PRESSURE INVESTIGATION!

PROBLEM PRESENTATION / EXPLORATION

A. CHALLENGE: What is the farthest distance a stream of water can be made to squirt out of a hole poked into a half gallon milk carton (or 2 liter bottle)? What are the factors (that you can manipulate) that govern how far the water will travel?

B. Rules
   1. Everyone must use the same type of container.
   2. The only thing that may be put into the container is tap water.
   3. The only "tools" that may be used are a pencil, scissors, nail, or other device for putting the hole in the milk carton. (If plastic bottles are used, a smooth hole can be made by heating the nail, etc., in a flame. The hot nail melts the plastic quickly and neatly.)
   4. Any other equipment for carrying out the exercise must be approved by the teacher.
   5. To make ready for judging, the student must put a piece of tape over the hole and present it to the teacher. The teacher will quickly remove the tape to allow the water to squirt. An alternative way that this can be done is to place the water in the container with your finger over the hole, then put a rubber stopper into the hole at the top of the 2 L bottle. Removing your finger will not result in the water squirting out. WHY? When you want the water to squirt out quickly remove the rubber stopper.
   6. Distances will be measured from the base of the milk carton to the farthest point that the water squirts.

CLASS RESPONSE / CONCEPT INVENTION

A. After the competition, have the class decide which variables they considered in trying to squirt the water the greatest distance. Some important ones that they should have considered are:
   1. Amount of water put into the carton
   2. Size of the hole
   3. Distance of the hole from the bottom of the carton

B. Which of these variables had the most effect? Which had none? How could you prove this? This is a classic example of a separation and control of variables exercise. Use this opportunity to reemphasize the importance of holding all other variables constant while a single variable is changed.
   1. Poke the same size hole, 5 cm above the bottom of the container, in three different milk containers. Put tape over the holes. In the first carton add enough water to bring the level up to 10 cm high; in the second container add enough water to bring the level up to 15 cm high; and in the third container add enough water to bring the level up to the 20 cm level. After pulling the tape off the hole measure how far the stream of water goes for each of the three containers. Decide whether the amount of water in the carton makes any difference in the distance traveled by the water. [The higher the water level, the farther it squirts.]
   2. Poke different sized holes in three containers at the same height above the bottom of each container. Place tape over the holes. Fill the container completely full with water. Pull the tape off each hole and observe the streams of water. Decide whether the size of hole makes any difference in the distance traveled by the water. [The smallest hole will squirt the water the farthest]
   3. Poke the same size hole in each of three separate containers but at different

heights from the bottom. After putting tape over the holes, fill each container with the same amount of water. Pull the tape off the holes and observe the streams of water coming out. Decide whether the height of the hole makes any difference in the distance traveled by the water. [The hole with the shortest distance from the bottom squirts the farthest.]

C. One of the key conclusions that should be achieved in investigations B1 and B3 above is that **there is more force exerted** (evidenced by the longer stream of water) **when the column of water above the hole is higher**.

D. In addition to the conclusion that the height of water affects the distance the water squirts, the area to which the force is applied will also effect how far the water squirts. In other words the size of the hole is also important in determining the **FORCE PER UNIT AREA** which is our definition of **PRESSURE**.

1. A sugar cube measures about 1 cm on a side. The area of one face then would be about 1 cm^2.
2. Place a cement block (or other heavy object) on the single sugar cube. The huge amount of force concentrated on 1 cm^2 will smash the sugar cube immediately.
3. Now take 100 sugar cubes and lay them out on the floor to make a square 10 sugar cubes on a side. If the cement block is placed on this area (about 100 cm^2) the cement block should be supported without crushing the sugar cubes. In this case each sugar cube is supporting only 1/100 of the force. The pressure experienced by the single sugar cube was 100 times greater because of its smaller area. Therefore, with the same height of water pushing down on the small hole and the larger hole in the water container, the pressure experienced at the little hole was much greater and the stream of water squirted out farther.

