American Association of Physics Teachers
Guide to Physics Outreach

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Editor in Chief: Steve Shropshire
Whips: David Sturm, Frank Lock, Ann Reimers …

Dates:
Last week of August - Outline of Chapters; Case Study Contributions discussed [1-week prior submission deadline], Review of completed chapters
First week of October - Subheadings developed, who is contributing identified; Review Case Study Contributions
Second week of November - Draft chapters complete, Review progress
Winter Meeting - Review Document
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April
Summer Meeting - POTR Topical (panel) Discussion [Request Monday or Tuesday afternoon - Steve S. has a travel restriction on Wednesday]

Chapter 1, Introduction

Steve Shropshire, Idaho State University

Commented [1]: Steve is a great guy. This is a test of the comments.

Science outreach activities are wonderful in so many ways. They can generate much needed excitement and interest in science in students and in the public. They generate appreciation in the community for your profession and institution. Delivering them brings a sense of accomplishment, camaraderie, and community. Providing science outreach activities is also a great way to gain a deeper understanding of science and its application, and gain valuable communication skills. If you learn to successfully explain an aspect of science or technology to a 3rd grader, your own level of understanding is greatly enhanced. It is comparatively easy to communicate scientific ideas to another scientist. However, if we try to use the same techniques with a non-scientist, it is easy to annoy and alienate. If we want the general public to support the pursuit of science, we need to effectively convey its nature and benefits. The communication skills to be gained in providing science outreach will serve both you and your profession well.

Effective science outreach is fun and rewarding, but it is also greatly needed at this time in our society. Education is of great importance due to its effect on the development of future citizens. With the advance of technology, scientific literacy is essential for adequate participation in our society. Fewer students are interested in pursuing careers in science and engineering. There are concerns that the U.S. is falling behind other countries in science education and that innovation in this country will ebb. An unfortunate result of the No Child Left Behind legislation is that many states focused more on student progress in language, literacy, and mathematics than on science. Many states do not test student progress in science, while others did not set goals for student performance on science knowledge tests they implemented. This resulted in a significant drop in time, attention, and resources devoted to science education, especially in the elementary grades. Many students are entering junior high or high school with less knowledge and interest in science as a result. Even in states that do not neglect science education, there are a variety of social pressures that have a negative impact on student interest and enthusiasm towards learning about science. Whatever the cause, there is a common attitude among students and the public that science is too hard, too boring, and not worth the effort to understand. Due to limitations in school district budgets and teacher training, in many places students rarely get to do more than read about the more exciting aspects of science. Public perceptions of science and scientists are negatively influenced by images of the evil mad scientists and socially awkward geeks common in popular media, as well as a basic distrust of what is not understood. Science outreach can help reverse negative attitudes, expose people to more exciting aspects of science, spark interest and enthusiasm, and encourage communities to support science education.

There are many ways to get started with science outreach, but it is best to start small and keep it simple. The easiest approach is to get involved in an existing program at your school, local library, or museum, even if its focus is on science other than physics. If you want to start your own program, a thoughtful review of what resources you have is very useful. The following are some ideas on how to begin:

If you have a physics or science club, see what their interests are and get them involved. The Society of Physics Students (SPS) has chapters at most colleges and universities, and science outreach is strongly encouraged by the National SPS. They provide Science Outreach Catalyst Kits [reference: http://www.spsnational.org/programs/socks/index.htm] (SOCKs) with demonstration and outreach ideas to chapters for free.

Borrow some equipment for demonstrations and present them to folks outside your department. Student organization fairs or other public events at your school are a great place to start, as are single classrooms at a nearby elementary school. If you cannot take the equipment out of your building or off campus, invite a classroom from a local school to your facility for a field trip. You can easily start by contributing to a field trip that is already scheduled, or work with colleagues from other departments so that you are not doing it all.

If you are at a college or university, encourage your department to host an “open house” event open to the public with lab tours and hallway demos. You can easily scale this up to a full-blown demo show in a lecture hall. Short lectures or discussion sessions on popular science topics such as black holes, astronomy, or the physics of sports fit well into these events.

Offer to discuss science topics or present demonstrations on a local public access television channel, or on your local PBS channel. Most local PBS affiliates have science programming targeting public school classrooms, and would be very happy to involve you.

Get your students involved. If you are at a high school, offer extra credit for them to visit a elementary or middle school classroom to present demonstrations, involve the kids in a science activity, or to just talk about a cool science topic. If you are at a college or university, offer credit for them to visit a K-12 school. In addition to the fun stuff, they can also discuss careers in physics and how great your school is to high school students. One of the best ways to learn physics is to teach it to others, so your own students will benefit as well.

Build interactive exhibits for a hallway or other open space at your school. Passing students otherwise not interested in science just might tinker with it and get the spark they need to consider taking a science class. If done well, they might even learn something from the interaction. If you have students good with their hands, offer them extra credit to build an exhibit.

Find out if there is a Science Olympiad or science fair in your area in need of volunteers to run events or judge. If there is a museum nearby, ask them if you can visit to present demonstrations or hands-on science activities.
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Try setting up a table of demonstrations at a county fair, at a farmers' market, in a local mall, or at a sporting event. Van de Graaff generators and liquid nitrogen demos are quick and easy to set up, and always draw a crowd.
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After some practice and experience, try visiting a high school class, presenting to an assembly of several elementary classes, visiting a retirement community, Boy and Girl Scout groups, or even a junior high classroom (by far the toughest audience).

Contact your local Boy and Girl Scout councils and offer to help with science merit, skill, or activity badges.

With skill and experience, you can tackle larger events, such as a haunted science lab around Halloween, or a pumpkin catapult competition.

Determine your strengths and build on them. Keep things safe and sane. Avoid the appearance of risk and danger. We have enough problems shaking the "mad scientist" image. Science should not be scary (except in a fun way near Halloween). Keep it fun, and avoid pressuring your students to help. Practice presenting demonstrations or hands-on science activities to your students or science club outside of class. To really hone your presentation skills, entice your drama club to visit in exchange for pizza, and use them as a trial audience. Ask them for pointers and listen to their advice.

If you want to make outreach a regular activity, seek funding for, and obtain designated equipment. This will greatly speed up preparation time. Good sources of funding are your school's public relations and alumni offices, and local community foundations. Talk to your school's office of sponsored programs (external funding) for specific proposal funding ideas. ·

In all cases, support from your school, college, and department can make a big difference in resources, funding, and long term success. A very useful selling point to obtain support is that science outreach improves public perception, goodwill, and community support. It also has the potential to increase enrollment at your school, particularly in the sciences and engineering, and improve the science preparation of incoming students. At Idaho State University, we have more than doubled both our enrollments in physics classes and the number of physics graduates over the last 10 years, and our administration credits our numerous outreach programs as a factor in this.

The most important thing in any outreach activity is to have fun. It is very contagious.

Chapter 2, Demonstration Shows

David Maiullo, Rutgers University

Chapter 2, Demonstration Shows

Stanley Micklavzina, University of Oregon. (Last edit July 23, 2015. More later.)

I have attempted to develop lecture demonstration shows incorporating two methodologies. One making sure there is a building theme in the show tying together concepts and the application of concepts. The second being Physics and Artistic Performance. Ultimately, I would like to have a show people come to see for the performance and the science is in the show. I think this would expand the audience that attends the show and therefore, influencing a larger audience, not just the people who are interested in science already. Still working on that, but themes and shows that bridge that idea are:

- **Physics of Rock 'n Rol**l. This is a show I have been doing in 2015 in honor of The International Year of Light. Lots of Physics in a Rock 'n Roll or modern DJ concert. Between the music and the lights, you can display demos for wave phenomena and light characteristics in a very fun way. Kids, teens and adults have come to really enjoy this show.
- **Physics of Vaudeville.** I have had the chance to work with local jugglers and other Vaudeville type performers to put together a show that can involve the physic of what they are doing as well as set up models to display physics phenomena such as Special Relativity. This type of show was featured in an AAPT Demo Show in Portland Oregon. You can see a video of that show HERE and more information HERE. (Special thanks to Vernier Software for sponsoring that show.)
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Chapter 3, Travelling Exhibits

Brian Jones, Colorado State University

Chapter 4, Media Delivery

Brian Jones, Colorado State University

Chapter 5, Venues

David Maiullo, Rutgers University

Divide into categories of show types.

1. Hands-On,
2. Demo Shows (presentations - radio as well as video broadcasts)
3. Make-n-Take

Bars, Hospitals (mental, VA, county etc.), Assisted Living Centers, Museums, Libraries, Smithsonian, Schools, Parks, Swimming Pools, Beaches, National Parks (campfire programs), Scout Groups, Family Reunions, Alumni groups, Malls, Summer Camps, Parking Lots (Walmart, IKEA, REI etc.), Festivals and Fairs, Churches, Tailgating Events, Half-time shows, Lobby tables, Services Clubs (Kiwanis, Elks, Lions, Rotary, etc), Symphony Orchestras,

Chapter 6, Teacher Support

Steve Shropshire, Idaho State University

Providing teachers with materials, resources, or professional development is one of the most effective and lasting methods of science outreach. Even slight improvements in the teaching ability of an educator will have a positive impact on hundreds of current and future students. If you are college or university faculty, endearing teachers to you and your school can influence what their students will choose to study if they go to college. Providing support to local teachers, especially in grades 7 - 12, is a great tool for recruitment. If you are a high school teacher, you can influence K-8 students' choice of classes they will take in high school. Outreach even to fellow high school teachers has the potential to improve your teaching effectiveness as well as that of your colleagues. To be most effective, the support provided to teachers should be adjusted to their grade level and course topics, and chosen to align to state or national science education standards.

The teachers most in need for professional development and support in science education are often disinclined to seek it out. Offering to involve their students in a science outreach program will give you an opportunity to interact with them and assess their needs. Teachers in general will be more receptive to support and professional development if you have already demonstrated interest in, and commitment to, the educational needs of their students.

For all grade levels, stress involving students in interactive activities and lessons. Use current research-based pedagogical techniques. If you are unfamiliar with current work, excellent summaries are available through the Physics Education Research (PER) User's Guide [Ref]. An important theme in PER is that qualitative understanding of physical phenomena and mathematical principles are best initially developed from activities rather than from a textbook or lecture. Whenever possible, encourage teachers to use activities to introduce concepts rather than to verify concepts. Encourage the use of research based models of instruction such as Science Journals, Learning Cycles, Modeling, guided inquiry, ranking tasks, etc.. Teachers with low confidence or less experience in teaching science will tend to use direct instruction. They will rely on students learning the material primarily through textbook reading, and cook-book labs because it is easier and requires less competency on the part of the instructor. Avoid criticizing teachers who rely on less interactive instruction. Instead, show them the benefits of interactive instruction by presenting material to them using these methods.

<u>Elementary Teacher Support</u>

Like most of the people in our society, many elementary teachers lack positive attitudes towards science, and physical science in particular. Many teachers are enthusiastic about teaching life and earth science, but are less comfortable teaching physical science. When pressured by administration to focus on language, literacy, and math, it is very tempting for teachers to skip physical science completely, and spend what little time they are allotted for science education on biology, geology, and natural history. Because of this, elementary teacher support is the most challenging, but can have the biggest impact.

Providing demonstrations, an exhibit show, or fun science activities is great for getting kids excited and sparking interest. However, without follow-up from their teachers, the long-term impact on these students is limited. Incorporating teacher support into school outreach can magnify your impact and encourage teachers to cover physical science topics when they otherwise would not. Support can range from simply providing written explanations for what you did with their students to extensive professional development programs.

Even if you have experience in providing professional development to elementary teachers, you can greatly enhance any impact of outreach to this group by partnering or consulting with education faculty at a local college. The best people to contact for this are those who instruct the elementary science teaching methods courses. They can help with choosing appropriate demonstrations and activities, and in aligning them to state and national education standards.

In any outreach effort to elementary schools, a first step in providing teacher support should be to provide written descriptions of each of the activities or demos you provided to their students. The descriptions should be written at the 3rd - 5th grade reading level to allow teachers to provide them directly to their students if they so choose. Providing information on how to extend these with additional class activities or take home experiments is the next logical step. Information on where teachers can go online for related activities is also helpful, as is providing a listing of good books on science activities, projects, and basic science content. Encourage them to share any book listings with their school librarian.

The next level would be to provide information on activities or demos that are more than simple extensions of whatever you provided to their students. If possible, go through these lessons with the teachers in a short workshop after school or on an in-service day. Activities and lessons you suggest teachers use must be short, requiring no more than an hour to complete. Most teachers cannot spare more than that in a day on science. In order for teachers to implement what you provide, they need to know where and how to fit it into their curriculum. Experienced teachers with strong interest in science will take what you provide and know exactly how to utilize it in their instruction. Unfortunately, these teachers are few and far between in these grades. Most teachers will need some direction on how to incorporate physical science activities into their instruction. Since some teachers have avoided physical science, they will need convincing in order to change their habits. This is where a college education faculty member with experience in science teaching methods can help. The following are some suggestions on how to increase your impact on the science teaching practices of elementary teachers. Implementing even one of the following will make a difference.

In written descriptions of each activity, lesson, or demo you suggest teachers use, provide brief statements on how they are aligned to state and national education standards. Be sure to stress alignment with any applicable math, language, and literacy standards, since student performance in these areas is mostly what is tested. Science is an ideal vehicle for instruction in math, reading, and writing since it can involve all these subjects and supplies a context. People learn material more efficiently when there are clear linkages to other subjects and clear applications. We do not learn isolated facts easily.

Find out what science and math texts teachers are using and reference each activity, lesson, or demo you cover to specific grade level, unit, chapter, and lesson in these texts.

Use common and inexpensive materials, such as plastic pop bottles, tape, pvc pipe, clay, coffee cans, balloons, etc.. Rodney Edge's *String and Sticky Tape Experiments* [Ref] book has many good ideas for this. Teachers have limited funds, if any, for science supplies, and will have to acquire enough stuff for all their students. Common materials are less threatening to teachers lacking confidence in teaching science than the technical laboratory equipment more common in high school and college science classes. This also applies to their students.

Use toys whenever possible. Toys will engage elementary students (and teachers) better than devices designed to illustrate a science topic, even if the devices are constructed from common household materials. This is especially true for people less confident and comfortable with doing science. There are several excellent books devoted to using toys to teach science [Refs].

Find out what books are on the reading list for the school or district you serve, and organize science activities and demos you present to one or more stories on the list. This can engage students to science topics better than isolated presentations not linked to other studies. The material you suggest teachers use will more likely be implemented if connections to what else they are required to present is clear. This is a great way to sneak more science into the curriculum.

Middle School Teacher Support

Science instruction in middle school is usually provided in specific subject area classes such as physical science, earth science, and life science. Science teachers are usually better prepared and confident in science instruction than their elementary colleagues. In many districts these are the first grades where physical science is seriously covered. However, many middle school teachers lack content knowledge and have limited pedagogical skills in physical science. As such, most of the tactics and suggestions described above for elementary teacher support are valid for middle school teachers. An exception to this is the need at the elementary level to keep lessons and activities short. Middle school physical science teachers have much more time to spend on each topic, so more in depth activities and lessons are possible. They have the opportunity to utilize inquiry learning to a greater extent, and should be encouraged to do so.

Science projects and competitions are more common in middle school, and teachers frequently need help. Many of these events, such as the national Science Olympiad, Leggo Robotics, and science and engineering festivals require expertise beyond a teacher's skill set. This is where you and your students can serve as science coaches and classroom heros.

High School Teacher Support

If you are faculty or staff at a college or university, outreach to high school teachers is well worth the effort. While they typically have more content knowledge than their K-8 colleagues, high school teachers frequently still need help in this area. Most high school physics teachers had the bulk of their training in some other field of science, and do not have any physics course work of their own beyond the introductory level. Many are not familiar with pedagogy developed specifically for introductory physics. Even the best physics teacher can benefit from new labs, activities, and demos you might be able to share. The greater content knowledge of high school teachers makes outreach to this group less of a challenge than with K-8 teachers, and there are potential benefits in recruitment of their students to your college.

There is much overlap and equivalence between introductory college physics and what is taught in high school. In many cases the textbooks are the same. Many of the skills you have for effective introductory instruction can be implemented successfully at this level. This makes outreach to high school teachers much easier. Benefits to less experienced high school teachers and to experienced instructors teaching out of their primary discipline are thus more immediate than with outreach to K-8 teachers.

If you are a high school teacher, you are in an even better position to provide effective outreach and support to other high school teachers. You are in the best position to know what resources, content knowledge, activities, labs, and pedagogy are most needed, and how to implement them successfully. Much can also be gained by doing this. Even the most expert teacher can learn new and better ways of doing things while sharing best practices with our colleagues.

In all outreach efforts involving high school teachers, it is important to stress the value of resources, support, and professional development available through the national American Association of Physics Teachers (AAPT) and your local AAPT section. The American Journal of Physics, the Physics Teacher magazine, the ComPADRE Digital Library, The Physics Educator blog, the YouTube Physics Teacher Channel, the AAPT Physics Bowl, the High School Physics Photo and Video contests, and the Physics Teaching Resource Agents program are especially useful at this level [reference web links]. Very few high school physics teachers teach only physics. In smaller schools, especially in rural areas, only one or two teachers instruct all of the science classes. Most do not identify themselves as physics teachers. These teachers have the most to gain from the AAPT, and are also the least likely to seek AAPT membership and the resources and support it can provide. Encourage AAPT membership, but to not alienate teachers by pushing this point too strongly. Membership in professional societies for every disciple a teacher instructs is often impractical as well as expensive. Do encourage attendance of local AAPT section meetings, use of AAPT resources, participation in AAPT programs, and collaborations with other teachers of physics in your region. One of the most important and effective ways to support high school physics education is to help build a network of supportive colleagues.

All teachers like new teaching toys. Providing teachers with something as simple and cheap as a vortex cannon made from a 5-gallon plastic bucket [Ref], or a water rocket made from a 2-liter plastic bottle [Ref] can often make them more receptive to other support you can provide. College and university faculty are frequently given introductory physics texts by publishers for review, in hopes that the texts will be adopted for classes. Give these to high school teachers whenever possible.

