FUN WITH ARCHIMEDES' PRINCIPLE

MANISH YADAV

This article presents the journey of a group of science teachers who explore Archimedes' principle, and related concepts, through well-loved fables like that of the Thirsty Crow, as well as a series of simple, open-ended experiments with readily available materials.

Although most teachers agree on the need for experiments in the teaching and learning of physics, experimentation in schools often consists of students being asked to follow a series of instructions so as to arrive at a predetermined result or verify a previously stated law. This approach is aimed more at getting predictable results rather than encouraging students to use experiments to explore questions. This is perhaps one of the reasons why teachers see very little value in conducting experiments in their classrooms. How do we rethink the kind of experiments we use to teach physics in school?

We explore this question by using an experiment-based approach to understand Archimedes' principle. Each of these experiments may be demonstrated by the teacher, or performed by students as group activities. Ask students to predict what they expect to see before the experiment is performed. Draw them into discussion to help them recognise the prior experiences and assumptions that form the basis of their predictions. Once their predictions have been tested through experimentation, ask students to reflect upon and discuss their observations with each other. This approach will allow students to **arrive** at an understanding of the principle, on their own, through deeper inquiry.

Can the thirsty crow story be true?

Many of us have heard of the story of the thirsty crow that used pebbles to get to the water in a clay pot. But how many of us have attempted to verify this story? We designed this experiment to help begin an exploration of Archimedes' principle (see **Activity Sheet I**). Start by reading out the story. Then encourage your students to experiment with a variety of materials to bring water to the brim of a pot. This will get them to think more deeply about the floating and sinking properties of objects in water.

Factors that cause sinking or floating

We designed this experiment to help students think more deeply about the floating and sinking properties of objects, and their relationship with properties of the liquids into which they are dropped (see **Activity Sheet II**). For simplicity, you can even start this experiment with one liquid — water. Ask students a variety of questions to get them to identify factors that influence floatation. Students at the school level will most likely answer these questions by mentioning concepts like mass, volume, density, area, etc. You may also get responses like colour or length. Selecting objects that vary widely in colour and length can be used to demonstrate that these properties have no connection with floatation (see **Box 1**).

Box 1. What kind of objects can we use for this experiment?

There is no rule about the set of objects chosen for this experiment. They've been chosen because they display different conditions of floatation in different liquids. Teachers can choose to have an entirely different set of objects that fulfil this same broad condition.

The volume of objects and the liquid they displace

We designed this experiment to explore the relationship between the volume of objects and that of the liquid they displace (see **Activity Sheet III**). To do this, we test the floatation of cuboids and spheres made of wood, metal, and glass in water. Start this experiment by asking students to calculate the volume of the cuboids and spheres by making necessary measurements and using appropriate mathematical formulae. Once they finish doing this, ask students to drop these objects one-by-one into the water in the measuring jar. By marking the level of water in the measuring jar before and after each of the objects are dropped into it, students can calculate the volume of water displaced in each case. Encourage your students to compare these values with the volumes calculated at the beginning of this experiment. Can they identify any broad patterns?

These are some observations that are typical of this experiment:

- The volume of an object that sinks is equal to the volume of the liquid it displaces.
- The volume of an object that floats is greater than the volume of the liquid it displaces.

These observations can be expressed mathematically:

V_{object} = V liquid displaced when object sinks.

V_{object} > V liquid displaced when object floats.

Mass and density in floatation and sinking

We designed this experiment to explore the relationship between the mass and volume of objects and that of the liquids they displace with their floatation (see **Activity Sheet IV**).

This activity has two stages. In the first stage, ask students to measure the mass of cuboids made of wood, iron or soap, and calculate their volume and density. Then ask them to dip the cuboids one-by-one in water, and record the mass and volume of displaced water in each case. Given the fact that objects of the same volume can show different floatation properties (one floats while the other may sink), encourage students to use these observations to explore the relationship between the mass, volume, and density of an object with its tendency to sink or float. You can also ask them to test this relationship with objects of irregular shape (see **Box 2**). This will help them arrive at a relationship like this:

Box 2. Does the shape of an object have any role to play in its tendency to sink or float?

Give students some clay or aluminum foil and a tub of water. Encourage them to use the clay or foil to carve out differently shaped objects of the same mass, drop them in water and record the volume, mass, and density of water they displace. Since differently shaped objects have different contact areas, they may displace different volumes of water.

Does the shape of a boat help it float? What makes it sink?

