Miscellaneous

Balloon Morphing: How Gases Contract and Expand

(from http://www.sciencebuddies.com)

Objective

To investigate how gases expand and contract with temperature, using latex balloons.

Introduction

Imagine your friend has a cold January birthday and you bundle up and go to the store to buy him a "Happy Birthday" **Mylar®** balloon. You pick out a plump, cheerful balloon and head back to your car. By the time you get home though, you realize that the balloon you picked out isn't so plump anymore. In fact, it's starting to look a bit limp already! Should you take it back to the store? Is it defective? What's going on?

Everything in the world around you is made up of **matter,** including the balloon you just bought *and* what's inside it. Matter comes in four different forms, called **states.** The states, going (generally) from lowest energy to highest energy are **solids, liquids, gases,** and **plasmas.** Gases, like the helium gas inside your balloon, take the shape of the containers that they are in. They spread out so that all the space is filled up evenly with gas **molecules.** The gas molecules are not connected together. They move in a straight line until they bounce into another gas molecule or hit the wall of the container, and then they rebound and continue off in another direction until they hit something else. The combined motion energy of all of the gas molecules in a container is called the **average kinetic energy**.

This average kinetic energy (energy of motion) changes in response to temperature. When the temperature *increases,* the average kinetic energy of the gas molecules also increases. The molecules move faster and have *more frequent* and *harder* **elastic collisions** with the inside of the container. So, when your balloon was in the store, at room temperature, it was plump and full. When the balloon was taken outside into the cold January air, though, the average kinetic energy of the gas molecules was *lowered,* so the elastic collisions of the molecules with the inside wall of the balloon became *less frequent* and *weaker,* making your Mylar balloon saggy.

What do you think would happen if you took a room-temperature balloon and put it inside a car on a hot day? The average kinetic energy of the gas molecules inside would increase, creating more frequent and forceful collisions with the inside walls of the balloon. The balloon would look very puffy and full, and because Mylar balloons are not stretchy and elastic, the balloon might even burst.

In this chemistry science fair project, you'll investigate these changes in average kinetic energy by using a different kind of balloon—a **latex** balloon, which is able to expand and contract as the force and frequency of the elastic collisions change with temperature.

Terms, Concepts and Questions to Start Background Research

- Mylar
- Matter
- States (of matter)
- Solid
- Liquid
- Gas
- Plasma
- Molecule
- Average
- Kinetic energy
- Elastic collision
- Latex
- Proportional
- Linear

Questions

- How do gases behave?
- How does temperature affect gas molecules?
- What happens in an elastic collision?

Bibliography

This source describes the different states of matter:

- EdInformatics.com. (1999). *States of Matter.* Retrieved January 23, 2009, from http://www.edinformatics.com/math_science/states_of_matter.htm

This source discusses what gases are and how they behave:

- Rader, A. (2007). *Looking For a Gas*. Retrieved January 23, 2009, from http://www.chem4kids.com/files/matter_gas.html

This source provides an interactive tool to investigate what happens when gases are heated and cooled:

- BBC. (n.d.). *Gases Around Us*. Retrieved January 23, 2009, from http://www.bbc.co.uk/schools/ks2bitesize/science/activities/gases.shtml

This source discusses elastic and inelastic collisions:

- Nave, C. R. (2005). *Elastic and Inelastic Collisions*. Retrieved January 23, 2009 from http://hyperphysics.phy-astr.gsu.edu/Hbase/elacol.html

This source describes how to turn an expanding balloon into a model of the expanding universe:

- Schlumberger Limited. (2008). *The Expanding Balloon*. http://www.seed.slb.com/labcontent.aspx?id=11156

For help creating graphs, try this website:

- National Center for Education Statistics (n.d.). *Create a Graph*. Retrieved May 23, 2008, from http://nces.ed.gov/nceskids/CreateAGraph/default.aspx

Materials and Equipment

Note: To do this science fair project, you will need to place balloons in areas with three distinctly different temperatures:

1. Room temperature
2. Hot temperature (well above room temperature); for example, under a lamp, outdoors on a hot day, or inside a car on a hot day
3. Cold temperature (well below room temperature); for example, in a freezer, or outdoors on a cold day

- Latex balloons, round rather than oblong (1 package; you will only need 3, but should have extra in case any of them pop).
    - *Note:* Larger balloons allow you to see circumference changes more easily, but if you plan to use a freezer for your cold-temperature trials, your balloon must be able to fit in the freezer when inflated, so a small- to medium-sized balloon is a better choice if your freezer is not very large.

- Marker
- Thermometer with a range that spans the temperatures you will be testing (below freezing to well above room temperature)
- Cloth tape measure with millimeter (mm) markings
- Helper
- Clock
- Lab notebook
- Graph paper

Experimental Procedure

Preparing for the Balloon Tests

1. Blow up one of the balloons until it is quite full, but not close to popping, and tie it off.
2. Mark the balloon with the number 1.
3. Measure the circumference of this first balloon with the cloth tape measure, selecting the fullest part of the balloon to measure, as shown in Figure 1 on the right. Hold the tape measure snug on the balloon, but not so tight that the balloon is being squeezed by the tape measure and changing its shape. Record this starting circumference in your lab notebook.
4. Blow up the second balloon so it looks about the size of the first balloon, but don't tie it off yet. Pinch the opening closed between your thumb and finger so the air can't escape. Have your helper measure the circumference of the second balloon, just as you measured the first balloon. Adjust the air in the second balloon until its circumference is within 0.5 cm of the starting circumference of the first balloon, as follows:
    - If the circumference of the second balloon is smaller than the starting circumference of the first balloon, then blow up the second balloon some more.
    - If the circumference of the second balloon is larger than the starting circumference of the first balloon, then let some air out of the second balloon.
5. Tie off the second balloon and mark it with the number 2.

Figure 1. This drawing shows where to measure the circumference of the balloons.

6. Repeat step 4 for the third balloon, adjusting the circumference until it is within 0.5 cm of the starting circumference of the first balloon, and then tie it off and mark it with the number 3.
7. Make a data table, like the one shown below.

Circumference Data Table

Temperature (°F)	Balloon 1 Circumference (mm)	Balloon 2 Circumference (mm)	Balloon 3 Circumference (mm)	Average Circumference (mm)	Average Circumference Cubed (mm^3)

Testing Your Balloons at Room Temperature

1. Measure the temperature of the room with the thermometer and record your measurement in the data table.
2. Measure the circumference of each balloon with the tape measure, selecting the fullest part of each balloon to measure, as shown in Figure 1. Hold the tape measure snug on the balloon, but not so tight that the balloon is being squeezed by the tape measure and changing its shape. Record your measurements in the data table.

