MSET Demonstration Package

Buoyancy

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 engineering 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.

Buoyancy Introduction

In this unit students will explore buoyant forces and the effects that the volume of the submerged object will have on the buoyant forces. Students will derive the formulas present to calculate the flexure properties of beams of various geometric shapes and materials. Students will apply engineering practices to determine the relationship between strength, stiffness, and deflection. Students will synthesize data to examine stiffness as it relates to support span and change in load. 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. Basic skills in geometry to understand how volume is calculated.
2. Recognition of the relationship between gravity and mass.
3. Understanding of how the sum of forces, upward and downward, should equal 0 when the sample is at equilibrium.
4. Understanding what material and physical properties can affect buoyancy.
5. Have basic algebra knowledge of combining stress equations.
6. Have basic mechanical skills to configure MSET based on written and visual instructions.

Table of Contents

UbD Chart – Buoyancy

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

<u>Next Generation Science Standards</u>

Engineering Design:
HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints in interactions within and between systems relevant to the problem.

Forces and Interactions:
3-PS2-1 Plan and conduct an investigation of the effects of balanced and unbalanced forces on the motion of an object

MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects

HS-PS2-3 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during collision.

<u>Massachusetts State Standards</u>

Technology and Engineering:
HS-ETS1-4. Use a computer simulation to model the impact of a proposed solution to a complex real-world problem that has numerous criteria and constraints on the interactions</td>
<td colspan="2">Transfer</td>
</tr>
<tr><td colspan="2">Students will be able to independently use their learning of buoyant force, Archimedes' Principle, and Newton's Laws of Motion to determine the buoyant force exerted on an object and therefore make relevant decisions when designing a structure that will float.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr>
<td>UNDERSTANDINGS
Students will understand that…
1. Buoyancy depends of the volume of the liquid displaced, the density of the liquid, and the constant of gravity.
2. Buoyancy force changes as an object is further submerged and once fully submerged, buoyant force is constant.
3. As an object is submerged deeper, pressure increases. Therefore, the pressure on the upward force of a submerged object is greater than the downward force, creating buoyancy.
4. Buoyant force is equal to the weight of the fluid displaced by an object. (Archimedes' Principle)
5. Buoyancy is related to Newton's 3rd law of motion.</td>
<td>ESSENTIAL QUESTIONS

1. How can Archimedes' Principle be used to explain buoyancy?
2. Why do objects become buoyant when submerged?
3. Why are some objects more buoyant than others?
4. Explain how Newton's 3rd Law is relevant to the concept of buoyancy.</td>
</tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr>
<td>Students will know…
• Buoyancy force is the upward force when an object is being submerged in a liquid
• Archimedes' Principle
• Newton's 3rd Law of Motion</td>
<td>Students will be skilled at…
• Apply mathematical computations to mathematical model(s) to calculate various outcomes
• Interpret graphs to draw conclusions</td>
</tr>
</table>

HS-ETS3-4(MA). Use a model to illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure. Analyze situations that involve these forces and justify the selection of materials for the given situation based on their properties. Grade 8 – Physical Science 8MS-PS2-1. Develop a model that demonstrates Newton's 3rd Law involving the motion of two colliding objects. Introductory Physics: HS-PS2-3. Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. HS-PS2-10 (MA). Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.		• Use computer software to collect data and model the deflection in an object as it relates to the support span • Apply the scientific method in an experiment

Evidence

Assessment Evidence

PERFORMANCE TASK(S):

1. Students will use the MSET device to conduct an experiment to plot a progression of water displacement while an object is being submerged. Using formulas related to Archimedes' Principle and Newton's 3rd Law, students will calculate the buoyant force applied to the object. Students will use this procedure to designing a structure in future lessons.

