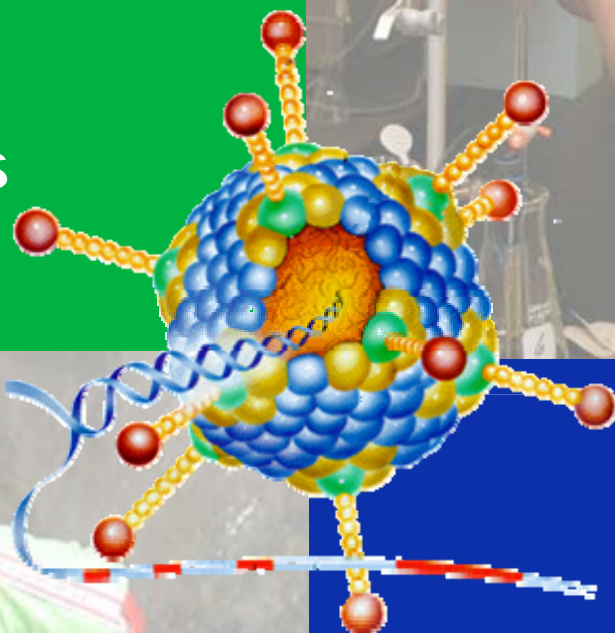


# Surface Tension

## Teacher's Guide



*The waterCAMPWS*  
Center for Advanced Materials  
for Purification of Water with Systems



**Curriculum Connection:** Biology, Physics, or Environmental Sciences

**Bloom's Taxonomy:**

**Grade Level:** 7-10

**Topic:** Surface Tension

**Lesson Duration:** 30-60 minutes

### Purpose

Surface Tension has significant impacts on the survival as well as the processes needed for day to day existence of living beings. For example, insects such as water striders depend on the surface tension of water to move around and capture food. Most household detergents contain Sodium Docedyl Sulfate (SDS) which reduces the surface tension of water. If local water reaches a specific concentration of detergent, water striders will break the surface tension and sink. Surface tension is also essential for the transfer of energy from wind to water to create waves. Waves are necessary for rapid oxygen diffusion in lakes and seas. Understanding surface tension and what affects it is vitally important for researchers and engineers alike because new solutions for treating water have to maintain water's delicate and complex balance.

### Learning Goals and Objectives

1. Students will learn key vocabulary associated with surface tension, including hydrophobic, cohesion, adhesion, solvent, etc.
2. Students will test surface tension in situation with additives and without.
3. Students will explain surface tension and its importance on various ecologies.
4. Students will understand the relationship between water purification and surface tension.

### Benchmarks and Standards

#### Illinois State Learning Standards:

- *11.A.3b* Conduct scientific experiments that control all but one variable.
- *12.C.4a* Use kinetic theory, wave theory, quantum theory and the laws of thermo-dynamics to explain energy transformations.
- *12.C.4b* Analyze and explain the atomic and nuclear structure of matter.
- *12.D.4a* Explain and predict motions in inertial and accelerated frames of reference.
- *12.D.4b* Describe the effects of electromagnetic and nuclear forces including atomic and molecular bonding, capacitance and nuclear reactions.
- *12.E.3b* Describe interactions between solid earth, oceans, atmosphere and organisms that have resulted in ongoing changes of Earth (e.g., erosion, El Nino).
- *13.A.4a* Estimate and suggest ways to reduce the degree of risk involved in science activities.

