Will it sink or float?

Buoyancy explains why some objects float while others sink, helping us understand how objects behave in liquids and gases (fluids). This concept is important for designing ships, submarines, hot air balloons, and even for understanding natural events, like how fish swim or how clouds form in the atmosphere.

The goal of this learning unit is to encourage students to think about floating and sinking in terms of buoyant force.

Unit Objectives: (i) Understand the concept of buoyant force and its origin (ii) Explore and explain why objects float or sink (iii) Measure and calculate buoyant force using simple apparatus (iv) Investigate the dependence of buoyant force on physical properties (v) Develop and use representational models of forces in fluids

Minimum Time required: 3 sessions (40 min each)

Type of Learning Unit: Laboratory

Have you ever seen that some objects float on water while others sink? It's interesting that sometimes heavy objects float and light ones sink. Can you think about why this happens?

You can take some everyday objects and test whether they float or sink.

Q 1. What do you feel when you try to lift something from under the water? Does it feel heavier or lighter than when it's outside the water?

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Encourage responses such as "it feels lighter," "there's less weight," or "water moves or splashes." Guide the discussion towards the idea that objects feel lighter when lifted underwater.

Q 2. What do you think will happen if you push a floating object—like a tennis ball or an empty bottle—under the water and then let it go? Will it stay there, sink, or come back up?

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When an object that is usually 'floating' in water *will rise up.*

Do it yourself! - Task 1: Exploring forces underwater

Materials: Bucket/ beaker (with water) and an empty plastic bottle or plastic container

Take a bucket or a beaker and fill it with water. Now take an empty plastic bottle or container that is sealed tightly with a cap. Try to push it down to the bottom of the bucket. What do you observe?

Q 3. What did you notice when you pushed the bottle underwater? What forces do you think are acting on it? Try to draw a simple diagram to show these forces. You can use arrows to show the direction of the forces.

The purpose of this question is to encourage students to visually represent the problem. Students might initially draw actual objects, while some may use arrows to show the forces acting on the object in a particular direction. Students could draw two diagrams: one where the object is pushed to the bottom but the hand hasn't been removed, and another when the hand is removed, allowing the object to float.

Consider a floating object, like a plastic bottle in a bucket of water. If the water is still, the bottle will not sink and will continue floating. In a tug of war, when equal forces are applied in opposite directions, the knot on the rope stays in the same place. If more force is applied in one direction, the knot moves in that direction. Students should apply the concept of "net forces" to understand the floating object in both situations (floating and underwater).

For a floating object, the 'weight of the object' is the downward force caused by Earth's gravitational pull, which can be calculated as $W = m * g$, where 'm' is the mass of the object and 'g' is the acceleration due to gravity. To balance this downward force, there must be an upward buoyant force equal to the weight of the object.

When the object is pushed underwater, the forces acting on it are unbalanced. Once the hand is released, the buoyant force will be greater than the weight of the object, causing it to rise. Students should be able to represent these forces using arrows to show direction. Teachers can guide students to represent balanced forces with equal-length arrows pointing in opposite directions, and unbalanced forces with arrows of different lengths.

Note that buoyancy isn't just in water—air is also a fluid. The same principle applies to balloons, birds, and airplanes, which experience buoyant force in the air.

Now we know why objects feel lighter in water or sometimes float up on their own. This happens because of a force called buoyant force. Let's now try to measure this force using a simple activity.

Task 2: Measuring the weight of an object underwater:

Materials: (i) Stones (roughly the size of half the palm) (ii) Any objects that float (iii) Spring balance (for weighing) (iv) Glass beaker with water

No.	Condition	Object's weight outside water (N)	Object's weight inside water (N)	Object's weight inside salt-water (N)		Buoyant force	
						For water	For salt-water
1	Sinking						
2	Sinking						
3	Sinking						
4	Floating						
5	Floating						

Table 1

Q 4. For a given object, how is its weight in air different from its weight in water? Which physical property do you think explains this difference?

