POWER POINT GUIDE: DENSITY, FLOAT OR SINK?

SLIDE 1

Show the movie trailer. (click on image picture to link to movie trailer).

Ask students these questions following the trailer:

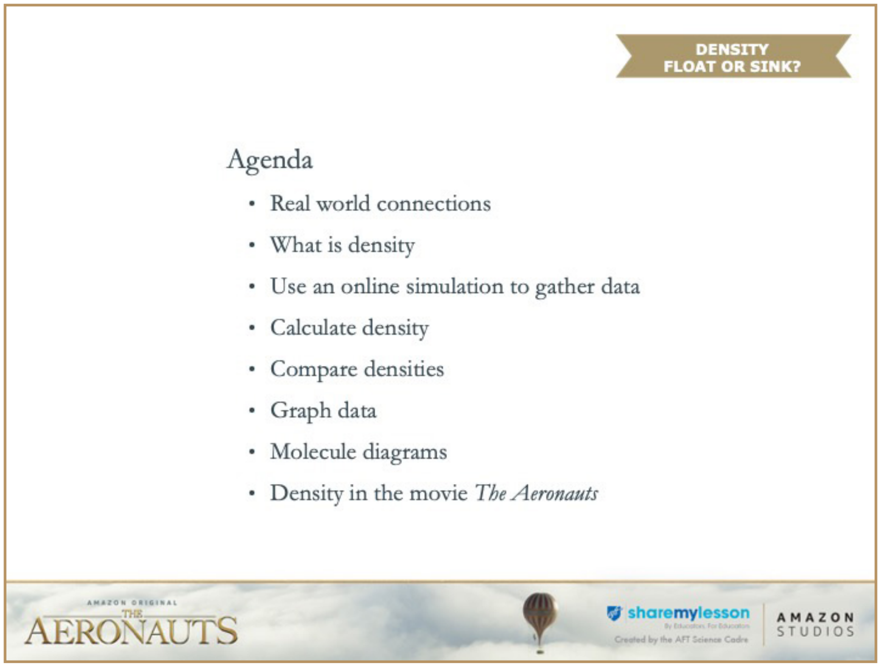
- What science concepts do you think Amelia Wren, and other aeronauts need to know to be able to operate their balloon?

https://www.dictionary.com/browse/aeronaut

LEARNING TARGETS

- Use a digital simulation to collect science data
- Use displacement to determine the volume of an object.
- Calculate density.
- Draw molecule diagrams to model the density of solids and liquids.
- Predict if a material will float or sink given the density of the material and the density of the fluid .
- Compare the density of the gas inside the balloon used in the movie *The Aeronauts* with the density of the gas in our atmosphere.

AMAZON ORIGINAL THE AERONAUTS sharemylesson By Educators, For Educators Created by the AFT Science Cadre AMAZON STUDIOS


DENSITY
FLOAT OR SINK?
Agenda
• Real world connections
• What is density
• Use an online simulation to gather data
• Calculate density
• Compare densities
• Graph data
• Molecule diagrams
• Density in the movie *The Aeronauts*
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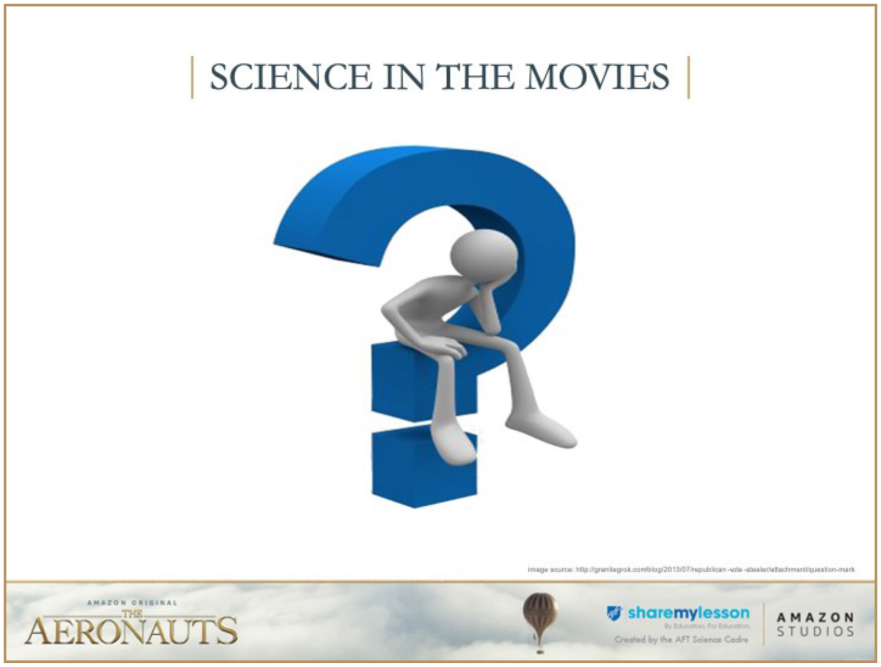


Ask students:

- Why is an understanding of density important in the real world?
- What are some real-life situations where an understanding of density is important?

Safe boating requires an understanding of the concept of density.

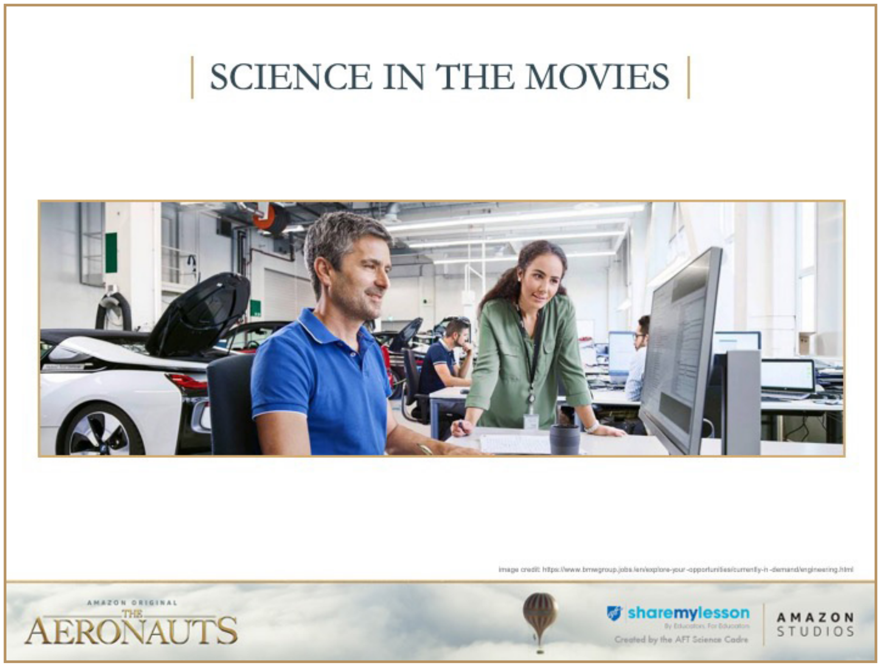
Construction—If you know the density of a countertop, you know how strong you need to build the cabinets to support the weight of that countertop.

This type of work can be done by a general contractor. Right now, the average salary for a general contractor is $59,000 per year, but can be as high as $116,000 per year.[1]

[1] https://www.ziprecruiter.com/Salaries/General-Contractor-Salary

Does anyone know what this car is? – Bugatti, fastest street car manufactured?

Engineers consider the density of materials that they use to build cars. The less dense the material that they use to make the car, the faster it will be able to go and it will get better gas mileage.

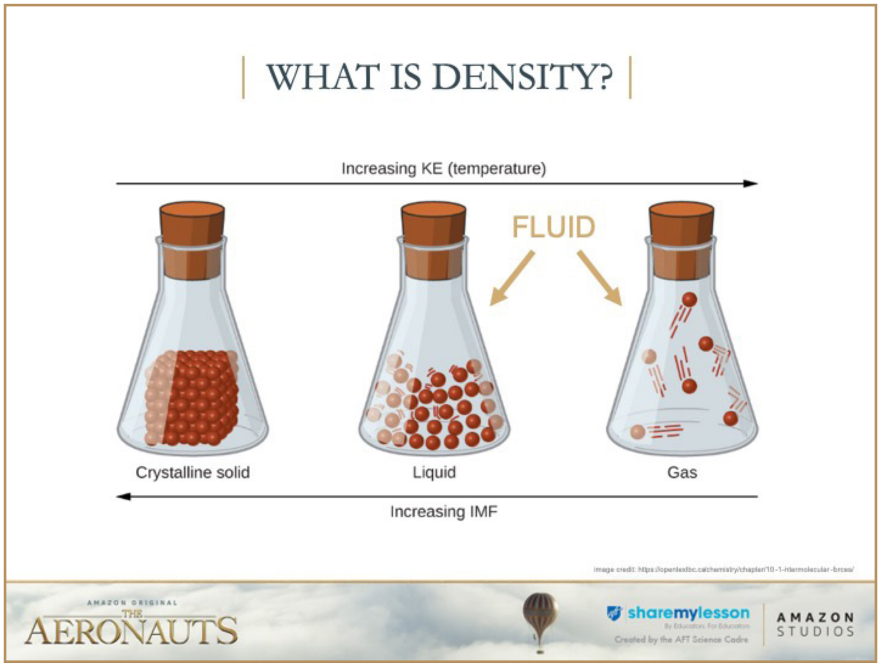


This work would be done by an automotive engineer.

