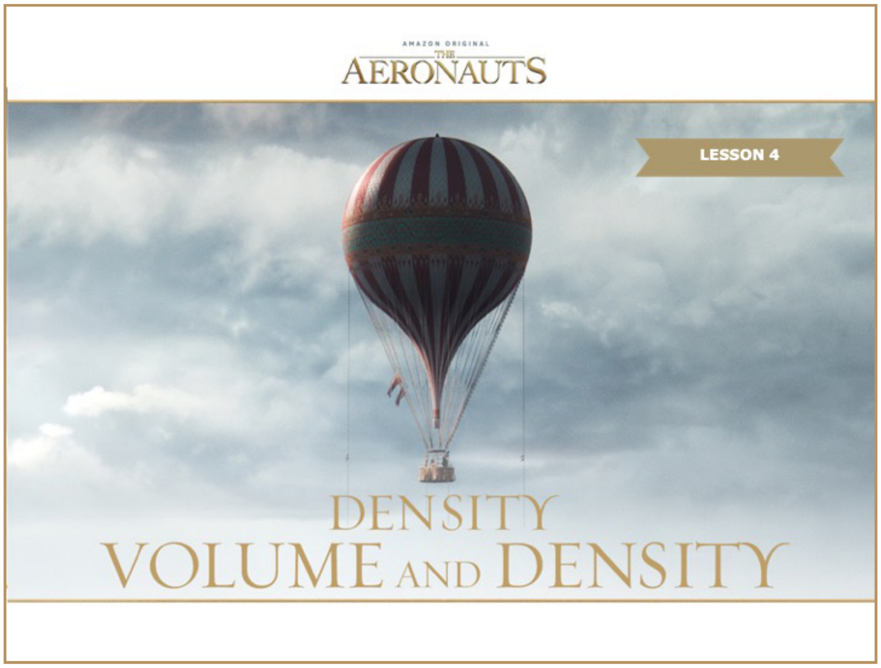
# POWER POINT GUIDE: VOLUME AND DENSITY

SLIDE 1

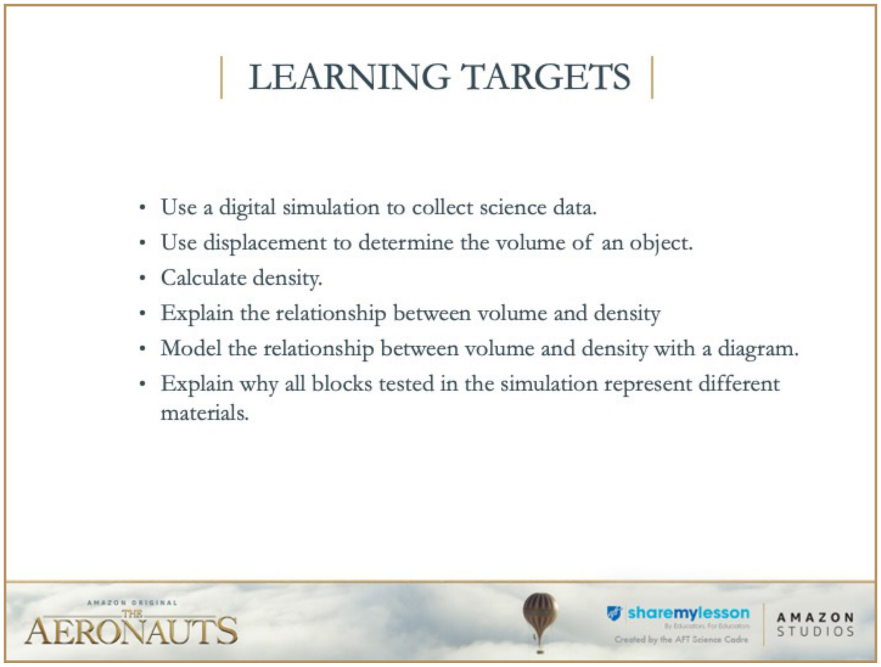



Show the movie trailer. (click on image picture to link to movie trailer).

