Fall 2018 CSAAPT Meeting at Tidewater Community College in Virginia Beach, VA

Make and Take: Everyone will make a Levitating Orb, which illustrates electrostatic repulsion and a device made of lead sinkers and string that will demonstrate the acceleration of gravity. We will also do some simple experiments with an Eddy Current device.

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This document includes basic instructions on how to construct the levitating orb, gravitational acceleration demo (Dropping a String of Marbles) and the Eddy Current Device.

Equipment List:

Levitating Orb: 0.5 meter long piece of ¾ inch PVC pipe (1/2 inch will also work), Christmas tinsel, wool cloth/hair. Science Bob sells "good (thin and narrow)" tinsil a reasonable price. There is an error in the write-up, because it says that the tinsil is positive charged, when it is just polarized.

String of Marbles: 2.25 meter long cotton string, 6 lead fishing weights (Size 4 Removable Split Shot). We found that a good initial distance was 8 cm. Then the distances of the split shot from the bottom would be 8 cm, 32 cm, 72 cm, 128 cm and 200 cm. This makes the string short enough that you can hold it off the ground without standing on a chair. You can also use a great initial distance and use only 5 split shot. It is helpful to drop it onto a piece of metal (pie plate, sheet of aluminum, etc.) (Note: if you have a second floor balcony in your school, a really impressive demo is to have the distance be 1 ft, 4 tt, 9 ft, and 16 ft.

Eddy Current: 1 foot long piece of ¾" copper pipe (L works best, but M is also OK), neodymium magnets. These magnets can be bought at Educational Innovations or many other science supply websites.

Educational Innovations sells a set of 25 neodymium magnets that fit nicely into a ¾ " copper pipe. If you have Type L you will need at least 2 of these magnets. If you use type M pipe then you will need at least 3. If you can afford to get a 2 foot long copper pipe, it is even more impressive. Many other neodymium magnets will work, but you need to make sure that they will easily fit in the pipe.

String and sticky tape experiments

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Dropping a string of marbles

The ear can provide quite an accurate measurement of time in the absence of a clock. We are very sensitive to changes in beat in music, and Galileo is thought to have timed spheres rolling down an inclined plane by singing a song with a very steady rhythm. Even today, darkroom workers use this method of timing where the slightest amount of stray light can fog a film. (For example, "Onward Christian Soldiers" has a beat of about half a second.) An experiment on the acceleration due to gravity, g, can easily be performed using this ability. You require five marbles, a piece of string, and some sticky tape. The string should be as high as the room, but we will suppose this is 8 ft. The marbles are taped to the string at intervals proportional to the squares of the whole numbers, i.e.,

Number	0	1	2	3	4
Square	0	1	4	9	16
Distance	0	6 in.	24 in.	54 in.	96 in.
Difference		6 in.	18 in.	30 in.	42 in.

Now, stand on a chair holding the string as shown in the figure. The bottom marble should not quite touch the floor. Drop the string, and listen to the clicks. They are more audible if you drop the string into a trash can, or onto a metal plate.

You can repeat the experiment with a string having marbles spaced at uniform 2-ft. intervals. Do you hear the time between clicks get shorter as the higher marbles from this last string strike the floor? Qualitatively, the higher marbles have been accelerated for a longer time, and are travelling faster, covering the same distance in a shorter time as they approach the floor than do the marbles starting near the floor.

Quantitatively, we have the familiar formula

$$\text{distance} = \frac{1}{2} g \ (\text{time})^2$$

We spaced the marbles on the nonuniform string so the square roots of successive distances are proportional to whole numbers. The time taken between successive clicks should then be constant, about 0.176 sec. Shift one of the marbles up or down the string to test the sensitivity of your ear to the time between clicks. A change of 20% is easily detectable, and some people can do much better than this.

