Fall 2013 AAPT Demo Show at Sun Valley HS

The Fall 2013 AAPT Demo Show took place at Sun Valley High School in Aston, PA. There was terrible weather and terrible traffic, so many people were late and the officers' meeting was severely truncated. We did discuss hosting sites for the Spring 2014 meeting. After an excellent dinner, we moved to a classroom for the demo show. Marc distributed a sheet for people to sign up for PA Act 48 credits, and a few people got their email addresses added to or updated on the SEPS mailing list.

Also, Marc has a clock in chrons (the metric unit of time, 1000 cron/day), with the numbers replaced by the labels Sigma F, m, a, E, m, c^2, p, m, v, f, mu, N. He says he inherited it from a predecessor.

Art Zadrozny (West Chester East)

Art started us off by talking about the difficulties of conveying our own love of science and the amount of fun we have to students -- how do we convince them to have fun in our classes? Since lab reports are such a big part of what we do, he works to make lab reports more fun by giving students bonus points for creative lab report covers. The catch is that to receive the bonus point, the covers must be creative AND relevant. He shared a simple and elegant submission from a student for their first lab, in which students measure the circumference and diameter of a circle and hopefully determine that pi is the constant ratio. A student entitled their lab "Circling Accuracy", and drew a circle with an arrow pointing to the center. Art shared his collection of students' lab report covers, passing around a binder. His second-year students, who were already familiar with the activity and his expectations, had created some particularly nice ones.

Barry Feierman (Retired, Westtown School, West Chester University)

After discussing a variety of tantalizing demos he would have brought if it hadn't been too much stuff to carry in the rain (looking at the timbre of Native American flutes by collecting data from a microphone, the lie detector he's building for Vernier), Barry presented a simple classroom activity that uses only one piece of equipment: a bag of popcorn from Wawa, with a clear window in the bag so you can see the popcorn.

Barry selected 10 "volunteers" (conscripts) from the audience, and presented them with a challenge: spend about ten seconds looking through the clear opening on the bag, and estimate the total number of kernels in the bag. He passed the bag around and everyone came up with an estimate, wrote it on an index card along with their name, and passed it to the front. He then tabulated everyone's name and estimate on a spreadsheet in front of the class, and had the spreadsheet calculate the average and standard deviation.

While Barry was tabulating, the audience discussed the number of popcorn kernels it would take to bury the United States nine miles high (approximately a mole, according to Albert Einstein), and our strategies for determining the true number of kernels in the bag at the end of the activity, without having to count them all.

The group's average estimate for the number of kernels was 1462, with estimates ranging from 360 to 4000 kernels. The standard deviation was 1216.

Then Barry challenged us, now that we knew how everyone else voted, to take a second look at the bag and make a second estimate of the number of kernels. We passed our second estimates up, and he tabulated them in the second column of the spreadsheet. Barry explained that what he was looking at here was if people changed their minds the second time, and if they did, did they change them in the direction of the average. Nine of the ten participants did change their minds, six of them in the direction of the average.

The point of the exercise is to illustrate (in a concrete, tangible manner) how in any group of people, you get this convergence toward the middle, and help students wrap their minds around what it's like and how it happens. It happens even if some people don't change their minds, but most do revise their estimates in the direction of the average. The second standard deviation would be much smaller (although actually, I calculated it and the second standard deviation was 1284 because someone revised their estimate from 1000 to 4000; the second mean was 1817). This quantifies peer pressure/bias for the students. Barry says that if you do it with very young kids, about 8 years old, they don't care, and you see very little convergence. PhD psychology students converge almost immediately.

What was the true number of kernels in the bag? Barry reports that the number was 472 -- his freshmen always insist on counting, and the range is generally between 470 and 480 kernels. The experiment can also be done with nails, M&M's, etc, but popcorn is definitely more interesting than nails!

Ron Pedelty (West Chester East)

Ron presented a force vs. pressure demo, similar to the Bed of Nails demo but requiring much less advance preparation . "It takes a while to accumulate the equipment" he said, and produced a fleece blanket full of about 2 gallons of broken glass. He advised us when doing this demo to take off our shoes, being as dramatic as we like (mismatched socks, bandaids, etc), and he demonstrated (although his socks did match and his feet appeared intact).

How to walk barefoot on glass: you need a lot of glass. Make sure you have a stool to stabilize yourself if you lose your balance. Make sure to feel carefully before putting your foot down. And then it works! You can even crush the glass under your heel, without injury.

