Whatever Floats Your Boat

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Field of Interest: Physics, Buoyancy, Density

Brief Overview:
Mentees will understand density and buoyancy by making boats, playing trivia games, and making their own lava lamps.

Agenda:

- Introduction (5 min)
- Module 1: Is it a floater? (5 min)
- Module 2: Layering Lavalamps (20-25 min)
- Module 3: We're getting cRAFTy (15-20 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:

- ➔ Density
- ➔ Buoyancy
- ➔ Pressure
- ➔ Gravity
- ➔ Archimedes Principle
- ➔ States of Matter
- ➔ Solubility
- ➔ Immiscible
- ➔ Displacement
- ➔ Pressure
- ➔ Surface Area
- ➔ Weight Distribution

Background for Mentors

Module 1

- Density
- Buoyancy
- Gravity
- Archimedes Principle

When an object is dropped into a liquid, it could either float or sink. The object's **Density** is a main determiner of the float or sink mechanics as it describes how much substance is packed into a certain volume. An example of a high density object is lead as the molecules are packed tightly together compared to air, a low density material where molecules are spread far apart. The formula for density is $Density = \frac{mass}{volume}$ which is key for determining sinking or floating.

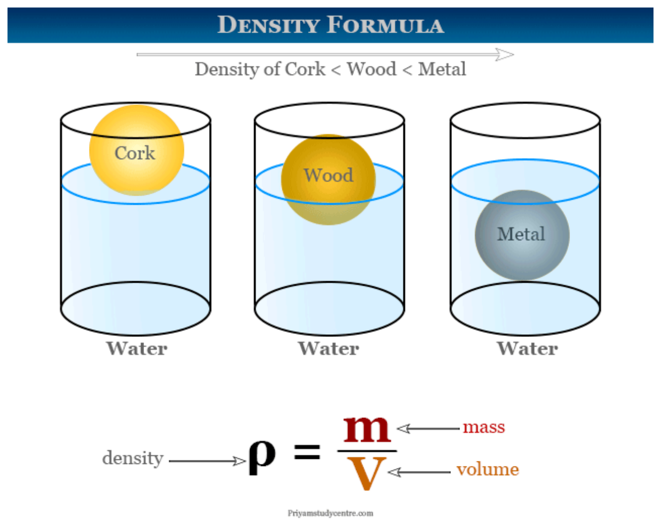
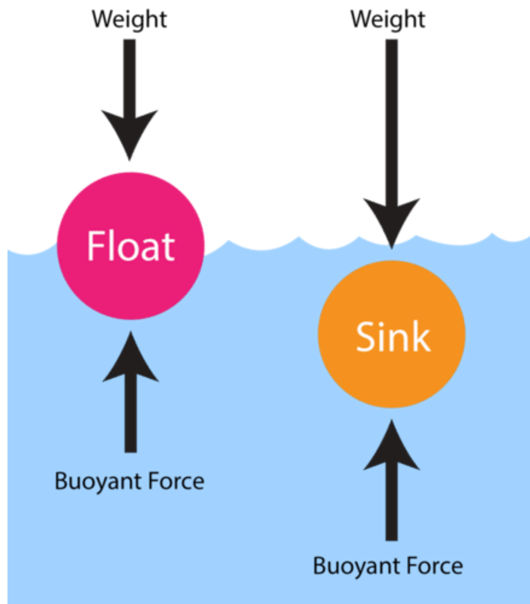


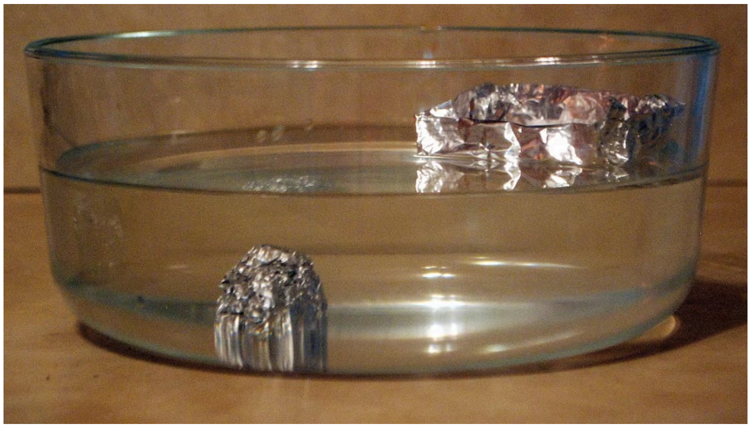
Figure 1: Objects either floating or sinking based on mass

Gravity is the force that pulls everything toward the Earth. This force gives every object / material a specific weight based upon its mass. If an object is dropped into a liquid, gravity pulls it downward, however the liquid also pushes the object back up in retaliation. To calculate the force of gravity for an object, it is $F_g = m * g$ where m is the mass of the object and g is the gravitational force.