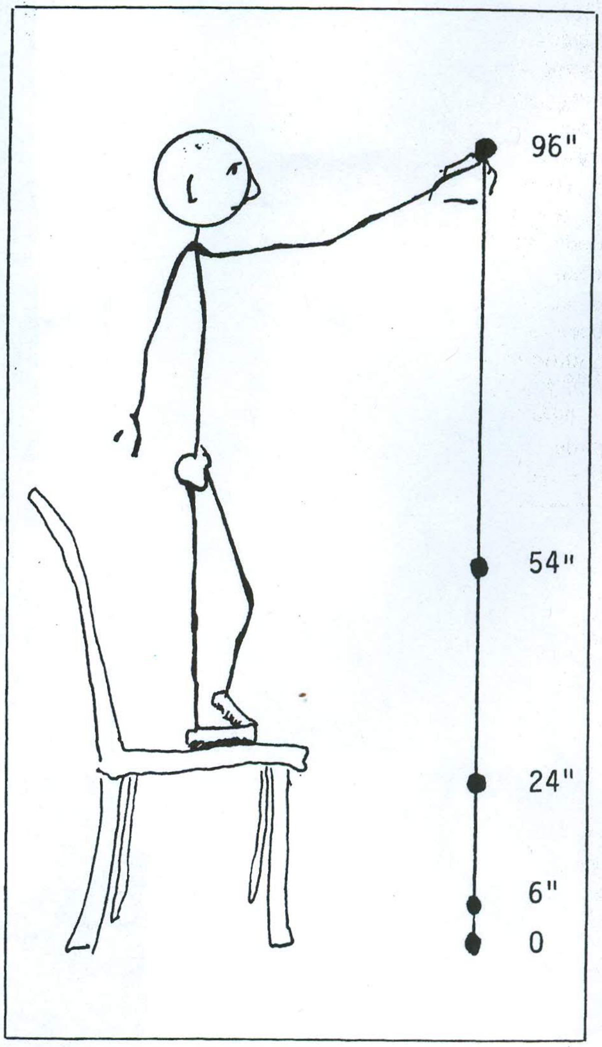
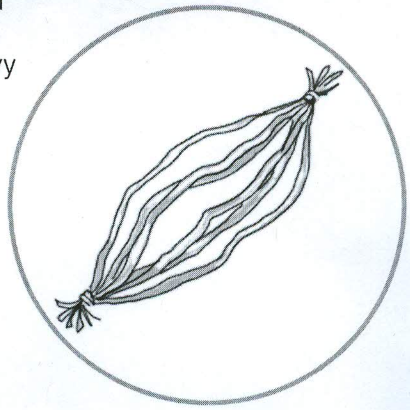


Fig. 1. Dropping the string of marbles

MAKE A LEVITATING ORB!

YOU WILL NEED:

- 1 inch (2.5 cm) wide PVC Pipe about 24 inches (60cm) long. You can also use a regular balloon if you do not have a PVC pipe.
- Mylar tinsel for Christmas trees. There are many types of tinsel - you should look for the thinnest and narrowest possible. The tinsel used n the video is about 1 millimeter wide. If it is much wider than that, the orb may be too hevy to levitate.
- A head of clean, dry hair
- Scissors



WHAT TO DO

1. Arrange 6 strands of mylar together and tie them together in a knot at one end.

2. Tie them together again about 6 inches (15cm) from the first knot.

3. Cut the loose mylar strands off just past each knot.

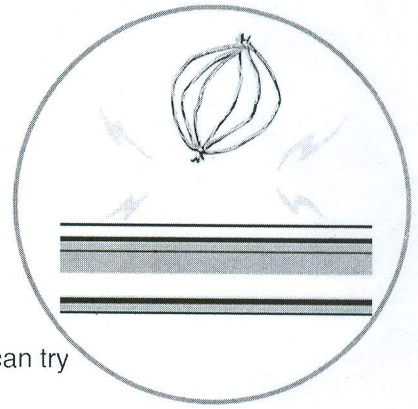
4. Charge the PVC pipe by rubbint it back and forth through your hair for 10 seconds.

5. Hold the mylar orb (by the knot) above the charged pipe and let it drop and touch the pipe.

6. It should repel away and start floating. If the tinsel keeps sticking to the pipe, the tinsel is probably not thin enough and you will need to try another kind, or order some from us. “Recharge” before each levitation.

HOW DOES IT WORK?

It is all about static charges. Similar static charges repel away from each other. When you rub the pipe in your hair you give the pipe a negative static charge. The orb is attracted to the pipe at first because the orb has a positive charge. As soon as the orb touches the pipe, it picks up a negative charge. Since the pipe is negative and the tinsel orb is now negative, they repel away from each other and the orb levitates! The orb will also take on more of a “ball” appearance when charged since all the tinsel strands are repelling away from each other. Did you notice the orb is attracted to other objects around you - including you? That is because most objects (including you) have a positive charge.



MAKE IT AN EXPERIMENT:

The project above is a DEMONSTRATION. To make it a true experiment, you can try to answer these questions:

1. Does the number of mylar strands affect how well the orb levitates?

2. Do different materials (hair, fur, wool) build up better static charges?

3. How long does the static charge last / how can you make it last longer?

4. Do different widths of pipe affect the floating ability of the orb?

Educational Innovations Inc

#ED-100	Thick Copper Tube, 18 cm (7")
#ED-125	Thick Aluminum Tube, 36 cm (15")
#ED-140	Thick Copper Tube, 60 cm (24")

Eddy Current Tubes

1. An eddy current is a current set up in a conductor in response to a changing magnetic field. Lenz's law predicts that the current moves in such a way as to create a magnetic field opposing the change; to do this in a conductor, electrons swirl in a plane perpendicular to the changing magnetic field.