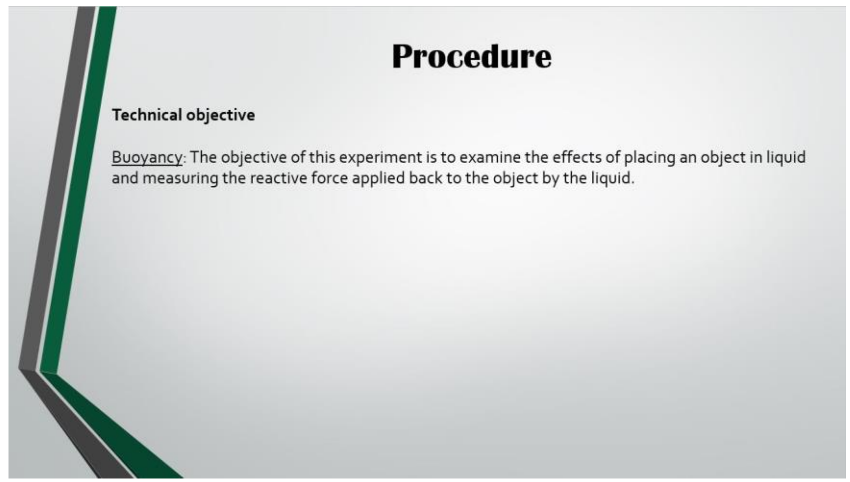
OTHER EVIDENCE:
The essential questions will be used as an entrance/exit slip to determine growth in understanding.

Stage 3 – Learning Plan

Summary of Key Learning Events and Instruction

See outline of Buoyancy experiment summary included.

PowerPoint Template for Instruction – Buoyancy



Procedure

Approach

Buoyancy: In this experiment a sample of known volume will be lowered into a vessel of water. As it is lowered, the buoyancy force on the sample will be measured.

Standards/Established Goals

Next Generation Science Standards

Engineering Design:

- HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem.

Forces and Interactions:

- 3-PS2-1 Plan and conduct an investigation of the effects of balanced and unbalanced forces on the motion of an object
- MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects
- HS-PS2-3 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during collision.

Standards/Established Goals

Massachusetts State Standards

Technology and Engineering:

- HSHS-ETS1-4. Use a computer simulation to model the impact of a proposed solution to a complex real-world problem.
- HS-ETS3-4(MA). Use a model to illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure. Analyze situations that involve these forces and justify the selection of materials for the given situation based on their properties.

Introductory Physics:

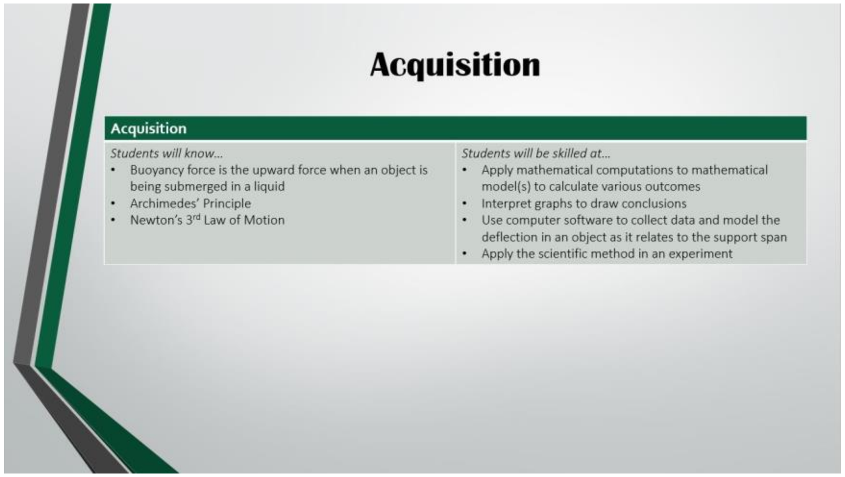
- HS-PS2-3. Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- HS-PS2-10 (MA). Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.