The average salary for an automotive engineer is, $76,142, but can be as high as $121,000 per year.[1]

[1] https://www.glassdoor.com/Salaries/automotive-engineer-salary-SRCH_KO0,19.htm

Aeronauts of the 19th century and even today depend on the density of the gas inside their balloon. The density of the gas inside the balloon is what controls the behavior of the balloon, whether it will ascend or descend at any given time.

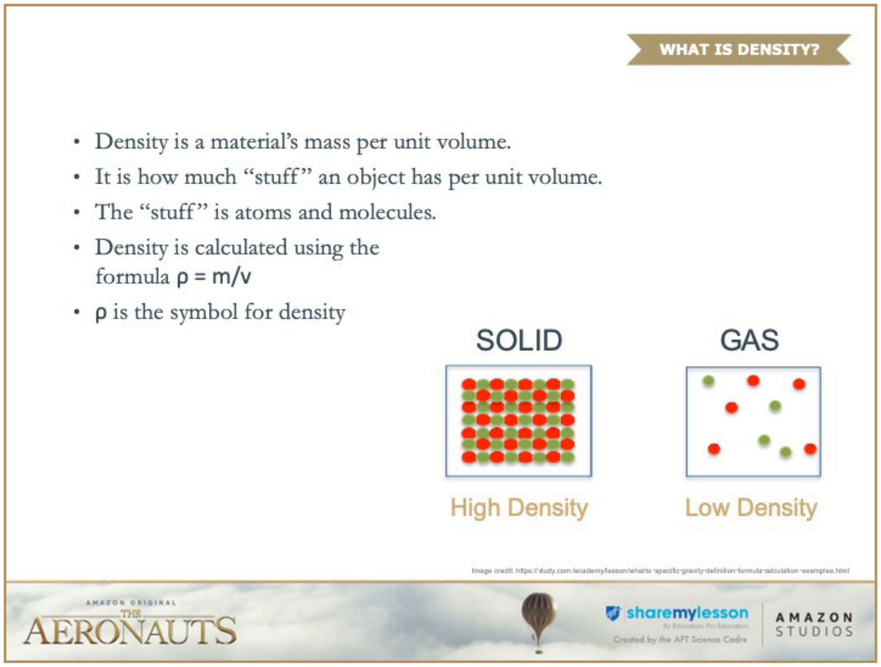


In our simulation, we are going to collect data that will allow us to determine the density of a variety of solids.

- The three states of matter that are common on earth are **solid, liquid, and gas.**
- In our lesson today we will be collecting data about the density of solids.
- In solids, the particles are packed tightly together. The intermolecular forces between molecules are strong enough that the particles cannot move freely. Therefore, solids have a definite shape and volume.[2]
- Liquids **AND** gases are considered fluids because they can flow.
- In liquids and gases, the forces between the molecules are weak enough that the molecules can move over or alongside one another[1], or flow.

[1] https://www.scientificamerican.com/article/go-with-the-flow/

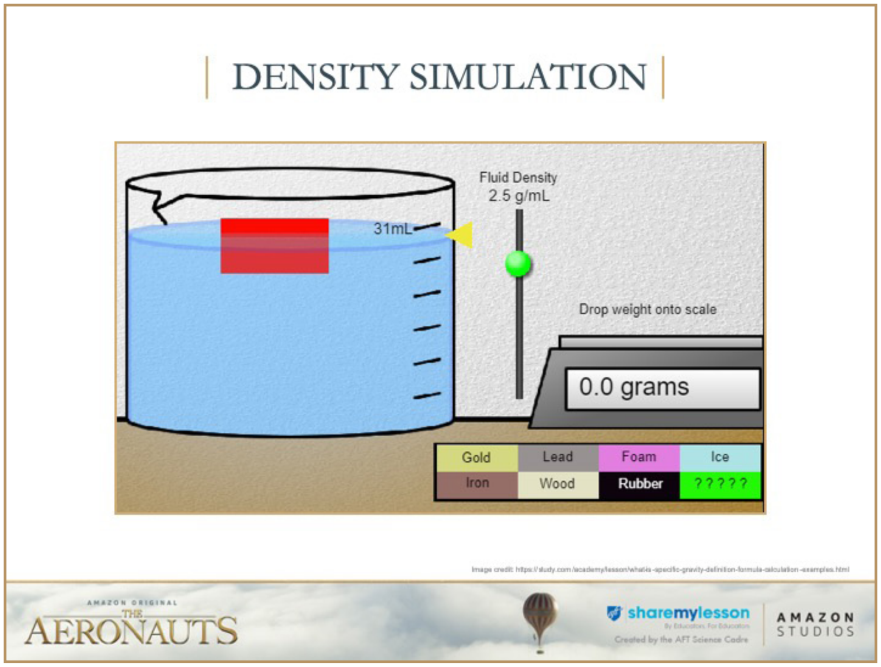
[2] https://courses.lumenlearning.com/boundless-chemistry/chapter/classification-of-matter/



Teacher Hint: If available, pass around density cubes so students can feel that objects that are the same size, do not necessarily have the same mass. If you don't have density cubes, consider filling plastic Easter eggs with different materials like sand, or marshmallows, etc

So, what is density?

- Density is a material's mass per unit volume.
- It is how much "stuff" an object has per unit volume.
- The "stuff" is atoms and molecules.
  - Look at the pictures. Both boxes have the **same** volume. The circles represent atoms. We can tell by the arrangement of the molecules that the box on the left is a solid and the box on the right is a gas. The solid has high density because there are more atoms. The gas has low density because there are fewer atoms. Solids have higher density than gas because the molecules are held close together by strong intermolecular forces. If we are comparing a solid to a gas, there are more molecules in the same size sample of a solid.
- Density is calculated using the formula **$\rho = m/v$**
- **ρ** is the symbol for density



We are going to explore density using an online simulation.

Teacher Hint: *Use the word "fluid" to describe the liquid in this simulation. The content knowledge in this simulation will be used to help students understand why the balloon in the movie *The Aeronauts* floats in air, which is also a fluid.

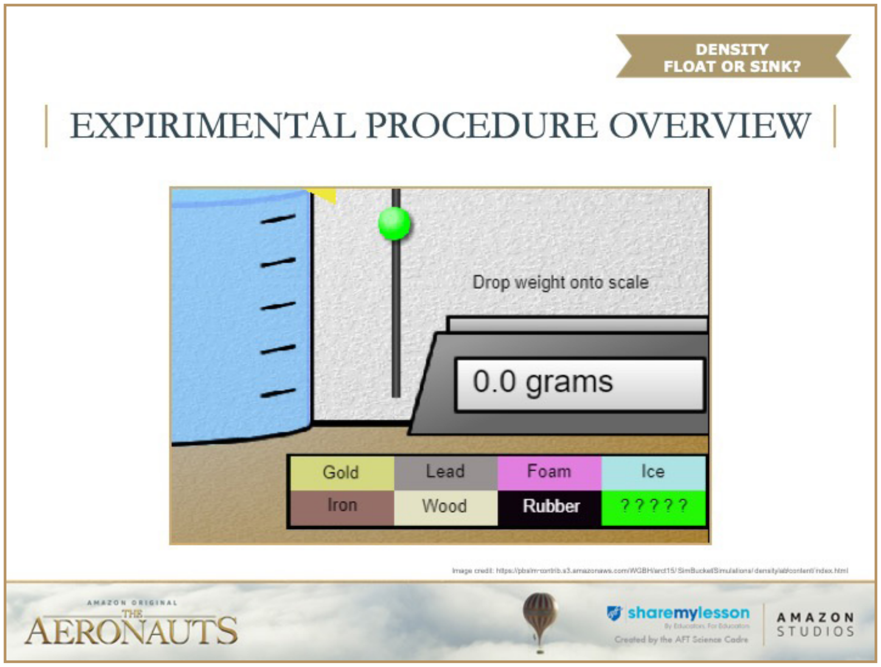
Give the students time to play with the simulation and see what all they can manipulate. When they are finished, have them share their favorite feature with a partner. Then have students come forward and demonstrate simulation features (on a white board or using the projecting computer)

Make sure they know they can:

- Drag objects to the electronic balance
- Read the mass of the objects on the electronic balance
- Read the volume of water on the beaker
- Drag a floating object under water
- Change the fluid density (by moving the green circle up and down the vertical scroll bar)
- The randomize button drops objects of an unidentified substance into the simulation (pink button at the top of the window)
- The reset button refreshes the simulation to original settings. (black button at the top right of the window)

*Use the word "fluid" to describe the liquid in this simulation. This is building content knowledge that will help students understand the science behind their upcoming balloon engineering design challenge. Using the term "fluid" instead of water helps students understand that we are observing a phenomena that occurs in all fluids, including air, not just water.

