National Aeronautics and
Space Administration

Teaching From Space
Education Working Group
Johnson Space Center

Educational Products	
Teachers and Students	Grades 5-12

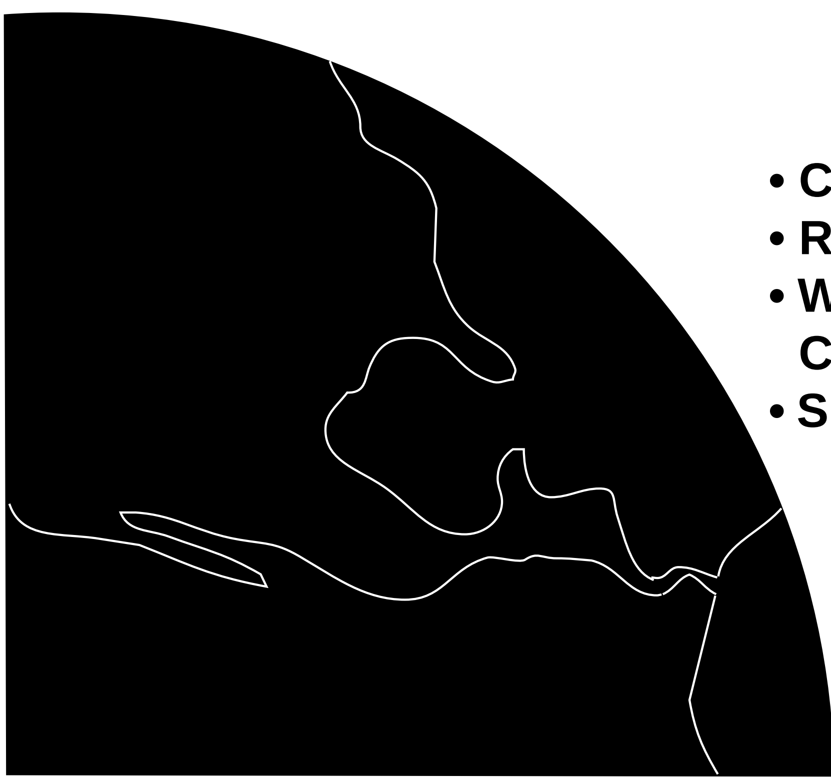
Education Videoconference

For Teachers and Students in Grades 5-12

Chemistry
Physical Science
Mathematics

A Pitch for Microgravity

Activity Packet



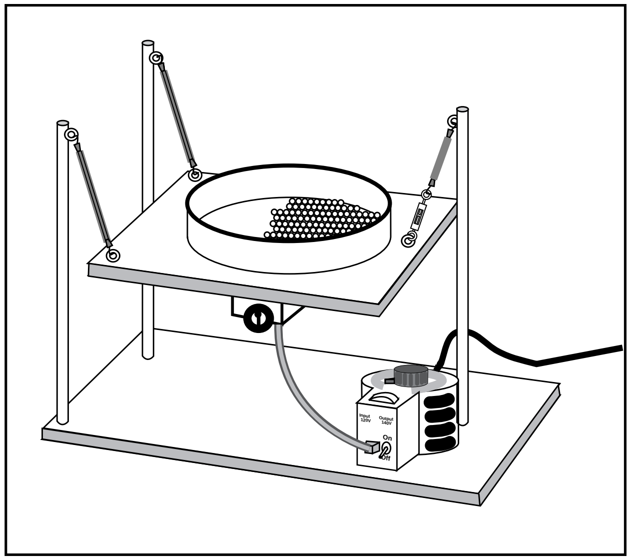
- **Crystallization Model**
- **Rapid Crystallization**
- **Wire Supported Droplet Combustion Experiment**
- **Surface Tension**

Educational Product	
Teachers and Students	Grades 5-12

National Aeronautics and
Space Administration

Teaching From Space
Education Working Group
Johnson Space Center

Crystallization Model



OBJECTIVE:

To demonstrate how atoms in a solid arrange themselves.

