

Candle Flame in Microgravity

Objective:

- To observe candle flame properties in freefall.

Science Standards:

- Science as Inquiry
- Physical Science
 - position and motion of objects
- Unifying Concepts & Processes
- Change, Constancy, & Measurement
- Science & Technology
 - abilities of technological design

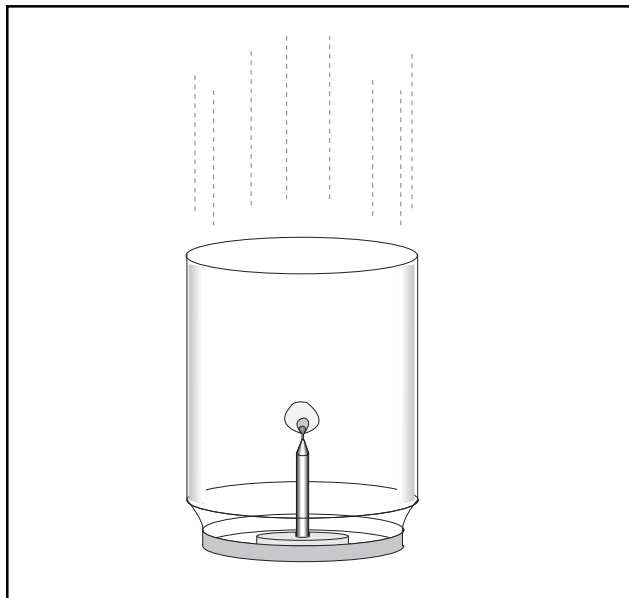
Science Process Skills:

- Observing
- Communicating
- Collecting Data
- Inferring
- Predicting
- Interpreting Data
- Hypothesizing
- Controlling Variables
- Investigating

Activity Management:

Before attempting this activity, be sure to conduct the Candle Flames activity. Doing so will sharpen the observation skills of the students. This is important because, in this activity, students will be observing the size, shape, and color of a candle flame as it is falling.

Investigating candle flames in microgravity can be done as either a demonstration or an activity. If used as a demonstration, only one candle drop jar is necessary. If used as an activity, one candle drop jar is needed for each student group. Clear plastic food storage jars are available at variety



A burning candle is encased by a clear plastic jar and dropped for a study of flames in microgravity.

MATERIALS AND TOOLS

- Clear plastic jar and lid (2 liter volume)*
- Wood block
- Screws
- Birthday candles
- Matches
- Drill and bit
- Video camera and monitor (optional)
- Eye protection
- * Empty 3-lb plastic peanut butter jar can be used.

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.

The wood block and screws called for in the materials and tools list can be replaced with a lump of clay. Press the lump to the inside of 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. The wood block and screws make a longlasting candle drop jar.

If you are using wood blocks and screws, prepare the candle drop jars by drilling a hole in the center of the block to hold the end of the candle. Drill two pilot holes into the wood for the screws. Finally, drill holes through the plastic jar lid. 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.

If you are using this as an activity, divide students into groups of three. Save the student reader for use after the experiment has been conducted. Students will drop the candle at least three times during their investigation. During the drops, there are three jobs that must be performed. One student will drop the candle, another will catch it, and the third will observe the properties of the candle flame as it falls. The jobs should be rotated through the group so each student performs each job once.

Since fire is used, be sure everyone working with the activity wears eye protection. The 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.

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.

Assessment:

Use the student pages for assessment. For additional work, have students actually build a model of the microgravity experiment they are instructed to design in the last step on the student pages. The students can present their ideas to the rest of the class and exhibit their device.

Extensions:

1. If videotape equipment is available, videotape the candle flame during the drop. Use the pause control during the playback to examine the flame shape.
2. 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 up a large box or plastic trash can with Styrofoam packing material or loosely crumpled plastic bags or newspaper.