#### NSES Standards: In grades 9-12, students will learn:

- *Content A* Abilities necessary to do scientific inquiry & understandings about scientific inquiry.
- *Content B* Structure and properties of matter, motions and forces, and interactions of energy and matter
- *Content E* Abilities of technical design and understandings about science and technology
- *Content F* Personal and Community health, population growth, natural resources, environmental quality, natural and human induced hazards, and science and technology in local, national and global challenges
- *Teaching A* Plan an inquiry-based science program for their students
- *Teaching B* Guide and facilitate learning
- *Teaching D* Design and manage learning environments that provide students with the time, space and resources need for learning science.
- *Teaching E* Develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

## Materials and Equipment

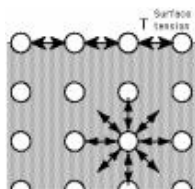
Materials required for this lesson are (for each group of students):

- Beaker
- Straight pins
- Water
- Wire (24 cm. long to
  - make a cradle for
  - straight pin)
- Medicine-cups (to hold 1
  - part Joy)
- Water soluble pens
- Liquid detergent (Joy) &
  - Glycerin
- Square wire frame (use
  - the same wire from
  - cradle)

## Introduction

### Surface tension

Why do the water molecules form a membrane instead of overflowing? Why are rain drops spherical, instead of being wide?



The answers to these questions are linked to the polar nature of water molecules. Water molecules are called polar molecules because they have an unequal sharing of the total 10 electrons in the molecule. The ability of ions and other molecules to dissolve in water, in addition to other unique properties of water are the results of this polarity.



### Demonstration:

*Class participation involving guessing the number of pennies that can be accommodated in a jar full of water without water overflowing (Fig 1a) - Springing board for discussions on Surface Tension*

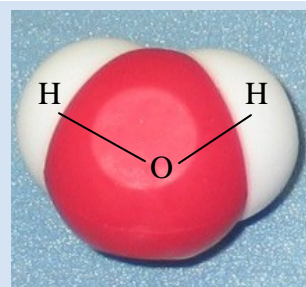
**Polar molecules-** Hydrophilic or "water-loving"; used to describe molecules or groups that are soluble in water, having polar covalent bonds that do not cancel each other out. *Source -* [http://www.biochem.northwestern.edu/holmgren/Glossary/Definitions/Def-P/polar\\_molecule.html](http://www.biochem.northwestern.edu/holmgren/Glossary/Definitions/Def-P/polar_molecule.html)



*Figure 1a Properties of water surface*  
*Source -* <http://htdconnect.com/~chargers/chem/seccsurftens.htm>

### Hydrogen Bonding:

Water has a simple molecular structure. It is composed of one oxygen atom and two hydrogen atoms. This is shown in Fig 1b. Each hydrogen atom is covalently bonded to the oxygen via a shared pair of electrons. Oxygen also has two unshared pairs of electrons. Thus there are 4 pairs of electrons surrounding the oxygen atom, two pairs involved in covalent bonds with hydrogen, and two unshared pairs on the opposite side of the oxygen atom. Oxygen is an "electronegative" or electron "loving" atom compared with hydrogen.



*Figure 1b Water molecule - Structure*  
*Source -* <http://www.geog.ouc.bc.ca/physgeog/contents/8a.html>

Due to the uneven distribution of electrons, water is a polar molecule. Water has a partial negative charge ( $\delta^-$ ) near the oxygen atom due to the unshared pairs of electrons, and partial positive charges ( $\delta^+$ ) near the hydrogen atoms. This is shown in Fig 2a.

An electrostatic attraction between the partial positive charge near the hydrogen atoms and the partial negative charge near the oxygen results in the formation of a hydrogen bond in Water.

Fig 2b depicts the Hydrogen Bond in water molecule.

Surface tension, capillary action, density of ice, viscosity of liquids, high heat capacity of water, and the properties of water as a universal solvent are uniquely tied to the hydrogen bond. Water rising up the roots to the tops of the tallest trees (capillary action), ice floating on lakes preserving animal and plant life below from being destroyed (density of ice), water's moderating effect on climate (high heat capacity), the wide variety of solutions that can be made because water is the solvent; chicken soup, kool-aid, latex paints, pop, etc., are everyday life applications of hydrogen bonding, the basis for surface tension.