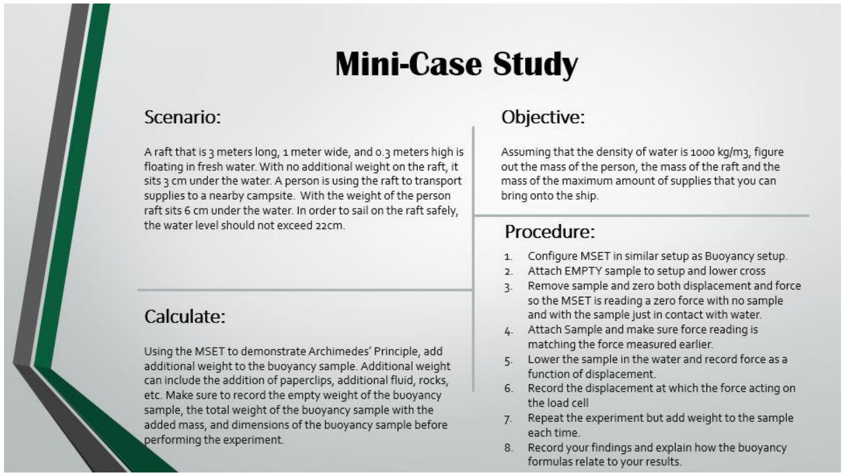
Grade 8 – Physical Science

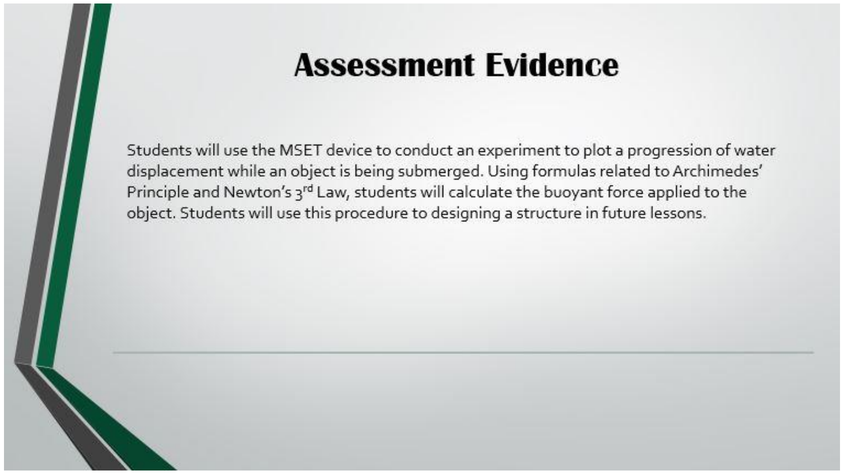
- 8MS-PS2-1. Develop a model that demonstrates Newton's 3rd Law involving the motion of two colliding objects.

Meaning

Meaning	
UNDERSTANDINGS: *Students will understand that…* 1. Buoyancy depends of the volume of the liquid displaced, the density of the liquid, and the constant of gravity. 2. Buoyancy force changes as an object is further submerged and once fully submerged, buoyant force is constant. 3. As an object is submerged deeper, pressure increases. Therefore, the pressure on the upward force of a submerged object is greater than the downward force, creating buoyancy. 4. Buoyant force is equal to the weight of the fluid displaced by an object. (Archimedes' Principle) 5. Buoyancy is related to Newton's 3rd law of motion.	ESSENTIAL QUESTIONS: 1. How can Archimedes' Principle be used to explain buoyancy? 2. Why do objects become buoyant when submerged? 3. Why are some objects more buoyant than others? 4. Explain how Newton's 3rd Law is relevant to the concept of buoyancy.