Testing Your Balloons in the Cold Area

1. Place the thermometer and all three balloons—one at a time, if necessary—in the area where you have chosen to do your cold-temperature testing; such as in the freezer.
2. Wait approximately 1 hour. If you can only put one balloon in at a time, this step will take 3 hours.
3. Remove the balloon(s) from the freezer and *immediately* measure the circumference(s) and record your measurements in the data table.
4. Record the temperature inside your cold area in the data table.
5. Repeat steps 1–3, if necessary, until all three balloons have been tested in the cold area.

Testing Your Balloons in the Hot Area

1. Wait 20 minutes to allow your balloons to come to room temperature.
2. Place the thermometer and the balloons—one at a time, if necessary—in the area you have chosen to do your hot-temperature testing; such as inside a car on a hot day.
3. Wait approximately 5–10 minutes, or until you can see obvious changes. If you can only put one balloon in the hot area at a time, this step will take up to 30 minutes.
4. Remove the balloon(s) from the hot area and *immediately* measure the circumference and record your measurements in the data table(s).
5. Record the temperature inside your hot area in the data table.
6. Repeat steps 1–4, if necessary, until all three balloons have been tested.

Analyzing Your Data Table

1. For each temperature, calculate the average circumference and enter your calculations in the data table.
2. For each temperature, *cube* the average circumference by multiplying the average circumference by itself three times. For example, if the average circumference is 60 mm, then the average circumference cubed is 60 X 60 X 60, or 216,000 mm^3.
3. Plot the temperature on the x-axis (in °F) and the average circumference cubed on the y-axis (in mm^3). You can make the line graph by hand or use a website like Create a Graph to make the graph on the computer and print it.
4. Assuming the balloon is a sphere, the volume is **proportional** to the circumference cubed, meaning there is a **linear** relationship between volume and circumference if you plot them on a graph. In your graph, is there a linear relationship between the circumference cubed and the temperature? If not, was there a greater change in circumference cubed in going from room temperature to a cooler temperature, or in going from room temperature to a warmer temperature? As the temperature increases, what do you think happens to the space between the gas molecules inside the balloon? What do think happens to the space between the gas molecules inside the balloon as the temperature decreases?

Variations

- Create a balloon model of the expanding universe. Place three small pieces of masking tape at different locations on a lightly inflated balloon that is clamped shut with a clothespin. Make a dot in the center of each piece of tape and have each one represent a different galaxy. Measure the distance between all the galaxies and the circumference of the balloon. Record the distance between all the galaxies and the circumference of the balloon. Blow up the balloon more, clamp it closed again, and repeat your measurements. Repeat this two more times, adding more air each time. In several graphs, plot the circumference of the balloon on the x-axis and the distances between the galaxies on the y-axis.

Buoyancy of Floating Cylinders

(from http://sciencebuddies.com)

Objective

The goal of this project is to measure how the tilt angle of cylinders floating in water depends on the aspect ratio (length/diameter) of the cylinder.

Introduction

If you place a wooden disk in water, it floats 'face up,' i.e., with the circular cross-section parallel to the surface of the water. However, if you place a long wooden cylinder in water, it floats with the circular cross-section perpendicular to the surface of the water (see Figure 1).

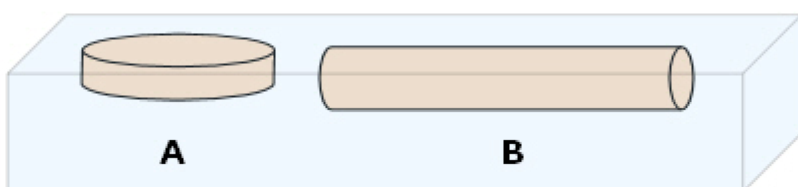

Figure 1. Illustration of a floating disk (A) and a floating cylinder (B).

If you think about it, a disk is a cylinder, too. A disk is just a very short cylinder, and 'disk' is just a special name for this type of cylinder. How short does a cylinder need to be before we call it a disk, or is there something more to it? A coaster for a hot cup of coffee certainly fits our concept of a disk. A ceramic coaster might be almost a centimeter tall and ten centimeters in diameter. However, we wouldn't call a one-centimeter length of pencil lead a disk, we'd call it a cylinder. That's because the diameter of the pencil lead is only 0.05 cm (0.5 mm). So apparently we consider both the length *and* the diameter of a cylinder when we're deciding whether or not it's a disk.
A handy way to consider both numbers at once is to use a ratio. For example, if we can use the ratio:

$$\frac{\text{length of the cylinder}}{\text{diameter of the cylinder}}$$

The coaster has an aspect ratio of 1/10, and the pencil lead has an aspect ratio of 1/0.05 or 20. So perhaps what we mean by a disk is a cylinder with an aspect ratio < 1.

Does the way a cylinder floats also depend on its aspect ratio? Since the disk floats face-up, but a longer cylinder floats with the circular faces perpendicular to the surface, does that mean that there are cylinders with intermediate aspect ratios that would float at intermediate angles? Do an experiment to find out!

Terms, Concepts and Questions to Start Background Research

To do this project, you should do research that enables you to understand the following terms and concepts:

- aspect ratio.

More advanced students should also study:

- buoyancy,
- volume,
- mass,
- density,
- center of gravity,
- center of buoyancy,
- righting moment.

Questions

- What is the difference between the center of gravity of the cylinder and its center of buoyancy?

Bibliography

- Here are some good background resources on buoyancy:
  - Junior Engineering, 1997. "Buoyancy," Utah State University [accessed December 29, 2006] http://www.juniorengineering.usu.edu/workshops/buoyancy/buoyancy.php
  - Wikipedia contributors, 2006. "Buoyancy," Wikipedia, The Free Encyclopedia [accessed December 29, 2006] http://en.wikipedia.org/w/index.php?title=Buoyancy&oldid=97455729.
- For more advanced students interested in the forces involved in determining the tilt angle, this article provides a good introduction to the concept of a righting moment:
  Shepard, J., 2003. "Stability: Capsizing Can Turn Your Whole Day Upside-Down,"

About: Powerboating [accessed January 19, 2007] http://powerboat.about.com/library/weekly/aa061903a.htm.

