

Gravity-Driven Fluid Flow

Objective:

- To study gravity-driven fluid flow that is caused by differences in solution density.

Science Standards:

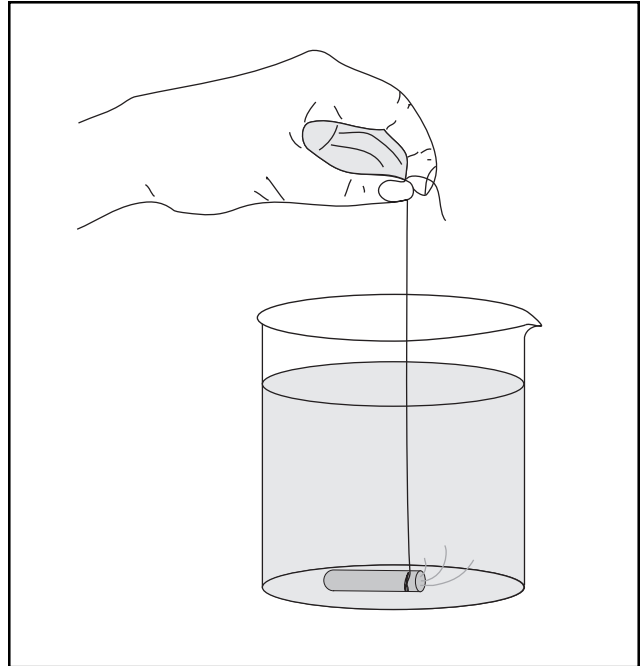
- Science as Inquiry
- Physical Science
 - position and motion of objects
 - properties of Objects and Materials
- Unifying Concepts and Processes
- Change, Constancy, & Measurement
- Science and Technology
 - abilities of technological design

Science Process Skills:

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

Activity Management:

In this activity, students combine liquids of different densities to observe the fluid flow caused by gravity-driven buoyancy and settling. The activity is best done in student groups of two or three. It can also be done as a demonstration for the entire class. In this case, obtain an overhead projector and place beakers on the lighted stage. The light from below will illuminate the contents of the jars to make them easily visible from across the room. To reduce distraction, cover the projector lens to prevent blurry images from falling on the wall or screen behind. Caution: Be careful not to spill liquid on the projector.



Water of different densities is mixed to produce gravity-driven fluid flow.

MATERIALS AND TOOLS

- 2 large (500 ml) glass beakers or tall drinking glasses
- 2 small (5 to 10 ml) glass vials
- Thread
- Food coloring
- Salt
- Spoon or stirring rod
- Measuring cup (1/4 cup)
- Water
- Paper towels

If using this as an activity, provide each student group with a set of materials. Salt canisters, food coloring dispensers, and measuring cups can be shared among groups. The materials list calls for glass beakers or tall drinking glasses. Other containers can be substituted such as mason jars or plastic jars like those in which peanut butter is sold.



The vials are available from school science supply catalogs for a few dollars per dozen. Choose glass vials with screw tops and a capacity of 3 to 4 ml. Small cologne sample bottles can be substituted for the vials. It is important that the vials or bottles are not too large because the process of lowering large containers into the beakers can stir up the water too much. It is recommended you tie the string around the neck of the vial yourself to make sure there is no slippage.

The student instructions ask the students to conduct three different experiments. In the first, the effects of saltwater and freshwater are investigated. In the second, the effects of warm and cold water are investigated. The third experiment is an opportunity for students to select their own materials. They might try mixing oil and vinegar, sugar and saltwater, or oil and water. It may be necessary for the third experiment to be conducted on another day while the new materials are collected.

Give each student group at least one set of instructions and two data sheets. Save the student reader for use after the experiment.

Assessment:

Discuss the experiment results to determine whether the students understand the concepts of buoyancy and sedimentation. Collect the student pages for assessment of the activity.

Extensions:

1. How could this experiment be conducted if it were not possible to use food coloring for a marker? (In experiments where the density of the two fluids is very close, the addition of food coloring to one fluid could alter the results.)
2. Design an apparatus that can be used to combine different fluids for experiments on the future International Space Station.
3. Design an experiment apparatus that would permit the user to control the buoyancy and sedimentation rates in the beakers.
4. Design an experiment to measure the gravity-driven effects on different fluids in which the fluids are actually gases.