BACKGROUND:

Crystalline solids are substances whose atoms or molecules are arranged into a fixed pattern that repeat in three dimensions. Crystalline materials generally begin as a fluid of atoms or molecules in either the liquid or gaseous state. As they change to the solid state, the atoms or molecules join together in repeating patterns. Materials that do not form these patterns are called *amorphous*. Glass is a good example of an amorphous material.

The usefulness of a crystal depends its structure. All crystalline materials have varying degrees of defects. Defects can take many forms. Gem-quality diamonds sometimes have small inclusions of carbon (carbon spots) that diminish their light refraction and thereby reduce their value. In other crystalline materials, defects may actually enhance value. Crystals used for solid state electronics have impurities deliberately introduced into their structure that improve their electrical properties. Impurity atoms may substitute for the normal atoms in a crystal's structure or may fit in the spaces within the structure. Other defects include vacancies, where atoms are simply missing from the structure, and dislocations in which a plane of atoms is missing. The important thing about crystal defects is to be able to control their number and distribution. Uncontrolled defects can result in unreliable electronic properties or weaknesses in structural metals.

Many forces can affect the structure of a crystal. One of the most important forces that can influence the structure of a growing crystal is gravity. Growing crystals in microgravity can reduce gravity effects to produce crystals with better defined properties. The information gained by microgravity experiments can lead to improved crystal processing on Earth.

The connection between the force of gravity and the formation of defects varies from very simple and straightforward to complicated and nonintuitive. For example, mercury iodide crystals can form from the vapor phase. However, at the growth temperature (approximately 125 degrees Celsius) the crystal structure is so weak that defects can form just due to the weight of

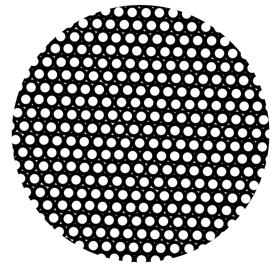
MATERIALS NEEDED:
Wood base and supports
Shallow pan
3 Small Bungee cords
Small turnbuckle
Surplus 110 volt AC electric motor
Motor shaft collar
Variable power transformer
Several hundred BBs

the crystal. On the other hand, the relationship between residual fluid flows caused by gravity and any resulting crystalline defects is not well understood and may be very complex.

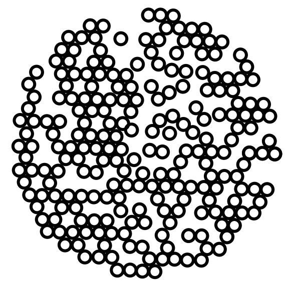
This activity consists of a two-dimensional demonstration that illustrates the process of crystal structure formation and defect formation. BBs, representing atoms of one kind, are placed into a shallow pan which is vibrated at different speeds. The amount of vibration at any one time represents the heat energy contained in the atoms. Increasing the vibration rate simulates heating of a solid material. Eventually, the atoms begin to separate and move chaotically. This simulates melting. Reducing the amount of vibration brings the atoms back together where they "bond" with each other. In this demonstration, gravity pulls the BBs together to simulate chemical bonds. By observing the movement of BBs, a number of crystal defects can be studied as they form and transform. Because of movements in the pan, defects can combine (annihilation) in such a way that the ideal hexagonal structure and new defects will form.

Sample Crystal Defects

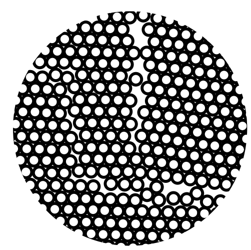
The following diagrams show a magnified view of an ideal two-dimensional crystalline structure (hexagonal geometry) and a variety of defects that the structure might have.



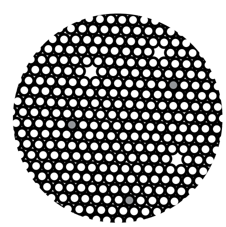
Ideal crystalline structure.



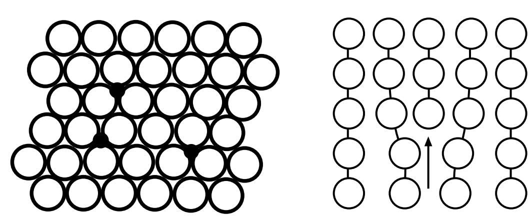
Amorphous or glassy structure (when stationary) or a liquid structure (when in motion).



