**Title of Lesson:** Density and Biotechnology

**Target Grades**: 9th Grade Physical Science, 7th Grade Math

**Time Required:** 2 45-minute periods (Lessons can be stand-alone)

**Alignment to Standards:**
7.RP.A.2. Recognize and represent proportional relationships between quantities.
7.PS1.3 Classify matter as pure substances based on composition.

**Materials Needed:**
**Density block set**
**Wood blocks of various shapes**
**Electronic balance**
**Rulers**

**Background Information:**

Large scale advanced manufacturing is currently expanding to the use of additive manufacturing through 3D printing. Large 3D printers can create things like houses and cars with many other potential applications. Typically the materials used in 3D printing are petroleum derived, which leads to environmental and economical concerns when scaling up printing. Using petroleum-derived filament in your school's 3D printers to make somewhat small items is not as concerning as the large amount of material that is used in the processes to make these large scale items. Due to these concerns, the use of bio-derived materials is currently being researched.

Just like an alloy of two metals is useful because the desirable properties of the two different metals can be utilized while the less desirable properties are minimized, with bio-derived materials the economical, environmental, and structural benefits of biomass can be merged with the functionality of petroleum-derived materials. Bio-derived materials lend a stability and strength to the large scale items, while using petroleum-derived materials alone can lend to warping. To visualize this mixture, think of sawdust or woodchips mixed with plastics. Some of the variables that must be investigated in this novel area of research include the size of particles of the bio-derived materials, moisture content, optimal blends, processing protocols, and sustainability.

This lesson gives students a chance to look at the properties of different woods and polymer materials to discuss the benefits of the physical properties in both materials science and bioenergy. This lesson also give students the opportunity to measure different sized pieces of different woods – oak, pine, and poplar – to plot the density in the form of a mass-volume graph. Students can also discuss the implications of different densities of wood for both energy production and bio-derived additive manufacturing.

**Lesson Objectives**:
Students will be able to identify physical properties of materials.
Students will be able to calculate volume of solid objects.
Students will be able to plot mass to volume and identify the resulting slope as density.
Students will be able to predict the properties of a mixture of two substances.

**Instructional Process:**

Density Cubes:

Introduce Problem to Students
3D printers have become more common in schools and even homes in recent years. They provide a way to make rapid prototypes of small custom designed objects. (Provide examples of 3D printed items to students or allow them to watch a 3D printer work.) On a large scale, custom engineered 3D printers are being used to make very large items like cars and even small homes. (Share examples of some large items that have been produced using additive manufacturing on a large scale.) Just like these printers are custom engineered, the materials used in them must also be custom engineered. One potential source of materials for 3D printing is bio-derived materials. Our smaller-scale commercially obtained 3D printers use polymer filament, which you might call "plastic-y" in texture. This material has limitations when it comes to production size, so scientists need to find ways to add strength and stability to the materials when they make large items, and one potential avenue is using the bio-derived materials. The petroleum-derived filament is also not as sustainable as bio-derived materials, which becomes even more problematic as you make bigger things – and more of them!

Your task is to investigate the properties of some materials and consider their use in mixed materials for applications such as large scale 3D printing.

Laboratory Activity:
1. Measure the sides of the cubes to calculate the volume. Enter this value in the data table.
2. Mass each of the cubes. Enter this value in the data table.
3. Calculate the density for each cube.
4. Look at each cube and note some of the observable physical properties. Is it rigid or pliable? Is it easy to shape? Would it be easy to melt? How strong is the material? Enter your observations into the data table.
5. Complete the reflection questions.

Wood Density:

Introduce Problem to Students

When considering different avenues of bioenergy production – whether it be using wood in your wood stoves as logs or pellets or using timber products as a feedstock for cellulosic bioethanol – the properties of the biomaterials is critical to consider. One of these properties is density.

Your task is to investigate the density of different types of wood and consider the implications of this property on the energy production of these types of wood.