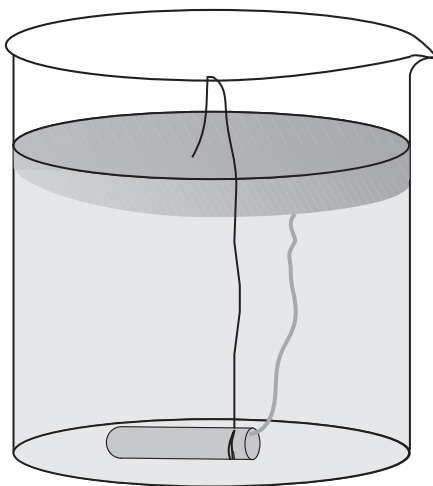
Gravity-Driven Fluid Flow

Gravity is an important force at work in the movement of fluids. Fluids can be liquids or gases. The important thing about fluids is they can flow from place to place and can take the shape of the container they are in.

When you pour a liquid from one container into another, gravity is the driving force that accomplishes the transfer. Gravity also affects fluids “at rest” in a container. Add a small amount of heat to the bottom of the container and the fluid at the bottom begins to rise. The heated fluid expands slightly and becomes less dense. In other words, the fluid becomes buoyant. Cooler fluid near the top of the container is more dense and falls or sinks to the bottom.

Many crystals grow in solutions of different compounds. For example, crystals of salt grow in concentrated solutions of salt dissolved in water. In the crystal growth process, the ions that make up the salt come out of solution and are deposited on the crystal to make it larger. When this happens, the solution that held the molecule becomes a little less salty than it was a moment

ago. Consequently, the density of the solution is a little bit less than it was. This, in turn, causes a fluid flow in the solution. The slightly less salty solution is buoyant and rises to the top of the container while saltier, or more dense, solution moves in to take its place.



Dyed freshwater in saltwater beaker

Scientists are interested in gravity-driven fluid flows because they have learned that these flows, when occurring during the growth of crystals, can create subtle changes in the finished crystals. Flaws, called defects, are produced that can alter the way those crystals perform in various applications. Crystals

are used in many electronic applications, such as in computers and lasers.

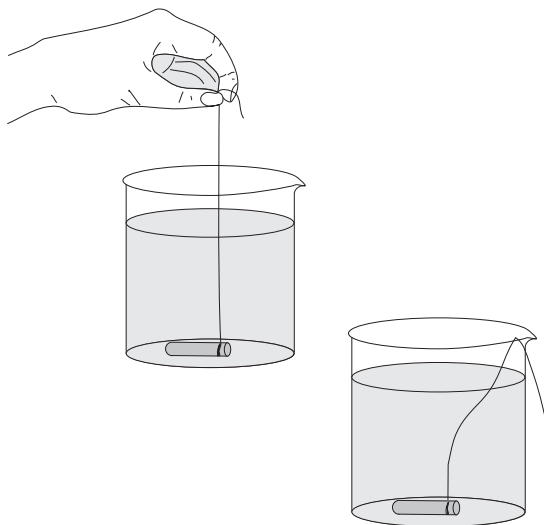
To learn how to grow improved crystals on Earth, scientists have been growing crystals in the microgravity environment of Earth orbit. Microgravity virtually eliminates gravity-driven fluid flows and often produces crystals of superior quality to those grown on Earth. One of the major areas of materials science research on the International Space Station will involve crystal growth.



Gravity-Driven Fluid Flow

Procedure

1. Fill the first beaker with freshwater and set it on the lab surface. Also fill the second beaker with freshwater. Into the second beaker add approximately 50 to 100 grams of salt. Stir the water until the salt is dissolved.
2. Dip the first small glass vial into the beaker with freshwater. Fill it nearly to the top. Add a couple of drops of food coloring to the water in the vial. Close the top of the vial with your thumb and shake the water until the food coloring is mixed throughout. Place this vial next to the saltwater beaker.
3. Partially fill a second vial with salty water and food coloring. After mixing, place it in front of the beaker filled with freshwater.
4. Wait a few minutes until the water in the two beakers is still. Gently lift one of the vials by the string and slowly lower it into the beaker next to it. Let the vial rest on its side on the bottom of the beaker and drape the string over the side as shown in the pictures. Answer the questions on the data sheets and sketch what you observed in the diagrams.
5. Place the second vial in the other beaker as before. Make your observations, sketch what you observed, and answer the questions about the data.