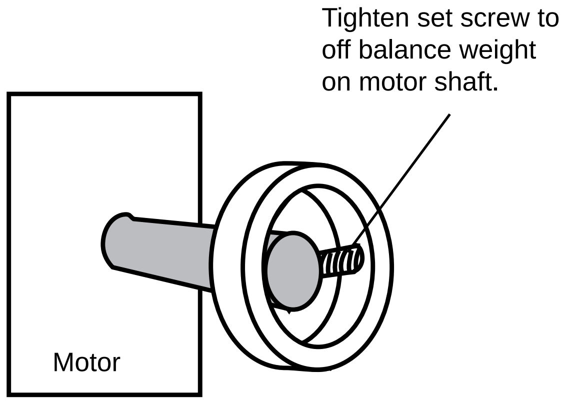
Crystalline structure with surface (grain boundary) defects.



Crystalline structure with point defects (vacancies and substitution impurities).



Crystalline structure (further magnified) with interstitial and edge dislocations.



Oversize collar mounted on motor shaft.

In
PROCEDURE:
Constructing The Vibrating Platform

Note: Specific sizes and part descriptions have not been provided in the materials list because they will depend upon the specific dimensions of the surplus electric motor obtained. The motor should be capable of several hundred revolutions per minute. Adjust the materials and support platform to fit the motor.

Step 1. Mount three vertical supports on to the wooden base. They can be attached with corner braces or by some other means.

Step 2. Mount the surplus motor to the bottom of the vibrating platform. The specific mounting technique will depend upon the motor. Some motors will feature mounting screws. Otherwise, the motor may have to be mounted with some sort of strap. When mounting, the shaft of the motor should be aligned parallel to the bottom of the platform.

Step 3. Slip the collar over the shaft of the motor and tighten the mounting screw to the shaft. See the diagram below for how the shaft and collar should look when the collar is attached properly.

Step 4. Suspend the platform from the three vertical supports with elastic shock cords or springs. Add a turnbuckle to one of the cords for length adjustment. Shorten that cord an amount equal to the length of the turnbuckle so that the platform hangs approximately level.

Step 5. Using hook and loop tape, mount the pan on the upper side of the vibrating platform.

Step 6. Place several hundred BBs in the pan. If the BBs spread out evenly over the pan, lengthen the turnbuckle slightly so that the BBs tend to accumulate along one side of the pan.

Step 7. Turn on the motor by raising the voltage on the variable transformer. If the device is adjusted properly, the BBs will start dancing in the pan in a representation of melting. Lower the voltage slowly. The BBs will slow down and begin to arrange themselves in a tight hexagonal pattern. If you do not observe this effect, adjust the leveling of the platform slightly until you do. It may also be helpful to adjust the position of the motor slightly.

PROCEDURE:
Studying Crystal Defects

Step 1. Turn up the voltage on the variable transformer until the BBs are dancing about in the pan. This represents melting of a solid.

Step 2. Shut the variable transformer off. This represents rapid cooling of the liquid to a glassy (amorphous), state. Observe and sketch the pattern of the BBs and defects you observe.

Step 3. Turn up the voltage again and gradually reduce the vibration until the BBs are moving slowly. Observe and sketch the pattern of the BBs. Describe the formation and annihilation of defects.

QUESTIONS:

1. Could this demonstration be conducted in microgravity?

2. Why is it important to conduct crystal growing experiments on NASA's International Space Station?

FOR FURTHER RESEARCH:

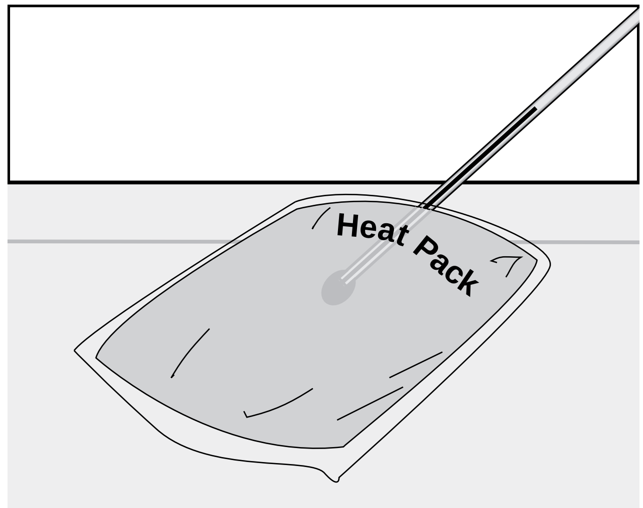
1. Design a crystal growing experiment that could be used on the International Space Station. Conduct a ground-based version of that experiment. How would the experiment apparatus have to be changed to work on the space station?

Educational Product	
Teachers and Students	Grades 5-12

National Aeronautics and
Space Administration

Teaching From Space
Education Working Group
Johnson Space Center

Rapid Crystallization



OBJECTIVE:

To investigate the growth of crystals under different temperature conditions.

BACKGROUND:

Crystals are solids composed of atoms, ions, or molecules arranged in orderly patterns that repeat in three dimensions. The geometric form of a crystal visible to the naked eye can be an external expression of the orderly arrangement inside. Many of the unique properties of materials, such as strength and ductility, are a consequence of crystalline structure.

It is easy to get confused about the nature of crystals because the word crystal is frequently misused. For example, a crystal chandelier is not crystal at all. Crystal chandeliers are made of glass which is a solid material that does not have a regular interior arrangement. Glass is called an *amorphous* material because it does not have a regular interior arrangement of atoms.

Scientists are very interested in growing crystals in microgravity because gravity often interferes with the crystal growing process to indirectly produce different types of defects in the crystal structure. The goal of growing crystals in microgravity is not to develop crystal factories in space, but to better understand the crystal growing process and the effects that gravity can have on it.

In this activity, crystal growth will be studied with chemical hand warmers. The hand warmers are sold in full-line camping and hunting stores. They consist of a plastic pouch filled with a food-grade solution of sodium acetate and water. Also in the pouch is a small disk of stainless steel. Snapping the disk triggers the precipitation and crystallization of the sodium acetate. As the solid material forms from solution (precipitation) the chemicals release heat (*heat of solution*) that maintains the pouch temperature at about 54 degrees Celsius for a half hour. This makes the pouch ideal for a hand warmer. Furthermore, the pouch is reusable indefinitely by reheating and dissolving the solid contents again.

The pouch is designed so that at room temperature, the water contains many more molecules of sodium acetate than would normally dissolve at that temperature. We call this a *supersaturated* solution. The solution remains that way until it comes in contact with a seed crystal or some way of rapidly introducing energy into the solution which acts as a trigger for the start of crystallization. Snapping the metal disk inside the pouch delivers a sharp mechanical energy input to the solution that triggers the crystallization process. Crystallization takes place so rapidly that the growth of crystals is easily observable.

PROCEDURE:

Note: This activity involves small groups of students. Because the activity requires boiling water, students should be cautious when removing the heat packs from the boiler carefully to avoid scalding burns. If you would prefer, handle procedure 1 of the activity yourself.

Step 1. Prepare the heat packs by boiling each until all crystals have dissolved. Using tongs, remove the pouches and place them down on towels to dry off excess water.

Step 2. Each student group should place a pouch on a styrofoam food tray and slide the bulb of a thermometer under the pack. When the pouch temperature is below 54 ^{o} C, snap the internal metal disk to trigger crystal growth. Before doing so, move the disk to one corner of the pouch.

Step 3. Using the data sheet on the next page, the students should observe the crystal growth in the pouch.

Step 4. Repeat the activity several times, but cool the pouch to different temperatures. To encourage the pouch to cool more rapidly, place it on a hard surface such as a metal cookie sheet or a table top. Return it to the styrofoam to measure its temperature and trigger the crystallization.

QUESTIONS

1. Is there any relationship between the initial temperature of the pouch and the temperature of the pouch during crystallization?
2. Is there a relationship between the initial temperature of the pouch and the time it takes for the pouch to completely solidify?
3. Do other materials, such as water, release heat when they freeze?
4. What do you think would happen if the heat pack were crystallized in microgravity? What effect does gravity have? Hold the pack vertically with the steel disk at the bottom and trigger the solidification. Repeat with the disk at the top. Using two thermometers, measure the temperature of the top and bottom of the pack during crystallization.