The idea being conveyed here is that: 1 piece of glass is bad, like the pointy end of thumbtack, lots of force on a very small area. But lots of pieces of glass are safe and easy, like flat end of thumbtack, with the force distributed over a larger area. A high surface area produces a low pressure.

At the end, Ron advised us, make sure there's not just one piece stuck to your foot, though, or you'll demonstrate the opposite (painfully). He has never cut his feet doing this demo.

Mary Pandya (Owen J Roberts HS)

Mary shared a demo she originally saw at an AP conference. Now in the days of the iPod, we've all been wondering what we should do with our boomboxes. If we have one in our classroom, students come in, and have no idea what it does. No, you do not put your iPod into it. The most important feature of a boombox is the following: there are no headphone jacks, just wires for speakers. Speakers work based on idea that when AC current flows through wire coiled around speaker cone, it shakes, and then the air shakes, generating a cool sound wave. But of course, sound doesn't require air as a medium, it just requires *a* medium. So you can turn anything into a speaker. Mary proceeded to turn her jaw into a speaker for our edification.

When doing this demo, you should first turn on the boombox, making sure there's a good 80s CD inside, and play some music first so students born after 1990 can observe how boomboxes work. Then unplug one speaker and plug it into a tongue depressor with a coil of wire around it. Put the wire-wrapped tongue depressor between the two ends of an strong, expensive (like $500) U-shaped magnet, and you can see the tongue depressor begin to shake when you turn the boom box on. To turn your jaw into a speaker, hold the giant horseshoe magnet so the tongue depressor is in the middle, wrap plastic around the tongue depressor for sanitary purposes, bite down on the tongue depressor, and you can hear the music. Someone standing close to you can hear the music, too -- be sure to get someone else to listen! Have students come through and listen to your face; if everyone wants to try being a speaker, maybe let them take turns after school.

Mary points out that this exact principle is used to make percussion headphones for people born without ear canals, and reminds anyone attempting this demo that the coils do get warm over time, so don't leave it plugged in forever.

Bob Schwartz (Retired Lower Merion, now part-time at Kohelet Yeshiva HS)

Bob is currently teaching at a school where the students all get iPads, and the combination of an iPad camera with a computer projector is a great substitute for a document camera.

Bob suspended his "document camera" above a rotating Lazy Susan he bought at a winery, so that we could see about half of the turntable's circle as it spun. He then placed his iPhone on the Lazy Susan, set to display a picture of Ron standing on glass from a few minutes before. As anyone with a smartphone is familiar, phones contain accelerometers to allow them to detect their orientation and adjust the image accordingly. And if something is moving a circle, we all know that it is accelerating. So if you place a phone on a rotating platform, which direction will the image rotate in?

Bob held the phone vertically (in "portrait" orientation) so the image adjusted to match, and carefully lay it on the Lazy Susan so it was tangent to the circle. He asked us to predict which way the picture would reorient itself when he began to rotate the turntable: would the bottom of the photo go toward the inside of the circle, or toward the outside? Then he spun it, and we observed that it flipped so the bottom of the photo was aligned toward the outside! This is a great demonstration of artificial gravity: if you were the little person inside the picture, you'd feel an apparent "gravitational force" towards the outside.

We discussed the subtlety of explaining to the students that the actual acceleration is towards the inside, and trying to avoid perpetuating the centrifugal force misconception. This is a good time to highlight the equivalence principle: have students think about a car accelerating (or a car stopping). What will the accelerometer do then? Don't assume that if something is actually accelerating in a certain direction, the accelerometer points that way. It might be possible to demonstrate this with the cell phone accelerometer, by giving it a constant acceleration (e.g. with a fan cart?) and a long space in which to accelerate in, but the cell phone needs to spend a while at constant acceleration before it notices and switches the image, so this might be more difficult than it seems.

Pasco does have an accelerometer wired to point inward in that circumstance, but that's just circuitry, and smartphones are much more readily available these days.

Bob also shared some great iPad apps available for a low cost. The first two, Video Physics and Graphical Analysis, are available from Vernier for $4.99 each.