Q 5. How can you find out how strong the buoyant force is in each case using the weights you observed? (Hint: Think about the difference between the object's weight in air and its weight in water.)

Allow students to think and discuss their ideas. Help them understand that when the object is in water, the buoyant force acts upwards on the object. This buoyant force partially balances the weight of the object. As a result, the weight of the object will show a reduced reading on the spring balance when it is underwater. The weight of the object underwater is called the apparent weight, which is also the reduced weight.

The difference between the two readings (the weight in air and the weight underwater) gives us the buoyant force acting on the object. This is based on the natural definition of apparent weight, which is the reduction of the object's weight underwater due to the buoyant force acting opposite to gravity:

Apparent Weight = Actual Weight - Buoyant Force.

Q 6. What is the value of the buoyant force for objects that float? When will an object float, and when will it sink?

The magnitude of the buoyant force on a floating object is equal to the weight of the object in air. An object will sink if the buoyant force is less than the weight of the object. It will float if the buoyant force equals or exceeds the weight of the object.

Q 7. How does the buoyant force in water compare to the buoyant force in saltwater for each object?

The difference between an object's actual weight and its apparent weight in normal water or saltwater gives us the buoyant force for each liquid. You will notice that the buoyant force in saltwater is greater than in normal water. This will also be reflected in the difference in the object's apparent weight in the two liquids. That’s why objects float more easily in denser fluids.

Q 8. Take one of the stones and measure its weight at different depths in the water. What do you observe? What conclusions can you make from this?

It is observed that the weight of an object underwater stays the same, no matter how deep it is placed. This means that the buoyant force on the object does not depend on how deep the object is in the water.

Task 3: What is the origin of buoyant forces?

Take an empty plastic bottle and make small holes at different levels, from the bottom to the top. Then, fill the bottle with water. Observe how far the water stream from each hole falls (Figure 1).

Figure 1

You will notice that the water stream from the top hole travels the shortest distance, while the stream from the bottom hole travels the farthest.

If time allows, the facilitator should demonstrate this activity. It can also be repeated foreach group.

Q 9.Why does the water from the bottom hole travel the farthest?

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The stream from the bottom hole goes the farthest because the pressure is higher at greater depths in a fluid. This higher pressure pushes the water out with more force, making the stream travel farther.

Q 10. What does this tell us about the pressure in a fluid at different depths?

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Pressure in a fluid increases with depth. This means that the pressure at the bottom of an object in a fluid is higher than the pressure at the top. As a result, the water pushes upward on the bottom of the object with more force than it pushes downward on the top. This difference in force creates a net upward force called the buoyant force.

More details for explanation:

- Pressure is the force acting on a surface per unit area.
- In a fluid, pressure is caused by the weight of the liquid above a surface.
- This pressure is exerted in all directions—up, down, and sideways.

However, pressure is not the same at all points in a fluid. It increases with depth because the deeper you go, the more liquid there is above that point. So, more weight means more pressure.

In the case of a submerged object, like a plastic container in water:

- The pressure at the bottom of the container is greater than at the top.
- The horizontal forces cancel each other out.
- The vertical pressure difference creates a net upward force—this is the buoyant force or upthrust.

This is why objects in fluids experience an upward push—because of the pressure difference between the bottom and top surfaces.

<u>PART II:</u> So far, we have explored the concept of buoyant force in fluids. We conducted an activity to measure its magnitude and examined the concept behind its origin.
“The buoyant force arises from the pressure difference in fluids. The pressure on the bottom of an object submerged in the fluid is greater than the pressure on the top, creating a net upward force. This upward force is what we refer to as the buoyant or upthrust force.”

Now, let us consider the factors that influence the buoyant force.

Q.11. What do you think are some properties of the object and the fluid that can change or influence the buoyant force? Write your answers separately for the object and the fluid.

