Surface Tension-Driven Flow

Objective:

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

Science Standards:

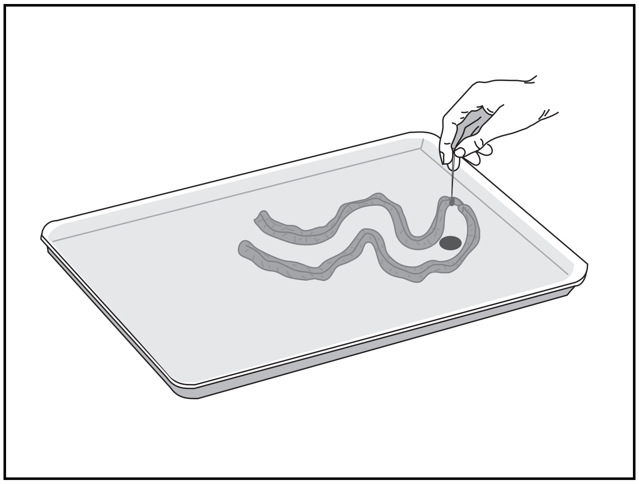
Science as Inquiry
Physical Science
- position and motion of objects
- properties of objects and materials
Unifying concepts and processes
Change, Constancy, & Measurement
- evidence, models, & exploration

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.

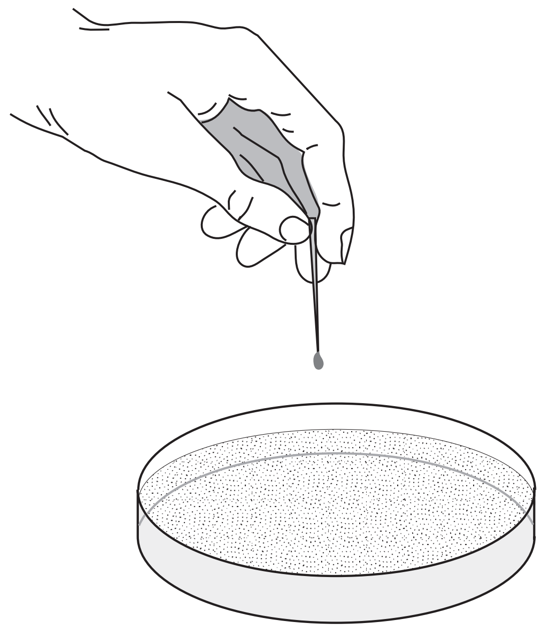
Save the student reader for use after the activity.

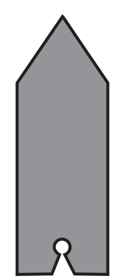
Assessment:

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 ancl 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.

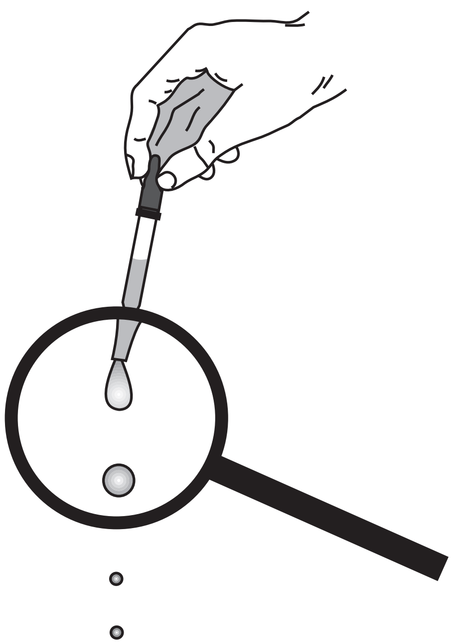




Surface Tension Paper Boat
(actual size)

Surface Tension

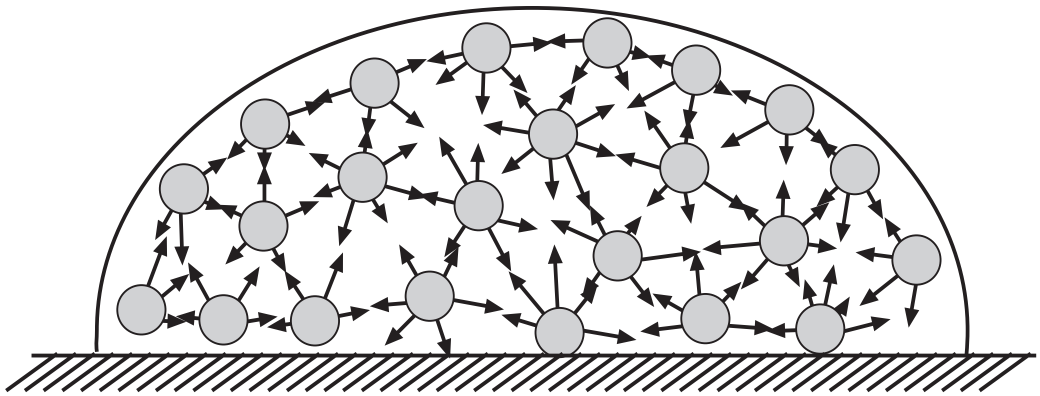
If you have ever looked closely at drops of water, you will know that drops try to form spherical shapes. Because of gravity's attraction, drops that cling to an eye dropper, for example, are stretched out. However, when the drops fall they become spherical.



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.

Student Work Sheet - 1

Surface Tension-Driven Flows

Team Members:

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.
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.

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.