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.
• Explain the relationship between volume and density
• Model the relationship between volume and density with a diagram.
• Explain why all blocks tested in the simulation represent different materials.
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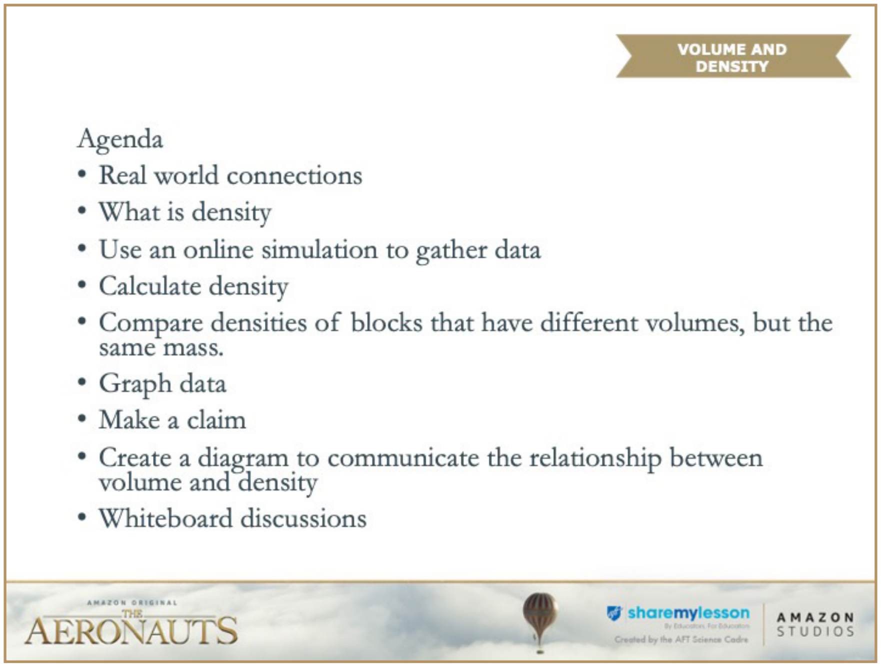
VOLUME AND DENSITY
Agenda
• Real world connections
• What is density
• Use an online simulation to gather data
• Calculate density
• Compare densities of blocks that have different volumes, but the same mass.
• Graph data
• Make a claim
• Create a diagram to communicate the relationship between volume and density
• Whiteboard discussions
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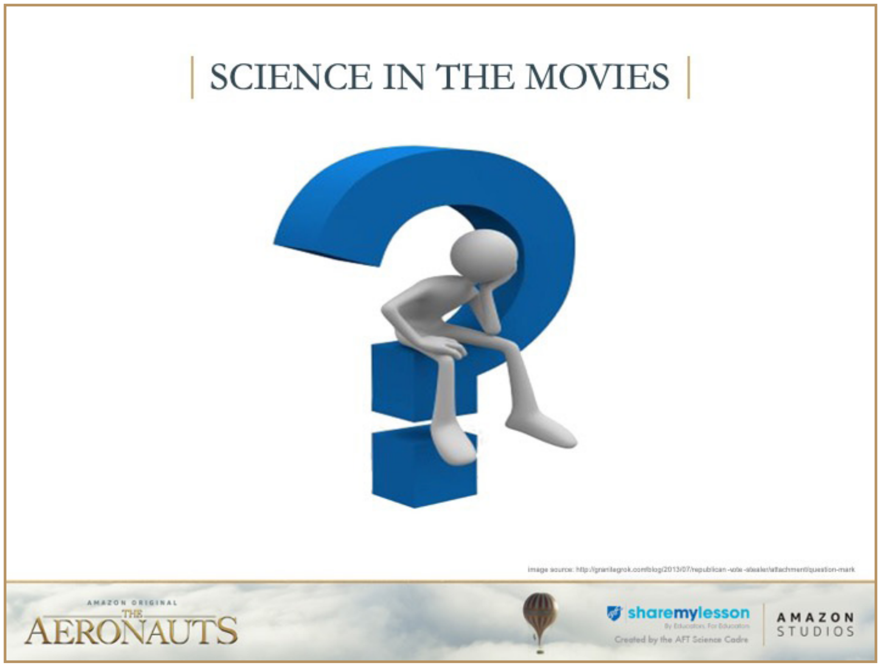



Ask students:

- 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.

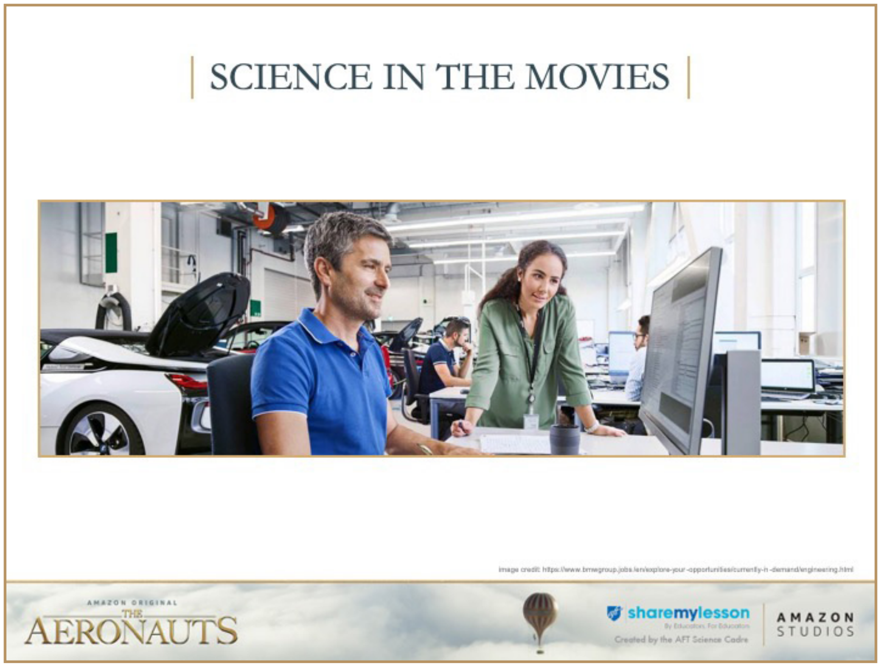

Construction—If you know the density of a countertop, you know how strong you need to build the cabinets to support the weight of that countertop.


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.

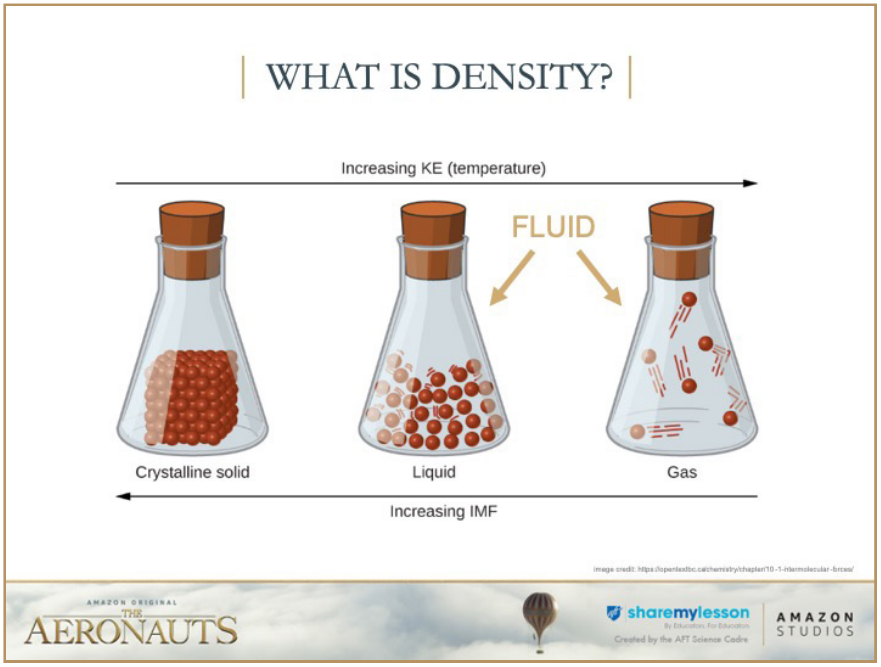



This work would be done by an automotive engineer.