Materials and Equipment

To do this experiment you will need the following materials and equipment:

- wood dowels,
- small handsaw for cutting dowels to various lengths, notes:
  - You may even want to visit a hobby store to purchase a small aluminum miter box with a razor saw to go along with it. With a miter box to hold the dowel in place, it is easier to make perpendicular cuts.
  - X-acto and Zona are two quality brand names to look for. Both companies offer miter boxes and saws.
- dish pan or large plastic box,
- water,
- food coloring,
- metric ruler,
- protractor,
- pencil,
- blank paper,
- graph paper,
- calculator.

Experimental Procedure

1. Use a hand saw to cut cylinders of various lengths from a long piece of dowel. You'll need to experiment and figure out what range of lengths you need in order to see different tilt angles in water!
2. Measuring the aspect ratio of your cylinders is easy. Just measure the length (in cm) and the diameter (in cm), then divide the length by the diameter.
3. Measuring the tilt angle of the floating cylinders is a bit trickier. Here's how:
   - Carefully float the cylinders in water with food coloring added.
   - Allow the cylinders to float, undisturbed, for several hours.
   - The dye from the food coloring will stain the underwater portion of each cylinder. After a few hours, there will be a distinct line of dye marking the water line on each cylinder.
   - Remove the cylinders from the water and allow them to dry.
   - Note: if you like, you can also float the cylinders in colored liquid Jello, then allow it to set in the refrigerator. (You may need to occasionally nudge

the cylinders away from the edge of the dish.) The food coloring in the Jello will stain the submerged portion of each cylinder.

4. Use the following steps to measure the tilt angle of each cylinder:

a. Using a pencil and ruler, draw a straight line on a piece of paper.

b. Place the dyed cylinder over the straight line, and tilt it until the dye line on the cylinder is parallel with the line on the paper (Figure 2A).

c. Holding the cylinder in place, place a ruler against the cylinder at the same angle. (Figure 2A).

d. Move the cylinder out of the way and use the ruler to draw a straight line that intersects with the original line on the paper.

e. Use your protractor to measure the angle between the two lines (Figure 2B).

f. To keep track of your measurements, we suggest that you use a separate sheet of paper for each cylinder. Label each angle drawing with the length, diameter, and aspect ratio of the cylinder.

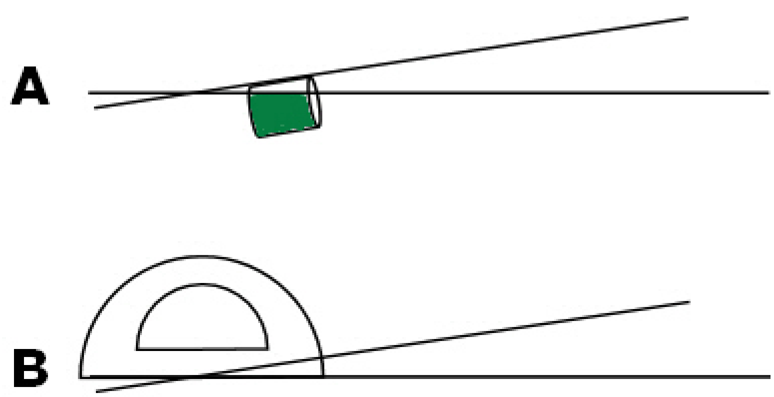

Figure 2. Measuring the tilt angle of the dyed dowel.

5. Make a table of your results like the one below:

Length (cm)	Diameter (cm)	Aspect Ratio (length/diameter)	Tilt Angle (°)

6. Make a graph of your results by plotting tilt angle (y-axis) vs. aspect ratio. Over what range of aspect ratios does the tilt angle change?

Variations

- Try dowels of different diameters, but with the same density. For each diameter, cut dowels of various lengths and measure their flotation angles. Make a graph of flotation angle (y-axis) vs. length of the cylinder (x-axis). Use a distinct symbol for each diameter. How do the graphs compare for each cylinder diameter? Now make a graph of flotation angle (y-axis) vs. aspect ratio of the cylinder (length/diameter). Use the same symbols as before. How do these graphs compare?
- Try cylinders with different densities. Is the relationship between flotation angle and aspect ratio the same or different? Can you find cylinders made of different materials but with the same density? Do they have the same relationship between flotation angle and aspect ratio?
- For more advanced students: can you come up with an explanation of the physics behind the tilt angle vs. aspect ratio relationship? Can you figure out an equation that describes the relationship between tilt angle and aspect ratio? The following article will be a useful reference: Gilbert, E.N., 1991. "How Things Float," *The American Mathematical Monthly*, 98 (3, March): 201–216.

Just Keep Cool-How Evaporation Affects Heating and Cooling

(from http://www.sciencebuddies.com)

Objective

The objective of this chemistry science fair project is to investigate several aspects of evaporative cooling.

Introduction

Evaporation is the process by which molecules in a liquid escape into the gas phase. In any liquid, such as a glass of water at room temperature, the molecules in the liquid are moving. They bump into each other as they meander about the liquid. The speed with which they move depends on the temperature—in hotter liquids, the molecules move faster. The average speed depends on temperature, but around this average speed, there will be some molecules moving faster (more energetically), and some moving slower. When the more-energetic molecules are near the liquid's surface, they can escape into the gas above. As more and more of the most energetic molecules evaporate into the gas, the average energy of the molecules left behind decreases, so the liquid cools.

The rate of cooling caused by evaporation depends on the rate at which molecules can escape from the liquid. You might have noticed that when you pour rubbing alcohol on your skin, it cools your skin more than when you pour water on it. This reflects the greater **volatility,** or tendency to evaporate, of the rubbing alcohol.

The Experimental Procedure for this science fair project has three sections. They might seem unconnected at first, but each is related by the underlying concept of **evaporative cooling.** In the first section of the Experimental Procedure, you will compare evaporative cooling caused by water, rubbing alcohol, and cooking oil. The cooling effect studied in this part of the procedure is the basis for **swamp coolers.** In these cooling devices, outside air is blown over a wet surface and then into the home. You are familiar with the principle if you have ever had wet clothes on with a breeze blowing—the evaporation of water cools you off, just as it cools the wet surface in the swamp cooler. Thermal **energy** in the hot air is "extracted" and used to convert some of the liquid water into water vapor. Because energy is used to evaporate water, the air is cooled after passing over the wet surface. The cool air is then circulated around the interior of the building.

