MSET Demonstration Package

Density

Mentis Sciences Education Toolkit Vision and Development History

Located in the historic Mill District of downtown Manchester, Mentis Sciences is an engineering firm which provides advanced material design and manufacturing capabilities to Department of Defense customers. Mentis specializes in the design, development and testing of advanced composite materials with a goal of providing unique flexibility, rapid development and prototyping for various composite applications.

Mentis Sciences, Inc. was founded in 1996 by John F. Dignam, following more than thirty years of service at the Army Materials Research Lab, where he served as the Director of Missile Materials. John F. Dignam spent most of his lifetime promoting national security and developing the most effective material systems to aid in countering global threats. He founded Mentis Sciences to continue promoting innovation, expertise, and emerging materials and manufacturing technologies, that will enhance U.S. security and promote economic growth.

His legacy continues under the strong and visionary leadership of John J. Dignam, who brings unique and innovative technical expertise to solving some of the nation's most daunting engineering challenges. The core values of ethics, integrity, community service, and commitment to excellence instilled by John F. Dignam live on with John J. Dignam and the Mentis team, and are apparent in every aspect of the company's structure, personality, and operations.

Mentis Sciences Internship Program recruits local high school students in good academic standing who reside in the HUBZone area of Manchester, NH. Successful youth with good attitudes and high motivation to work and learn have come through various avenues including non-traditional avenues like the Manchester Police Athletic League, The Salvation Army, and Manchester's Office of Youth Services.

Mentis makes a serious commitment of its resources to support the internship program by providing short courses in STEM related disciplines, student engineering activities and mentoring activities. In result of these courses, Mentis Sciences started to see a gap in STEM education. Biology and Life Science concepts were often the focus of science in the classroom, technology often included a smartphone app and engineer was nonexistent. Our interns and every student deserve to be introduced to STEM concepts with tools and resources that allow them to experience concepts hands-on and in a collaborative environment.

With this vision for our students, Mentis transferred skills used in their own manufacturing facility every day and descaled the concepts and tests into one integrated unit. Mentis has developed an integrated STEM toolkit that configures to complete 40 STEM tests. With limited lab space and budgets for lab testing equipment being tight, the Mentis Sciences Engineering Toolkit (MSET) departs from the high cost limited functionality of current educational testing systems.

The MSET offers a unique view into the world of material testing and physical science. Data indicates the MSET Program increased student participation in the classroom, interest in STEM careers and opportunities for females in STEM. Students develop a deep understanding in STEM, engineering and physical science concepts.

In many ways, the internship program and new shared vision has provided Mentis employees a new sense of purpose in their work. Mentis is now expanding their vision for the MSET program, beyond their own interns and are offering the MSETs STEM educational opportunities to other schools and educational partners in their community and around the United States.

Mentis believes that every student, no matter their upbringing or education status, should have the opportunity to learn, pursue their dreams and have the high-quality resources to so. This enrichment MSET program has proven to be beneficial, providing life-changing experiences for interns, students, as well as Mentis employees. We are excited to share it with you.

Density Introduction

In this unit students will explore how density of various materials are calculated and how density is the relationship between mass and volume. Students will be taught the relationship between mass and weight and how they differ. Students will work towards a further understanding of material properties and how such properties are calculated. The goal of this exercise is to prepare students and apply these concepts in an inquiry-based project where they design a structure.

The materials in this section have been created and organized to assist teachers in the design of lessons that use the MSET equipment and applied inquiry-based projects that are aligned with the Next Generation Science Standards, as well as the Massachusetts Science and Technology/Engineering Curriculum Framework.

Teachers

Teachers should review the Understanding by Design unit plan with particular attention to the Essential Questions students will be expected to answer by the conclusion of the unit. Throughout the lessons and experiences, teachers should assess students' progress toward their capacity answering the essential questions. Finally, teachers should use the rubric to assess students' comprehension and application of the foundational principles associate with the lesson, experiment and materials covered in the unit.

Students

It is assumed that students participating in this unit will have experience in the following areas:

1. Further develop their skills in geometry to understand how volume is calculated.
2. Be able to recognize the relationship between gravity and mass when converting the output of the load cell to the mass of the object.
3. Understanding that the density of the material is not directly related the volume.
4. Have basic algebra knowledge of combining stress equations.
5. Have basic mechanical skills to configure MSET based on written and visual instructions.

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UbD Chart – Density

<table>
<tr><th colspan="3">Desired Results</th></tr>
<tr><td rowspan="6">STANDARDS/ESTABLISHED GOALS

<u>Next Generation Science Standards</u>

Matter and its Interactions:
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

<u>Massachusetts State Standards</u>

Matter and its Interactions:
MS-PS1-7(MA). Use a particulate model of matter to explain that density is the amount of matter (mass) in a given volume. Apply proportional reasoning to describe, calculate, and compare relative densities of different materials.

