SeaGlide_TEAM	Density & Buoyancy Unit Plan	Lesson # 3 - 4 (60 minutes each)

Description:

Students will take the role of a naval engineer. It is their job and duty to assist with the continued maintenance of NAVY vessels. Recently, one of the submarines has been unable to rise and sink in the water. From their training, their knowledge that the ship's density affects its ability to rise and fall within the water. The students must devise a way for the ship to increase and decrease its density without sacrificing the crew or its current equipment.

Students will be able to:

- Discover density through a water-based lab activity
- Calculate the density of a given object using its mass and volume
- Utilize density to calculate an object's buoyancy
- Apply logic and reasoning to directly connect density to buoyancy and vice versa
- Understand that density and buoyancy can be mechanically manipulated

Students will understand:

Density is a physical property that explains how many atoms are packed into a space or an object. By determining density, scientists are able to explain and take advantage of its properties. These phenomenon include: the ability to swim in water (human body density < water's density) and flight (airplane/hot air balloon density = air density). Through knowledge of density, doctors are able to centrifuge blood and separate it into its constituents for research purposes. By calculating and understanding density, many everyday occurrences can be explained and even predicted. This extends the understanding of intermolecular forces taught previously to real-world connections and applications.

Key Definitions & Concepts: [1]

- **Density**: the ratio between mass and volume or mass per unit volume.
- **Buoyancy**: an upward force exerted by a fluid that opposes the weight of an immersed object.
- **Mass**: the fundamental measure of how much matter is in something.
- **Volume**: the amount of space that a substance or object occupies, or that is enclosed within a container.
- **Physical Property**: any property that is measurable, whose value describes a state of a physical system; examples include: solubility, polarity, density, melting and boiling points, etc.

Standards: [Copied from: 2]

5-PS1-3: Make observations and measurements to identify materials based on their properties.

- Throughout the lab activity in this lesson, students are observing the changes in water volume when objects are placed inside of graduated cylinders. The students are then taking quantitative observation by recording the changes in volume, then applying them to determine the density of the object.

3.2.7.A1 Explain how materials are characterized by having a specific amount of mass in each unit of volume (**density**).

- Density is defined as the amount of matter confined into a given space. Through this lesson, students will be discovering how density can be measured using relatively simple techniques. The calculating of an object's density is used throughout chemistry and physics through advanced methods; however, this approach helps students fundamentally understand density.

	Background Information	

Prior Knowledge:

- All things are made of matter and atoms.
- Matter can exist in three states: solid, liquid, and gas.
- These states determine how compact and/or spread apart the atoms are from one another.
- Natural phenomenon, like freezing and melting, occur when atoms interact with on another.
- Know the various intermolecular forces and their strengths

Science Practices: [Copied from: 3]	**Core Ideas: [Copied from: 4]**	**Cross Cutting Concepts: [Copied from: 5]**
• Planning and Carrying Out Investigations • Developing and Using Models	• Structure and Properties of Matter	• Patterns • Energy and Matter • Structure and Function

Possible Preconceptions/Misconceptions: Lesson #1: Density

During this lesson, students may have difficulty determining how to go from milliliters (mL) to centimeters-cubed (cm^3) in order to calculate an object's density. By nature, volume is how much space is being occupied. When students realize that $1\ cm^3 = 1\ mL$, they will be able to easily calculate the density of a given object. Students may also confuse weight with mass. An object that contains a large amount of atoms has the potential to be heavy, but this is only the case for objects that are solids and liquids. In the case of gases, a balloon may be more dense than a block of ice, but the ice is heavier due to the force of gravity being exerted on it. An additional misconception in this lesson is the relationship between density and an molecule's molecular weight. The instructor should reinforce to students that, as the molecular weight of an molecule increases, the amount of moles within its volume increases. Thus, density is directly proportional to a molecule's molecular weight.

Possible Preconceptions/Misconceptions: Lesson #2: Buoyancy [6]

Following the video *Physics - What is Buoyancy*, students may believe that buoyancy is affected by how much air is present in an object, like a balloon, instead of considering the comparisons of weight and/or density and how they can affect an object's buoyancy. Students will discover that, in the case of a balloon, the air inside the balloon is less dense than the air outside of the balloon.

Things for the instructor and students to remember:

1) Balloons float only if inflated with helium because helium weighs less than the surrounding air (consists of mostly oxygen, nitrogen, argon, and carbon dioxide).

2) Balloons that sink are those that have been manually inflated (consisting of carbon dioxide). This is where confusion might arise because the weight of the gas inside the balloon is still lighter than the surrounding air, but because the density of carbon dioxide in the balloon is greater than the surrounding air, the balloon slowly sinks towards the ground.

A possible misconception is that the ship is being pushed down by its own mass. However, in physics, weight is understood as the object's mass multiplied by the force of gravity pulling the object. Students are partially correct in saying that the weight of the ship is important, but the misconception exists because gravity must be taken into account. This is because the mass is already being considered via the buoyancy equation.