In the second section of the procedure, you will look at the temperature change that occurs when water (sweat) evaporates off of skin. Sweating is a physiological response that uses evaporative cooling as a mechanism to remove excess heat.

In the third section, you will look at evaporative cooling in the kitchen. When heat is applied to water to make it boil, some of the energy can be lost to evaporative cooling. You will investigate how evaporative cooling affects boiling time by comparing how long it takes to boil a pot of water both with and without a lid.

Terms, Concepts and Questions to Start Background Research

- Evaporation
- Volatility
- Evaporative cooling
- Swamp cooler
- Energy

Questions

- Why are some liquids more volatile than others?
- Swamp coolers are most often used in areas that are hot and dry. Would a swamp cooler work in hot, muggy conditions?
- Dogs do not sweat, but is their cooling mechanism similar to that of humans?

Bibliography

- Chem4kids.com. (2007). *Evaporation of Liquids*. Retrieved October 23, 2008, from http://www.chem4kids.com/files/matter_evap.html
- Air & Water, Inc. (2007). *Swamp Cooling—Not Just for Swamps*. Retrieved November 4, 2008, from http://www.air-n-water.com/faq_swamp.htm

Materials and Equipment

- Measuring cup
- Water
- Rubbing alcohol
- Cooking oil, such as olive oil
- Plastic plates, disposable (4)

- Paper towels (12)
- Clear tape
- Ballpoint pen
- Infrared thermometer; available online, from websites like www.amazon.com
- Stopwatch
- Small fan; if you do not have a small fan, you will need an extra plate.
- Pots to boil water, identical, 2-qt. size or larger, with lids (2); you can use one pot repeatedly if you do not have identical pots.
- Stovetop
- A helper
- Lab notebook
- Graph paper

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Experimental Procedure

Evaporative Cooling in Buildings

1. Fill a measuring cup with tap water and allow it to come to room temperature.
    a. The rubbing alcohol and the oil should also be at room temperature.
    b. This step is just to ensure that the liquids are at the same temperature at the start of the experiment.
2. Place four disposable plastic plates, with the up sides down, on a work surface.
    a. Use a waterproof surface (such as tile or laminate) since you will be using alcohol that could damage wood finish.
3. Fold each paper towel in half twice, so that each has four layers.
4. Place a folded paper towel on top of each plate.

    a. The plates keep the towels from being in contact with the work surface, which would affect their temperature. You could also use Styrofoam™ or other insulating material.
5. Tape the edges of the paper towels to the plates.
6. Label the paper towels 1–4.
    a. In the next step, the paper towels will be treated as follows:
        - 1: no liquid
        - 2: water
        - 3: rubbing alcohol
        - 4: oil
7. Start the stopwatch.
8. Take the temperature of the paper towels with the infrared thermometer.
    a. Take three readings of each paper towel.
    b. Keep the direction and distance between the thermometer and each plate the same.
    c. Record the temperatures and times in a data table in your lab notebook.
9. Pour water on paper towel #2, just enough to wet it.
10. Pour rubbing alcohol on paper towel #3, just enough to wet it.
11. Pour oil on paper towel #4, just enough to wet it.
12. Take the temperature of each paper towel, and record the temperature and time in your lab notebook.
13. Repeat the temperature readings three more times, at 2-minute intervals.
14. Which paper towel has the lowest temperature? What was the largest temperature difference between two paper towels that you noted? Record all observations in your lab notebook.
15. Repeat steps 1-14 two more times, with fresh paper towels, but you can rinse and reuse the plates. Average the results in your final report.
16. Repeat steps 1-15 three more times, only for these trials, with the fan gently blowing over the paper towels. If you do not have a fan, use a paper plate as a fan. Your helper can fan as you take and record the temperature at 2-minute intervals. Did the fan change the results? Why?

Evaporative Cooling on Skin

In this section, you will look at the cooling effect of evaporation on human skin.

1. Mark a small spot on your arm with a ballpoint pen.
2. Measure the temperature of the skin on your forearm near the pen mark.
    a. As in the section before, take two more readings and average them.
3. Pour some room-temperature water on your arm.

4. Take the temperature of your skin near the mark. Record all data in your lab notebook.
5. Take a temperature reading every minute until your arm dries.
6. Repeat steps 1-5 two more times.
7. Now repeat steps 1-6 of this section three times, this time using the fan or helper with the paper plate to blow air on your arm. Average all the results.
8. Graph your results.
9. What temperature change did you see?
10. Repeat steps 1-9 of this section using rubbing alcohol. What is the difference in the temperatures between water and alcohol?

Evaporative Cooling When Boiling Water

You have looked at two beneficial aspects of evaporative cooling—one used to cool buildings and one used to cool people. In this section, you will look at a situation where evaporative cooling is a source of energy waste and thus, something to avoid.

1. Add 2 qt. (8 cups) of tap water to each pot.
2. Check the starting temperature of the water with the infrared thermometer. Record the time and temperatures in your lab notebook.
3. Start two burners on your stovetop. They should be set to the same setting.
4. Cover one of the pots with a lid, but not the other.
5. Put the pots on the burners.
6. Use the infrared thermometer to record the temperature of the water every 3 minutes.
    - Measure the temperature of the open pot by pointing the thermometer at the surface of the water.
    - Measure the temperature of the covered pot by briefly removing the lid and pointing the thermometer at the surface of the water.
7. Determine how long it takes for the water in each pot to come to a boil.
8. Stop taking the temperature of a pot when it is at a full boil. Use your judgment as to when this point is reached.
9. Repeat two more times and average your results.
10. Graph your results. Put "Covered" and "Uncovered" on the x-axis, and "Time to boil" on the y-axis. What was the time-to-boil difference between the two pots, in minutes and in percent change?

Variations

- Try other liquids for the first section, such as sugar or salt solutions, nail polish remover, etc.
- If you have access to a sensitive scale, weigh the paper towel with the alcohol during the course of the procedure. Find a relationship between weight change and temperature. For example, "on average, 1 gram (g) of alcohol was evaporated every minute to keep the paper towel 3 degrees cooler than room temperature."
- Demonstrate how a swamp cooler works in a model house made out of cardboard. Look up some design ideas online. Remember, the air coming in from the fan needs an open window or door to escape out of. This is a consideration for real houses with swamp coolers.
- Do some research on the energy used by your stove and calculate how much energy you used to boil the water on your stovetop with and without the lid. You might look at the gas meter to estimate how much gas is used. Make some rough guesses to come up with an estimate of how much energy could be saved nationally if everyone used a lid on a pot of water set to boil.
- Devise a method for reliably measuring small changes in temperature due to evaporation of low-volatility liquids, such as oil.

