10) DEMONSTRATION: Cross-over depth

Here is a class demonstration you might want to do, showing the concept of cross-over depth. In the text, the context was magma surrounded by mantle. Here we have a balloon stead of magma and water instead of the mantle, but the principle of cross-over is the same. Pressure causes decrease in volume, which causes higher density compared to surrounding material, which eventually reaches a point of no return where the magma/balloon will sink and never be able to rise again. Of course, in this demo you can make the balloon rise again by pulling it up with the hook on the end of your wire.

NOTE: If you don't have the time, energy, or budget to do this demo but would like to see it in action, there is a video posted on the YouTube playlist. There is also a "how to" video showing how to do the steps listed in the directions below.

<u>You will need</u>:

supplies you will need (plus the plastic tube)

- a clear plastic fluorescent tube protector (available at home supply stores that sell fluorescent tubes)
- a tube of caulk (or you could try substituting a soft, waterproof glue such as Quick Grip or Goop)
- a plastic cap that is about the same size as the end of the tube, such as a cap from a milk jug or a glass coffee drink bottle
- a wire coat hanger (a used one from your closet is fine)
- a few water balloons (or other small balloons-- not large balloons)
- a few small binder clips (3/4 inch and 1/2 inch)
- a twistie tie or rubber band
- a 1/4" diameter eye bolt
- a wing nut or regular nut that fit the eye bolt (optional-- I used just binder clips)
- paper clips to adjust weight of bolt
- a pan to catch any water that might leak out of the tube
- a pitcher of water to fill the tube
- possibly a pair of pliers to help you bend the coat hanger

If you want to make a holder, you will also need:

- a piece of corrugated cardboard
- some strong tape, such as duct tape

holder for tube, made from a piece of cardboard

<u>How to assemble the tube</u>:

1) Take the plastic plugs out of both ends of the tube. Use the caulk to stick the cap onto one end of the tube. Make sure the seal is watertight! Let it dry.
2) If you would like to have a holder for the tube so that you don't need a person to hold it during the demo, cut a hole in the piece of cardboard that is the same size as the tube. Tape the cardboard to a chair seat.

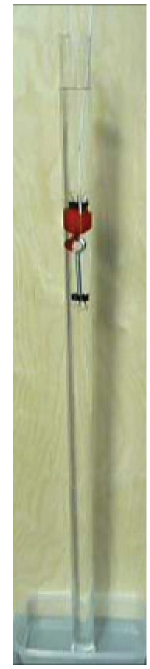
<u>How to assemble the sinking balloon</u>:

1) Blow up the balloon just a small amount, so that it will fit into the tube without touching the sides. You don't want the balloon to get stuck.
2) Attach the balloon to the eye bolt using the twistie tie or a rubber band.
3) Clip the top of the balloon with a small binder clip.
4) You will use the nut and possibly the washers to adjust the weight of the balloon as you try the experiment.

<u>What to do with the coat hanger</u>:

The hanger will be used to make a device that can both push your balloon down until it reaches cross-over depth and also to retrieve your balloon from the bottom of the tube. Retrieving the balloon with the hook allows you to repeat the experiment without having to empty and refill the tube.

1) Straighten out the hanger so you have one long piece of wire.
2) Bend one end to make a small hook. Look at the picture to the right to see relative size of the hook compared to the balloon.
3) Be prepared to make some adjustments to the hook if you have trouble slipping it into the top binder clip. You will not use the hook on the way down. The bottom of the hook will be used to push the balloon down to cross-over depth. When the balloon reaches the bottom, use the hook to snag one of the metal loops on the top binder clip and pull the balloon up.



<u>What to do</u>: (Remember, there is a video of this on the YouTube playlist.)
1) Fill the tube with water, but not quite to the top.
2) Put the tube into the holder if you made one. If not, you might want to recruit someone to hold the tube.
3) Put the balloon into the top of the tube. The balloon should float. If not, take off some weight.
4) Push the balloon down a little bit at a time with the coat hanger tool you made. Every few seconds, let the balloon go and see what happens. You want to find the point at which the balloon will stop rising to the top. If you push the balloon all the way to the bottom and it still rises, you need to add more weight.
5) When you have adjusted the weight so that the balloon achieves neutral buoyancy (goes neither up nor down) at close to the middle of the tube, you are ready to do the actual demo.
6) Explain that in this demo, the balloon will represent magma being created in the mantle and the water column will be the mantle. The magma is compressible. That means if you squeeze it, the atoms can move closer together so the magma takes up less space. In the demo, we will see compression of the air inside the balloon. The molecules of nitrogen and oxygen (and other gases) will move closer together as they are squeezed so that the air will take up less space. As it takes up less space it becomes more dense. When the density of the air inside the balloon is the same as the density of the water, the balloon will stay in one places, not rising or sinking. Now push the balloon down until it reaches the neutral point.
7) Now explain that as we continue to force the balloon down, eventually the density of the air inside will become greater than the water surrounding it and as a result, the balloon will sink. Things that are more dense will always sink. Give the balloon a final nudge, forcing it down below the cross-over depth. Watch as the balloon sinks (without being pushed) to the bottom of the tube. Then use the hook to retrieve the balloon and bring it back up. Repeat the demo several times, allowing students to push the balloon themselves.

What was the point of this demo?
To remind us that cross-over depth is a real phenomenon and applies to magma, not just balloons. Based on the findings of magma studies, magma has a cross-over depth that prevents it from coming up through the mantle. Diagrams like the one shown here (from Wikipedia) supposedly "show" magma plumes rising from a depth of 2500 km. The computer was programmed by someone who apparently did not know the chemistry of magma and decided to interpret the dense areas deep in the mantle as rising magma.