The upward push on an object submerged in water from the liquid is called **Buoyancy.** The upward buoyant force on a submerged object in a fluid is equal to the weight of the fluid that the object has displaced which is also known as **Archimedes Principle**. The buoyancy force can be calculated by $F_{buoyant} = \rho_{fluid} \cdot g \cdot V_{displaced}$, where ρ_{fluid} is the density of the fluid, *g* is the acceleration of gravity, and $V_{displaced}$ is the volume of fluid displaced by the object.

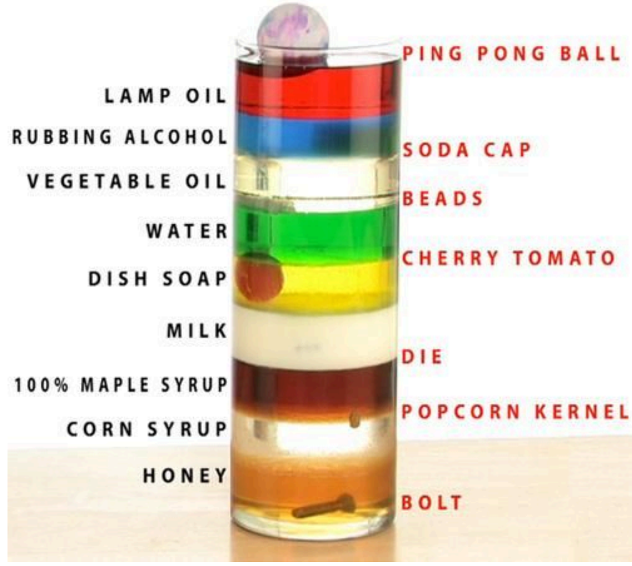
If the force of gravity on the object submerged underneath water is greater than the buoyant force acting on the object, the object will sink. If the buoyant force is greater than the object's gravitational force, then the object will float.

	 Figure 2: If weight and buoyancy are equal the object will float. If weight is heavier than buoyancy, the object will sink.

Module 2 ● Displacement ● Surface Area ● Weight Distribution ● Pressure	Besides density, there are other fundamental physical principles that explain why some objects float while others sink. When an object is placed in water, it pushes water out of the way which is called **displacement**. The amount of water that is displaced goes hand in hand with the strength of the buoyant force or the upward force exerted by the water that counteracts. If there is a greater volume of water displaced by the object, the buoyant force will be greater, allowing the object to stay more afloat. Another important factor is **surface area**. The shape of an object determines how its weight is distributed across the surface beneath it. For example, compare a crumpled ball of tin foil with a flat sheet of tin foil placed gently on water. The flat sheet has a larger surface area, which allows its weight to be spread out more evenly. When weight is distributed over a larger area, the **pressure** on any single point is reduced. **Pressure** is the amount of force applied over a specific area (Pressure = Force ÷ Area). Increasing the surface area lowers the pressure exerted on the surface, allowing it to displace more fluid. In contrast, a smaller or uneven shape concentrates weight in one spot, increasing pressure and making it more likely for the object to sink  Figure 5: The tin foil ball has more pressure in a single point and less surface area, resulting in it sinking. The tin foil boat has more surface area, reducing pressure at a single point and displacing a greater volume of water allowing it to float. Equally important is **weight distribution**. On a raft for example, if all of the weight was distributed on one side of the boat, it would tip and flip over even if the raft is large in surface area. Weight distribution refers to how the total weight is spread out over a surface. When weight is evenly distributed, the center of gravity remains balanced, allowing the raft to float

	longer and hold more weight. Engineers use this same concept in designing real ships, ensuring that weight is properly balanced to maintain stability and prevent capsizing.

