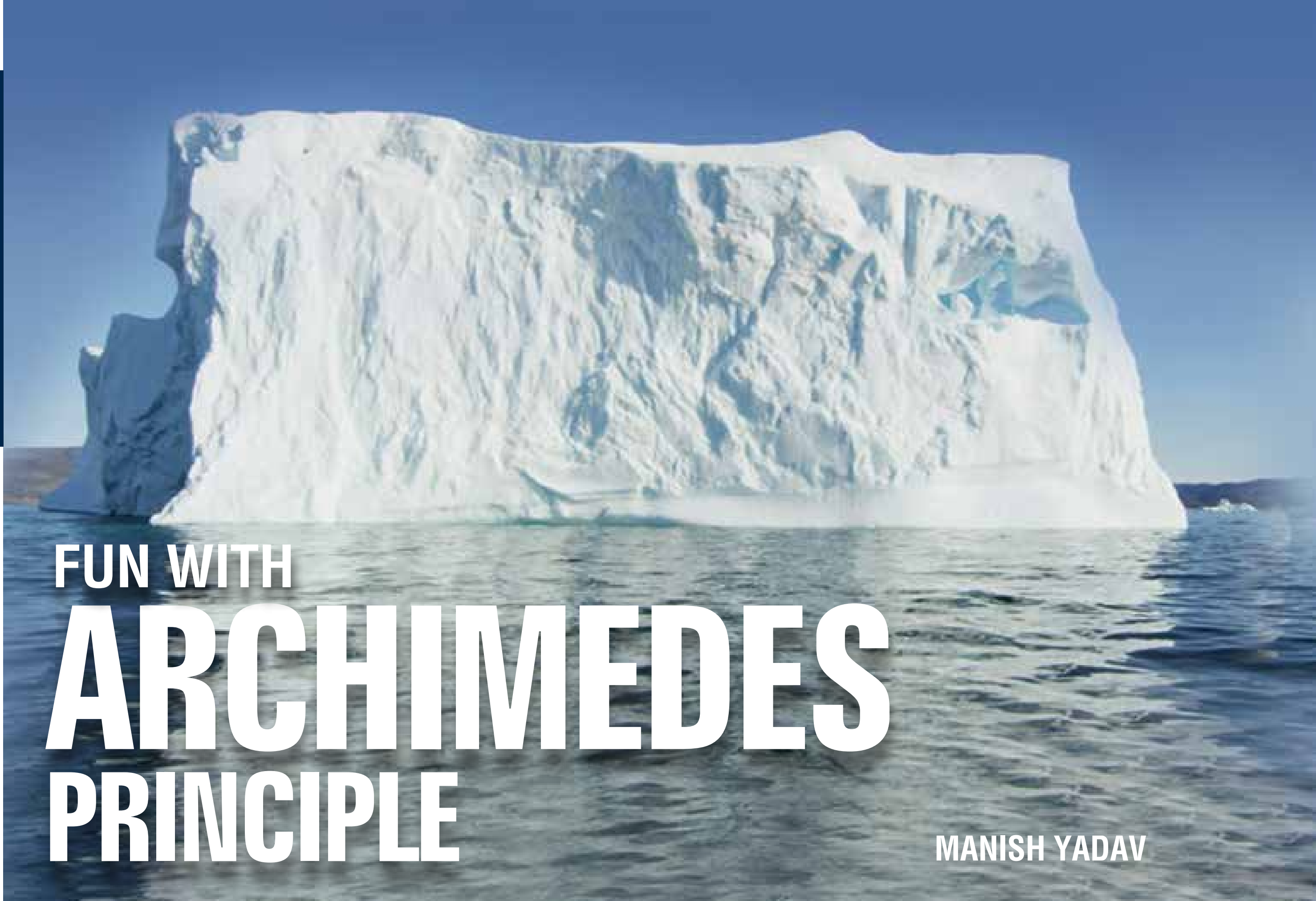

FUN WITH ARCHIMEDES PRINCIPLE

MANISH YADAV

This article presents the journey of a group of science teachers in exploring 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 material.

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 themselves. This is perhaps one of the reasons why teachers see very little value in conducting experiments in their classrooms. How, then, do we rethink the kind of experiments we use to teach physics in school? In this article, we use Archimedes principle to explore answers to this question.