Acquisition
Acquisition
Students will know...
• Buoyancy force is the upward force when an object is being submerged in a liquid
• Archimedes' Principle
• Newton's 3rd Law of Motion
Students will be skilled at...
• Apply mathematical computations to mathematical model(s) to calculate various outcomes
• Interpret graphs to draw conclusions
• Use computer software to collect data and model the deflection in an object as it relates to the support span
• Apply the scientific method in an experiment


Mini-Case Study
Scenario:
A raft that is 3 meters long, 1 meter wide, and 0.3 meters high is floating in fresh water. With no additional weight on the raft, it sits 3 cm under the water. A person is using the raft to transport supplies to a nearby campsite. With the weight of the person raft sits 6 cm under the water. In order to sail on the raft safely, the water level should not exceed 22cm.
Objective:
Assuming that the density of water is 1000 kg/m3, figure out the mass of the person, the mass of the raft and the mass of the maximum amount of supplies that you can bring onto the ship.
Calculate:
Using the MSET to demonstrate Archimedes' Principle, add additional weight to the buoyancy sample. Additional weight can include the addition of paperclips, additional fluid, rocks, etc. Make sure to record the empty weight of the buoyancy sample, the total weight of the buoyancy sample with the added mass, and dimensions of the buoyancy sample before performing the experiment.
Procedure:
1. Configure MSET in similar setup as Buoyancy setup.
2. Attach EMPTY sample to setup and lower cross
3. Remove sample and zero both displacement and force so the MSET is reading a zero force with no sample and with the sample just in contact with water.
4. Attach Sample and make sure force reading is matching the force measured earlier.
5. Lower the sample in the water and record force as a function of displacement.
6. Record the displacement at which the force acting on the load cell
7. Repeat the experiment but add weight to the sample each time.
8. Record your findings and explain how the buoyancy formulas relate to your results.


Assessment Evidence
Students will use the MSET device to conduct an experiment to plot a progression of water displacement while an object is being submerged. Using formulas related to Archimedes' Principle and Newton's 3rd Law, students will calculate the buoyant force applied to the object. Students will use this procedure to designing a structure in future lessons.

MSET Experiment Procedure– Buoyancy

Technical objective

The objective of this experiment is to examine the effects of placing an object in liquid and measuring the reactive force applied back to the object by the liquid.

Background

When an object is placed in liquid, a reactive force from the liquid pushes back on the object.
An example of this is when a person holds a ball in their hands and pushes the ball into water.
Before pushing the ball into the water, the only force on the ball is due to gravity. This is shown in Figure 1 and can be calculated using Equation #1.

$$W = m(g) \quad \text{eq. (1)}$$

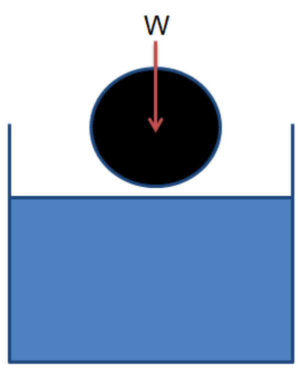


Figure 1: Ball Just Before it is Placed on the Surface of the Water

Figure 2 shows the ball partially submerged in water. There is still a downward force from gravity acting on the mass of the ball. However, a second force acting in the opposite direction, is now applied to the ball. The reactive force is called buoyancy.

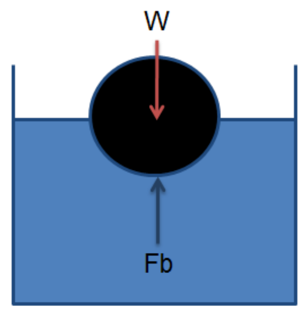


Figure 2 - Ball partially submerged

The amount of buoyancy generated depends on the volume of liquid displaced "V", density of the liquid "ρ", and constant due to gravity "g" shown in Equation #2.

$$Fb = V(\rho)(g) \qquad \text{eq. (2)}$$

As the ball is forced deeper into the water, the volume of water displaced increases as does the buoyancy force. The buoyancy force will increase until the ball is completely submerged shown in Figure 3. At this point the reactive buoyancy force will stop increasing and remain constant.