High school teachers often serve as informal career guidance counselors and college preparation advisors. An important form of support is to provide them with information on careers in physics, what companies and organizations hire physics graduates, and what salaries to expect. The American Institute of Physics (AIP) Statistical Research Center [http://www.aip.org/statistics/] is a great resource for this information. Information on the colleges and universities in your region that offer physics degrees, and what scholarships are available for this study is also worthwhile to communicate, especially if you are associated with one of them. Outreach and high school teacher support are excellent ways to recruit good students to a college or university. If you are a college or university faculty member and endear a teacher to you, they are more likely to advise students to consider your institution.

Chapter 7, Logistics

Jeremy Benson, Northern Illinois University

Logistics

- Planning
- ○ Marketing / Publicity
- ■ Creating Awareness
- ■ Publicizing Events
- ○ Scheduling/ Booking
- ■ Booking Info
- Person Contacting
- Principal (if applicable)
- Location
- Grades / Classes Attending
- Policies - cancellation, late, etc.
- Insurance / Liability Concerns
- ■ Scheduling
- Keep detailed schedule to avoid conflicts
- Document number of Shows and schedule for each event.
- ■ Show Info
- Audience
- Content
- Materials / Equipment Needed
- ■ Venue Specifics
- Check in / Load in Procedure
- Seating Arrangements / Capacity
- Electrical Outlets
- Tables
- Access to Water
- ■ Other Special Considerations
- Students with special needs
- ○ Loud Noises / Flashing Lights
- ○ Other Differentiation Needs
- Different sites restrictions
- ○ Open Flame policies? (NSTA)
- ○ Latex - other allergies
- ○ no free scissors at the alternative school
- ○ visiting the school at the detention center
- ■ Staffing Options
- Community Groups

- Kiwanis Club
- Seniors’ Groups
- Scout Groups
- Student Groups
- Parents
- Teachers
- Event
    - Packing / Transport
    - Setup
    - Staff Training
    - Cleanup
- Post Event
    - Payment
    - Revenue Tracking
    - Audience Tracking
    - Expense Tracking
    - Assessment (refer to the chapter)
    - Thank you letters
    - Surveys (possible type of asssessment)

Chapter 8, Safety
Steve Shropshire, Idaho State University

To ensure that your outreach efforts educate, inspire, and excite your intended audiences, safety must be a priority. Not adhering to accepted safety practices in science activities, presentations, and other forms of outreach can promote recklessness and behavior that may lead others to harm. Even worse, you may bring harm to property, yourself, or others in a very public way. Most people have limited exposure to physics and the practice of science in general. One bad experience can make a very lasting and negative impression, so it is of utmost importance to do whatever you can to make what exposure to science you provide be both positive and enlightening. You have the opportunity to have additional beneficial impacts on behavior and attitudes in how you address safety. By being obvious in making your outreach as safe as possible you allay concerns of those with negative impressions of science, and you set a good example to youth who will need good safety habits of their own in laboratory situations and when they enter the workforce.

The goal of this chapter is not to cover all of the practices and concerns you need for successful and safe science education. There are several excellent publications [provide Refs] on safe practices that cover this in depth, such as the AAPT publication *Safety in Physics Education* [Ref], and the National Science Teachers Association (NSTA) publication *Safety in the Science Classroom* [Ref]. All outreach practitioners should also be familiar with the U.S. Department of Labor Occupational Safety & Health Administration (OSHA) Standards [https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910]. The following is designed more as an overview of basic practices, and safety suggestions specific to common science outreach activities.

When planning a science outreach activity, always ask yourself "what is the worst thing that could happen?". Do whatever you can to prevent it and minimize harm if it does happen. If you cannot reduce the risk to the point where the consensus of physics educators would be that it is safe, do not do it. If you are unsure as to what this point is, ask your colleagues. The PIRA listserve [Ref] described in Chapter 2 is an excellent forum for such questions. Make your safety precautions obvious. Justify them, explain them, and consider them an important part of your outreach. Do not take precautions when not needed, such as wearing eye protection when there is no risk of flying debris, chemical exposure, or projectiles. Taking unnecessary and irrelevant precautions may lead your target audience to dismiss valid safety issues you address.

Most outreach events involve direct physical proximity and contact with your audience.

Choose how you stage these with safety in mind. If you are presenting demonstrations to a static audience, be sure to have a sufficient buffer zone between you and them. Do not just plan the size of this space on what you expect to happen, but on what can occur on accident. An errant elbow or stumble can dislodge, break, or even fling devices or debris that are heavy, hot, or have sharp edges. Avoid behavior that might tempt people, especially children, to “rush the stage”. Tossing items or projecting debris between you and the audience can prompt this. For events without a static audience, such as science exhibit shows, interactive demos or activities, or any situation where people will be close by design, do not use equipment that needs any space around it for safety. Be sure all devices are robust and not easily dislodged or broken. Do not have anything that could cause harm through close unplanned contact. If you expect small children, do not use anything with small easily detachable parts that could be a choking hazard.

The following sections cover hazards common in physics outreach; projectiles, physical and mechanical, thermal, pressure, noise, electrical, chemical, laser, and radiation. A basic overview of each hazard and standard practices are provided. Illustrative, but by no means exhaustive, examples of best practices in common demonstrations and activities are given for each section.

<u>Projectiles</u>

Demonstrations or activities involving projectiles all require space between where they are expected to travel and any audience. Even small, light, and soft objects can be a hazard to eyes. For this reason eye protection is necessary for you, any assistants, and any participants close enough to be in any danger from unexpected but possible projectiles or flying debris. If it does not make any pedagogical difference, use smaller lighter projectiles when possible. Older versions of the *simultaneous fall* [PIRA 1D60.20] demo, where two balls simultaneously dropped and projected horizontally hit the floor together, use heavy metal balls. Newer versions with much lighter bright plastic balls are safer and more visual.

Control the path of projectiles and associated debris as much as possible. Fix launching mechanisms in place so trajectories are predictable. For heavier projectiles such as metal rings from *jumping ring* devices [PIRA 5K20.30], containment or catching systems can improve safety. If you use a jumping ring device in an interactive exhibit, this is a necessity. Containment can be as simple as a stop at the top of a tall tube extension from the iron core. Do not launch metal rings or other heavy or fast moving projectiles into a crowd and expect people to catch them. When launching *water rockets* [PIRA 1N22.20], *air rockets* [TPT 7, 453 (1969)], *stomp rockets* [http://en.wikipedia.org/wiki/Stomp_rocket], or other unguided or untethered outdoor rocket, have a clear launch area free of observers and a cleared range area where landings are expected. Avoid vertical launches because unexpected breezes or other unforeseen variations can easily shift impact sites into your audience. For projectiles that can produce high speed debris, such as from *pencil and plywood* [PIRA 1F30.50] or ping pong cannon (*vacuum bazooka*) devices [PIRA 2B30.70, AJP 72(7), 961], full containment systems are necessary. Plexiglass or acrylic shields around target and impact sites work well for this.

Physical and Mechanical

Any device or activity that involves something moving, has sharp edges or points, or uses strong magnets is potentially hazardous. Consider the likelihood of a device striking, pinching, puncturing, cutting, or falling on someone, and do what is possible to limit these effects. For example, in *rotating stool* demos [PIRA 1Q40.10] use dumbbells instead of other weights to protect fingers from bashing if the subject falls or strikes something. Placing mats around the stool will also help prevent injury from falls. Contain long hair or loose clothing when using devices that involve rapidly spinning parts, such as bicycle wheels [PIRA 1D50.40, 1Q30.10,1Q40.30 D&R M-354, Meiners 12-3.11], gyros [1Q50.00, 1Q50.20, 1Q50.25], power drills [PIRA 1D50.70, D&R M-366], or motors [PIRA 5K40.40, Sutton M-139, Sutton E-229, AJP 48(10) 887, Meiners 17-3.2]. For exhibits or interactive demos that use these devices, contain or block access to spinning parts that might catch hair or clothing. Any situation where Neodymium or other strong magnets are in use has a potential pinch hazard. For exhibits, rigidly fix these magnets when possible. Close supervision is required if you allow subjects to handle them, such as with *eddy current tubes* [PIRA 5K20.25, AJP 73(1) 37] or induction coils [PIRA 5K10.20]. A strong magnet can severely pinch skin between it and ferrous metal or another magnet.

An example of a common demonstration that involves significant puncture, pinching, cutting, and impact trauma injuries is the *bed of nails* [PIRA 1F20.25, 1K30.10, TPT 14(2) 119]. In a popular variant of this demo a subject lies on a bed of nails and concrete or cinder blocks placed on their chest are broken with a sharp blow from a sledgehammer. Improper performance of this has resulted in serious injury in very public situations. As a result, this is one of the few demos explicitly forbidden in the NSTA Minimum Safety Practices and Regulations for Presenters, Workshop Leaders, and Advertisers [http://www.nsta.org/docs/SafetyGuidelines.pdf] for NSTA meetings. This variant is not to be done by or with volunteers. The performer to swing the sledge should be expert. Practice swinging and hitting a small target accurately and with consistent force needed to break the blocks is highly recommended. The performer who lies on the nails must have eye and full face protection, wear a long sleeved shirt, long pants, and gloves to protect skin from flying debris. Long heavy gloves are recommended for additional protection from nail puncture. The most common injury in this demo is from a glancing or missed blow with the sledgehammer that strikes a hand, the abdomen, or chest of the performer on the nails. A plywood board larger than the contact surface of the blocks placed under the blocks, and the performer keeping hands and arms far away from the blocks will limit these injuries.

Thermal

Some of the most exciting and engaging demonstrations involve either fire or liquid nitrogen. They are also involved in many of the injuries and a significant fraction of property damage in demos gone wrong. Appropriate precautions and wise selection of demos, activities, and exhibits involving thermal hazards can prevent the vast majority of injuries and damage.

Open flames should not be used in any exhibit or interactive activity without direct and close supervision. At least one fire extinguisher in addition to those inherent in the facility should be close at hand and prominently displayed during any situation where fire or excessive heat are possible. Clear the demonstration area of flammable materials, constrain long hair and loose clothing of presenters, and keep the audience static and at a safe distance. If the demonstration surface is not stone or some other inflammable material, cover it with fireproof mats or tiles if the flame is larger than what is typical from a few candles. Welding mats work well for this. Such coverings are necessary with demos involving Bunsen burners, small gas stoves and burners, and material deliberately set on fire, such as in *flame tornado* [PIRA 2C50.35] or *alcohol vapor rocket* [PIRA 1N22.35, D&R M-426] demonstrations. Always wear eye protection, lab aprons or coats, and gloves when performing demonstrations that burn.

Balloons larger than 40 cm (16 inches) in diameter filled with hydrogen gas should not be ignited indoors. They should never be ignited in a room with ceilings lower than 3 m (10 feet). Keep them away from heat sensors present in some smoke detectors. It is recommended that you spend them from strings so they are far from any other flammable material and at least one meter below the ceiling. Light them with a long lighter while wearing a long sleeved glove and eye protection, or better still, with a candle or match attached to the end of a meter-long stick or rod. Inflate them in a well ventilated area in immediate proximity to where you intend to ignite them. Never transport balloons inflated with hydrogen.

Demonstrations requiring a steady source of flame larger than that from a small gas stove or burner should only be done outside or in large rooms with high ceilings and good ventilation, such as lecture halls and gyms. A common such demo is the 55 gallon drum crush [PIRA 2B30.20, Sprott 2.4, D&R F-025]. If done inside, it should be situated far from any walls, and with one or more large welding mats placed underneath the flame source.

Presentations involving objects hot enough to burn or cold enough to freeze skin must not be done as exhibits, and performed in interactive situations only under close supervision. The most common examples are thermal expansion demos, such as the *bimetal strip* [PIRA 4A30.10], the *ball and ring* [PIRA 4A30.20], and *break the bolt* [PIRA 4A30.30]. The *ice bomb* [PIRA 4C20.20] and *break the bolt* demos have the added hazard of flying hot or cold metal debris. Protective shielding between the devices and audience are necessary.

Liquid nitrogen (LN) demonstrations are popular in physics outreach, but require significant safety precautions. Even though it is possible to immerse your bare hand in LN for a second or two, do not do this in a presentation. If someone follows your example on their own they can get frostbite if the LN soaks into clothing, gets trapped in a fold of skin, or their exposure is longer than one second. Wear eye protection when working with LN and use tongs to place items into it and to retrieve them. Do not allow observers to come into direct contact with LN. When possible, choose items with low thermal conductivity for immersion. If dropped they are less likely to harm an observer with quick curious fingers. When smashing objects frozen in LN [PIRA 4A40.30], such as flowers and racquetballs, be sure to do it in a way to protect observers from flying debris. When making LN ice cream, do not chill the mixture to the point of a hard freeze. Only serve the mixture soft. It is very easy to chill it to the point where it will freeze saliva, cause micro-cracks in teeth, and even cause frostbite. Do not chew or eat items immediately after immersion in LN, such as Cheetos, graham cracker pieces, etc.., nor should you put any LN in your mouth, even if you spit it right out immediately. Yes, you can get a cool frost breath effect, but this can also cause microfractures in your tooth enamel that will lead to cavities and other problems later. Never ingest LN. It can cause severe damage to your esophagus and stomach. Do not splash or spill LN onto floors near anyone. It can soak into clothing or shoes and cause frostbite. Transport LN only in thermos or dewar containers, and secure these containers so they cannot tip or spill during transport. Always vent LN containers and never seal them, or pressure will build and cause an explosion.

Solid carbon dioxide (dry ice) also requires special handling. Even though it is possible to hold dry ice in your bare hands, do not do so in a presentation. As with LN, the potential for people in your audience to hurt themselves or others by trying this on their own is high. Always wear gloves and eye protection. Slivers of dry ice can spall off at high velocity from rough handling or internal pressure from sublimation, especially when submerged in water or heated. Do not allow observers to come into direct contact with dry ice.

Pressure

Pressure hazards can either involve explosions or implosions. Both have the potential to produce flying debris, shock wave injuries, and hearing damage. In all cases where devices are pressurized or evacuated to pressures significantly different from atmospheric pressure eye protection and long sleeved shirts and pants are strongly recommended. Do not use devices that rely on pressures significantly different from atmospheric in an exhibit, and use them in interactive situations only with close supervision. Allow sufficient space between the device and observers to protect from flying debris, or provide additional protective shielding.

For demonstrations involving vacuum chambers, only use thick walled lexan or glass containers designed to withstand large pressure differences. Secure these containers so they cannot tip over or fall. Always inspect the container before evacuation for cracks and other defects. Many demonstrations rely on pressure to propel projectiles, such as the *tennis ball cannon* [PIRA 1H11.20, D&R M-562], *liquid nitrogen cannon* [PIRA 1H11.30, F&A Hk-11], *dry ice cannon* [PIRA 1H11.30, F&A Mi-2], and *vacuum bazooka* [PIRA 2B30.70, AJP 72(7), 961]. Always inspect these as well prior to use for defects or flaws that could cause an explosions or implosions. For explosive devices, use solid metal tubing when possible. Metal soup cans duct taped together can easily rupture.

There are numerous OSHA regulations regarding the compressed gases frequently used in outreach. Always secure cylinders. Use pressure regulating valves for dispensing non-liquefied gasses. Do not leave the cylinder valve open when not in use. Do not store oxygen and hydrogen cylinders together. Remove regulators for transport, and secure the valve with a valve-protection cap. Carbon dioxide cylinders contain liquefied gas and do not require pressure regulators. They are used in the *pencil and plywood* [PIRA 1F30.50] and the cart and fire extinguisher [D&R M-566] demonstrations. Ruptures of tubing and fittings directing the high speed gas in these and similar demos can flay exposed flesh, so wear heavy gloves, protective clothing, and eye protection.

Two of the most dangerous and controversial demonstrations ever done in physics outreach are the LN and dry ice bombs. LN or solid CO_2 is placed in a sealed container, usually a plastic bottle. This is considered an explosive device by law enforcement. Numerous people have been maimed by these, so it is best not to do this as part of any outreach effort. If you decide you absolutely have to do it for the “wow” factor, you must take the following safety measures. Inform law enforcement. Remember that this is a bomb. Ask if one of their officers, and if possible, a local fire marshall, can arrange to be present to evaluate your safety measures. If they find them lacking, or otherwise request that you do not do it, listen to them. Use LN and not CO_2. The time it takes for pressure to build inside the container is much more rapid and predictable with LN. Use a plastic beverage bottle no larger than 750 ml. Other containers and larger plastic bottles are less predictable, and materials other than thin plastic produce more dangerous shrapnel. Do not do this inside unless your space is very large, such as a gymnasium, and you can detonate the device no closer than 20 m from the nearest observer. The sound intensity level can spike well over 120 dB within this distance. Provide as much baffling for the sound as possible. Hanging heavy rugs to the side and behind the detonation site with at least a meter of open space behind them is one way to help baffle the sound. Wear full face shielding, heavy padded clothing, heavy gloves, and ear protection rated for firearms. Do not fill the container more than half full. Use a funnel to fill the bottle, and take the time after filling but before sealing to warm the threads and top of the bottle to ensure a tighter seal. A hair dryer works well for this. Practice filling a vented bottle while wearing all of the protective gear well before the event. Quickly seal the bottle and place the bomb in a container strong enough to withstand the blast and direct any debris upward. A thin metal trash can or wastebasket is not sufficient. Never use a plastic bucket. Use a thick walled metal drum if possible. Fill the bottom of the metal container with at least 6 cm of water to provide a thermal sink. This will result in a more rapid pressure build up and detonation. When placed in water, these devices will usually detonate between 10 and 60 seconds after sealing. Without water or some other heat sink, they can take several minutes, and tempt the rash to “check on it”. Under no circumstances look into the metal containment vessel after sealing the plastic bottle. After placing the bomb in the containment vessel, quickly move at least 10 m from the detonation site. If it does not detonate within one hour, wait until all audience members have left the building before approaching the device. Don heavy clothing, i.e. multiple heavy winter coats, overalls over jeans, and a heavy bathrobe over all of that. Wear heavy welding gloves, full face shielding, and ear protection rated for firearms. Cover the containment vessel, take it outside to a large open area cleared of people. Find some way to dump the bomb out of the container from a distance. Ask a law enforcement officer to shoot the device from at least 30 m away with a pellet or BB gun to safely disarm it. Then promise them that you will never do it again.

