DEMONSTRATIONS FOR CHILDREN OF ALL AGES - THE CORK CANNON

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Demonstrations are one of the most useful techniques for teaching science to anyone, regardless of age. Demonstrations attract attention and normally make the observer want to learn more about what is happening. This paper reports on *The Cork Cannon*, one of the favorite demonstrations done in the demonstration road show, *Phun Physics*, that travels to schools within about 60 miles of Charlottesville. The Department of Physics and the Center for Science, Mathematics, and Engineering Education sponsor this demonstration show, which was seen by about 8000 persons during the last school year. Although quite simple, the Cork Cannon demonstration is rich in pedagogy and can be used to illuminate several ideas, including temperature, pressure, phase change, heat conduction, water vapor, humidity, projectile motion, air resistance, atmosphere, and kinetic theory.

Performing demonstrations with liquid nitrogen is one of the most exciting activities for children of all ages, from 6 to 60. College and university instructors use it in introductory physics and chemistry courses to demonstrate a multitude of concepts. Of course, it also helps that using liquid nitrogen is fun and attracts the students' attention. I use the *cork cannon* at the beginning of most demonstrations that use liquid nitrogen, whether it is in an introductory college physics class, an inservice class for K-12 teachers, or a demonstration show for children. The demonstration is lively, gets attention, and has lots of different principles that can be discussed, depending on the level of the audience.

In essence the cork cannon consists of a metal pipe, closed at one end, into which liquid nitrogen is poured and a cork is inserted into the open end (Figure 1). As the liquid nitrogen boils, pressure builds up until the cork pops off. I first saw such a device demonstrated by Gerald Royce of Purdue University at an American Association of Physics Teachers meeting/workshop a few years ago. The first one I built is shown in the photo.

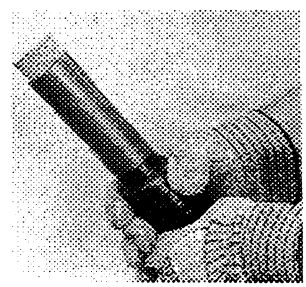

Figure 1. The Cork Cannon

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Safety is the key in both constructing and using the cork cannon. Liquid nitrogen can seriously burn, and any projectile, the cork in this case, can cause damage. I started off by deciding that I wanted to use large corks for two reasons: 1) a student would be more likely to catch or deflect a large cork than a small one, and 2) a larger cork would slow down more than a smaller one due to air resistance. Corks are light objects and can easily be caught in a parabolic flight. Also, the corks do not become very cold in the process.

CONSTRUCTION

I started out by going to the physics stockroom to see what size corks we had. I liked the #20 and #22 corks and decided on #20 when I looked up the price of the larger corks. Large corks are very expensive. I eventually had to purchase additional corks and paid $94 to buy a hundred #20 corks from Fisher Scientific. As a result we always try to reclaim the corks after a demonstration and use them over and over. Thus far, corks are not a collectible item for students, and we easily retrieve them. Next I found a suitable brass pipe that the cork would fit. The inside and outside diameters of the brass pipe are 3.84 cm and 4.66 cm, respectively. Its length is 27 cm. We inserted a copper plug into one end of the pipe and welded it to seal that end. Over half of the brass pipe is covered with pipe insulation that was obtained at a building supply company. This was then wrapped with black plastic electrical tape. We always wear gloves when handling the cork cannon for demos and have never felt uncomfortably cold. The demo is short, and the pipe insulation works very well.

CANNON USE AND SAFETY

I can attest by personal use that it is absolutely essential to become familiar with the use of the cork cannon before demonstrating it in a class with students. One holds the cannon (brass pipe) in one hand and, with the other, pours liquid nitrogen from a small (1 L) dewar into the pipe. The liquid boils away quite rapidly at first, and the pipe does not want to be completely filled. Almost invariably it will be difficult to place a cork into the pipe during the first few seconds, because of the rapid boil off of nitrogen. The placement of the cork into the pipe takes practice. If the cork is fit too loosely into the pipe, it simply falls out to the laughter of the students. If one uses a rubber mallet to place the cork securely into the pipe, normally one of two things happens. Corks are not perfect solids, and sometimes the nitrogen gas can find a way to escape around the fringes, because of cavities in the cork. One is then faced with the problem of getting the cork out; that generally must wait until all the nitrogen

has boiled away and a sharp instrument like a knife is inserted into the cork to pry it out. The spontaneity of the demonstration is lost. The other thing that can happen is that the cork will suddenly shoot out at tremendous speed - usually at an awkward moment and hitting something you don't want to hit. During my second use of the cork cannon (and the last time I ever used a rubber mallet!), the cork popped out, went up at about a 70^0 angle, hit and busted a fluorescent light bulb in the ceiling. Fortunately no one was hurt, and the fluorescent bulb fixture should have been covered, but it was not.

I tell you this unfortunate story so that you will be careful to pay attention to safety concerns and to practice their use. Gloves and safety glasses must always be worn when using the cork cannon. Never point the cannon at the audience. Some demonstrators never shoot the corks towards an audience, but I like shooting them well over the heads of the students who love to catch the corks. The students, of course, like it when we shoot the corks in a high arc towards their teacher. One has to be careful. This demonstration is best done in a large room or auditorium. In a small room, it is possible for the cork to bounce off the ceiling or a wall. The best advice is to not do the demonstration in a small classroom and always to point the cannon in a safe direction.

By practicing a few times with the cork cannon one learns just how hard to insert the corks into the cannon. We normally place the cork into the pipe with our fingers and then bang the cork with our palm while wearing gloves. I am now fairly consistent with the palm bang and can shoot the corks a distance of 6-10 m with ease and regularity. We find that, after the first couple of corks are launched, we have to shake the cannon a little to help the nitrogen boil off. One needs to be careful during this shaking in order not to move the cannon inadvertently in an unsafe direction, because the corks shoot out unpredictably. We normally shoot 5 or so corks out with one filling of liquid nitrogen, and we don't repeat the demonstration. The point is made with one filling of liquid nitrogen.

DISCUSSIONS

There are many science discussions that can go along with the cork cannon depending on the audience. For college classes we talk about phase change from liquid to gas. We always ask if anyone knows the temperature of liquid nitrogen. Then we go into a discussion of temperature scales: fahrenheit, celsius, and kelvin. With small children, we ask what is the

coldest thing they know. They invariably say ice or snow, and usually someone knows that their temperature is 32^0F, and we mention the temperature in celsius. They are surprised to learn that liquid nitrogen boils at an approximate temperature of -300^0F. They cannot imagine such a cold temperature and this naturally leads to a discussion of temperature ranges. We talk about pressure and how atoms and molecules bouncing around inside the container cause pressure. Atoms move slowly when colder, but speed up considerably when warmer.

We may start an interesting discussion by asking is what is the white cloud that we see when we are pouring the liquid nitrogen into the pipe. Sometimes we have to remind them by safely pouring out some liquid nitrogen and letting them observe the white cloud again. We find that we almost always get the answer that the white cloud is nitrogen gas. Then we go through the discussion of what is in the Earth's atmosphere. They eventually relearn that nitrogen is a colorless gas and can't be the white cloud. Then we proceed to discuss water vapor in air and how it is condensed into small water droplets by the extreme cold of liquid nitrogen. We remind them that this is similar to fog seen on cold mornings or to the white cloud observed when they breathe out when it is very cold. This is a favorite lesson.

I have built a second cork cannon that is about 6 cm longer than the first, but I have found that it did not operate appreciably better. I had hoped that we could shoot more corks from one filling of liquid nitrogen, but there was no consistent difference. ■