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.

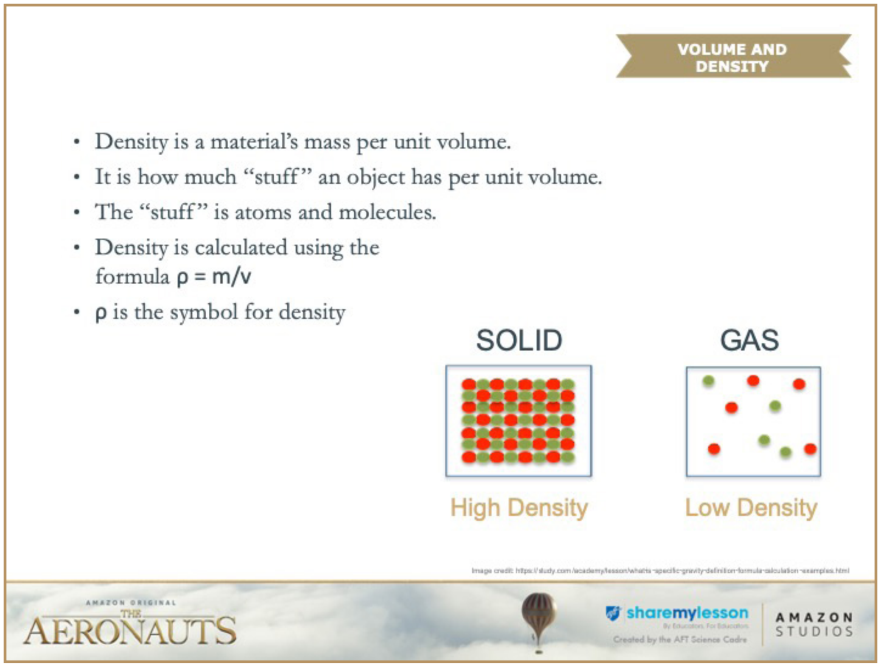



In our simulation, we are going to collect data that will allow us to determine the density of a variety of solids.

- 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/

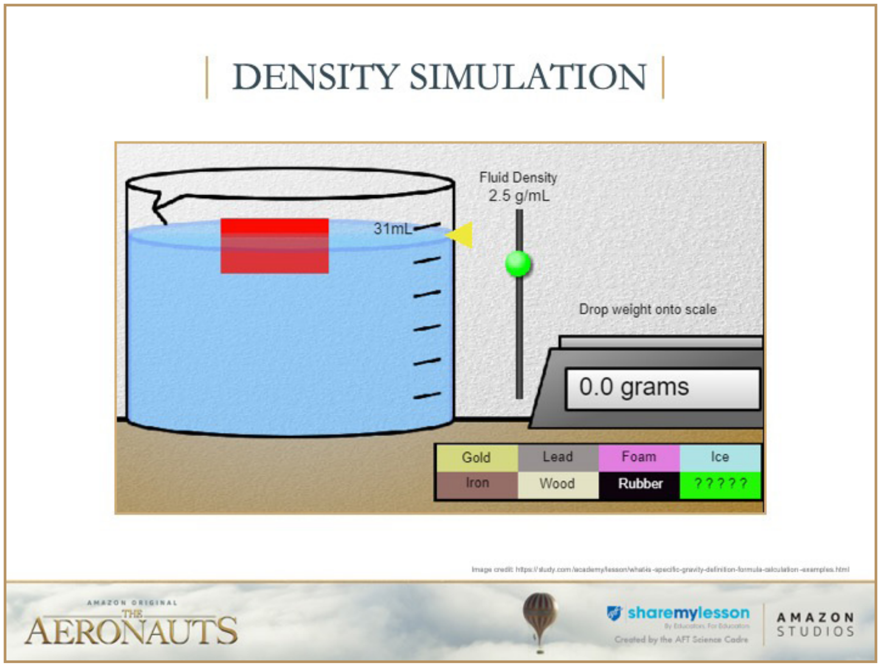
[2] https://courses.lumenlearning.com/boundless-chemistry/chapter/classification-of-matter/




**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 $\boldsymbol{\rho = m/v}$
- $\boldsymbol{\rho}$ is the symbol for density




We are going to explore density using an online simulation.

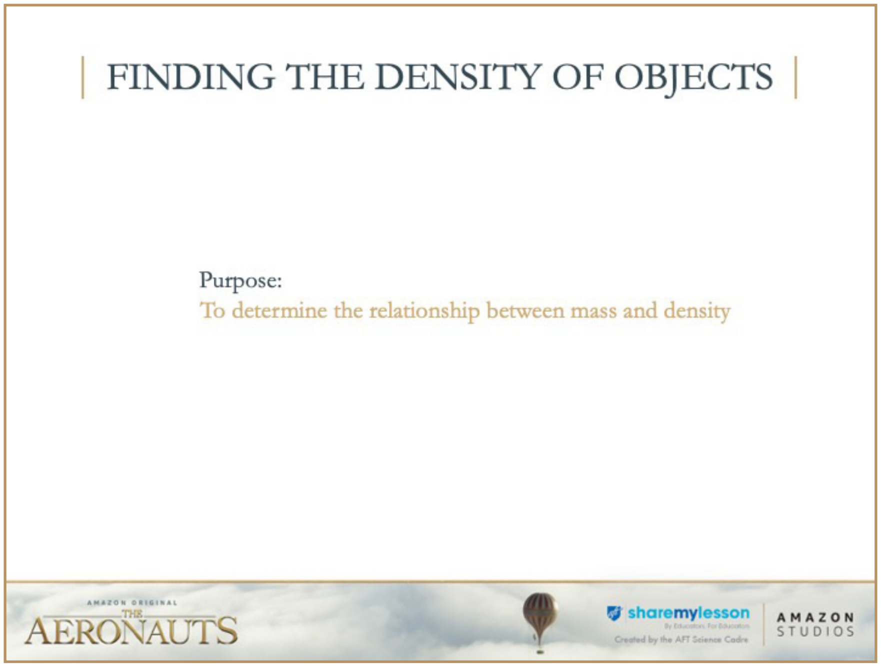
**Teacher Hint:** *Use the word "fluid" to describe the liquid in this simulation. The content knowledge in this simulation will be used to help students understand why the balloon in the movie the Aeronauts floats in air, which is also a fluid.


