Cover and steam for 3.5 hours, checking water level and adding water as it evaporates. Cool 10 minutes and unmold. Serve warm with hard sauce on top.

Sauce
1 cup confectioners' sugar, sifted
5 Tbs. butter
1/8 tsp. salt
1 Tbs. brandy or rum (or substitute 1 tsp. of vanilla)

Beat butter until soft. Gradually add the sugar and beat until well blended; add salt and brandy. When the sauce is very smooth, chill thoroughly.



The SPS staff would like to formally congratulate our esteemed editor of publications, Professor Dwight Edward Neuenschwander, upon the publication of his elegant new tome, *Emmy Noether's Wonderful Theorem*. We especially appreciate the opportunity to celebrate with him the life and science of one of the most-deserving, but least recognized, scientists in history. Congratulations, Ed, and kudos to you for all that you do for the physics community!

Photo by Ali Lambert

Atop the world's largest cyclotron at TRIUMF, paperclips experience some fringe magnetic field and stand upright, dancing atop the table's surface. High-school student Ali Lambert artfully captured this iconic experience of all visitors to the lab. This image won first place in TRIUMF's local competition.

International Nuclear Physics Conference (INPC)

July 4–9, 2010
Vancouver, British Columbia, Canada

by Anne Andrew, University of Colorado, Denver

While perusing the websites of my top picks for graduate school, I came across an announcement for the International Nuclear Physics Conference (INPC) to be held at my first-choice school, the University of British Columbia in Vancouver (UBC). I was very excited until I noticed that in order to be considered for the student grant program and poster session, you had to be in a graduate program. The INPC is held every three years, so this would be my only chance to attend until 2013. I decided to be bold.

Since I'm almost done with my degree and I have been working on a relevant research project (a cyclotron particle accelerator), I asked if there was any way that the INPC board would let me apply for the conference. To my great surprise, and to the surprise of my professors, during the week of finals last spring I received notice that I had been accepted and would be presenting a poster at the conference.

Photo by Mindy Hapke and Nicole Bienvenu, courtesy of TRIUMF

The author with her poster at INPC.

The conference began on a Sunday with opening ceremonies and a public lecture given by Dr. Lawrence Krauss, who gave a wonderful talk on following an atom from its creation at the beginning of the universe all the way up to present day.

Monday and Tuesday were filled with fascinating plenary lectures and exhibits on topics covering the field of nuclear physics. On Monday and Tuesday evening the student poster sessions were held. There were hundreds of student posters. I presented my poster, "Proposed Construction and Modernization of a One Meter Radius Cyclotron," on Tuesday evening. There were 174 posters in my session.

The poster session was so much fun. I talked to many fascinating people and learned a lot. I seemed to catch the eye of many people from TRIUMF (The Tri-University Meson Facility - though now they have many more universities involved) who were excited about my project to build a small-scale cyclotron. By the end of the night I found out that I was picked as one of


The UBC campus.

Photo courtesy of UBC Public Affairs

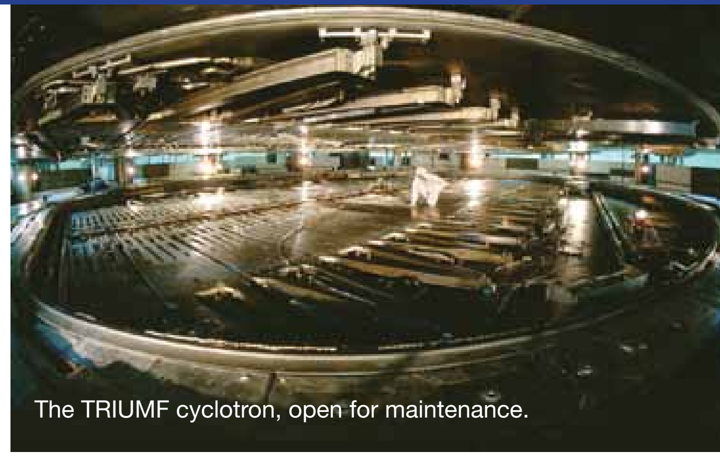

The TRIUMF cyclotron, open for maintenance.

Photo courtesy of TRIUMF

eight student finalists of that night's session and I had a possible investor for my project!

Wednesday opened with a few talks, and then we were free for the afternoon. I spent the day walking around the UBC campus. It was just beautiful. The campus is on an area of endowment land that stretches out into a part of the ocean that is protected by Vancouver Island.

Thursday opened as usual with some fascinating talks. At eleven o'clock the judges went through the posters of the student finalists. As one could imagine, my stomach was in a knot. I was not chosen, but I was happy just to be there.

Friday was the day I had been looking forward to the most. We were given a guided tour of TRIUMF, home of the world's largest cyclotron. It was an amazing facility and, for me, was the highlight of an amazing trip! The tour took most of the day and was absolutely fascinating. I got to stand on the 18-meter cyclotron and watch a paper clip move along the magnetic field lines as we walked on top of the cyclotron. I even found the research group I want to join during graduate school.

Before I knew it, it was already Saturday morning and time to catch my flight back to Denver. What an amazing trip! The next International Nuclear Physics Conference will be held in Italy in 2013, and I highly recommend going. For images, abstracts, and posters from the 2010 conference, visit http://inpc2010.triumf.ca/index.html.

Read Anne's complete article online at www.spsnational.org/meetings/reports/.

