Flame Tornado and Water Jug Race

Density of Gases

Introduction

A paper towel is soaked in lighter fluid and ignited, producing a 15–20 cm high flame. When this is placed on a screened-in Lazy Susan, and slowly spun, the flame is spontaneously transformed into a roaring meter-high pillar of fire. In the second demonstration, students are invited to participate in a race—who can empty their jug of water the fastest? They soon find out that gravity is not the only force that can help them! Two seemingly unrelated activities—or are they?

Concepts

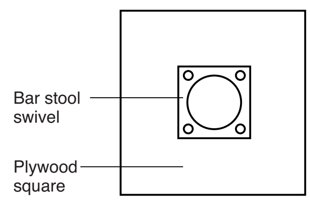
- Atmospheric pressure
- Combustion
- Centrifugal force
- Density

Materials

For Flame Tornado Demonstration

Aluminum screening, 80–100 cm wide, 260–270 cm long
Charcoal lighter fluid or kerosene
Water
Butane safety lighter
Large Lazy Susan (40 cm diam)*
Paper fasteners
Paper towels
Pipet, disposable
Soda can
Tin snips

**If a large "Lazy Susan" is not readily available, a bar-stool swivel (available at most hardware stores) can be attached to the center of a 2′ × 2′ × $^3/_8$″ square of plywood. Placing the plywood swivel-side down on the floor or demonstration bench serves as an adequate Lazy Susan (see Figure 1).*



For Water Jug Race Demonstration

Bucket or wash basins, large enough to hold equivalent jug volume, 2
Funnels, large, 2
Large clear jugs, 2

Safety Precautions

Kerosene or charcoal lighter fluid is a moderate fire risk; moderately toxic by inhalation. Keep all flammable materials away from demonstration. Have a fire extinguisher handy. Wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

For Flame Tornado Demonstration

1. Roll the screen into a tube that fits on the Lazy Susan, resting just inside the lip. The screen length specified above should be enough to wrap twice around, with about 10–20 cm of extra (3-ply) overlap.

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2. To hold the screen in a cylinder shape, poke the paper fasteners through along the length of this overlap about every 15 cm, then spread the ends of the fasteners open (see Figure 2).

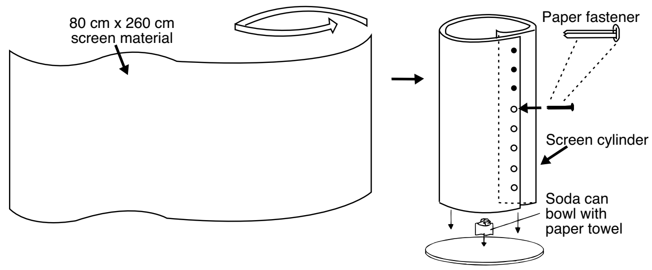
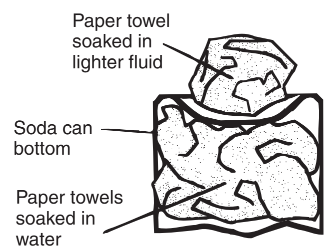


Figure 2.

3. Using tin snips, cut off the bottom one-third of an empty soda can.
4. Moisten several paper towels with water and stuff them into the bottom of the can.
5. Place the can with the wet paper towels upside-down on the center of the Lazy Susan so that concave bottom of the can is upward and creates a small "bowl."
6. Wad up a half-sheet of dry paper towel and place it in the concave bowl (see Figure 3).
7. Using a pipet, soak the paper towel with lighter fluid or kerosene. The wet paper towels under the can act to weigh the can down, to hold it in place, and to provide a heat sink so that neither the can nor the Lazy Susan beneath gets too hot.



For Water Jug Race Demonstration

1. Fill the two jugs up completely with tap water.

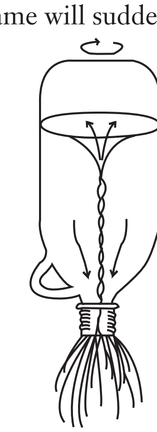
Procedure

Flame Tornado Demonstration

1. Light the fuel-soaked paper towel with a Butane safety lighter and observe the flame.
2. Gently spin the Lazy Susan and observe any changes in the flame.
3. Carefully center the screen cylinder on the Lazy Susan, and give the Lazy Susan a gentle spin. The flame will suddenly grow to a tall, roaring vortex of fire!
4. Stop the spinning, and the flame immediately resumes its original form.
5. Repeat steps 3–4 several times.