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)

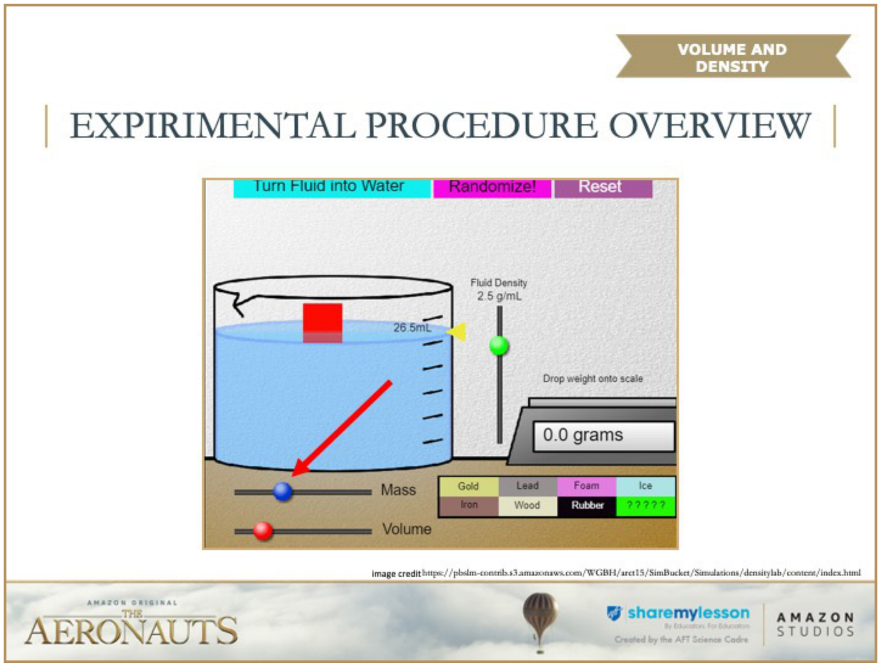
Make sure they know they can:

- 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)
- Change the mass and volume of an object (by moving the blue and red buttons along the horizontal scroll bars)
- Turn the fluid into water (click on the light blue button at the top left of the window)
- 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 “Volume and Density data recording sheet.”




For this experiment you will test a variety of material samples with the same mass, but different volumes.

Determine the mass of the samples using the digital balance. Determine the of the test materials using fluid displacement.

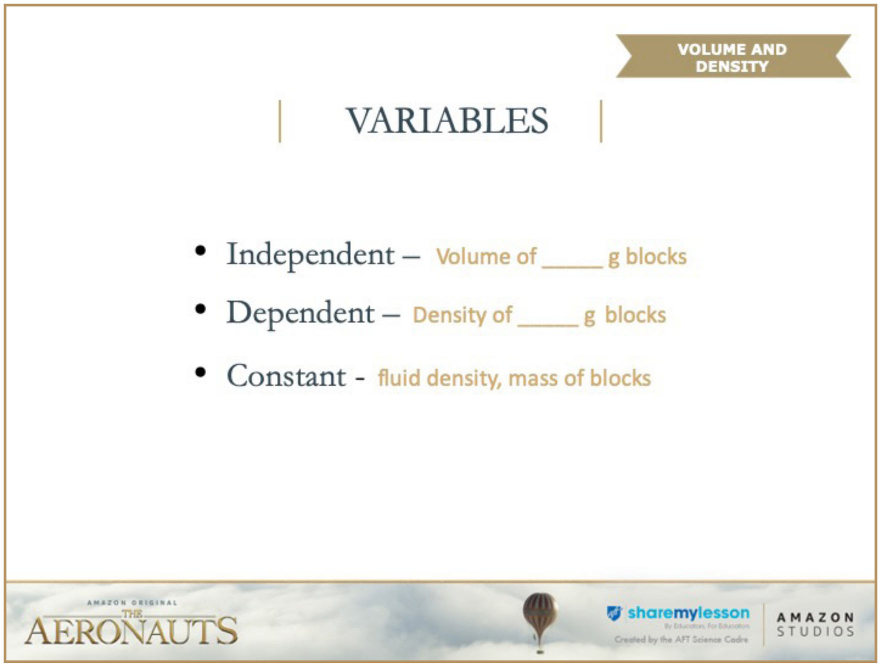
Calculate the density of each block using the formula **ρ = mass ÷ volume**
After we have tested ten different blocks, we will look for patterns and trends in the data to determine if there is a relationship between volume and density.

**WARNING:** This simulation is a model that allows you to investigate density. Every model has strengths and weaknesses. Every time we adjust the volume, we have chosen a new test material. In the sample, the test material will always look like the same red box, which could trick you into thinking it is the same substance with a different volumes. Remember as we do this activity, that every time you change the volume, you have selected a new and different test material.

Density is a property of materials.

- Every sample of gold, no matter what the volume will be 19.3 $g/cm^3$
- Every sample of lead, no matter what the volume will be 11.3 $g/cm^3$
- Every sample of iron, no matter what the volume will be 7.87 $g/cm^3$

The **ONLY** way we can test the relationship between volume and density of a given mass is to use samples of **DIFFERENT** materials.




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 the mass of the blocks. We are testing different mass to see how the density of these masses differ. Since we are **TESTING** different masses, mass is the independent variable. After you have determined the volume of the blocks you will be testing, add the volume to the blank.

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

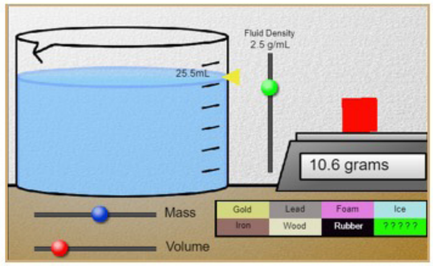
**DEPENDENT VARIABLE:** The dependent variable is density of the blocks. We are looking at objects that have different mass to see how the density of these objects differ. Since we are comparing the density of these objects, density is the dependent variable. After you have determined the volume of the blocks you will be testing, add the volume to the blank.

