Spark, Spin, and Freeze - Demonstration Outline

SSF is the SPS Outreach Club. It's mission is to inspire people to become interested in the way the world works, and to drive students to pursue careers in STEM. This document outlines how to perform the main SSF show.

This demonstration is accessible to a broad audience, and the parents are often as or more interested than the students. I try to explain all the science in easy to understand terms throughout the outline as a suggested "script" for the show. Don't feel like you need to follow it word for word

These demonstrations have been performed many times, including annual shows at Morningside Elementary School for their Family Science Night and at Kittredge Magnet School for a similar event. It has also been used to teach K-12 teachers, at physics field day, and for various other events and summer schools for elementary through high school aged students. Many of these events need to keep happening every year, and new annual events should be planned. Word of mouth is insane, and we have gotten requests by several others schools and individuals to bring the show to them.

This show consists of three demos, and can be done in either series or parallel. Sometimes we have a single, small captive audience, but other times we have like 60 people at a time in a huge room, so we make three stations and rotate them through each demo. We have signs for each station, about 2.5 foot by 5 foot in size. The files for them are in this folder, if they need to be reprinted (for free in the IT office in Howey). These are very useful if you are rotating the audience. Each of the three demos can easily be done in 10-15 minutes, depending on how much depth you go into, for a run time of 30-45 minutes. They could also probably be extended.

When done in series, end with freeze since it's messy. Starting with spark makes spin seem less interesting (to me, damn tesla coil), so Spin, Spark, then Freeze is the best order. It just doesn't roll off the tongue as well as a name.

I like it better if the audience is on their feet for the demonstrations, because they can see better and because they feel more like they are participating if they are up, but that is not always possible.

Without further ado, I give you Spark, Spin, and Freeze! Go teach some kids some SCIENCE!!!

-Gilly Gumption
Spring 2015

Spin

You need:

- The two rods, one red, one blue, that have different moments of inertia
- The bicycle wheel attached to a rope
- The bicycle wheel not attached to the rope
- The stool that spins and the two orange ring weights
- If you can, use the huge yellow “schwarzschild” model, with the blue spheres.

I like to start out with a comparison to linear momentum. When you push something, it keeps going until it is stopped by something like friction. The same thing happens for rotation. When you spin something, it keeps spinning, *in the same orientation*, unless something changes it.

Start out with the bike wheel on the rope. Let it dangle. Try to make it stand up, and show that it falls. Now, spin it up while the wheel is vertical, and show that it stays spinning upright when hung. It wants to keep spinning in a certain way, and resists change. And since it falls a little under gravity, you get precession as the angular momentum is transferred to another axis of rotation. Basically, if the wheel tilted down and it didn’t precess, that would change the total angular momentum of the system. Since it also rotates, the angular momentum is the same before and after the tilt. How cool!

Now make someone sit on the spinny stool, and spin up the bike wheel that isn’t on a rope. Hand it to them, one hand on each handle, and then have them rotate it around the axis coming out of their chest. Left hand down, right hand up, etc. They and the stool will spin. This is the same effect as in the hanging wheel! Momentum is conserved by transferring it to a different axis. Let a few people play with “steering” themselves.

Next get the red and blue rods. They are the same weight, but one of them has the weight at the center, and the other one has it at the ends. Something about the rod (the moment of inertia) changes when you move the weight with respect to the axis of rotation. Let a bunch of people try to spin the rods.

Have another person sit on the stool. Have them extend their arms, and spin them.. Step back, and then tell them to bring in their arms. Not much will change. Now give them the two orange weights and tell them to hold their arms out again. Repeat the spinning, and this time when they pull in they will probably fall off the chair! This is fine, and always gets a laugh. Explain that when they bring their arms in, *it's like they are switching from the blue rod to the red rod.* A little bit of energy made the red rod move quickly, while it took a lot to move the blue rod. You’re basically putting a lot of momentum into the blue one, and then turning it into the red one, so it speeds way up. You can mention that this is how ice skaters spin.

