LESSON 15: Floating Paper Clips

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5–10 minutes

DESCRIPTION

Utilize a careful technique to make a paper clip "float" on top of water.

OBJECTIVE

This lesson demonstrates a property of liquids known as surface tension and explains the difference between surface tension and buoyancy. Students use a careful technique to keep a paper clip suspended on the surface of a cup of water. The lesson can be simplified to reinforce the different properties of matter.

CONTENT TOPICS

Scientific inquiry; measurement; states of matter; properties of matter; attractive forces (surface tension)

MATERIALS

- ❑ Plastic cups
- ❑ Water
- ❑ Forks
- ❑ Tissues or toilet paper
- ❑ Paper clips
- ❑ Liquid soap

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 190 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Liquids are a state of matter that have a definite volume but no definite shape. Examples of liquids are water and orange juice. One unique property of liquids is called surface tension. Surface tension is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Surface tension is also the reason liquids tend to keep a low surface area. For example, water droplets will tend to form into a sphere rather than spreading out flat.

An object suspended by water's surface tension is different from an object that is floating because of buoyancy. Buoyancy is the upward force that a fluid exerts on an object that enables the object to float. The buoyant force on an object is equal to the weight of the fluid displaced by the object. A fluid is any substance made up of particles that flow or move freely such as liquids and gases. Fluids easily change shape when a force is applied. Displacement is the act of moving something out of its original position or of one substance taking the place of another.

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Weight is also a measure of force. **Weight** is a measure of the pull of gravity between an object and the earth. Therefore, an object will float when the upward force on an object (buoyant force) is greater than the downward force on the object (gravity or the object's weight).

In the experiment, the force of buoyancy is not enough to allow a paper clip to float. The metal that makes up the paper clip is denser than the water. In addition, because its metal structure is so thin, the amount of water the paper clip displaces is minimal. Thus, the paper clip has a greater weight than the water it displaces. If you simply drop a paper clip in water, it will sink.

However, using a specific technique, a paper clip can essentially sit on top of the water. By placing a piece of tissue or a fork on the water first, a platform is created for the paper clip. When the paper clip is laid horizontally on the water, and the platform is removed, the paper clip will remain suspended. If you push the paper clip slightly, it will sink. Remember, the paper clip is not floating; it is sitting on the surface of the water being supported by surface tension.

In contrast, soap is a **surfactant**. A surfactant (or surface active agent) is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of soap is added to the water, the surface tension of the water is reduced. Even a single drop of soap will reduce the surface tension of water enough that the paper clip can no longer rest on top.

FORMULAS & EQUATIONS

Over 2,000 years ago, ancient Greek mathematician Archimedes discovered how buoyancy works. He determined the following:

> **Buoyant force on an object = weight of fluid displaced by object.**

Therefore, if a boat weighs 1,000 pounds, it will sink into the water until it has displaced 1,000 pounds of water. If the boat displaces 1,000 pounds of water before it is submerged, the boat will float. If more and more weight is added to the boat, such as when a leak allows water to enter the boat, the weight of the boat will exceed the weight of the water it displaces and sink.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states of matter and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on displacement can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶A paper clip placed horizontally on the surface of a cup of water using a careful technique will stay on top of the water because of surface tension. If soap is added, the paper clip will sink.

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DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Utilize a careful technique to make a paper clip "float" on top of water.

OBJECTIVE

This lesson explores the liquid state of matter and a unique property of liquids known as surface tension.

OBSERVATION & RESEARCH

Matter is anything that has mass and takes up space. It is everything around us! It is characterized and classified by its properties. Mass and volume are two basic properties of all matter. Mass is a measure of the amount of matter in a substance. Volume is a measure of the amount of space an object occupies.

Matter exists primarily as a solid, liquid, or gas on the earth. Solids have a definite volume and a definite shape. Examples of solids are chairs, books, and paper clips. Liquids have a definite volume but no definite shape. Examples of liquids are milk and water. Gases have no definite shape and no definite volume. Examples of gases are the oxygen and water vapor in the air we breathe.

Along with differences in shape and volume, the different states of matter have other unique properties. For example, surface tension is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid.

Water has a very high surface tension because of strong attractions between the water molecules (hydrogen bonding). In this experiment, simply dropping the paper clip in the water easily breaks the surface tension. As a result, the paper clip falls to the bottom of the cup. However, when placed horizontally on the surface with a careful technique, the high surface tension of the water supports the paper clip on the surface.

Liquid dish soap is a different type of liquid substance, called a surfactant (or surface active agent). A surfactant is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of soap is added to water, the surface tension of the water is reduced, and the paper clip falls to the bottom of the cup.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 190, and then challenge students to get other materials to rest on top of the water. Discuss what is causing these items to float or sink. Is it surface tension, buoyancy, a combination of both, or something else entirely?