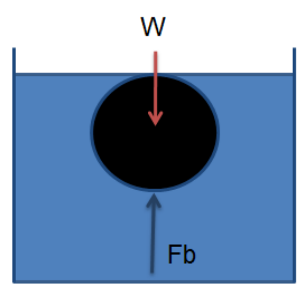


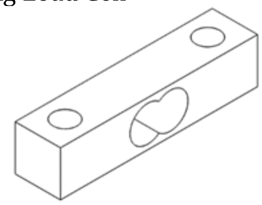
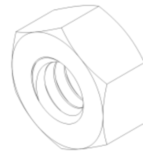
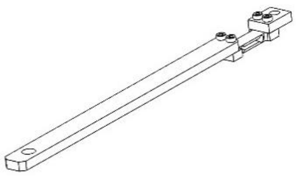
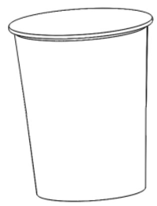
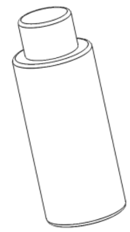
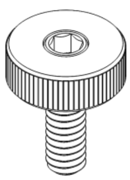
Figure 3 - Ball completely submerged

Approach

In this experiment a sample of known volume will be lowered into a vessel of water. As it is lowered, the buoyancy force on the sample will be measured.

Experiment Setup

1. Gather the following components:

5kg Load Cell 	4mm Hex Wrench 	Hex Nut 
100g Load Cell Assembly 	Water Vessel 	Buoyancy Sample 
5/8” Thumbscrew 		

1. Attach the tower to the base plate as shown in the Quick Setup Guide. **Safety shield must be used for this experiment; it has been omitted from the following illustrations for clarity purposes.**
2. Use the 4mm hex wrench to remove any load cell that is attached to the carriage

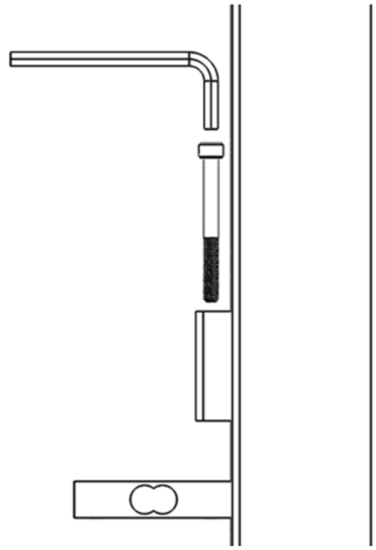


Figure 4: Load Cell Orientation

3. Carefully place the water vessel, filled with 500ml of water, in front of the MSET base.
4. Attach the buoyancy sample cap to the unthreaded hole of the load cell extension with one of the 5/8" thumbscrews and the hex nut. See Figure 5. **Handle the 100g loadcell carefully. It is fragile and can be easily damaged.**