Race Your Marbles to Discover a Liquid's Viscosity

(from http://www.sciencebuddies.com)

Objective

To determine the viscosity of common liquids by measuring the transit time of marbles through the liquids.

Introduction

On a cold winter morning, have you ever tried to squeeze some honey out of the honey bear onto your toast? It's pretty tough, huh? Honey is one of those liquids that is very sensitive to temperature. As the temperature goes down, the **viscosity,** or resistance to flow, goes way up and you can squeeze and squeeze all you want, but very little honey comes out. If you set the honey bear in a pan of warm water for a few minutes and try again, what happens? One little squeeze and honey comes gushing out all over your toast. The viscosity, or resistance to flow, goes way down as the temperature goes up.

As a measure of a liquid's resistance to flow, viscosity can be thought of as **friction** inside the liquid. If, for example, you try to ride your bike with the hand brakes on (a form of friction), it is difficult to roll the bike forward. The resistance to motion is high. Likewise, in highly viscous liquids (those with high internal friction), the resistance to *flow* is high.

Viscosity is a very important quality of liquids that scientists, engineers, and even doctors are frequently trying to measure and change. It is difficult, for example, to transport highly viscous crude oil through offshore pipelines, so scientists and engineers use a variety of methods to try and lower the oil's resistance to flow through the pipelines. Likewise, in medicine, doctors try to keep blood viscosity in the correct range. If blood is "too thick," or viscous, a patient can develop blood clots. If blood is "too thin,"or lacks viscosity, however, then the patient is at risk for bruising or bleeding events. Blood viscosity, like most things in medicine, has a happy medium.

Volcanologists (people who study volcanoes) have a big interest in viscosity, too. The viscosity of molten rock or magma determines how easily a volcano will erupt, and what shape the lava flows and resulting mountains will take on. A very thin and fluid magma erupts more easily and forms gentle mountain slopes, while a very thick magma erupts explosively and forms a fat lava flow and steep mountain slopes. So, if you see a mountain formed from a volcano, you can estimate the viscosity of the magma that formed it just by looking at the angle of its slope!

Common liquids around your house (thankfully) don't form mountain slopes though, so to measure their viscosities, you have to use some other method. One of the oldest methods is the dropped-sphere method—a glass marble or sphere of some other material is dropped into a column of a liquid. If the liquid is very viscous (imagine cold honey), it will take a long time for the marble to drop to the bottom of the column. Dropping the marble into a less viscous liquid (like water) will take much less time.

Viscosity of a liquid can be calculated from the time elapsed, provided that you know the height of the column and the densities of the sphere and the liquid. **Density** is a measure of how "compact" something is. It is the ratio of mass to volume, and is a measure of how much matter is packed into a space. Think of a 1-inch cube of bread. Then think of a 1-inch cube of potato. The potato is denser than the bread (there is more "stuff" in the same space). You can calculate density yourself for an object by using a scale to find out the object's mass and then dividing that by the object's volume. You can also look up the densities of many common substances, like glass, stainless steel, water, seawater, oils, etc. in materials tables.

Knowing the time it took to travel through the column of liquid, the height of the column, the density of the sphere, and the density of the liquid, you can then calculate the viscosity of the liquid with the viscosity equation:

Equation 1:

$$\text{Viscosity} = \frac{2(\Delta P)ga^2}{9v}$$

where:

- **Viscosity** is in newton-seconds per meter squared ($Nsec/m^2$).
- **Delta (Δ) P** is the difference in density between the sphere and the liquid, and is in kilograms per meter cubed (kg/m^3).
- **g** is the acceleration due to gravity and equals 9.81 meters per second squared (m/s^2).
- **a** is the radius of the sphere in meters (m).
- **v** is the average velocity, defined as the distance the sphere falls, divided by the time it takes to fall in meters per second (m/s).

So, now it's time to race some marbles and see if common liquids in your home are thick or thin!

Terms, Concepts and Questions to Start Background Research

- Viscosity
- Friction
- Density
- Terminal velocity
- Inverse relationship
- Direct relationship

Questions

- What is liquid viscosity?
- How does viscosity change (in general) with temperature?
- Why is it important to understand viscosity?

Bibliography

This source discusses what viscosity is, its importance to understanding volcanology, and how to measure viscosity in the laboratory:

- Hawai'i Space Grant College, Hawai'i Institute of Geophysics and Planetology, University of Hawai'i. (1996). *Viscosity Teacher Page.* Retrieved September 6, 2008, from http://www.spacegrant.hawaii.edu/class_acts/ViscosityTe.html

Materials and Equipment

- Tall, slender drinking glasses or glass jars with straight sides, equally sized (4)
- Marker, water soluble (1)
- Ruler, preferably metric
- Glass marbles, equally sized (5)
- Safe liquids to test (4), approximately 1/2 gallon of each, such as
    - Corn syrup
    - Honey
    - Cooking or vegetable oils
    - Glycerin
    - Seawater
    - Milk
    - Water

    - Molasses
- Stopwatch
- Strainer
- Liquid dish soap
- Dish towel
- Access to sink
- Graduated cylinder, at least 1,000-mL size (1); available at science supply stores, such as Carolina Biological. Note: the larger the graduated cylinder, the easier it is to do testing.
- Lab notebook
- Helper

Experimental Procedure

Preparing Your Glasses for the Marble Race

1. Measure down about 2 cm from the top of each glass with the ruler, and mark the 2-cm location with the water-soluble marker.
2. Fill each glass with a different test liquid, all the way up to the 2-cm mark.

Racing Your Marbles

1. Have a helper hold two marbles level with the tops of two glasses. You hold two marbles level with the tops of two glasses also.
2. Say, "Ready, Set, Go!" and then you and your helper should drop your marbles at the same time and see which marble hits the bottom first and which one hits the bottom last. Record your observations in your lab notebook. If you have trouble figuring out a clear winner between two liquids, race the marbles with just those liquids a second and third time after first completing the next set of steps: Marble Retrieval and Cleanup.