Introductory Physics:
HS-PS1-7. Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to evaluate the quantities (masses or moles) of specific reactants needed in order to obtain a specific amount of product.</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to independently use their learning to make determinations and applications about density in modern technology.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…
1. Explore and describe the densities of various materials through measurement of their masses and volumes.
2. Classify and compare substances on the basis of characteristic physical properties that can be demonstrated or measured.
3. Contrast and explain the physical properties such as density, thermal or electrical conductivity, solubility, magnetic properties, melting and boiling points, and know that these properties are independent of the amount of the sample.</td><td>ESSENTIAL QUESTIONS

1. What is mass?
2. What is weight”?
3. How are mass and weight different?
4. What are the two components of mass?
5. What is density?
6. How is density measured?
7. How does density impact the decision to use various materials in projects?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…
● Definition of mass.
● Definition of weight.
● The relationship between mass and weight.</td><td>Students will be skilled at…
• Apply mathematical computations to determine density.</td></tr>
</table>

		● Interpret graphs to draw conclusions regarding density of various matter. ● Use computer software to collect data and model density of various materials and matter. ● Apply the scientific method in an experiment.

Evidence
Assessment Evidence
PERFORMANCE TASK(S): There is one performance task and one experiment related to density. The experiment and performance task will be conducted over a few class periods. Assessment evidence will be collected from the experiment to help evaluated student understanding: 1. In the performance task students will examine 7-8 different fruits with respect to mass, weight, volume and density. The students will hypothesize potential results and then explore the concepts through methods such as displacement and the utilization of the MSET. Students will evaluate results and graph the findings to draw conclusions that they will compare to their hypotheses. 2. In the experiment, the students will utilize the MSET device, learn to measure and calculate the specific gravity of various materials and compare their findings to published materials. Students will apply their results to examine a real-world problem with respect to selection of materials in regards to density. Assessment evidence will be in the form of calculations and results depicted in tables and graphs included in students' final reports. They will then discuss the possible reasons for the variance in the published and experimental findings. .
OTHER EVIDENCE: The essential questions will be used as an entrance/exit slip to determine growth in understanding. The following computational problem will also be used as an entrance and exit slip.

Stage 3 – Learning Plan

Summary of Key Learning Events and Instruction

See outline of Density experiment summary included.

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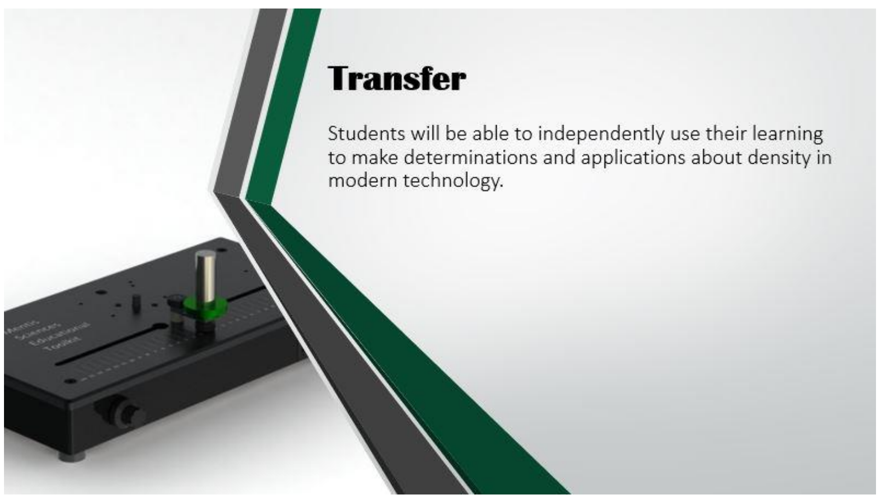
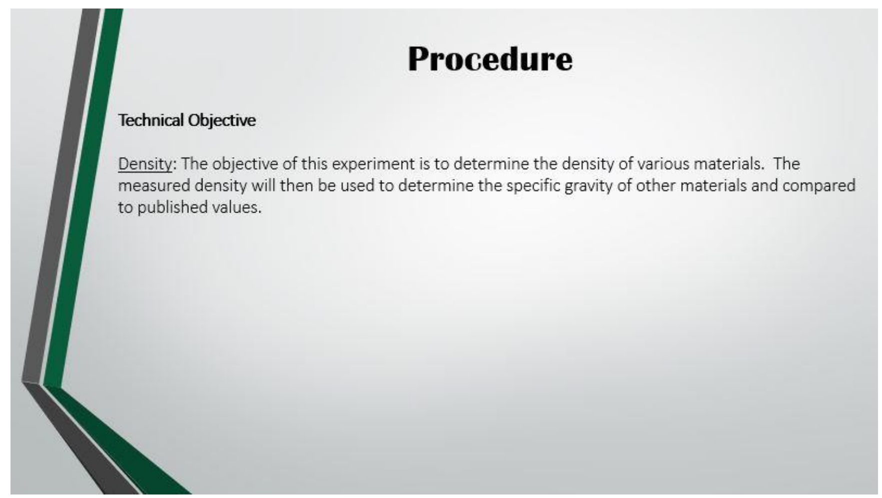
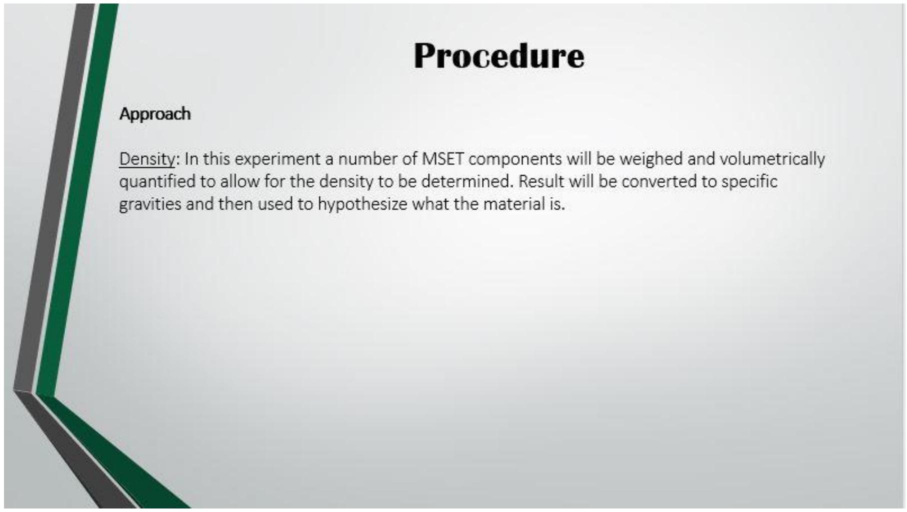
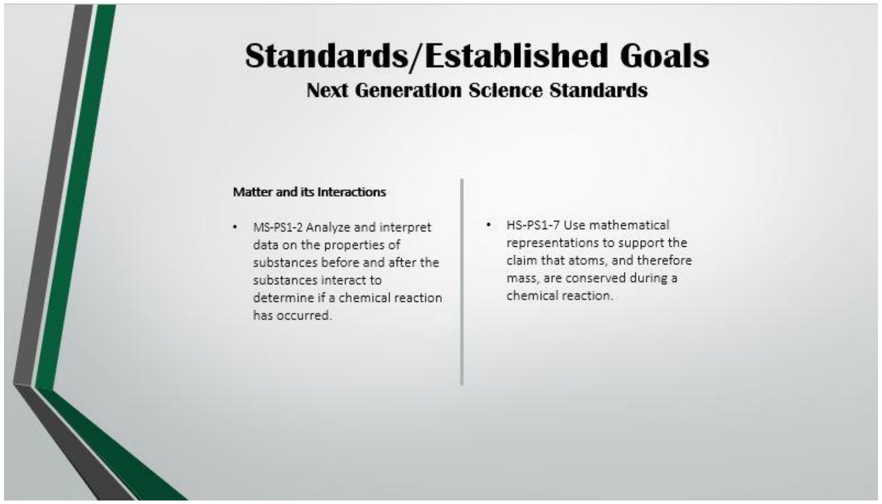
PowerPoint Template for Instruction – Density