Activity 1: The Thirsty Crow and Archimedes Principle

Many of us have heard of the story of the thirsty crow that used pebbles to drink water from a clay pot. But have you ever attempted to verify this story? What role does the initial level of water in the pot have on the crow's chances of reaching it? Instead of dropping many small pebbles, what if we were to gently drop one big stone into the pot? What else (marbles, vegetable pieces, etc.) can be dropped into the pot to get to the water in it? What conclusion can we draw from this investigation? Would it be accurate to say that the water level rises to the brim only if the pot is filled with sufficient water to start with? Is this 'sufficient' water level half or two-thirds of the volume of the pot?

Thirsty Crow Story

One hot summer day, a thirsty crow was searching for water. After much searching, it found a 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 each of these pebbles, one-by one, into the pot. The water level rose. The crow drank this water and flew away happily.

Figure 1. Verifying the thirsty crow story: Teachers from the 'Let's do Physics' module, Training workshop, Nawai Dec 3-4, 2012. Source: Azim Premji Foundation, Tonk team.

As you can see, this simple story can help us begin an exploration of the Archimedes principle. Imagine yourself to be a science teacher conducting this experiment in the physics classroom - you will most likely see a lot of happy faces discussing the water level and pebbles. We did this activity with science teachers, and as you can see in Fig. 2, they had a lot of fun searching for answers to these questions.

It is important to engage students in a discussion once they finish this activity. Teachers can use questions like, 'can we drop Thermocol pieces to raise the water level' to draw their attention towards sinking and floating properties of different materials.

Activity 2: Factors that influence floatation

The floating or sinking of an object in a liquid depends on both the properties of the object as well as the properties of the liquid in which the object is dropped.

Process: Best performed as a group activity. Ask students to predict whether a particular object will float or sink in each of the three liquids provided, based on prior experience or through assumptions. Encourage them to think of floatation in terms of both the properties of the object they drop into these tumblers, as well as the properties of the liquids within these tumblers. Once they have made their predictions, ask them to test their predictions by dropping different objects into the liquids given to them.

Sinking or floating: You can ask students a variety of questions to get them to think more deeply about floating and sinking properties of objects and their relationship with properties of liquids into which they are dropped. Examples of such questions include – 'did you find any objects that float in all three liquids? Is there a reason why an object that sinks in glycerol, sinks in alcohol and water too? Why does this object sink/float in all three liquids? A crushed Aluminium foil is floating in water - could you think of a way to make it sink?'

This activity naturally leads to our next question - 'what are the properties of the objects or the liquids that influence floatation?' For simplicity, let us first consider only one kind of liquid, like water, and the