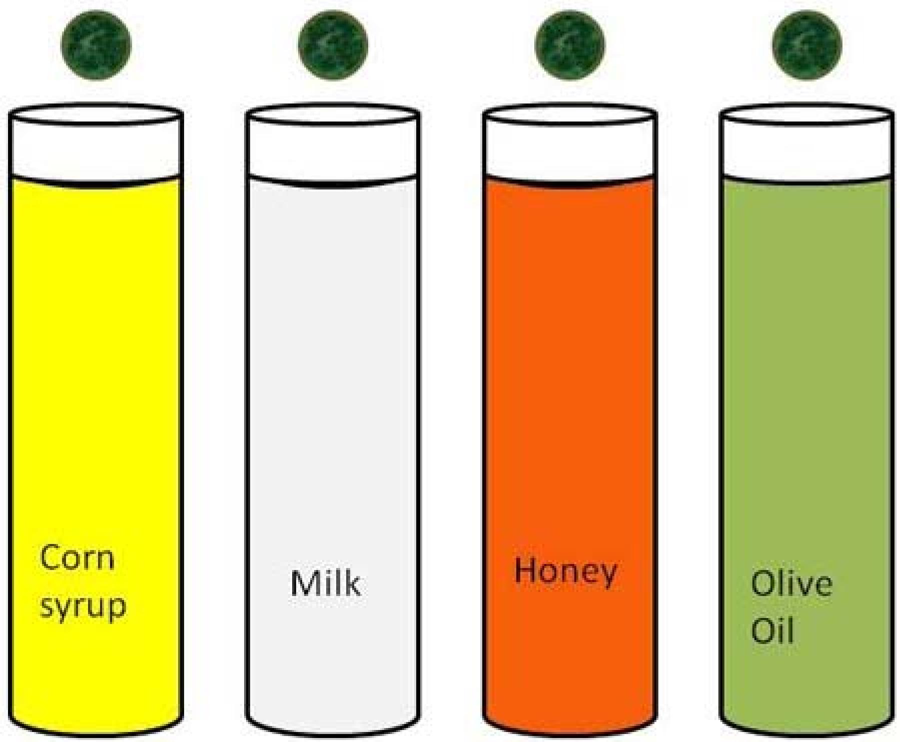

Figure 1. This drawing shows the setup of glasses and example liquids for the marble race.

Marble Retrieval and Cleanup

1. Place the strainer inside a sink or over a large bowl set inside a sink.
2. Pour the contents of each glass (the liquid and the marble) slowly into the strainer.
3. Retrieve the marbles from the strainer and wash and dry both the marbles and the glasses.

Preparing the Graduated Cylinder to Measure the Viscosity of Each Liquid

1. Fill the graduated cylinder up with one of the liquids to a level 5 cm below the top of the cylinder, as shown in Figure 2.
2. Measure down at least 2 cm below the surface of the liquid (as shown in Figure 2) and mark a starting line on the graduated cylinder with the marker. The starting line needs to be lower than the surface of the liquid to allow time for your marble to reach its **terminal velocity** before you start taking measurements.
3. Measure up from the bottom of the graduated cylinder, approximately 5 cm, and mark an ending line on the graduated cylinder with the marker. You don't want the ending line to be at the bottom of the cylinder because the marble will slow down as it approaches the bottom, due to interactions with this boundary.

4. Measure the distance between the starting point and the ending point. Record this distance in your lab notebook. This is the distance that you will use to calculate the speed of the marble as it travels through the liquid. Remember, the average speed is equal to the distance traveled, divided by the time it took to travel that distance. Now you're ready to test and get some travel times.

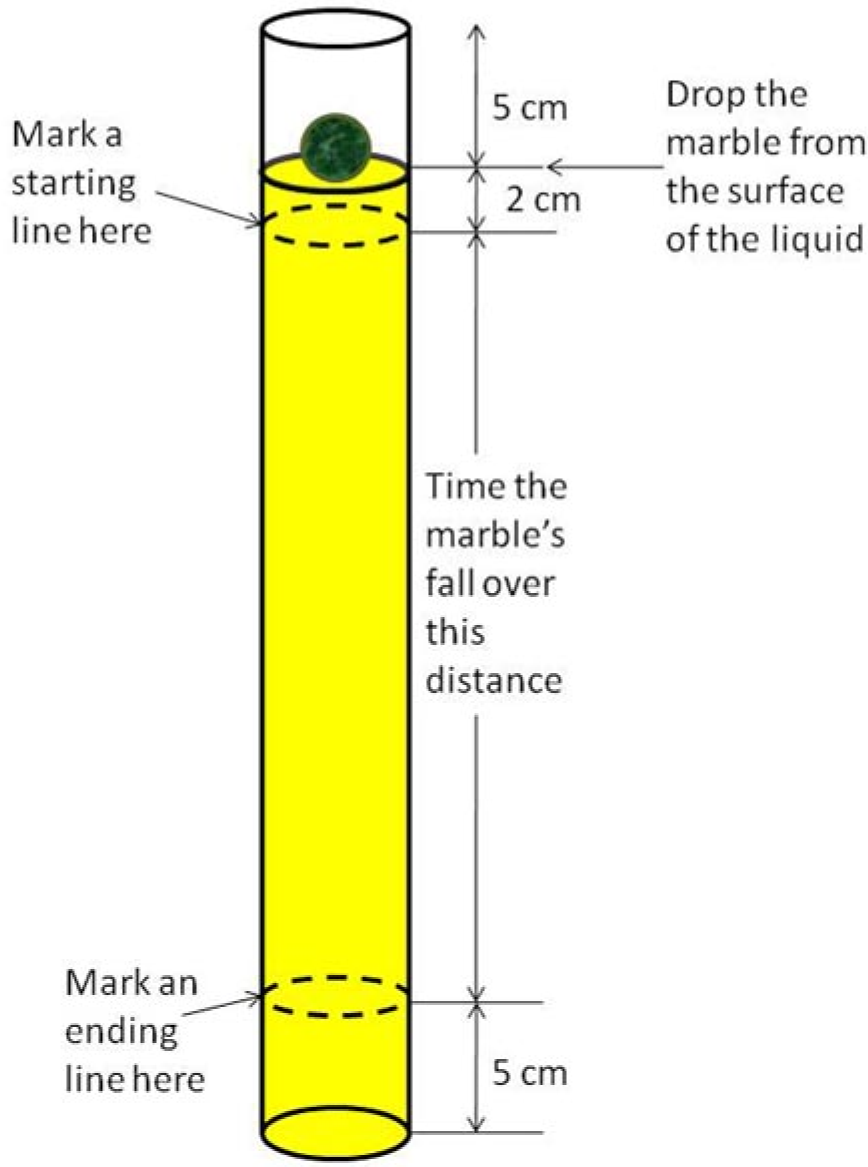

Figure 2. This drawing shows how to prepare the graduated cylinder for testing.