**CONSTANT VARIABLES:** Constant variables are the factors that are intentionally kept the same. In this simulation, we can vary the fluid density and volume, but we should keep it the same.

VOLUME AND DENSITY

| blocks<br>Note: each block is a different substance | mass of the blocks | volume of displaced fluid | | | volume of blocks | density $\rho = m/v$ |
|---|---|---|---|---|---|---|
| | | final volume ($v_f$) | initial volume ($v_i$) | volume of displaced fluid $v_f - v_i$ | | |
| example | 2.5 g | 29.6 mL | 25.5 mL | 4.1 mL | 4.1 cm$^3$ | 1.64 g/ cm$^3$ |

$V_{displaced\ fluid} = V_f - V_i$
$V_{displaced\ fluid} = 29.6\ mL - 25.5\ mL$
$V_{displaced\ fluid} = 4.1\ mL$




$\rho$ = mass ÷ volume
$\rho = 2.5g \div 4.1cm^3$
$\rho = 1.64\ g/cm^3$

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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:** Select a mass. It does not matter what the vmass is, as long as you keep it constant throughout the investigation.

**Step 2:** Find the mass of the material.

- Drag the sample (block) 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. 29.6mL – 25.5 mL is 4.1 mL. Record this volume in the volume of displaced fluid column.
- This means that the material sample took up the space that was occupied by 4.1 mL of fluid.
- The volume of the material sample is the same as the volume of 4.1 mL of fluid.

**Step 6:** Identify volume of the material sample (block).

- 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 4.1 mL of fluid, the volume of the material sample is 4.1 cm3.
- Record the volume of the solid.

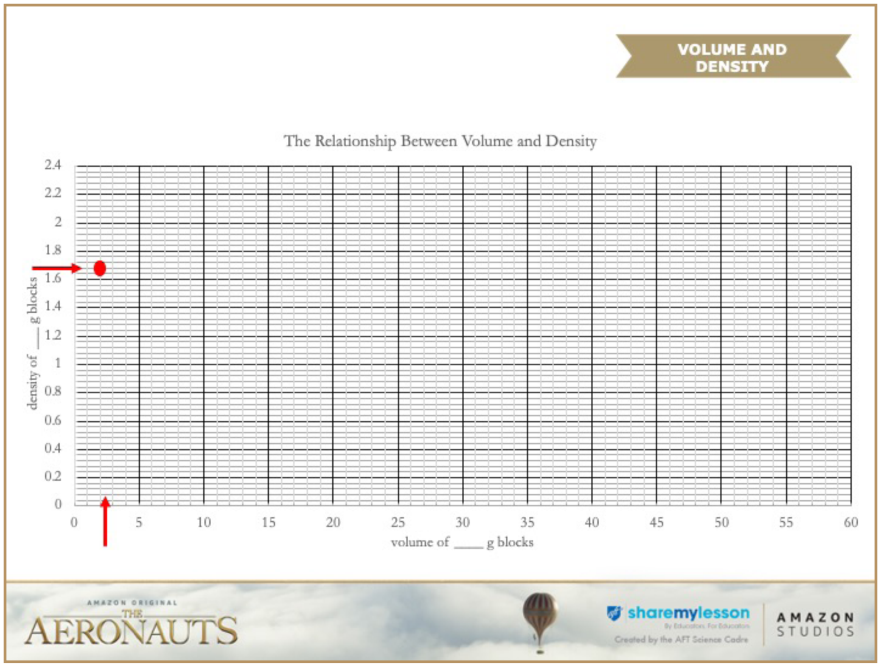
**Step 7:** Calculate density of the material sample (block).

- 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 2.5g by 4.1cm$^3$. The density of the material is 1.64 g/cm$^3$.

**Step 8:** Find the density of blocks with different volumes.

- From here you can move the red circle along the horizontal volume scroll bar to create new test materials.
- As you move the red circle along the bar, the size of the red box will change.
- Continue to use displacement to determine the volume of each block.
- The initial volume of fluid in the beaker will stay the same.
- You do not have to re-check the mass of each sample. Mass is constant.

**REMEMBER:** Each sample with a new volume is a new material, even if the block looks the same.




Graph the results of each test on the graph paper.

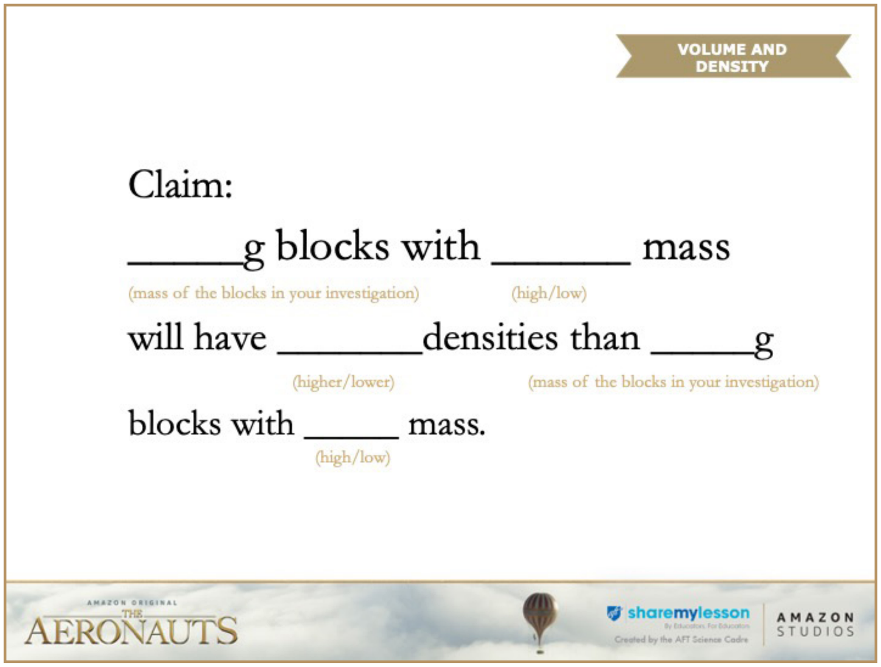
Here is how we would graph the example data. **Do not** graph the example data on your paper.

