Density

Author(s): Ms. Adrienne Maribel López

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Subject: Physics

Grade Level: 6th-8th grade

Standards: ***NYS Learning Standards for Mathematics, Science, and Technology-- Intermediate (www.emsc.nysed.gov)***

Standard 1;Scientific Inquiry, Key Idea 3- 3.2
Interpret the organized data to answer the research question or hypothesis and to gain insight into the problem.
Standard 1; Mathematical Analysis, 1
Abstraction and symbolic representation are used to communicate mathematically.
Standard 4; Physical Setting, 3.1
Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity; Observe and describe properties of materials, such as density, conductivity, and solubility.

Schedule: Three to four 45-minute class periods

CCMR Lending Library Connected Activities:

Buoyancy

Objectives: To further student understanding of density by comparing liquids of different densities quantitatively and qualitatively.	**Vocabulary:** Density Mass Quantitative Volume Qualitative
Students Will: - Apply their knowledge of the density formula by using the graduated cylinder and balance to determine the densities of liquids - Synthesize their knowledge by discussing whether or not their numerical results agree with their observations of the four liquids when poured into one glass beaker or graduated cylinder. - Create Explanations and 2-D models of how a Cartesian Diver works and how it illustrates the mathematical components of the density equation.	**Materials:** **For Each Station (2-4 students)** ___ 10 ml Graduated Cylinder ___ Bottle(s) Glycerin ___ Bottle(s) Vegetable Oil ___ Bottle(s) Syrup ___ Bottle(s) 90% Alcohol **For Class** ___ Electronic Balance **Teacher Will Need to Provide** ___ Beakers or cups ___ Triple Beam Balances
Safety	No safety concerns are associated with this activity.

Science Content for the Teacher:

Density = mass ÷ volume

Density is an intrinsic property of all matter (i.e. it is dependent on the *type*, not the amount, of matter). It measures the **ratio** of mass to volume; in other words, *it is a measure of how much matter (mass), is packed into how much space (volume).* The higher the mass to volume proportion the higher the density because the *mass is more tightly packed into a certain amount of space.* In middle school, students usually encounter density in grams per cubic centimeter or grams per milliliter (1 g/cm^3 for solids or 1g/mL for liquids, since 1 cm^3 = 1 mL). Thus, density (in units of g/cm3) is the mass of 1 cubic centimeter (cm3) of the substance.

Since water has a density of 1 gram per milliliter— 1 g/mL (or 1 g/cm^3), a material or object with a density higher than one will sink and anything with a density lower than one will float.[1]

As one can see from the Density Equation (d = m/V), there are two ways of changing the density of an object: either changing the mass or changing the volume. If you change both equally, say by cutting an object in half, the density stays the same because you changed both parts of the proportion equally. Middle school students are accustomed to this from math, and can readily tell you that in solving equations "what you do to the numerator you must also do the same to the denominator" to keep the equality. Conversely, if you only change either the numerator or the denominator, or you change either unequally, you've changed the equality. In terms of the density equation, as the *mass gets bigger the density increases* because mass is in the *numerator*, but as the <u>*volume* gets bigger the density *decreases*</u> because volume is in the <u>denominator</u>. This makes sense to even the less math-oriented students when they see that $^2/_1$ punched into the calculator does not give the same numerical value as ½. Thus density **increases** either by *increasing the mass* or by <u>decreasing the volume</u>.

One must be very careful not to confuse mass with weight. Although close to the surface of the Earth they can be interchangeable, they are NOT the same thing. When students use the triple-beam balance they should realize they are finding the <u>mass</u>, not the weight, of an object. Mass is a property that does not change (until you add more, of course), whereas weight depends on the pull of gravity. On the moon the weight of a hammer would definitely change (decrease), but its mass would not. Conversely, on Jupiter the weight would be much heavier (because Jupiter is bigger and thus has a larger gravitational pull), but its mass would be the same on Jupiter, Earth, or the moon. It is important for middle school students to understand this distinction. Mass does not depend on gravity, weight does.[2]

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[1] Units are essential! I omitted them here for simplicity but do not omit them when discussing density with students.

[2] New York State Learning Standard 4, Physical Setting, Key Idea 1, states that students should understand that "Earth and celestial phenomena can be described by principles of *relative* motion and *perspective*." i.e., among other concepts, weight is not constant throughout the universe.

<u>Preparation:</u>

In order to scaffold their use of the mathematical formula for density, students need to have already been introduced to density conceptually at least once prior to these activities. This should not be their first introduction to density.