<u>Noise</u>

Few things excite and engage better than the occasional boom. Unfortunately, loud noises can also damage hearing. If any of your demonstrations produce loud noises, use a sound intensity meter while practicing the demo to determine the separation needed between the demo and your audience for safety. The hearing damage threshold depends on the duration of the sound and the frequency range {REF https://www.nidcd.nih.gov/health/hearing/pages/noise.aspx]. In general, higher frequencies are more damaging than lower frequencies at the same sound intensity level. Keep in mind that younger children have more sensitive hearing and a lower pain threshold than adults. As a general rule of thumb, for loud demos lasting less than 10 seconds, you should keep the sound intensity level less than 90 dB where your audience is to be. You and any assistants within this distance must wear ear protection. Keep in mind, the sound intensity level at a given distance is Affected by the size and construction of the room. Perform your sound intensity level measurements in a room similar to where you plan a presentation. Common demonstrations that can produce dangerous sound intensity levels include detonating hydrogen filled balloons, detonating balloons filled with a hydrogen - oxygen mix, *Chladni plates* [PIRA 3D40.30, F&A Sb-1, AJP 59(7) 665, AJP 51(5) 474] *Ruben's tube* [3D30.50, Meiners 19-3.5], and the *shattering goblet or beaker* [PIRA3D40.55, TPT 28(6) 418].

Electrical

Many demonstration devices, and almost all interactive exhibits used in physics outreach are built from scratch by students, staff, or faculty. For devices drawing electrical power, care must be taken to make them safe and OSHA compliant. Always provide a ground connection, and install a ground fault circuit interrupt (GFCI) if the device draws excessive current or may be used near liquids or in potentially damp situations. Avoid using devices that require more than 5.0 Amps of current in an exhibit, and use them in interactive activities only if close supervision is provided. Wear insulating gloves when working with these devices. Examples include the *jumping wire* [PIRA 5H40.30, D&R B-020], *Ampere's motor* [PIRA 5H40.71, Meiners 31-1.3, Meiners 31-1.4], *jumping ring* [PIRA 5K20.30], *weld a nail* [PIRA 5K30.40, F&A Em-4, Sutton E-239], *electromagnetic can breaker* [PIRA 5K20.65], and *pickle glow* [5D30.30] devices. The *pickle glow* demo is particularly dangerous, and should never be done without a GFCI.

Always have a grounded sphere near an operating *Van de Graaff generator* [PIRA 5A50.30]. People with open wounds, IV or UT catheters, wound drains, or other conditions where the skin is broken are micro-shock sensitive. Do not allow people with this condition to touch or come near an operating *Van de Graaff*, *Tesla coil* [5N20.00], or *induction coil* [5N20.10]. A popular Van de Graaff activity is where you have one person on an insulated stand with one hand on the generator, and a line of people holding hands near by. The person on the stand and a person at one end of the line touch hands and the whole line of people feel the shock. Never do a variation of this where more than one person are on insulated stands. The amount of charge that can build up may be enough to cause electrical burns, injury, and even death from ventricular fibrillation.

Chemical

Few demonstrations or activities common in physics outreach require the use of chemicals. If you use a chemical during outreach, you must abide by the Chemical Hygiene Plan for your institution. This may involve having Material Safety Data Sheets (MSDS) for each chemical you use with you wherever you use them. The most common class of chemicals used in physics outreach are alcohols, all of which are highly flammable with low vapor pressures. Do not use alcohol lamps. There are far safer options, such as hot plates, heat guns, bunsen burners, or even propane camp stoves. If a demonstration involves burning alcohol, do so in dim lighting, and never in bright sunlight. Alcohol flames are not very bright. Many people seriously injured from burning alcohol on flesh or clothing were not initially aware they were even on fire due to the low visibility of the flames.

Laser

Never expose anyone's eyes to direct or reflected laser light. Always design exhibits and plan demonstrations and activities involving lasers with this in mind. Do not allow members of your audience to direct the path of a laser unless close supervision is provided. If a class III laser (1 - 500 mW) is part of an exhibit, be sure to post an American National Standards Institute (ANSI) Danger sign [http://ansi.org/] warning of laser hazard. Do not use class IV lasers (> 500 mW) in physics outreach due to risk of radiation burns, fire hazards, and eye damage.

Radiation

The only device common in physics outreach that produces ionizing radiation is the *cathode ray tube* [PIRA 5H30.10, 5H30.15] and *gas discharge tubes* [PIRA 5H10.25, 5M20.10, 5M20.20]. Keep observers at least 2 m away from these devices when in operation. For most locations and devices, this will limit the radiation exposure to less than twice normal background. When using a Geiger-Muler tube, or *Geiger counter* [PIRA 7D10.10] and radioactive materials, use naturally occurring sources of radiation as much as possible. Man-made sources of radiation, no matter how weak or strong, are subject to regulation by the Environmental Protection Agency through regulations 40 CFR [http://www.ecfr.gov], OSHA through regulations 29 CFR [http://www.osha29cfr.com/], and the Nuclear Regulatory Commission through regulations 10 CFR [http://www.nrc.gov/reading-rm/doc-collections/cfr/]. Even with naturally occurring sources of radiation, you should not allow the public to come in contact with radioactive material.

Chapter 9, Administration

Pati Sievert, Northern Illinois University

Chapter 10, Assessment

Steve Lindaas, Minnesota State University Moorhead

1. Background
2. Designing assessment
   a. Audience
      i. Administrators
      ii. Grants and other funding sources
      iii. Practitioners -
         1. Internal dissemination
         2. External dissemination
   b. Types
      i. Formative
      ii. Summative
   c. Design
      i. Objectives
      ii. Working backwards once you know what you want...
   d. Application
      i. Formal
      ii. Informal
3. Applications
   a. Examples
   b. Rubrics

What is the purpose of your assessment? Why are you assessing your activities? Whether you are trying to improve the effectiveness of your activities or need data to generate support or find funding assessment can help. Knowing your motivation is key to making assessment useful. Plan your assessment when planning your activities. Build your assessment plan into your event to minimize pain and anguish and maximize the value of the information you are collecting. Do you have someone tasked with taking pictures and quantifying the audience? Simple planning can improve your data (not to mention minimize stress and time spent trying to recreate information).

Know Your Audience

Depending on your audience your assessment will vary. The data that will be useful for you to have when talking to an administrator, potential funder or your team members may not be the same. Even if the information is similar the analysis and emphasis often changes.

- Administrators

- Grants and Funding Sources
- Practitioners - internal and external (dissemination)

Types of Assessment
Assessment can either be formative or summative. In addition you can have both qualitative and quantitative measurements with measures including both pre- and post- tools.

Formative assessment is conducted while an activity is occurring and is used to make adjustments right away. Noting that your audience is falling asleep and making appropriate adjustments is an informal formative assessment. Having workshop participants fill out a survey during a break can be formative if used to make adjustments after the break.

Summative assessment is conducted at the completion of your event. A survey that is completed after your event is a form of summative assessment.

Backwards by design reference

Rubrics for various types of assessments

Chapter 11, Staffing
David Sturm, University of Maine

One of the major challenges for any Outreach program is in developing a pool of reasonably well-trained volunteers. Although there have been a number of Outreach programs built completely around volunteers, for long-term success it is recommended that a full-time staff member or faculty member be the leader of a program. Many great efforts have been led by those without a more permanent position, but there are many issues in liability, school relations, and sponsorship that are tremendously improved if the program leader is an employee of a school or organization.

The actual needs for staffing will completely depend on the size and scope of a program and its programming. We look at a variety of program options and types first.

For the purposes of staffing out a program, we'll mention only the **guest lecture** type of program where a school or center faculty member goes out and gives guest lectures on a topic of interest in physics, without a focus on demonstrations. This has traditionally been many physics department's ideas of what outreach is. Some might call it "colloquium on the road". It has little to no needs for staffing beyond the lecturer.

The first category would be the **one-person program**, Science Guy/Girl type program, with a single primary presenter. This type of show follows the classic Mr. Wizard or Bill Nye method of having a presentation of demonstrations across physics, or themed to a particular category. Universities commonly employ this method where the department's "PIRA person", usually the staff member or faculty member in charge of demonstrations travels into schools with a van load of demonstrations. Examples include Rutgers' Dave Maiullo's programming, Syracuse's Orange Physics with Sam Sampere, and UMaine's Mainely Physics Road Show with David Sturm. Often volunteers are enlisted to load in and load out, both at the origination points, and then also at the presentation site.

The second category would be the **presenter with helpers program** with a lead presenter (who might or not be in charge of the outreach program), assisted by colleagues who might present one or two demos, but always travel along with the presenter. Examples include the University of Iowa's HawkEyes on Science, the Physics Bus from Arizona, and the Physics Van from the University of Illinois.

The third category would be the **delivered program** where exhibits are delivered and set up as self-serve stations, with perhaps some demonstrator-led exhibits included. UMaine's Mainely Physics Road Show uses this model at science fairs and engineering expositions where physics is included among many other booths.

The fourth category will be one of the most complex, the **multiple-exhibits, staffed, many-room program**. This involves the greatest need for staffing. The most well-known example of such a program is the superb Little Shop of Physics at Colorado State University that Brian Jones has built over the last 20+ years.

Many outreach programs once established often can provide all categories of presentation with adequate prep time. Colorado's Little Shop often starts groups with a central presenter-with-helpers-led program, rather than simply sending them off to the rooms with exhibits.

Volunteers
Training
Liability
Associated staff

Staffing Options
Community Groups
Kiwanis Club

Scout Groups
Student Groups
Parents
Teachers

Chapter 12, Funding

David Sturm, University of Maine

Funding sources brainstorming list

College/campus:

Department of Physics (and Astronomy)
Dean's offices, Sciences, Engineering
President/Provost/Chancellor
Admissions offices
Enrollment management offices
Career offices
Development/Advancement offices
Grant-writing offices
Alumni Associations
Campus research labs with outreach requirements

If student volunteers are involved:
Student organizations (Society of Physics Students, Sigma Pi Sigma, many Engineering associations)
Student government associations
Student recreation/activities
Student housing activities

Off campus:

- **Education related:**
  - State Departments of Education
  - State Math-Science alliance programs
  - School districts, school boards
  - Superintendents' offices
  - Principals of schools
  - School-based PTA/PTO
  - Gifted and talented programs

- **Commercial interests:**
  - Power companies, other utilities
  - National cable television companies in the market
  - Local television/radio stations (free or low-cost advertisement)
  - Local newspaper/magazines (in-kind donations)
  - Chamber of Commerce
  - Arts councils, etc.

City councils
City recreation departments

Professional organizations:

APS
AAPT
PTRA
PIRA
ALPhA
SPS
AIP
other AIP affiliates
OSA: Optical Society of America
MRS: Materials Research Society
AAS:
ASP:
NSTA:
NCTM:
etc.

Commercial organizations & companies:
US:

PASCO
Vernier
Ward's Science (Sargeant Welch/VWR/CENCO)
Science First/Science Source/Daedalon
American 3B

Chapter 13, Publicity

Steve Shropshire, Idaho State University

goal: to seek a wider audience, reach more people. not aggrandizement

paragraph on isolated event promotion

besides posting of flyers on billboards at your institution, in community centers, grocery stores, and other businesses:

prominent post on event calendar on web site for your institution

contact local sd offices and ask them to forward an email to all principals

offer to appear on a local public access, local news station, or local public broadcasting service (PBS) station. ask to have your event listed on their community or event calendar, either on air or on their web site.

contact the local interest or education editor at your local newspaper to submit article

contact local radio stations to get announcement on community or event calendar, either on air or on their web site.

post on Pinterest https://www.pinterest.com/

paragraph on overall program promotion

all of the above plus:

local SD principal meeting

present at regional NSTA and state affiliate meetings

present at a regional PTA or PTO meeting

Boy Scouts: go to https://beascout.scouting.org/ and click on “volunteer”, enter zip code, will get phone & email contacts for local council, cub scout packs & Boy Scout Troops

Girl Scouts: go to http://www.girlscouts.org/ and click on “Volunteer” under the “For Adults” tab. Enter a zip code to get contact info for council & troops.

present at a local meeting of local Kiwanis, Rotary, or other community service organization meeting

Chapter 14, Alignment to Standards

Steve Lindaas, Minnesota State University Moorhead
Alice Flarend,

1. Introduction to standards
2. Purpose for standards
3. Using standards
   a. Formal
   b. Informal
   c. Best practices
4. Links to standards
   a. National standards (NGSS)
   b. State standards
      i. MN = SciMathMN
      ii. ?? Need input/help identifying state resources

Every activity you do can be linked to at least one if not multiple standards. Making these links obvious has multiple benefits. In addition you can always strengthen your alignment to standards. Of course you have to be familiar with the standards in order to make and improve these links.

Chapter 15, Resources

Stan Micklavzina, University of Oregon and David Maiullo, Rutgers University

SPS Involvement and Grants from national Office

Chapter 16, Example Vignettes - Case Studies

Liquid Nitrogen Demo Show

Submitted by: Paul Nord, Brittany Barkus, Valparaiso University
Venue: Public Park, Fair, Classroom
Group Size: Small, up to 30 at a time
Time: 1 hour

Materials:

- Liquid Nitrogen (LN2), 4 to 8 liters
- Flowers, 6 to 12 carnations or other flowers
- Balls (ping pong balls, raquetballs, bouncy balls, etc.)
- Small styrofoam container or large styrofoam cups (inexpensive cooler)
- Tongs
- Heavy Gloves

Pennies (post 1986 with zinc core)
Wood Block
Hammer and nails
Banana, and other fruit
Balloons (long skinny balloons work well)

- Ice Cream ingredients*
  - -½ gallon milk
  - -1 quart Cream (Half and Half)
  - -3 cups Sugar
  - -1 tsp Vanilla
  - *May need to be adjusted depending on group size.

Ice Cream making and serving
Large metal bowl (no glass or plastic)
Wooden or Plastic Stirring Spoon
Spoons and Cups
9 volt battery
LED Unit (LED and 330 Ohm resistor in series connected to a 9 volt battery snap connector)
clear Pyrex beaker

Safety Concerns:
Keep kids from touching or getting too close to LN2 or items chilled to cryogenic temperatures. (See safety chapter for more information.)

Theory:
material properties at cryogenic temperatures, extreme environments, phase change (LN2 expands 700 times when warmed to a gas at STP) and chemical properties

Demos:

Frozen Flowers

Dip flower into LN2 and let it sit for about 1 minute. Remove from LN2 and have a student hold the stem and smash it against the floor.

Frozen Fruit

Freeze various fruits and observe the phase changes. Try smashing them.

A fun one to try is the "banammer." Cut a banana in half and stick a rod or end of a spoon through it and put it in LN2 for a few minutes. Then, take a nail and wooden board and try to hammer in the nail.

Balls

Put various balls into the LN2. Try ping pong balls, racquet balls, tennis balls, bouncy balls, or anything else you can find! Most should reach LN2 temperatures in a minute or two. Frozen racquet balls sound like billiard balls when dropped on a hard surface. Bouncy balls sound like marbles. Some will bounce better (higher coefficient of restitution at low temperatures.). Most will shatter if thrown hard enough.

Let the fragments warm up before allowing anyone to touch them.

Balloons

Air in balloons will condense to a very small volume when chilled with LN2. Fill styrofoam container to a 1-inch depth. Using a gloved hand or tongs, push balloons into the liquid. The balloons deflate quicker with more surface area in contact with the liquid.

Balloons can be removed and tossed onto the table where they will inflate.

Ice Cream

Combine the ingredients in a metal bowl. Add LN2 slowly. Stir constantly.

Mix to a soft-serve texture. Frozen chunks may be too cold to safely eat.

Two to three liters of LN2 are required to chill a gallon of milk.

Fractured Penny

Pennies made since 1986 (citation needed) are manufactured with a zinc core surrounded by a thin copper cladding. Zinc becomes brittle at LN2 temperatures. Chill a penny in LN2. Remove it carefully with tongs and place it onto wood block. When you strike the penny with a hammer it easily shatters into many pieces.

Liquid Nitrogen Soap Explosion (outside)

Fill a bucket or large bowl half full with soapy water. Quickly dump in a 1 liter or more of LN2 and step back. A soapy froth of bubbles erupts quickly from the bucket.

Chemical Reactions and Speed of Chemical Reactions

Snap the LED unit onto the 9 volt battery. Place this into the clear beaker and fill the beaker with liquid nitrogen. As the battery cools the LED will become dimmer and will go out completely when the battery reaches liquid nitrogen temperature. The chemical reaction has now slowed to an extent where it is no longer able to light the LED. Remove the battery and LED unit from the liquid nitrogen and allow them to warm up. As the battery warms the LED will start to glow. The warmer the battery gets the brighter the LED will shine.

References:

Legality of destroying US coins: http://en.wikipedia.org/wiki/Elongated_coin#Legality

Additional Liquid Nitrogen Demonstrations

Submitted by Dale Stille, Co-Coordinator “Hawk-Eyes on Science” and “Hawkeyes in Space” outreach programs, Univ. of Iowa. dale-stille@uiowa.edu

Lead Bell

A lead bell has a dull sound at room temperature when struck by a mallet but will ring nicely when struck after being cooled in liquid nitrogen.

Lettuce

For events where many people are allowed to dip an item in liquid nitrogen, lettuce makes a good alternative to the more expensive flowers. Romaine Lettuce is easier to use than a head of lettuce but both work well for this demonstration.

Fruit

Lemons, oranges, and grapes are interesting after cooling in liquid nitrogen.

Teapot

Use a teapot that whistles when water in it boils. Pour in liquid nitrogen instead of water and it also whistles as the liquid nitrogen boils.

Hero’s Engine

Pour liquid nitrogen into a Hero’s engine. As the liquid nitrogen boils the Hero’s Engine rotates.

Light Bulb Filament

SAFETY PROCEDURES NEED TO BE OBSERVED FOR THIS DEMONSTRATION!! Pour liquid nitrogen into a 1000 ml beaker. Remove the glass envelope from a light bulb without damaging the filament. Screw the filament into a rubberized light socket that has been attached to a wooden or PVC rod. Dip the filament into the liquid nitrogen and plug in the unit. The filament will glow and remain intact until it is removed from the liquid nitrogen.

