Surface Tension: Liquids Stick Together
Student Advanced Version

In this lab you will learn about properties of liquids, specifically cohesion, adhesion, and surface tension. These principles will be demonstrated by adding drops of different liquids to pennies to determine the strength of molecular attraction.

Key Concepts:

- **Cohesion** is the attraction of molecules among its own kind; i.e. between two water molecules. Because of cohesion, water and other liquids form thin films and drops. This is why water bugs can walk on water, and why a carefully placed paper clip will float.
- **Adhesion** is the attraction between different substances; i.e. between a water molecule and a copper molecule. Adhesion powers a certain process that allows water molecules to move upward through a narrow tube. The attraction of water to the walls of a tube sucks the water up more strongly than gravity pulls it down (i.e. water moving up a plant's roots).
- **Surface tension** is a property of a liquid that allows them to resist external forces. It combines the concepts of cohesion and adhesion. Surface tension is caused by a strong attraction between the molecules (cohesion) that cause them to link together and remain uniform, even when placed on differing surfaces (adhesion). When the molecules possess weak positive interactions, as is the case with rubbing alcohol, surface tension will be small compared to other liquids.
- **Hydrophobic** or "water-fearing" molecules are molecules that do not like to be near water. Water molecules have a **dipole**, meaning that one side of the molecule has a slightly positive charge and one part has a slightly negative charge.

Part 1 - Drops of Water on a Penny

In this portion of the lab you will determine which liquid has the highest surface tension: water, soapy water, or rubbing alcohol. In order to do this, you will determine the number of droplets that can fit onto a penny without spilling over for each liquid. The liquid that can fit the most droplets onto the penny has the highest surface tension, because it can hold onto itself the tightest!

Q1. Using your own words, define surface tension.

Q2. List two examples of surface tension in everyday life:

Q3. Make a prediction: The penny will hold the greatest number of drops when I use…

(a) clean water
(b) soapy water
(c) rubbing alcohol

Q4. Approximately how many drops of clean water do you think the penny will hold? Soapy water? Rubbing alcohol?

Q5. Explain the reasoning behind your prediction

Procedure:

1. **Fill a dropper** with water.

2. **Place the penny**, heads up, on top of a paper towel.

3. **Hold your dropper** about 1-inch above the penny and **add drops of water** to the surface of the penny until it overflows.

4. *Record the number of drops of water* the surface of the penny can hold in the table on the next page under the column labeled "Run 1."

5. **Repeat** steps 2-4 two more times and record your results for "Run 2" and "Run 3."

6. **Repeat** the experiment (steps 2-6) for rubbing alcohol and then soapy water. Be sure to rinse and dry the penny thoroughly between experiments! You should also clean the droppers if you are reusing them.

7. *Add the number of droplets of water the penny held for Run 1, Run 2, and Run 3 and write this total in the column labeled "Sum of Runs."*

8. *Divide this number by three, the number of runs performed, and record this number in the column labeled "Average."* This is the average number of drops the penny held for your three runs.

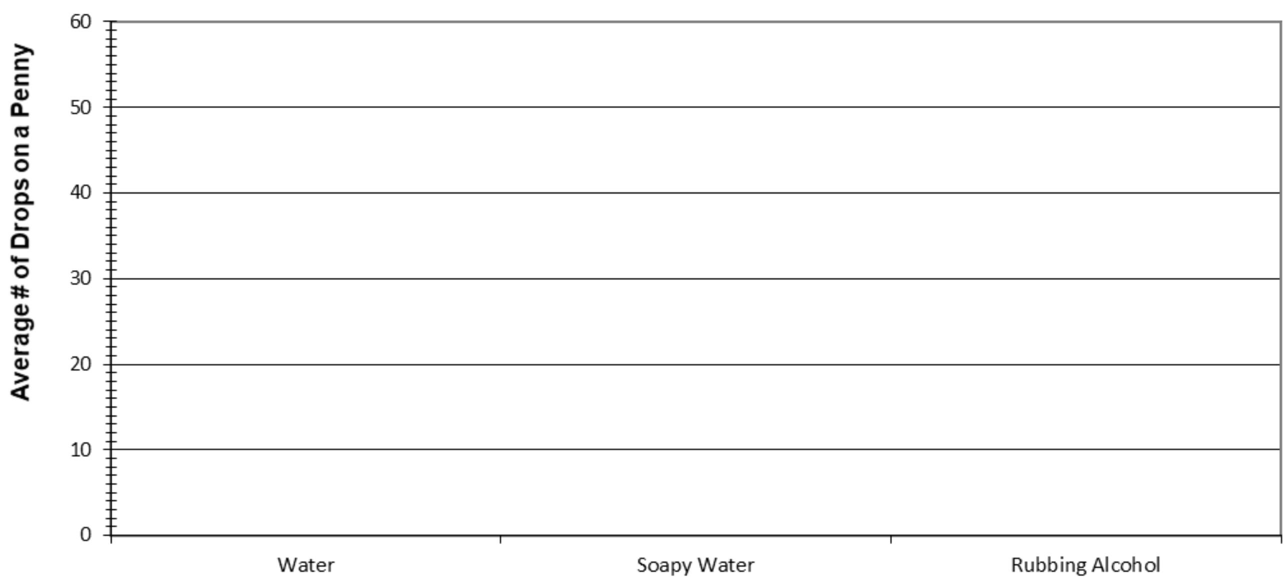
9. **Repeat** this process with the results from soapy water and rubbing alcohol.