Lesson Plan - 5E(+) Model

Engage: Lesson #1: Density [7]
The instructor will tell the students the story of Archimedes (link from Thoughtco), who discovered how to determine the density of an object without melting it down. Instead of melting down the king's crown to determine if the metal was gold, Archimedes would place the crown in water to see how much water was displaced (in mL or cm^3). Archimedes would then calculate the mass of the crown (in g). By determining these two values, Archimedes was then able to compare the density of the crown to the density of gold, thus figuring out if the crown was made of real gold. This introduces students to how they will be determining density through the lab activity. The instructor will briefly explain the story and distribute the worksheet *The Story of Archimedes*. This activity should take up to 5 minutes.

Engage: Lesson #2: Buoyancy
The instructor will begin the lesson by distributing a *Pre Quiz* that tests student knowledge on the previous topic of density. The pre quiz also serves as a concept check for the instructor, providing them information on student retention of density and if any misconceptions still exist. The final question on the pre quiz serves as a preview for the following lesson, testing students to extend their understanding of density. Allow the students to have 5 minutes to complete the pre quiz.

Explore: Lesson #1: Density
Part I: Introduction
The instructor will begin the lesson by showing students two objects: a small ball and a larger one. The instructor will then ask students a question that should be along the lines of "which ball would take up more space?" This question will act as a segway to promote a class discussion on objects and their mass as it relates to density. This class discussion should take about 5 minutes to complete.

Part II: *Benchmark Lesson*: Finding Volume: Water Displacement: [8]
During the discussion, the instructor will distribute the worksheet *Finding Volume: Water Displacement* where students will predict the density of different objects based on their size and structure. This is a lab-based activity where students determine density based on data collected, and they will be able to see this within different scenarios. Students are utilizing the concepts learned from the previous worksheet and actively applying them through this experiment. The concept questions are designed as benchmarks for the students to test their understanding of this lesson's goals. These questions test

whether or not students can connect the importance of volume to an object's density. This activity should take up to 10 minutes.

Part III: *Investigation Lesson*: Calculating Density [9]
The worksheet titled *Calculating Density* challenges students to apply their understanding to several math problems involving density. The first three questions of the worksheet move increase in complexity by challenging the students through mathematical problems that have the students calculating density based on given information. The fourth and final question on the worksheet prompts the students through a real-world connection to density, prompting students to devise an experiment to test the phenomenon of ice floating on water. This activity should take less than 15 minutes to complete.

Explore: Lesson #2: Buoyancy [6]
Part I: Introduction
The instructor will show students the video Physics - What is Buoyancy?. This 3 minute video serves as an introduction to the foundational concepts relating to buoyancy. The instructor will follow the video by distributing students the *What Is Buoyancy* worksheet. This worksheet serves as a way for students to learn the important concepts from the video and gain an understanding of what buoyancy is. After the video, the instructor should discuss their answers from the worksheet. This activity should take up to 10 minutes.

Part II: *Benchmark Lesson*: Calculating Buoyancy
The students will move on to the next worksheet titled, *Calculating Buoyancy* worksheet. Students will be challenged to extend their understanding of density towards an application through buoyancy. After distribution of the worksheet, the instructor will separate the class into groups of two or three. This worksheet allows students to see how density affects buoyancy and to what intensity. This worksheet is an introduction for students to begin measuring buoyancy based off of certain given factors. Through the prior activities, student learned how to define buoyancy and devised a conceptual understanding of how it can be manipulated. Through this worksheet, students will extend this knowledge by being able to both conceptually and mathematically represent changes in buoyancy when any of the following values are variable: density, volume, mass, and/or weight. Allow the students 15 minutes to complete this worksheet.

Part III: *Investigation Lesson*: Submarine Design
After the *Calculating Buoyancy* worksheet, students will be given a prompt that provides them with common submarine specifications and a problem statement. This activity is a real-world connection that engages the students to think like Naval Engineers. The purpose of this activity is to have students apply the concepts of density, buoyancy, weight, volume and mass to an underwater craft. Students will need to think critically as to what variable can be easily adjusted to allow the submarine to float. This investigation serves as a direct connection to the SEAGlider since the purpose of the syringe inside the water bottle is to make the SEAGlider more or less buoyant depending on if the syringe is either taking in or expelling water. This activity should take up to 20 minutes.

Explain:
Throughout the exploration of these lessons, students will engage in discussions and activities that seek to discover their understanding of the topic at-hand as it relates to density and buoyancy.

Instructors should informally observe and listen to students' discussions during the activities; this will aid in addressing any questions or concerns that some students may have. Students are expected to formalize their answers from the experiment during the density lesson, and write about it based on their observations from their data collected. Students must also verbalize their understanding of the material via the concept check questions throughout each of the lessons. Through the elaboration from the buoyancy lesson, students have an additional opportunity to show their understanding about density and buoyancy in a creative real-world application.

