The Annual Pumpkin Drop

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Aren't you sick of the image of physicists as dull nerds? Wouldn't you like to portray physics as the fun and exciting adventure it is? We may have stumbled upon just the ticket! For the last ten years, our campus chapter of the Society of Physics Students has presented the Annual Pumpkin Drop. Our experience shows that it generates the kind of positive image and excitement that physicists deserve. Local television stations, newspapers, community members, university students, K-12 teachers and students all give rave reviews to our annual autumn celebration.

Of course, throwing fruits and vegetables from tall campus buildings is generally frowned upon by university authority figures. Therefore, we had to come up with a suitable rationale. The idea of reenacting famous physics experiments is certainly not new, but it provides excellent grounds for such madness. Legend[1] has it that Galileo Galilei demonstrated his law of falling bodies by climbing to the top of the Tower of Pisa so that he could drop a large ball and a small ball at the same time. In Galileo's *Two New Sciences*, Simplicio argues Aristotle's position that heavier objects should fall faster. Salviati answers: "I greatly doubt that Aristotle ever tested by experiment whether it be true that two stones, one weighing ten times as much as the other, if allowed to fall, at the same instant, from a height of, say, 100 cubits, would so differ in speed that when the heavier had reached the ground, the other would not have fallen more than 10 cubits. But I who have made the test can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as much as a span ahead of a musket ball weighing only half a pound, provided both are dropped from the heights of 200 cubits."[2] We claim to be reenacting this great moment in the history of science using pumpkins.

In our region, pumpkins are available in stores for only the two weeks preceding Halloween. This severe time constraint actually works in our favor for several reasons. The general mood of people on this holiday is just giddy enough to pique their interest in the destruction of vegetative matter. Even better, elementary-school teachers are at their wits' end on Halloween, trying to keep their very distracted students focused on their studies. Halloween is also a day when the local news media are desperately in search of a novel story angle. We have never had a problem getting a large crowd, usually about 1000, or getting on the local evening news. High noon on Halloween turns out to be the perfect time for the Annual Pumpkin Drop.

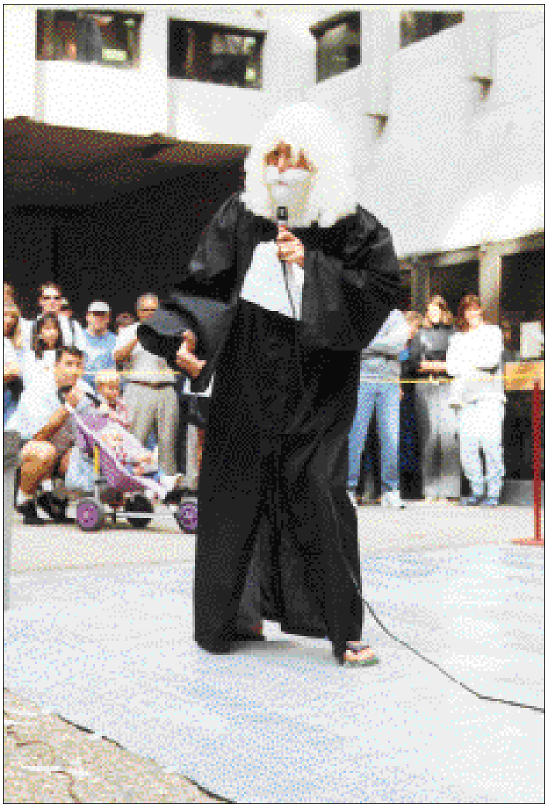


Fig. 1. Galileo (played by Michael Janus) explains his law of falling bodies.