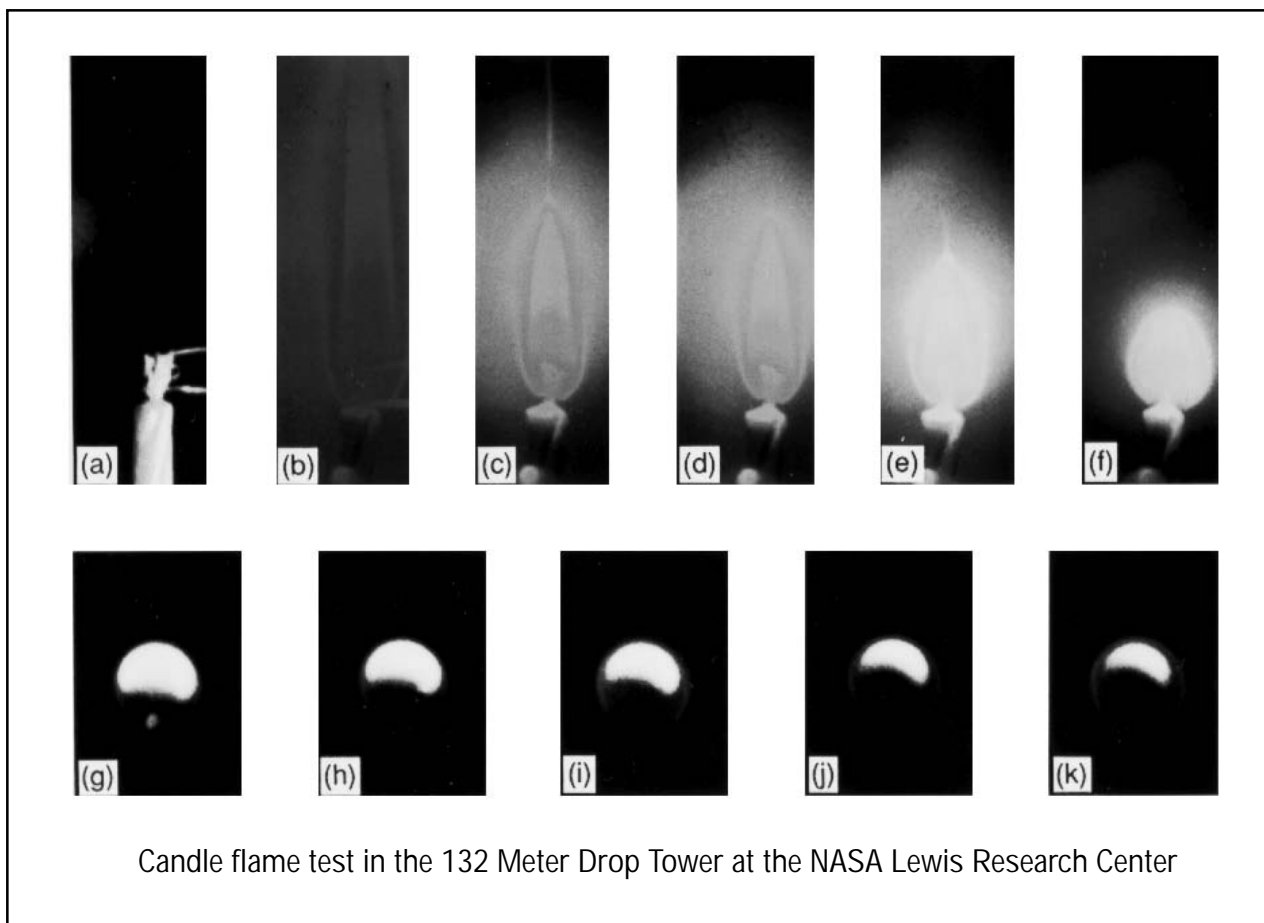


Candle Flames in Microgravity

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

The sequence of pictures, at the bottom of this page, illustrates a combustion experiment conducted at the NASA Lewis Research Center 132 Meter Drop Tower. These pictures of a candle

flame were recorded during a 5-second drop tower test. An electrically heated wire was used to ignite the candle and then withdrawn 1 second into the drop. As the pictures illustrate, the flame stabilizes quickly, and its shape appears to be constant throughout the remainder of the drop. Instead of the typical teardrop shape seen on Earth, the microgravity flame becomes spherical. On Earth, the flame is drawn into a tip by the rising hot gases. However, convection currents are greatly reduced in microgravity. Fresh oxygen is not being delivered to the candle by these currents. Instead, oxygen works its way slowly to the flame by the process of diffusion. Soon, the flame temperature begins to drop because the



combustion is less vigorous. The lower temperature slows down the melting and vaporization of the candle wax. Candles onboard the first United States Microgravity Laboratory, launched in June 1992, burned from 45 seconds to about 1 minute before being extinguished because of the dropping temperature and reduction of wax vapor.

Combustion studies in microgravity are important to spacecraft safety. Unlike house fires on Earth, you can not 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.

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.



Candle Drop

Candle Drop Team Members:

What is the color of the flame?

Predict what you think will happen to the candle flame when the candle is dropped.

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. 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. Data are recorded by the observer in the table on the next page.
5. Repeat step 4 twice more but rotate the jobs so each team member gets the chance to drop the jar, catch the jar, and write down observations.



Candle Drop Data Table

Team Member:

1

2

3

Candle flame shape			
Candle flame brightness			
Candle flame color			
Other observations			

What changes took place when the candle flame experienced microgravity?

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

Why do you think these changes took place?

Design a candle flame experiment that could be used on the International Space Station. Write out, on another piece of paper, the experiment hypothesis 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.