Second Experiment Procedure:

1. Empty the two beakers and rinse them thoroughly.
2. Fill one beaker with cold water and the other with warm water.
3. Repeat steps 2 through 5 in the previous experiments.

Original Experiment:

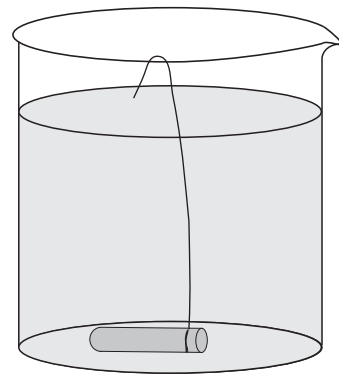
1. On a blank sheet of paper, write a proposal for an experiment of your own design that uses different materials in the beakers. Include in your proposal an experiment hypothesis, a materials list, and the steps you will follow to conduct your experiment and collect data. Submit your experiment to your teacher for review.
2. If your experiment is accepted for testing,
 - gather your materials
 - conduct the experiment
 - submit a report summarizing your observations and conclusions

Gravity-Driven Fluid Flow Data Sheet

Research Team Members:

Beaker and Vial:

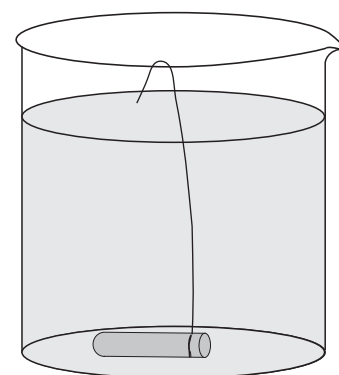
1. Water in beaker (check one)
Fresh _____
Salty _____
2. Water in vial (check one)
Fresh _____
Salty _____
3. Describe and explain what happened



Sketch what happened.

Beaker and Vial:

1. Water in beaker (check one)
Fresh _____
Salty _____
2. Water in vial (check one)
Fresh _____
Salty _____
3. Describe and explain what happened



Sketch what happened.



Surface Tension-Driven Flow

Objective:

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

Science Standards:

Science as Inquiry

Physical Science

- position and motion of objects

- properties of objects and materials

Unifying concepts and processes

Change, Constancy, &

Measurement

- evidence, models, & exploration

Science Process Skills:

Observing

Communicating

Measuring

Collecting Data

Inferring

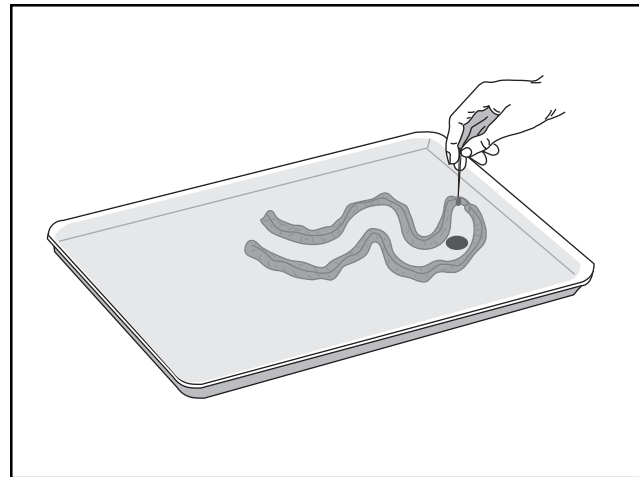
Predicting

Interpreting Data

Investigating

Activity Management:

The purpose of this activity is to demonstrate how surface tension changes can cause fluids to flow. It requires shallow trays with raised edges such as cafeteria trays. Large Styrofoam food trays from a supermarket can also be used, but they should be the kind with a smooth surface and not a waffle texture. Light-colored trays make a better background for seeing the surface tension effects. Encourage students to try different mazes and investigate the effects of wide versus narrow mazes.



A clay maze is constructed on a cafeteria tray. Water is added. A drop of liquid soap disrupts the surface tension of the water and creates currents that are made visible with food coloring.