The unique physical properties, including a high heat of vaporization, strong surface tension, high specific heat, and nearly universal solvent properties of water are also due to hydrogen bonding. The hydrophobic effect, or the exclusion of compounds containing carbon and hydrogen (non-polar compounds) is another unique property of water caused by the hydrogen bonds. The hydrophobic effect is particularly important in the formation of cell membranes. The best description is to say that water "squeezes" non-polar molecules together. Some of the properties of water resulting from its dipolar nature and Hydrogen bonding are Cohesion and Adhesion.

### Surface Tension:

The surface tension of a liquid is defined as the energy required for breaking through the surface. Liquids like water, which have strong molecular interactions have high surface tensions.

There are two types of molecular interactions acting on molecules of a liquid in a container. There is a force of attraction between molecules in liquids and there is a force between the liquid molecules and the walls of the container.

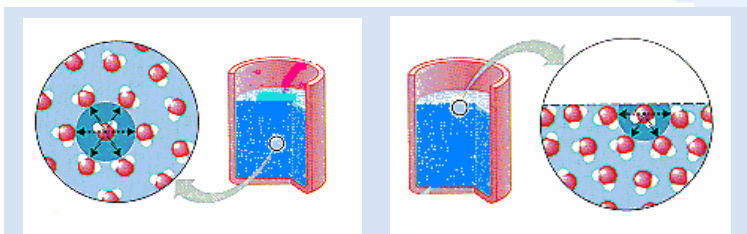


Figure 3 Molecular interactions in water- Below the surface

Figure 4 Molecular interactions in water – At the surface

Source - <http://www.howe.k12.ok.us/~jimaskew/chem/liquid.htm>

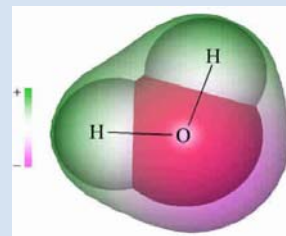


Figure 2a Water molecule – Polarity

Source -

<http://htdconnect.com/~chargers/chem/seccsurftens.htm>

**Hydrogen bond** - A weak bond involving the sharing of an electron with a hydrogen atom. Source - [http://www.biochem.northwestern.edu/holmgren/Glossary/Definitions/Def-H/hydrogen\\_bond.html](http://www.biochem.northwestern.edu/holmgren/Glossary/Definitions/Def-H/hydrogen_bond.html)

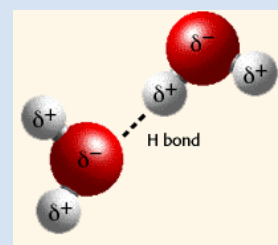


Figure 2b Hydrogen Bond in Water molecule

Source -

<http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page3.html>

**Universal solvent** - A substance such as water that has the ability to dissolve both bases and acids.

Source -

<http://www.luminet.net/~weonah/hydro/h2o.htm>

**Hydrophobic** - Literally means water fearing, from the Greek hydro - "water" and phobo - "fear." Source - <http://www.nanoword.net/library/def/Hydrophobic.htm>

**Cohesion** – All the forces of attraction among particles of a liquid. Source - [http://home.nas.net/~dbc/cic\\_hamilton/dictionary/c.html](http://home.nas.net/~dbc/cic_hamilton/dictionary/c.html)

The force of Cohesion acts between the water molecules in a container. This is due to the Hydrogen bonding between the water molecules. This is shown in Figure 3. Below the surface of the liquid, the force of Cohesion between molecules is the same in all directions as each water molecule is pulled equally in all directions by other molecules.

However, for a molecule on the surface of the liquid, there will be a net inward force that pulls it back into the body of the liquid since there will be no attractive force acting from above the molecule. This is depicted in Fig 4. The pulling of surface molecules into the body of the liquid causes the surface to contract and become as small as possible. As a result, the liquid tries to take on the shape that has the smallest possible surface area — the shape of a sphere.

Thus the molecules on the surface try to resist being stretched or broken, creating a tension on the surface and the liquid is said to possess Surface tension. The magnitude of the force that controls the shape of the liquid is called the **Surface Tension**. The stronger the bonds between the molecules in the liquid, the greater will be the surface tension.