Beaker and Bernoulli Bag

Pour liquid nitrogen into a 1 or 2 liter beaker. Secure a Bernoulli Bag to the beaker with rubber bands. As the liquid nitrogen boils the Bernoulli Bag will inflate to its full length of 8 feet.

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Chemistry Related Demonstration Show

While these demonstrations listed are chemical in nature, most of them can be used to describe or compliment physics concepts and other physics demonstrations.

Event: Outreach Presentations on topics dealing with Chemistry and Chemical Reactions.

Submitted by Dale Stille, Co-Coordinator “Hawk-Eyes on Science” and “Hawkeyes in Space” outreach programs, Univ. of Iowa. dale-stille@uiowa.edu

Venue: Public outreach programs, STEM events, High School Venues.

Group Size: 1 to 100

Time: Usually 50 to 60 minutes.

Safety Concerns:

Several of these demonstration should only be performed by experienced personnel while observing the proper precautions.

Lab coat, safety glasses, Latex or Butyl Rubber Gloves, and hearing protection are a must. A “Science Ready” classroom will make this presentation much easier.

Some of these demonstrations will require a fume hood.

Adequate ventilation will be needed.

Observe smoke detector placement when doing anything with flames.

A fire extinguisher should be located nearby if needed.

Chemical resistant table tops should be used.

Proper disposal of all waste products is required.

Materials:

Materials are listed below in the descriptions. Procedures for each of these demonstrations can be found in many different demonstration books and textbooks. A particularly good resource for demonstrations of this type is the series “Chemical

Demonstrations" by Bassam Z. Shakhashiri, Volumes 1 thru 5.

1. Spectroscopy Chemicals.

Small samples of spectroscopy chemicals are placed in separate petri dishes and wet with several milliliters of either methyl or ethyl alcohol. Light the alcohol with a grill lighter and observe the characteristic flame color from each sample. Chloride salts of Barium, Boron, Calcium, Lithium, Potassium, Sodium and Strontium are commonly used.

2. Aluminum Foil and Cupric Chloride.

100 ml of a saturated solution of cupric chloride is placed in a 400 ml beaker. A 4 inch wide X 8 inch long piece of tin foil is rolled and one end placed in the solution. After several seconds the tin foil starts to dissolve and elemental copper is precipitated in the bottom of the beaker.

3. Calcium Acetate and Ethyl Alcohol.

A simple version of Sterno. 10 ml of a solution of calcium acetate (85 g of calcium acetate dissolved in 200 ml water) is mixed with 100 ml of ethyl alcohol. A non-pourable gel quickly forms. This gel is flammable and may be used to cook, heat water, or used as a portable alcohol burner.

4. The Blue Bottle Experiment.

One gram of sodium hydroxide is dissolved into 100 ml of water in a 250 ml Erlenmeyer flask. After dissolution, one gram of dextrose or glucose is added and allowed to dissolve. Finally add 4 drops of a 1% solution of methylene blue in ethyl alcohol. Let the flask stand open for several minutes until the solution becomes colorless. Tightly stopper the flask. When shaken vigorously the solution will turn blue again. Let stand for several minutes and it will turn colorless again. Repeat the cycle. Basically by shaking the flask you mix oxygen from the air in the flask into the solution which is indicated by the color change. Can be used to demo the dissolving of atmospheric gases by the oceans and the result of that process.

5. Acid and Chalk.

A simple demonstration to show the results of acid rain on limestone and other building materials. Grind up several pieces of chalk with a mortar and pestle and place the dust in a 600 ml beaker. Pour 5 to 10 ml of HCL onto the chalk dust and observe the breakdown of the chalk and release of CO2.
Best done in a fume hood.

6. Permanganate and Glycerin.

A demonstration showing spontaneous combustion from the oxidation process. A small pile of potassium permanganate is placed in a petri dish. A small amount of glycerin (less than 5 ml) is poured onto the permanganate. The oxidation process will raise the temperature of the glycerin until the ignition point is finally achieved at which time the glycerin will burst into flames. Usually this will be about 2 minutes after the glycerin is poured onto the permanganate. Best done in a fume hood and away from smoke detectors.

7. Oxygen Liberation - Peroxide and Manganese Dioxide.

A spoonful of liquid dishwashing soap is stirred into a beaker containing some 30 % hydrogen peroxide. A small amount of MnO_2 is thrown into the solution so that it quickly sinks to the bottom of the beaker. Oxygen is quickly liberated as shown by the large column of soap bubbles growing out of the beaker. Basically a reaction made to happen with the addition of a catalyst. This will be less messy if a large pan is placed under the beaker to catch the bubbles generated. Don't touch the bubbles as they still have appreciable amounts of 30 % hydrogen peroxide on them.

8. Ammonium Chloride Smog.

Two 50 ml beakers, one containing 20 ml of hydrochloric acid and the other containing 20 ml of ammonium hydroxide are place in a clear airtight container. A white cloud of ammonium chloride smog will quickly form between the two beakers and will soon fill the box to such an extent that you can no longer see through it. Wear gloves, safety glasses, and protective clothing when starting this experiment and do it in a fume hood if possible.

9. Styrofoam Cup and Acetone.

A Styrofoam drinking cup is placed in a petri dish and a small amount of acetone is poured onto it. The cup will dissolve over the course of several minutes until there is only a small white blob left in the petri dish. Used as a demo to show that harsh chemicals not naturally found in the environment are needed to break down most plastics.

10. Nylon.

7 ml of hexamethylenediamine / sodium hydroxide solution and 7 ml of adipoyl chloride / hexane solution or poured into a small beaker with minimal mixing. Use a paper clip to pull on the film that develops at the interface of the two liquids. A strand of Nylon is easily pulled from the beaker and can be passed around to the audience after it is washed with water several times. (You can buy these two solutions already prepared from many commercial suppliers. However, if you wish to make your own you will need 6 grams of hexamethylenediamine, 2 grams of sodium hydroxide, and 100 ml of distilled water for one solution and 4.6 grams of adipoyl chloride in 100 ml of hexane for the other solution.)

11. Clock Reaction – The Belousov-Zhabotinsky Reaction.

Four solution are needed. A = 3 ml of conc. Sulfuric acid, 500 ml of water, 21 g of potassium iodate. B = 180 m. of 30 % hydrogen peroxide, 320 ml water. C = 8 g malonic acid, 1.9 g manganese (II) sulfate dihydrate, 500 ml water. D = 2.5 grams potato starch, 500 ml water. Add equal volumes of A, B, and C in a beaker. Then add 2 ml of solution D. The color changes should oscillate for at least 15 minutes going from colorless to yellow to blue. Several drops of Ferroin indicator can be used to make the color changes more visible.

12. Polyethylene Oxide.

Non-Newtonian fluids may be explored with a solution/gel of polyethylene oxide. Start to pour the liquid gel from one beaker into another beaker and the fluid will continue to flow even after you tilt the beaker up to a degree that the liquid should quit pouring. The fluid will keep flowing until the beaker is empty. Great for showing the characteristics of long chain polymers.

13. More Polymers – Growing Crystals.

Two kinds of growing crystals are described here. Some small carbon-based water-absorbing polymers are added to a beaker of water. Over a period of several hours they will swell to many times their starting volume. These are sold commercially as "Phantom Crystals" which are reportedly about 25% Hydroxyethyl Methacrylate, methacrylic acid, acrylamide copolymer, cross-linked homopolymer for the absorption and desorption of water, and 35% silica to stabilize the system. Very nice as they have virtually the same index of refraction as water and will seem to disappear when the grown crystals are placed in a water filled beaker.

Gigantic Growing Spheres. Basically the same stuff as that described above only in sphere shape. When placed in water these will expand up to a diameter of about 2 inches. They will retain their spherical shape and are therefore very good for use as lenses or variable focus lenses. These will take about 24 hours to expand to full volume.

14. Flame Thrower.

A demonstration to show why you should not smoke while applying hairspray or use paint thinner or paints with flammable solvents near a water heater or furnace. A can of hairspray with an alcohol solvent is sprayed over a lit grill lighter resulting in a flame thrower type action. A can of WD-40 will also work.

15. Calcium Carbide Cannon.

The standard calcium carbide cannon. Water is placed into the bottom of the cannon and a small amount of calcium carbide is dropped into it. Acetylene gas is evolved and can be ignited with the sparker assembly of the cannon. This will produce a very loud noise so a caution to the audience and hearing protection are a must.

16. Critical Concentration Gas Explosion.

A mailing tube type can where the top slides over an inner cardboard tube attached to the bottom of the can. A hole is punched into the bottom and into the top of the can. A tube is inserted into the bottom hole and natural gas is allowed to flow into the assembled can for several seconds. The gas is turned off and the tube removed. Light the gas coming from the top hole with a grill lighter. The flame will be several inches high initially, but as the concentration of gas in the can diminishes the flame will become smaller until it can't be seen at all. What is happening is that air is being drawn in at the bottom of the can and is mixing with the remaining gas in the can. Eventually a "critical" concentration is achieved, a small explosion results, and the top of the can flies into the air. Demonstrates how a gas leak in a house can cause an explosion that completely destroys the structure.

17. Dust Explosions – Two Versions.

A metal paint can with a friction fit type lid. A hole is placed into the side of the can and a length of small diameter Tygon tube is inserted and run into a beaker that is placed in the bottom of the can. Some Lycopodium powder is placed in the beaker. A lit candle is placed inside the can opposite the beaker. Place the lid on the can and lightly tap it into place. Blowing into the Tygon tube will produce a small dust cloud of powder inside the can which will ignite. Since this is confined by the can the resulting explosion will blow the top off the can.

A metal paint can has a lit candle placed into it and the can is placed on the floor. A small amount of powdered non-dairy creamer or corn starch is poured into your hand. Throw the powder down into the can and a small cloud of flames will result. Basically shows that anything will burn if ground up fine enough and mixed with enough air. Both of these are demonstrations of grain elevator explosions, sugar refinery explosions, or other types of explosions where a "critical" concentration of "dust" is the cause. Even most metals will burn under these conditions.

18. Piezo Poppers.

A "grill" style butane lighter that has been modified. Longer wires from the piezo sparker assembly are run out the end of the lighter and through the cap of a film canister that has been attached to the end of the lighter with hot glue. Adjust the distance between the ends of the protruding wires so that a good spark is produced when the trigger of the grill lighter is pulled. Put 3 drops of methyl or ethyl alcohol into the canister and press it onto the cap that is glued onto the grill lighter. Shake the unit to mix the alcohol with the air in the canister. Pulling the trigger on the grill lighter will ignite the alcohol/air mixture in the film canister. The canister will pop off the end of the grill lighter with great velocity. This is basically a one shot, one cylinder gas engine.

19. Oxygen Accelerates Combustion Rate.

Soak a couple of animal crackers in some liquid oxygen. Place them in a petri dish and ignite with a grill lighter. The cracker will burn completely within several seconds.

20. Ammonium Dichromate Volcano.

A small pile of ammonium dichromate is placed onto a metal plate (to absorb the heat). A Bunsen burner is held to the top of the pile until the decomposition reaction is self-sustaining. A realistic looking “volcano” will grow. (The initial and final products must be handled and disposed of according to established procedures and with the proper precautions.)

21. Mentos and Coke.

This is best done outdoors. Several Mentos tablets are dropped into a 2 liter bottle of Coke. Surfactant and nucleation actions will cause all the Coke to spew forth from the bottle in a spectacular fashion.

22. Heat of Crystallization – The Sodium Acetate Heat Pack.

Reversible and exothermic chemical reactions can be explored with the standard reusable heat pack which contains food grade sodium acetate. Activate the pack by flexing the metal disk inside the pack and heat will be produced as the sodium acetate goes from liquid to solid form. Boiling the heat pack in water for 20 minutes will turn the sodium acetate back to liquid form.

23. “The Balloons”.

Make sure you read the safety precautions detailed in Chapter 8 regarding this demonstration. Both eye and hearing protection will be needed for this demonstration. Basically this is a demonstration of the power released when hydrogen and oxygen are combined to make water. This is the primary reaction used by NASA to get the space shuttle into orbit.

The slow reaction. A 12 inch diameter balloon is filled with hydrogen and tied to a 3 foot long string. Tape the string to a lecture bench so that the balloon floats in midair without anything else around it. Ignite the balloon with a candle on the end of a 2 meter long meter stick (the proverbial 10 foot pole), and observe the swirling motion of the fireball. This swirling motion is due to the fact that oxygen has to migrate in from the atmosphere around the hydrogen filled balloon to complete the reaction and this takes some time. Hence the statement that this is a “slow reaction”.

The fast reaction. A 12 inch diameter balloon is fill with approximately 1/3 hydrogen and 2/3 oxygen and tied to a 3 foot long string. Tape the string to the lecture bench so that the balloon floats in midair without anything else around it. Make sure that everyone in the audience covers their ears as this will be quite loud. Ignite the balloon with a candle on the end of a 2 meter long meter stick (the proverbial 10 foot pole), and observe how fast this reaction is compared to the other balloon, even though you make about the same amount of water with each. Only the speed of the reaction has changed because the reactants were already mixed inside the balloon. Everyone in the audience will feel the shock wave from this demonstration.

Optional. Fill a balloon with helium and pop it with the candle. This demonstrates that there is some energy in the stretched balloon membrane as evidenced by the "popping: noise produced. Then fill a balloon with oxygen and pop this with the candle. Sounds just like the helium balloon described above as the oxygen has nothing to react with other than the nitrogen and oxygen already in the atmosphere around it. If either of these two were reactive in the same way as the hydrogen and oxygen reaction, you would essentially start a chain reaction that would burn off the entire atmosphere of the Earth when you popped the balloon with the candle.

ss place at the ends of an aluminum rod. The center of mass of this system is between the two masses but not at the center of the rod. The second system has a very large diameter mass (red giant) at one end and a lighter and smaller mass at the other end. This system will have the center of mass inside the larger diameter mass.
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BOOTH OR WALK BY STYLE *STEM* DISPLAYS

Event: Outreach Presentations for STEM festivals, Award ceremonies, etc.

Submitted by Dale Stille, Co-Coordinator "Hawk-Eyes on Science" and "Hawkeyes in Space" outreach programs, Univ. of Iowa. dale-stille@uiowa.edu

Venue: Booth style public outreach, STEM events. Two to 6 people are usually needed to man the booth depending on the venue.

Group Size: 1 to 20 at a time

Time: Usually 1 to 4 hours. The demonstrations are usually set up ahead of time in "station" format and the audience circulates from one demo to the other at their leisure with some explanation by the booth personnel.

Materials:

Plasma plate.
1 inch thick copper plate and magnet.
Genecon generator, 6 v. light, hand generator flashlight, Faraday flashlight.
Solar cell powered motor or Ferris Wheel with spotlight.
Thompson style coil with aluminum rings and coil connected to 6 v. light bulb.
Fluorescent materials with LED lights.
Spectrum tubes with fireworks glasses.
Zig's Tube.
Lenz's law – Pendulum swing assembly, rings and plates with and without cuts, horseshoe magnet.
Lenz's law – Copper tube and magnets, copper, aluminum, or wood slugs.
Digital VOM, copper and magnesium plates.
Ferromagnetic fluid in a tube, magnets.
Magnet, paper clip attached by string to a block, plates of different materials.
Two 1 inch thick copper slabs, Plexiglas spacer, neodymium magnets.
Modified grill lighter with film canister assembly, alcohol.
Desk model Newton's Spheres cradle.
Happy / Sad ball set.
Simple motor made from paper clips, speaker wire, # 21 copper magnet wire, a stack of 5 square magnets from Radio Shack, and a 6 v. lantern battery.
Memory Wire Butterfly.
Rheoscopic fluid in a clear plastic bottle.
16 oz. clear soda bottle, plastic test tube, iron filings, neodymium magnets.
Grapes, 6 inch rod or dowel, rotating pivot, large neodymium magnets.
Magnet array and thin plate of graphite.
"Vectron" flying saucer.
X-ray or 35 mm slide viewer, Karo Syrup, birefringent materials.
Euler's disk.

Safety Concerns:

Head up for the jumping rings in launch mode.

Keep the neodymium magnet away from any iron materials or objects, or from other magnets.

The following demonstrations have been used at one time or another for these

kinds of presentations.

1. Plasma Plate with Dept. Info.

A real attention grabber. A 12 or 14 inch plasma plate with the words “Department of Physic and Astronomy” in 2 inch tall letters around the rim. We use it to discuss two of our department’s main missions which is the study of the Aurora and the Van Allen Radiation Belts. Basically a gas filled plate connected to a Tesla coil.

2. Copper Plate and Magnet.

Ask the question “What two things do you need to generate electricity”. Answer is some copper or aluminum and a magnet. (Note that silver, gold, platinum, and several other metals with loosely bound electrons will also work but are not commercially viable for large scale electrical instrumentation and transmission.) Drop a neodymium magnet which is at least 2 inches in diameter onto a copper plate that is at least 1 inch thick. The magnet will float onto the plate due to the large currents generated in the plate as the magnet moves over it. If you move the magnet over the copper plate you will feel a “gluey” or “moving in molasses” type sensation due to the large currents you are generating in the plate. Turn the plate vertical and “stick” the magnet onto the plate. Note how slowly the magnet falls off.

3. Genecon generator and 6 v. flashlight bulb, hand generator flashlight, Faraday flashlight.

Now that you have shown what is needed to generate electricity you can start to talk about how electricity is commercially generated. Have a student turn the handle as fast as they can on the Genecon generator to light the bulb for as long as they can. They will get very tired very quickly even though they are only generating enough power to light a large flashlight bulb. Then ask “How big are the generators that power this room / school / city”. Once you get an answer for that you then ask “What is used to turn the handles on those generators”. Answers of “hydro, coal or fossil fuels, nuclear, solar, or wind” should be elicited (wind power generation is a BIG thing in Iowa). You could also discuss here that “coal and fossil fuels and nuclear” all do the same thing which is to heat water to create steam which is used to turn the handle.

The hand generator flashlight or the Faraday flashlight may be used in place of the Genecon generator and bulb cited above. The hand generator flashlight has no batteries so the bulb is made to shine by squeezing a handle which drives a small generator. As long as you can keep the generator going the light will continue to shine. The Faraday flashlight is a linear generator, that is, a neodymium magnet that is moved back and forth through a coil of copper wire that is connected to a super capacitor and the light bulb. If the capacitor is discharged, you can turn the flashlight on and each movement of the magnet through the coil will produce a flash of light in the light bulb.