Credits: Tim Green URL: https://www.piqsels.com/en/public-domain-photo-sgymf.

This can lead to a discussion about how the shape of boats and ships are designed for floating despite being made of material that has a much higher density than seawater.

	Volume Relation	Mass Relation	Density Relation (Mass / Volume)
Sink	Vo = Vw	Mo > Mw	Do > Dw
Float	Vo > Vw	Mo = Mw	Do < Dw

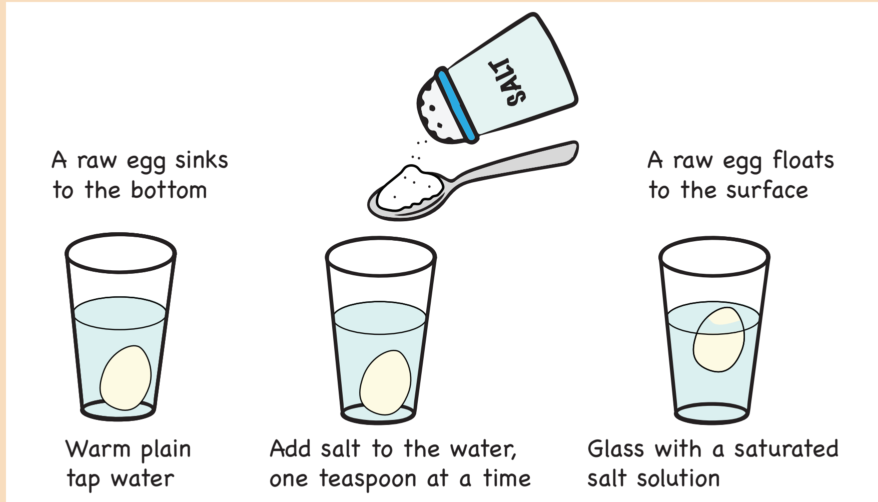
Here,

- Vo stands for the volume of the object.
- Vw for the volume of water displaced by it.
- Mo stands for the mass of the object.
- Mw stands for the mass of the water displaced by it.
- Do stands for the density of the object.
- Dw stands for the density of the water displaced by it.

Box 3. Will an object's tendency to float or sink change if it is dropped in a liquid with the same density?

We know that objects float on the surface of liquids of higher density, or below the surface of liquids of equal density. We also know that objects sink in liquids with a density lower than their own.

You can help students arrive at this understanding with an egg, some tap water, and some table salt. Ask students to predict if the egg would float or sink if dropped into water. Once they have made their predictions, drop the egg into the water, and allow students to watch it sink. Then, start adding salt to the water, gradually adding enough to cause the egg to start floating. Ask students what they think the salt does to the water to cause the egg to float.



Why does salt make an egg float in water?

Adapted from: R. Bishop, How Salt Behaves, WORLDkids. URL: https://kids.wng.org/node/1942.

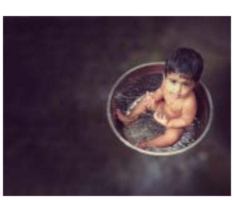
You can also explore this question by dropping a piece of carrot first in some tap water, and then in a saturated sugar or citric acid solution at room temperature.

In the second stage, you can extend this exploration to other liquids, like alcohol, citric acid, salt solution, and sugar solution (see **Box 3**). Ask students to think of factors that cause an object to float (partially or fully) in one liquid and sink in another. This will help establish the fact that floating and sinking do NOT depend upon object properties alone.

Conclusion

These are just some ideas for experiments that can be used to explore a concept in physics in more engaging ways. This kind of approach provides students with the opportunity to **explore** and **discover** these concepts for themselves. Through such experiences, they begin to construct their own knowledge. Wouldn't you want to try these experiments out too?

Key takeaways



- Students can develop a strong understanding of Archimedes' principle through a series of simple, enjoyable, and open-ended experiments with readily available materials.
- An experiment-based approach that encourages students to predict, test, reflect, and discuss observations can help them 'arrive' at an understanding of core concepts and principles, on their own, through deeper inquiry.