**Step 1:** Complete the x and y axis labels by adding the volume of the blocks you tested in your investigation.

**Step 2:** Add a scale to the y-axis that is appropriate for your data.

**Step 3:** Find a location on the grid that is both directly above the volume of the object AND directly across the density of the object. Mark this point with a dot. It is OK if all your data points do not fit on the graph.

**Step 4:** Draw a line of best fit that represents the trend shown in the data points.

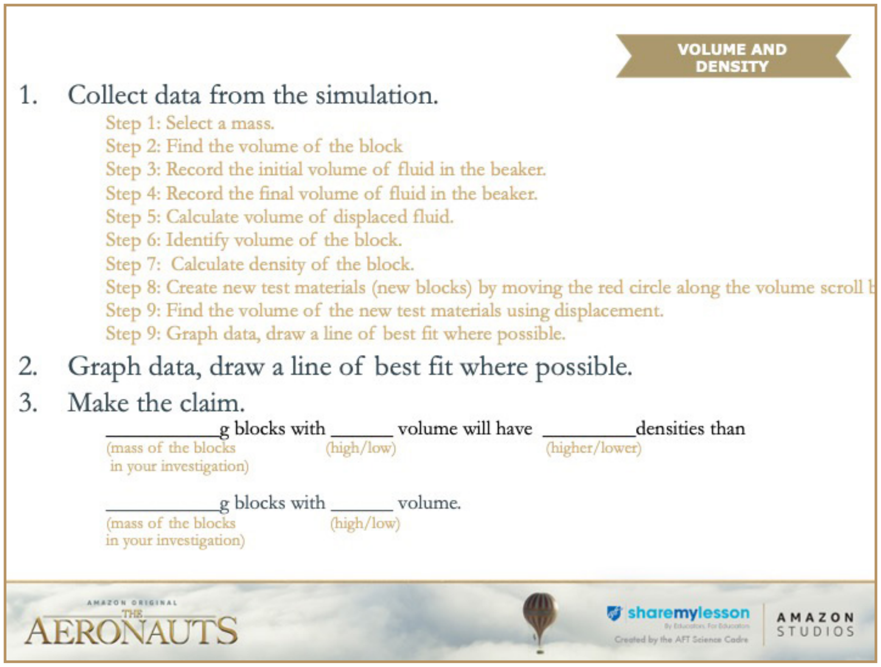



After scientists gather data, they summarize their findings by making a claim.

The data becomes the evidence to support the claim.

For the claim:

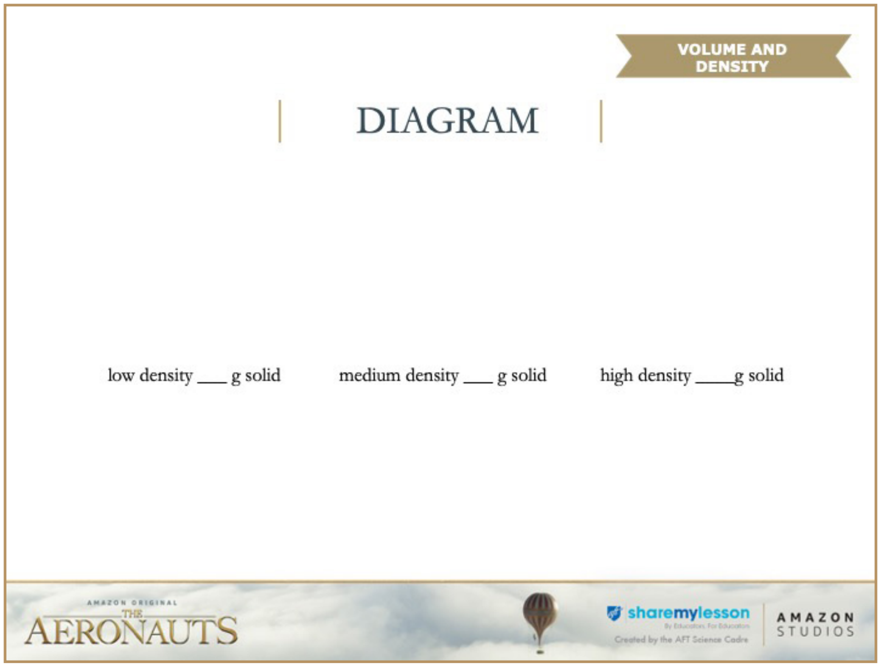
- Look at the data table and the graph. What is the relationship between mass and density.




Students work in groups of 3-4. Each group should choose a mass value that is different than the default volume value in the simulation.

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

## SLIDE 23




**Step 1:**

- Update the labels with the mass of the solid tested in your investigation

**Step 2:**

- Communicate what you learned in this investigation by drawing a box with a size that would represent a low density solid, a medium density solid, and a high density solid. These boxed represent the volume of the blocks you tested in your investigation.

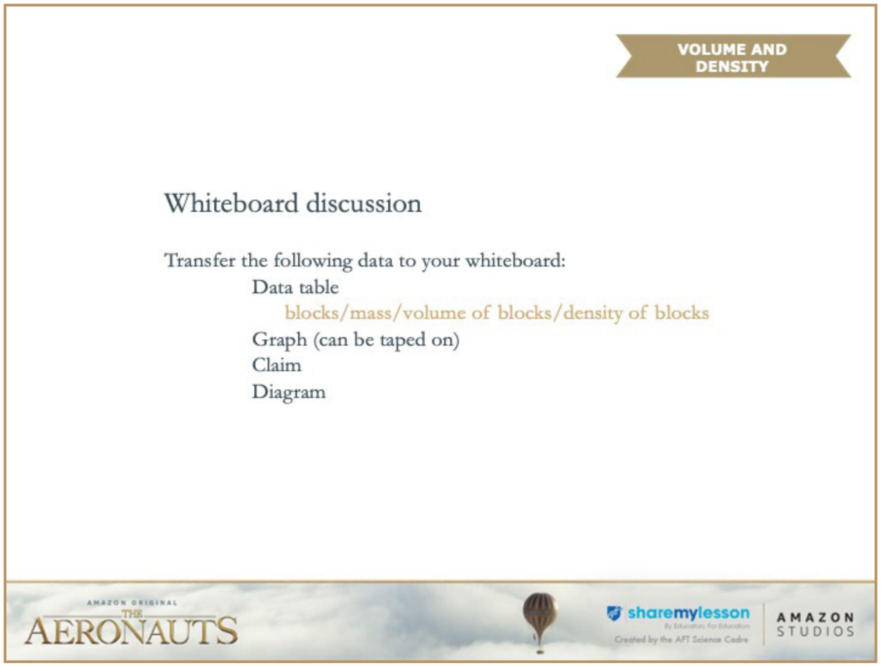
**Step 3:**

- Label each box with the mass of the blocks you tested in your investigation.