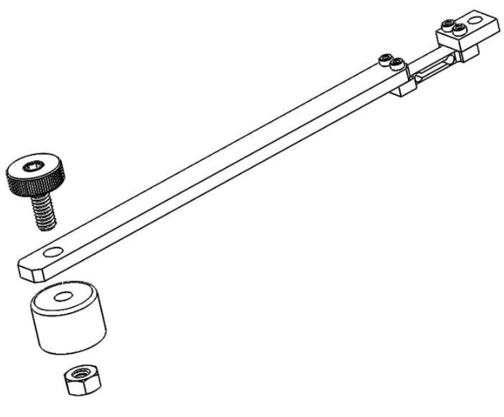


Figure 5: Assembly of Buoyancy Cap to Load Cell Extension

5. Thread the buoyancy sample onto the cap. See Figure 6:

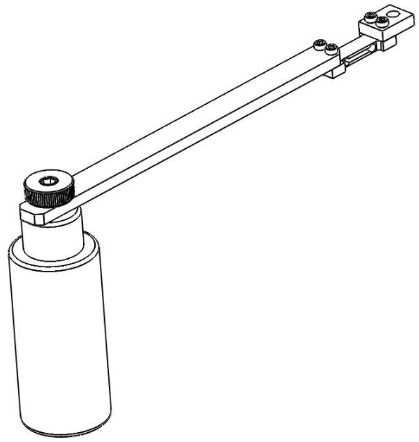


Figure 6: Buoyancy Sample Attached to Cap

6. Raise the carriage until the top is level with the 8cm mark on the tower scale.
7. Attach the load cell extension to the load cell with the remaining ¾" thumbscrew as shown in Figure 7.