Module 3 • States of Matter • Solubility • Immiscible	There are three fundamental **States of Matter** including solids, liquids, and gases. When different types of matter are submerged into liquids, their behaviors vary based upon unique physical properties particularly density and **Solubility,** the ability of a substance to dissolve in another substance to form a solution. For example, when a solid alka-seltzer tablet is dropped into water, it initially sinks because it is denser than the surrounding liquid.. However, because the alka-seltzer is a soluble substance, it begins to dissolve producing gas bubbles. The gas bubbles are carbon dioxide (CO2) which is significantly less dense than water, resulting in the gas rising rapidly from the bottom of the surface, clearly illustrating the different densities of matter.  Figure 3: Alka-seltzer tablet reacting to water, creating CO2 bubbles Typically when mixing liquids, the molecules blend uniformly or react with one another, often resulting in new colors, textures, or substances. However, not all liquids are capable of mixing with each other as some are **Immiscible** meaning they remain separate due to differences in molecular structures and chemical properties. Oil for example does not mix with liquid. It floats on top of the water because it is less dense than water and has different polarities. Differences in density can cause one liquid to rise above the other. Simultaneously, buoyant forces help maintain the separation between two layers, explaining why distinct layers can form between two liquids rather than combining into one solution.

	 Figure 4: Liquids have different densities and will float / sink below one another depending on their characteristics

Introduction

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Concepts to Introduce

Buoyancy
Upward force on objects submerged under water that allow it to float.
States of Matter
Substances have different physical properties that cause it to react differently in liquids
Surface Area
The shape of an object can determine whether or not it will sink / float

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Questions to Pique Interest

Who has ever swam before? Does anyone know why we are able to float and not sink to the bottom of a pool?
Why can I stick my hand through liquids but not through solid objects?
If I have two pieces of tin foil that are the same weight, why does a crumpled up piece of paper sink and a flat sheet float.
Imagine we are all on a boat. If we all moved to one side of the boat, would it tilt or stay the same?

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Scientists, Current and Past Events

Archimedes is the founder of buoyancy, discovering it when testing if the kings crown was gold or not.
The melting polar ice caps are decreasing the density of salt water, causing sea levels to rise.
Link to Article
Aircraft carriers are able to float even though they are so heavy because they hold massive air pockets that decrease the overall density of the ship. .

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Careers and Applications

In Aerospace, engineers deal with buoyant forces / density with the principles of air, working with fluid dynamics and weight distribution for flight stability
In Naval architecture / marine engineering, the process of building boats requires vast knowledge in buoyant forces, ensuring vessels stay afloat and can handle loads safely.
In civil / mechanical engineering, people design machines and structures that need to have proper weight balance and force distribution for safety and efficiency.

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Module 1: Is it a floater?

Learn about density and buoyancy with everyday items. Mentees will guess whether an object will float or sink understanding how gravity, air, surface tension,

Teaching Goals	Materials
1. **Density**: how much of something is packed into a certain space 2. **Buoyancy**: the force that helps things float in water or air 3. **Gravity**: the force that pulls everything toward Earth 4. **Archimedes Principle:** An object immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces.	Per site: • 1 Mandarin Orange • 1 Ping pong ball • 1 Rock or Coin • 1 Clear cut plastic water bottle

Different Methods for Teaching

Real-Life Examples: Try to have mentees think about swimming and why they are able to float. Discuss how we have air in our lungs that decrease our bodies density, making the buoyant force greater than our force of gravity.

- You can specify that if we let out all the air in our lungs in the water we would sink to the bottom.

Mentees who can't swim: Ask mentees to consider why lifejackets are so reliable and important to wear even if you know how to swim. It is because the air and materials inside have a very low density which allows us to float.

For older sites: Drawing out the different forces can be helpful. Use varying length of lines to represent the amount of force.

Procedure

1. Empty out the plastic container and fill it with water. Either use the sink inside the classroom or a bathroom if necessary.
2. Ask mentees whether the object will float or sink before demonstrating each object.
3. Begin with a rock. This one should be the easiest as it will sink. Ask mentees beforehand if it will sink or float
4. Next, ask mentees if the ping pong ball will float or sink. Then place a ping pong ball on top of the water. It will float and explain how the buoyant force is greater than the object's weight because it is light and less dense due to the air inside.

Figure 1: Mandarin orange floating with skin vs Without skin

5. Finally, do the mandarin orange with and without the peel. Because there are air pockets inside the unpeeled mandarin orange it will float but without the peel, it will sink. Ask mentees will it float with the skin, demonstrate, then take the peel off and ask again. Explain after why it floats / sinks.	

Classroom Notes

Test the mandarin with the peel first!!! and ensure there are no punctures in it.
Make it clear from the beginning that the mentees will not be allowed to eat the mandarin and that it is only a demonstration.