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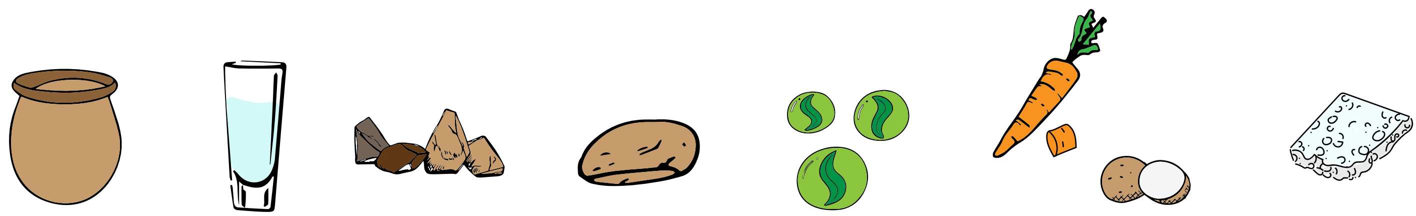
Note: Source of the image used in the background of the article title: https://pixahive.com/photo/a-toddler-bathing-in-a-tub/. Credits: Petrichor, Pixahive. License: CC0.

ACTIVITY I : THE THIRSTY CROW STORY

Have you heard this story before?

It was a hot summer day. A thirsty crow was searching for water. After much searching, it found an earthen pot with some water in it. The crow tried to push its head into the pot, but couldn't reach the water in it. It then tried to tilt the pot so that some water would flow out, but the pot was too heavy for it. Looking around, the crow spotted many small pebbles. It used its beak to drop these pebbles, one by one, into the pot. The water level rose till the crow could reach it with its beak. The crow drank its fill, and flew away.

You will need:



An earthen pot, some water, some small and big pebbles, one big stone, some differently sized marbles, some differently sized vegetable pieces, some pieces of thermocol.

Think about & discuss:

- Do you think it's possible to get to water in a pot like this? Why?
- In your opinion, what is the least amount of water a pot would have to contain for a crow to reach it by dropping pebbles into it? How would you check this?
- How many small pebbles would you need to reach the water? Instead of dropping many small pebbles, what if we were to gently drop one big stone into the pot? What do you think would happen?
- What else (marbles, vegetable pieces, thermocol, etc.) could be dropped into the pot to raise the water-level in it?
- Would it be correct to say that the water level rises to the brim only if the pot is filled with enough water to start with? Is this water level half or two-thirds of the volume of the pot?

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ACTIVITY II: FACTORS THAT AFFECT FLOATATION

Aim:

To identify factors that influence the floating or sinking of an object in a liquid.

You will need:

- Liquids: three glass tumblers (each with a volume of 250 ml) — one filled with water, a second with a sugar/salt solution, and a third with alcohol.
- Objects: A piece of cork, an eraser, turmeric, betel nut, a metal paperclip, a piece of candle, a cut-pencil piece, some clay, some differently sized pieces of carrot and potato, and a ball of crumpled aluminum foil.

What to do:

- Imagine that you drop each of the objects one-by-one in each of the three solutions. Do you think they will sink or float?
- Now, actually drop each of these objects in each of these solutions. Observe if they sink or float.
- Record your predictions & observations in the table.

Think about:

1. Which of your predictions were different from your observations? How would you explain the difference?

2. What kinds of objects tend to float? Is there anything common between them that causes them to float?

3. What kinds of objects tend to sink? Is there anything common between them that causes them to sink?

4. A crushed aluminum foil floats in water. Could you think of a way to make it sink?

5. Did you find any objects that sink in all three liquids? Can you think of a reason why an object that sinks in alcohol, sinks in water and a sugar/salt solution too?

6. Did you find any objects that float in all three liquids? Why do you think these objects float in all three liquids?

7. Did you find any solutions in which all these objects sink? Can you think of a reason why a solution that causes a metal pin to sink causes a cork to sink too?

8. Did you find any solutions in which all these objects float? Why do you think all objects float in this solution?

Discuss with others:

- What properties of an object make it sink or float?
- What properties of a solution make an object sink or float in it?

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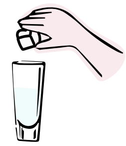
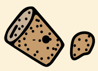
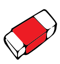
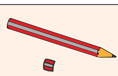
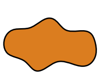
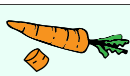
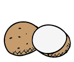
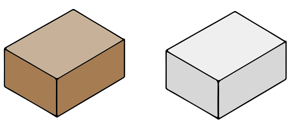
OBJECTS	SOLUTIONS					
	 Water		 Sugar/salt solution		 Alcohol	
	Predicted	Observed	Predicted	Observed	Predicted	Observed
 Piece of cork						
 Eraser						
 Turmeric						
 Betel nut						
 Metal paperclip						
 Piece of candle						
 Cut pencil piece						
 Clay						
 A piece of carrot						
 A piece of potato						
 Ball of crumpled aluminum foil						

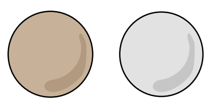
ACTIVITY III: OBJECTS & SOLUTIONS

Aim:
To explore the relationship between the volume of objects and the volume of the liquid they displace.

