Candle Flame In Microgravity

Lesson 2 of 2

Grade Level: 5-8
Subject: Physical Science
Prep Time: 10-30 minutes
Activity Duration: One class period
Materials Category: Special requirements

National Education Standards				
Science	Mathematics	Technology		Geography
		ISTE	ITEA	
2a, 3b				

Objective: To observe a candle flame's properties in freefall.

Materials:

- Clear plastic jar and lid (2-liter volume)
- Wood block*
- Screws*
- Birthday candles
- Matches
- Drill and bit*
- Eye protection
- Video camera and monitor (optional)

*The wood block and screws can be replaced with clay, and there would be no need for a drill and bit.

Related Links:

New Science: A New Flame
http://kids.msfc.nasa.gov/News/2000/News-Flames.asp
Microgravity Combustion Science
http://spaceflight.nasa.gov/station/science/microgravity/combustion.html

Candle Flame In Microgravity

Teacher Sheets

Pre-lesson Instructions

- Students will be working in groups and using fire. Make certain to go over lab safety rules. Eye protection should be worn.
- Be sure all materials are either centrally located or already distributed to the groups.
- Before attempting this activity, be sure to conduct the candle flames activity in Lesson One. Doing so will sharpen the students' observation skills. This is important because, in this activity, students will be observing the size, shape, and color of a candle flame as it is falling.
- This activity can be done as either a demonstration or a group activity.
- Clear, plastic food storage jars are available at variety stores, but plastic peanut butter jars will work as well. The jars should be 1-quart or half-gallon size (3-pound size if peanut butter jars are used). The oxygen supply in smaller jars runs out too quickly for proper observations.

Background

Combustion, or burning, is a rapid, self-sustaining chemical reaction that releases a significant amount of heat. Examples of common combustion processes are burning candles, forest fires, log fires, the burning of natural gas in home furnaces, and the burning of gasoline in internal combustion engines. For combustion to occur, three things must normally be present: a fuel, an oxidizer, and an ignition stimulus. Fuels can be solid, liquid, or gas. Examples of solid fuels include filter paper, wood, and coal. Liquid fuels include gasoline and kerosene. Propane and hydrogen are examples of gaseous fuels. Oxidizers can also be solid (such as ammonium perchlorate, which is used in Space Shuttle booster rockets), liquid (like hydrogen peroxide), or gas (like oxygen). Air, which contains oxygen, is a particularly common oxidizer. An electrical spark is an example of an ignition stimulus.

The objectives of NASA's microgravity combustion science program are to enhance our understanding of the fundamental combustion phenomena that are affected by gravity, to use research results to advance combustion science and technology on Earth, and to address issues of fire safety in space. The program, which operates under the direction of NASA's Microgravity Research Division, combines the results of experiments conducted in both ground-based, low-gravity facilities and space facilities and supports research in how flames ignite, spread, and extinguish under microgravity conditions.

Combustion studies in microgravity are important to spacecraft safety. Unlike house fires on Earth, you cannot run outside of a Space Station and wait for the fire department to arrive. Fires have to be extinguished quickly and safely. To do this, it is essential to understand how fires are ignited in microgravity and how they spread. The goal is to make sure that a fire never gets started.

Flames in the microgravity of space look completely different. Instead of a teardrop shape, a candle's flame is shaped like a ball. And instead of being yellow, the flame is blue. Air currents around the candle's flame cause the teardrop shape we are used to on Earth. As the air near the flame is heated, it becomes lighter, and rises. Heavier, cooler air flows in to replace it, and is also heated and rises. This creates a steady flow around the flame, called a convection current. In microgravity, there is no "heavier" or "lighter." So, there are no convection currents around the flame to shape it, and it spreads out into a ball.

Convection currents around a candle flame also carry soot particles upward. This gives the flame a yellow color. In space, a flame burns with very little soot, and the flame is a blue color.

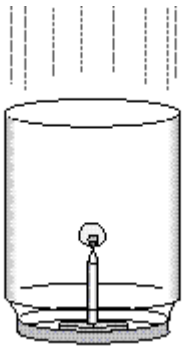
In the absence of buoyancy-driven convection, as in microgravity, the supply of oxygen and fuel vapor to the flame is controlled by the much slower process of molecular diffusion. Where there is no "up" or "down," the flame tends toward sphericity. Heat lost to the top of the candle causes the base of the flame to be quenched, and only a portion of the sphere is seen. The diminished supply of oxygen and fuel causes the flame temperature to be lowered to the point that little or no soot forms. It also causes the flame to anchor far from the wick, so that the burning rate (the amount of wax consumed per unit time) is reduced.

Flame on Earth  Flame in microgravity

Guidelines

1. Read the 5-8 NASAexplores article, "Fire Prevention In Space," and discuss why combustion studies in microgravity are important to spacecraft safety using the background information.
2. Review candle flame properties by making a list of terms that can be used to describe flame shape, size, color, and brightness on the board.
3. If the activity is used as a demonstration, only one candle drop jar is necessary. If it is used as a group activity, one candle drop jar is needed for each student group.
4. If using clay instead of the wood block and screw, press the lump of clay inside the jar lid, and push the end of the candle into the clay. It will probably be necessary to reform and/or reposition the clay after a couple of drops.
5. If you are using the wood block and screw, which makes a long-lasting candle drop jar, prepare the candle drop jar by drilling a hole in the center of the block to hold the end of the candle.
6. Drill two pilot holes into the wood for the screws, and drill holes through the plastic jar lid.