Procedure
Approach
Density: In this experiment a number of MSET components will be weighed and volumetrically quantified to allow for the density to be determined. Result will be converted to specific gravities and then used to hypothesize what the material is.


Standards/Established Goals
Next Generation Science Standards
Matter and its Interactions
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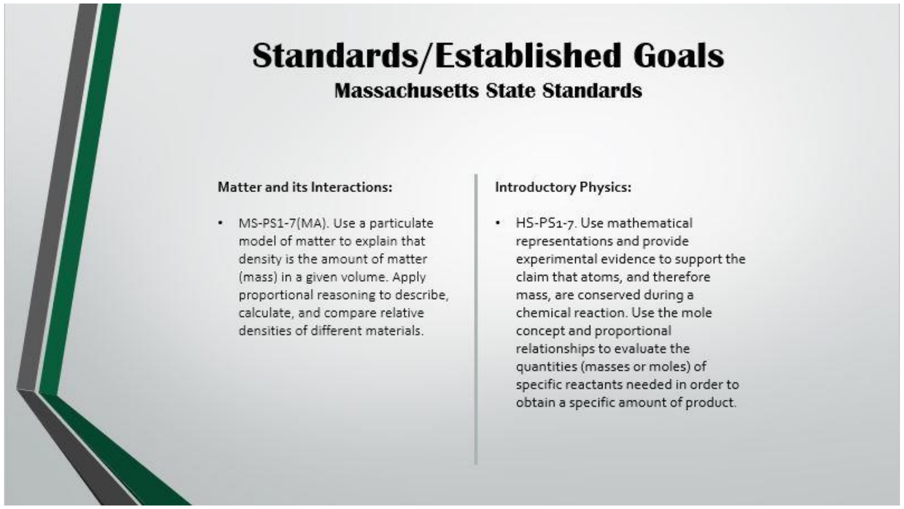
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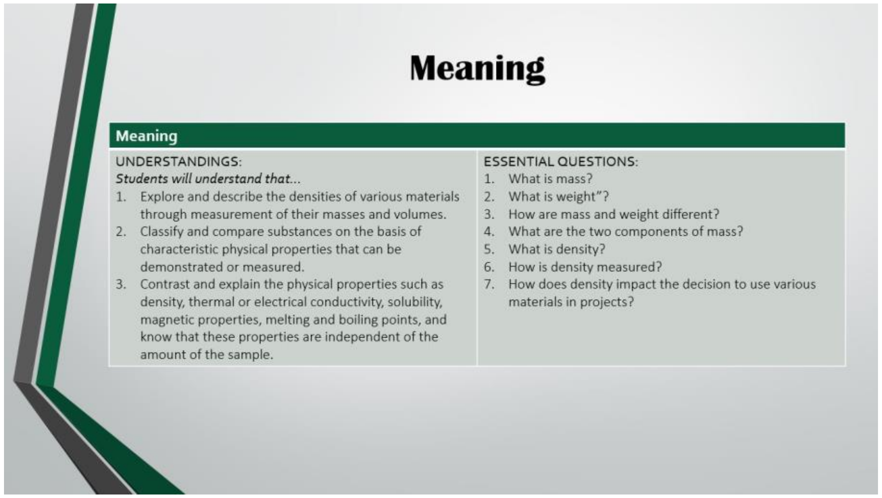
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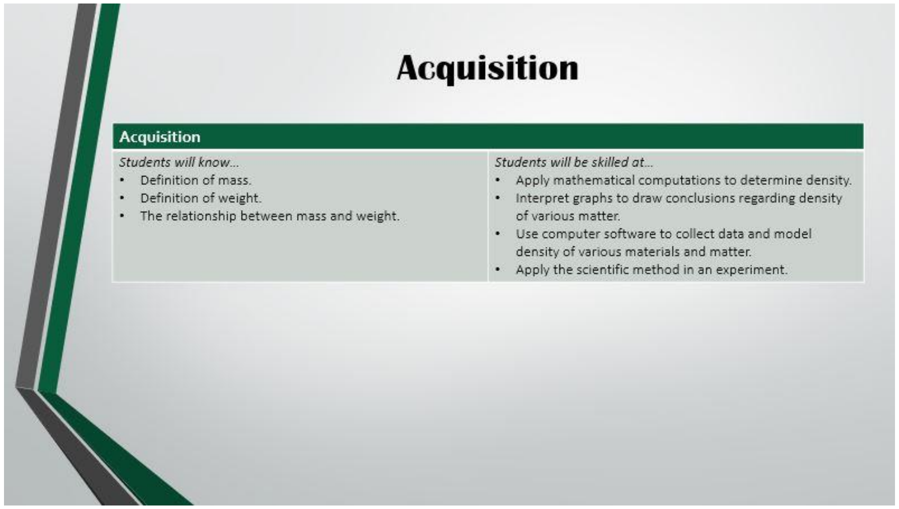
3. Contrast and explain the physical properties such as density, thermal or electrical conductivity, solubility, magnetic properties, melting and boiling points, and know that these properties are independent of the amount of the sample.