Have students record the purpose for the lab on the “Float or Sink data recording sheet”.

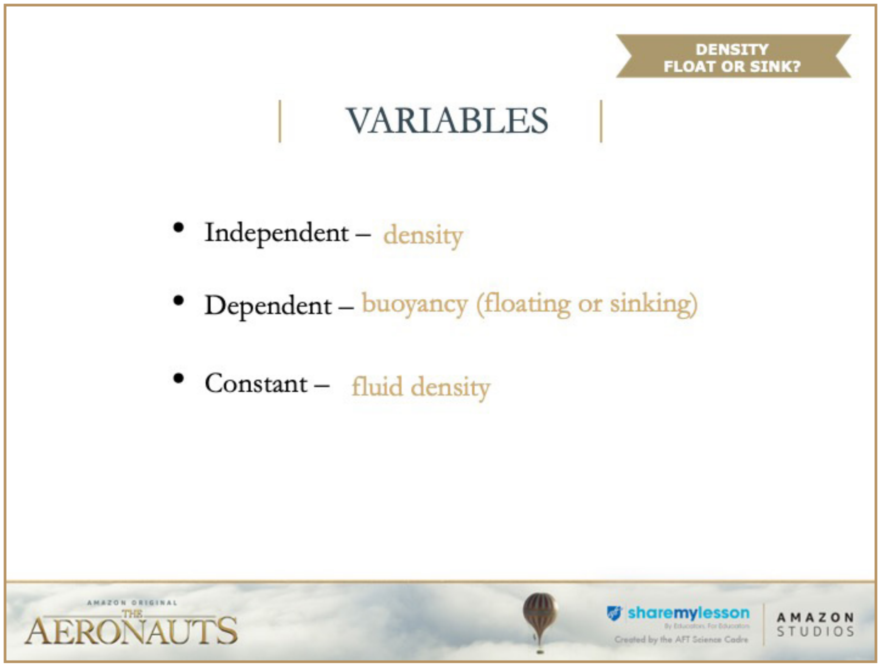


For this experiment you will use the Randomize Feature. When you click "Randomize!" a new material will be introduced into the simulation.

- Determine the volume of each material using fluid displacement.
- Determine the mass of each material using the digital balance.

Calculate the density of the material using the formula **ρ = mass ÷ volume**

- Compare the relationship between the density of the material to the density of the fluid.
- After we have tested ten different materials, we will look for patterns and trends in the data and see if we can predict why objects of different densities sink or float.



Help the students identify the variables

Given our purpose and the experimental directions what are the independent, dependent and constant variables?

INDEPENDENT VARIABLE:

The independent variable is the one variable students are changing. In this experiment, the independent variable is density. We are trying to determine if a material will sink or flat based on density of the object.

Students may think the material samples are the independent variable, HOWEVER varying the materials we test is the only way to vary density.

DEPENDENT VARIABLE:

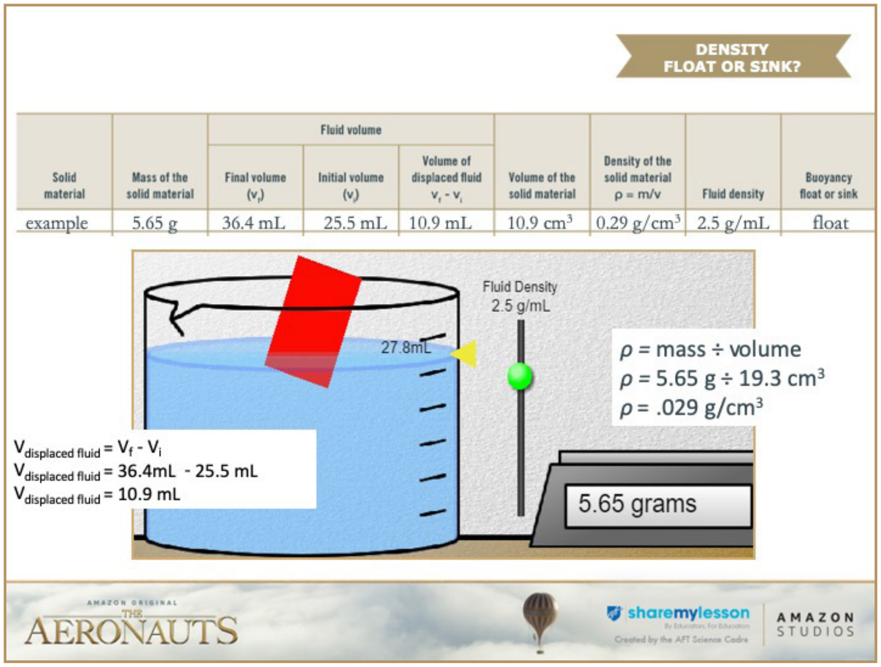
The dependent variable is buoyancy, whether the object floats or sinks. We are looking at objects of different density to determine if they will sink or float.

CONSTANT VARIABLES:

Constant variables are the factors that are intentionally kept the same.

In this simulation, we can vary the fluid density, but we should keep it the same.

Students may question why different size material samples are used. They may think that the sizes of the material samples should be kept constant. Let them know this is a valid point. Let students know that because the independent variable is density, the goal is to test objects that have different densities. Even in the real world, it would be hard to find samples of materials with varying density that were all the same size. Also, this may be the simulations way of reinforcing that each sample, despite being red in color is a different material. Additionally, using material samples that are different volumes gives us practice determining volume by displacement.



Solid material	Mass of the solid material	Fluid volume: Final volume (v_f)	Initial volume (v_i)	Volume of displaced fluid $v_f - v_i$	Volume of the solid material	Density of the solid material $\rho = m/v$	Fluid density	Buoyancy float or sink
example	5.65 g	36.4 mL	25.5 mL	10.9 mL	10.9 cm^3	0.29 g/cm^3	2.5 g/mL	float

We will do one example together to model how to complete the data table. Complete the example row of the data table as we go along.

STEP 1: Click on "Randomize." A new material will drop into the simulation.

STEP 2: Find the mass of the material.

- Drag the sample to the digital balance.
- Record the mass of the sample on your data recording sheet.
- Make sure you include the unit for mass, grams (g).

STEP 3: Record the initial volume of fluid in the beaker.

- Observe the volume of fluid.
- Record the volume of the fluid in the initial volume column (v_i).
- Make sure you record unit for volume mL.

STEP 4: Record the final volume of fluid in the beaker.

- Drag the material sample into the beaker.
- If it floats like this sample, drag it down until it is fully submerged.
- Record the new water level on the beaker in the final volume (v_i) column.

STEP 5: Calculate volume of displaced fluid.

- The material sample displaces water in the beaker so now the water level is higher.
- To find the volume of displaced water, subtract the initial volume from the final volume. 36.4mL – 25.5 mL is 10.9mL. Record this volume in the volume of displaced fluid column.
- This means that the material sample took up the space that was occupied by 10.9 mL of fluid.
- The volume of the material sample is the same as the volume of 10.9 mL of fluid.

STEP 6: Identify volume of the material sample.

