Name **Period** **Date**

Archimedes' Principle

Driving Questions

Why do some things float and some things sink?

Background

Archimedes (287 to 211 B.C.) lived in Syracuse on the island of Sicily and is considered to be one of the greatest mathematicians of all time. Archimedes is widely credited as the principle reason for the failure of the Romans in their first attempt to capture Syracuse. According to several accounts, Archimedes applied his considerable talent to the defense of the city, and he invented several novel machines to repel the Roman siege engines. One of the things that Archimedes is best known for today is his observations of the behavior of objects placed in fluids.

Materials and Equipment

For each student or group:

- Data collection system
- Force sensor
- Rod stand
- Short rod
- Overflow can
- Objects to submerge
- Small cup to add water to the overflow can
- Cup or beaker to catch water from overflow can
- Balance (1 per class)
- Right-angle clamp
- String, 25 cm
- Water, 500 mL
- Ruler
- Graduated cylinder, 25-mL (optional)

Safety

Add these important safety precautions to your normal laboratory procedures:

- Restate the caution when using electronics around liquids.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

◯	◯	◯	◯
Calculate the force due to gravity on the volume of displaced water (weight in N).	Completely submerge an object in water, collecting the volume of water displaced by the object.	Show that the change in net force on the object before and after submersion is equal to the weight of displaced water.	Measure the net force acting on the submerged object.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set Up

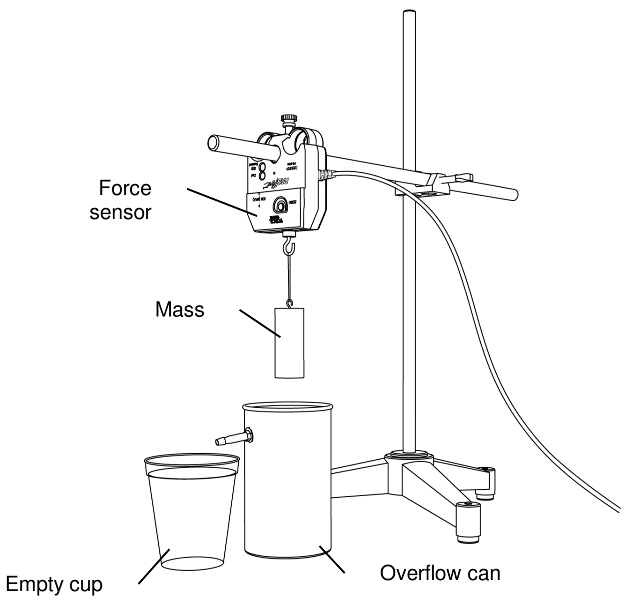
1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect the force sensor to the data collection system. �(2.1)

3. ☐ Display force (pull positive, or inverted) in a digits display. �(7.3.1)

4. ☐ Attach the force sensor to the rod stand using a short rod and the right angle clamp.

5. ☐ Press the “zero” button on the force sensor.



6. ☐ Why do you think it is important to press the "zero" button on the force sensor?

7. ☐ Place the overflow can below the force sensor.

8. ☐ Tie a loop of string to the object, long enough to allow the object to be submerged completely in the overflow can when hung and lowered from the force sensor.

9. ☐ Place a dry cup (catch basin) under the spout of the overflow can.

10. ☐ Fill the overflow can with water to the limit.

Note: To reach the fill limit of the can, overfill the can allowing the excess water to pour from the spout. When the spout has stopped dripping, the can will be completely filled. Be sure to empty the catch basin after doing this.

11. ☐ Why is it important to fill the water to the point that it begins to run out of the spout of the overflow can?

Collect Data

12. ☐ Use the balance to measure the mass of the empty cup (catch basin) in kg, record the mass of the cup in Table 1, and then replace the cup in its original position.

13. ☐ Why is it important to measure the mass of the empty cup?

14. ☐ Measure the mass of the object you will submerge in the water in kg, and record the mass of the object in Table 1.

15. ☐ Use your ruler to measure the dimensions of your object, use your knowledge of geometry to calculate its volume, and then record the volume in Table 1.

16. ☐ Begin monitoring force with your data collection system. �(6.1)

17. ☐ Use the string loop to hang the object from the force sensor hook. Make certain the object is not swinging before recoding data, and then record the force exerted by gravity on the object in Table 1.

18. ☐ Loosen the thumbscrew that holds the right angle clamp to the rod stand, and slowly lower the object into the overflow can. Displaced water from the overflow will pour into the empty cup (catch basin).