ESSENTIAL QUESTIONS:
1. What is mass?
2. What is weight"?
3. How are mass and weight different?
4. What are the two components of mass?
5. What is density?
6. How is density measured?
7. How does density impact the decision to use various materials in projects?


Acquisition
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Students will know...
• Definition of mass.
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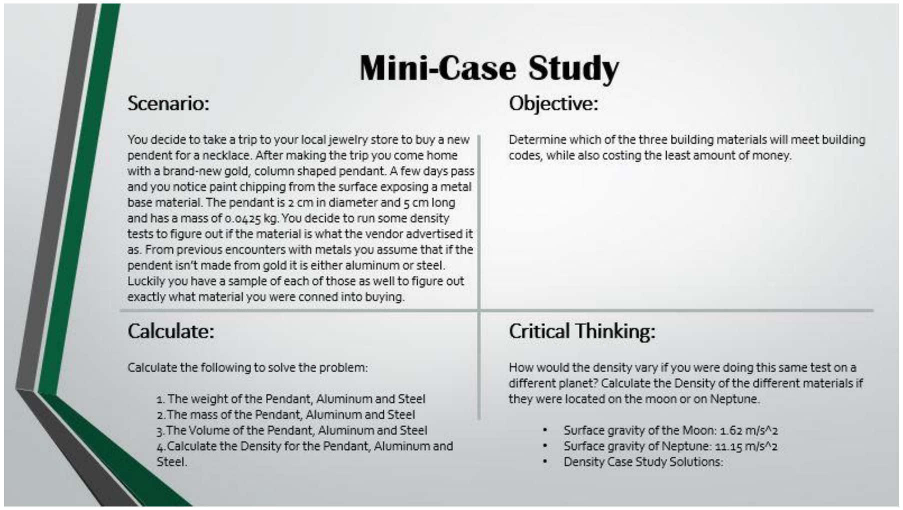
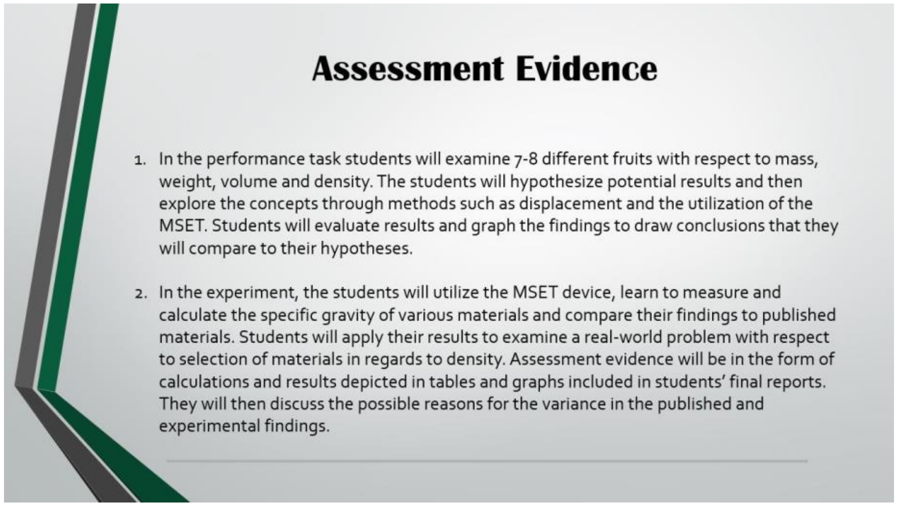
Students will be skilled at...
• Apply mathematical computations to determine density.
• Interpret graphs to draw conclusions regarding density of various matter.
• Use computer software to collect data and model density of various materials and matter.
• Apply the scientific method in an experiment.


