

# Soap-Powered Boat Lesson Plan

Suggested Age / Grade Level	Curriculum Covered	Duration
Grade 3 - 8 (8 - 13 years old)	Molecules and Surface tension Forces & movement, Newton's 3rd Law, Marangoni effect	1 hr

## **Overview**

*Students will investigate the concepts of forces and movement, as well as surface tension. Students will also be able to apply what they have learned by conducting a simple experiment that can stimulate them to try and explain why a soap-powered 'boat' moves across the water's surface.*

## **Learning goals**

- Investigate the concepts of surface tension, forces & movement
- Understand Newton's Third Law and the Marangoni effect

## **Materials**

- Piece of cardboard (ex: tissue box, juice carton, etc.). Note: more waterproof materials like juice cartons work best.
- A tray or tub of water
- Scissors
- Detergent or dish soap
- Optional: plastic bread tab, toothpick, paper, hole puncher

## **Instruction for Soap Powered Boat**

1. Fill tray or small tub with water
2. Cut a rectangle from piece of cardboard
3. Make cuts on the rectangle to it looks like a pentagon
4. Draw and cut a notch/channel shape at the back of the boat **Tip:** use a hole puncher to create a hole and cut a slit that reaches a hole
5. Place boat in tub or tray of water
6. Put a drop of soap or detergent in notch by putting it on your finger and pressing lightly on the hole or carefully pour the soap or detergent into the hole

## Key terms

**Molecule:** Although we can't see it, everything is made up of molecules. For example, water is made up of water molecules and oil is made up of oil molecules.

**Cohesion:** when the molecules in a substance are attracted to each other

**Adhesion:** when molecules are attracted to dissimilar molecules

**Surface tension:** an effect where the surface of a liquid is strong

**Hydrogen bond:** Water molecules have intermolecular forces called hydrogen bonds between them. The oxygen and hydrogen atoms are slightly attracted to each other in this cohesive force.

**Intermolecular force:** an electromagnetic force that acts between molecules

**Newton's 3 laws of motion:** laws that affect everything that moves around you!

**Force:** any push or pull on an object

**Newton's 3rd law:** states that for every action there is an equal and opposite reaction

**Variable:** something that changes or can be changed in an experiment

**Marangoni effect:** this effect describes how a liquid with high surface tension pulls more strongly on the surrounding liquid than a liquid with low surface tension

**Surfactant:** lowers the surface tension of a liquid (ex: soap. The soap in this experiment broke down the surface tension of the water by weakening its' hydrogen bonds.)

## Lesson Summary

### Surface Tension

- Some small objects can float on the surface of liquid due to **surface tension**, even though they normally couldn't float.
- Surface tension is also the reason why some insects (ex: water striders) can walk on the surface of water.
- The molecules at the surface of the water don't have any water molecules above them, and so they bond even more strongly to the ones next to and beneath them. The water molecules below the surface are pulled together equally in all directions, but those on top are pulled together more tightly, as they don't have water molecules above them.
- Surface tension is caused by **cohesion**
- This extra-strong cohesion at the surface of the water creates a kind of 'elastic film' of high tension and this is what allows some insects to walk on water

### Forces and Movement

- Sir Isaac Newton was interested in many topics such as gravity, astronomy and even the rules about how objects move! He created his 3 laws of motion.
- Newton's 3rd Law: if object A exerts a force on object B, then object B also exerts an equal force on object A. The forces are exerted on different objects.

- The movement of the detergent provides a 'pushing force' backward into the water surface as the detergent molecules spread out, sending the boat forward (In other words, an equal and opposite motion)

### **Marangoni Effect**

- If you change the surface tension of some parts of the liquid you introduce a difference in surface tension, or a 'gradient'.
- The presence of a surface tension gradient will cause the liquid to flow from areas of low surface tension to areas of high surface tension.
- In this case, the fluid from the soap region flowed towards the water region
- There's fluid coming out of the back of the boat because of the net force between liquids with different surface tensions.
- The fluid coming out of the back of the boat is what propels the boat forward.
- As the soap molecules reduced the water's surface tension behind the boat, it created enough of a force to push the lightweight boat across the surface.
- The boat was pulled towards the areas of high surface tension by the water in front of the boat.
- As you might have learned from experience, to repeat the experiment you probably had to get clean water without soap so that the surface tension is equal throughout the water