4. Solar cell powered motor or Ferris Wheel and one million candlepower spotlight.

Bring up the member of the audience who mentioned solar power as one of the methods to generate electricity. Give them the large spotlight and have them shine it onto the solar cell that is connected to either a small motor with a large propeller attached or the small motor that turns a toy Ferris Wheel. Discuss the fact that this is a “one step” method for generating electricity. That is, the sun shines on the cell and you get electricity. This is unlike fossil fuels or nuclear where you have to burn or concentrate the fuel to create heat to boil water to make steam to turn the generator to make electricity. You can also ask at this point “what things found in nature use solar power to create energy”. (Plants or trees).

5. Thomson style coil and Aluminum rings, copper coil connected to a 6 v. light bulb.

The Thomson coil can used to explore the principles of induction, electromagnetic radiation, radio transmitters, circuits, and more. Usually we bring an athletic member of the audience up to experiment with the two aluminum rings we give them. When the solid ring is placed on the coil and the Variac powering the coil is turned up the ring will float up the iron core. Turning the Variac up will make the ring float higher until at some point it levitates above and falls off the iron core. Then we hand the student the ring with a cut through it and have them repeat the experiment. The ring does not respond no matter how high the Variac power is turned up. The student is then asked to look at and compare the rings and usually it does not take them long to discover the cut in the non-responding ring. Then we turn the Variac off with a switch and turn in all the way up. When the solid ring is placed on the coil and the switch turned on the ring jumps to the ceiling and the student catches it on the way down. Then the ring with the cut is placed on the coil and the audience is polled to see what they think will happen. A large percentage of them will still think the ring will jump because you are putting more power into the coil. Of course the ring does not move when the switch is turned on. Discuss that the cut in the ring is exactly like a light switch on a wall which “cuts” the circuit when it is turned off and the lights go out, and “completes” the circuit when turned on and the lights come on. Electrons need a complete “circuit” to flow. We then show that the coil is also a transmitter by placing a coil of wire attached to a 6 v. light bulb over it. As you turn up the Variac the bulb lights up. Also move the coil and bulb up and down the iron core and observe.

6. Fluorescent material and different color LED lites.

LED keychain lites ranging in color from red to ultraviolet can be easily found. Get a large sheet (at least 1’ X 1’) of the fluorescent material and try “drawing” on it with the LED lites. You will find that the colors red, orange, and yellow show almost no activation of the material. The green and blue will show some activation. It is not until you get to the ultraviolet light that you will see bright and sustained activation of the material. You will also find that white LED lites will provide decent activation of material although not as good as the ultraviolet lites. This basically shows the concept of increasing activation energy with decreasing wavelength or a pseudo-photoelectric effect.

7. Spectrum tubes (H2, He, Ne, Hg) with “fireworks” spectrum glasses.

The spectrum glasses have been passed out at the beginning of the presentation and are now brought out and discussed. The glasses are holographic diffraction gratings (as in made with a laser) or in scientific terms they are simple spectrometers. With these spectrometers the audience will be able to look at the different “fingerprints” of elements and be able to determine what some of the common things around them are made of or have in them. So, we first turn on the H2 spectrum tube and make sure that everyone can see the 3 main lines and the pattern of those lines. Then we go to He and discuss why it has so many more lines. We then do Ne and Hg and talk about the common uses of these two elements in the world the audience lives in. Coming back to how astronomers are able to tell what suns, gas clouds, nebulae, etc. are made of without actually going there and collecting a sample we turn on the H_2 and He tubes and point out that when astronomers look at our Sun, these are the two main fingerprints that they see. Hence, why their (the audience's) text books say that ours is a young sun composed of mostly Hydrogen and Helium. Some discussion on how their spectrometers are able to give them a rough idea of concentration can also take place here.

8. Zig's Tube.

The "V" channel and magnet ball bearing are fixed inside a Plexiglas tube. Rolling the magnet down the "V" channel no matter what the angle will show considerable damping. Turning the tube 180 degrees, so the ball does not roll on the channel, will allow the ball bearing to roll without damping. Designed by Zig Peacock, University of Utah.

9. Lenz's Law – magnetic damping.

A swing with a rigid pendulum that will swing between the poles of a horseshoe magnet. The pendulum bob can be rings or plates of copper, aluminum, Plexiglas, etc. Solid rings or plates of the copper and aluminum will quickly have their swinging motion damped. The Plexiglas, the rings that have a cut in them, and the plates that have many cuts through much of their diameter will show no appreciable damping.

10. Lenz's Law – tube and magnet.

A neodymium magnet dropped through a copper or aluminum tube will display an amazingly slow fall. The thicker the side walls of the tube, the better. A slot may be cut in the tube to make it easy to see the magnets fall. Slugs of copper, aluminum, wood, etc. that are the same size as the magnet may also be used for comparison.

11. Human Battery.

Plates of copper and magnesium are connected to a digital VOM set on the 2000 mv scale. Place one hand on each plate and your body will act as the electrolyte and the meter will show a voltage of 1.4 v. A zinc plate may also be used but the resulting voltage will not be as high.

12. Ferromagnetic Fluid.

The commercially available tube of ferromagnetic fluid in light mineral oil. The fluid will show the magnetic field lines of a magnet that is brought near. The fluid can also be moved around the tube with the magnet. This type of technology is used to lubricate bearings in space where gravity is an issue.

13. Magnetic Shielding.

A magnet is used to suspend a paper clip in mid-air. The paper clip is tied to a block and the magnet is above the paper clip so that a gap of at least ¼ inch exists between the paper clip and the magnet. Sheets of glass, copper, aluminum, lead, wood, mirror, stone, fiberglass, sheet metal or steel, etc. can be inserted between the paper clip and magnet. The paper clip will only fall when the magnetic field of the magnet is confined within the sheet metal or steel.

14. Eddy Current Levitator.

Two 1 inch thick slabs of copper that are 4 inches in diameter are stacked on top of each other and separated a distance of 2 inches with a piece of Plexiglas. A 7/8 inch diameter X 1 inch long neodymium magnet is placed in the gap. A stack of smaller neodymium magnets may be moved by hand over the top slab to levitate the magnet in the gap so that it floats between the plates without touching either of them. Essentially the thick copper plates provide enough magnetic damping on the magnet within the gap that its movement speed is slower than the human reaction time that is controlling the magnet stack.

15. Newton's Spheres

The standard desk model of Newton's Spheres is used to describe simple case conservation of momentum.

16. Happy / Sad Balls.

A set of Happy / Sad balls that are 1 ¼ inches in diameter. They look the same but are made from two different polymers. One bounces, the other does not. The audience can be astounded if the demonstrator is good at sleight of hand.

17. Simple homemade motor.

A simple motor assembled from paper clips, speaker wire, # 21 copper magnet wire, a stack of 5 square magnets from Radio Shack, and a 6 v. lantern battery.

18. Memory Wire Butterfly.

A commercial memory wire (nitinol wire) toy in the shape of a common butterfly. As the wire is tickled with a 6 volt current, the wire expands and contracts flapping the wings of the butterfly.

19. Rheoscopic Fluid.

A commercially available or homemade solution of "pearlized" type soap particles suspended in water. When rotated or shaken, the laminar and turbulent flow regions within the water can be seen.

20. 3-D Magnetic Fields.

A quantity of iron filings are placed inside a 16 oz. plastic soda bottle which has the label removed. A plastic test tube is inserted into the soda bottle as far as possible. Electrical tape is wrapped around the top of the test tube so that it is secured in the mouth of the soda bottle but does not fall into the bottle. A small stack of neodymium magnets is slid into the test tube and the bottle is rotated so the iron filings completely cover the magnet stack. A 3-D view of the magnetic field around the magnet stack will be produced. To reset the demo, insert an iron rod into the test tube until it sticks to the magnet stack and then use it to draw the stack out of the test tube. The iron filings will fall back into the bottom of the soda bottle ready for the next demonstration.

21. Push a grape.

Two large grapes are placed on each end of a 6 inch long dowel or Plexiglas rod. The rod is suspended with string so that it is horizontal and able to rotate freely or it may also be placed on a low friction rotating pivot (available from PASCO). A large neodymium magnet brought near one of the grapes will cause it to move away from the magnet. (Water is slightly diamagnetic, and the high water content in the grape will try to move out of the magnetic field).

22. Diamagnetic Levitator.

A 3X3 array of ½ inch square neodymium magnets (nine magnets total) are stuck to a metal plate in a N-S-N or S-N-S arrangement. A thin flat piece of graphite will float above and in the center of the array. A piece of paper may be slid between the magnets and the graphite to show that it is really floating above the array.

23. "Vectron" flying saucer.

A tethered, remote control flying saucer which has an LED array that can be programed to display 4 different messages such as "Department of Physics and Astronomy" or "Hawk-Eyes on Science" as the saucer rotates in flight. Great attention getter.

24. Polarization – birefringence.

Place a large polarizer over the viewing surface of a X-ray or 35 mm slide viewer. Place birefringent materials such as cellophane, mica, stressed Plexiglas, CD blanks, clear plastic knives/spoons/forks, or clear bottles of Karo syrup on the viewer. Rotate another large polarizer above these materials and observe.

25. Euler's disk.

A commercially available Euler's disk. Essentially a heavy circular disk that is rotated on a slightly concave plate. The paradox = the pitch of the sound produced as the spinning disk slows down actually goes up in

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MODERN PHYSICS DEMO SHOW

Event: Outreach Presentations on the topic of Modern Physics
Submitted by Dale Stille, Co-Coordinator "Hawk-Eyes on Science" and "Hawkeyes in Space" outreach programs, Univ. of Iowa. dale-stille@uiowa.edu
Venue: Public outreach programs, STEM events.
Group Size: 1 to 100
Time: Usually 50 to 60 minutes.
Materials:
Fusion Demonstrator.
Specially cut Polaroid's.
Chaos pendula of several varieties.
Photoelectric effect – Braun electroscope, zinc or aluminum plate, germicidal UV lamp, electrostatic rods.
Fluorescent materials with photon micro-lites of different colors/wavelengths including UV.
Nano-gold solutions.
Faraday Rotation apparatus with laser array.
Mousetraps and superballs.
Laser balloon popper.
Cloud chamber with sources.
Ink and Glycerin unit with syringe and dyed glycerin
Quantum dots in solution with UV lamp or light illuminator, optional Ocean Optics

spectrometer.
Microwave transmitter and receiver with metal Fresnel plate array.
Laser, adjustable mirror, beam splitter, photodiode or solar cell, Radio Shack #277-1008 mini audio amplifier.

Safety Concerns:
Do not shine the lasers at the audience.
Keep the neodymium magnet away from any iron materials or objects.

1. Fusion Demo.

A demonstration of the strong nuclear force made from 3 neodymium magnets that are 7/8 inches in diameter X 1 inch long and one iron slug of the same size. Construction details can be found at "A model to illustrate forces in nuclear fusion", AJP, 69 (9), Sept. 1994, p. 804. by E. Kashy and D. A. Johnson.

2. Polaroids at 45 degrees.

Normal Polaroid's used for demonstrations are cut so that one side is parallel and the other side is perpendicular to the long chain polymers in the film. However, if you cut a new set of Polaroid's so that the sides are 45 degrees to the direction of the polymer chains you can get a change from transmission to non-transmission if one of the Polaroid's if flipped from front to back which does not happen with the regular Polaroid set.

3. Chaos Pendulum.

Several styles of chaos pendulums are shown. An overhead projector model with a pendulum where the magnet is the pendulum bob which is suspended and swung over an array of other magnets of various orientations. Several variations of planar double pendulums. "Space Circles" and "Revolution" plus a changeable orientation pendulum with magnetic ends.

4. Photoelectric effect.

The textbook photoelectric effect done with a Braun Electroscope connected to a zinc plate, a germicidal UV lamp, and a set of electrostatic charging rods. A ball of steel wool is used to clean the oxide coating off the zinc plate. The zinc plate and electroscope system is then given a negative charge using a piece of PVC rod rubbed with some cat's fur. Turn on the small germicidal UV lamp and shine it onto the zinc plate. The system will discharge as the negative charge is driven off. Next charge positively with a piece of Plexiglas rod rubbed with silk. Bringing the UV lamp near will produce no effect. Due to their similar work functions, a piece of aluminum or an aluminum soda can with the paint rubbed off of it can be used in place of the zinc plate. You will still need to clean the oxide coating off the aluminum with the steel wool before each use just as with the zinc.

5. Fluorescent material and different color LED lites.

LED keychain lites ranging in color from red to ultraviolet can be easily found. Get a large sheet (at least 1' X 1') of the fluorescent material and try "drawing" on it with the LED lites. You will find that the colors red, orange, and yellow show almost no activation of the material. The green and blue will show some activation. It is not until you get to the ultraviolet light that you will see bright and sustained activation of the material. You will also find that white LED lites will provide decent activation of material although not as good as the ultraviolet lites. This basically shows the concept of increasing activation energy with decreasing wavelength or a pseudo-photoelectric effect.

6. Nano-Gold particles.

Gold exhibits very visible color changes depending on particle size. Instead of the normal gold color everyone is familiar with in their normal experience, nano-particles of gold will have a distinctive color depending on size when in solution. Two popular colors for nano-size particles of gold are red and purple. Most of the distinctive red color in mediaeval stained glass windows in churches is due to nano-size gold particles.

7. Faraday Rotation Demonstration.

A piece of Terbium doped glass rod is held in place inside a small plastic tube. A laser pointer is directed through the glass and polarizers on each side of the glass rod are set so there is minimum transmission of the laser light. A set of magnets is placed over the glass rod which changes the rotation angle of the laser light. Reset the polarizers to minimum transmission and record the change in the angle of rotation. An array of lasers with colors from red to purple will show a greater angle of rotation with decreasing wavelength. A larger angle of rotation can be shown by cooling the glass rod with liquid nitrogen.

8. Mousetrap Fission Demonstration.

An array of modified “quick-set” mousetraps has two ¾ inch diameter super balls (neutrons) placed on each trap. The traps are usually enclosed with a transparent cover of some sort with a hole for an initiating ball (neutron). Drop the initiating ball into the center of the mousetrap array which starts the chain reaction. Time for completion of the reaction is less than two seconds.

9. Laser Balloon Popper.

One of our cross discipline demonstrations. A green laser is set in a holder pointing upward so that it cannot be moved. The holder has two shelves that balloons can be placed between so that they don’t move. The balloon system we use is to have a 12 inch black (actually very dark green and blue dyes) balloon that is blown up inside a 14 or 16 inch clear balloon. The dye of the dark balloon will absorb the green laser beam and create a hot spot while penetrating the clear balloon with no effect at all. Therefore, you can pop the inner balloon without damage to the outer balloon. Talked about in medical terms this is akin to targeting cells or diseases by tuning the wavelength of the laser. A very large area of present laser research for medical applications as evidenced by the recent announcement of the non-invasive use of lasers to diagnose whether an individual has malaria, dispensing with the invasive need for taking a blood sample. The diagnosis is also done in seconds as opposed to the minutes or hours needed for the blood sample diagnosis.

10. Cloud chamber.

A Wilson cloud chamber is used to show the tracks from cosmic rays and the particles from radioactive decay products using the common Pb-210, radium paint or pitchblende ore, or Thorium doped welding rods.

11. Time Reversal.

The “Ink in Glycerin” demonstration. Basically a clear cylinder placed inside another clear container or beaker with a 1 to 2 inch gap between the outer wall of the cylinder and the wall of the container. Glycerin is poured into this gap and a column or ink, food coloring, or glycerin dyed with Methylene Blue is inserted into the glycerin using a syringe with a long needle attached. Turn the inner cylinder 7 to 10 times in one direction and the rotational shear will smear the column of dyed glycerin. Turn the cylinder the same number of turns in the other direction and the dyed glycerin column will reform.

12. Quantum Dots.

A set of commercially available or homemade solutions of quantum dots. These are small nano-size molecules that fluoresce with different colors depending on molecular size. Usually a Buckyball type molecule with a metal ion trapped in the center. Different metal ions can be used to adjust the size of the molecule. A UV lamp or small UV micro-lite shines into the quantum dot solution and the fluorescence is observed. The fluorescence may also be directed into an Ocean Optics spectrometer for a more in depth analysis.

13. Microwave Fresnel Lensing.

A set of concentric ring plates made of aluminum or tin metal. A 12 cm microwave transmitter is placed at the correct distance in front of the plate array. A receiver on the back side of the plates can be moved to find the focal point of the plate array.

14. Bend a Wall.

A laser beam is directed at an adjustable mirror attached to a wall. The mirror is adjusted so the beam is directed right back into the laser. A beam splitter is then inserted into the beam and the beam that is split off is directed into a photodiode or solar cell (detector) that is connected to the Radio Shack # 277-1008 mini audio amplifier. A whine or buzzing sound will be heard when you press upon or tap the wall to which the adjustable mirror is attached. Basically a “poor man’s” Michelson Interferometer with the whine or buzz created by the fringes passing over the detector.

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HAWK-EYES ON SCIENCE OUTREACH DEMO SHOW

Event: “E&M / Electromagnetic Spectrum / Quantum Mechanics / Astronomy and Atmosphere / Information Storage / “Lasers” Demo Show / The Four Forces = E&M, Gravity, Weak and Strong Nuclear Forces.
Special Note: These demonstrations were specifically chosen for their topic versatility. At one time or another we have presented programs on each of the topics listed above using the same set of demonstrations by just changing the level at which we talk, or

how we talk about or describe each one. This is why I have provided some extra explanation about the demonstrations described below and how we discuss them in general.

Submitted by Dale Stille, Co-Coordinator “Hawk-Eyes on Science” and “Hawkeyes in Space” outreach programs, Univ. of Iowa. dale-stille@uiowa.edu

Venue: Public outreach programs, ages = preschool thru K-12 thru Adult Education programs.

Group Size: 6 to 600

Time: Usually 50 to 60 minutes, but has been tailored to fit 30 minute up to 2 hour time slots.