Testing Your Liquids

1. You or the helper should hold a marble at the surface of one of the liquids.

2. The other person should zero out the stopwatch.
3. The person holding the stopwatch should say "Go!" and have the other person drop the marble. As the marble passes the starting point, which was marked in the previous section, the person holding the stopwatch should start the stopwatch. As the marble passes the ending point, which was marked in the previous section, the person holding the stopwatch should stop it.
4. Record the time elapsed in a data table.
5. Repeat steps 1-4 of this section, with the same liquid and graduated cylinder, four more times with four other marbles.

Measured Time Data Table

Liquid name	Trial 1 time (sec)	Trial 2 time (sec)	Trial 3 time (sec)	Trial 4 time (sec)	Trial 5 time (sec)	Average of times (sec)
Example: Corn syrup						

Marble Retrieval and Cleanup

1. Place the strainer inside a sink or over a large bowl set inside a sink.
2. Pour the contents of the graduated cylinder (the liquid and the marbles) slowly into the strainer.
3. Retrieve the marbles from the strainer and wash and dry the marbles and the graduated cylinder.
4. Repeat the experiment up to this step, starting from Preparing the Graduated Cylinder to Measure the Viscosity of Each Liquid, for the remaining test liquids.

Analyzing Your Data Chart

1. Calculate the average for the five time trials for each liquid and enter it in your data table.
2. Calculate the average velocity for each liquid by dividing the distance, measured in step 4 of Preparing the Graduated Cylinder to Measure the Viscosity of Each Liquid, by the average time it took to travel that distance. Record your calculation in a second data table.

3. Remember Delta P from the viscosity equation, Equation 1? Calculate Delta P, the difference in densities between the marble and each liquid, by using the table below. Record each Delta P calculation in your data table. *Note:* If you tested a liquid that is not in this table, you will have to look up its density online, or calculate the density yourself, using a scale.

Common Approximate Densities (kg/m^3)

Water	1000
Corn syrup	1380
Molasses	1400
Honey (room temperature)	1500
Vegetable or cooking oils	920
Glycerin	1260
Ocean water	1030
Milk	1030
Glass marble	2800
Stainless steel	7800

4. *If you know the diameter of your marbles,* divide the diameter by 2 to get the radius of the marbles. *If you don't know the diameter of your marbles,* measure the diameter with a ruler, and then divide by 2 to get the radius. Record the radius of your marbles in your lab notebook.
5. Calculate the viscosity of each liquid using Equation 1 from the Introduction. Record the calculations in a data table.

Viscosity Data Table

Liquid name	Calculated average velocity (m/s)	Delta P (kg/m^3)	Viscosity (kg/meter sec)
Example: Corn syrup			

6. Compare your viscosity test results with the marble race results. Do they match up and make sense? Did the liquids with the lowest viscosities win the race? Plot the viscosity of each liquid on the y-axis and the calculated average velocity on the x-axis. Is the relationship between viscosity and velocity **inverse** or **direct?**

Variations

- Choose one liquid and repeat the experiment using different sizes and densities of spheres. For example, try different diameters of glass marbles, stainless steel balls, or BB's. (*Note:* For your viscosity calculations, the density of a stainless steel ball bearing is 7,800 kg/m^3. If the diameter of any of your spheres is more than half the radius of the graduated cylinder, you should purchase a larger-diameter graduated cylinder to avoid having the spheres interact with the sides of the cylinder.) Are the velocities of the different spheres different? What about the measured viscosities from those velocities? Are they the same? Obtain some statistics, such as the standard deviation, on your measured viscosities.
- Choose a very temperature-sensitive liquid, such as honey, and evaluate how viscosity changes as a function of temperature.

The Flammability Of Household Fabrics

(Project found at http://youth.net/nsrc/sci/sci045.html#anchor781569#anchor782686)

Purpose

To find out more about the flammability of household fabrics used in the home.

Materials

- ☑ Seven different types of fabric (nylon, satin, taffeta, terry cloth, brush t-shirt cotton, broad cloth, linen, and rayon)
- ☑ Non-flammable container
- ☑ Matches
- ☑ Stopwatch

Safety Concern: Matches. Students will wear non-flammable gloves and goggles while doing this project. Students will also make sure that the fabrics are burned in a non-flammable container, outside.

Procedure

1. Cut each fabric into the same size square.

2. Fold each fabric over.

3. Light each corner of the fabric and begin to time how long it burns. Continue timing until there is no flame and the cloth smolders.

4. Record your data in a table.

What type of car anti-freeze is the most environmentally friendly?

(Project found at http://www. all-science-fair-projects. com/)

Purpose

Determine which automobile anti-freeze is most biologically safe.

Material

- ☑ Five pans (9½x14x5)
- ☑ Potting soil
- ☑ Spray bottle filled with water
- ☑ Grass seeds
- ☑ Peat moss
- ☑ Yarn
- ☑ Ruler
- ☑ Two lamps
- ☑ Recycled anti-freeze
- ☑ Four different brands of anti-freeze

Safety Concerns: Anti-Freeze. Students will wear gloves, goggles, and apron when using anti-freeze. Anti-freeze will be stored in proper containers and put in an area out of reach for young children and pets. Any spilled anti-freeze will be THOROUGHLY cleaned.

Procedures

1. Gather all materials.

2. Fill a 9½x14x5 pan with 4 cm of soil.

3. Sprinkle 250mL of grass seeds evenly in the pan.

4. Fill a normal spray bottle with water.

5. Spray water bottle 40 times around the pan evenly.

6. Cover seed with ½ cm soil.

7. Spread dirt evenly.

8. Sprinkle a light layer of peat moss over soil.

9. Spray water bottle another 40 times evenly over the soil.

10. Partition pan with a grid of yarn.

- ⊗ Take four 29 mm pieces of yarn and wrap them around the width of the pan 3-cm apart.
- ⊗ Take one 38 mm pieces of yarn and wrap them around the pan length 3-cm apart.