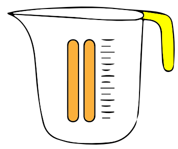
You will need:



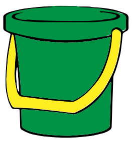
2 cuboids (one made of iron and the other of wood)



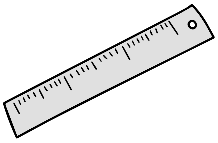
2 spheres (one made of wood, the other of glass)



A measuring jar



A bucket of water



A half-foot scale/ measuring tape to measure the dimensions of the cuboids/spheres

What to do:

- Calculate the volume of the cuboids and spheres.
- Drop each of these objects in a measuring jar filled with water. Observe any change in volume of the water inside the jar.
- Record your observations in the table below.

Objects	Measured volume	Does the object sink or float in water?	What volume of water does the object displace?

Think about:

1. Which objects displace a volume of water that equals their own volume? Do you think this has anything to do with the properties of the object?
2. In which cases is the volume of the object different from the volume of the water it displaces? Do you think this has anything to do with the properties of the object?
3. Does the volume of displaced water ever exceed the volume of the object dropped into it? Why do you think this happens?

i wonder... Rediscovering school science

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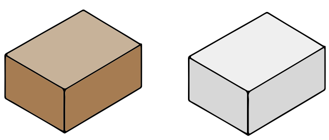
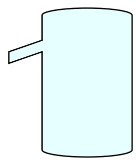
ACTIVITY IV: HOW AN OBJECT'S MASS, VOLUME & DENSITY AFFECT ITS FLOATATION

Aim:
To explore the relationship between the mass, volume, and density of objects with their tendency to sink or float.

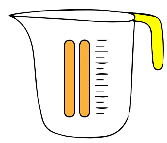
You will need:



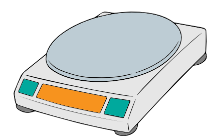
One cuboid block of wood and another of iron of the same dimensions (identical except for the material)



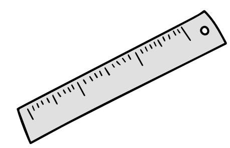
An overflow jar



A measuring jar



An electronic balance to measure mass of the displaced liquid (with an accuracy in grams)



A half-foot scale to measure the dimensions of the cuboids

What to do:

- Find the volume, mass and density of each of the cuboids:
  - o Use the electronic balance to weigh each of the cuboids. The reading that appears on the balance will be of its mass (= w/g, where w = weight & g = acceleration due to gravity = 9.8 m/s^2 on earth).
  - o Calculate the volume of the cuboids using the scale to make necessary measurements.
  - o Calculate the density of the cuboids using the formula: density = mass/volume.
- Use the electronic balance to weigh the empty measuring cylinder. Then, fill the overflow jar with water. Place the measuring cylinder below the spout of the overflow jar. Dip the wooden cuboid into the water in the overflow jar. Record the volume of water that is displaced from the overflow jar into the measuring cylinder. Now, weigh the measuring cylinder with the displaced water (subtracting the mass of the empty cylinder from this value will tell you the mass of the displaced water).
- Repeat this process with the iron cuboid.
- Record your measurements & observations in the table on the next page.

Think about:

1. Which of the two cuboids floats in water, and which one sinks? Since both cuboids have the same volume, how is the sinking or floating of an object related to its mass and density?

2. Which of these three properties of an object — its mass, volume, or density — can you correctly calculate using the water displaced by it?

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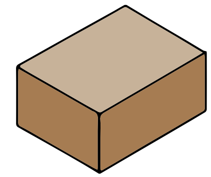
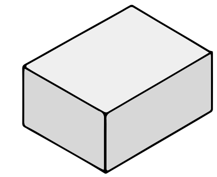


Wood cuboid



Iron cuboid

		Wood cuboid	Iron cuboid
Does the object sink or float?			
Mass	Of object		
	Of water displaced by object		
Volume	Of object		
	Of water displaced by object		
Density	Of object		
	Of water displaced by object		

References:

1. Physics in the Elementary School, Harry O. Gillet, The Elementary School Teacher, Vol. 4, No. 10 (Jun., 1904), pp. 688-692.
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