Vacuum Chamber Experiments

This is a really fun demonstration to watch and to perform and it is a proven crowd pleaser. In order to make this demo sharp every time it is very important to read through the script and information in this packet THOROUGHLY to make sure you understand each teaching point and you can convey the scientific concepts of the experiments to your audience.
Once you are comfortable with the script watch at least two different staff members perform the demonstration and then run through the procedure a few times without props before having a staff member observe you in a full rehearsal.

Main Teaching Points

- There are two ways to get a liquid to boil: Add heat or subtract air pressure. The lower the atmospheric pressure above a liquid, the lower the temperature needed to bring that liquid to a boil.
- A liquid can exist only when there is sufficient atmospheric pressure above it to keep the molecules of the liquid from jumping out of their container. On Earth (at sea level) water boils at 100º C (212º F). At this point molecules are moving so fast that the pressure of the atmosphere above the water is not sufficient to keep them in the container, and they leap out as steam. In Denver, where there is less atmospheric pressure to hold the water molecules down, it takes less energy for the water molecules to escape, so the water boils at only 201°F instead of 212 °F.
- On Mars the atmospheric pressure is so low (0.7% of Earth's sea level pressure) that liquid water cannot exist even at cold temperatures; it boils away, even without any added heat.
- The air pressure on Mars is about the same as the Earth's pressure at 100,000 ft.

Equipment:

The vacuum pump is stored under the experiment bar, and should not be moved. The props are stored the drawers at the back of the Experiment Bar, the food items are in a labeled box.

- Bell jar and base plate
- Balloon blown up to the size of a plum, already tied
- Cup of Warm Water
- Marshmallow man: Chocolate Covered Peeps or Cookie, cocktail sticks, small marshmallows

- A 4 inch by 4 inch bubble wrap packing material with several bubbles intact
- Shaving cream
- Optional: atmospheric pressure mat

Suggested ways of presenting demo

Prior to show

1. Talk to the volunteer at the experiment bar and advise them what time you will be doing the Vacuum Chamber demonstration
2. Retrieve the headset microphone for the Experiment Bar from the 2003 storage room.
3. Clear the Mars Puzzle and other experiments away from the area
4. Find the atmospheric pressure mat if you want to use this as part of the demonstration
5. Put bell jar and base on the experiment bar (some performers like to use the grey box ,stored under the bar, to make the experiment higher)
6. Plug in the vacuum pump power cord and bring the end of the vacuum hose to the top of the demo stage.
7. Place your props close to hand on the edge of the Experiment Bar
8. The yellow soapbox can be used to make the show announcement and if preferred can be used to stand on throughout the performance.
9. You can use the Atmospheric Pressure Mat to start getting the visitors interested in the experiments you will be doing (see diagram at end)

Steps in Performing this Demo

1. Have a visitor lift the top off the vacuum chamber (easy) and then show how the vacuum pump works by evacuating some air for about 15 seconds. Now have a visitor try and lift the top off (impossible). Showing that the base plate clings to the bell jar. Ask visitors for an explanation. They will probably talk about suction. If so, clarify that suction is actually a false concept. Outside air pressure (14.70 pounds per square at sea level, 12 pounds per square inch in Denver) pushes the plate up onto the jar. Open the valve and let air back in. Call for observations of the sound the air makes as it reenters the jar. The wind speed is very fast because the outside pressure is very great compared to the interior of the jar. The greater the pressure difference, the faster the wind speed when filling it.
2. Place the cup on the base plate and add cup of water (this must be fresh water to work properly). Have guests observe as bubbles start to form in the water. Notice that there are 2 types of bubbles. The smaller bubbles that cling to the sides of the cup are dissolved air that has been released from solution. If this were an astronaut's bloodstream, those bubbles would cause "the bends." The larger bubbles are water vapor escaping

from all parts of the liquid. Water molecules at room temperature travel at hundreds of miles per hour, but can't evaporate because they are being held down by the thick air. But when the air is taken away, the water molecules have enough speed to leap right out of the liquid without first being heated. After the water has boiled, have one or more visitors test the temperature of the water to verify that you have boiled water without adding heat.

   a. Extra note: when you first turn on the pump, you might see a bit of moisture, a small cloud form inside the jar. This because the air inside the jar is moist, and when the pressure drops, the air temperature cools. This principle is called Gay-Lussac's Law. The cooled moist air forms a miniature cloud, but it quickly disappears because even the moisture is evacuated from the jar by the pump.

3. Place the balloon in the jar and ask for predictions. Evacuate the air and explain. When you open the air valve, note the way the balloon behaves in the very high speed wind.
   a. Extra note: You can estimate the decrease of pressure on the inside by noting how many times larger the balloon gets. If it is 10 times larger, this means the pressure is 10 times lower or 10% of the original pressure. This inverse relationship of pressure to volume is called Boyles Law.
4. Marshmallow man: do this only if you have a sufficient crowd, more than a handful. Here is a good time to tell a story about Marvin the astronaut who went into space but decided not to wear his space suit. Place the marshmallow man on top of an inverted cup and ask for predictions. <u>Observation:</u> the cookie expands for a while, then seems to burst and shrink. Letting the air in causes it to shrink even further. <u>Explanation:</u> A marshmallow is a foam, which is a mass of small bubbles with air trapped inside. The lower pressure causes the tiny bubbles of air to expand, but when they reach their limit, they burst, leaving a gummy residue. DO NOT GIVE THE COOKIE AWAY because it is a mess, and there could be a visitor with a food allergy. Just say, "We're not allowed to have food in the Museum."
5. Bubble wrap. This is a good prop to follow the marshmallow because here you can see actually bubbles as they expand and burst. It's like a microscopic view of the marshmallow.
6. Shaving cream. Place a small pile of shaving cream at the bottom of the cup. MAKE SURE IT IS NO BIGGER THAN A JAWBREAKER. You can do several cycles of expansion and contraction. Look at the remains of the foam after several cycles. It still smells like shaving cream, but it look likes white glue.