Video Physics is a pared-down program similar to Tracker and the video analysis features in Logger Pro's regular desktop software. Bob first showed us a video of a fountain, with a young girl running around, and a bird that flies in. He used Video Physics to draw dots tracking the water droplets in the fountain. Then he selected the "graph" option and the program produced a y vs. x graph (trajectory), x-component of position vs. time, x-component of velocity vs time (although it appeared pretty noisy because it was autoscaled), y-component of position vs time, and y-component of velocity vs time. Bob says that if you get the other program (Graphical Analysis) you can open that data in Graphical Analysis and, "trace" through the graph to identify different points. You can also make little flags at different points in the graph, tap flags and get statistics, do linear and quadratic curve fitting, etc. (His graph yielded an acceleration due to gravity of 19 m/s/s = 0.5 (32 t^2), which could be used to calculate the actual scale of the picture. For instance, you could work backwards from that and find the girl's height. You can also change the coordinate system, by moving the axis in the graph. This is an application that helps students see the physical meaning behind the numbers.

There may also be versions of these apps for iPhone, but so far Vernier hasn't developed anything for Android yet.

Bob suggests a simple fact to introduce to our students to help them visualize the acceleration due to gravity: 9.8 m/s/s (or 32 ft/s/s) is about 22 mph/s. Since students think in miles per hour, not feet per second (or m/s), this gives a different appreciation of the nature of freefall. Can your car accelerate of 22 mph/s? (Short of falling off a cliff?)

Another useful app is eScope 3-in-1, which turns your iPad into an oscilloscope for $1.99.

Bruce Williams (Delaware Valley Friends)

Bruce shared a trick he originally discovered accidentally when trying to cool a drink off by putting it in the freezer. About twenty minutes before he began his presentation, he placed a small glass bottle of Coke in a cooler containing ice and rock salt to cool off. While waiting for it to cool, he shared another demo about lab safety.

He lit a portable methane can and placed a coffee can with a hole in the bottom over it, so that the flame emerged through the hole in the top. The little flame started out relatively yellow and big, but as it continued to burn it got smaller and bluer, less and less threatening-looking, more and more safe-looking (to the students, anyway). "It gets down to this little blue button that's beautiful." Bruce asked us what we expected to happen when it finally ran out of gas. And when it did run out of gas, the whole metal can popped up in the air, with a fireball underneath, demonstrating why you should always wear safety goggles, no matter how "safe" something appears: you never know if something is actually getting safer, or if it's reaching a dangerous critical point.

At this point, Bruce's soda bottle was cool enough (he said it takes about 30 minutes), and he pulled it out and attempted to pour it into a glass. It began to pour, but froze quickly as it poured, becoming completely solid. We discussed explanations for this phenomenon: the bottle is super-cooled but not frozen, and when the bottle is opened, carbon dioxide comes out of solution, cooling it further, and leaving behind nucleation sites for crystallization to begin.

Marc Baron (Sun Valley)

Marc shared a lab he does lab every year with all his physics students -- his AP class just did it this week. It's basically a scale-in-an-elevator lab using a Logger Pro force plate, which works because most schools have an elevator. The lab demonstrates 1D acceleration, and can easily be connected to Newton's Laws. The elevator is a predictable and familiar object, and can be used to fight the common misconception among students that accelerating always causes things to speed up. (We physics teachers try to describe the positive acceleration of backwards slowing down things and they get all confused.) Marc displayed a graph created in an elevator using a force plate: 180 seconds long, 3 trips up and down, picking out the first 30 seconds (1st trip) to analyze. He tells students at the beginning of the lab that if you're in an elevator "if you feel heavy", you've got to be accelerating in 1 direction, while "if you feel light", you've got to be accelerating in the other direction. He says a really uncomfortable jerky elevator is great for this, because the changes in velocity are so dramatic. But even so, some of the starts and stops just show up as quick spikes in force, not as plateaus.

He asks students the question, "is the elevator safe, or is it dangerous?" If you're falling, you're falling at 9.8 m/s/s. Obviously that's dangerous. What number is safe? Is 1 m/s/s safe? They discuss. (1 m/s/s is a good ballpark of safe, anyway.)

The graph allows students measure how heavy they feel when accelerating in one direction, and how light they feel in the other direction. Each stop/start is a spike/plateau, while things like the door rumbling open create small blips. The key thing here is how easy it is for students to see the similarity between moving up/slowing down and moving down/speeding up, since both look identical on the force graph. Students can also use the measured forces to calculate acceleration, reinforcing the idea of acceleration in one direction or the other. Marc said he didn't define direction of acceleration for the students; he just had them do that. They usually come up with something like this: "If the spikes go down, you feel lighter, and acceleration is downward. If the spikes go up, you feel heavier, and acceleration is upward."