FOR FURTHER RESEARCH

1. What do you think would happen if the heat pack were crystallized in microgravity? What effect does gravity have? Hold the pack vertically with the steel disk at the bottom and trigger the solidification. Repeat with the disk at the top. Using two thermometers, measure the temperature of the top and bottom of the pack during crystallization.
2. Try chilling a heat pack pouch in a freezer and then triggering the solidification.
3. Identify other ways the word "crystal" is misused.
4. Compare a piece of granite with a piece of obsidian. Both rocks have approximately the same composition. Why are they different from each other.
5. Research about some of the applications of crystalline and amorphous materials.

MATERIALS

Heat pack hand warmers (1 or more per group)
Water boiler (an electric kitchen hot pot can be used)
Styrofoam meat tray (1 per group)
Metric thermometer (1 or more per group)
Observation and data table (1 per student)

Heat Pack Experiment Data Sheet

Name: ______________________________

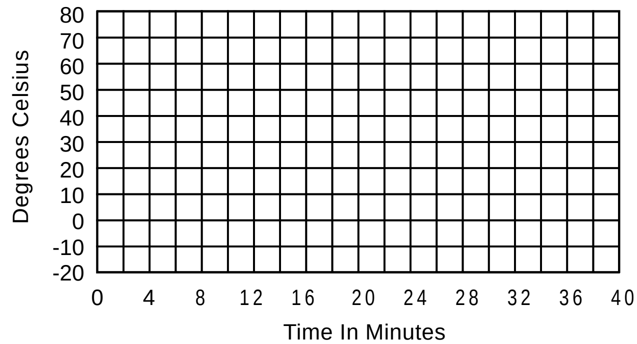
Test Number: ___________

Initial temperature of pouch: ____________

Final temperature
at end of crystallization: ____________

Describe the crystals
(shape, growth rate, size, etc.)

Cooling Graph



Sketch of Crystal

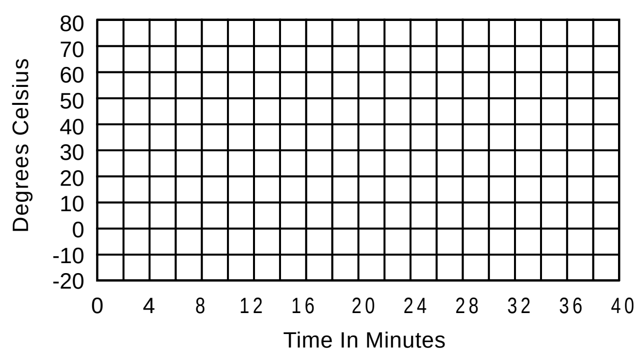
Test Number: ___________

Initial temperature of pouch: ____________

Final temperature
at end of crystallization: ____________

Describe the crystals
(shape, growth rate, size, etc.)

Cooling Graph



Sketch of Crystal

Educational Product	
Teachers and Students	Grades 5-12

National Aeronautics and
Space Administration

Teaching From Space
Education Working Group
Johnson Space Center

Wire Supported Droplet Combustion Experiment

OBJECTIVE:

To measure and observe the development of flames produced by igniting a droplet of flammable liquid.

BACKGROUND:

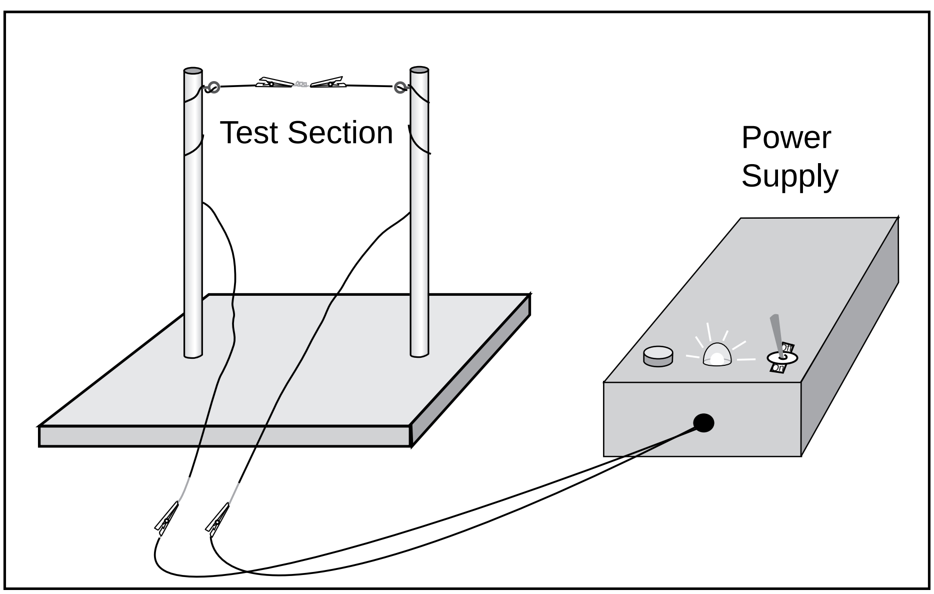
Microgravity research into combustion centers on three main areas: combustion of gases, combustion of liquid fuels (single droplets and sprays), and combustion of solid fuel and flame spread. This experiment explores the combustion of single droplets of a liquid fuel.

When a droplet of liquid fuel ignites on Earth, the temperature of the surface of the fuel changes from room temperature to hundreds of degrees in a fraction of a second. This leads to large density differences and hence, to the potential existence of strong buoyancy-driven fluid flows. Because of these flows, the droplet is consumed very quickly. In microgravity, the strength of buoyancy-driven flows is greatly reduced. This slows down flame spread and lengthens the time the combustion will last.

To study droplet combustion on Earth and in microgravity, a droplet is formed on a fiber which acts as a support for the drop. Without this fiber, the drop would fall to the bottom of the test chamber on Earth. In microgravity, the droplet would drift away from the center of the test device and be difficult to investigate precisely. The fiber (wire in the Earth experiment) stabilizes the drop for study.

APPARATUS DESCRIPTION:

The power supply used for this experiment is identical in design to a model rocket launch control box. The device will supply electricity to the test section only



MATERIALS NEEDED:

Power Supply

Project Box (18.9x10.8x6.0 cm)
D Cell Battery Holder
Holder for Bayonet Base Lamp
#1847 Lamps, 6.3 volts (1)
Momentary Push-button Switch
Toggle Switch
Hook-up or bell wire (1 meter)
24" Jumper Leads (2)
4 D-Cells

Test Section

Wooden base 1x8x8 inches
2 Dowels 5/8 inches diameter by 10 inches long
2 small screw eyes
24" Jumper Leads (2)
30 gauge or smaller galvanized florist wire (1 spool)
Charcoal Lighter Fluid
Eye Dropper
Safety Goggles

when the On/Off switch is set to On and the push-button switch is depressed. The wires mounted to the dowels on the test section can be directly attached to the power supply. Using jumper leads with microclips permits separating the test section and power supply for easy storage or for other uses.

Holes are drilled into the project box for the two switches, arming light, and wire leads. Follow the wiring diagram on the next page for assembly.

The stand for the test section is made from a board that is drilled to receive two dowels. Small screw eyes are attached to the upper ends of the dowels to hold the jumper leads in the correct position. When the leads are aimed towards each other, the microclips should be about 1 cm apart. This gap will be bridged by the ignition wire coil. Step 1 in the section that follows will explain how the coil is made.

You may find it necessary to try different kinds of wire or increase the voltage of the power supply to achieve a rapid ignition. This is because different brands of florist wire vary in gauge and resistance. If the ignition is too slow, the fuel may evaporate before the wire ignites. Balancing the wire's gauge and resistance with the power supply will insure reliable ignitions.