Materials:

Copper plate and Neodymium magnet.
Genecon generator and small 6 v. flashlight bulb.
Hand generator flashlight and linear Faraday flashlight.
Solar cell powered motor or Ferris Wheel and one million candlepower spotlight.
Thomson style coil and Aluminum rings, copper coil connected to a 6 v. light bulb, Variac with switch.
Radio communicator, closed iron core.
Optical communicator, fiber optics cable, remote controls.
Fiber optics demonstrator kit and green laser pointers.
Laser tape measure.
6 color laser array with large 5” X 8” diffraction grating.
Laser balloon popper.
Spectrum tubes (H_2, He, Ne, Hg) with “fireworks” spectrum glasses.
Vacuum accelerator with vacuum pump, pop can array with protective cover, hearing protectors and safety glasses.
Calabi-Yau cube.
Holograms.

Safety Concerns:

Hearing and Eye protection to be used with the vacuum cannon.
Do not shine the lasers at the audience.
Keep the neodymium magnet away from any iron materials or objects.
A clear covered enclosure for the pop can array when using the vacuum accelerator.

Demos:

1. Copper Plate and Magnet.

Ask the question “What two things do you need to generate electricity”. Answer is some copper or aluminum and a magnet. (Note that silver, gold, platinum, and several other metals with loosely bound electrons will also work but are not commercially viable for large scale electrical instrumentation and transmission.) Drop a neodymium magnet which is at least 2 inches in diameter onto a copper plate that is at least 1 inch thick. The magnet will float onto the plate due to the large currents generated in the plate as the magnet moves over it. If you move the magnet over the copper plate you will feel a “gluey” or “moving in molasses” type sensation due to the large currents you are generating in the plate. Turn the plate vertical and “stick” the magnet onto the plate. Note how slowly the magnet falls off.

2. Genecon generator and 6 v. flashlight bulb, hand generator flashlight, Faraday flashlight.

Now that you have shown what is needed to generate electricity you can start to talk about how electricity is commercially generated. Have a student turn the handle as fast as they can on the Genecon generator to light the bulb for as long as they can. They will get very tired very quickly even though they are only generating enough power to light a large flashlight bulb. Then ask “How big are the generators that power this room / school / city”. Once you get an answer for that you then ask “What is used to turn the handles on those generators”. Answers of “hydro, coal or fossil fuels, nuclear, solar, or wind” should be elicited (wind power generation is a BIG thing in Iowa). You could also discuss here that “coal and fossil fuels and nuclear” all do the same thing which is to heat water to create steam which is used to turn the handle.
The hand generator flashlight or the Faraday flashlight may be used in place of the Genecon generator and bulb cited above. The hand generator flashlight has no batteries so the bulb is made to shine by squeezing a handle which drives a small generator. As long as you can keep the generator going the light will continue to shine. The Faraday flashlight is a linear generator, that is, a neodymium magnet that is moved back and forth through a coil of copper wire that is connected to a super capacitor and the light bulb. If the capacitor is discharged, you can turn the flashlight on and each movement of the magnet through the coil will produce a flash of light in the light bulb.

3. Solar cell powered motor or Ferris Wheel and one million candlepower spotlight.

Bring up the member of the audience who mentioned solar power as one of the methods to generate electricity. Give them the large spotlight and have them shine it onto the solar cell that is connected to either a small motor with a large propeller attached or the small motor that turns a toy Ferris Wheel. Discuss the fact that this is a “one step” method for generating electricity. That is, the sun shines on the cell and you get electricity. This is unlike fossil fuels or nuclear where you have to burn or concentrate the fuel to create heat to boil water to make steam to turn the generator to make electricity. You can also ask at this point “what things found in nature use solar power to create energy”. (Plants or trees).

4. Thomson style coil and Aluminum rings, copper coil connected to a 6 v. light bulb.

The Thomson coil can used to explore the principles of induction, electromagnetic radiation, radio transmitters, circuits, and more. Usually we bring an athletic member of the audience up to experiment with the two aluminum rings we give them. When the solid ring is placed on the coil and the Variac powering the coil is turned up the ring will float up the iron core. Turning the Variac up will make the ring float higher until at some point it levitates above and falls off the iron core. Then we hand the student the ring with a cut through it and have them repeat the experiment. The ring does not respond no matter how high the Variac power is turned up. The student is then asked to look at and compare the rings and usually it does not take them long to discover the cut in the non-responding ring. Then we turn the Variac off with a switch and turn in all the way up. When the solid ring is placed on the coil and the switch turned on the ring jumps to the ceiling and the student catches it on the way down. Then the ring with the cut is placed on the coil and the audience is polled to see what they think will happen. A large percentage of them will still think the ring will jump because you are putting more power into the coil. Of course the ring does not move when the switch is turned on. Discuss that the cut in the ring is exactly like a light switch on a wall which "cuts" the circuit when it is turned off and the lights go out, and "completes" the circuit when turned on and the lights come on. Electrons need a complete "circuit" to flow. We then show that the coil is also a transmitter by placing a coil of wire attached to a 6 v. light bulb over it. As you turn up the Variac the bulb lights up. Also move the coil and bulb up and down the iron core and observe.

5. Radio communicator, closed iron core.

The leads of two -15 turn, 4 inch diameter coils are connected to 1/8 inch phono plugs. One coil is connected to the headphone jack of a CD player (or any other portable device with a headphone jack). The other coil is connected to a Radio Shack mini audio amplifier (# 277-1008). Essentially you now have a very low power radio station (broadcaster) and a receiving station (the listener at home). Bring the coils near each other in a parallel configuration and the song playing on the CD will be heard. Turn one of the coils so that it is perpendicular to the other and the signal will fade. Now turn down the broadcasting signal until the song can be faintly heard when the two coils are held about 2 inches apart. Then take the iron U-core scavenged from an old transformer and insert it into the coils without any of the items touching each other. The signal will get louder with the addition of the iron core. If you close the top of the iron U-core with another piece of iron the coupling between the two coils will be maximized with a large increase in volume. Discuss how iron likes magnets and therefore likes magnetic fields. Also discuss what other modern devices use radio waves to transmit communication signals. And finally discuss how this system with the closed iron loop is a transformer and how transformers work, what they do, and how they are used in everyday life.

6. Optical communicator, fiber optic cable, remote controls.

A red or green LED in series with a 47 ohm resistor and powered by a 3 volt battery pack is connected to a 1/8 inch phono plug. This unit is then plugged into the headphone jack of a portable CD player. The leads of an encapsulated solar cell are connected to another 1/8 inch phono plug and this is plugged into a Radio Shack mini audio amplifier (#277-1008). The LED intensity is modulated when a song is playing from the CD player even though this can't be seen with the human eye. However, the modulations can be picked up with the solar cell and the song is heard to play when the light from the LED falls onto the solar cell. Show that this form of communication is "line of sight". Then use the fiber optic cable to transmit the signal from the transmitter to the receiver even though there are knots, bends, and kinks in the fiber optic cable. Discuss how modern fiber optic cables are used to transmit the bulk of modern day communications, how the signal can be split or amplified with little degradation, and how this form of transmission if immune to most forms of electromagnetic interference. Also discuss why it is important that people do not dig and inadvertently "break" a fiber optic cable bundle. Show that all audience members are familiar with this form of communication by replacing the LED and CD unit transmitter with a common remote control. The IR signal from the remote control is easily heard from the solar cell receiver unit. A variation: A simple case of multiplexing can be done using two transmitters, one with a red LED and the other with a green LED. Both of these are directed into a 1 inch diameter X 24 inch long piece of Plexiglas rod that has the ends polished. If you turn down the lights in the room, the color inside the rod is yellow and you will pick up the mixed signal of both communications when you place the receiver at the other end of the rod. However, by placing either a red or a green filter between the end of the rod and the receiver, you can choose which signal is transmitted and which signal is blocked.

7. Fiber optics demonstrator kit and green laser pointers.

The fiber optics demonstrator kit is two pieces of polished Plexiglas (one straight and one curved) that are designed to show the total internal reflection phenomenon that happens inside a fiber optics cable. If you shine a laser pointer (we use green for ease of visibility with large audiences) at some angle into the end of either of the fiber optics demonstrators the total internal reflections of the laser beam in the demonstrator are clearly visible. Changing the angle of the laser beam as it enters the demonstrator will change the number of reflections inside the demonstrator.

8. Laser tape measure.

Now that we have introduced lasers in the communication and fiber optics devices described above we usually ask the audience “How many lasers do you have at home”. We always get someone that says that they have one to amuse their pets. Then we start asking who has a computer, a DVD player, a Blu-Ray player, etc. We then ask if anyone has any relatives or knows of anyone in the construction business. This is when we show and have a conversation about laser tape measures, surveying equipment, measuring the distance to the moon, and large scale multiple spacecraft astronomy projects that use lasers to accurately measure the distance between those spacecraft (all examples that use lasers to measure distance). Both the LIGO and the defunct LISA astronomy programs are discussed at this point.

9. 6 color laser array with large 5” X 8” diffraction grating.

Lasers of many different colors (wavelengths) are now common with the advent of the laser diode. Our array contains 6 laser pointers with colors and wavelengths of red = 650 nm, red = 632 nm (HeNe gas laser wavelength), yellow = 593.5 nm, green = 532 nm, blue = 473 nm, and a purple = 405 nm. A large 5 inch X 8 inch diffraction grating held in from of the laser array show that each is a single wavelength, that the red colors are “bent” at a larger angle than the purple, and that the red colors are not the same even though the human eye is not able to distinguish any difference between the two reds. Discuss how you can send multiple laser communications through the same fiber optic cable (multiplexing) using different color lasers and filters to retrieve each separate communication.

10. Laser balloon popper.

One of our cross discipline demonstrations. A green laser is set in a holder pointing upward so that it cannot be moved. The holder has two shelves that balloons can be placed between so that they don’t move. The balloon system we use is to have a 12 inch black (actually very dark green and blue dyes) balloon that is blown up inside a 14 or 16 inch clear balloon. The dye of the dark balloon will absorb the green laser beam and create a hot spot while penetrating the clear balloon with no effect at all. Therefore, you can pop the inner balloon without damage to the outer balloon. Talked about in medical terms this is akin to targeting cells or diseases by tuning the wavelength of the laser. A very large area of present laser research for medical applications as evidenced by the recent announcement of the non-invasive use of lasers to diagnose whether an individual has malaria, dispensing with the invasive need for taking a blood sample.

The diagnosis is also done in seconds as opposed to the minutes or hours needed for the blood sample diagnosis.

11. Spectrum tubes (H2, He, Ne, Hg) with "fireworks" spectrum glasses.

The spectrum glasses have been passed out at the beginning of the presentation and are now brought out and discussed. The glasses are holographic diffraction gratings (as in made with a laser) or in scientific terms they are simple spectrometers. With these spectrometers the audience will be able to look at the different "fingerprints" of elements and be able to determine what some of the common things around them are made of or have in them. So, we first turn on the H2 spectrum tube and make sure that everyone can see the 3 main lines and the pattern of those lines. Then we go to He and discuss why it has so many more lines. We then do Ne and Hg and talk about the common uses of these two elements in the world the audience lives in. Coming back to how astronomers are able to tell what suns, gas clouds, nebulae, etc. are made of without actually going there and collecting a sample we turn on the H2 and He tubes and point out that when astronomers look at our Sun, these are the two main fingerprints that they see. Hence, why their (the audience's) text books say that ours is a young sun composed of mostly Hydrogen and Helium. Some discussion on how their spectrometers are able to give them a rough idea of concentration can also take place here.

12. Vacuum accelerator with vacuum pump, pop can array with protective cover, hearing protectors and safety glasses.

Switching gears back to some of the discussion in # 2 above, we discuss how our atmosphere is not the normal condition of the universe (which the volume is composed of mostly what we call empty space or vacuum) and how we can use our atmosphere to do large amounts of work as evidenced by the many wind turbines or wind farms that we have here in Iowa. We then show them the 40 mm Ping-Pong ball that will be accelerated down through our PVC vacuum tube accelerator using nothing but the power of our atmosphere pushing the ball and the damage that may result when the ball is directed into some empty pop cans. While this discussion is going on the vacuum pump has been running and evacuating our accelerator. With eye and hearing protection in place and directions given to the other audience members to cover their ears, a member of our audience punctures the membrane at the end of the accelerator. Air rushes into the accelerator, pushing the Ping-Pong ball down through our PVC tube, exiting at high velocity into the array of empty pop cans (with protective cover in place) at the other end. Our 7 ½ foot long accelerator will usually be able to accelerate the ball completely through three pop cans and dent or partially penetrate the 4th can.

13. Calabi-Yau cube.

We use a glass cube with a Calabi-Yau manifold image in it that has been created with a laser. Other glass crystals cube or shapes with images inscribed in them will work equally well. These are all examples of information storage using lasers. We then ask what forms of laser information storage they are familiar with and eventually get to the CD and DVD read / write storage capabilities of their computers, DVD players, or Blu-Ray players. We may also discuss at this time just how much information could be packed into our cube with a laser.

14. Holograms.

Another form of information storage with a laser. We have several large holograms available. Two versions of “The Kiss”, and one of “Ben Franklin in his Laboratory”. We discuss how the image (information) that they see is dependent on the viewing angle and how the amount of information stored on that single sheet of film is so large as to be essentially a 5 second movie. Discussions on how holograms are used today for authentication, security measures, etc. are also done at this time.

15. Plasma Plate with Dept. Info.

A real attention grabber. A 12 or 14 inch plasma plate with the words “Department of Physic and Astronomy” in 2 inch tall letters around the rim. We use it to discuss two of our department’s main missions which is the study of the Aurora and the Van Allen Radiation Belts. Basically a gas filled plate connected to a Tesla coil.

OTHER DEMONSTRATIONS USED ON OCCASION FOR THIS PROGRAM

Rotating Stool and Weights, bicycle wheel.

The standard freely rotating stool with a pair of 5 lb. dumbbells to show conservation of angular momentum. A bicycle wheel that has sand in the tire or lead added to the rim for extra mass may also be used with the rotating stool to show conservation of angular momentum.

Rotating Hoberman Sphere

A 30 inch diameter Hoberman Sphere with the mobile attachment installed is hung from a ball bearing fishing swivel. When you rotate the sphere in its open position and then pull the string to collapse it, the sphere spins faster due to the conservation of angular momentum.

Beds of Nails, small Beds of Nails, and balloons.

Two 24 inch X 36 inch beds of nails used to “sandwich” a person lying on the nails while one or two audience members stand on the top bed of the sandwich. Additional helpers are needed to insure that the audience members are able to get up onto and off of the top bed of nails without injury to the person in the sandwich. Also a set of 4 small Beds of Nails that are 1 foot square. Nail spacings of ½ inch, 1 inch, 2 inches are explored by rolling an inflated balloon over them and pressing down. The balloon will pop when rolled over and pressed upon the 2 inch spaced nails. As a spoof, a single large railroad spike is placed in the 4^{th} board.

Rocket Cart.

A cart or bicycle that is powered by a 10 to 20 lb. directed stream CO2 fire extinguisher. Very loud so be sure to advise your audience to cover their ears. Also direct them not to stand at the rear of the cart when doing the demonstration as there will always be some flying debris when doing this outdoors. The rider wears eye and hearing protection. A sail may be attached to the cart in front of the fire extinguisher if desired.

Liquid Nitrogen Demonstrations.

See the “Liquid Nitrogen Demo Show” portion of this Chapter.

Fusion Demo.

A demonstration of the strong nuclear force made from 3 neodymium magnets that are 7/8 inches in diameter X 1 inch long and one iron slug of the same size. Construction details can be found at “A model to illustrate forces in nuclear fusion”, AJP, 69 (9), Sept. 1994, p. 804. by E. Kashy and D. A. Johnson. Used to discuss the strong nuclear force.

Faraday’s Law Demo.

An 8 inch diameter coil is connected to a large galvanometer and moved between the poles of a horseshoe magnet. The large coil can be replaced with a 2 inch diameter coil and a 1 inch diameter stack of magnets if it is desired to show that it does not make any difference whether it is the coil or the magnet that is moving.

Piezo poppers.

A “grill” style butane lighter that has been modified. Longer wires from the piezo sparker assembly are run out the end of the lighter and through the cap of a film canister that has been attached to the end of the lighter with hot glue. Adjust the distance between the ends of the protruding wires so that a good spark is produced when the trigger of the grill lighter is pulled. Put 3 drops of methyl or ethyl alcohol into the canister and press it onto the cap that is glued onto the grill lighter. Shake the unit to mix the alcohol with the air in the canister. Pulling the trigger on the grill lighter will ignite the alcohol/air mixture in the film canister. The canister will pop off the end of the grill lighter with great velocity. This is basically a one shot, one cylinder gas engine.

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Halloween Demos

Event: Halloween Holiday Events
Submitted by Dale Stille, Co-Coordinator “Hawk-Eyes on Science” and “Hawkeyes in Space” outreach programs, Univ. of Iowa. dale-stille@uiowa.edu
Venue: Public outreach programs, ages = preschool thru K-12 thru Adult Education programs.
Group Size: 6 to 2500
Time: 2 to 4 hours. The demonstrations are usually set up ahead of time in “station” format and the audience circulates from one demo to the other at their leisure.
Materials:
As listed below.

1. Vortex rings – Vortex Cannon with or without smoke machine
A vortex ring cannon made from a 5 gallon bucket with a 4 inch hole in the bottom. Tap on the rubber membrane covering the mouth of the bucket to generate the vortex ring. You can blow out candles at a distance, move peoples hair from a distance, or you can fill the bucket with smoke from a smoke generator to see the rings as they propagate through the air.
2. Theremin
A small kit style Theremin with a single antenna. As people walk close to the hidden Theremin, eerie or ghostly sounds will be heard.
3. Anamorphic Images
An image that is on a piece of paper is unrecognizable until a cylindrical mirror of the right diameter is placed at its vertex at which point the image shown in the mirror becomes obvious. Supply participants with a grid pattern, a mirror, and some colors so that they can create their own anamorphic images.
4. Rav’n’ lites – tricolor LED’s

The LED's in this light are red, green, and blue. However the light cycles between the colors so quickly that the observer sees only white light. If you put the light on a string that is 2 to 3 feet long and twirl it around you will be able to see repeating short arc patterns of the primary red, green, and blue colors.