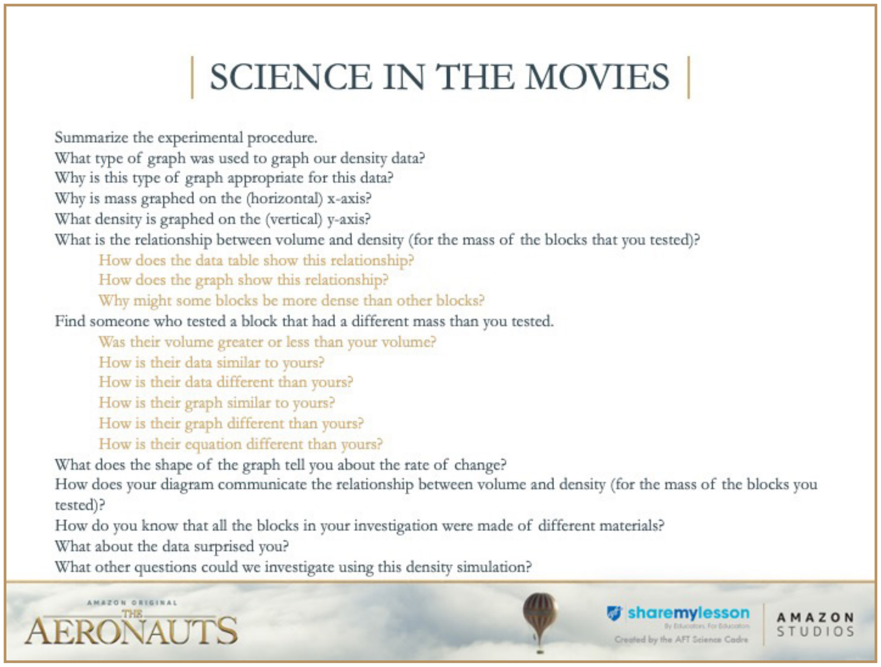
**Teacher Hint:** Do not guide students to draw the correct diagram at this time. Have students share their diagrams in the white board discussion and question each other as to why they choose to draw the boxes the size that they did.

*A correctly drawn diagram will have a large box for the low density solid, a smaller box for the medium density, and the smallest box for a low density solid.*

## SLIDE 24




Each student group transfers their data to their whiteboard.




These questions can be used to guide a class whiteboard discussion.

Summarize the procedure.

- Use the digital balance to find the mass of the blocks. Use displacement to determine the volume of the blocks you will test. Test new materials by changing the mass of the blocks. Calculate the density of each block using the formula **ρ = mass ÷ volume.**

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

- Scatter plot

Why is this type of graph appropriate for this data?

- Both variables were quantitative.

Why is mass graphed on the (horizontal) x-axis?

- Mass was the independent variable; the independent variable is graphed on the x-axis.

What density is graphed on the (vertical) y-axis?

- Density was the dependent variable; the dependent variable is graphed on the y-axis.

What is the relationship between volume and density (for the mass of the block you tested)?

- As the volume of the blocks increased, density decreases.

  How does the data table show this relationship?

  - Blocks with a small volume had a high density, blocks with a high volume had a low density

  How does the graph show this relationship?

  - The line of best fit has a negative slope. A negative slope shows that as the independent variable (volume of the blocks) increased, the dependent variable (density of the blocks) decreased.

  Why might some blocks be more dense than other blocks? (based on what students learned in density labs 1 & 2)

  - Blocks that have a high mass are usually made from heavier atoms. Sometimes the atoms may be more tightly packed based on the size of the atom or the structure of the molecules.

Find someone who tested a block that had a different mass than you tested.

- Was their mass greater or less than your volume? – answers will vary

  How is their data similar to yours?

  - The data shows the same trend; as the volume of the blocks increased, density of the blocks decreased.

  How is their data different than yours?

  - If the mass was greater, density values will be larger.
  - If the mass was smaller, density values will be smaller.

  How is their graph similar to yours?

  - All graphs will show an inversely proportional relationship (curved line with a negative slope).

  How is their graph different than yours?

  - If the mass was greater, the rate of change will initially be steeper, (if the scale on the graphs is similar).
  - If the mass was smaller, the slope of the line will be less steep. (if the scale on both graphs is similar).

What does the shape of the graph tell you about the rate of change?

- **Teacher Hint:** Slides 26 & 27 will help with this discussion. The shape of the curve shows the rate of change is not constant. At first, density is decreasing rapidly with volume, the it decreases gradually.

How does your diagram communicate the relationship between volume and density (for the mass of the blocks you tested)?

- Density is a property of materials. The density of any given material, regardless of the mass of the sample will always be the same. If each of these blocks had a different density, than each block must have been made of a different material.

How do you know that all the blocks in your investigation were made of different materials?