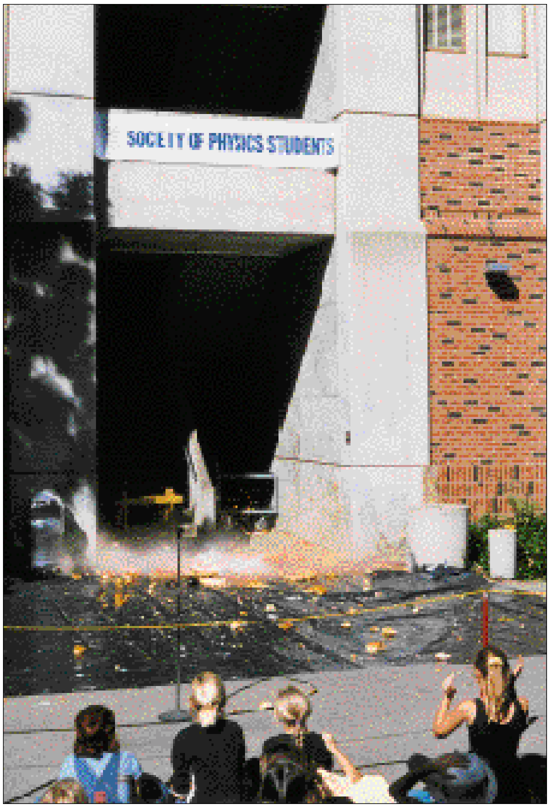
Some Showmanship

A student dressed up in medieval garb takes the role of Galileo (see Fig. 1). and acts as the master of ceremonies. Galileo generally begins by describing his law of falling bodies, which states that all objects regardless of their mass fall toward Earth at the same rate — at which point, a stuffed mannequin (a "falling body") tumbles from the roof. This gives Galileo a chance to criticize and at the same time introduce his "rooftop" assistants. We traditionally do three drops (see Fig. 2). The first drop features two pumpkins of the same size, but one is filled with water to "weight it down." The second drop compares two pumpkins of the same size, but one is filled with light fluffy whipped cream to buoy it up. The third drop is the legendary Galileo experiment

Fig. 2. Left, two pumpkins are released at (nearly) the same time.

Fig. 3. Right, elementary-school students are thrilled by the pumpkins striking the ground at the same time.

(Photos by Barry Knowles)



with a large pumpkin and a small pumpkin. The crowd particularly enjoys counting down from ten. This program takes about ten minutes.

To illustrate that Galileo's law works for more than just pumpkins, we have tried cantaloupes, honeydews, even giant zucchinis, and of course, watermelons, which are a favorite of the bloodthirsty crowd. We have even used a rubber chicken to answer the proverbial question "Which comes first, the chicken or the eggplant?".

For a couple of years we had a particularly ambitious group of students who went on to illustrate the applicability of Galileo's law by having vegetables hit the ground in time with the cannon blasts of the *1812* Overture. They did this by using two CD players, one at the top where the pumpkins are released and one at the bottom that the crowd could hear. Both CD's were set to the same spot on the recording. Then Galileo explained that since all objects take the same time to fall, his assistant at the top will start his recording when he releases a "timing pumpkin." Another assistant started the recording for the crowd when the timing pumpkin hit the ground. The assistant at the roof needed only listen for the cannon blasts on his CD to know when to release a pumpkin. The pumpkin struck the ground when the crowd heard the cannon blast. While I was never really convinced that the pumpkins, cantaloupes, watermelons, and pineapples struck the ground in time with the cannon blasts, it didn't dampen the enthusiasm of the crowd the slightest bit!

Some Preparations

Begin preparations for your pumpkin drop well in advance. As you might expect, your local administrators will find many reasons why it's a bad idea. It will take time to convince them that they are wrong! Focus on how the project develops an interest in science for students on your campus as well as local grade-school students. Point out that giving your students the opportunity to put on an event like this develops the kinds of organizational skills that their eventual employers will value. Remind skeptics about the positive and free publicity their institution will receive. And don't forget to promise that you will clean up the mess!

Safety, of course, is a primary concern. We drop our pumpkins from about 20 meters up. Going higher than this is unnecessary and problematic due to the physics (see below). We rope off an area six to ten meters away from ground zero on all sides, which provides a good safety zone (see Fig. 3). Pumpkins tend to collapse onto themselves and only a few smaller pieces acquire enough kinetic energy to reach the crowd. Some spectators in the front row do get showered with seeds. Other fruits and vegetables act differently. The internal "meat" of watermelons seems to vaporize while chunks of the rind travel much greater distances than pumpkin parts. Also, the safety of the people on the roof must be assured. We recently switched locations due to these concerns.

About a month before Halloween, we send flyers describing our reenactment of Galileo's experiment to all our local elementary schools. Each flyer is addressed to "Excited Science Teacher"; we've had as many as 15 classes attend.

The local news media are notified about a week in advance with a follow-up call two days before. The TV stations always have their crews show up at the last minute. We don't tell them, but we always plan to start a few minutes late. We are glad to accommodate them because their coverage of the Pumpkin Drop has always been very positive toward science in particular, and the university in general. We also place posters around campus, but after ten years, everyone knows about the Annual Pumpkin Drop.