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of physical measurements can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on states of matter and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

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EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If students try different techniques to put the paper clip on the water, does the action of the paper clip change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

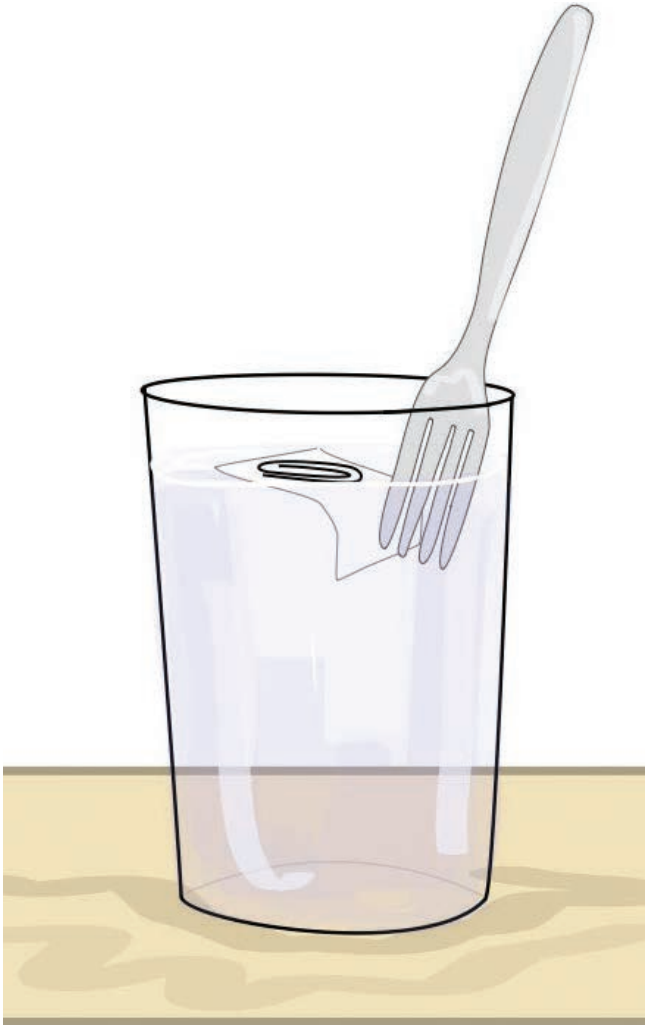
1. Fill a cup with water. Be sure there is no soap residue in the cup.
2. Place a piece of tissue or toilet paper, big enough to support the paper clip, on the water.
3. Gently place the paper clip horizontally on top of the tissue so that the tissue supports the paper clip.
4. Use a fork to very gently submerge the tissue by pushing down on the tissue from its edges. Do not touch the paper clip with the fork.
5. Once the tissue is submerged, watch as the paper clip continues to be suspended on the surface of the water.
6. While the paper clip is suspended, add one drop of soap to the water where the paper clip is suspended. Watch as the paper clip sinks.
7. Repeat the experiment, but this time, add one drop of soap to the water first. See if you can make the paper clip "float."

Tissues and toilet paper typically come in layers. Only one layer is needed and works the best.

If you cannot get the tissue to work, you can just use the fork. Place the paper clip on the fork and hold the fork so the paper clip is resting on the fork at the water's surface. Then, slowly submerge the fork in the water. The paper clip should remain suspended on the water's surface.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens to the paper clip when the tissue paper or fork is submerged? What happens when soap is added? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.



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ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the property of surface tension.
- Describe the force of buoyancy and how it relates to fluids and displacement.
- Differentiate between surface tension and buoyancy.
- Describe the effects of soap, a surfactant, on surface tension.
- Define and identify different types of measurements, such as mass and volume (see ***Differentiation in the Classroom***).
- Compare and contrast the different states of matter and provide examples of each (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, ask the students if a paper clip will float or sink in water. See if the students can get a paper clip to float on top of the water before explaining the procedure for this experiment. Tell the students that you can get the paper clip to float. Show them the suspended paper clip, and ask them if they know how this is possible. Ask them if they know what surface tension is and the role it plays in this experiment. Have the students try the experiment.

K-4 See **Lesson 26: Swimming Specs** for a simplified lesson on surface tension.

5-8 See **Lesson 7: Milk Rainbow** for a more advanced lesson on surface tension.