CONCEPT EXTENSION

A. CHALLENGE: If two milk cartons (half gallon and quart) or two plastic Coke® bottles (2 L and 1 L) are both filled to the height of 25 cm with water and both have holes of equal size spaced at 5 cm above the bottom of the carton, which carton will squirt the water farther?

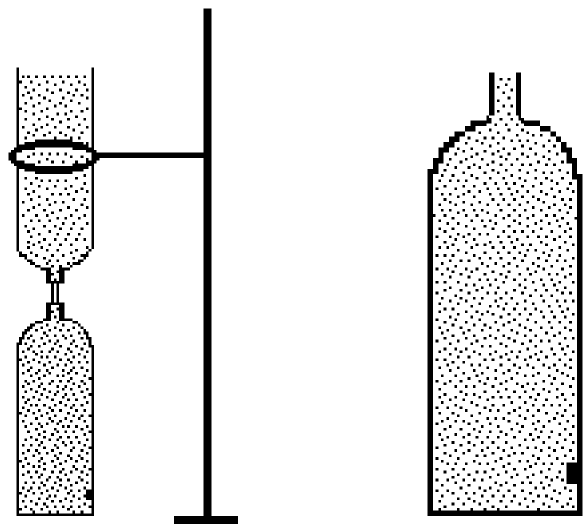
1. It is probable that many students will predict that the half gallon milk carton with squirt the water farther. They are centering on the fact that there is more water in the carton and consequently that there is more force being exerted at the hole.
2. But contrary to this assumption the streams of water should cover the same distance. It is the height of the column of water that is important not the amount of water.

B. If there are doubters in the class, try to give them a concrete example of the importance of the height of the column of water rather than the amount of water being the factor that dictates the amount of pressure.

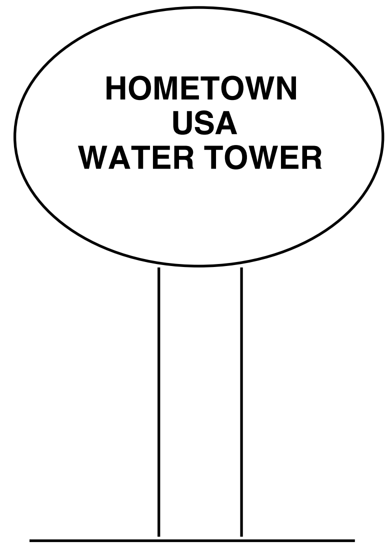
1. Use a total of one half gallon of water for both of the following tests.
2. Both containers must have a hole of the same diameter punched at 5 cm above the bottom of the container.
3. After taping over the hole, all of the water should be put into the first container (2 L bottle).
4. You will need two 1L bottles for the second test. The lower one should have the hole punched out in the same way, same size, and distance above the bottom as was done the 2L bottle. Make sure you tape over the hole. Cut off the bottom of the second 1L bottle. Prepare two one holed stoppers that will fit into the 1L bottles. Into each stopper insert the opposite ends of a short piece (4 cm) of glass tubing. Submerge all three pieces (the two bottles and

the rubber stoppers/glass tubing) into the sink or large tub so that everything is filled with water. While still under water insert the stoppers into the two 1L bottles so that the two bottles are now connected. There should not be any air bubbles. Remove the setup from the tub of water placing the bottle with the hole on the table and elevating the bottle without a bottom above the table. Support the upper bottle with a ring and ring stand.

5. Now both bottles have approximately 2L of water in them. All that remains now is to remove the tape and see how far the stream shoots in each case. The demonstration can be even more graphic if a piece of rubber tubing was linked to the two 1L bottles. Now by physically lowering or raising the upper bottle the pressure can be decreased or increased according to the height of the column of water above the hole.



C. How would you design a water tower to maintain water pressure for a small town? Where would you locate the water tower? [At the highest point in town.] What shape would you make it to insure the greatest water pressure? [Since height is the most important factor, many towns use a large water tank that is high in the air with a pipe coming out of the bottom that extends down to the ground instead of a cylindrical tank of the same height. In this way it does not require as much water to get the same water pressure. (See diagram below.)


HOMETOWN
USA
WATER TOWER