Elaborate: Lesson #1: Density

Students will analyze a unique phenomenon of water. This phenomenon is not explicitly covered in most of the current curriculum systems, but it is the reasoning behind why ice floats on top of liquid water. Using their learned knowledge of intermolecular forces and density, students will explain how this phenomenon occurs. This real-world example is seen in everyday life, but is relatively unexplained. Students will employ critical-thinking by being taken through a simplified version of the scientific method. They will explain what they are testing, how they would test it, and their expected results for the experiment.

Elaborate: Lesson #2: Buoyancy

Through the investigation lesson portion of the elaboration, students will be evaluating and proposing a solution to a given problem statement about a malfunctioning submarine. This activity is a real-world connection that engages the students to think like Naval Engineers. The purpose of this activity is to have students apply the concepts of density, buoyancy, weight, volume and mass to an underwater craft. This serves as a direct connection to the SEAGlider since the purpose of the syringe inside the water bottle is to make the SEAGlider more or less buoyant depending on if the syringe is either taking in or expelling water.

Evaluate:

These lessons are constructed to have both informal and formal evaluations throughout its entirety. The informal evaluations occur throughout each of the lessons, but specifically during the engage sections where the instructor will facilitate class discussions. These discussions will flow into the exploration sections where students will use their skills in making predictions and observations to later analyze their findings through activities and worksheets. Due to the quantitative nature of the various assessments, students are able evaluate their own understanding of the material and revise their solutions with minimal instructor leads. The combination of the experiment report, the worksheets and the submarine activity serves as the formal evaluations in this lesson.

Enrich:

This unit can be differentiated into a higher-level chemistry class. Because density is defined as the amount of matter confined in a space, the concept of solubility may be discussed. When a solute is dissolved in a solvent, the solvent becomes more dense due to the increase in matter existing within it. However, once the maximum amount of solute is dissolved, the solvent becomes saturated and will be the most dense that it can be. This concept applies to several chemistry applications, such as organic and inorganic studies.

All associated documents are attached below

Reference *Annotated Bibliography* on the very last page of this packet

Worksheets for Density Lesson

Name: ____ Date:____________________

The Story of Archimedes

1. How was density measured before Archimedes' approach? How did this pose a problem? (HINT: Archimedes needed to determine the density of the king's crown)

2. How did Archimedes determine the crown's density?

Name: ____ Date:____________________

The Story of Archimedes

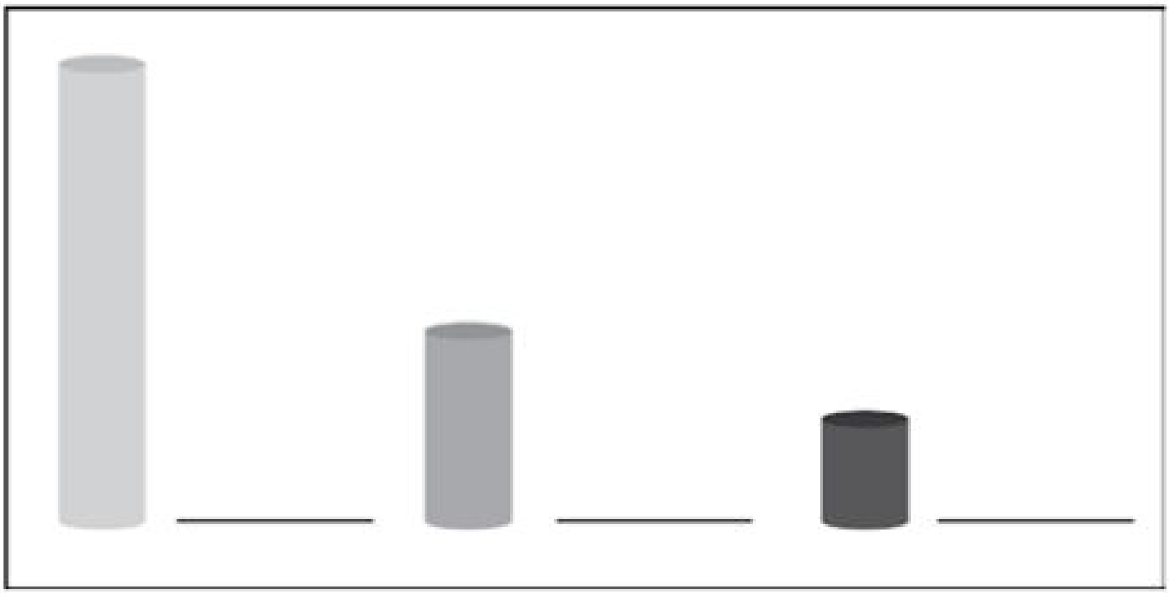
1. How was density measured before Archimedes' approach? How did this pose a problem? (HINT: Archimedes needed to determine the density of the king's crown)