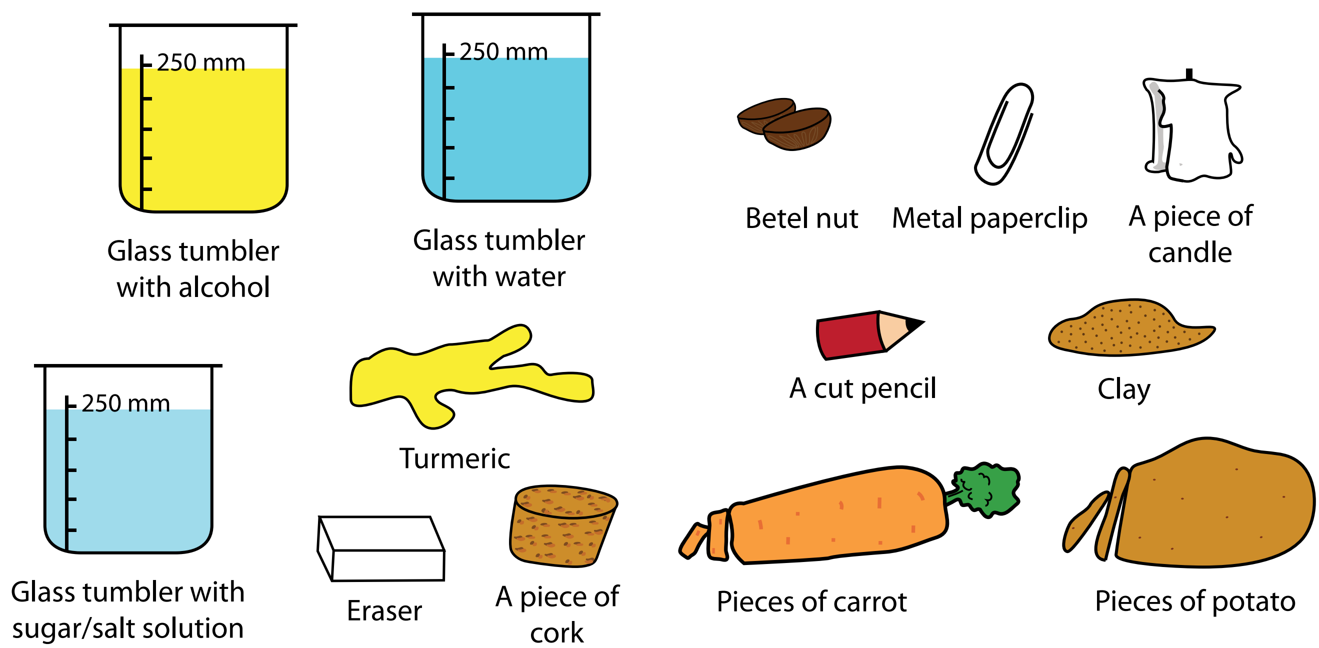

Figure 2. Required Resources for Activity 2. 3 glass tumblers (each with a volume of 250ml) - one filled with alcohol, a second with water, and a third with a sugar/salt solution. A piece of cork, an eraser, turmeric, betelnut, a metal paperclip, a piece of candle, a cut-pencil piece, some clay, and some pieces of carrot and potato.

> 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.

different kind of objects floating in it. Students at the school level will most likely answer this question 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 in Activity 1 can be used to demonstrate that these properties have no connection with floatation.

Activity 3: Exploring the relationship between the volume of objects and the liquid they displace

> The displaced volume of liquid is equal to the volume of the object within the liquid.

Process: Ask students to calculate the volume of the cuboids and spheres by making the necessary measurements and using the appropriate mathematical formulae. Once they've finished 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 objects are dropped into it, students can calculate the volume of water displaced in each case.

Compare these values with the volumes calculated at the beginning of this experiment.

Some observations typical of this experiment are given below:

a. The volume of sunken objects is equal to the volume of the liquid it displaces.

b. The volume of floating objects 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.

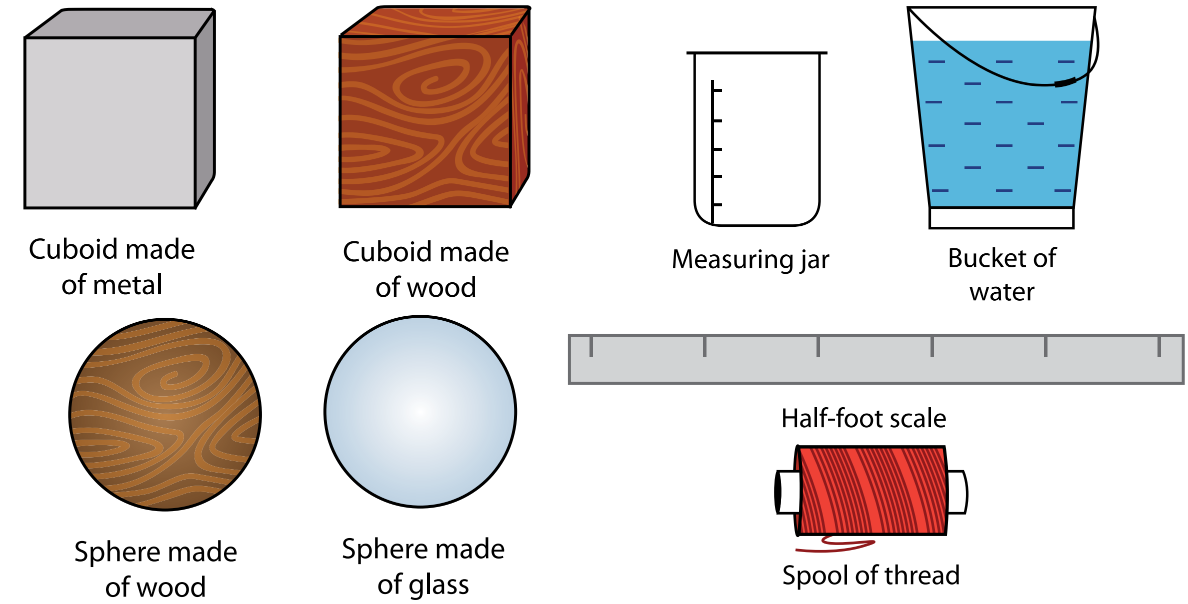

Figure 3. Required Resources for Activity 3. 2 cuboids (one made of iron and the other of wood), 2 big spheres (one made of wood, the other of glass), a measuring jar, a spool of thread, a bucket of water and a half-foot scale to measure the dimensions of the cuboids.