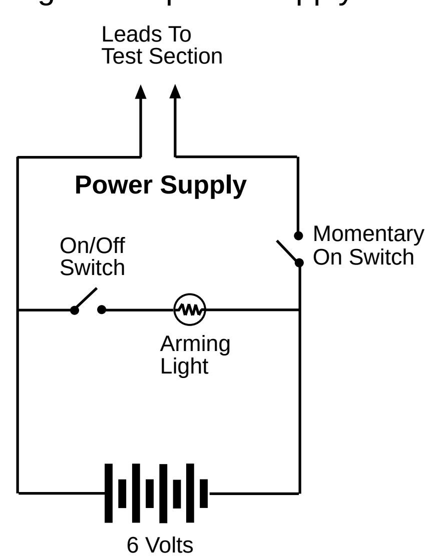
PROCEDURE:
Ground Control Experiment

Step 1. Wrap a short piece of ignition wire around the small nail to form a tight coil of 5 loops. While making sure the ignition light on the power supply is turned off, use the coil you just created to span the gap between the two alligator clips in the test section.

Step 2. Put on your eye protection. Use the eye dropper to deposit a drop of charcoal lighter fluid on the wire coil you mounted in the test section. The coils will support the drop.

Step 3. Turn on the ignition light on the power supply. When ready to observe the combustion process,

Wiring diagram for power supply



press and hold the push button switch until the liquid ignites.

Step 4. Record the observations you were able to make on the data sheet about the flame produced. How long did it last? What was its shape? What color was it? How bright was the flame?

Step 5. Repeat the experiment several times. Use the video camera to capture the droplet ignition on video- tape. Replay the tape on a video playback machine. Advance the videotape with the step or slow motion control to make the flame process last longer. (Note: Each second of a videotape consists of 30 frames. Thus, a video tape play back unit permits you to observe the flame in intervals of one 30th of a second.) Again, record date in the chart. Make sketches of the shape of the flame at different stages in its development.

QUESTIONS:

1. What do you think were the primary forces acting on your flame to cause it to act as it did?

2. What do you think burning droplet would do in microgravity?

PROCEDURE: Microgravity Experiment

Step 1. Observe the videotape of the *Fiber Supported Droplet Combustion Experiment* that was conducted on the Second United States Micro-gravity Mission (STS-73). Note: The tape will be available from NASA Teacher Resource Centers in late 1995 or early 1996.

Step 2. Record the observations you were able to make on the data sheet about the flame produced. How long did it last? What was its shape? What color was it? How bright was the flame?

QUESTIONS:

1. What do you think were the primary forces acting on the flame in microgravity to cause it to act as it did?

2. Were there any differences in the way the droplets combusted on Earth and in microgravity?

FOR FURTHER RESEARCH:

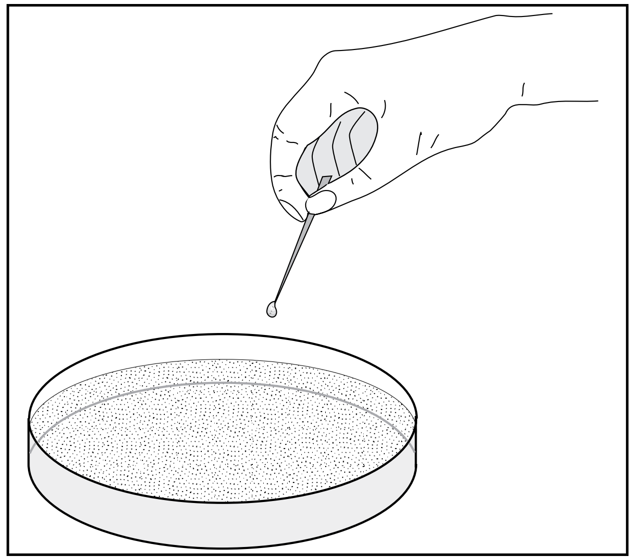
1. Learn about automatic fire extinguisher systems in use in restaurants, airplanes, public buildings, and other for commercial applications. Do these devices take advantage of gravity to aid in the extinguishing process.
2. Design a fire extinguisher that could work in microgravity.

Educational Product	
Teachers and Students	Grades 5-12

National Aeronautics and
Space Administration

Teaching From Space
Education Working Group
Johnson Space Center

SURFACE TENSION



OBJECTIVE:

To study surface tension and the fluid flows caused by differences in surface tension.