2. How did Archimedes determine the crown's density?

Name: ____ Date:___________________

Finding Volume: Water Displacement [8]

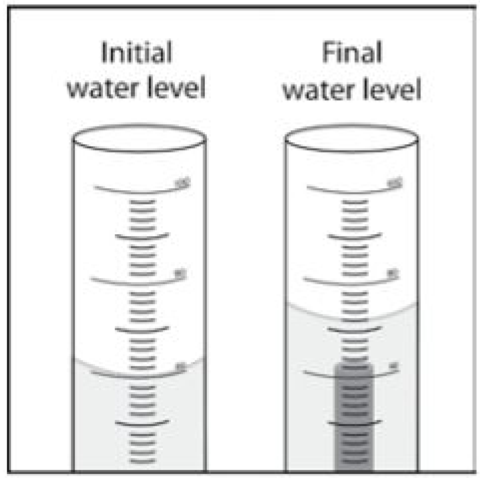
1. Predict the densities of each of the rods depicted below by matching the density description with the appropriate rod.



Least dense   Medium dense   Most dense

2. Explain why you think each rod is either the most, medium or least dense.

3. Look at the picture below showing the water level in a graduated cylinder before and after a sample is submerged. Answer the following questions:



   a. What does the difference in water level tell you about the sample?

   b. If you submerged a cube with a volume of $1cm^3$ in a graduated cylinder filled with 40 mL of water, how much would the water level rise?

4. What is the density of a sample whose mass is 50g with a water displacement from 60 mL to 85 mL? (pay attention to units).

Name: ____ Date: ____________________

Finding Volume Experiment

Directions: Work in a group of two or three. Each group has five samples, each with the same mass but are made of different material. Carefully measure the volume of each sample, and calculate the density using the methods taught by the Water Displacement worksheet. Use those density values to determine the materials of the five samples.

Sample	Initial Water Level (mL)	Final Water Level (mL)	Volume of the Rod (cm^3)	Mass (g)	Density ($\frac{g}{cm^3}$)
A				15.0 g	
B				15.0 g	
C				15.0 g	
D				15.0 g	
E				15.0 g	

Concept Challenge!

Must the initial water level be the same for each sample? I.e. what is the significance of the initial water level in relation to the volumes of the samples?

Identify the Samples:

Material	Approximate Density ($\frac{g}{cm^3}$)	Sample (A - E)
Copper	~9.00 g/cm^3	
Aluminum	~2.7 g/cm^3	
NaCl	~2.2 g/cm^3	
Sodium Bicarbonate	~2.2 g/cm^3	
Sugar	~1.6 g/cm^3	

Concept Check!

During the Water Displacement worksheet, you made a prediction about the density of a small, medium and long rod that has the same mass. Based on this experiment, were your predictions correct? If yes, explain why. If no, correct your predictions and provide an explanation for why you made these changes.

Name: ____ Date:_____________________

Calculating Density

Solve the following problems showing all your work including equations and units.

1. Calculate the mass of a liquid with a density of 3.2 g/mL and a volume of 25 mL.

2. An irregular object with a mass of 18 kg displaces 2.5 L of water when placed in a large overflow container. Calculate the density of the object.

3. A graduated cylinder has a mass of 80 g when empty. When 20 mL of water is added, the graduated cylinder has a mass of 100 g. If a stone is added to the graduated cylinder, the water level rises to 45 mL and the total mass is now 156 g. What is the density of the stone?

4. Water is known for several of its unique properties. One of these properties is its ability to float on top of itself. This phenomenon is unusual because all compounds, except water, do not exhibit this. Using your knowledge of density and the intermolecular forces of water, explain how ice floats above liquid water.

Design an experiment to test this phenomenon and hypothesize about your expected results. Be sure to include detailed explanations of these hypotheses.

Test Method:

a. What are you testing for?

b. How would you test for your answer in part (a)?

Hypotheses:

a. What result(s) would you expect from your designed testing method?

b. Why? (Hint: discuss density and intermolecular forces properties)

Worksheets for Buoyancy Lesson

Name: ____ Date: ___________________

Pre-Quiz

1. In your own words, define and describe density.

2. Give an example of density using two liquids.

Bonus!

Because of the mass and volume of a cruise ship, we find that its density is greater than that of water. Explain why a cruise ship floats on water instead of sinks. (Hint: think about the relationship between density and displacement). Provide as much detail as possible.

Name: ____ Date:____________________

What Is Buoyancy?

1. What happens when an object is placed in a fluid in terms of the pressure change?

2. What is buoyant force?

3. Using your answers from above, explain how a ship is able to float.

Name: ____ Date:____________________

What Is Buoyancy?

1. What happens when an object is placed in a fluid in terms of the pressure change?

2. What is buoyant force?

3. Using your answers from above, explain how a ship is able to float.

Name: ____ Date: ____________________

Calculating Buoyancy [9]

1.) A medical ship weighs 10,000 kg. What volume of fresh water (d = 1025 kg/m^3) will the ship displace?