Let the students explore and share their ideas about which properties might affect the buoyant force. For example:

- **For objects:** weight, volume, density, temperature, material, shape, surface area, colour, whether the object is hollow or porous.
- **For fluids:** density, volume, temperature, viscosity, and colour.

The following tasks are designed to explore which of these factors affect the buoyant force and how they do so. In each task, we will focus on one specific factor.

Let's explore these questions to understand more about the buoyant force and why some objects float while others sink.

Task 3: Does the buoyant force depend upon the weight of the object?

A small stone sinks right away, while a large ship floats. This makes us wonder, "Does the buoyant force on an object depend on its weight?" Let's find out.

When asked to predict, students might assume that lighter objects float and heavier ones sink. Teachers should encourage them to test this idea through experiments.

To test if buoyant force depends on weight, we need to consider objects with different weights but keep other factors the same so we only test one variable. In this case, we will keep the volume the same. In the table below, we provide the weight measurements of 5 different plastic containers with closed lids (Figure 1), each having a volume of 100 cm^3. We add a different number of marbles to each container, so the weight of each container is different. Then, we measure the weight of the container both outside and inside the water using a spring balance, just like we did in task 2.

Figure 2

Object no.	Volume of the container (cm^3)	Weight of the container- outside water (N)	Weight of the container- inside water (N)	Buoyant force
1	100	110	35	
2	100	125	50	
3	100	135	60	
4	100	150	75	
5	100	220	145	

Table 2

Q 12. What relationship do you observe between the buoyant force and the weight of objects that have the same volume?

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After calculating the buoyant force for objects with different weights, students should notice that the difference between actual weight and apparent weight stays the same for all containers. This shows that for objects with the same volume but different weights, the buoyant force does not change. This means the buoyant force does not depend on its weight.

We will check if it depends on the volume of the object.

Task 4: Does the buoyant force depend on the volume of an object?

In the previous task, we explored how the buoyant force relates to the weight of the object. Now, let's investigate whether the buoyant force changes with the volume of the object by observing how it varies in objects with different volumes.

We will start by taking objects of the same weight but different volumes, then follow the same procedure as in Task 3 to calculate the buoyant force. In the table below, we provide the mass and volume measurements of 5 objects. These objects are cylindrical in shape and made from different materials: iron, ceramic, plastic, wood, and foam. The dimensions, mass, and volume of these objects are listed in the table below.

Object no.	Material	Radius (cm)	Height (cm)	Vol of the object (cm^3)	Object's mass outside water (mg)	Object's mass inside water (mg)	Buoyant force
1	Iron	1.5	3.8	27	100	73	
2	Clay	2.0	3.6	45	100	55	
3	Plastic	2.2	4.0	60	100	40	
4	Wood	2.5	4.1	80	100	20	
5	Foam	2.8	4.1	100	100	0	

Table 3

Q 13. What relationship do you observe between the magnitude of the buoyant force and the volume of objects that have the same weight?

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It is observed that for objects with the same weight but different volumes, the buoyant force is different. As the volume increases, the buoyant force also increases.
These tasks show that the buoyant force depends on the volume of the object submerged in the liquid, not on its weight.

In Table 2, the important data for calculating the buoyant force is the mass of the objects—both in air and in water. The other details help students understand the type, size, and scale of the objects used in the experiment.

From Tasks 2, 3, and 4, it is clear that the buoyant force depends on the density of the fluid and the volume of the object. It does not depend on the mass of the object that is submerged.

Extended Task 5: Density--Sinking & Floating:

In the previous tasks, we explored how weight and volume affect the buoyant force.

If we change the weight of an object while keeping its volume constant, the buoyant force for these objects _____________ changes/ does not change.

If we change the volume of an object while keeping its weight constant, the buoyant force for these objects _____________ changes/ does not change.

From Task 2, recall that for a floating object, the magnitude of the buoyant force is __________ (more/ less/ equal) to its weight in air. So, to keep an object floating, the magnitude of the buoyant force should always be __________ (more/ less/ equal) to the weight of the object. An object will sink if the magnitude of the buoyant force is __________ (more/ less/ equal) than the object's weight outside water.