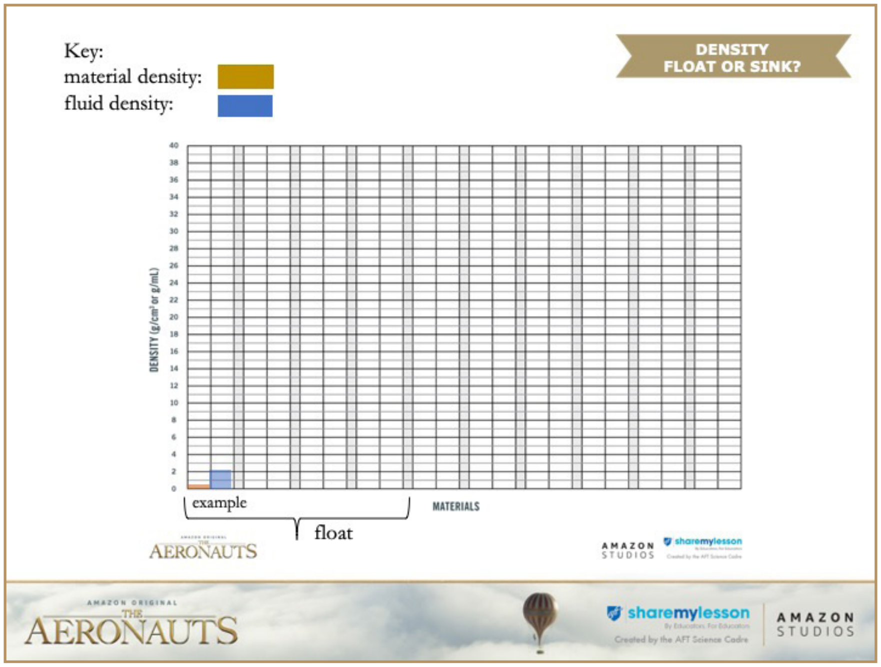
- Milliliters is a unit of measure that describes the volume of a liquid.
- The material is a solid. Cubic centimeters is a unit of measure that describes the volume of a solid.
- 1mL of liquid is the same volume as 1 cubic centimeter.
- Since our material sample displaced 10.9 mL of fluid, the volume of the material sample is 10.9 cm^3.
- Record the volume of the solid.

STEP 7: Calculate density of the material sample.

- Now we know the mass of the material sample and the volume of the material sample so we can calculate the density.
- Calculate density by dividing the mass of the object by the volume of the object. We divide 5.65g by 10.9cm^3. The density of the material is 0.29 g/cm^3.

STEP 8: Record the density of the fluid.

STEP 9: Record the buoyancy of the object by identify if it floated or sank.



Graph the results of each test on the graph paper.

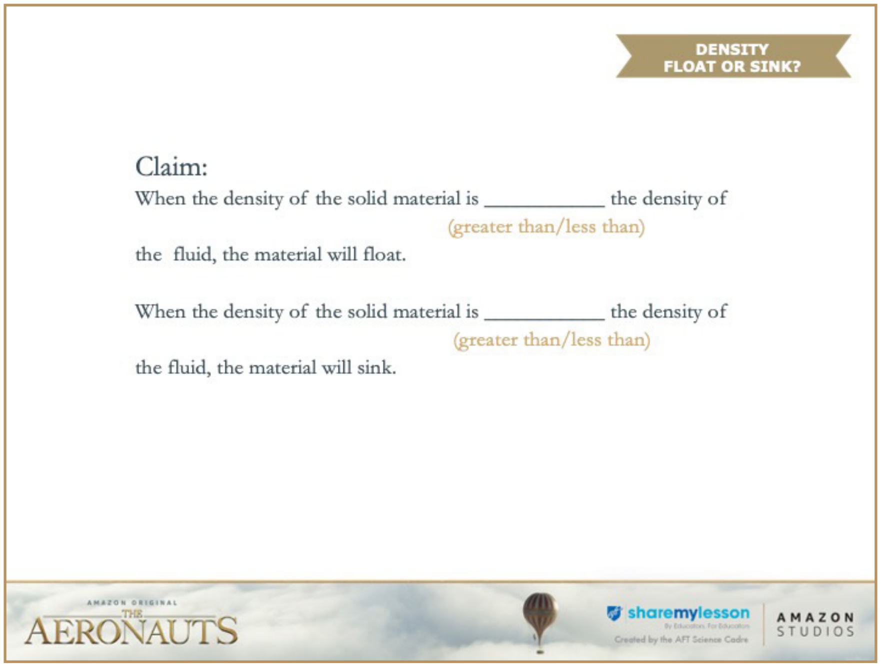
- We are going to graph the density of the material and the density of fluid for each test.
- Here is how we would graph the example data. **Do not** graph the example data on your paper.

- The density of our example materials was 0.29 g/cm, so I will add a bar that is less than halfway between 1 and 0 g/cm^3.
- The density of the fluid was 2.5g/mL so I will add a bar of a different color that is halfway between the lines for 2 and 3g/mL.
- We can graph these units on the same vertical axis because 1mL is the same volume ad 1cm^3.

- Create a key on your graph that communicates the colors that represent water and the materials.

- Graph all the objects that float on one side of your graph, and all the objects that sink on the other side of your graph. Label each side.

SLIDE 21

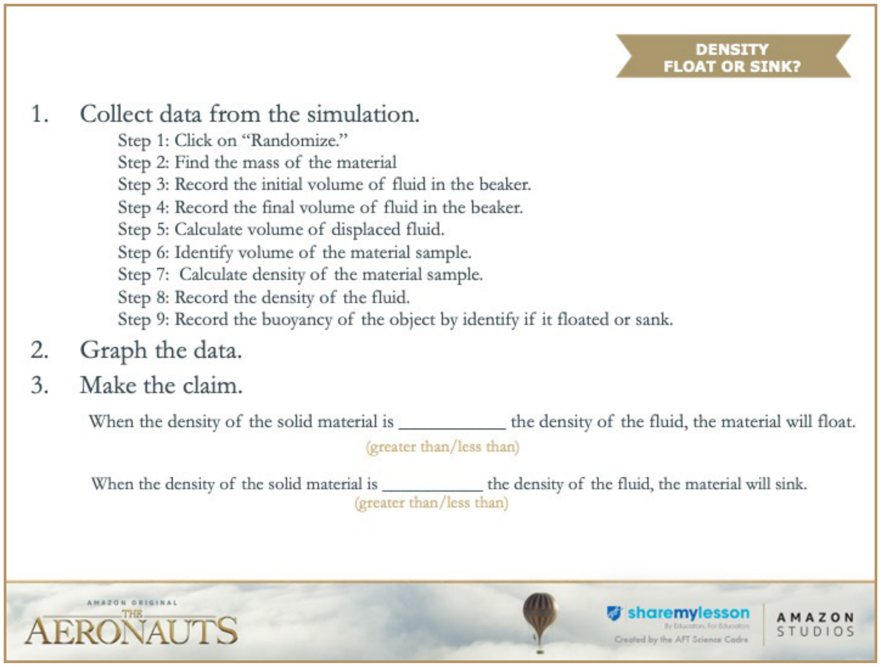


After scientists gather data, they summarize their findings by making a claim.

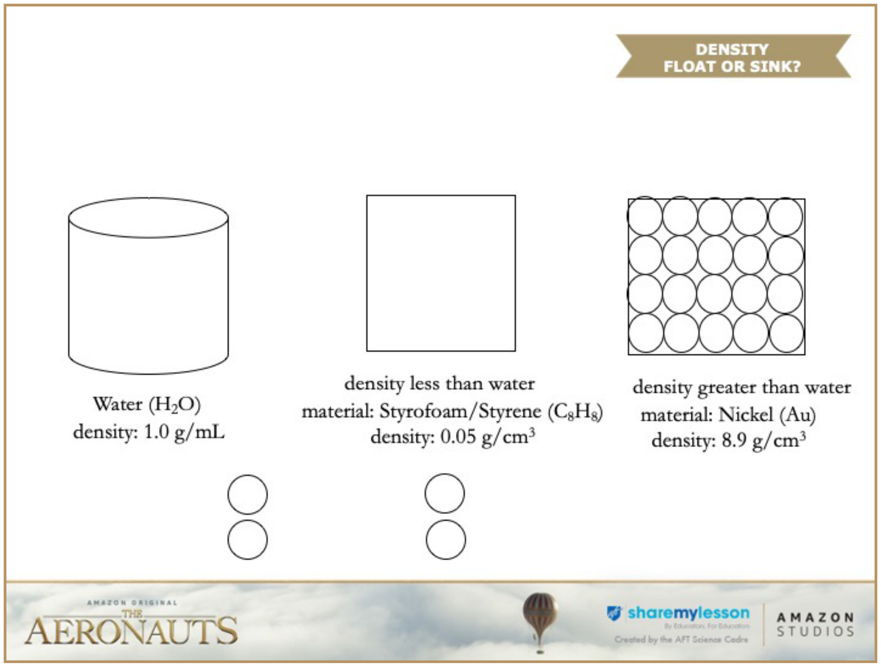
- The data becomes the evidence to support the claim.

