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Schrödinger's Otter – *Educators Edition*

Otterbein University

Department of Physics

Greetings from the Otterbein Physics Department! In this newsletter we describe demonstrations, activities, and teaching methods we have found particularly useful or interesting. We hope you do too! Please send us your comments, and let us know if you have specific topics or teaching issues you'd like to see addressed in future editions.

Nathaniel Tagg, Chair

Demo Corner

Inertia

Here is a collection of our favorite inertia demos.

1. Hanging weights – top/bottom string

   This one is classic. Using fairly weak string or thread, hang a mass from a horizontal bar. Hang another string from the bottom of the mass. Now ask the class which string will break first when you pull down using the bottom string. In fact you can make either string break first, depending on whether you pull slowly and steadily or quickly. If slow, then the tension in the top string is larger than in the bottom string – it supports the weight of the mass as well – and it breaks first. If you pull down quickly, the bottom string breaks first since the inertia of the mass prevents it from moving (much) before the bottom string has already broken; the top string is mostly unaffected. It is useful to have extra strings ready so that the demo can be repeated several times.

2. Apple Climbing Knife

   A nice surprising visual. Take a long carving knife and stick the point into an apple. Then holding the knife by the handle and with the point down, hit the handle repeatedly with your hand or (better!) a mallet or hammer. The apple will rise on the blade of the knife. The explanation is that when you hit the knife, it moves down but the apple's inertia keeps it from moving much in this brief time. So you are driving the knife through the apple.

3. Coin Snatch

   Can be used at parties or to win money in bets, but be sure to practice! Ask an assistant to hold a coin In their outstretched palm. Snatch the coin reliably using its own inertia: extend your fingers and keep them fairly rigid, then drive them down onto the hand of your assistant. The idea is to have your fingers quickly push their hand down. The coin will be briefly left behind due to its inertia, and if you just close your fingers after knocking the hand down then you will catch it.

4. Dart Guns

   Get two identical spring loaded dart guns – cheap kids toys work fine. Add a mass to one of the darts, for example with duct tape or similar. Now, hold the two guns side by side, pointing down. Ask the class which dart will hit the ground first when the triggers are pulled (at the same time). Answer: the light dart – it has less inertia, so the spring accelerates it more at the beginning. Of course, once the darts have left the guns, they fall with approximately the same acceleration (show

(Continued on page 2)

(Continued from page 1)

this by just dropping the darts together from rest), and this is the basis of the most popular wrong answer, that they hit at the same time.

5. Slinky drop

Another classic. Impressive videos of this are available on line, but we find it's more effective to actually do it in person. Let a slinky hang motionless, holding it from the top. (It is not necessary that it be exactly motionless, but the quieter the better.) The question is, what happens when the top of the slinky is released? You can give the class choices and let them vote, after talking it over among themselves. Options for the bottom are (1) it hangs motionless for a while; (2) it starts falling immediately along with the rest of the slinky; and (3) it starts to rise as the slinky contracts (it is a spring after all!). The demonstration shows that (1) is correct.

The explanation in terms of inertia is that the different parts of the slinky all have inertia. Imagine that the slinky is a collection of rings connected to one another. The bottom ring cannot accelerate until the forces on it change; this means it will do nothing until the ring above it starts to move, and so on up the chain to the top. But each ring has some inertia and so it takes a little time to move appreciably. The top ring moves a bit, then the one below it and so on down to the bottom. The result is an appreciable time before the bottom ring moves at all.

Elaborations are possible for more advanced students. Another way of explaining the result is to say that the bottom link cannot move until an influence has had time to propagate from the top to the bottom. Such an influence could be described as a longitudinal wave propagating down the slinky, and this wave has some finite speed. So, some time will elapse before the bottom moves.

Another advanced point would be to note that the center of mass of the slinky should fall as a projectile, since the only external force acting on the slinky is that of gravity. (We neglect air resistance, of course.) So you can have a student estimate the location of the center of mass, and drop a ball from that point at the same time the slinky is released. The center of mass is somewhere toward the bottom of the slinky, since the coils are closer together there. Assuming they are in the right ball park, the ball and slinky will hit the floor at close to the same time – very satisfying.