2.) Find the weight of the air in a room with dimensions of 20 ft x 12 ft x 15 ft. The weight density of air at sea level is 0.08 lbs / ft^3.

3.) An iron anchor weighs 250 pounds in air (Newtons) and has a weight density of 480 lbs / ft^3. If it is immersed in sea water that has a weight density of 64 lbs / ft^3, how much force would be required to lift it while it is immersed?

4.) An aluminum bar weighs 17 pounds in air. How much force is required to lift the bar while it is immersed in gasoline? The weight density of aluminum is 170 lbs / ft ^{3} and that of gasoline is 42 lbs / ft ^{3} .

5.) How much does a 20 ft x 10 ft x 8 ft swimming pool filled with water weigh? Assume the water has a weight density of 62 lbs / ft ^{3} .

6.) A balloon weighing 80 kg has a capacity of 1200 m^3 . If it is filled with helium, how great a payload can it support? The density of helium is 0.18 kg/m^3 and the density of air is 1.30 kg/m^3.

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
2531 JEFFERSON DAVIS HWY
ARLINGTON, VA 2242-5160

Congratulations Recruit!

Welcome to the NAVY. As per your hiring as a naval engineer, it is your job and duty to assist with the continued maintenance of NAVY vessels. Recently, one of our submarines has been unable to rise and sink in the water. Below is brief information on the vessel and its crew:

- The mass of the ship and its crew remains relatively constant (26,000 tons surfaced, 48,000 tons submerged) (1 ton = 907.185 kg).
- The ship's engine and propellers are functioning properly.
- The ship displaces its weight in water (water displaced in m^3 = weight kg).
- The ship is pushed down on and into the water by gravity (9.8 m/s^2).
- The ship's hull is hollow and fixed (volume = 26 km^3)

From your training, you know that the ship's density affects its ability to rise and fall within the water. With one other Recruit, devise a way for the ship to increase and decrease its density **WITHOUT** sacrificing the crew or its current equipment.

Good Luck and Welcome to the Navy, Recruit!

Director, Engineering Division

Name: ____ Date:____________________

Group Member(s): ____

Submarine Design

1. What values remain constant?

2. What is the Buoyant force of the submarine above water? Below water?

3. What must change in order for the submarine to float on the water versus remain submerged in the water? You may refer back to the given information for clarification.

4. Defend your answer to the question above. Why can this value be changed and how?

Answer Keys for Density Lesson

Name: ______________Answer Key_______________________ Date:_____________________

The Story of Archimedes

1. How was density measured before Archimedes' approach? How did this pose a problem? (HINT: Archimedes needed to determine the density of the king's crown)

   Density was originally measured by melting the metal into a cube, then taking the mass. This posed a problem because Archimedes was not allowed to melt the king's crown.

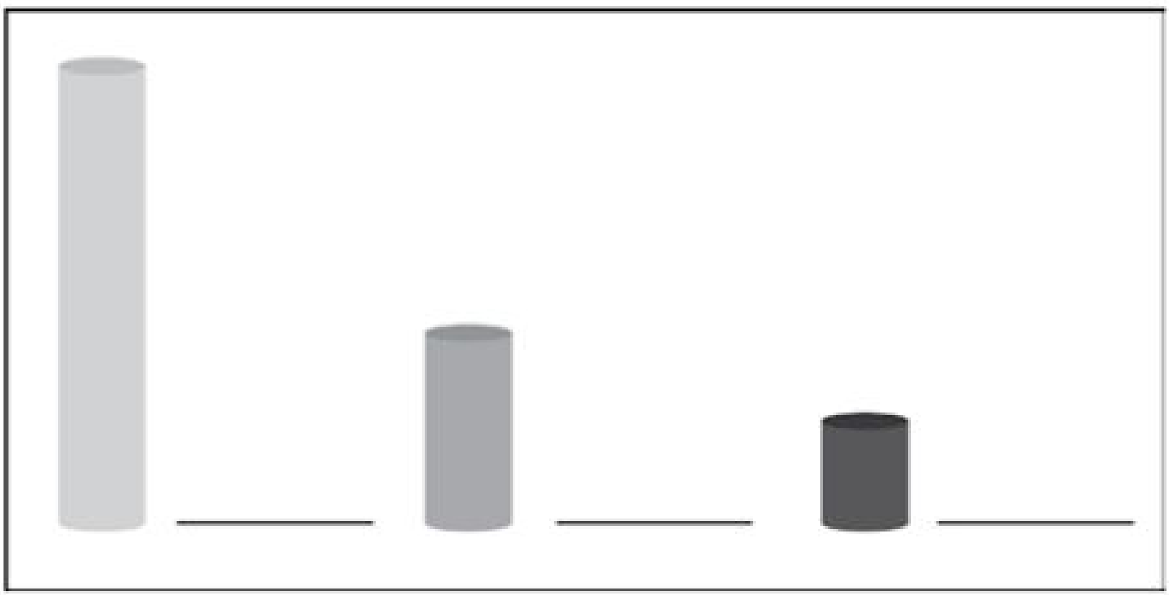
2. How did Archimedes determine the crown's density?