For the claim:

- Look at all the materials that floated. What is the relationship between the density of the material and the density of the liquid?
- Look at all the materials that sank. What is the relationship between the density of the material and the density of the liquid?



Project this slides while the students work to keep them on task.



REASONING

Good scientists do not just make a claim. They explain why. Why is a fluid like water denser than some materials, but less dense than others? A good scientist explains the reason the results of their investigation turned out the way it did. One of the tools scientists use to communicate phenomena is models. Models represent a system or part of a system and are used to communicate ideas to others.

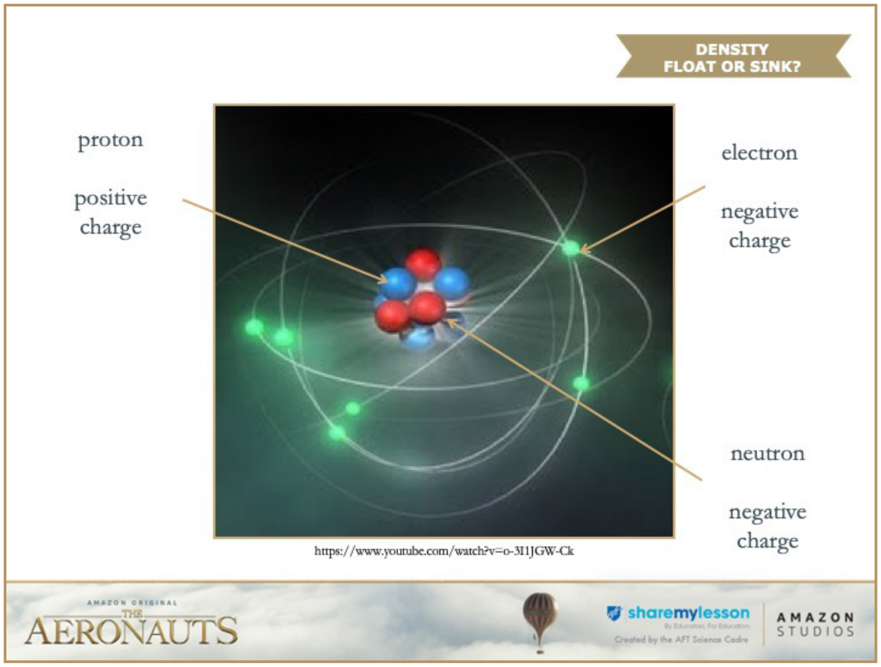
We are going to use particle models to communicate why the materials, and a fluid could have different densities.

- Density is influenced by the number of particles (atoms/molecules) in a given volume. It is also influenced by the mass of those particles.
- The two boxes on the left represent one cm3 samples from two of the materials you tested. We will draw a model to represent a liquid in the container on the right. We use water for our example because it is a familiar and common example of a liquid.

Let's start with a material that is more dense than water. A 1cm^3 sample of pure nickel would have a density of 8.9 g/cm^3[1]

- Add circles to the nickel diagram to represent the nickel atoms. Because this is a solid, the atoms are arranged in a regular pattern. Due to strong forces between the atoms, the atoms stay in a fixed position. The atoms do vibrate in place while holding their fixed position.
- Now let's look at a material that is less dense than water. Foam is a good example. Styrofoam has a density of 0.05 g/cm^3
- Why is Styrofoam have such a low density compared to Nickel?

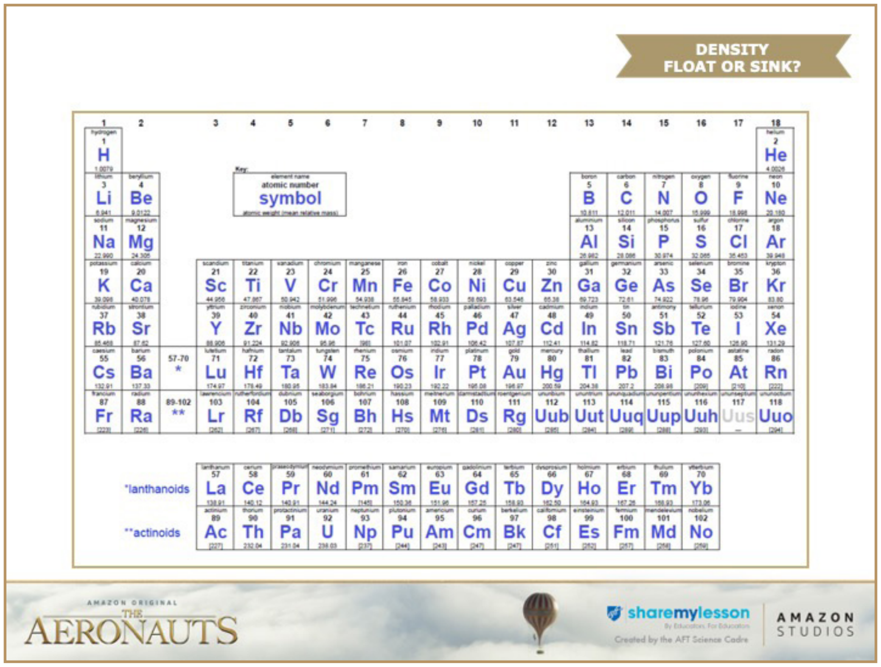
[1] https://www.angstromsciences.com/density-elements-chart



REASON 1 – THERE IS A DIFFERENCE IN THE MASS OF THE ATOMS IN NICKEL AND STYROFOAM.

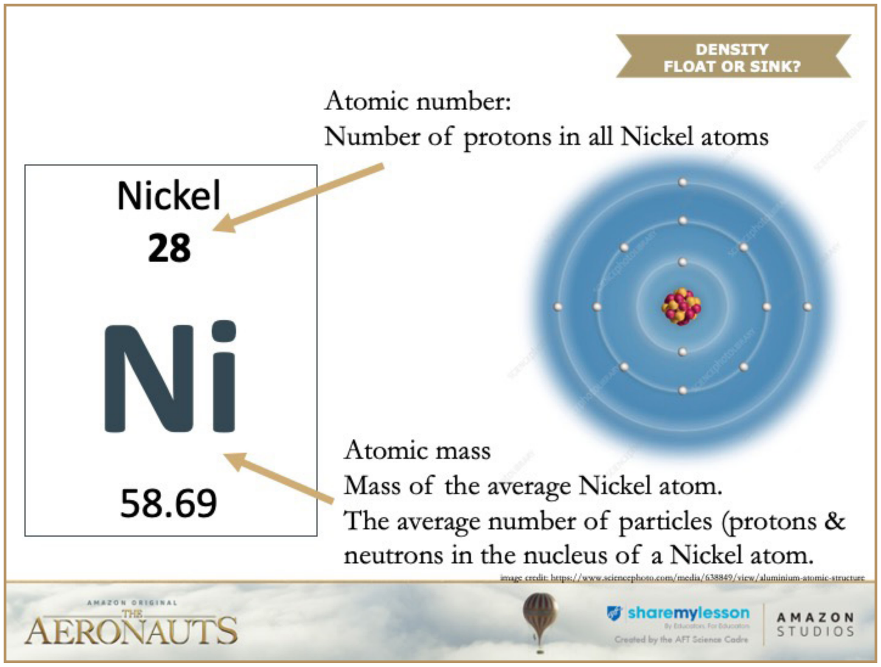
All materials are made from atoms. This is an atom.

- An atom has a center called a nucleus and an area around the nucleus called the electron could.
- The nucleus contains particles called neutrons and protons.
- The mass of the atom is determined by the number of protons and neutrons in the nucleus. The more protons and neutrons in the nucleus, the heavier the atom is. The electrons are so small that their mass is insignificant.



The periodic table of elements provides information about each known atom.

One of the facts we can look up on the periodic table is the mass of atoms.