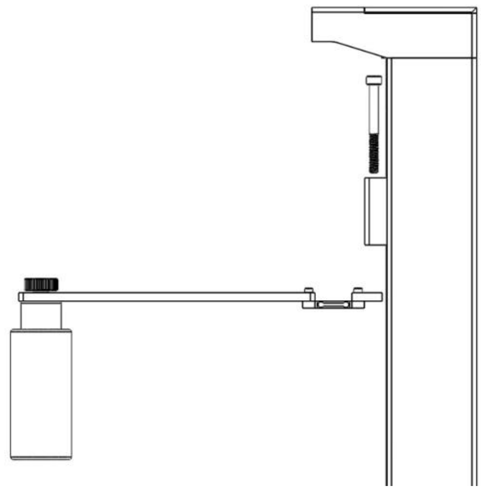


Figure 7: Assembly of Load Cell Extension to Load Cell

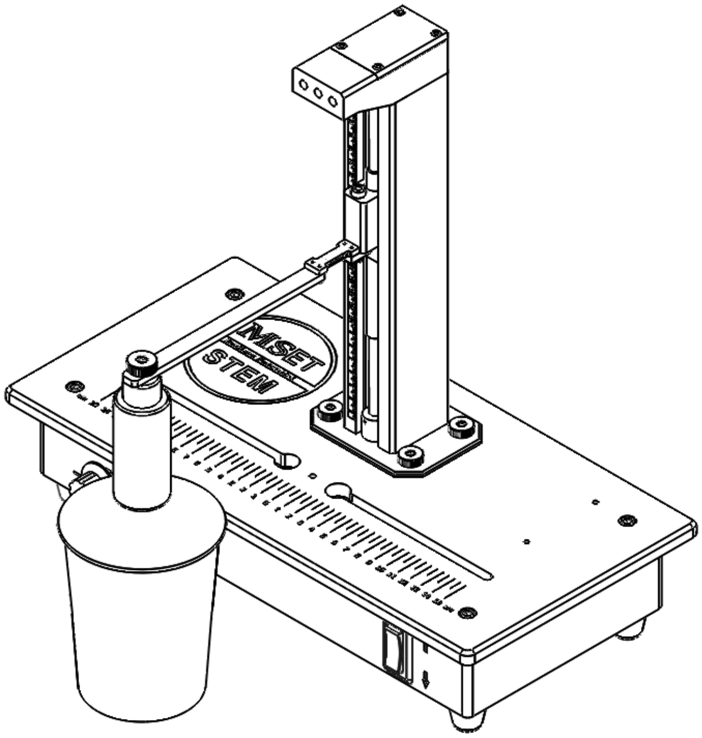


Figure 8: Final Buoyancy Setup

8. Plug the load cell into port 1 of the SIM.

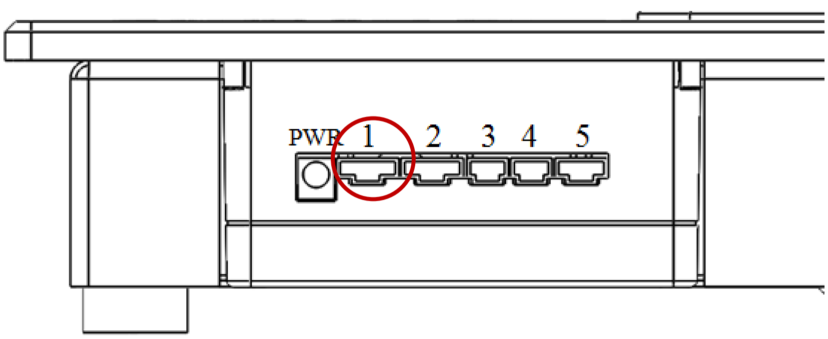
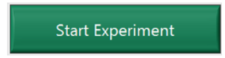


Figure 9: Port 1 on SIM

Experimental Procedure

1. Put on safety glasses.

2. In the MSET software, click "Buoyancy" then 

to launch the buoyancy experiment.

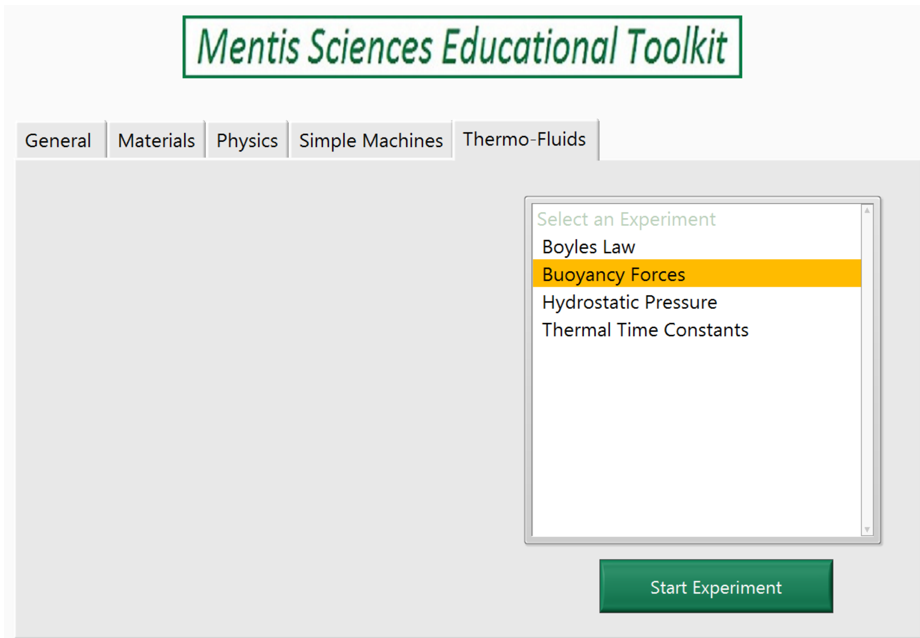


Figure 10: Location of Buoyancy Experiment

3. Select the 100g load cell from the menu options.

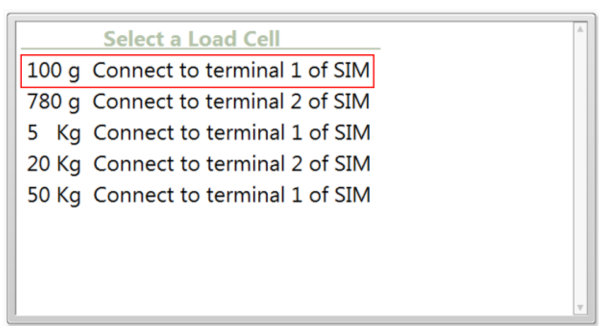
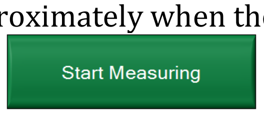


Figure 11. Load Cell Options

4. Lower the carriage until the test sample just touches the surface of the water (approximately when the carriage is at the 13cm mark on the tower scale).

5. Click 

to begin reading the sensors.