11. Fill a normal spray bottle with water.

12. Spray the spray bottle 40 times evenly around the pan twice a day.

13. Repeat steps 2-12 with four other pans.

14. Place two lamps with 60-watt bulbs above the pans (One on each side) and begin growth.

15. Repeat steps 11-12 everyday for 18 days.

16. Take a ruler and measure the height of the four intersections of yarn.

17. Add up all measurements for each pan (four measurements per pan) the find the mean of each pan of grass height.

18. Take first brand of anti-freeze and put 100 mL in a normal spray bottle with 100mL water.

19. Spray the spray bottle until empty evenly around the pan.

20. Repeat steps 18-19 with another pan and a different brand of anti-freeze.

21. Repeat step 20 with all other pans and anti-freezes except the one control (leave it without anti-freeze [spray controlled with 200mL water])

22. Repeat steps 11 and 12 for 6 more days.

23. Day 6, measure and record data of the four intersections from the soil to where the green stops.

24. Record mean for all pans.

Which Household Items Lubricate Metal The Best?

(Project found at http://youth.net/nsrc/sci/sci045.html#anchor781569#anchor782686)

Purpose

Which household items lubricate metal the best?

Materials

- ☑ Baby oil
- ☑ Liquid soap
- ☑ Vegetable oil
- ☑ Vaseline
- ☑ Board 6" x 42"
- ☑ Smooth aluminum sheet to cover the board
- ☑ Steel block ½" x ½" x 6" (round edges on corners)
- ☑ Four brushes, marked 1, 2, 3, & 4
- ☑ Graduated cylinder
- ☑ White vinegar
- ☑ Stopwatch
- ☑ Something to raise one end of the board 24"

Procedure

1. Set up the board.

2. Measure 5mL of the liquid into the graduated cylinder. Using the appropriate brush, apply the 5mL to the block, as evenly as possible.

3. Place the block on the ramp and let it go. Start the stopwatch when the block is let go. Stop the watch when the front edge of the block touches the end of the ramp.

4. Use the vinegar and paper towels, clean the metal block and aluminum sheet on the ramp between each test. Do not touch the surfaces because of the oil from your fingers.

What are the Effects of Polyacrylamide and Polyacrylate on Soil Erosion?

(from All Science Fair Projects/http://www.all-science-fair-projects.com/project451_38.html)

Purpose

To determine the effects of polyacrylamide versus polyacrylate on erosion.

Materials

Dirt
Polyacrylamide
Polyacrylate
Twelve trays
Box
Cup

Procedure

1. Fill the twelve trays with 227.25 grams of dirt.

2. Get one, two, three, four, and five grams of polyacrylamide and polyacrylate.

3. Place one gram of polyacrylamide in a tray, two in the next, and so.

4. Repeat Step #3 for the polyacrylate.

5. Spread the polyacrylate and polyacrylamide evenly in each of the twelve trays.

6. Place the trays in a box at an angle.

7. Each day for five days, pour 100 mL of water through each of the twelve trays. Collect the runoff in a cup.

8. Measure the amount of erosion in each cup.

Is the Burning of Trash a Viable Alternative to Landfills?

(from All Science Fair Projects/ http://www.all-science-fair-projects.com/project464_38.html)

Purpose

To determine if burning trash is an alternative to land fills. Does the burning of trash create more air pollution?

Materials

10g of wood chips
10g of plastic Ziplock™ bag
10g of charcoal
10g of cardboard
stopwatch
metal can
matches

Procedure

1. Get ten grams of wood chips.

2. Place the wood chips in a metal can.

3. Set the wood chips on fire. Using the stopwatch, time how long the wood chips burn. Record this information.

4. Placed the remains in the bag. Weigh the remains of the burned wood chipping was weighed and recorded on a chart. (Be sure to subtract the weight of the bag from the weight of the bag and chips.)

5. Repeat Steps #1-#4 for the plastic, tissue and cardboard.

Which Combination of Materials Are Best For Mars Temperatures?

(from All Science Fair Projects/ http://www.all-science-fair-projects.com/project70_7.html)

Purpose

The purpose of this experiment was to find out which type of fabric combinations could be used in space suits for astronauts exploring Mars.

Experimental Design

The constants in this study were

* Number of tests of each spacesuit prototype, (3).
* Size of water containers
* Amount of water in containers.
* Time of exposure to warm and cold conditions.
* Type of thermometer
* The temperatures that the combinations were tested in

The manipulated variable was the combination of fabrics used for each prototype.

To evaluate the responding variable I measured the water temperature at the start of the experiment and at the end. I also used a thermometer outside the prototype to measure the air temperature. All temperatures were measured in degrees Celsius.

Materials

QUANTITY	ITEM DESCRIPTION
4	Mercury Thermometers (Celsius)
30cmx30cmx37cm	Polyester Lycra fabric
31.4cmx31.4cmx38.4cm	Camouflage fabric

30.5cmx30.5cmx37.5cm	Fleece fabric
30.8cmx30.8cmx37.8cm	Aluminized Mylar
30cmx30cmx37cm	foam fabric
32.5cmx32.5cmx39.5cm	Flannel Backed Vinyl
32cmx32cmx39cm	Vinyl
31.3cmx31.3cmx38.3cm	Rubber Coated Nylon
32cmx32cmx39cm	Nylon Cordura fabric
1 pair	Scissors
1 bottle	Liquid Stitch™
1 spool	Brown Thread
1	Sewing Needle
1	Heating Device
3	Plastic Containers
1	Ice Chest Cooler
10 kilo.	Dry Ice
1,273mL	Water
1 pair	Rubber Gloves

Procedures

1. Cut out fabrics

2. Make three different combinations of fabrics.

3. Once the fabric combinations are complete, glue the fabrics for each combination together.

4. Sew all edges of prototypes together except for top.

5. Sew Velcro® around lids of prototypes

6. Fill plastic container with water to top (make sure temperature is close to 37* C.)

7. Put thermometer in bottle to get starting temperature.

8. Slide bottle in spacesuit prototypes.

9. Velcro lid to the body of spacesuit.

10. Place heaters around spacesuit prototypes.

11. Measure temperature of outside environment.

12. Wait 1 hour and record temperature.

13. Repeat steps 1-12 for cold environment except: Place spacesuit prototypes in freezer.

14. Repeat steps 1-12 for cold environment except: Place spacesuit prototypes in cooler with dry ice.