BACKGROUND:

The spherical shape of liquid drops is a result of surface tension. Molecules on the surface of a liquid are attracted to their neighbors in such a way as to cause the surface to behave like an elastic membrane. This can be seen in drops of rain, drops of oil, dewdrops, and water beading on a well-waxed car.

Beneath the surface of a liquid, molecules are attracted to each other from all directions. Because of this attraction, molecules have no tendency to be pulled in any preferred direction. However, a molecule on the surface of a liquid is pulled to each side and inward by neighboring molecules. This causes the surface to adjust to the smallest area possible, a sphere. Surface tension is what allows objects such as needles, razor blades, water bugs, and pepper to float on the surface of liquids.

The addition of a surfactant, such as liquid soap, to a liquid weakens the surface tension. Water molecules do not bond as strongly with soap molecules as they do with themselves. Therefore, the bonding force that enables the molecules to behave like an elastic membrane is weaker.

In a microgravity environment, buoyancy-driven fluid flows and sedimentation are greatly reduced. When this happens, surface tension can become a dominant force. Furthermore, microgravity makes it easier to study surface tension-driven flows than to study them in a normal gravity environment. An analogy to this process would be like trying to listen to a flutist (the surface tension-driven fluid flows) during a thunderstorm (the buoyancy-driven convection).

PROCEDURE:
Part One

Step 1. Fill the beaker, jar, or glass with water.
Step 2. Sprinkle some pepper on the water surface. Observe what happens to the pepper.
Step 3. Stir the water vigorously. Observe what happens to the pepper.
Step 4. Add new water to the container and mix in a few drops of liquid dish detergent. Carefully stir the water to

MATERIALS NEEDED*:
Beaker, clear jar, or drinking glass
Shallow dish or petri dish
Stirring rod
Water
Black pepper
Clear liquid dish detergent
Toothpick
Eyedropper
Wax paper squares (20 X 20 cm)
Metric rulers
*per group of students

dissolve the detergent, but try not to create any bubbles.

Step 5. Sprinkle pepper on the water surface. Observe what happens to the pepper.

Step 6. Fill the shallow dish or petri dish with water.

Step 7. Sprinkle some pepper on the surface. Observe any movement of the pepper on the surface.

Step 8. Touch one end of the toothpick into a drop of detergent to pick up a small amount of the detergent. Carefully touch the end of the toothpick to the surface of the water in the center of the dish. Be careful not to disturb the water. Observe any movement.

Step 9 (optional) Steps 6-8 can be demonstrated to the entire class by placing the dish on the stage of an overhead projector.

QUESTIONS:

1. Why did the pepper float on the water?
2. Why did the pepper sink when the water was stirred?
3. Does the amount of detergent affect the results of the experiment? Is more or less detergent better?
4. How does detergent enable us to wash dishes?

PROCEDURE:
Part Two

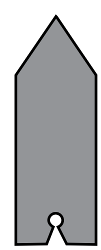
1. Fill an eyedropper with water. Carefully squeeze the bulb of the dropper to form a drop at the other end. Make sketches of the shape of the drop as it forms.
2. Place a drop of water on a square of wax paper. Make a sketch of its shape as it appears from both the top and the side. Measure the drop's diameter and height.
3. Add a second drop of water to the first and again sketch its shape and measure its diameter and height.
4. Continue adding water to the first until the drop becomes the size of a quarter.
5. Add a small amount of liquid detergent to the drop. Write a brief description of what happens to the drop.

QUESTIONS:

1. Is there any mathematical relationship between the number of drops placed on the wax paper and the diameter and height of the resulting water pool?
2. What shape would the water take in a microgravity environment? Would the wax paper be necessary for the experiment?

FOR FURTHER RESEARCH:

1. Make a surface tension-propelled paper boat by cutting a small piece of paper in the shape and size shown below and floating it on clean water. Touch a small amount of detergent to the water in the hole at the back of the boat.



2. Design an experiment to test whether the temperature of a liquid has any effect on surface tension.
3. Try floating needles on water and observe what happens when detergent is added.