MATERIALS AND TOOLS

Cafeteria tray (with raised edge)

Plasticine modeling clay

Water

Liquid soap

Food coloring

Toothpick

Paper towels

Bucket or basin for waste water

Water handling will be a bit of a problem. After a drop of liquid soap is applied to the water, the water must be discarded and replaced before trying the activity again. Carrying shallow water-filled trays to a sink could be messy. Instead, it is recommended that a bucket or large waste basket be brought to the trays so the trays can be emptied right at the workstation.

When soap is applied to the water, food coloring at the water's surface will be driven along the maze by the disruption of the water's surface tension. Make sure students observe what happens to the water at the bottom of the tray as well. A reverse current flows along the bottom to fill in for the water that was driven along the surface.

Save the student reader for use after the activity.

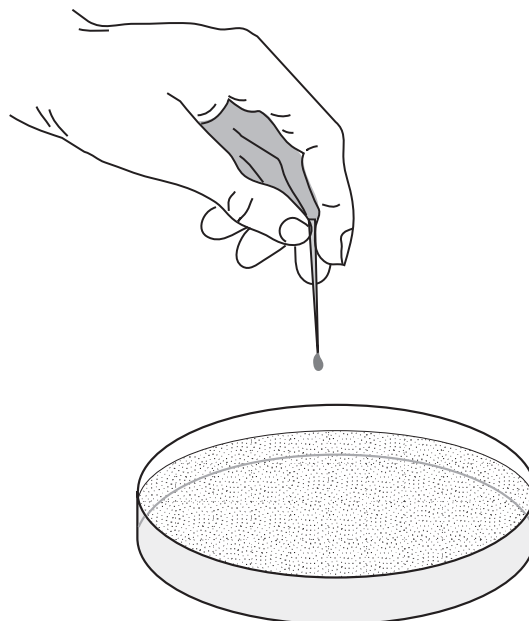
Assessment:

Conduct a class discussion to ensure the students understand that variations in surface tension in a fluid cause fluid flow. Collect the student pages.

Extensions:

1. Demonstrate additional surface tension effects by shaking black pepper into a glass of water. Because of surface tension, the pepper will float. When a drop of soap is added to the water, the pepper will sink. This same effect can be seen in a broader view by placing water into a petri dish and adding pepper and then soap. The pepper will be driven to the sides of the dish where particles will start sinking. The petri dish experiment can be done as a demonstration with an overhead projector.
2. Make a surface tension-propelled paper boat by cutting a small piece of paper in the shape shown to the right and floating it on clean water. Touch a small amount of detergent to the water in the hole at the back of the boat.
3. Design an experiment to test whether the temperature of a liquid has any effect on surface tension.

4. Try floating needles on water and observe what happens when detergent is added. To float the needle, gently lower it to the water's surface with a pair of tweezers.



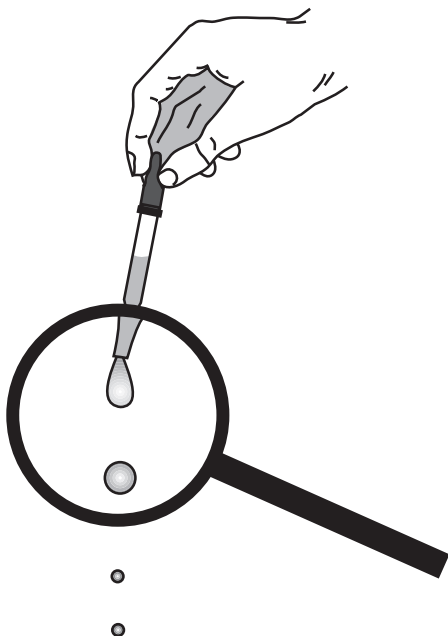
Surface Tension Paper Boat
(actual size)