   Because the magnetic fields of the eddy currents oppose the magnetic field of the falling magnet; there is attraction between the two fields. Energy is converted into heat. This principle is used in damping the oscillation of the lever arm of many mechanical balances. At the end of the arm a piece of flat aluminum is positioned to move through the magnetic field of a permanent magnet. The faster the arm oscillates, the greater the eddy currents and the greater the attraction to the permanent magnet. However, when the arm comes to rest, the attraction is negligible.

2. If a single neodymium magnet has the same mass as a single cow magnet, the neodymium magnet will fall at a slower rate because its magnetic field strength is greater.

3. Two neodymium magnets fall at a slower rate than one because the magnetic field strength has increased. The time of fall within the tube increases with the addition of other magnets. There is a point where the effect of the increase in mass becomes greater than the increase in magnetic field strength. Then, the group of magnets falls faster.

4. Thicker tubes increase the falling time due to stronger eddy currents from the greater number of conducting electrons. Suggest an experiment to determine the thickness of the tube by determining the rate of fall of a magnet within the tube.

5. Determine the time for one magnet to fall through the 7 inch copper tube and measure the time for the same magnet to fall through the 15 inch aluminum tube. The falling times should be approximately the same. Relate the length of the tubes to the conductivity of the metals.

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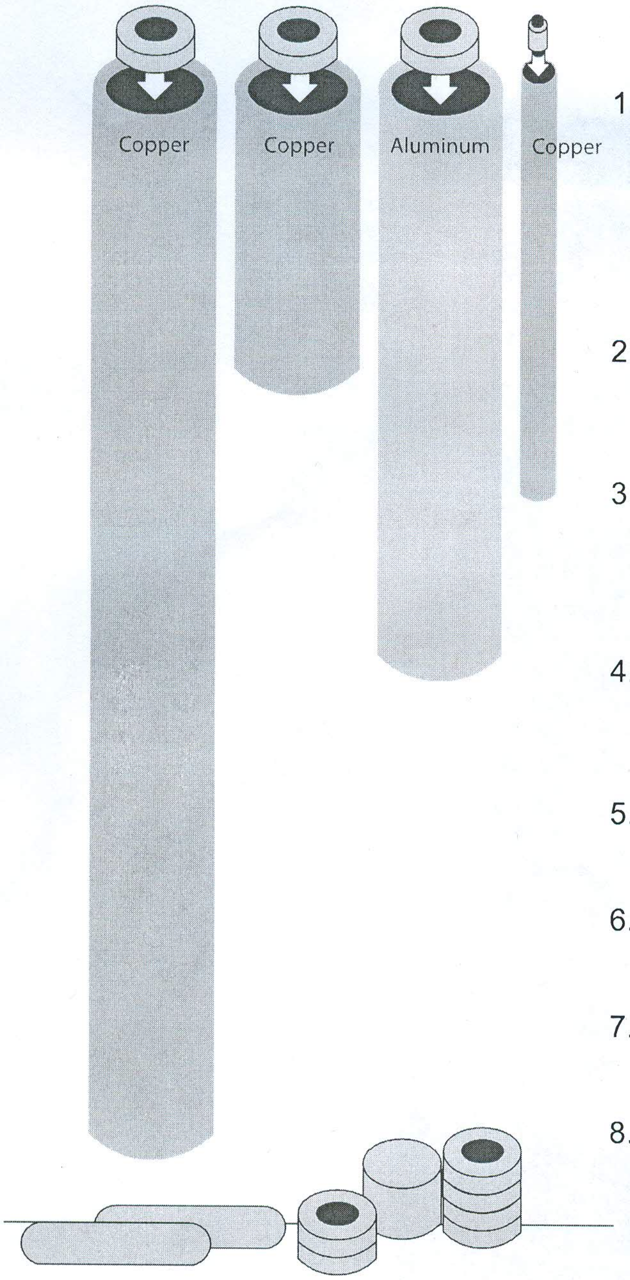
Student Activity: The Eddy Current Tube



Areas for investigation:

1. How will magnets of different magnetic field strengths affect falling time? Try dropping 2 cow magnets that have the same mass but different magnetic field strengths down the same tube one at a time.

2. How does the falling time of neodymium magnets compare to the falling time of cow magnets?

3. Allow multiple neodymium magnets to attract together. How does changing the number of magnets affect the falling time?

4. Do both single and multiple neodymium magnets fall down the tube at a constant velocity?

5. How does changing the thickness of the tube affect falling time?

6. How does changing the length of the tube affect falling time?

7. How does changing the material of the tube affect falling time?

8. How does cooling the tube down with liquid nitrogen affect falling time?