After the Demo

Rinse out the cup and save it. Make sure everything stowed is back to where you found it and the container for the food products is closed well.

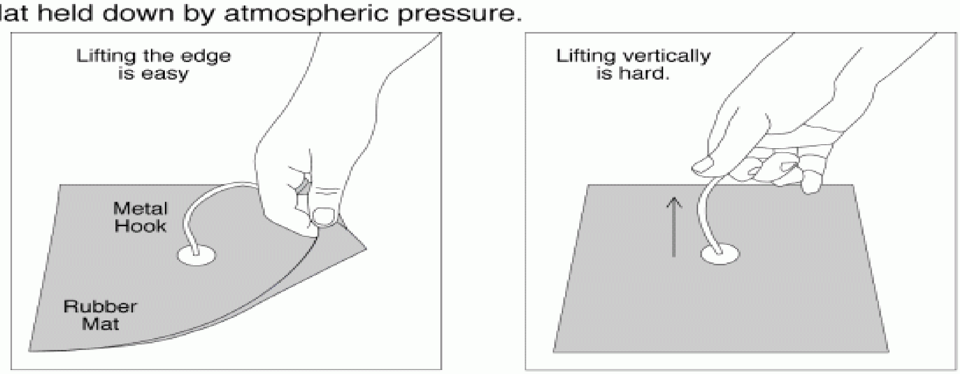
Fast Facts

- The air pressure on Mars is only 0.7% of Earth air pressure (sea level). Even ice can evaporate at this low pressure, or to use the proper term, ice "sublimes" from Mars's poles without ever becoming a liquid. We see the processes of sublimation occurring on Earth when dry ice (solid carbon dioxide) changes to a gas without becoming a liquid first.
- The air pressure in Denver is only 84% of air pressure at sea level.

Atmospheric Pressure Mat

FLUID STATICS **C+30+62**

Mat held down by atmospheric pressure.



The atmoshperic mat consists of a 10.5" square sheet of Neoprene that lays flat and does not allow air between it and the surface below. Given that atmospheric pressure at sea level is approximately 14.7 lb/in2, the mat theoretically experiences 1620 lbs of pressure. This makes it near impossible to pull the mat off the table by pulling straight up on the hook. However, by peeling the mat off the table, the air creates equal pressure on both sides of the mat allowing it be easily removed.

Obviously, due to imperfections in the rubber and the presence of air (particularly under the hook), one requires far less than 1600 pounds of force to lift the sheet. A force transducer or a spring scale can be attached to the hook if you want to show the class how much force is exerted.

Operating Tips & Potential Problems

- Keep the mood light and make this a lot of fun.
- Make sure you call for lots of predications and comments from visitors. Don't make this a lecture. You are exploring what will happen with them.
- Be sure to clean up after yourself, and return all trays and moveable experiment stations to their proper storage places. Make sure that the containers for the food products (cookies and marshmallows) is closed well. This will help them not dry out and last longer as well as lower the risk of attracting critters like mice who would like to eat the food.
- The vacuum pump, located under the Experiment Bar lab bench, should NOT be taken out for display purposes. It is heavy, noisy and full of oil. Leave it under the cabinet in the space below and show only the hose that connects to it, not the pump itself.

Background materials (websites, videos, articles, digital collections links)

- http://www.physlink.com/Education/AskExperts/ae306.cfm - Site answers this question, "How can you boil a liquid without heating it?"
- http://mars.jpl.nasa.gov/allaboutmars/facts/- How Mars compares to Earth both in atmospheric composition/density and other factors.

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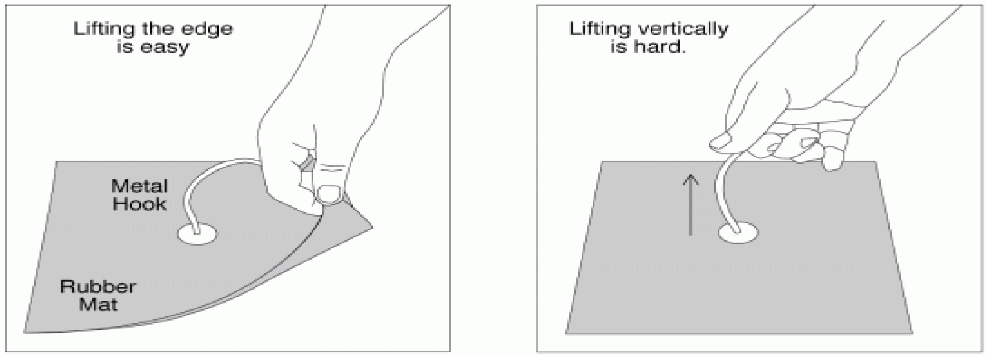

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