Marc used to do this demonstration with a regular bathroom scale, and it was much harder to take readings while accelerating. The force plate makes it easy.

He also uses the force plate to emphasize the difference between mass and weight. If you bob your knees up and down a bit on a scale, the dial swings wildly as you rock up and down, even though your mass obviously isn't changing. The problem is that the bathroom scale tells you your weight. But we teach students that Weight = mass * gravity. So how does this change? At no time does the earth's gravitational pull change… at no time does your mass change. Yet the needle swings wildly. Of course, the bathroom scale doesn't actually tell you weight, it tells you the normal force, which is a variable force. This drives kids nuts, even though it's obvious to us: you put a block on a table and lean on it, and the normal force on the block changes. So the bathroom scale allows us to highlight the variability of normal force. (Marc reinforces the importance of this with an essay question on the difference between mass and weight on the exam; students know about this in advance.)

We discussed the difficulties caused by SI base units vs. English units. In SI, mass is measured in kg and weight in newtons; in the English system, weight is measured in pounds, while mass is measured (obscurely) in slugs. Marc finds it incredibly troubling that we're trying to teach the difference between mass and weight and kids come in without even knowing the unit for mass. This is aggravated by how cereal boxes (and everything else) list weights in pounds and ounces, and then list grams as the equivalent. We hypothesized that the distinction between mass and weight might be simpler in other countries, where they don't have to deal with pounds. The abbreviation for pounds (lbs) actually stands for libres, like the Zodiac scales, which is a 2-pan balance, so it really does measure mass and not weight -- this confusion has been present since the very beginning. Slugs only used in shotgun calibers and fishing weights. Bill Berner says the University of Pennsylvania has an actual slug (32 lbs), because they taught physics before WWII when they needed slugs.

Someone points out that international kids are actually confused in the opposite direction: they know their weight is in kg so it's not a mass. Rob says that in Russia they define m*g as the force due to gravity, and weight as the normal force, which is what the "weight on the scale" actually is every time. This clarifies the "weightlessness" in space: anything you do to weigh yourself will give the normal force, and avoids having to distinguish between "actual weight" and "apparent weight", but is uncomfortable for people who define weight differently.

Keri Salvador (Olney Charter HS)

This was Keri's first time sharing something! She teaches students who've never had physics before, and they begin by reviewing conversions and dimensional analysis.

Keeping examples relevant to their lives is always key, so she tries to put conversions/dimensional analysis into relevant terms. Instead of asking how many centimeters you can put across a basketball, she asks them to picture (and calculate) how many matchsticks go across a basketball. She uses the scale applet at htwins.net/scale2 to get pictures of objects at different scales; it also has music in the background. There's a scroll bar at the bottom that you can use to scroll to different scales, and when you click on the object, it tells you the size. Objects range in size from the Planck length to the known universe. It's a good independent assigment to have students explore, and makes a good change from the Powers of Ten video. Ask students, "How many e coli can you fit on a strand of hair?", or "How many oak trees can you fit in the Statue of Liberty", using familiar objects in unfamiliar ways to have students practice dimensional analysis, and help put size into perspective.

Later it was pointed out that the size of the Minecraft world is also listed on the applet, somewhere out by the planets.

Bill Berner (Demonstration Lab at the University of Pennsylvania)

Bill began by updating us on news and events at the University of Pennslvania. The Lab for Research on the Structure of matter hosts NSF-sponsored Lectures for Science Teachers with free pizza about once a month. On October 17th before the lecture they're letting the hoi polloi into the new nanotechnology building. The lecture is at 6 pm on Walnut a smudge east of 33rd St, and the nanotech facility is a big glass building. Because nanotech needs clean rooms, and Penn is hoping for private sector funding, the glass building is arranged so visitors can see the research without interfering with the controlled environment inside the clean room. The new nanotech building is orange and architecturally fascinating, with a huge cantilevered thing coming out of one end, lots of conversation nooks. It's fun to imagine them filming a Bond movie there.

Bill also updated them about the Penn traditionally-Holiday Demo Show, which has had difficulties recently because it's hard to get a lecture hall before exams -- everyone is holding review sessions in all the lecture halls. But on the 2 days before Penn starts in he spring he can get an auditorium. So the tentative dates for the demo show are Monday and Tuesday January 13 and 14, which are the last 2 days before the students show up again. The theme will be Electricity and Magnetism!