Surface Tension



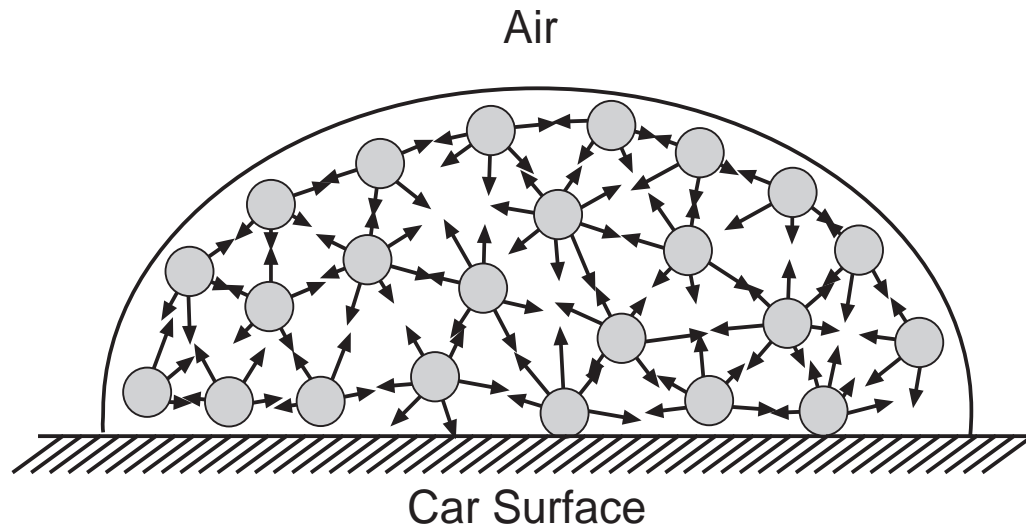
If you have ever looked closely at drops of water, you will know that drops try to form spherical shapes. Because of gravity's attraction, drops that cling to an eye dropper, for example, are stretched out. However, when the drops fall they become spherical.



The shape of a water drop is a result of surface tension. Water is composed of molecules consisting of two hydrogen atoms and one atom of oxygen. These molecules attract each other. In the middle of a drop of water, molecules attract each other in all directions so no direction is preferred. On the surface, however, molecules are attracted across the surface and inward. This causes the water to try to pull itself into a shape that has the least surface area possible—the sphere. Because of gravity, drops resting on a surface, like water drops on a well-waxed car, flatten out somewhat like the figure above.

The molecules on the surface of a liquid behave like an elastic membrane. You can easily see the elastic membrane effect by floating a needle on the surface of a glass of water. Gently lower the needle to the water surface with a pair of tweezers. Examine the water near the needle and you will observe that it is depressed slightly as though it were a thin sheet of rubber.

The addition of a surfactant, such as liquid soap, to water reduces its 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. If you put a drop of liquid soap in the glass with the needle, the surface tension is greatly reduced and the needle quickly sinks. When you added liquid soap to the water in the experiment, the surface tension was weakened in one place. The water on the surface immediately began spreading away from the site of the soap. The clay walls channeled the flow in one direction. To make up for the water moving away from the site where the soap was added, a second water current formed in the opposite direction along the bottom of the tray.



Molecules inside a water drop are attracted in all directions. Drops on the surface are attracted to the sides and inward.

Because a microgravity environment greatly reduces buoyancy-driven fluid flows and sedimentation, surface tension flows become very important. Microgravity actually makes it easier to study surface tension-driven flows. On Earth, studying surface tension in the midst of gravity-driven flows is like trying to listen to a whisper during a rock concert. The importance of surface tension research in microgravity is that surface tension-driven flows can interfere with experiments involving fluids. For example, crystals growing on the International Space

Station could be affected by surface tension-driven flows, leading to defects in the crystal structure produced. Understanding surface tension better could lead to new materials processing techniques that either reduce surface tension's influence or take advantage of it. One example of a positive application of surface tension is the use of sprayers to paint a surface. Surface tension causes paint to form very small droplets that cover a surface uniformly without forming drips and runs.

Surface Tension-Driven Flows

Team Members:

4. Dip the toothpick in the liquid soap and touch the end of the toothpick to the water at the end of the maze beyond the dye. Observe what happens.
5. Try a different maze to see how far you can get the dye to travel.

Setup Instructions:

1. Roll clay into long "worms" 1 to 2 centimeters in diameter. Lay the worms out on the tray to produce a narrow valley about 3 to 4 centimeters wide that is closed on one end. Squeeze the worms so they stick to the tray and form thin walls.
2. Add water to the tray until it almost reaches the tops of the maze walls. Let the water settle before the next step.
3. Add a drop of food coloring to the maze near its end. Drop the coloring from a height of about 5 centimeters so that some of the food coloring spreads out slightly on the surface while the rest sinks to the bottom.

Questions:

1. Why did the surface water move?
2. Did water near the bottom move as well? If it moved, why?

Make a sketch of the clay maze you constructed. Use arrows to show the direction of surface water movement after you added the soap. Use dashed line arrows to indicate the direction of any subsurface currents.