2011 Meetings to watch for…

American Physical Society
April Meeting
April 30–May 3, Anaheim, CA

Conference on Lasers and
Electro-Optics 2011
May 1–6, Baltimore, MD

American Astronomical Society
218th Meeting
May 22–26, Boston, MA

161st Meeting of the Acoustical
Society of America
May 23–27, Seattle, WA

American Crystallographic Association
2011 Annual Meeting
May 28–June 2, New Orleans, LA

American Association of Physics
Teachers Summer Meeting
July 30–Aug 3, Omaha, NE

Astronomical Society of the Pacific Education
and Public Outreach Conference
July 30–Aug 3, Baltimore, MD

2011 Joint Meeting of the American
Association of Physicists in Medicine
& Canadian Organization of Medical
Physicists
July 31–Aug 4, Vancouver, BC, Canada

83rd Annual Meeting of The Society of
Rheology
Oct 9–13, Cleveland, OH

Frontiers in Optics 2011 / Laser Science
XXVII
Oct 16–20, San Jose, CA

AVS International Symposium and
Exhibition & 2011 Industrial Physics Forum:
Energy
Oct 30–Nov 4, Nashville, TN

162nd Meeting of the Acoustical Society of
America
Oct 3–Nov 4, San Diego, CA

American Geophysical Union 2011 Fall
Meeting
Dec 5–9, San Francisco, CA

Need funding to attend a meeting? Visit www.spsnational.org/meetings.

Action, Camera, Light!

Frontiers in Optics 2010, Laser Science XXVI Conference and the AIP Industrial Physics Forum
October 24–28, 2010, Rochester, NY

By Josh Geller, University of Rochester

As a senior physics and mathematics major at the University of Rochester, I've just begun to comprehend how little I know about physics and mathematics, but I am lucky to have had some opportunities to explore research into such quantum optics topics as entanglement and single photon sources through summer work and lab classes at the U of R. I am particularly excited to be a reporter for this meeting, because the research I've pursued thus far was in focus at this meeting, and I am excited to interact with the many leading scientists and presenters.

I started the first day of the conference at six in the morning, too early a time for a college senior to wake up, and a time when in Rochester in October it is still dark. I woke up to the hurried phone call of my friend Dev, who was to drive the four of us SPS members attending the conference – Wendi, Corey, and me (running late) – to the morning's award ceremony. First to be picked up, I was barely ready at such an unusually early time but was particularly excited for two of the day's events: 1. the award and plenary session; 2. the student symposium on undergraduate research.

After about thirty minutes of introductions, the formality yielded the floor to Professor Eberly, whose Frederic Ives Medal / Jarus W. Quinn Endowment presentation referenced the very material from my freshman class that had drawn me to quantum optics and entanglement and pushed me toward attending this meeting. He offered a concise reminder of the interesting questions still open in quantum mechanics, by thinking about the curious behavior of two photons' polarizations under correlated measurements.

The Schawlow Prize lecture followed, discussing coherent x-rays generated by ultrafast tabletop lasers. Henry Kapteyn, one of the prize recipients, gave the talk. Both Professor Kapteyn and recipient Margaret Murnane are from JILA (the Joint Institute for Laboratory Astrophysics) at the University of Colorado.

The second half of the opening session included a lecture from Steven Block, a biophysicist from Stanford University, who prefaced his speech by telling the audience that we were in for "a bio lesson for physicists." In his charismatic portrayal of his work on the use of a laser-based optical trap for studying gene regulation, he mentioned his study of basewise stepping, claiming that some of his lab's work in this direction was more or less an "in-your-face experiment" his lab did on a weekend just because the optical trap allowed for it. Funny guy!

The closing talk of the morning session, given by Alain Aspect of the Laboratoire Charles Fabry Institut d'Optique in France, was a bit of excitement I'd been looking forward to. His talk demonstrated the Hanbury Brown and Twiss setup using atoms rather than photons.

Immediately following the opening session, the four of us undergraduates met with Dr. Tom Olsen, Assistant Director of SPS and Sigma Pi Sigma, who had helped to procure our passes to the conference. Back from lunch with him at Dinosaur Barbeque, a Rochester favorite two blocks away from the conference center, we attended the student poster session where I was amazed to see Alain Aspect asking questions of each presenter.

Winding through the student poster session area, we found our way into a symposium on the biomedical applications of lasers. This was one of four special symposia held by the Industrial Physics Forum (IPF), organized by the American Institute of Physics and the Optical Society of America, devoted to novel physics in industry. Had we stayed to see the evening IPF speakers, we would have seen the topic change to applications of lasers in environmental science. Fortunately, AIP has archived video recordings of these talks at http://www.aip.org/industry/ipf/2010/presentations.html.

But our time to skip class had passed for now, and we were to head back to school to finish the day with plans to attend the OSA student members' social event that evening. Amazed to find Steven Block stopping by to meet students, I was lucky to speak with him briefly at the OSA social, located at a local tavern in downtown Rochester. I asked Professor Block about how he ended up pursuing biophysics, and if he liked biology or physics more. He quipped that though he did enjoy biology, physics was admittedly the "mother science."

Continued online. Read Josh's complete article at www.spsnational.org/meetings/reports/.

Photo by Liz Caron, AIP

[left to right] Josh Geller (author), Corey Adams, Dev Ashish Khaitan and OSA Fellow Boris Zeldovich.

The SPS Observer

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