Title: Surface Tension Measurements of an Oscillating Water Blob

Experimental Objectives: Estimate the surface tension of water both with and without surfactants by measuring the oscillation period of a free-floating water blob of known mass.

Educational Objectives:

1. Understanding and Applying Newton's Laws of Motion (NGSS HS-PS2-1)
    - Objective: Students will understand how forces and motion interact by observing and analyzing the oscillatory motion of a water blob in microgravity.
    - Explanation: By initiating and measuring the oscillations of the water blob, students will apply Newton's laws of motion to explain the forces acting on the water blob and how these forces result in periodic motion. They will calculate the period of oscillation and relate it to the restoring force due to surface tension.
2. Analyzing and Interpreting Data (NGSS HS-PS4-1)
    - Objective: Students will develop skills in data analysis by measuring the period of oscillation from video footage and using this data to calculate the surface tension of water.
    - Explanation: Students will use video analysis techniques to extract quantitative data on the oscillation period of the water blob. They will then apply mathematical formulas to interpret this data, fostering their ability to analyze real-world phenomena and draw meaningful conclusions from experimental results.
3. Understanding Properties of Materials and Fluids (NGSS HS-PS1-3)
    - Objective: Students will explore the physical properties of water, specifically surface tension, and understand its significance.
    - Explanation: By performing the calculations to determine the surface tension of water, students will gain insights into the cohesive forces at play within liquids. This knowledge will enhance their understanding of material properties and their applications in different environments, such as microgravity.

Materials and Equipment Required (Include quantity and volume):

1. 50 mL water in a drink bag with straw (x1)
2. 50 mL syringe or dropper (2x)
3. 50 mL surfactant (dish soap or detergent) in a drink bag with straw
4. 1-Quart (or similar) Ziploc bag (to contain materials and water blobs)
5. Washcloth (to absorb blobs)

Experimental Procedures:

1. Gather the materials in a Ziploc bag
2. Fill one of the two syringes with 50 mL water
3. Fill the other syringe with 10 mL surfactant
4. Creating the Water Blob:

- Using the syringe, carefully form a water blob of volume ~10 mL. This step should be recorded such that the syringe volume markings are visible before and after the blob is generated.
- Allow or cause the blob to gently separate from the syringe tip and float freely.

5. Recording the Oscillations:
- Displace the blob slightly to initiate oscillations. This can be done by gently tapping the blob or applying a small force to it.
- Record the motion of the water blob using the camera. Ensure that the camera captures the blob from a stable position, and use a plain background or one with a grid pattern to aid in analysis.
- Record at least 5 cycles of oscillation for the blob.
- Capture the water blob in the Ziploc bag or absorb with washcloth

6. Repeat with smaller blob:
   - Repeat steps 4-5 with a blob of size 5 mL
7. Repeat with 1 mL surfactant:
   - Using the syringe, carefully form a water blob of volume 10 mL.
   - Record its oscillations as before
   - Using the surfactant syringe, inject ~1 mL of surfactant into the water blob and record the new oscillations of the soap + water blob (at least five oscillations).
   - Capture the water blob in the Ziploc bag or absorb with washcloth
8. Return items to the Ziploc bag for storage.

Note that students will perform the analysis to estimate surface tension with/without surfactant by measuring the oscillation period from a frame-by-frame analysis of the video data. The measurement depends on a good estimate of the mass of the blob derived from the blob volume, so careful recording of the syringe volume markings before and after the blob generation is crucial.

Expected Outcome:

- Data: An estimated value for the surface tension of water with uncertainty
- Data: An estimated value for the surface tension of soapy water with uncertainty
- Learning Outcome 1: Understanding Fluid Dynamics and Surface Tension
  - Students will gain a fundamental understanding of surface tension and its role in the behavior of fluids, especially in a microgravity environment.
  - Explanation: By observing and calculating the oscillation period of the water blob, students will learn how surface tension influences the stability and shape of liquids. They will understand the cohesive forces at the liquid's surface that contribute to surface tension.
- Learning Outcome 2: Application of Mathematical and Physical Principles
  - Students will apply mathematical formulas and physical laws to analyze experimental data and derive meaningful conclusions.
  - Explanation: Through calculating the radius, volume, and oscillation period, students will practice using formulas for volume, surface tension, and oscillation

frequency. They will also enhance their skills in rearranging equations and performing unit conversions.

- Learning Outcome 3: Data Collection and Analysis
    - Students will develop skills in accurately collecting and analyzing experimental data.
    - Explanation: Students will measure the period of oscillation using video analysis, calculate the volume of the water blob, and use these measurements to determine the surface tension. They will learn how to handle experimental data, identify sources of error, and improve measurement techniques.
- Learning Outcome 4: Real-World Applications of Physics
    - Students will understand how theoretical physics concepts are applied in real-world scenarios, such as in aerospace and microgravity research.
    - Explanation: The experiment will demonstrate how principles of fluid dynamics and surface tension are critical in various applications, including space exploration. Students will appreciate the importance of experimental physics in advancing technological and scientific knowledge.

Total Estimated Astronaut Time (minutes): 30 Minutes

- 10 minutes to gather materials and read procedures
- 15 minutes to perform the experiment
- 5 minutes to clean up and stow materials

Extensions For Classroom Consideration:

Discuss the effect of changes in water temperature on the dynamics of the water blob and implications for applications of surface tension-based technologies in space.

Discuss the effect of changes in air temperature and pressure on the dynamics of the water blob and implications for applications of surface tension-based technologies in space.

Predict the changes in blob dynamics for different liquids, such as isopropyl alcohol, cooking oils, etc.

Is there an analog experiment that can be conducted on Earth under gravity that would yield reliable results?

Note that the students will need to derive or be provided the relationship between surface tension and oscillation period, which can be found in the literature or derived from first principles.