Mini-Case Study
Scenario:
You decide to take a trip to your local jewelry store to buy a new pendent for a necklace. After making the trip you come home with a brand-new gold, column shaped pendant. A few days pass and you notice paint chipping from the surface exposing a metal base material. The pendant is 2 cm in diameter and 5 cm long and has a mass of 0.0425 kg. You decide to run some density tests to figure out if the material is what the vendor advertised it as. From previous encounters with metals you assume that if the pendent isn't made from gold it is either aluminum or steel. Luckily you have a sample of each of those as well to figure out exactly what material you were conned into buying.
Objective:
Determine which of the three building materials will meet building codes, while also costing the least amount of money.
Calculate:
Calculate the following to solve the problem:
1. The weight of the Pendant, Aluminum and Steel
2. The mass of the Pendant, Aluminum and Steel
3. The Volume of the Pendant, Aluminum and Steel
4. Calculate the Density for the Pendant, Aluminum and Steel.
Critical Thinking:
How would the density vary if you were doing this same test on a different planet? Calculate the Density of the different materials if they were located on the moon or on Neptune.
• Surface gravity of the Moon: 1.62 m/s^2
• Surface gravity of Neptune: 11.15 m/s^2
• Density Case Study Solutions:


Assessment Evidence
1. In the performance task students will examine 7-8 different fruits with respect to mass, weight, volume and density. The students will hypothesize potential results and then explore the concepts through methods such as displacement and the utilization of the MSET. Students will evaluate results and graph the findings to draw conclusions that they will compare to their hypotheses.
2. In the experiment, the students will utilize the MSET device, learn to measure and calculate the specific gravity of various materials and compare their findings to published materials. Students will apply their results to examine a real-world problem with respect to selection of materials in regards to density. Assessment evidence will be in the form of calculations and results depicted in tables and graphs included in students' final reports. They will then discuss the possible reasons for the variance in the published and experimental findings.

MSET Experiment Procedure– Density

Technical objective

The objective of this experiment is to determine the density of various materials. The measured density will then be used to determine the specific gravity of other materials and compared to published values.

Background

Density of a substance "ρ", is defined as the mass "m", per unit volume "V" as expressed in Equation #1. The density is generally reported at standard atmospheric conditions (pressure and temperature but will vary as this change. For example, water can exist in three physical states: solid, liquid, and gas; the most common being a liquid. If the temperature of liquid water exceeds 100 degrees C, it will change to a vapor. At temperatures of 0 degrees C and below water will transform to a solid know as ice.

1 kg of liquid water, will evaporate into 1 kg of steam above 100 degrees C. Similarly, 1 kg of water will form 1 kg of ice, below 0 degrees C. The mass remains unchanged at each state; however, the volume of 1 kg of steam, water, or ice differ.

$$\rho = \frac{m}{V} \qquad \text{eq. (1)}$$

The density of other substances is commonly expressed as the specific gravity "Sg". Specific gravity is the ratio of the density of Material X "ρ_x", to the density of water "ρ_{water}" shown in Equation #2.

$$Sg = \frac{\rho_x}{\rho_{water}} \qquad \text{eq. (2)}$$

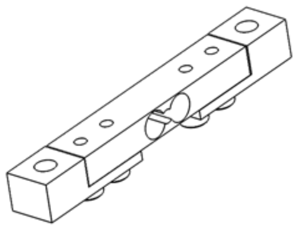
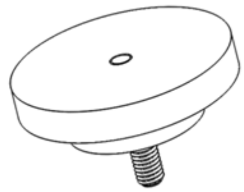
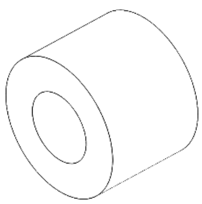
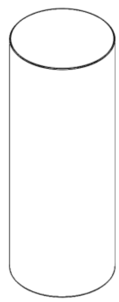
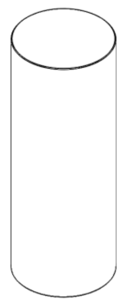
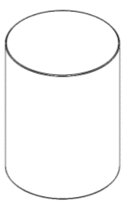
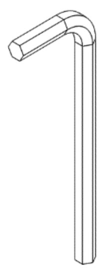
Specific gravity of a substance can be used to determine the potential reaction of liquids. As an example, if oil is spilled on water and the specific gravity of the oil is less than 1, then oil is prone to float on the surface of water.