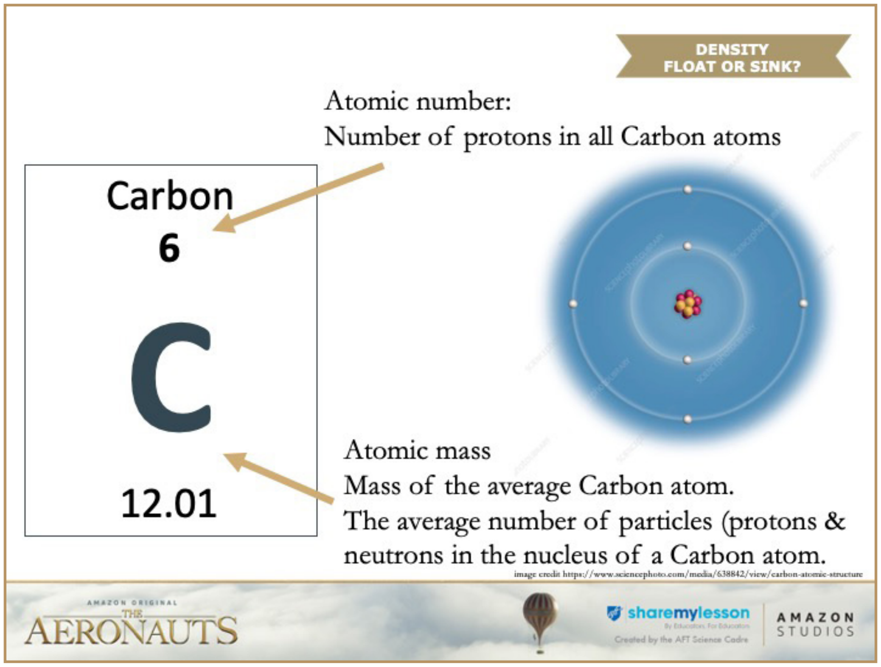
One of the things the periodic tells us about an element is the mass of the element.

- This number is the atomic mass.
- This means the average Nickel atom has a mass of 58.69 atomic mass units (AMU).
- Protons have a mass of 1 AMU.
- Neutrons have a mass of 1 AMU.
- Electrons are so small that their mass is insignificant.

This tells us that the average nickel atom has about 59 particles (protons and neutrons) in the nucleus.

All nickel atoms have 28 protons.

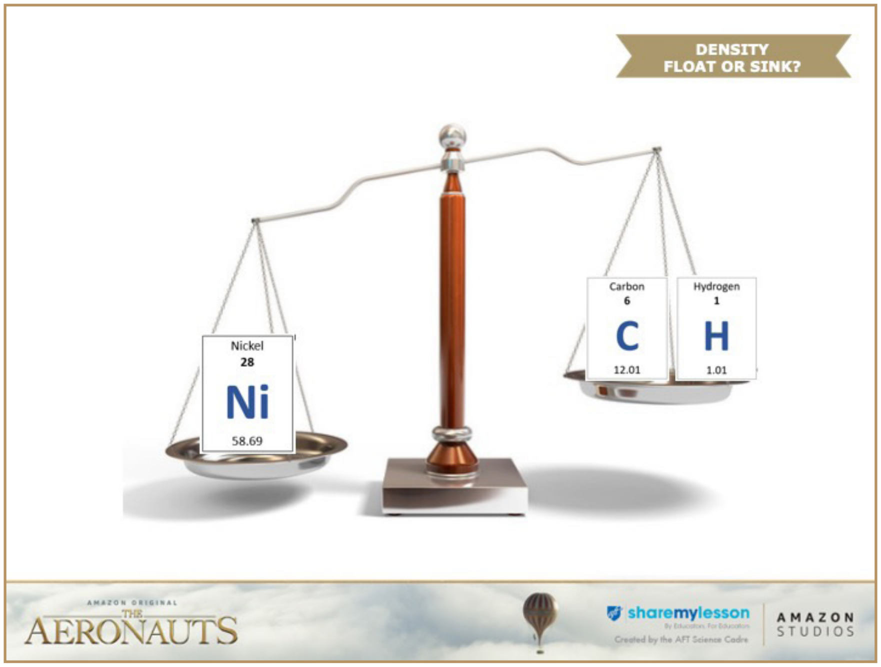
- The atomic mass is not exactly 59 because some isotopes of Nickel can have different numbers of neutrons.
- Nickel 58 has 30 neutrons.
- Nickel 60 has 32 neutrons.
- Nickel 61 has 33 neutrons.
- These different versions of iron atoms are called isotopes. The atomic mass of 58.69 for Nickel is the average off all the isotopes of Nickel weighted for the abundance of each isotope in nature.



Styrofoam is made from long chains of styrene molecules. A styrene molecule is made from Carbon and Hydrogen atoms

Here is carbon.

- The average carbon atom has an atomic mass of 12.01 AMU.
- This means the average carbon atom has about 12 particles in the nucleus.

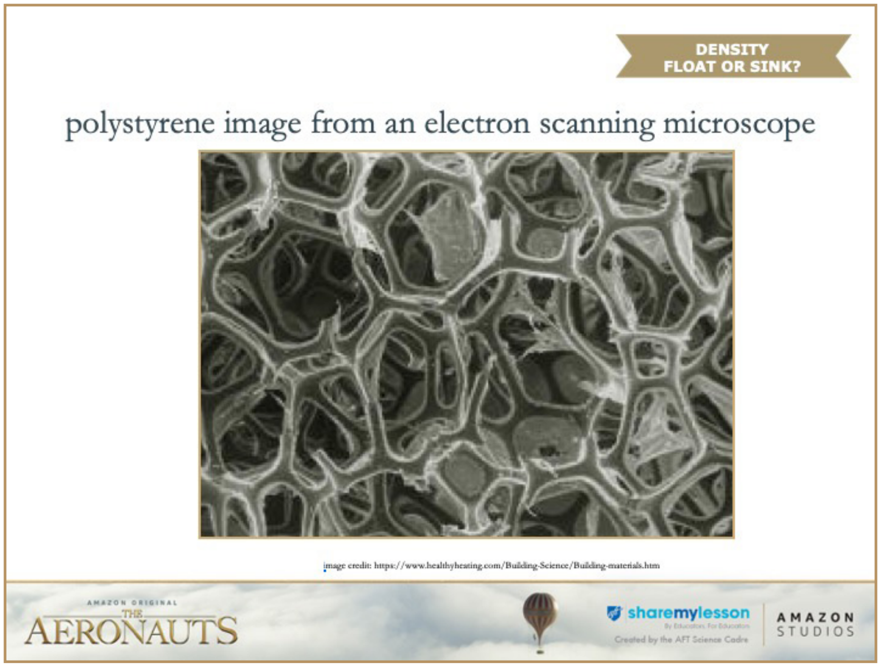


An atom of nickel is heavier than an atom of carbon. Each atom of nickel weighs 4 times as much as an atom of Carbon.

Because there are more protons and neutrons in a nickel nucleus, the nickel atom is a little bigger than the carbon atom, but not much. If we have a block of pure nickel and a block of pure carbon, there would probably be a few more carbon atoms in that block, but because each nickel atoms has much more mass than the carbon atom, the nickel block will still be more dense.

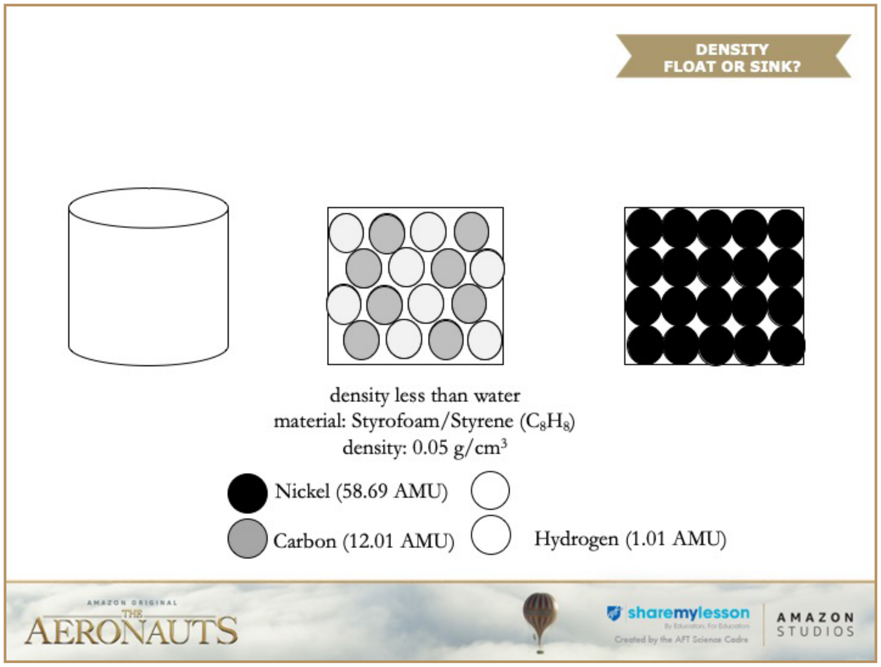
Hydrogen, the other atom in the styrene molecule weighs even less than carbon, with an atomic mass of 1.01

One reason nickel is denser than Styrofoam because nickel atoms are heavier than the atoms found in Styrofoam.