The Nobel Prize in Chemistry was announced this week, and it was given to Martin Karplus, brother of physicist Robert Karplus who did one of the first really accurate checks of QED, and was highly regarded enough to work at IAS in Princeton. Robert at one point made the mistake of going to his kid's gradeschool class and trying to explain static electricity, where he realized that it was way harder than explaining QED. He got sucked into the problems of teaching, and spent the rest of his career trying to figure out how to teach physics, back in the 1950s. He used a scientist's approach and researched everything. He came across Piaget's research, which suggested 4 stages of learning, with the last two stages being Concrete and Abstract, but Robert Karplus discovered in trying to teach physics that Piaget's idea that we move past concrete in grade school was totally wrong. In abstract theoretical fields, the transition from concrete to abstract happens way later, hopefully sometime in college. This emphasizes how we really do need to lead with concepts, because people need something to hang onto before you start throwing out formulas and equations. Robert Karplus died of a heart attack at age 63 in 1990. Martin Karplus is his 83-year-old brother, and the Nobel Committee recognized his work in modeling organic molecules, which is the basis for quantum design in drug molecules.

So Bill's demo focuses on the concepts, and is an affordable demo anyone could buy and build. The main ingredient in his apparatus is pegboard, which is cheap, readily available, and easy to cut into a variety of shapes.

If you can find an overhead projector, you're probably familiar with using an overhead projector to demonstrate the inverse square law. You point the projector at the board and look at the image. First, hold it close to the board, about 30 cm away, and use chalk to outline the square created by the light. Then go to 60 cm away, and again draw the square: if you align the projector right, it's easy to see that the same light is now lighting four squares!

Pegboard can be used to do a very similar demonstration illustrating Gauss's Law. The holes in the pegboard create rays of light, which show up as dots projected on the board, and which you can visualize as flux lines flowing through an area. Hold the pegboard close to the board and the flux lines are close together; back it up, and you've spread them out, with the same number of flux lines now covering four times the area.

What else can you do with pegboard? Illustrate the cosine effect of radiation. Stick long bolts with nuts through pegboard, so they are directed perpendicular to the plane. Take a hollow square of wire, and you can examine how many "flux lines" pass through the square in different orientations. When the square is aligned parallel to the plane, lots of flux lines pass through; if you turn the shape on an angle, not nearly as many lines pass through the area. This helps illustrate the real reason seasons occur -- because of earth's tilt, not because of distance. There's a Lillian McDermott tutorial where students actually count the number of flux lines passing through area and graph it, using this apparatus.

Finally, Bill used pegboard to show a modified version of a classic center of mass demo. To find the center of mass of an object, all you have to do is hang it from one point on the object, hang a plumb line from that point, and chalk down along the plumb line. Then pick another point, rehang the plumb line, and chalk down that line. The intersection of the lines is the center of mass. This works well with pegboard, because you can cut it into all kinds of strange shapes with a jigsaw, and if the center of mass falls on a hole, you can stick an axel through that hole and the pegboard will rotate very easily about that balance point. If it doesn't fall on a hole, you could easily drill one.

Where is the center of gravity of a pole vaulter? A good high jumper/pole vaulter never gets their center of gravity above the bar; instead they arch their body and put it above the bar one piece at a time. Bill put up on the projector a picture of a pole vaulter demonstrating this technique. With pegboard we can actually check that this is true. He cut out a pole vaulter shape of peg board so it actually matched exactly, by putting the peg board in front of the projector screen and tracing the shape. He showed us that it exactly matched by holding it up against the screen. Now it's easy to find the center of mass of the pole vaulter: hang it from one peg, trace line down below the support point, then pick another support point, and trace down. The common intersection point (center of mass) will always be below the support point, in the empty space where the pole is. If you put paper behind the cut-out pole vaulter shape, you can mark off the support points exactly and actually show where that is.

Marc's AP Students:
One of our host's AP students shared his favorite science website: Randall Munroe's XKCD "What If". (http://what-if.xkcd.com) Readers send in questions to physicist-turned-cartoonist Munroe, and he answers them with the best facts and methods science has available: there are 63 "What If" posts now. One post involves a giant diamond sphere hitting the earth; in another he addresses what it would be like if an entire rainstorm were squeezed into one drop, or what would happen if you lifted a mountain into the air. Marc's students in ROTC especially enjoyed the post about what it would be like if you tried to use machine guns to make a jet pack: you can in fact use a machine gun to produce enough thrust to push a person into the air, and with a sufficiently powerful gun strapped to your back, you could use it to jump mountains!