Also, materials such as steel, or polymers are generally characterized using material properties such as strength. Although a material may have good mechanical properties, they may weigh too much for practical use. For this reason, it makes sense to be able to quickly calculate the weight given a known volume, and the density, or specific gravity. The relationship between weight, mass, and gravity is shown in Equation #3.

$$W = mg \qquad \text{eq. (3)}$$

Experimental Setup

1. Gather the following components:

780g Load Cell 	Impact Target 	Load Cell Bolt 
Load cell Spacer 	Aluminum Density Sample 	Steel Density Sample 1 
Steel Density Sample 2 	4mm Hex Wrench 	

2. Attach the impact target to the load cell using the ¾” thumbscrew.
3. Attach the load cell to the baseplate using the 7/8” thumbscrew and load cell spacer ensuring the arrow is facing downward. Refer to Figure 1.

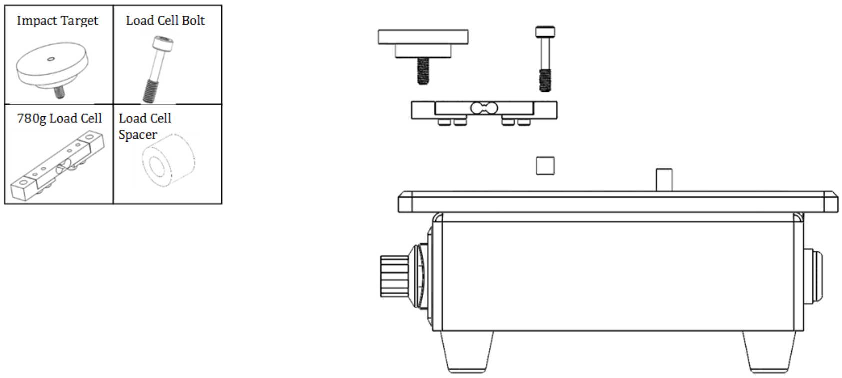


Figure 1: Placement of Load Cell with Impact Target

4. Plug the 780g load cell into port 2 at the back of the SIM.

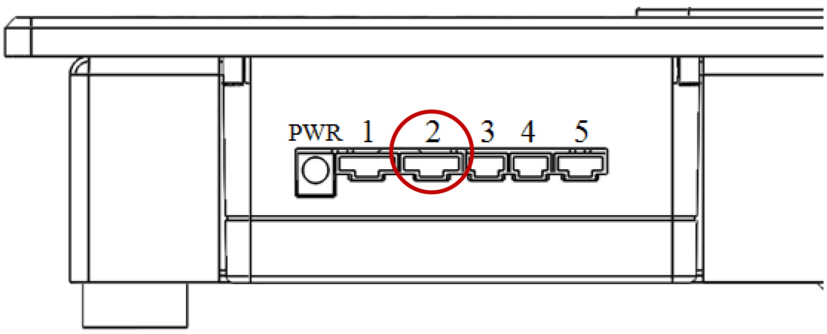
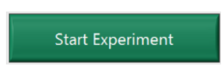


Figure 2: Port 2 on SIM

Experimental Procedure

1. In the MSET software, click “Density” then 

to launch the density experiment.

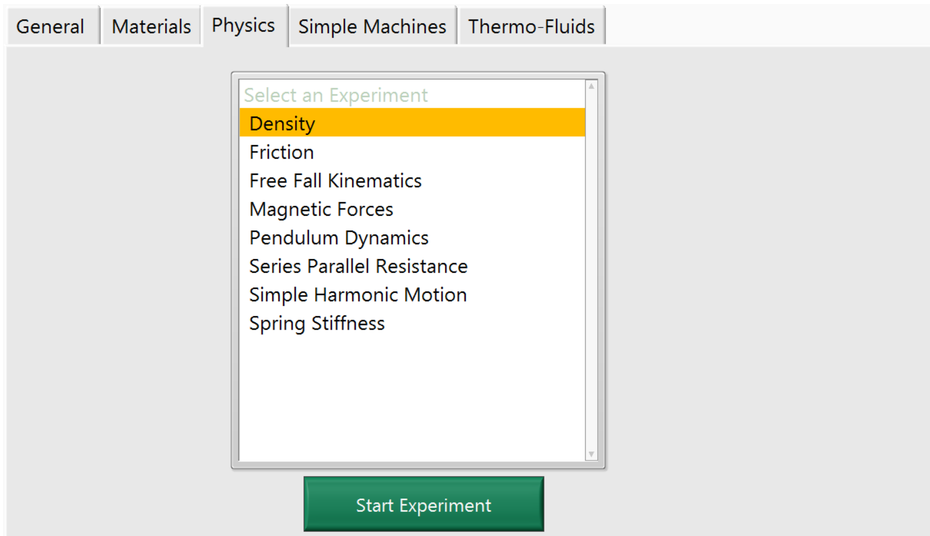


Figure 3: Location of Density Experiment

2. Click Start Measuring to begin reading the load cell.
3. Press and hold Zero Readings on the MSET program to zero the load readout.
4. Click Log Data to begin collecting data.
5. Carefully place the aluminum sample on the impact target.