6. Bottle Blowout

Fill a glass bottle about half full (or a little more) of water. Hold it solidly by the neck over a bucket or trash can, then hit down sharply on the top of the bottle with a rubber mallet. (This can be done with the hand, but it is really not worth it.) When done correctly, the bottom of the bottle will blow out.

This one is rather subtle. What happens is that the bottle is driven down sharply by the blow, but the inertia of the water means it stays behind (briefly). There is thus a vacuum created below the water, and the pressure difference (atmospheric pressure on top, very low pressure on bottom) drives the slug of water down against the bottom of the bottle, blowing it out. Super slow-motion videos are available online that show this clearly.

As with all demos, be sure to practice this before trying it in front of students!

(Continued on page 3)

(Continued from page 2)

Atmospheric Pressure

Here are a couple of demos that can help make the magnitude of atmospheric pressure (about 14.7 lb/in2) strikingly perceptible to students.

The first is an old chestnut. Lay a cheap meter stick on a table so that about 1/3 of its length hangs over the edge. Then spread newspaper flat over the part of the stick that is on the table. It is important that this be as flat as possible, and that there are no air pockets or places where air can sneak in under the paper. Then, hit down sharply with your hand on the hanging end of the stick. When done correctly it will snap off; the atmospheric pressure pushing down on the paper holds the table end of the stick in place. As always, practice. It helps to use a flimsy meter stick (or other stick) since in practice it is impossible to press all the air out from underneath the newspaper.

An even more dramatic and fun demonstration is to shrink wrap the students themselves. For this you will need a shop-vac and a large plastic bag. Large trash bag will work fine, though for bigger students even larger and heavier contractor bags are better. (They also last longer.) Have the student get in the bag. They should sit down on the floor either on their knees or criss cross applesauce. Pull the bag up over their shoulders and gather it around their neck. Leave their head out of the bag! Next, put the vacuum hose of the shop-vac in the bag. It can go down by their neck, and the student should just hold the end of the hose next to their chest. It's a good idea to have them use their hands to make a little cone around the hose opening, to try and keep the bag itself from sucking into the hose when the vacuum is turned on. Gather the bag around the neck and hose – it doesn't have to be tight around the neck, just make sure there are no real gaps or holes. Then turn on the vacuum and suck the air out of the bag. With the air removed from inside the bag, the force of the atmosphere outside of the bag will be delivered to the student. This is quite striking – most students will be essentially unable to move at all!

Note that they will still be able to breathe (they are usually laughing at this point), and the bag does not squeeze the neck at all. Just switch off the vacuum to release them.

The real trick is to make sure the seal around the neck and shoulders is good enough. Again, it does not have to be really tight, since when the vacuum is switched on the bag will collapse around the student's body, and this tends to help seal around the edges. If you are not getting good vacuum, try re-arranging the bag at the opening. As always, practice is your friend.

Convection

For this one you will need two small jars with identical openings (baby food jars work very well), some food coloring, and a laminated card. With enough supplies, students can do this activity themselves.

Fill one jar with cold water and add a bit of food coloring. Fill the other jar with warm water and add a different color. (It's only important that there be a significant temperature difference between the two jars; the specific temperatures don't really matter.) Now take one jar, cover with the laminated card, and turn it over. Place it on top of the other jar so that the mouths are aligned, let things settle down, and then slowly remove the card. What will happen?

(Continued on page 4)

(Continued from page 3)

When the warmer water is on the bottom, it will rise – convection will mix the colors, usually very quickly. But when the warmer water is on top, the colors will stay separated, often for a matter of hours.

It is important that the jar that will be on the bottom be completely full to the brim, so that when the card is removed water from above does not drop down, forcibly mixing the two. The top jar does not need to be absolutely full, though of course it can be.

For a visual demonstration of convection cycles, set an aluminum pie plate just above the table using books or similar around the edges. Put about a half inch of water in the plate, and set a small tea candle under the plate at its center. Light the candle so that the center of the plate is heated by the flame, then use a syringe to place a small drop of food coloring in the water just above where the flame is heating. Put the drop down near the bottom of the water, on the surface of the pan. Then watch as heat from the candle drives the food coloring up and out in the classic convection pattern.

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SCHEDULED EVENTS
Starry Mondays
Astronomy Lecture Series

1st Monday of each month; Science center at 7pm excluding holidays
Everyone is welcome.