Some Physics

Judging by the earlier quote, Galileo apparently understood that there are small errors that will keep the two objects from landing at precisely the same instant. The effects of air resistance are described by the drag force given by $F_d = \frac{1}{2} CA\rho v^2$, where C is the drag coefficient (typically around 1),[3] A is the cross sectional area of the pumpkin, ρ is the air density, and v is the speed of the falling pumpkin. Assume a spherical 45-N (l0-lb) pumpkin 30 cm in diameter. From a height of about 20 m, they strike the ground with a velocity of, roughly,

$$v = \sqrt{2gh} = \sqrt{2(10)(20)} = 20 \text{ m/s}$$

Using the average speed of 10 m/s, the average force of air resistance is,

$$F_d = \tfrac{1}{2}(1)[\tfrac{1}{4}\pi(0.3 \text{ m})^2](1.3\frac{\text{kg}}{\text{m}^3})(10 \text{ m/s})^2 = 4.6 \text{ N.}$$

This force is large enough to make a noticeable difference in the acceleration from the assumed value of g. Because pumpkins are hollow, however, two pumpkins of different sizes can have equal accelerations. Applying Newton's second law gives the acceleration of the pumpkin:

$$a = \frac{F_g - F_d}{m} = \frac{mg - \frac{1}{2}CA\rho v^2}{m} = g - \frac{CA\rho v^2}{2m}$$

Note that the acceleration depends on the ratio of the mass to the surface area. Since the pumpkin is hollow, the mass is contained in the outer shell. Therefore, the mass will grow, roughly speaking, as the surface area. So the acceleration of the falling pumpkins may not be exactly g and it won't be exactly constant, but it will be very nearly the same value for both pumpkins, which is all that really matters.

It turns out that a far greater concern is the fact that the pumpkins must be released at the same time with very little error. The distance traveled by a pumpkin falling with an acceleration g for a time t is given by the kinematic equation, $x = \frac{1}{2} gt^2$.

The extra distance covered (dx) in the extra time (dt) is, $dx = gtdt = vdt$, where v is the speed with which the pumpkins strike the ground. This result is not surprising because the extra distance fallen by the pumpkin that is released first is traveled at the final speed v. Therefore, the extra distance should just be the final speed multiplied by the extra time. For the pumpkins to strike the ground within 10 cm of each other traveling at 20 m/s, the pumpkins must be dropped within a time difference of

$$\Delta t = \frac{\Delta x}{v} = \frac{0.10}{20} = 5 \text{ ms.}$$

This is, of course, quite unlikely. To minimize this problem, we usually have one rather muscular student release both pumpkins, one from each hand, taking care simultaneously to drop both hands out from under the pumpkins, as opposed to allowing the pumpkins to roll off the fingers. When this prescription is followed, the pumpkins generally land with timing close enough to convince the crowd. Our crowd is rarely upset when the pumpkins don't land together; they just want to see them splat!

We have had ten years of great fun with our Annual Pumpkin Drop. If you would like to stage such an event at your institution, please feel free to contact us through our website at http://132.241.70.202/sps/activities.html. At this site you will find more pictures of the Annual Pumpkin Drop and a short video of two falling pumpkins.

Acknowledgments

The Annual Pumpkin Drop is sponsored by the California State University Chico Chapter of the Society of Physics Students. Chapter members do a tremendous amount of work to ensure the quality of these programs. In particular, Ben Catching and David Snyder deserve special recognition for conceiving the idea and making the first Annual Pumpkin Drop happen. University employees in the Facilities Management and Services Department and Environmental Management, Health and Safety Department provide indispensable assistance. In particular, Joe Covert, Don Sleeper, Bill McGinnis, Jeff Mott, and Jim Williams are always helpful.

References

1. It is generally believed that Galileo never actually conducted this experiment. This issue is thoroughly discussed in *Aristotle, Galileo, and the Tower of Pisa* by Lane Cooper (Kennikat Press, New York, NY, 1935).
2. Galileo Galilei, *Dialogues Concerning Two New Sciences*, translated by H. Crew and A. De Salvio (Northwestern University Press, Evanston, IL, 1950) p. 60.
3. D. Halliday, R. Resnick, and J. Walker, *Fundamentals of Physics*, 5th ed. (Wiley, New York, 1997), p. 114.