Conservation of angular momentum implies that the same amount of momentum causes the chair to rotate at different rates, depending on how far away the weight is. This is a perfect segway into kepler's second law. You can talk about comets, or binary black hole collisions. The main idea is that things move faster when they are close and slower when they are far away. Next you bring people over to the yellow model, and throw in different combinations of balls and watch them orbit. Show how the balls move more quickly when they are nearer the center.

Spark

This one is a lot of fun. This is what you will need:

- Tesla Coil
    - Things to poke it with:
        - Long pvc pipe with wire in it, clipped on to the ground wire attached to the coil
- Van De Graff Generator
    - Things to poke it with:
        - Hemisphere with paper strips taped to it, to place on top
        - ~8inch diameter metal ball on stand, connected to a wire that is run to ground
        - ~2 foot flourescent bulb with clear window
        - rod with metal sphere on one end and wooden handle
- Electrostatic Rods
    - 2 Orange Plastic Rods
    - Felt to rub them with
    - 1 Clear Glass Rod
    - Wool to rub it with
    - Stand to hang one orange rod horizontally from its center

Charged Rods

Start out by explaining that everything is made up of charged particles. Usually there is the same amount of both, so things are electrically neutral. Bring the orange rod close to the hanging rod. Nothing happens at all! Now rub the ends of both rods with felt. This time they repel! Let it really get spinning so everyone can see. This happens because we moved charged particles from the felt to the rod. Since charged particles of the same kind hate being near each other, they push against each other. They would prefer to be balanced and equally distributed. Now rub the glass rod with the wool, and show that the hanging rod is attracted to it. This is because the charges are opposite and they want to cancel each other out. They pull each other closer because thing naturally want to be neutral. If you can't find a glass rod, you can also show attraction by just charging one rod. Then it will induce a charge separation and draw the rod towards it.

"So this is pretty cool, but I can only do so much with my hands. Back in the early 1900s, a guy named Van de Graff invented this machine to do it for him. It's basically the same thing, you have a belt running up and down that rubs past a little brush in the top of this ball here. It is literally carrying charges from the ground to the ball on the top (or vice versa). We can build up much more charge with this!"

Van De Graff

(Note: Have a wire running from the ground port. This wire should end in a clip so that you can attach different types of pokers to the end to vary the spark you get. I recommend the ball-rod with the wooden handle. Because it is a sphere, charge can build, and you get big sparks. Pointy things spark before very much charge can build, and don't make good sparks.)

Place the hemisphere with the paper strips on top and turn it on. The strips repel, because they are all the same charge, and they want to get away from each other. Its the same as before! Discharge the ball with the poker and show how the strips fall when they are discharged. Take off the paper strips. Now poke the sphere with the discharge rod to make sparks. Also touch it with the fluorescent bulb, which will light up. If you dont want to get shocked, clip the discharge wire to the other end of the bulb. This will make it brighter too. This demonstrates that it is actually electricity that is driving this demo. Connecting the wire to the other large sphere metal sphere to use as a poker will let you get HUGE sparks (in the winter; Humidity kills sparks).

Tesla Coil

Now you move on to the tesla coil. **Always make sure no one in the audience has a pacemaker before you activate the tesla coil. They will die.** Make sure everyone stands at least 10-15 feet away from the coil, and orient it so that the spark-gap (the super bright thing on the front) is not pointed at the audience, cause it will burn their eyes out if they stare at it. You should also not stare at it. Also, do not believe anyone (Dr. Greco…) who tells you it is safe to touch the tesla coil's lightning. Seriously, don't be stupid. It touched me, and it was <u>not fun</u>. Also a teacher (not at tech) was recently sued by the parents of some students who he literally tattooed with scars from a tesla coil. **So don't touch the lightning.**

Now that we have safety out of the way, on to the science! Explain that, whereas the van de graff continuously builds DC charge on the top, the tesla coil throws it up and down really fast (someone should calculate the frequency based on the components, or look it up based on model number). [Note, skip over this part for younger audiences: It goes so fast because at the end of each of the 60hz cycles from the wall, the large capacitor is full, and the potential causes a spark across the gap. While the spark is present, it acts like a wire, and the circuit oscillates much much faster than 60 hz.][After this should be fine] It "rings" like a bell. It is amplified because there are so many more coils on the red tube than in the copper spiral. Each time the fast circuit oscillates, the electric field at the top gets so strong that it is able to rip the electrons off of the atoms in the air. That is what you are seeing as lightning.