19. ☐ Tighten the thumbscrew to hold the object fully submerged, but not touching the bottom of the can.

20. ☐ Record the new "resultant" force measurement in Table 1.

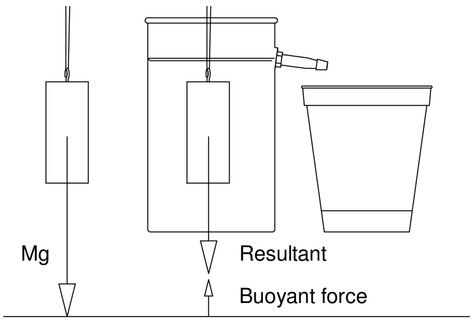
21. ☐ Use the balance to measure the mass of the cup (catch basin) and water that has overflowed from the can, and record the mass in Table 1.

22. ☐ Use the graduated cylinder to measure the volume of the water that has overflowed from the can, and record the volume in Table 1.

If you are not using a graduated cylinder, use the mass of the water calculated in the next step and the conversion of 1,000 cm^3/kg for water to determine the volume.

Analyze Data

If the mass of the object does not change when it is submerged, but the net force does, we must be observing the action of a second force on the object. This force is called Buoyant Force. The force on the submerged object is the resultant of the vector addition of the force of gravity and the buoyant force acting on the object.



23. ☐ Calculate the mass of the displaced water in kilograms by subtracting the mass of the empty cup from the mass of the displaced water and cup together, and record the mass in Table 1.

24. ☐ Calculate the weight of the water in newtons by multiplying the mass of the water by the acceleration of gravity (9.81 m/s^2), and record the weight in Table 1.

25. ☐ Calculate the buoyant force by subtracting the force on the submerged object from the force due to gravity, and record the force in Table 1.

26. ☐ Calculate the density of your object from the measured mass and volume, and record the mass in Table 1.

27. ☐ Repeat the Collect Data and Analyze Data steps for a second object that has a different mass and record the results in Table 1.

Data Analysis

Table 1: Object buoyancy data

Parameters	Object 1	Object 2
Object		
Mass of the empty cup (kg)		
Mass of the object (kg)		
Volume of the object (cm^3)		
Force of gravity on the object (N)		
Resultant force on submerged object (N)		
Mass of cup and water displaced by the object (kg)		
Volume of water displaced by the object (cm^3)		
Mass of the water displaced by the object (kg)		
Weight of the water displaced (N)		
Buoyant force (N)		
Density of water (kg/cm^3)		
Density of the object (kg/cm^3)		

Analysis Questions

1. Compare the mass of the object to the mass of the displaced water.

____

____

2. Compare the volume of the object to the volume of the water displaced.

____

____

3. **Compare the buoyant force to the weight of the displaced water.**

4. **Compare the density of your object to the density of water.**

5. **What do you think is the greatest source of error in your measurements, and why?**

6. **If you neglected to subtract the mass of the cup in your measurements what would be the percent error due to the cup in the mass of water measurement?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **What would a submerged object do if the buoyancy force were greater than the weight of the object?**

2. Imagine a person in a deep pool. What happens if the person:

a. Let the air out of their lungs? Why?

b. Take a deep breath and hold it? Why?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. A completely submerged object displaces its own:

- **A.** Density of fluid.
- **B.** Weight of object.
- **C.** Volume.
- **D.** Weight of the fluid in the container.

2. What is the buoyant force acting on a 20-ton ship floating in the ocean?

- **A.** 20 tons.
- **B.** Less than 20 tons.
- **C.** More than 20 tons.
- **D.** Depends on the density of seawater.

3. A lobster crawls onto a bathroom scale submerged at the bottom of the ocean. Compared to its weight above the surface, the lobster will have an apparent weight under water that is:

- **A.** Less.
- **B.** The same.
- **C.** More.
- **D.** Depends on the density of seawater.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. The weight of an object acts downward, and the ___________ force provided by the displaced fluid acts upward. If these two forces are equal, the object does not sink. ___________ is defined as mass per unit of volume. If the density of an object exceeds the density of water, the object will ___________.

2. ___________ most famous discovery was that an object submerged in a fluid is buoyed up by a force equal to the ___________ of the liquid the object ___________. This law is called "Archimedes Principle."

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
Buoyant	Archimedes’
Density	Displaces
Float	Mass
Sink	Weight