REASON 2 – THERE ARE FEWER STYRENE MOLECULES IN A 1CM³ BLOCK OF STYROFOAM THAN IN A 1CM³ BLOCK OF NICKEL.

As part of the Styrofoam manufacturing process, polystyrene is expanded with air. As a result the molecules are not as tightly packed and there is empty space. Here is a picture of polystyrene foam from an electron scanning microscope.


DENSITY
FLOAT OR SINK?
density less than water
material: Styrofoam/Styrene (C_8H_8)
density: 0.05 g/cm^3
Nickel (58.69 AMU)
Carbon (12.01 AMU)
Hydrogen (1.01 AMU)
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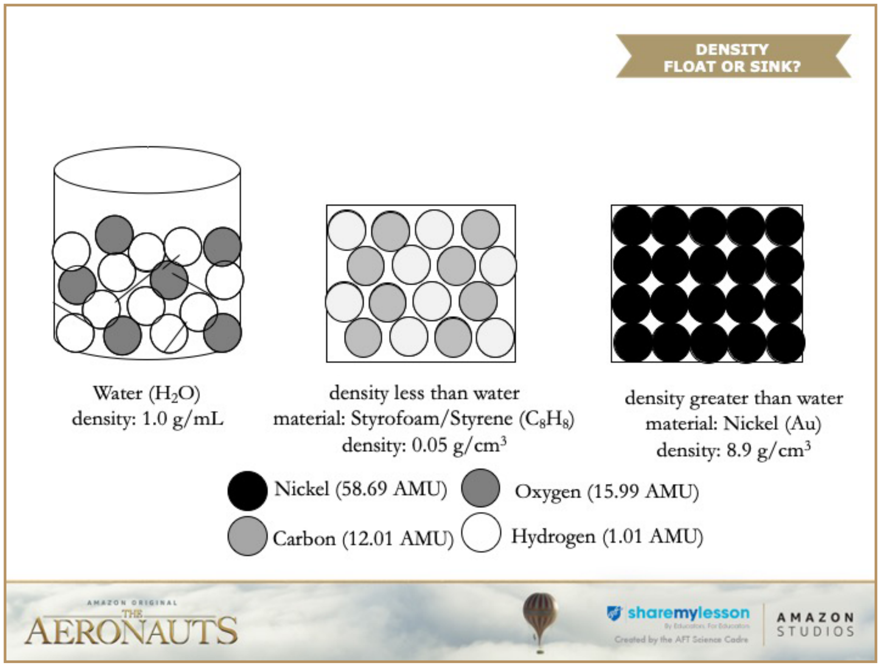


Water is a liquid.

- The intermolecular forces between molecules in a liquid are not as strong as the intermolecular forces in a solid.
- As a result liquids can flow and move past each other and don't have the same highly ordered packing arrangements as solids.
- Liquids will take the shape of their container.

How can we draw the molecular model for liquid to reflect these differences?

- Molecules not in an ordered arrangement
- Lines on some of the molecules to show they move

Water is made from Hydrogen and Oxygen. We already know the atomic mass of Hydrogen. The atomic mass of Oxygen is 15.99 AMU

How can we use color to show the relative atomic mass of oxygen?

- Darker grey than carbon

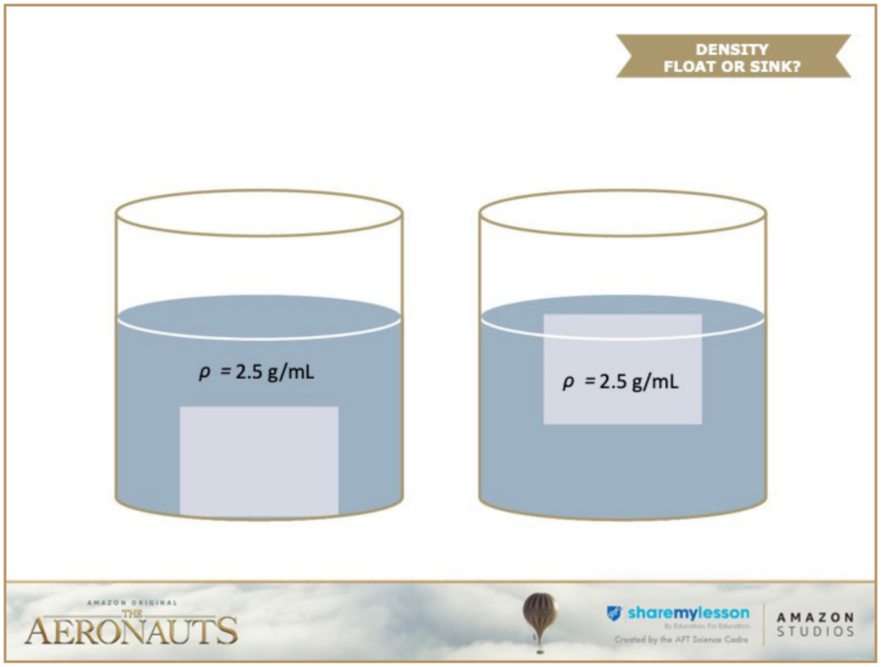
Why would Water be denser than styrene?

- Water molecules are more tightly packed than styrene molecules.
- Oxygen is heavier than carbon.

Why is water less dense than nickel?

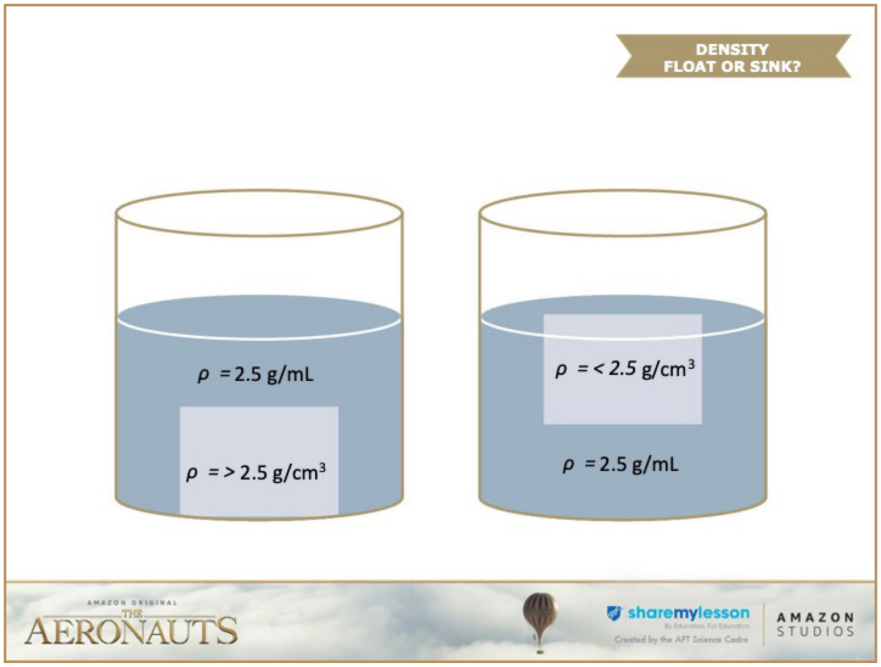
- ❖ Nickel atoms have a very high atomic mass

[1] https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_-_The_Central_Science_(Brown_et_al.)/11%3A_Liquids_and_Intermolecular_Forces/11.1%3A_A_Molecular_Comparison_of_Gases%2C_Liquids%2C_and_Solids



We will also create a diagram to compare the densities of materials that float and sink.

Label your beakers with the density of liquid that you used in your experiment.