There is also a force of Adhesion between a liquid and the walls of the container. When the force of adhesion is more than half as large as the force of cohesion between the liquid molecules, the liquid is said to "wet" the solid. A good example of this phenomenon is the wetting of paper by water. The force of adhesion between paper and water combined with the force of cohesion between water molecules explains why sheets of wet paper stick together.

Water wets glass because of the force of adhesion that results from interactions between the positive ends of the polar water molecules and the negatively charged oxygen atoms in glass. As a result, water forms a meniscus that is concave, curving upward in a small-diameter glass tube, as shown in Fig 5a.

The term meniscus comes from the Greek word for "moon" and is used to describe anything that has a crescent shape. The meniscus formed by water in a burette results from a balance between the force of adhesion pulling up on the column of water to wet the walls of the glass tube and the force of gravity pulling down on the liquid.

Mercury does not wet glass and hence forms a convex meniscus, with the edges curving downwards. This can be seen in Fig 5b.

### Significance:

Surface Tension has significant impacts on the survival as well as the processes needed for day to day existence of living beings.

Water striders are insects, which are dependent on surface tension of water to move around and capture food. Pollution of the water can impact the organism's life functions and essential

**Surface Tension** - Is the force exerted along the surface of a fluid that causes it to "bead up" and form into drops. Water has high surface tension and hence beads up easily; while alcohol has low surface tension and does not often show droplets. *Source* - <http://www.answers.com/topic/surface-tension>

**Adhesion**- Forces of attraction between a liquid and another surface. *Source* - [http://home.nas.net/~dbc/cic\\_hamilton/dictionary/a.html](http://home.nas.net/~dbc/cic_hamilton/dictionary/a.html)

**Meniscus**- The curved upper surface of a non-turbulent liquid in a container that is concave if the liquid wets the container walls and convex if it does not. *Source*- <http://www.answers.com/meniscus>



Figure 5a **Meniscus formation in water**



Figure 5b **Meniscus formation in Mercury**

*Source* - [http://cwx.prenhall.com/bookbind/pubbooks/hillchem3/medialib/medialib\\_portfolio/11.html](http://cwx.prenhall.com/bookbind/pubbooks/hillchem3/medialib/medialib_portfolio/11.html)

**Water Strider**- Is a predatory insect (order Hemiptera, family Gerridae) that relies on the surface tension of water to walk on top of it; they live on the surface of ponds, slow streams, marshes, and other quiet waters. *Source*- <http://www.answers.com/water%20strider>

activities. Most household detergents are known to contain Sodium Docedyl Sulfate (SDS) which is known to reduce the surface tension of water. Thus at a specific concentration of the detergent, the water strider will break the surface tension and sink. Fig 6a shows a water strider in its natural habitat.

Surface Tension is the reason why rain drops, drops of oil etc tend to be spherical in shape. This is shown in Fig 6b.

The high surface tension of water allows for the formation of water droplets (Fig 6c) and waves. Surface tension is also essential for the transfer of energy from wind to water to create waves. Waves are necessary for rapid oxygen diffusion in lakes and seas.

Surface tension also allows plants to move water (and dissolved nutrients) from their roots to their leaves, and the movement of blood through tiny vessels in the bodies of some animals.



Figure 6a Water Strider

Source - <http://home.att.net/~larvalbugrex/striders.html>



Figure 6b Spherical shape of rain drops



Figure 6c Water droplets

## Activities

1. Present the introduction to this lab or some other related appropriate introduction to surface tension.
2. Divide students into groups. Distribute to each group the materials needed for the lab.
3. Allow the students to follow the procedures listed in their lab books.
4. Have students complete the comprehension and analysis questions in their lab books.
5. Conclude the lab with a discussion of their results.

## Conclusion

Have the students clean up the lab. If there is time, discuss the results of the experiment as a class.

## Assessment

The lab book should provide an assessment tool for this lesson.