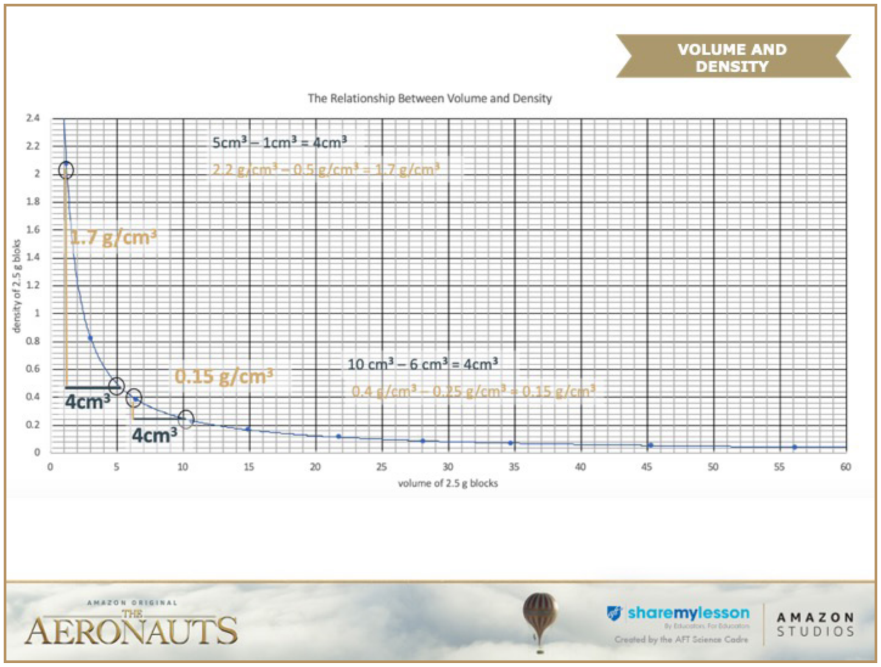
- Density is a property of materials. The density of any given material, regardless of the volume of the sample will always be the same. If each of these blocks had a different density, then each block must have been made of a different material.

What about the data surprised you?

- (answers will vary)

What other questions could we investigate using this density simulation?

- **Teacher Hint:** Do not ask this question if you have done all four density labs.
- (answers will vary)




**Teacher Hint:** Depending on your comfort level with the content and student discourse, save this content for the whiteboard discussion and help students discover what this curve fit means through questioning and discussion.

How is the shape of this graph different than the shape of the mass/density graph? (only ask this question if students did density lesson 3)

- The line on this volume/density graph is curved, the line on the mass/density graph was straight.
- The line on this volume/density graph has a negative slope, the line on the mass/density graph had a positive slope.

What does the negative slope of the graph tell us about how density is changing withvolume.

- A negative slope tells us that for the blocks we tested volume increases, density decreases when mass is constant.
- The straight line on the mass/density graph told us that mass and density were changing at aconstant rate. Every time mass increased by 1 gram, density increased by 0.25 g/$cm^3$. (only say this if students did density lesson 3)

What does this curved shape tell us about the rate of change? Let's look at a few points on the graph to find out.

- First, lets look at a section of the graph where the volume of the 2.5g block was low.
- I have chosen points on the graph that represent a volume of 1$cm^3$ and 5$cm^3$, that is a change in volume of 4 $cm^3$.
- The 1$cm^3$ block had a density of 2.2 g/$cm^3$. The 5$cm^3$ block has a density of 0.5 g/$cm^3$.

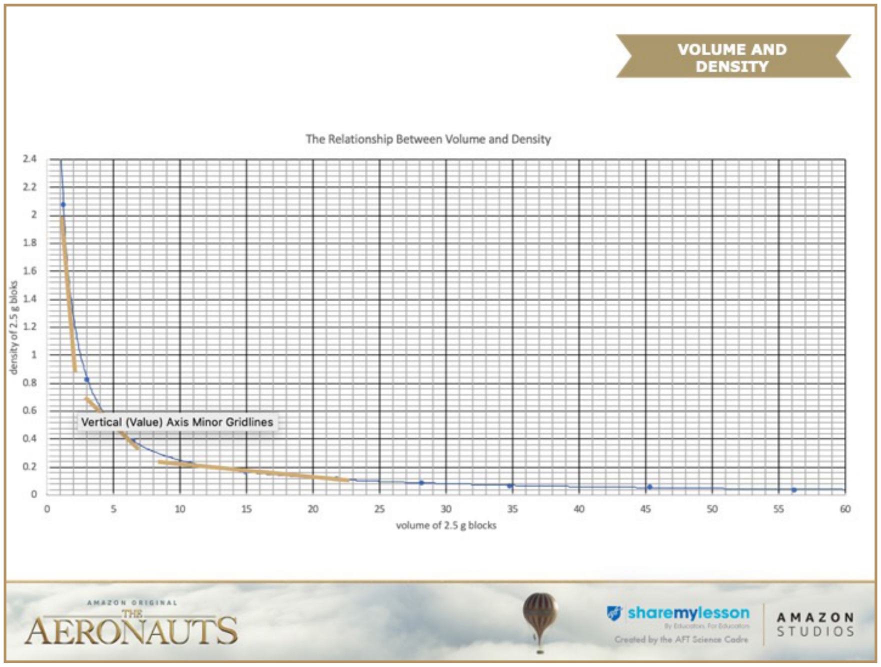
- The difference in volume these two blocks is 1.7 g/$cm^3$

Now let's look at two places on the graph that represent blocks at slightly higher volume.

- I have chosen points on the graph that represent a volume of 6$cm^3$ and 10 $cm^3$, that is a change in volume of 4 $cm^3$.
- The 6$cm^3$ block had a density of 0.4 g/$cm^3$. The 10$cm^3$ block has a density of 0.25 g/$cm^3$.
- The difference in volume these two blocks is 15 hundredths of a g/$cm^3$!

The rate of change is much smaller.

- If we look down the graph, we can see the rate of change keeps getting smaller and smaller.




**Teacher Hint:** Depending on your comfort level with the content and student discourse, save this content for the whiteboard discussion and help students discover what this curve fit means through questioning and discussion.

A good test to tell how where the rate of change is rapid and the rate of change is gradual is to draw a straight line that follows the shape of the curve.

- The steepness of the line is an indicator of the rate of change.

Here is a line along the curve.

- Here is another line along the curve.
- Is this line steeper or less steep? **Steeper**
- What does this tell us about how density is changing? **Density is decreasing rapidly.**
- Is this line steeper or less steep than the other two lines? **Less steep**
- What does this tell us about how density is changing? **Density is decreasing gradually**