Module 2: Build-A-Boat

Mentees will compete to make the best boat possible that can hold as many pennies as possible. They will be given a small tin foil sheet and will turn it into a boat.

Teaching Goals	Materials
1. **Surface Area:** The total area covering the outside of an object 2. **Weight Distribution:** How weight is spread out 3. **Displacement**: The force spread over an area 4. **Pressure:** The amount of force applied over a specific area	Per Site: • 200 Pennies Per mentee: • 1 Tin foil (per mentee) Per group: • 4 Large Containers (groups of 4-6) • Paper Towels

Different Methods for Teaching

1. **Surface Area:** Have mentees think about two different-sized boxes (i.e. a shoe box vs. a large Amazon/TV box). Which box would take more wrapping paper to cover the whole thing? More surface = more wrapping
2. **Weight Distribution:**
    a. Have mentees think about holding their backpack with only one shoulder vs both.
    b. What about putting all their school supplies on one side of their backpack vs. having everything distributed evenly. Which would feel better?
    c. Why do their school desks have 4 legs instead of 1? If there is only 1, usually there's a base, ask them why that may be.
3. **Displacement:** If you filled a cup full with water and had a mentee toss a rock into it, would the water spill over?
4. **Pressure:** Ask mentees if they have ever popped a balloon. Discuss how it pops.
    a. Pushing a balloon with just one finger vs. squishing it between your palms. Does the balloon pop?
    b. *Alternative:* Poking wrist with one finger vs. palm of hand. Where is all the force focused?

Full classroom procedure	
1. Each student will be given a 6x6 tin foil sheet and be given 3 minutes to fold the edges of the sheet to make a boat. Show examples and explain how they need to prioritize a boat that has good surface area but also tall enough. 2. After the time is up, have two students at a time place pennies into their boat. Explain how they need to place it in different parts of the boat in order to improve weight distribution and keep gravity from pulling down in one singular point 3. After the boat sinks, tally up how many pennies each boat held and continue with the next students.	**Figure 1:** *Tin foil boat holding pennies and staying afloat.*

Classroom Notes

Potentially have mentors place pennies into the boat. Mentees may steal pennies. Make sure mentees boats can fit inside the plastic container before testing.

Module 3: Layering Lavalamps!

Mentees will be using an iterative procedure to build their own approximation of a fractal.

Teaching Goals	Materials
1. **States of Matter:** Solid, liquid, and gas, each with different shapes and movement of particles 2. **Solubility:** How well a substance can dissolve in liquid 3. **Immiscible**: Liquids that do not mix	Per Mentee: • Empty water bottle per mentee • Water • Vegetable oil • Water-based food coloring • Alka-Seltzer tablet

Different Methods for Teaching

States of Matter: Have mentees brainstorm different solids (keeps its shape), liquids (keeps shape of the container), and gases (spreads out to fill the space, often invisible)

Solubility: Have mentees think about things that dissolve in water (Sugar/Salt in water, Honey in hot tea, etc.)

Immiscible: What about things that don't mix with water? (Sand in water, Oil in water, etc.)

Lavalamp Procedure

1. Fill the plastic bottle with **1/4** water and add one drop of food coloring. Try to use a funnel or be careful when pouring it in.
2. Next add **1/2** oil, and leave the rest of the bottle with **1/4** air. WE DO NOT WANT THE BOTTLE TO OVERFLOW!
3. Cut an alka seltzer tab in ⅛-¼ so it fits inside the plastic bottle. It should begin to fizz, sending carbon dioxide bubbles up.
4. Because the oil is less dense than water, it will sit on top of the water. The alka-seltzer tab will create gas bubbles of carbon dioxide that carry that colored water to the top and then sink as the gas escapes from the water bottle.
5. Discuss how the carbon dioxide / air bubbles are less dense than water so it ends up floating.

Figure 1: Lavalamp w/ alka-seltzer tablet

Figure 2: Lava lamp example with water mixture and

	wax, demonstrating density differences in liquids.

Classroom Notes
Make sure that mentees do **NOT** mix the water and oil together/shake the bottles!! DO NOT OVERFILL THE WATER! IT WILL SPILL OVER AND CAUSE A MESS

Conclusion

Ask mentees how objects float and emphasize the importance of buoyancy. Give them real world examples of boats and how buoyancy is in everyday life. Have mentees explain one thing they learned today.