Laboratory Activity:

1. Measure the dimensions of the first oak wood block and calculate the volume. Mass the block. Enter these values in the data table and repeat for the other 2 oak wood blocks. Calculate the density for each individual wood block and enter these values on the data table. Record the density values of your classmates for their oak wood blocks. Calculate the average density of all wood blocks.
2. Plot your volume (x) vs. the mass (y) on a graph. Share your data with your classmates and collect their data. Plot the volume (x) vs. mass (y) for your classmates measurements and calculations for the oak wood blocks. Find the best-fit trend line that includes your 3 points and your classmate's points. Estimate the slope of this line.
3. Repeat steps 1 & 2 for the poplar blocks and the pine blocks.
4. Complete the reflection questions.

**Notes:**

It is important to keep the wood blocks separated by type, so it may be helpful to label them by type. The wood samples can be acquired at a local hardware store, and it is suggested that you cut them from the same board to maintain consistency within one distinct species.

You may choose to directly provide your students with the specific formulas to calculate the volume in order to expedite the activity, or you could provide them with a formula sheet to use as a reference to select appropriate formulas.

An alternative task could include asking students to determine which wood samples go together based on their density calculations.

Name:___________________________________ Date:_________________ Period:_________

# Density Cubes

**Materials**

Density Block Set
Ruler
Scale

**Procedure**

1. Measure the sides of the cubes in centimeters to calculate the volume in $cm^3$. Enter this value in the data table.
2. Mass each of the cubes in grams. Enter this value in the data table.
3. Calculate the density for each cube.
4. Look at each cube and note some of the observable physical properties. Is it rigid or pliable? Is it easy to shape? Would it be easy to melt? How strong is the material? Enter your observations into the data table.
5. Complete the reflection questions.

**Data Table**

| **Material** | **Mass (g)** | **Volume ($cm^3$)** | **Density ($g/cm^3$)** | **Observable Properties** |
|---|---|---|---|---|
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**Questions**

1. How does the density of the wood, metal, and polymer materials all compare?
2. What are some favorable properties of the wood?
3. What are some favorable properties of the metals?
4. What are some favorable properties of the polymers?
5. What is an alloy?
6. What is the purpose of mixing materials together such as alloying metals?
7. Choose 2 substances. What properties do you predict the mixture of those two substances would have? In what ways could that be beneficial?

Name:_________________________________ Date:________________ Period:________

# Density of Wood Blocks

**Materials**

Wood blocks – 3 each of pine, oak, and poplar

Ruler

Scale

**Procedure**

1. Measure the dimensions of the first oak wood block in centimeters and calculate the volume in $cm^3$. Mass the block in grams. Enter these values in the data table and repeat for the other 2 oak wood blocks. Calculate the density for each individual wood block and enter these values on the data table. Record the density values of your classmates for their oak wood blocks. Calculate the average density of all wood blocks.
2. Plot your volume (x) vs. the mass (y) on a graph. Share your data with your classmates and collect their data. Plot the volume (x) vs. mass (y) for your classmates' measurements and calculations for the oak wood blocks. Find the best-fit trend line that includes your 3 points and your classmate's points. Estimate the slope of this line.
3. Repeat steps 1 & 2 for the poplar blocks and the pine blocks.
4. Complete the reflection questions.

**Data Table**

| **Wood Block** | **Mass (g)** | **Volume ($cm^3$)** | **Density ($g/cm^3$)** | |
|---|---|---|---|---|
| Oak Block 1 | | | | Classmate density values: |
| Oak Block 2 | | | | |
| Oak Block 3 | | | | |
| Poplar Block 1 | | | | Classmate density values: |
| Poplar Block 2 | | | | |
| Poplar Block 3 | | | | |
| Pine Block 1 | | | | Classmate density values: |
| Pine Block 2 | | | | |
| Pine Block 3 | | | | |

Average Densities:

Oak ____________ Poplar ____________ Pine ____________

**Questions**

1. Describe your trend lines for the densities of each type of wood:

   a. Oak

   b. Poplar

   c. Pine

2. What does the slope of your trend line mean?

3. How does the slope of your trend line compare with the calculated average density of the wood for Oak, Poplar, and Pine? Is this the expected result? Why or why not?

4. How do the densities of the different woods compare?

5. How does density impact the potential of the biomass to be used for energy production? What other factors are important when selecting a feedstock for use in biofuels?