7. With the block in place, insert screws through the lid holes, and screw them into the wood block where you drilled the pilot holes. The candle drop jar is ready.



8. Students will drop the candle at least three times during their investigation.
9. During the drops, there are three jobs that must be performed:
    1. One student will drop the candle.
    2. One student will catch it.
    3. One student will observe the properties of the candle flame as it falls.
10. Since fire is used, remind students to wear eye protection.
11. This activity works best in a room that can be darkened. Coordinate the observations of the student groups so all are ready to drop the candle when the lights are dimmed.
12. Students will observe that the first time a birthday candle is lit, the flame is larger than when it is lit again. This happens because the wick sticks out farther from the wax on a new candle than it does on a used candle. The excess is burned quickly and the flame size diminishes slightly.

Discussion/Wrap-up

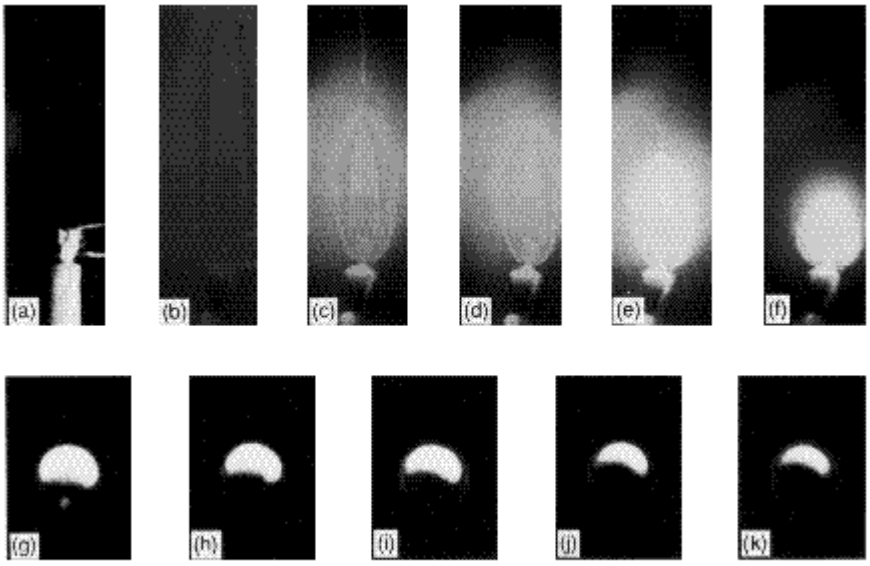
- Discuss the experiment, and review the Student Sheets.
- If videotape equipment is available, videotape the candle flame during the drop. Use the pause control during the playback to examine the flame shape.
- Use the Student Sheets for assessment.

Extensions

- Students could build a model of the microgravity experiment they are instructed to design in the last step on the student experiment sheet. The students can present their ideas to the rest of the class and exhibit their device.
- If a balcony is available, drop the jar from a greater distance than is possible in a classroom. Does the candle continue to burn through the entire drop? For longer drops, it is recommended that a catch basin be used to catch the jar. Fill a large box or plastic trash can with Styrofoam packing material or loosely crumpled plastic bags or newspaper.

Candle Flames In Microgravity

Microgravity experiments using drop towers and Space Shuttle Orbiters have provided scientists valuable insights on how things burn. In the typical experiments, a hot wire ignites a flammable material, such as a candle. Movie cameras and other data collection devices record the ignition and combustion process. Using these devices, scientists have learned there are significant differences between fires on Earth in normal gravity and those in microgravity.



Candle flame test in the 132 Meter Drop Tower at the NASA Lewis Research Center

Candle Flame In Microgravity

Student Sheets

NASA is studying flames at the Glenn Research Center in Cleveland, Ohio. A flame's shape, temperature, how fast it burns, the soot produced, and how fast the flame can be put out are all of interest to NASA's scientists.

These differences aren't just interesting. It is very important to know how flames might start, stop, or burn on spacecraft. After all, if your spacecraft catches fire, you can't rush outside to get away from it. If you got into a spacesuit quickly and rushed out, and your spacecraft burned up, then where would you go?

By studying flames in microgravity, scientists will learn what conditions would produce the worst fires in a spacecraft, and how to put them out, and the studies will also answer questions about fires on Earth.

Candle Drop

Procedure

1. Put on eye protection.
2. Light the candle, and screw the jar on to the lid. Observe the candle until it goes out.
3. Draw a picture of the shape of the candle flame below.

4. What is the color of the flame?
5. Predict what you think will happen to the candle flame when the candle is dropped.

6. Open the jar to release the bad air. Relight the candle, and screw the jar back on to the lid. Have one team member hold the jar as high off the floor as possible. On the count of three, the jar is dropped to the floor where a second team member is waiting to catch it. The third member acts as the observer. The observer will record data in the table.
7. Repeat step 4 twice more, but rotate the jobs so that each team member gets the chance to drop the jar, and write down observations.

Candle Drop Data Table

Descriptions	1	2	3
Candle Flame Shape			
Candle Flame Brightness			
Candle Flame Color			
Other Observations			

8. What changes took place when the candle flame experienced microgravity?

9. Compare these changes to the candle flame that was not dropped.

10. Why do you think these changes took place?

11. Design a candle flame experiment that could be used on the International Space Station. Write the experiment hypothesis, on another piece of paper, and sketch the apparatus that will be needed. Write a short paragraph describing the device, how it will work, and what safety procedures you would use.