Let us now explore how the density (ϱ) of an object affects whether it will float or sink.

Unlike in Tasks 3 and 4, where we studied how weight and volume affect the buoyant force, in this task we will focus on how the density of an object affects floating or sinking.

Place an empty sealed plastic container (like the one shown in Figure 2) in water. At first, the container floats on the surface of the water. Now, add some objects into the container—these could be marbles, small stones, sand, or even water. As you keep adding objects, the container starts to submerge. Keep adding and observe how the position of the container in water changes.

Q 14. When objects are added to the plastic container, does the mass or the volume of the container change? How?

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When objects are added to an empty container, its mass increases. Make sure students observe that while the volume of the material inside the container changes, the outer volume of the container stays the same. This is because we are only changing what's inside, not the container itself.

Also, it's important to understand that an object can either float (when the buoyant force balances the gravitational force) or sink. It cannot do both at the same time—there's no such thing as an object being partly floating and partly sinking.

Q 15. How does this affect the density of the container? When do you think the container will sink?

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In this situation, the total weight includes the weight of the container plus the weight of the stones or marbles placed inside it.

Even though the weight increases, the outer volume of the container stays the same. This causes the average density of the container (including its contents) to increase.

The container will sink when the buoyant force is no longer able to support the total downward force of gravity. This happens when the average density of the container becomes greater than the density of water.

Note: ***The density of the container's material isn't changing—we're still using the same container. What's changing is the average density of the entire object (container + marbles/stones).***

Example:
Think of large cargo ships. Even though they are made of heavy materials like iron and steel (which are denser than water), they don't sink. This is because their average density is kept low by having large hollow spaces inside. These spaces reduce the overall density, allowing the ship to float. So, it's not just the material's density that matters, but the average density of the whole object.

The figure below, there are six panels. Each panel shows a plastic container with marbles placed in a beaker filled with water. The same container is used in all six panels, but the number of marbles inside the container varies. Consequently, the weight of the container changes across panels, while its volume remains constant. As a result, the average density of the container differs in each case.

Q 16. For each container in the figure (or next to the panels), indicate whether its density (ϱ) is = 1, > 1, or < 1 (remember, the density of water is 1).

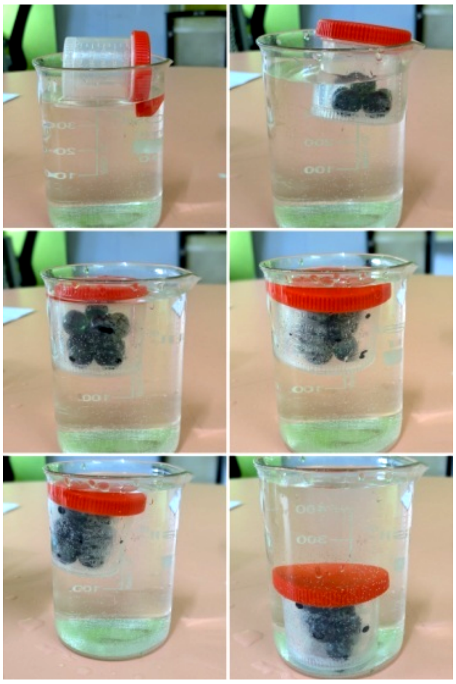

Figure 3

Whenever the container is floating in water, its density is less than 1 g/cm³, which is the density of water. However, in the last panel, where the container sinks, its density is greater than that of water.

An object can either float (when the buoyant force balances the gravitational force) or sink. It cannot be both floating and sinking at the same time, such as being partially floating or partially sinking.

The results from all the tasks above show that an object floats in water when the buoyant force is equal to or greater than the downward gravitational force. In simple terms, this happens when the object's average density is less than the density of the fluid it is in.

References

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