It's bluish-white color is caused by the spectral lines of nitrogen in the air. Each element has its own set of colors associated with it. You can probably smell ozone, which is created inside the sparks. This is because it is so hot that it allows chemistry to happen that normally can't happen. Bringing the fluorescent bulb anywhere near the coil (at least 5 feet away from the sparks!!) causes it to light up. Use the pvc poker with a long extension wire to poke the coil and make like 2 foot sparks. That usually ends the demonstration. Turn it on twice, then once again at the end of Freeze. **Never let the coil run for longer than 30 seconds.** Feel free to add whatever else works for longer performances. This one can be done in 10-15 minutes.

Freeze

This is the only demo that incurs a cost of materials. Usually it's about $30 a demo, + N2 if you hate to get it (see below on acquisition). **Never feed people frozen things with a high water content. Water has a high heat capacity, and it will freeze people's mouths badly. These are things like: strawberries, grapes, bananas, etc.** This is because when two things touch, they try to go to the same temperature. It takes a lot of energy to get that strawberry up to the same temperature as your cheek, and it just steals it from your mouth. It's bad.

You need:

- A dewar or three of N2, depending on how many people you will have attending (see below about acquiring)
- Large bowl to melt ice cream in
- Ladle
- Hammer
- Sufficient paper plates/pixie cups for each audience member (need at least 1 plate)
- Stuff to dip
    - Miniature Marshmallows
    - Ice cream - Chocolate, Vanilla, and Fruit are good choices. Not sorbet.
    - Balloons
    - Bananas
- Large Metal Bowl to put the N2 in
- Styrofoam Cooler to use with the balloon
- Something to get the stuff you dipped in back out. There is a big spatula-like thing with holes in it that works well for the ice cream.
- Superconducting Ceramic Levitation demo.

Melt the ice cream in a microwave before the show. Put it in a big bowl with a ladle.

Solids

Solids are made out of tiny atoms that are holding on to each other desperately. If you super-freeze them, they no longer have the energy to hold on to each other. Freeze a piece of a banana completely, fold it in a paper towel, then smash it with the hammer. Its brittle because of the weak bonds. DON'T LET ANYONE EAT A PIECE. Explain why they can't (see above).

Marshmallows

Marshmallows behave similarly. Dump a bunch of mini marshmallows into the N2, and mix them around. They immediately sound like glass, and people gasp. Scoop some of them out onto a paper plate and blow on it. Nitrogen gas billows off. Then eat one and crunch it loudly; it's safe. Feed them to people. Older audiences can simply pass around one plate, but younger ones (elementary/middle) need their own plates/pixie cups with like 2 on them or they will bum rush your table.

Balloon
Gasses are made up of atoms flying around in all directions really quickly, hitting the sides of the balloon. Blow up some a balloon and put it in the cooler. Then pour liquid N2 over the balloon, slowly, for like 30 seconds.The balloon will shrink as the gas cools. The atoms that make up the gas are slowing down and they aren't hitting the sides as hard, decreasing the pressure and causing the gas to contract. Pull it out of the cooler and people will gasp at the scrunched, angular shape. Wait until it starts to blow up again, and then blow on it. It will rapidly reinflate as it heats.

Superconductor Levitation
There is a box with some ceramic superconductors in the demo room. Take the copper cylinder and place it upright in one of the styrofoam cups. Put one of the ceramic disks on top. Then pour N2 on it until it just covers the ceramic. Now you wait like 4 minutes. Eventually, it will go crazy and start boiling. This is the latent heat coming out of the ceramic as it experiences a phase change. When it calms down, you have a superconductor. The levitation works by causing the ceramic to act like a magnetic mirror. When you place a magnet on top, it sees it's reflection balancing it perfectly and holding it in place. Use the tweezers to balance one of the small cube magnets in the air above the ceramic. Try to spin it along the obedient axis; it should spin for a while. If they fall off (they will) just use the metal needle to get them out of the cup.