REAL-WORLD APPLICATIONS

- Surfactants, such as liquid dish soap, detergents, fabric softeners, and shampoo, play an important role in cleaning products because they break up grease and stains. One side of a surfactant particle attracts the fats and oil, while the other side attracts the water. This interaction allows the water to mix with the fats and oils and wash them away.
- The effects of surface tension can be seen in the formation of raindrops or the “beading” of rainwater. Water will form into spheres (droplets) rather than spread out completely because of the attraction of water molecules. Likewise, ask students if they have ever filled a cup with water slightly above the rim without the water spilling over. Ask them if they can figure out why.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

OBSERVE & RESEARCH

1. Write down the materials you observe. _____

_____

_____

2. Predict how these materials may be used. _____

_____

_____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Liquid		
Surface tension		
Buoyancy		
Fluid		
Displacement		
Weight		
Surfactant		

4. Consider what will happen if you place a paper clip in a cup of water and why. Then, consider ways to keep the paper clip on the surface.

▶**Write your hypothesis.** _____

_____

_____

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

PERFORM YOUR EXPERIMENT

1. Fill a cup with water. Be sure there is no soap residue in the cup.
2. Place a piece of tissue or toilet paper, big enough to support the paper clip, on the water.
3. Gently place the paper clip horizontally on top of the tissue so that the tissue supports the paper clip.
4. Use a fork to very gently submerge the tissue by pushing down on the tissue from its edges. Do not touch the paper clip with the fork. Observe what happens.
5. If the paper clip remains on the surface of the water, add one drop of soap to the water where the paper clip is suspended. Observe what happens.
6. Repeat steps 1–4, but this time, add one drop of soap to the water *before* adding the tissue and paper clip. Observe.

ANALYZE & CONCLUDE

1. What happens when you first place the tissue on the water? _____

_____

_____

2. What happens when you place the paper clip horizontally on the tissue? _____

_____

_____

3. When the tissue is submerged, does the paper clip remain on top of the water? Why or why not? _____

_____

_____

4. What happens when you add soap to the water? _____

_____

_____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? _____

_____

_____

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter		
Mass		
Volume		
Solid		
Liquid		
Gas		

2. List other examples of surface tension. _____

_____

_____

3. Do all liquids have the same surface tension? How do you know? _____

_____

_____

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Water, forks, paper clips, tissue or toilet paper, liquid dish soap …

2. Predict how these materials may be used. The water may be used to drink, clean, or bathe. The forks may be used to pick up food. The tissue paper may be used to package something or for cleaning. Paper clips may be used to hold pieces of paper together. Liquid dish soap may be used to clean dishes. Together, these materials may be used to explore physical properties.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Surface tension	A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface "film."	
Buoyancy	An upward force that a fluid exerts on an object and enables the object to float.	
Fluid	Any substance made up of particles that flow or move freely, such as a liquid or gas.	
Displacement	The act of moving something out of its original position or of one substance taking the place of another.	
Weight	A measure of the pull of gravity between an object and the earth.	
Surfactant	Any substance with the ability to reduce the surface tension of a liquid; also known as a surface active agent.	

4. Consider what will happen if you place a paper clip in a cup of water and why. Then, consider ways to keep the paper clip on the surface.

▶**Write your hypothesis.** A paper clip will normally sink in water because it has a greater density than water and weighs more than the water it can displace. However, a paper clip can be suspended on top of water because of the water's surface tension.

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill a cup with water. Be sure there is no soap residue in the cup.
2. Place a piece of tissue or toilet paper, big enough to support the paper clip, on the water.
3. Gently place the paper clip horizontally on top of the tissue so that the tissue supports the paper clip.
4. Use a fork to very gently submerge the tissue by pushing down on the tissue from its edges. Do not touch the paper clip with the fork. Observe what happens.
5. If the paper clip remains on the surface of the water, add one drop of soap to the water where the paper clip is suspended. Observe what happens.
6. Repeat steps 1–4, but this time, add one drop of soap to the water before adding the tissue and paper clip. Observe.

ANALYZE & CONCLUDE

1. What happens when you first place the tissue on the water? When you place the tissue on the water, the tissue rests on the top of the water. The surface tension of the water prevents the tissue from sinking down to the bottom of the cup.

2. What happens when you place the paper clip horizontally on the tissue? When you place a paper clip on the tissue, the paper clip will rest on top of the tissue.

3. When the tissue is submerged, does the paper clip remain on top of the water? Why or why not? When the tissue is submerged, the paper clip remains on top of the water because of the surface tension of the water.

4. What happens when you add soap to the water? Adding soap reduces the surface tension of water. Soap, a surfactant, will cause the paper clip to sink.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

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ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter	Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth.	
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Solid	A state of matter characterized by a definite volume and definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	

2. List other examples of surface tension. Examples of surface tension include the beading of rainwater and skipping of rocks.

3. Do all liquids have the same surface tension? How do you know? No, all liquids do not have the same surface tension. Vegetable oil has a lower surface tension than water and will spread farther than water if the same amount of both liquids are poured on a flat surface.