10. *Plot* the average number of droplets for each liquid using the bar graph provided on the next page.

Data Table 1: Drops of liquid on a penny. (see next page for standard deviation calculation)

Name of Liquid	Number of Droplets			Sum of Runs	Average = Sum of Runs / Number of Runs	Standard Deviation
	Run 1	Run 2	Run 3			
Water						
Soapy Water						
Rubbing Alcohol						

Record your data in the table below and calculate the average for each liquid.



Instructions for calculating standard deviation:

Note: The formula to calculate standard deviation is the following:

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{N}}$$

σ	Standard deviation
$\sum$	Summation symbol, which indicates that you need to take the sum of whatever follows the symbol - in this case $(x - \bar{x})^2$.
$\bar{x}$	Mean average
x	Value of interest, in this case the number of drops
N	Number of trials

1. Write down the number of droplets of **clean water** that fit onto the penny in **Column A** of **Table 2** for the indicated trial.
2. Write down the average # of droplets of clean water that fit onto the penny (calculated in Question 1) in **Column B** of **Table 2**.
3. Subtract column B from column A (A-B) and write this value in **Column C**. It is okay if the value is a negative number.
4. Square the values in Column C and record these values in **Column D**.
5. Add all the values in Column D together and record this number **in Column E**.
6. Divide the value in Column E by 3 (the number of trials you performed). Record this value in **Column F.**
7. You're almost there! Take the square root of the value in Column F and record the solution in **Column G.** You have now calculated the standard deviation! Write this value in Data Table 1.
8. If time allows, repeat the process for Soapy Water (Table 3) and Rubbing Alcohol (Table 4).

Table 2: Calculating Standard Deviation for Water Measurements

Water							
	A	**B**	**C**	**D**	**E**	***F***	***G***
Trial #	x	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$	$\sum (x-\bar{x})^2$	$\frac{\sum (x-\bar{x})^2}{N}$	$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{N}}$
1							
2							
3							

Table 3: Calculating Standard Deviation for Soapy Water Measurements

Soapy Water							
	A	**B**	**C**	**D**	**E**	***F***	***G***
Trial #	x	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$	$\sum (x-\bar{x})^2$	$\frac{\sum (x-\bar{x})^2}{N}$	$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{N}}$
1							
2							
3							

Table 4: Calculating Standard Deviation for Rubbing Alcohol Measurements

Rubbing Alcohol							
	A	**B**	**C**	**D**	**E**	***F***	***G***
Trial #	x	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$	$\sum (x-\bar{x})^2$	$\frac{\sum (x-\bar{x})^2}{N}$	$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{N}}$
1							
2							
3							

Q6. Which liquid do you think has the highest surface tension? Why?

Q7. What is the surface tension of water? Of rubbing alcohol? (Hint: If you have access to a computer you can find these values online, or you can ask your teacher?).Were your predictions correct?

The surface tension of water is __________.
The surface tension of rubbing alcohol is __________.
My prediction was ***correct / incorrect*** *(circle one).*

Q8. What are the units of surface tension?