Dippin Dots
Liquids are like solids, but they have too much energy to stay still. Freezing them robs them of the energy they need to move freely, and they solidify. You will need to melt the ice cream in a microwave before the show, and then pour it into the bowl. Use a ladle to slowly pour some into the N2. It is more efficient to just pour a bunch and then smash the results into dippin dots than to try to pour it slowly enough to make dots. This also demonstrates that dippin dots are brittle, so the demonstration about what happens to solids in N2 still applies here. Again, depending on the audience, either pass it around on a single plate, or give them each some on a plate/cup.

End the show with a final burst from the Tesla Coil. They love that. Hope it goes well for you!
~~~
I stole this from the internet:
**1) Temperature effects on the state of different materials:**
Pour some liquid nitrogen into the bowl before making ice cream.
Liquid nitrogen is liquid air. Take a deep breath. That's mostly nitrogen at room temperature (68F/20C). Liquid nitrogen is air at 77 Kelvin (about -328F/-200C). See the "steam" coming off? It is evaporating and adding to the room air.
To help think about it, picture water. It's steam (gas) at high temperature (>212F/100C), liquid at room temperature (32-212F/0-100C), solid at low temperature(<32F/0C). When a kettle boils, does the steam go up or down? (up) Is this steam going up or down? (down) That's because it is colder (and therefore more dense) than the rest of the air in the room. If doing this demo in winter (or most of the year in Minnesota), drop some snow into the liquid nitrogen. It will actually cause the liquid nitrogen to boil because the liquid nitrogen thinks the snow is HOT (like 212F/200C hot)!
**2) Heat capacity and temperature-effects properties of materials:**
Here in Minnesota, just about everyone has gotten their tongue stuck on metal in the winter as a child (ok, that is a slight exaggeration). Anyway, ask students if they know about this phenomenon.
~~~

The trouble begins with the fact that putting together two things at different temperatures makes them want to reach the same temperature. So the metal tries to heat up to body temperature to match the tongue, but it takes a lot of energy to heat it up. Also, the metal conducts away each bit of heat as it comes, so the whole metal block is trying to heat up at the expense of the tongue. Only a little bit of surface needs to heat up for ceramic, most plastics and wood, because they are insulators - so the tongue heat doesn't conduct away from the surface.

Back to heat capacity. By definition, that is the amount of energy it takes to heat 1 gram of a material by 1C. Water and metal have a high heat capacity. Foam often has a low heat capacity, as does air.

So... if you **drop a strawberry into liquid nitrogen**, would you want to pop it right into your mouth? NO!! It will try to suck the energy out of your tongue and cheeks and roof and anywhere else it can to get 200+ degrees out of you!

What about a marshmallow? SURE!! Go ahead and try it. (Drop mini marshmallows into liquid for a minute, then onto the table first so that all liquid nitrogen is off of them.) Your mouth has plenty of energy enough to heat the marshmallow up 200+ degrees! As an aside, did the properties of the marshmallow change when it was 437F/225C cooler than room temperature? (They crunch like the dried marshmallows in cereal, but get soft again as they warm up). This is fun. I usually do a large marshmallow first. I'll pop it into my mouth and crunch it, then exhale so the cold air mists in front of me. I've given preschoolers mini marshmallows, so I'm sure they are safe for older kids too!

It is also fun to **lower a blown-up balloon into liquid nitrogen**. It shrinks and becomes less flexible. Then, it gets bigger as it warms back up. Also, bounce a racquet ball a bit, then drop it into the liquid nitrogen. When it stops boiling, throw the ball against the wall. It appears to explode as it shatters. Remember the Space Shuttle explosion in 1986? (Probably before middle school kids' time.) It was too cold that day and an o-ring (made of rubber) was below its glass transition temperature so that it wasn't flexible anymore and couldn't perform its job of sealing.