5. Infinite images mirror

Two flat mirrors are set some short distance apart facing each other. Place an object between the mirrors and when you look over the top of one mirror into the other mirror you will observe numerous images of the object that appear to recede into that mirror. A variation is to use plastic mirrors and drill a hole into the middle of one so you can look directly at the other mirror through this hole. You can also buy commercially available toys that are based on this design.

6. Emission lines with spectra glasses

Hand 1-D or 2-D spectrum glasses out to the audience and have them look at a set of spectrum tubes. The pattern of lines that they see for each gas are essentially the fingerprints of each element. Have the audience take their glasses home with them to look at things like Christmas tree lights or other point source style lights, fireworks, or other white light sources. They can also look at advertising signs to see if they can identify some of the gases used.

7. Plasma balls and Plasma plates with neon, argon, and small fluorescent lites.

Plasma balls or plates are essentially gas filled globes mounted on a Tesla coil. If you bring another gas filled tube near these that tube will also light up. Neon and argon filled light bulbs are still available in a variety of sizes and work quite nicely. More commonly found is the fluorescent light tube which also comes in a variety of sizes and shapes. Participants should be able to shut off the glowing fluorescent tube by holding the end of the tube in one hand and running their other hand from the other end of the tube down to their hand. See if a chain of participants will be able to light the tube.

8. Fluorescent material and different color LED lites

LED keychain lites ranging in color from red to ultraviolet can be easily found. Get a large sheet (at least 1' X 1') of the fluorescent material and try "drawing" on it with the LED lites. You will find that the colors red, orange, and yellow show almost no activation of the material. The green and blue will show some activation. It is not until you get to the ultraviolet light that you will see bright and sustained activation of the material. You will also find that white LED lites will provide decent activation of material although not as good as the ultraviolet lites. This basically shows the concept of increasing activation energy with decreasing wavelength.

9. Tesla coil and gas filled lites

See # 7 above. The only real difference is going to be that you can usually vary the power of a regular Tesla coil and they are more powerful than the coils in the plasma balls and plasma plates. Therefore, you can light your glass filled tubes from a greater distance and they will also glow with a brighter intensity. With a grounding rod you can also draw lightning like electrical arcs from the coil.

10. Einstein is watching you.

A Halloween mask or the commercially available masking plate of Einstein is used for this illusion. Illuminate the concave side of the mask with a light from below and observe from a distance of 5 to 10 feet. The mask will appear to be a convex image just like looking at a person facing you. Most eerily, the mask face will appear to turn and follow you as you walk side to side in front of it.

11. Squealing CO2

Leather gloves and safety glasses will be needed for this demonstration. Place a sheet of aluminum that is at least 1' wide X 1' long X ¼ inch thick and place it on a flat surface. Take a tennis ball sized chunk of dry ice and press it against the aluminum plate. The rapid sublimation of the dry ice will produce squeals that are quite loud and Halloweenish.

12. Glow in the dark stuff with quinine, fluorescent dyes, fluorescent rocks, fluorescent markers, etc.

Many materials will glow when placed under a UV lamp or "black light". Quinine water, extra virgin olive oil, black light posters, objects made from black light material (such as packets of glo-in-the-dark stars for a children's room), and fluorescent children's markers are readily available. Fluorescent dyes and rock set can be purchased from commercial suppliers if you don't wish to hunt for your own. Also realize that there are two common wavelengths for black lights. The ones found for use in dorm rooms or available from party supply outlets are usually of the long wavelength variety with wavelengths around 408 nm. The germicidal style UV lights have wavelengths around 254 nm. Some of the objects that will glow under one wavelength UV will not glow under the other wavelength. You may also wish to purchase a low power UV laser pointer for use with the liquids but precautions must then be taken to insure that the laser is not able to be pointed at the participants at any time. For example, affix the laser in a box so that it cannot be moved and is pointing straight up at the top of the box. From an opening in the side of the box you can place your liquid sample between the laser and the top of the box to see the fluorescence.

13. Glow sticks, necklaces, bracelets, etc.

Chemical light sticks, glow bracelets, or glow necklaces are great give away items for Halloween programs. These are composed of two liquids that are mixed together when a glass vial containing one of the liquids is broken inside a flexible plastic outer container. Chemical lights of any color of the rainbow are readily available.

14. Balloon in a bottle….one with a hole, one without

A balloon is stuffed into the mouth of an empty 16 oz. soda bottle and the neck of the balloon it then stretched across the mouth of the soda bottle so that the balloon will inflate inside the bottle when you blow into it. The bottle you give to the participants does not have a hole in the bottom of it so that no matter how hard they try they will not be able to inflate the balloon in the bottle. The bottle you use does have a hole in the bottom of it so you can easily blow up the balloon. If you cover the hole with your finger the balloon will not deflate either.

15. Van de Graaff with pie pans, felt bat

Place a stack of 4 inch or 9 inch diameter pie pans on the dome of a Van de Graaff generator. When the generator is turned on the pie plates will slowly float off one at a time. Or, cut the figure of a bat (the flying creature not the baseball bat) out of a piece of felt and place this on the dome of the Van de Graaff. The bat's wings and head will raise off the dome first as if it is looking at you before it finally floats/flies off the dome.

16. Lenz's law – copper tube

A neodymium magnet dropped through a copper or aluminum tube will display an amazingly slow fall. The thicker the side walls of the tube, the better. A slot may be cut in the tube to make it easy to see the magnets fall. Slugs of copper, aluminum, wood, etc. that are the same size as the magnet may also be used for comparison.

17. Colored shadows

Red, green, and blue, 25 or 50 watt incandescent lights are place about 1 foot apart and about 10 feet from a white screen. Turn on the lights on and observe that the light falling on the screen appears white. Stand a person or place some other object between the lights and the screen and observe that three different colored shadows are produced. Also note that the shadows are the secondary colors magenta, yellow, and cyan.

18. Plasma Skull or Plasma Brain

These are just plasma balls discussed above in # 7 which are in the shape of a human skull or brain. Other weird shape plasma ball/sculptures are also available which are very good for Halloween type presentations.

19. Wesson Oil and Index of Refraction

Wesson cooking oil and Pyrex glass have almost identical indexes of refraction. Therefore a Pyrex beaker can be submerged in the oil and made to virtually "disappear". A popular spoof is to submerge an intact beaker in the oil. Take another beaker and place it inside a Ziploc bag and break it with a hammer. Pour the broken pieces into the oil while invoking the spirits of the Halloween gods and then lift the unbroken beaker out of the oil.

20. Happy Sad Balls

Two balls that appear identical. One bounces and one doesn't. If you are good at sleight of hand you can have some fun with your audience.

21. Hanging Balloons – Coanda Effect

Two balloons are hung by strings so that they are about 1 foot apart. Gently blow a steady stream of air between the balloons and watch them move together. Eerie if the source of the air stream is not heard by or visible to the audience or the demonstrator seems to be able to make the balloons come together or come apart on command.

22. Liquid Crystal Thermo Sheets

Heat sensitive sheets that will show hand prints or images of other warm objects placed upon them. Even blowing your warm breath on one of the sheets will make cool patterns.

23. Faraday Cage and Radio

A radio is tuned to a clear radio station. Place a metal mesh screen cage over the radio and the sound goes away. Lift the cage even a little bit and the sound comes back.

24. Rotating Hoberman Sphere

A 30 inch diameter Hoberman Sphere with the mobile attachment installed is hung from a ball bearing fishing swivel. When you rotate the sphere in its open position and then pull the string to collapse it, the sphere spins faster due to the conservation of angular momentum.

25. Ball in an air stream – Coanda

A vacuum blower with a hose attached is either fix in place pointing upward or is held near the nozzle by a member of the audience. A 9 inch diameter or larger beach ball will float in the air stream even if the stream is tilted by as much as 45 degrees.

26. Acoustic Frog = wooden frog with mallet

A version of this is available from Educational Innovations. Basically just a hollow log in the shape of a frog with scales on its back. When struck or stroked along the scales with a wooden stick, the noise sounds like a bullfrog croaking.

27. Pumpkin Pendulum

The standard “nose basher” pendulum with the usual bowling ball type pendulum bob being replaced by a Halloween pumpkin. If done correctly, the pumpkin will not come back and “kiss” you on the chin.

28. Mirror Demo – 2 Concave mirrors – real image

The “Optic Mirage” demo. Two concave mirrors, one with a hole in it, are placed in contact facing each other. A quarter or other small object placed in the bottom of the mirrors will form a real image at the site of the hole in the top mirror.

29. Fun House mirrors

Large flat mirrors are made of Mylar or some other flexible and highly reflective material. When bent in a vertical or horizontal direction or made with a wavy design the images viewed will be wildly and sometimes hysterically distorted.

30. Disappearing Money Box

A larger version of the commercially available child’s toy where you drop money into a box that appears empty and the money disappears. Basically a mirror set at 45 degrees inside the box hides ½ of the volume of the box. Also known as the “rabbit in a box” magician's trick.

31. Duck-In Kaleidoscope

A kaleidoscope made from Plexiglas mirror stock. The mirrors are 1 foot wide by 2 or 3 foot long. When put together this kaleidoscope is large enough to be lowered over your head so you can view the interesting image produced.

32. A Giant Kaleidoscope

A giant kaleidoscope made from 3 pieces of 4' X 8' Plexiglas mirror stock. Hinge one side like a door and you can actually step into the kaleidoscope. Or, place the kaleidoscope on its side and view the image from one end.

33. Einstein in Dominoes

The image of Einstein made by arranging dominoes so that the dots form his picture when viewed from a distance. Also known as "pointillism" art.

34. Cylindrical Lenses

Cylindrical lenses made from large diameter Plexiglas rod. Place the rod over paper with the phrases "bob kicked pop", "choice oxide glass lamp", "titanium oxide", or other words and see which words are right side up and which are upside down. Also look at images such as the jack, queen, or king from a deck of playing cards.

35. Glass Flask lens with mineral oil

Fill a 4 inch diameter or larger round glass flask with light mineral oil. Use this lens to greatly magnify images on a piece of paper.

36. Concave and Convex Mirrors

View your image in large diameter concave and convex mirrors from inside and outside the focal length.

37. Spherical Mirror

A spherical hemisphere with mirrored surfaces on the inside (concave) surface and also on the outside (convex) surface. Hang a Ping-Pong ball from the rim of the mirror and let it swing in and out of the mirror while viewing the image.

38. Periscope

A periscope made from 4 inch diameter PVC pipe and elbows with Plexiglas mirrors inserted into them at 45 degrees. Turn the top elbow while viewing through the bottom elbow and watch the image rotate 360 degrees.

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LARGE SCALE DEMONSTRATIONS FOR OUTDOOR VENUES

Event: Outdoor STEM events, State Fair Presentations

Submitted by Dale Stille, Co-Coordinator "Hawk-Eyes on Science" and "Hawkeyes in Space" outreach programs, Univ. of Iowa. dale-stille@uiowa.edu

Venue: Public outreach programs, STEM events.

Group Size: 6 to 600

Time: Usually 50 to 60 minutes, but has been tailored to fit 30 minute up to 2 hour time slots.

Materials:

Copper plate and Neodymium magnet with Liquid Nitrogen and Styrofoam container.

"Pinning" Superconductor with Magnetic Rail and Liquid Nitrogen.
Solar cell powered motor or Ferris Wheel and one million candlepower spotlight.
Thomson style coil and Aluminum rings, copper coil connected to a 6 v. light bulb, Variac with switch.
Radio communicator, closed iron core.
Optical communicator, fiber optics cable, remote controls.
Laser balloon popper.
Vacuum accelerator with vacuum pump, pop can array with protective cover, hearing protectors and safety glasses.
Large Magdeburg Hemispheres with vacuum pump.
Rocket cart with CO_2 fire extinguishers and optional sail.
55 gal. barrel, 5 gal. can, 1 gal. can, 2 liter soda bottle, 16 oz. soda bottle.
Large and Small Vortex Generators
Chemical Light Sticks
Boomwhackers ™ and Palm Pipes.

Safety Concerns:

Hearing and Eye protection to be used with the vacuum accelerator and the rocket cart.
Do not shine the lasers at the audience.
Keep the neodymium magnet away from any iron materials or objects.
A clear covered enclosure for the pop can array when using the vacuum accelerator.

1. Cool a Copper Plate.

A plate of copper is cooled to Liquid Nitrogen temperatures. When a neodymium magnet of at least 2 inch diameter is dropped on the plate from a distance of about 1 foot high the magnet will bounce before touching the plate and then gently float onto the plate.

2. Superconductor and Magnetic Rail.

A "pinning" style superconductor that is approximately 2 inches square is cooled in Liquid Nitrogen and then placed upon a rail of neodymium magnets. The superconductor will float back and forth on the rail without falling off and will come to a stop when it reaches the end of the magnets on the rail. If the rail is made to be flexible you may pick it up and run the superconductor either on the bottom or top of the rail. With enough magnets you may also make a Mobius Strip with the rail and the superconductor will continuously travel the rail.

3. Solar Cell Motors.

High output solar cells are connected to low current motors. A large propeller can be connected to the motor or the motor can be used to drive a toy such as a Ferris Wheel. A one million candle power rechargeable spotlight may be used on those days that are dark and stormy.

4. Jumping Rings.

A commercial or homemade Thomson's coil is used to show mutual induction with copper or aluminum rings. Energizing the coil with maximum power will launch the rings 25 feet into the air.

5. Radio Communicator.

The leads of two -15 turn, 4 inch diameter coils are connected to 1/8 inch phono plugs. One coil is connected to the headphone jack of a CD player (or any other portable device with a headphone jack). The other coil is connected to a Radio Shack mini audio amplifier (# 277-1008). Essentially you now have a very low power radio station (broadcaster) and a receiving station (the listener at home). Bring the coils near each other in a parallel configuration and the song playing on the CD will be heard. Turn one of the coils so that it is perpendicular to the other and the signal will fade. Now turn down the broadcasting signal until the song can be faintly heard when the two coils are held about 2 inches apart. Then take the iron U-core scavenged from an old transformer and insert it into the coils without any of the items touching each other. The signal will get louder with the addition of the iron core. If you close the top of the iron U-core with another piece of iron the coupling between the two coils will be maximized with a large increase in volume.

6. Optical Communicator.

A red or green LED in series with a 47 ohm resistor and powered by a 3 volt battery pack is connected to a 1/8 inch phono plug. This unit is then plugged into the headphone jack of a portable CD player. The leads of an encapsulated solar cell are connected to another 1/8 inch phono plug and this is plugged into a Radio Shack mini audio amplifier (#277-1008). The LED intensity is modulated when a song is playing from the CD player even though this can't be seen with the human eye. However, the modulations can be picked up with the solar cell and the song is heard to play when the light from the LED falls onto the solar cell. Show that this form of communication is "line of sight". Then use the fiber optic cable to transmit the signal from the transmitter to the receiver even though there are knots, bends, and kinks in the fiber optic cable. Show that all audience members are familiar with this form of communication by replacing the LED and CD unit transmitter with a common remote control. The IR signal from the remote control is easily heard from the solar cell receiver unit.

7. Laser Balloon Popper.

One of our cross discipline demonstrations. A green laser is set in a holder pointing upward so that it cannot be moved. The holder has two shelves that balloons can be placed between so that they don't move. The balloon system we use is to have a 12 inch black (actually very dark green and blue dyes) balloon that is blown up inside a 14 or 16 inch clear balloon. The dye of the dark balloon will absorb the green laser beam and create a hot spot while penetrating the clear balloon with no effect at all. Therefore, you can pop the inner balloon without damage to the outer balloon. Talked about in medical terms this is akin to targeting cells or diseases by tuning the wavelength of the laser. A very large area of present laser research for medical applications as evidenced by the recent announcement of the non-invasive use of lasers to diagnose whether an individual has malaria, dispensing with the invasive need for taking a blood sample. The diagnosis is also done in seconds as opposed to the minutes or hours needed for the blood sample diagnosis.

8. Vacuum accelerator with vacuum pump, pop can array with protective cover, hearing protectors and safety glasses.

A 40 mm Ping-Pong ball is accelerated down through our PVC vacuum tube accelerator using nothing but the power of our atmosphere pushing the ball and the damage that may result when the ball is directed into some empty pop cans. With eye and hearing protection in place and directions given to the other audience members to cover their ears, a member of our audience punctures the membrane at the end of the accelerator. Air rushes into the accelerator, pushing the Ping-Pong ball down through our PVC tube, exiting at high velocity into the array of empty pop cans (with protective cover in place) at the other end. Our 7 ½ foot long accelerator will usually be able to accelerate the ball completely through three pop cans and dent or partially penetrate the 4^{th} can.

9. Large Magdeburg Hemispheres.

A set of Magdeburg hemispheres is made from 12 inch diameter Lexan or Aluminum plates. Ropes with handles are attached to each of the plates so that 6 or more people can pull on each plate. Evacuate the area between the plates and have the people try to pull them apart. Have them stop and show that the plates easily separate when you let the air back into the area between the plates. A safety feature that is added to the plates is a set of three ropes or bolts that will allow the plates to separate a distance of only 4 to 6 inches.

10. Rocket Cart.

A cart or bicycle that is powered by a 10 to 20 lb. directed stream CO_2 fire extinguisher. Very loud so be sure to advise your audience to cover their ears. Also direct them not to stand at the rear of the cart when doing the demonstration as there will always be some flying debris when doing this outdoors. The rider wears eye and hearing protection. A sail may be attached to the cart in front of the fire extinguisher if desired.

11. 55 gal. Drum/Barrel Crush.

Work your way up to the 55 gal. drum by first using a vacuum pump to evacuate and crushing some 16 oz. soda bottles, then move up to some 2 liter soda bottle, continue on to 1 gal. cans, followed by 5 gal. cans, and finally the 55 gal. drum. The experience can be enhanced by playing the song "Under Pressure" as demonstrated so effectively Stan Micklavzina.

Or, you can crush the cans using steam. Start with aluminum soda cans with 10 ml. of water that have been placed on a hot plate. When steam pours freely from the opening of the cans, take a large tongs and quickly invert the cans into a shallow pan of cold water. The steam will condense and the can will dramatically collapse. Then move up to 1 gal. cans with 50 ml. of water placed on a hot plate. When steam pours freely from the can you can tightly cap the can and spray some cold water on the sides to facilitate the collapse. Then place at least 3 Fisher burners under the 55 gal. drum and about 2 liters of water in the drum. Cap the drum when steam issues freely from the hole and then remove it from the flames. You can spray the sides of the drum with cold water, pour ice or dry ice onto the top of the can, or place the barrel in a small baby pool of water to reduce the time needed for the drum to collapse.