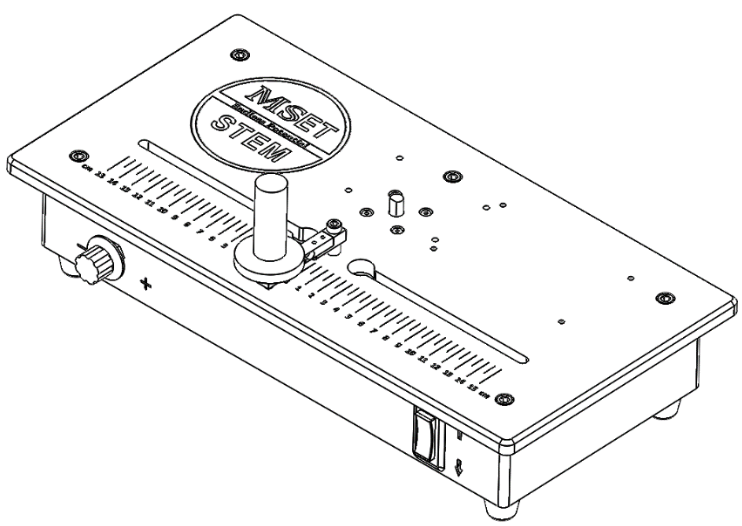


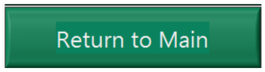
Figure 4: Placement of the Density Sample

6. Wait for the load to stabilize and record the value displayed.

7. Click 

then 

.
8. Press 

. A window will pop up notifying the user that data will be saved once 

is pressed at the end of the experiment.

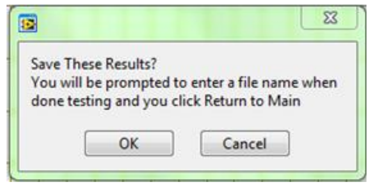
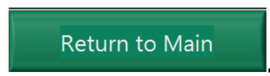


Figure 5. Save Results Prompt

9. Repeat steps 2-8 for steel samples 1&2.
10. After all samples have been weighed, press 

.
11. The data collection portion of this experiment is now complete.

Data Analysis

1. Calculate the volume of each sample and enter them into the table below.

Table 1: Measured Sample Volumes

Sample	Volume (m^3)
Aluminum	
Steel 1	
Steel 2	

2. Convert the weight of each sample to mass and enter them into the table below.

Table 2: Calculated Sample Mass

Sample	Mass (kg)
Aluminum	
Steel 1	
Steel 2	

3. Calculate the density of each sample tested and enter them into the table below.

Table 3: Calculated Sample Densities

Sample	Density (kg/m^3)
Aluminum	
Steel 1	
Steel 2	

4. Compare and discuss experimental and theoretical results including percent differences. What are some potential causes of differences between experimental and theoretical results?

Table 4: Theoretical Densities of Materials

Material	Density (kg/m^3)
Aluminum	2.70×10^3
Steel	7.8×10^3

MSET – DENSITY

Purpose

Develop an understanding of how the density of different materials varies, introduce basic volumetric calculations, weight measurements, and how they are used to calculate density, and specific gravity

Density

The density of liquids varies with their molecular structure, temperature, and atmospheric pressure. If two liquids such as vinegar and water are mixed together they will separate with the denser liquid settling to the bottom substances varies with less dense materials

Theory

The density of a material can be determined by measuring the mass "M", and volume "V" equated as follows:

$$\rho = M/V$$

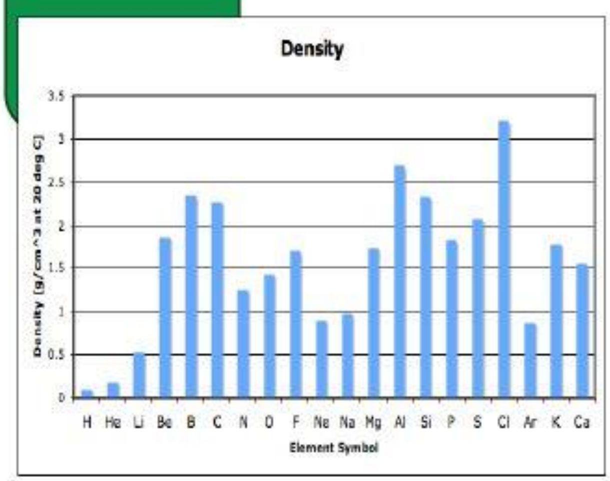
Specific gravity "Sg" is used to define the relative density of materials and is the ratio of the density of material "X" to that of water.

$$\mathrm{Sg} = \rho^{X}/\rho^{Water}$$

Setup

Results

A number of MSET components will be weighed and volumetrically quantified to allow for the density to be determined. Results will be converted to specific gravities and then used to hypothesize what the material is.