Activity 4: Exploring the relationship of mass and density in floatation and sinking

Process: Ask students to calculate the mass and volume of the cuboids by making the necessary measurements and using the appropriate mathematical formulae. Then ask them to dip the cuboids one-by-one in water kept in a measuring jar, and record the mass and volume of displaced water in each case. Encourage them to use these observations to explore the relationship between mass, volume and density; especially given the fact that objects of the same volume can show different floatation properties (while one floats, another may sink). After they've finished doing this, you can also ask students to test this relationship with objects of irregular shape. This will help them arrive at a relationship like this:

Here V_o stands for the volume of the object and V_w for the volume of water displaced. Similarly, D_o stands for the density of the object, while D_w stands for the density of the water displaced.

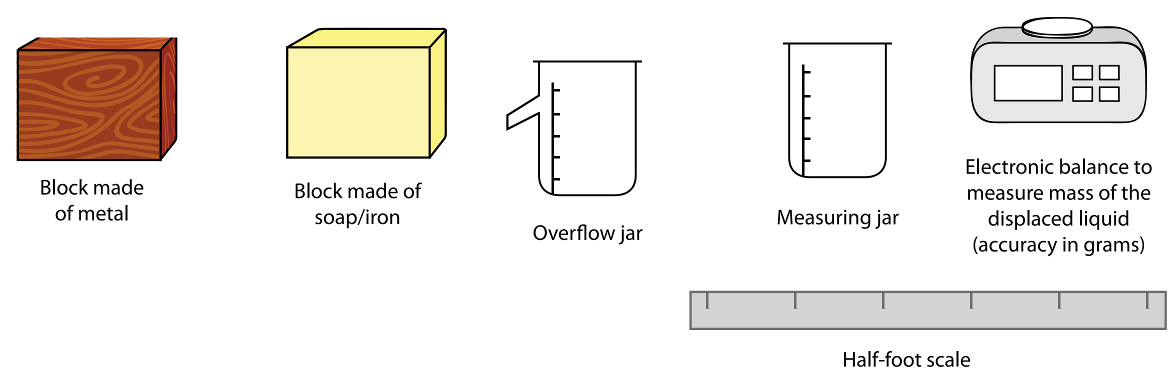

Figure 4. Required Resources for Activity 4. A block of wood and a block of soap/iron of the same dimensions (identical except for the material), an overflow jar, a measuring jar, an electronic balance to measure mass of the displaced liquid (accuracy in grams), and a half-foot scale to measure the dimensions of the cuboids.

	Volume Relation	Mass Relation	Density Relation (Mass / Volume)
Sink	$V_o = V_w$	$M_o > M_w$	$D_o > D_w$
Float	$V_o > V_w$	$M_o = M_w$	$D_o < D_w$

> Will the results of this experiment be different if the density of the object is the same as the density of the liquid in which it is dropped? You can explore this question by dropping carrot pieces first in water, and then in a saturated solution of citric acid/ sugar solution at room temperature.

> Objects float on the surface of liquids of higher density, or below the surface of liquids of equal density. They sink in liquids with a density lower than their own.

Once we explore the properties of objects, with reference to floatation, in one liquid (water), we can easily extend it to other kinds of liquids, like, alcohol, water, citric acid, salt solution and sugar solution. Ask students to think of how it is possible that the same object can float (partially or fully) and sink in different liquids. This is important to establish the fact that floating and sinking do NOT depend upon object properties alone. A simple demonstration of this fact can be seen using an egg in salt water (or carrot in citric acid). When we drop an egg into a jug of tap water, it will sink. By adding salt to tap water, the egg can be made to float as the density of saltwater is more than that of tap water.

This may lead to another question – 'Does the shape of an object have any role to play in flotation? Give students some clay/aluminium foil and a tub of water. Use different shapes made out of clay/aluminium foil, leading to different contact areas, to compare the different volumes of water displaced by them. This can lead to a discussion about how the shape of boats and ships are designed for floating, despite being made of material with a density much higher than seawater.

Conclusion

These are just some ideas for experiments that can be used to explore a concept in Physics in ways that make its teaching and learning more engaging. This kind of approach provides students with the opportunity to 'explore' and 'discover' physical concepts themselves, and through such experiences, begin to construct their own knowledge. We tried out these ideas with 35 Government teachers (Nawai, Rajasthan), and received very strong positive feedback. Wouldn't you want to try them out in class too?

Acknowledgement

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