   Archimedes placed the crown in a volume of water, then measured the difference after adding the crown. By doing so, Archimedes was able to obtain the crown's volume, then measure its mass using a scale.

Name: ____________Answer Key______________________ Date:____________________

Finding Volume: Water Displacement [8]

1. Predict the densities of each of the rods depicted below by matching the density description with the appropriate rod.



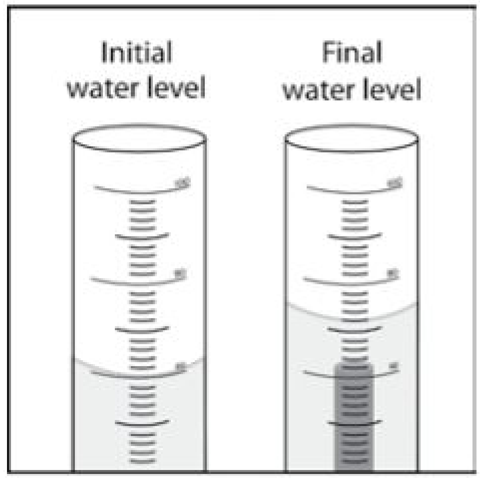
Least dense   Medium dense   Most dense

In order from left to right: Least dense, Medium dense, Most dense

2. Explain why you think each rod is either the most, medium or least dense.

   Rod 1 is the least dense because less matter is packed into the volume. This is shown by its very light shading. Rod 3 is the most dense because it contains a lot of matter in a small space. This is shown with its dark shading. Therefore, Rod 2 is medium dense because it is less shaded than Rod 3 and more shaded than Rod 1.

3. Look at the picture below showing the water level in a graduated cylinder before and after a sample is submerged. Answer the following questions:



   a. What does the difference in water level tell you about the sample?

      By adding the sample, additional volume was added to the sample. The water rose by 6 mL.

   b. If you submerged a cube with a volume of $1cm^3$ in a graduated cylinder filled with 40 mL of water, how much would the water level rise?

      1 cm^3 = 1 mL, therefore the graduated cylinder would rise by 1 mL, raising the volume to 41 mL total.

4. What is the density of a sample whose mass is 50g with a water displacement from 60 mL to 85 mL? (pay attention to units).

   85 mL (water + sample) - 60 mL (water) = 15 mL (sample)

   15 mL = 15 cm^3

   Answer: 50g / 15 cm^3 = 3.33 g/cm^3

Name: ________________Answer Key___________________ Date: ___________________

Finding Volume Experiment

Directions: Work in a group of two or three. Each group has five samples, each with the same mass but are made of different material. Carefully measure the volume of each sample, and calculate the density using the methods taught by the Water Displacement worksheet. Use those density values to determine the materials of the five samples.

Sample	Initial Water Level (mL)	Final Water Level (mL)	Volume of the Rod (cm^3)	Mass (g)	Density ($\frac{g}{cm^3}$)
A				15.0 g	
B				15.0 g	
C				15.0 g	
D				15.0 g	
E				15.0 g	

These values are dependent on the measurements of the students

Concept Challenge!

Must the initial water level be the same for each sample? I.e. what is the significance of the initial water level in relation to the volumes of the samples?

The initial water level does not necessarily need to be the same for each sample. For scientific purposes, the initial value must be consistent to help with maintaining accuracy. However, only the difference in water volume before and after the addition of the sample is needed to determine density.

Identify the Samples:

Material	Approximate Density ($\frac{g}{cm^3}$)	Sample (A - E)
Copper	~9.00 g/cm^3	
Aluminum	~2.7 g/cm^3	
NaCl	~2.2 g/cm^3	
Sodium Bicarbonate	~2.2 g/cm^3	
Sugar	~1.6 g/cm^3	

students' answers are dependent on instructors' sample labeling

Concept Check!

During the Water Displacement worksheet, you made a prediction about the density of a small, medium and long rod that has the same mass. Based on this experiment, were your predictions correct? If yes, explain why. If no, correct your predictions and provide an explanation for why you made these changes.

Answers will be dependent on student predictions prior to the lab activity and measurements taken during the lab activity. If student predictions were incorrect, they must include data collected from the experiment.

Name: __________Anwser Key_______________________ Date:_____________________

Calculating Density

Solve the following problems showing all your work including equations and units.

1. Calculate the mass of a liquid with a density of 3.2 g/mL and a volume of 25 mL.

   (3.2 g/mL) x (25 mL) = 80 g

2. An irregular object with a mass of 18 kg displaces 2.5 L of water when placed in a large overflow container. Calculate the density of the object.