1. Photocopy print materials (*Activity Sheets 1 and 2 and Discussion Sheet 1*).

2. Add red food coloring to the 90% Alcohol bottle and blue food coloring to the glycerin (or colors of choice).

3. Distribute the materials into eight 'stations' so that there are two stations of each of the four liquids for students to rotate among.

4. Give instructions for how students will rotate from one "liquid station" to another so that all groups of students get a chance to work with all four liquids—i.e. "the oil groups move to glycerin, the glycerin groups move to alcohol," etc.

5. About 15 minutes per station is usually enough time to find the density and clean up.

Classroom Procedure:

Day One:

Engage (Time: 10 minutes)
Ask students whether they've ever noticed what happens to oil and water when they are mixed, say, in a salad dressing or in puddles of a car mechanic's shop? Have they ever wondered why oil and water don't mix? Show students the prepared beaker with the four liquids separated into layers. Tell them what each layer is (syrup, glycerin, etc.) and ask them to be thinking about why the liquids separated into layers as they gather data from each liquid. Tell them that today and tomorrow they are going to discover for themselves why these liquids don't mix. Do not tell them that each liquid has a different density, as they will be able to conclude this for themselves from the data they collect.

Explore (Time: 30 minutes)
Students will gather data (mass using the triple-beam balance or electronic balance scale, volume using a graduated cylinder) and calculate density (using a calculator, if needed) of two liquids today. To scaffold their data collection and density calculation use the Activity Sheet.

Closing Exploration for Day One (5 minutes)
For formative assessment, at end of class, teacher may want to collect each group's obtained densities on a class chart.

Day Two:

Opening Exploration for Day Two (5 minutes)
Students review their data from previous day, and what they were trying to find out (why or how some liquids separate).

Explore, continued (Time: 25-30 minutes)
Students will continue to gather data and calculate the densities of their remaining two liquids. Continue to add groups' results to the class chart.

Explain (Time: 10-15 minutes)
In their groups, have students discuss what they've discovered about the four liquids and why they don't mix. One can guide this discussion by having students compare the numerical values obtained from the density calculation to their observations of the order of the layers. Have one "presenter" from each group share the group's reasoning, for how the liquids will interact, with the rest of the class.

Day Three:

Explain, continued
Teacher Explains (Time: 5-10 minutes)
Tell students that the density of water is 1.0 g/ml (or 1.0 g/cm^3). Ask them to look in their notebooks and tell you what the density of the liquids that sank were (they should be more than one), vs. the liquids that floated towards the top (less than one). Have students predict where water would separate if poured into the beaker containing the four separated liquids. Slowly pour some water (tinted with food coloring different from alcohol) into the beaker with the four liquid layers and watch it separate itself into the middle of the layers, as may have been predicted!

Extension Activities:

Extension Activity One:
Students can find the density of a rectangular prism of clay (using a ruler and balance) and of a crayon (using a graduated cylinder and balance) when they are: 1) whole, and 2) cut in half. They should first hypothesize whether the density of each will change or stay the same as a result of cutting. When students see for themselves that the density of an object does not change by cutting it, they tend not to forget that density is an intrinsic property.
Students will find that they get the same density, and will have to discuss why this occurred using the Density Formula as a guide.

Extension Activity Two:
Students can find the densities of some of the same liquids (say oil, water, and syrup) varying the volume (say 10 ml, 20 ml, 30 ml, 40 ml) to observe what happens to the mass

and density. As with the solids (in extension activity one), students will find that the density does not change even though the volume and the mass do. This activity more explicitly allows students to see that even though the density stays the same both mass and volume increase or decrease.

These extension activities work together well either performed on consecutive days or spiraled a few weeks apart to remind students that density is an intrinsic property.

Extra Activities:

Can follow up this activity with Buoyancy kit where students will build their own Cartesian diver and figure out how it works.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain
1	Shows leadership in the discussion and offers creative explanations.	Completes work accurately while providing an explanation for what is observed. Works very will with partner.	Provides an in-depth explanation of findings. Fills out worksheet clearly. Offers thorough explanation for the science behind the Cartesian Diver.
2	Participates in the discussion, offers a few ideas.	Completes work accurately and works cooperatively with partner.	Provides clear explanation of findings. Fills out worksheet clearly. Offers good explanation for the science behind a Cartesian Diver.
3	Contributes to the discussion.	Works cooperatively with partner, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Fills out some of the worksheet. Offers some explanation for the Cartesian Diver.
4	Does not participate in discussion.	Has trouble working with partner. Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out worksheet. Does not offer an explanation for the Cartesian Diver.