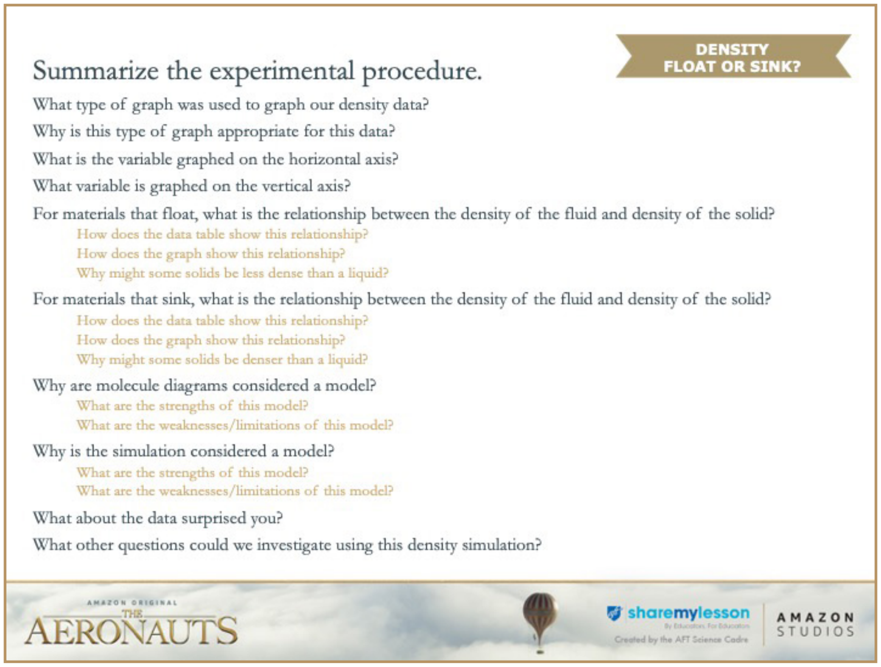
What do we know about the density of an object that sinks?

- It is great than the density of the fluid.

What do we know about the density of an object that floats?

- It is less than the density of the fluid.

Label the solid materials with their relative densities using greater than or less than symbols.



Students should work together to answer these questions in groups of two or three. Use fishbowl strategy for students to have a whole class discussion around these questions.

Summarize the procedure.

- Use the digital balance to find the mass of the materials, use displacement to determine the volume of the materials. Calculate the density of each object using the formula **ρ = mass ÷ volume**. Compare the density of each materials with the density of the liquid.

What type of graph was used to graph our density data? **bar graph**

Why is this type of graph appropriate for this data? **We were graphing the density of materials. Materials are qualitative data.**

What is the variable graphed on the horizontal axis? **Materials and fluid**

What variable is graphed on the vertical axis? **Density**

For materials that float, what is the relationship between the density of the fluid and density of the solid? **For materials that float, the density of the material is less than the density of the fluid.**

- How does the data table show this relationship? **The numeric values for the solid materials is less than the numeric value of the liquid**
- How does the graph show this relationship? **The height of the bar for the solid material is lower than the height of the bar for the liquid**

- Why might some solids be less dense than a liquid? **Some solids may be less dense because the molecules in the solid have less mass than the molecules in the liquid and/or the molecules in the solid may be spread out more than the molecules in the liquid.**

For objects that sink, what is the relationship between the density of the fluid and density of the solid? **For materials that sink, the density of the material is greater than the density of the fluid.**

- How does the data table show this relationship? **The numeric values for the solid materials are greater than the numeric value of the liquid**
- How does the graph show this relationship? **The height of the bar for the solid material is higher than the height of the bar for the liquid**
- Why might some solids be denser than a liquid? **Some solids may be denser because the molecules in the solid have higher mass than the molecules in the liquid and the molecules in the solid are often more tightly packed.**

Why are molecule diagrams considered a model? **Models are used to communicate ideas to others and include diagrams. This diagram communicates why different materials have different densities.**

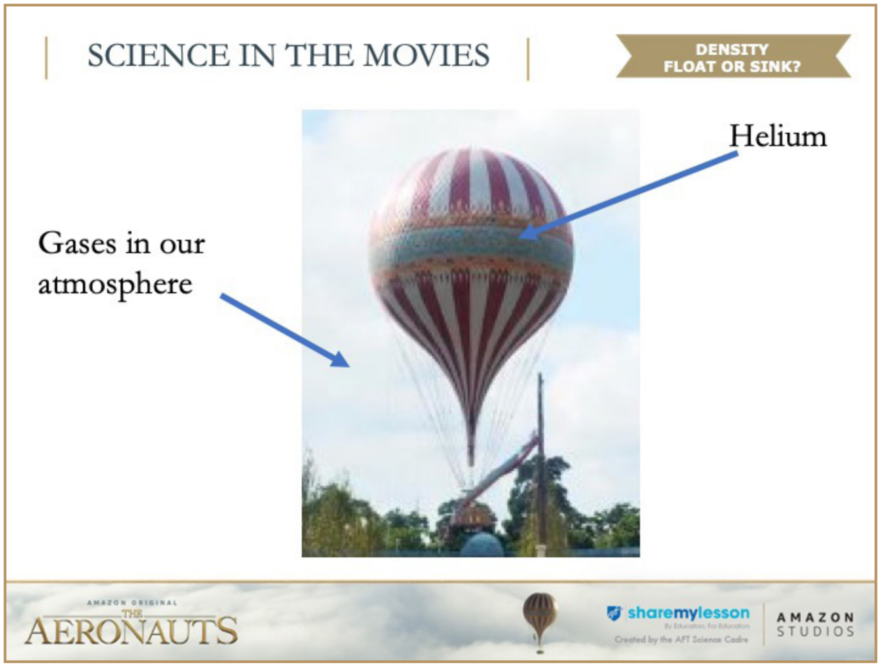
- What are the strengths of this model? **It shows the molecular arrangement of solids and liquids and compares the differences in mass of the molecules in each of the solids and the liquids.**
- What are the weaknesses/limitations of this model? **This model does not show that atoms are vibrating in place, it does not show the difference in size between the atoms.**

What about the data surprised you?

- **(answers will vary)**

What other questions could we investigate using this density simulation?

- Similar experiment but change the density of the liquid instead of the density of the solids.
- Relationship between mass and density. Relationship between volume and density.

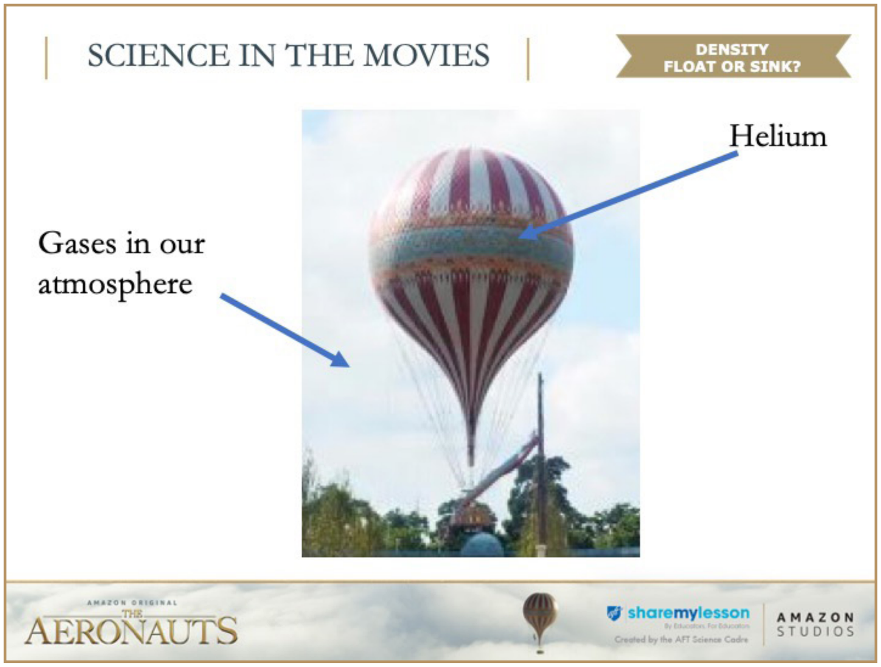


Aeronauts must understand density in order to operate their balloons.

- We just looked at why materials sink and float in liquid.
- What caused the balloon in the Movie the Aeronauts to sink and float in the atmosphere which is made from gas?

The hot air balloon in the movie *The Aeronauts* was filled with helium gas.

- The fluid surrounding the balloon was gas in our atmosphere.



Use the internet to look up the following information. Write a paragraph that answers the following questions. If you use the internet, cite your sources.

SAMPLE PARAGRAPH.

- The gas used in the balloon featured in the movie The Aeronauts was Helium. STP stands for standard temperature and pressure.[1] The density of Helium at STP is 0.178 g/L. The density of air at STP is 1.29 g/L.[2] The density of the gases inside the balloon is lower than the density outside the balloon. A balloon filled with Helium will ascend because helium is less dense than air. When a balloon pilot wants to descend, they can release helium from a vent at the top of their balloon.[3]

1 https://www.thoughtco.com/stp-in-chemistry-607533

2 http://www2.ucdsb.on.ca/tiss/stretton/Database/DofSTP.htm

3 https://balloonfiesta.com/Gas-vs-Hot