   (18 kg) / (2.5 L) = 7.2 kg / L
   Answer: 7.2 kg / L = 7.2 g / mL

3. A graduated cylinder has a mass of 80 g when empty. When 20 mL of water is added, the graduated cylinder has a mass of 100 g. If a stone is added to the graduated cylinder, the water level rises to 45 mL and the total mass is now 156 g. What is the density of the stone?

   45 mL (water + stone) - 20 mL (water) = 15 mL stone

   156 g (cylinder + stone) - 100 g (cylinder) = 56 g stone

   Answer: 56 g / 15 mL = 3.73 g / mL

4. Water is known for several of its unique properties. One of these properties is its ability to float on top of itself. This phenomenon is unusual because all compounds, except water, do not exhibit this. Using your knowledge of density and the intermolecular forces of water, explain how ice floats above liquid water.

   Ice floats on water because it is less dense than water.

   Design an experiment to test this phenomenon and hypothesize about your expected results. Be sure to include detailed explanations of these hypotheses.

   Test Method:

   a. What are you testing for?

      If ice is less dense than water

   b. How would you test for your answer in part (a)?

      Answers will vary based on student response. Students are expected to test ice in liquids of various densities to get the relative density of ice, then compare it to the known density of water.

   Hypotheses:

   a. What result(s) would you expect from your designed testing method?

      Answers will vary based on student response to Test Method Question (a).

   b. Why? (Hint: discuss density and intermolecular forces properties)

      Because of the uniform Hydrogen bonding in ice and the random Hydrogen bonding in water, water is more compact than ice and therefore less dense.

Answer Keys for Buoyancy Lesson

Name: ____ Date: __________________

Pre-Quiz

1. In your own words, define and describe density.

   Answers will vary based on student response. Students should state something similar to the following: Density is the amount of mass compressed into a given space or volume.

2. Give an example of density using two liquids.

   Answers will vary based on student response. In all responses, the least dense liquid will float on top of the most dense liquid. Example: Water is more dense than oil, so oil will float on top of water.

Bonus!

Because of the mass and volume of a cruise ship, we find that its density is greater than that of water. Explain why a cruise ship floats on water instead of sinks. (Hint: think about the relationship between density and displacement). Provide as much detail as possible.

Cruise ships have densities that are greater than that of water, but the amount of water present when a cruise ship floats is very high. Because of this, a cruise ship displaces an amount of water that exhibits a density greater or equal to the ship.

Name: ____ Date:____________________

What Is Buoyancy?

1. What happens when an object is placed in a fluid in terms of the pressure change?

   The pressure pushing up the the object increases as the depth increases.

2. What is buoyant force?

   When the pressure pushing up on an object is greater than the pressure pushing down on the object.

3. Using your answers from above, explain how a ship is able to float.

   A ship is able to float because of the amount of upward pressure that is exerted by the water is greater than the downward pressure being exerted by gravity. Due to the vast amount of water displaced by the ship, the pressure is so great that it is able to overcome the force of gravity and keep the ship afloat.

   A possible misconception is that the ship is being pushed down by its own mass. However, in physics, weight is understood as the object's mass multiplied by the force of gravity pulling the object. Students are somewhat correct in saying that the weight of the ship is important, but the misconception exists because gravity must be taken into account. This is because the mass is already being considered via the buoyancy equation.

Name: ________________Answer Key_____________________ Date: ____________________

Calculating Buoyancy [9]

1.) A medical ship weighs 10,000 tons. What volume of fresh water (d = 1000 kg/m^3) will the ship displace?

(10,000 tons) x (907.185 kg / ton) = 907,185 kg

V = m / d
V = (907,185 kg) / (1000 kg / m^3)
Answer: V = 907 m^3 = 907 L

2.) Find the weight of the air in a room with dimensions of 20 ft x 12 ft x 15 ft. The weight density of air at sea level is 0.08 lbs / ft^3 .

(20 ft) x (12 ft) x (15 ft) = 3.6 x 10^3 ft^3

Answer: (3.6 x 10^3 ft^3) x (0.08 lbs / ft^3) = 2.88 x 10^2 lbs

3.) An iron anchor weighs 250 pounds in air (Newtons) and has a weight density of 480 lbs / ft^3. If it is immersed in sea water that has a weight density of 64 lbs / ft^3, how much force would be required to lift it while it is immersed?

250 Newtons = (480 lbs / x ft^3) x (32.3 ft / s^2)
x ft^3 = 16.77 ft^3

B = d x g x V
B = (64 lbs / ft^3) x (16.77 ft^3)
Answer: B = 1073 lbs

4.) An aluminum bar weighs 17 pounds in air. How much force is required to lift the bar while it is immersed in gasoline? The weight density of aluminum is 170 lbs / ft ^{3} and that of gasoline is 42 lbs / ft ^{3} .