12. Vortex Ring Cannons/Generators.

A vortex ring cannon made from a 5 gallon bucket with a 4 inch diameter hole in the bottom. Tap on the rubber membrane covering the mouth of the bucket to generate the vortex ring. You can blow out candles at a distance, move peoples hair from a distance, or you can fill the bucket with smoke from a smoke generator to see the rings as they propagate through the air. A larger version can be made from a large 55 gal. garbage can or a large cardboard or Plexiglas box with a 6 inch diameter hole.

A vortex ring machine gun can be made by replacing the rubber membrane on the 5 gal. bucket with a 12 inch diameter speaker. Fill the bucket with smoke and then run a square wave into the speaker at 2 to 10 Hz. using a power amplifier so that there is significant speaker movement. If desired you may cut a hole into the side of the bucket so that you can insert the smoke generator there for a "continuous" mode of operation.

13. Wave Demonstrations – 3 versions.

One enhancement to all of the following is to give all the participants a chemical light stick. Dim the lights when doing the demonstrations for a highly visual experience.

Longitudinal Waves. 25 people or more from the audience come to the front of the demonstration area and stand shoulder to shoulder. Spread things out by having each person put his outstretched left hand on the right shoulder of the person standing next to them. A small push to the left on the first person in line will be transmitted through the whole line.

Transverse Waves. 25 or more people from the audience come to the front of the demonstration area and stand shoulder to shoulder. The first person in line raises their hands and then brings them back down. The next person in line does not raise their hands and bring them down until they see the first person do so. Human reaction time makes this look like a transverse wave traveling down the line.

Transverse Waves. The entire audience participates. One person starts walking at one side in the front of the audience and walks toward the other side. Those people in the audience that you pass in front of raise their hands and after you have passed they then lower them again. The wave travels from one side of the audience to the other. If desired you can keep the wave going by walking back and forth in front of the audience.

14. Palm Pipes and Boomwhackers ™.

Multiple sets of one or two octave Palm Pipes are made from ½ inch PVC tubing and color coded according to pitch using paint or colored tape. Color coding them the same as a commercial set of Boomwhackers ™ may make it easier for directing the audience but is not a requirement. Give a Palm Pipe to each person in the audience and show them how to play them by striking the end on the palm of their hand. 4 to 8 demonstrators now lead the audience in the playing of a song using the Boomwhackers ™. These are large and easy for the audience to see so that when a demonstrator strikes his hacker on a table at the front, the audience members who also have that color Palm Pipe strike theirs. Simple songs like “Mary had a Little Lamb”, “Twinkle, Twinkle Little Star”, and “Happy Birthday” are some of those that can be done and with harmony if desired.

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ASTRONOMY PRESENTATION DEMONSTRATIONS

Event: Astronomy and Atmosphere, Spacecraft, Satellites and the Univ. of Iowa connection, James A. Van Allen, the Van Allen Belts and the Van Allen Probes, Aurora, Whistlers, and the Heliopause, Telescopes.

Special Note: The following demonstrations have all been used for our astronomy outreach presentations at some point.

Submitted by Dale Stille, Co-Coordinator “Hawk-Eyes on Science” and “Hawk-Eyes in Space” outreach programs, Univ. of Iowa. dale-stille@uiowa.edu

Venue: Public outreach programs, ages = preschool thru K-12 thru Adult Education programs.

Group Size: 6 to 600

Time: Usually 50 to 60 minutes, but has been tailored to fit 30 minute up to 2 hour time slots.

1. Magnetometer Demonstration.

Two magnetic sensor probes are placed on the table at some separated by a distance of 1 foot to 18 inches. The interface is set to display the readings from both sensors simultaneously. A pendulum with a large neodymium magnet on the bob is swung over the probes. The two traces should look about the same but offset by about ½ second in time. This is how the Van Allen Probes spacecraft magnetometers were tested before launch. That is the entire spacecraft was hung on a cable, swung like a pendulum, and the readings from the magnetometer were recorded.

2. Radio Communicator / Transformer.

The leads of two -15 turn, 4 inch diameter coils are connected to 1/8 inch phono plugs. One coil is connected to the headphone jack of a CD player (or any other portable device with a headphone jack). The other coil is connected to a Radio Shack mini audio amplifier (# 277-1008). Essentially you now have a very low power radio station (broadcaster) and a receiving station (the listener at home). Bring the coils near each other in a parallel configuration and the song playing on the CD will be heard. Turn one of the coils so that it is perpendicular to the other and the signal will fade. Now turn down the broadcasting signal until the song can be faintly heard when the two coils are held about 2 inches apart. Then take the iron U-core scavenged from an old transformer and insert it into the coils without any of the items touching each other. The signal will get louder with the addition of the iron core. If you close the top of the iron U-core with another piece of iron the coupling between the two coils will be maximized with a large increase in volume. Discuss how iron likes magnets and therefore likes magnetic fields. Also discuss what other modern devices use radio waves to transmit communication signals. And finally discuss how this system with the closed iron loop is a transformer and how transformers work, what they do, and how they are used in everyday life.

3. Bend an Electron Beam with a Magnet.

A green electron beam is deflected using a neodymium magnet. Use the other pole of the magnet to deflect the beam in the opposite direction.

4. E/M tube and Magnet.

The standard Daedalon E/M unit is powered up and the beam is brought to a full circle by turning up the current in the Helmholtz coils. A neodymium magnet is brought near the tubes from the front or back sides. A spiraling electron beam is observed. This can be equated to synchrotron radiation spiraling around the magnetic field lines of the earth.

5. Copper Plate and Magnet.

Drop a neodymium magnet which is at least 2 inches in diameter onto a copper plate that is at least 1 inch thick. The magnet will float onto the plate due to the large currents generated in the plate as the magnet moves over it. If you move the magnet over the copper plate you will feel a “gluey” or “moving in molasses” type sensation due to the large currents you are generating in the plate. Turn the plate vertical and “stick” the magnet onto the plate. Note how slowly the magnet falls off. It’s all about the generation of electrical currents by moving magnetic fields.

6. Pith Ball Deflection.

A pith ball is charged and then shown to be deflected when charged rods are brought near. Not unlike sensors on the Van Allen Probes spacecraft.

7. Magnet and Iron Filings.

A magnet placed under a Plexiglas sheet is put on the overhead projector. Iron filings sprinkled on the sheet will show the magnetic field surrounding the magnet.

8. Spectrum Tubes and Spectrum Glasses.

The spectrum glasses have been passed out at the beginning of the presentation and are now brought out and discussed. The glasses are holographic diffraction gratings (as in made with a laser) or in scientific terms they are simple spectrometers. With these spectrometers the audience will be able to look at the different “fingerprints” of elements and be able to determine what some of the common things around them are made of or have in them. So, we first turn on the H2 spectrum tube and make sure that everyone can see the 3 main lines and the pattern of those lines. Then we go to He and discuss why it has so many more lines. We then do Ne and Hg and talk about the common uses of these two elements in the world the audience lives in. Coming back to how astronomers are able to tell what suns, gas clouds, nebulae, etc. are made of without actually going there and collecting a sample we turn on the H2 and He tubes and point out that when astronomers look at our Sun, these are the two main fingerprints that they see. Hence, why their (the audience's) text books say that ours is a young sun composed of mostly Hydrogen and Helium. Some discussion on how their spectrometers are able to give them a rough idea of concentration can also take place here.

9. Magnetic Field Around a Wire with Iron Filings.

A single wire through a Plexiglas sheet is placed on the overhead projector. A large current is run through the wire and iron filings are sprinkled on the Plexiglas sheet to show the magnetic field around the wire.

10. Plasma Tube and Plasma Plate.

The standard glass tube with electrodes inserted in the ends of the tube. A low current from an induction coil is used to run power to the electrodes as the tube is evacuated with a vacuum pump. A very cool pink/purple glow is produced from the plasma produced using the gases in our atmosphere. Also show our plasma plate and the variety of plasma balls we have. All of these can be used when discussing the aurora.

11. Solar Convection Demo.

A solution made by placing some aluminum powder into silicon copier oil. Pour some of this into a small frying pan that is on a hot plate set at low heat. Convection cells much like those seen on the surface of the Sun are produced. You may stir the solution to disturb the cells and watch as they reform. Zoom in on one or two of the cells with a video camera and observe the very visible convection going on inside the cell.

12. Sunspots.

An incandescent bulb with a large filament is placed on the overhead projector and adjusted so that it just glows visibly using a Variac. The glowing filament should be seen on the screen as a soft orange color. Now turn on the overhead projector and the filament will be seen as a dark shadow against the brighter background light of the overhead.

13. Satellites and Spacecraft. Models and Real.

Models of the Van Allen Probes, Voyager, Cassini, Juno, Hawkeye, PDP, and Injun V with signage are brought out of the display cases for presentation. The Van Allen Rockoons and instrumentation packages as well as the Explorer instrumentation package, full scale mockup of the Explorer spacecraft and the signage for these is also put on display. The Injun backup, PDP, and Hawkeye backup satellites can be brought out from storage for display as well as some of the instrumentation for Cluster I and some of the other satellites built here at the Univ. of Iowa. Interesting Note: The PDP (Plasma Diagnostic Package) satellite has actually been in space (taken by the space shuttle), taken data, and been returned (by the space shuttle). One of the few satellites to ever do so.

14. Orrery

Two Orrery. The simple Earth/Moon/Sun Orrery with a 60 watt light bulb in the Sun which can be turned on when desired to show eclipses. While the sizes of the Earth, Moon, and Sun are not to scale, the Moon does orbit the Earth the correct number of times each year and the tilt of the Earth is also correct.
The brass Orrery has a variable speed motor, shows some of the major moons around the planets, shows the asteroid Ceres and the outer solar system dwarf planet Eris. While the distance of the planets from the Sun is not to scale, and all the orbits are circular, the rotation rates of the planets around the Sun is accurate as is the rotation rate of the Moon around the Earth.

15. Solar Cells.

Turn on and shine the large spotlight beam onto the solar cell that is connected to either a small motor with a large propeller attached or the small motor that turns a toy Ferris Wheel. Discuss the fact that this is a “one step” method for generating electricity. That is, the sun shines on the cell and you get electricity. Continue to shine the beam onto the solar cell as you back away. Note that the greater the distance from the solar cell, the slower the motors turn which means the electrical energy produced is smaller. This example can be used to discuss why spacecraft going outside the orbit of Mars need to be powered by another method.

16. Human Battery.

Plates of copper and magnesium are connected to a digital VOM set on the 2000 mv scale. Place one hand on each plate and your body will act as the electrolyte and the meter will show a voltage of 1.4 v. A zinc plate may also be used but the resulting voltage will not be as high. This is used as a starting point to discuss what kind of batteries would be able to function and power spacecraft and satellites in space.

17. Polarizers and Birefringent or Optically Active Materials

Place a large polarizer over the viewing surface of a X-ray or 35 mm slide viewer. Place birefringent materials such as cellophane, mica, stressed Plexiglas, CD blanks, clear plastic knives/spoons/forks, or clear bottles of Karo syrup on the viewer. Rotate another large polarizer above these materials and observe. Used as a starting point in a discussion as to what kind of instruments and sensors to put on a spacecraft or satellite, and the technology needed to keep them functional in space. You can also discuss what determines the finite lifetime or functionality of satellites or spacecraft.

18. Geiger Counter and Samples.

The Geiger counter is used to investigate a variety of samples as well as listen to cosmic rays. You can also use a beta emitter and a neodymium magnet to explore the deflection of a particle stream by a magnet. A discussion of the detectors on the Van Allen Probes and some of the precautions taken to protect the satellites instrumentation can take place here. The following list can also be discussed if desired.

Commonly Found Radioactive Sources

1. Smoke Detector = Americium 241
2. Salt Substitute = Potassium 40
3. Radon = Can be collected on TV screens or with a statically charged balloon. Common in the Midwest and upper eastern states.
4. Coleman style Lantern Mantles = Thorium
5. Fiesta Ware = Uranium oxide
6. Antistatic Brushes = Polonium 210
7. Cigarettes = The tobacco plant concentrates Polonium 210 while it is growing and the smoke particles attract and collect Radon in the lungs when smoked. Double Whammy
8. TIG welding rod = Thoriated rod = 2% Thorium, good for cloud chamber source.
9. Thorium impregnated camera lenses – the Aero-Ectar lenses
10. Vaseline glass = Uranium oxide and also fluoresces under black light.
11. Cosmic Rays
12. Natural sources = Uranium concentrated in the dark bands from many of the rock collected in the west and southwest.

Other natural sources and their locations:

Allanite - Rosenthal, Ontario, Canada

Autunite - Montebras, France

Carnotite in Sandstone - Montrose Co., Colorado

Cyrtolite, uranium bearing - Bancroft, Ontario, Canada
Ellsworthite (Pyrochore in Calcite) - Hybla, Ontario, Canada
Euxenite - Voandelaka, Madagascar
Fergusonite - Madawaska, Ontario, Canada
Gummite with Uraninite, etc. - near Grafton Center, New Hampshire
Monazite - Elk Mtns., San Miguel Co., New Mexico
Monazite Sand - Idaho
Polycrase-Euxenite - Minas Gerais, Brazil
Samarskite - Mitchell County, North Carolina
Torbernite (Meta-Torbernite) - Mitchell County, North Carolina
Uraninite (Pitchblende) - Great Bear Lake, Northwest Territories
Uraninite - Mitchell County, North Carolina
Uranophane - Ruggles Mine, near Grafton Center, New Hampshire

19. Cloud Chamber.

A Wilson cloud chamber is used to show the tracks from cosmic rays and the particles from radioactive decay products using the common Pb-210, radium paint or pitchblende ore, or Thorium doped welding rods.

20. Meteorites and Tektites.

Meteorites or pieces of meteorites are put on display. Tektites formed from meteorite impacts are also shown.

21. Fusion Demo.

A demonstration of the strong nuclear force made from 3 neodymium magnets that are 7/8 inches in diameter X 1 inch long and one iron slug of the same size. Construction details can be found at “A model to illustrate forces in nuclear fusion”, AJP, 69 (9), Sept. 1994, p. 804. by E. Kashy and D. A. Johnson. Used to discuss the fusion process in stars.

22. Electromagnetic Spectrum.

6 examples we use when discussing the electromagnetic spectrum and the different regions of the spectrum used by telescopes, satellites, and spacecraft for exploration of space and the cosmos.

1. A dipole radio transmitter and receiving antenna with light bulb.
2. A dipole microwave transmitter and receiver.
3. An infrared camera

4. The white light spectrum with a grating or a prism.
5. The UV shown with UV sensitive materials, dyes, fluorescent materials, with short and long wavelength UV lamps.
6. A Geiger counter and samples emitting gamma rays.

23. Laser tape measure.

Now that we have introduced lasers in the communication and fiber optics devices described above we usually ask the audience "How many lasers do you have at home". We always get someone that says that they have one to amuse their pets. Then we start asking who has a computer, a DVD player, a Blu-Ray player, etc. We then ask if anyone has any relatives or knows of anyone in the construction business. This is when we show and have a conversation about laser tape measures, surveying equipment, measuring the distance to the moon, the lunar retroreflector, and large scale multiple spacecraft astronomy projects that use lasers to accurately measure the distance between those spacecraft (all examples that use lasers to measure distance). Both the LIGO and the defunct LISA astronomy programs are discussed at this point.

24. Rocket Cart.

A cart or bicycle that is powered by a 10 to 20 lb. directed stream CO2 fire extinguisher. Very loud so be sure to advise your audience to cover their ears. Also direct them not to stand at the rear of the cart when doing the demonstration as there will always be some flying debris when doing this outdoors. The rider wears eye and hearing protection. A sail may be attached to the cart in front of the fire extinguisher if desired.

25. Pulse Jet Engine.

A Dyno-Jet pulse jet engine used to begin discussions of rocket propulsion. Very loud and very dramatic. Mention the V1 and V2 rockets of WWII.

26. Rocket Platform.

A 16 foot long platform on Roller Blade wheels. Seat two or three "astronauts" from the audience at one end of the platform and have 4 to 6 other members of the audience act as the "propellant" by stepping off the other end of the platform which propels the astronauts and the platform in the opposite direction.

27. Balloon Rocket.

A long string is threaded through a straight drinking straw. The string is then stretched across the lecture room or demonstration area. A long airship style balloon is then blown up and taped to the straw. Let go of the mouth of the balloon and it will fly across the room using the string as a guide.

28. Liquid Nitrogen Demonstrations.

See the "Liquid Nitrogen Demo Show" portion of this Chapter.

29. Telescopes.

A variety of telescopes are shown in a "fashion show" type format. Telescopes displayed are Infrared, Microwave, Radio, Reflectors of different sizes, Refractor of different sizes, and a Solar Telescope. We also build the Galilean and Keplerian telescopes on the optics rail to show the difference between these two types of refracting telescopes.

30. Audio Demonstrations.

Audio examples of Lightning Whistlers of Earth, Jupiter, and Saturn are played. Audio of the Voyager spacecraft encountering the bow shock of Jupiter and traversing the heliopause can also be played. Audio of pulsars and solar oscillations are also available.

31. Black Holes.

A "wishing well" style fiberglass cone with 1 inch ball bearings and a rubber membrane stretched across a laundry basket with a 4 inch diameter steel ball and Ping Pong balls are used to discuss Black Holes and the curvature of space around a gravitational well.

32. Pulsar.

Two flashlights are placed facing outward on a rotating air table (a lazy susan or rotating platform can also be used). Turn on the flashlights, turn off the room lights, and spin the table. The "lighthouse" effect as the beams sweep the audience can be easily seen. Discuss audio and visible pulsars, and how to detect pulsars whose "beams" may not sweep toward the Earth.

33. Binary Star Systems.

Two types of binary star system models are shown. One with a small heavy mass and a large light mass place at the ends of an aluminum rod. The center of mass of this system is between the two masses but not at the center of the rod. The second system has a very large diameter mass (red giant) at one end and a lighter and smaller mass at the other end. This system will have the center of mass inside the larger diameter mass.