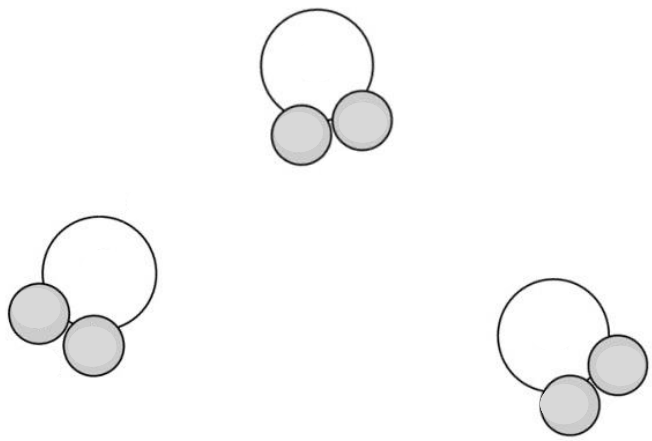
Q9. What variables might affect surface tension values?

Q10. What does your calculated standard deviation tell you about the reproducibility of your results?

Q11. How do you think calculating the standard deviation might help a researcher to determine if, for example, the number of drops of soapy water is significantly different from the number of drops of clean water that fit onto the penny?

Q12. Below is a cartoon depicting three water molecules. Please do the following:

a. *Label each atom of the molecule "H" or "O"(for hydrogen and oxygen, respectively)*
b. *Indicate the partial charge of each atom as positive (+) or negative (-)*
c. *Draw lines to indicate how you think the molecules "bond" or interact with one another.*



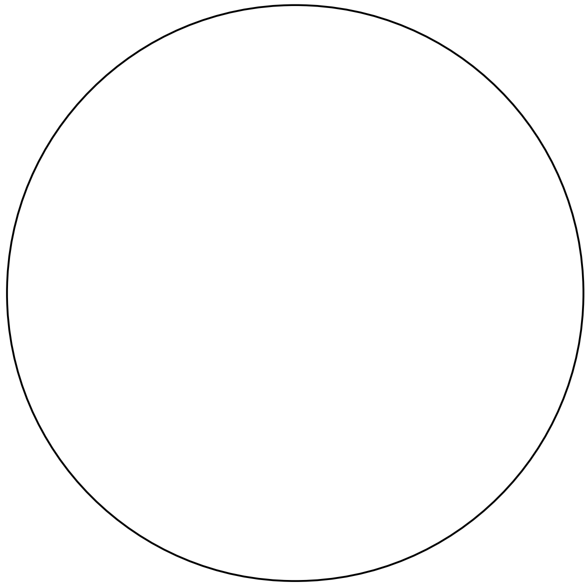
Part 2 - Tie Dye Milk

In this portion of the lab you will alter the ***surface tension*** of milk by adding a very small amount of dishwashing liquid to it. Milk produced by cows is mostly water (87.7%), but it also contains protein (3.4%), fat (3.6%), sugar (4.6%), and minerals (0.7%). When you add dishwashing liquid to the milk, the soap molecules move to the surface of the milk. They prefer the surface of the milk because they are ***hydrophobic*** or "water-fearing" and they can interact with air molecules at the surface versus being surrounded by water molecules in the bulk liquid. The soap molecules have to squeeze between the water molecules to gain access to the surface of the liquid. When the soap molecules get in between two water molecules, they decrease the water's ability to hold onto itself. This in turn causes the ***surface tension*** of the milk to decrease. To visualize the change in surface tension you will first add food coloring to the milk to create a design of your choosing. Then watch what happens you add soap using a toothpick!

Procedure:

1. **Fill** bowl ¾ full with milk.
2. **Place** a few droplets of food coloring into the milk (have fun making your design!).
3. *Draw a picture* of the design you made below in the space provided below.

4. **Dip** one end of the toothpick into dishwashing soap.
5. **Lightly touch** the soapy end of the toothpick to the milk surface.
6. *Draw a picture* of the design you made after you touched the surface of the milk with the soapy toothpick in the space provided on the next page.



Q13. Describe what happened when you touched the surface of the milk with the soapy end of the toothpick.

Q14. What do you think is happening to the ***surface tension*** *of the milk when you add the dishwashing soap?*

Q15. Soap molecules are ***amphipathic****, meaning they possess both a* ***hydrophobic*** *("water-fearing") and a* ***hydrophilic*** *("water-loving") domain. How do you think this affects the surface tension of milk, which is primarily composed of water?*

Q16. If you repeat the experiment do you get the same result? Why do you think this is?

Q17. Using the illustrations below depicting a water (milk) molecule and a soap molecule, draw a cartoon image of how the soap and water molecules align themselves at the surface of the milk in the space provided below.