Weight (gasoline) = (250 lbs) x [(480 lbs - 64 lbs)/480 lbs]
Weight (gasoline) = (250 lbs) x (0.87)
Weight (gasoline) = 218 lbs

5.) How much does a 20 ft x 10 ft x 8 ft swimming pool filled with water weigh? Assume the water has a weight density of 62 lbs / ft ^{3} .

(20 ft) x (10 ft) x (8 ft) = 160 ft ^{3}

Answer: (160 ft ^{3}) x (62 lbs / ft ^{3}) = 9920 lbs

6.) A balloon weighing 80 kg has a capacity of 1200 m ^{3} . If it is filled with helium, how great a payload can it support? The density of helium is 0.18 kg/m ^{3} and the density of air is 1.30 kg/m ^{3}.

m (lifted) = m (volume displaced)
m (displaced air) = (1200 m ^{3}) x (1.3 kg / m ^{3})
m (displaced air) = 1560 kg

m (supported) = (1560 kg) - (80 kg) - [(1200 m ^{3}) x (0.18 kg / m ^{3})]
Answer: m (supported) = 1264 kg

Name: ____________Answer Key_____________________ Date:_____________________

Group Member(s): ____

Submarine Design

1. What values remain constant?

   Mass (above water) = 26,000 tons
   Mass (submerged) = 48,000 tons
   Volume (ship's hull) = 26 km^3
   Volume (water displaced) = Mass
   Gravity (g) = 9.8 m/s^2

   (Students should realize that the density changes)

2. What is the Buoyant force of the submarine above water? Below water?

   Buoyancy (above water) = 2.10×10^{11} Newtons
   Buoyancy (submerged) = 7.13×10^{11} Newtons

3. What must change in order for the submarine to float on the water versus remain submerged in the water? You may refer back to the given information for clarification.

   The density of the ship must change in order to affect buoyancy.

4. Defend your answer to the question above. Why can this value be changed and how?

   Because the ship is surrounded by water, it can take advantage of this and increase its mass (and therefore density) by taking in water. *How this is done is open to student interpretation.*

Annotated Bibliography

[1] OpenStax. (n.d.). 1.3 Physical and Chemical Properties. Retrieved January, 2019, from https://opentextbc.ca/chemistry/chapter/physical-and-chemical-properties/

This reference was used for excerption purposes. The definitions and information in this reference was directly excerpted for definitions used in this unit plan.

[2] Nsta. (n.d.). Access the Next Generation Science Standards by Topic. Retrieved January 18, 2019, from https://ngss.nsta.org/AccessStandardsByTopic.aspx

This website was used in each lesson in the Water Chemistry & Biology module to select proper national set standards for science subjects that each lesson is centered around.

[3] Nsta. (n.d.). Science and Engineering Practices. Retrieved January 18, 2019, from https://ngss.nsta.org/PracticesFull.aspx

This website used in every lesson in the Water Chemistry & Biology module to find Standards for Science and Engineering Practices that are applicable in each lesson.

[4] Nsta. (n.d.). Disciplinary Core Ideas. Retrieved from https://ngss.nsta.org/DisciplinaryCoreIdeasTop.aspx

This website was used in each lesson in the Water Chemistry & Biology module to select appropriate disciplinary core ideas set forth by the NSTA that are at the center of each lesson.

[5] Nsta. (n.d.). Crosscutting Concepts. Retrieved from https://ngss.nsta.org/CrosscuttingConceptsFull.aspx

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[6] Memorise, D. (2017, July 17). Physics - What is Buoyancy? Retrieved February, 2019, from https://www.youtube.com/watch?v=khc2wUBsFU4

This reference was used as a learning tool to be used in the Density & Buoyancy unit plan. This reference was used for instructional purposes and was neither adapted nor excerpted.

[7] Helmenstine, A. M. (2018, March 31). How to Measure Volume & Density - A Tale of Archimedes. Retrieved February, 2019, from https://www.thoughtco.com/archimedes-volume-and-density-3976031

This reference was used as a student reading for the Density & Buoyancy unit plan. This reading was also used to develop the engagement half sheet in the associated unit plan.

[8] ACS, & MiddleSchoolChemistry. (2018, March). Finding Volume: The Water Displacement Method. Retrieved February, 2019, from http://www.middleschoolchemistry.com/lessonplans/chapter3/lesson2

This reference was used for excerption purposes. The images provided in this reference were beneficial in demonstrating density and its associated properties. These images were directly excerpted from the reference. MiddleSchoolChemistry is useful for finding and adapting 5E lessons in chemistry that contain inquiry-based activities.

[9] Hodanbosi, C., & Fairman, J. G. (1996, August). Buoyancy: Archimedes Principle. Retrieved March, 2019, from https://www.grc.nasa.gov/WWW/K-12/WindTunnel/Activities/buoy_Archimedes.html

This reference was used for excerption purposes. The questions listened in this reference were useful in assessing student understanding of density. The questions in this reference were directly excerpted. The use of this reference was also useful in drawing real-world connections and applications of density to students.