Water Jug Race Demonstration

1. Invite two students to come up and race one another to see who can empty out their respective bottles into the bucket or basin in the least amount of time.
2. Let the winner stay in, and race against the winner yourself.
3. Give the winner a 3-second head start, then turn the jug upside-down and swirl the bottle in a circular motion, creating a vortex inside the bottle (see Figure 4). The water in your jug will pour out unimpeded—you win!



Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Leftover lighter fluid or kerosene may be stored in a dedicated flammables cabinet for future use. Douse the charred paper towel with water before disposing of in the regular trash.

Tips

- Do not use plastic screening material.
- If the Lazy Susan has a lip, then the screen cylinder can be made to be seated just inside it. If there is no lip, make the cylinder a little narrower, leaving about a 2 cm border all the way around. Since the optimal spin is a rather slow one, there is no reason to attach the cylinder to the Lazy Susan.
- Instead of racing against the winner of the first water jug race, invite other student challengers to come up and try their ideas. Eventually a student may come up with the solution.
- Use large funnels to quickly refill the jugs with water.

Discussion

Not only does hot air rise, but, of course, cool air sinks! Since a flame is composed of hot gases, it naturally extends upward and begins to create convection currents around it. Above the flame, however, is relatively cooler (denser) air that is "trying" to sink straight downward, against the flow of the convection currents. Perhaps the flickering and dancing of a flame is due at least in part to these two opposing forces—the hot flame rising momentarily, then the colder air pushing back downward.

This applies of course to a typical flame where the only force is gravity. According to Newton's First Law of Motion, when an object is forced to travel in a circular path, the object will still tend to continue in a straight line motion. Thus its momentum always acts to carry the object to the outer edge of its circular path. This gives rise to a fictitious phenomenon known as centrifugal force. If the flame and the cooler air above it are placed in a spinning frame of reference, the above mentioned "centrifugal force" would act more on the cooler, denser air on top, pulling it to the sides—or pushing it? (It's a fictitious force anyway, so what difference does it make!?) This outward flow of the air on top acts to enhance, rather than block, the convection currents. Essentially, a partial vacuum is created directly above the flame, and so the flame grows upward—unimpeded.

In the water jug race, when the bottle is tipped over, the water cannot all pour out at once. Since atmospheric pressure is pushing upward on the water surface as the water is pushing downward on the air, the water tends to come out in a chug-chug-chug manner. Essentially the denser water and the less dense air are trying to exchange places, and they get in each other's way. This chugging can perhaps be likened to the flickering and dancing of a flame as the rising hot gases and the sinking cooler gases push back and forth against one another.

This applies of course to a typical jug of water being emptied. If the jug is tipped over gradually, so that the water pours out through the bottom of the opening as the air pours in through the top, then this chugging can be eliminated. This proves, however, to be a very inefficient way to empty the bottle, essentially because it does not take full advantage of gravity! Swirling the bottle in a circular manner creates a vortex inside the bottle. The above mentioned "centrifugal force" acts more on the water than on the air, pulling the water to the sides of the bottle—or pushing it (. . . it's a fictitious force anyway, so what difference does it make!?). With a directionality established, the water can pour out unimpeded along the perimeter of the opening while the air pours in unimpeded through the center.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: structure and properties of matter, chemical reactions, motions and forces

Acknowledgments

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Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Flame Tornado and Water Jug Race* activity, presented by Bob Becker, is available in *Density of Gases* and in *Bob Becker's Favorite Combustion Reaction Demonstrations*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Flame Tornado and Water Jug Race* are available from Flinn Scientific, Inc.

Catalog No.	Description
K0002	Kersene, 500 mL
AP1012	Bottle, Narrow Mouth, Glass, PVC-Coated, 2.5 L
AP8393	Tin Snips
AP4609	Rotational Turntable

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.