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Inquiry-Based Mini Project – Density

You decide to take a trip to your local jewelry store to buy a new pendent for a necklace. After making the trip you come home with a brand-new gold, column shaped pendant. A few days pass and you notice paint chipping from the surface exposing a metal base material. The pendant is 2 cm in diameter and 5 cm long and has a mass of 0.0425 kg. You decide to run some density tests to figure out if the material is what the vendor advertised it as. From previous encounters with metals you assume that if the pendent isn't made from gold it is either aluminum or steel. Luckily you have a sample of each of those as well to figure out exactly what material you were conned into buying.

After searching the internet you learn that the density of gold is 19,300 $kg/m^{3.}$

Calculate the following to solve the problem:

1. The weight of the Pendant, Aluminum and Steel
2. The mass of the Pendant, Aluminum and Steel
3. The Volume of the Pendant, Aluminum and Steel
4. Calculate the Density for the Pendant, Aluminum and Steel.

Using your calculations compare the actual density of Gold with your calculated density. If they match up, then your pendant is in fact gold. However, if the density is different compare it to the Aluminum and Steel densities to determine what your material is.

Sample	Mass (kg)
Pendant	
Aluminum	
Steel	

Sample	Volume (m^3)
Pendant	
Aluminum	
Steel	

Sample	Density (kg/m^3)
Pendant	
Aluminum	
Steel	

Critical Thinking: How would the density vary if you were doing this same test on a different planet? Calculate the Density of the different materials if they were located on the moon or on Neptune.

Surface gravity of the Moon: 1.62 m/s^2

Surface gravity of Neptune: 11.15 m/s^2
Density Case Study Solutions:

Given:

Dia_{gold}= 2cm
$Length_{gold}$ = 5 cm
$Mass_{gold}$ = 0.0425 kg
$P_{gold=}$ 19,300 kg/m^3
g_{earth}= 9.81 m/s^2
g_{moon}= 1.62 m/s^2
$g_{neptune}$= 11.15 m/s^2

Formulas:

$$Volume_{cyl} = \pi * r^2 * d$$

Where r is the radius of the cylinder and d is the length

$$\rho = \frac{mass}{volume}$$

$$Weight = mass * gravity$$

Teacher Solution Key - Density

1. The weight of the Pendant, Aluminum and Steel

Sample	Mass (kg)
Pendant	0.0425
Aluminum	0.039
Steel	0.113

2. The mass of the Pendant, Aluminum and Steel

Sample	Weight (N)
Pendant	0.416925
Aluminum	0.38259
Steel	1.10853

3. The Volume of the Pendant, Aluminum and Steel

Sample	Volume (m^3)
Pendant	1.5708E-05
Aluminum	1.44792E-05
Steel	1.44792E-05

4. Calculate the Density for the Pendant, Aluminum and Steel.

Sample	Density (kg/m^3)
Pendant	2705.634033
Aluminum	2693.525264
Steel	7804.31679

Critical Thinking:

Even though the weight of the materials on different planets would vary the density would not because density is not affected by the gravity but only mass and volume. The weight of the pendants are as follows:

Sample	Weight (N) on the Moon	Sample	Weight (N) on Neptune
Pendant	0.06885	Pendant	0.473875
Aluminum	0.06318	Aluminum	0.43485
Steel	0.18306	Steel	1.25995

Sample	Weight (N) on Earth
Pendant	0.416925
Aluminum	0.38259
Steel	1.10853

Inquiry-Based Mini Project Rubric – Density

	3	2	1	0	Score
Proper Use of Equipment	Used the MSET to collect data.	Struggled with using the MSET and getting accurate data. Was able to collect data with some assistance.	Even at the end of the experiment, struggled with the used of the MSET and could not accurately collect data.	Didn't use the MSET	
Accuracy of Use of Terminology	Used all terms accurately including, weight, volume, mass, density, and specific gravity.	May have used all of the terms but one or two were not used accurately.	Used some of the terms but not all of them, or the terms were used but not used accurately.	Didn't use any of the terms in the explanation of the solution	
Rationale for Solution	Provided a detailed rationale for the calculations made in the solution and for how being on another planet may affect the solution. Explanation included a clear description of the calculations made and how they led to the final solution as well as how the calculations may or may not	Provided a rationale for their solution, but could only briefly explain how their calculations of volume, mass, and density led to their solution.	Provided a rationale, but their explanation was lacking the proper connections between the concepts of mass, volume, and density as well as the calculations made.	Didn't provide a rationale for their solution	

	differ if the materials were on a different planet and why.				
Use of Mathematical Computations	Accurately completed calculations for volume, mass, and density of all the materials and provided and accurate comparison to determine if the pendant was gold. Was also able to calculate the weight of the materials on the moon and Neptune accurately in order to aid in the rationale for their solution.	May have accurately calculated, volume, mass, and density, however could not use it to explain whether the pendant was gold or not. Also, may have calculated weight for the objects on other planets but couldn't determine how the calculations would or would not affect the density.	Attempted to calculate volume, mass, and density of the materials as well as the weight of the objects on other planets but included some miscalculations.	Did not complete or include proper calculations for experiment.	