6. Press and hold Zero Readings on the MSET program to zero the load and displacement readouts.
7. Click Log Data to begin collecting data.

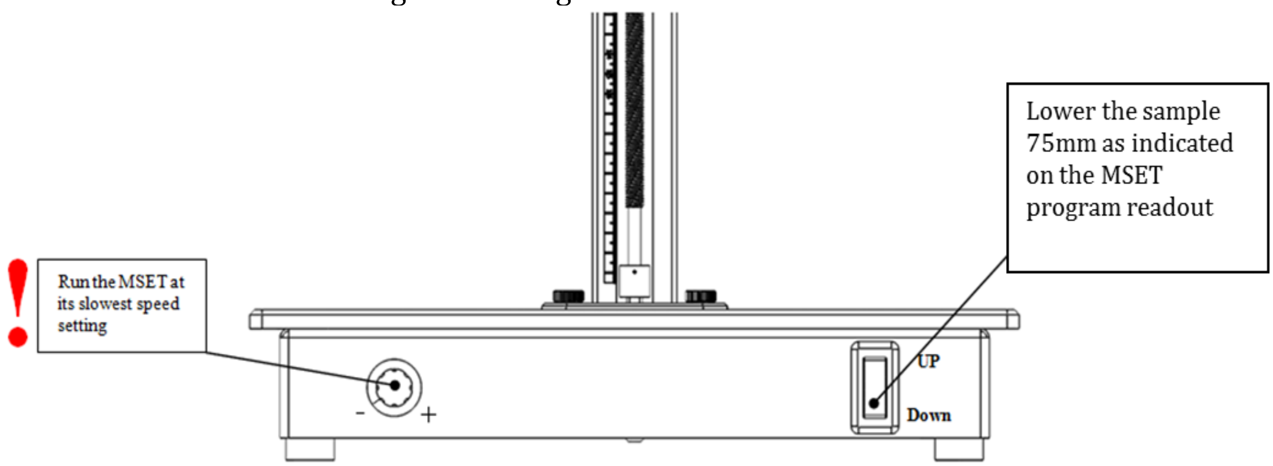


Figure 12: Experiment Operation

8. Lower the sample 50mm as indicated on the MSET program readout.
9. When the final displacement is achieved, release the direction control switch and click Stop Data Logging then Stop Measuring.
10. Press Save Results. A window will pop up notifying the user that data will be saved once Return to Main is pressed at the end of the experiment.

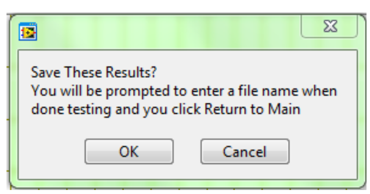


Figure 13. Save Results Prompt

11. Press Return to Main.
12. Input a suitable file name and press "ok".
13. The data collection portion of this experiment is now complete. Continue to the data analysis portion.

Data Analysis

1. Calculate the volume of water displaced using the geometry of the bottle and maximum distance submerged.
2. Calculate the theoretical buoyancy force on the test sample vs. depth.
3. Retrieve the raw data set by navigating to the C: drive then MSET > Thermo-Fluids. Identify the load at the maximum displacement. Compare and discuss experimental and theoretical results including percent differences.
4. Given a 2-meter square of negligible weight, determine the force exerted on it by water when half submerged.

MSET – BUOYANCY FORCES

Purpose

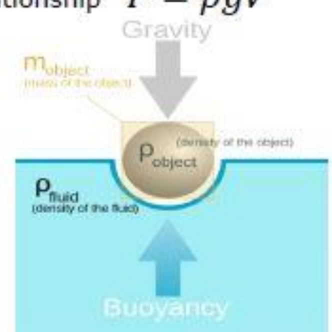
Evaluate the effects of submerging an object in a body of liquid that imparts a force on the body helping the body afloat.

Buoyancy

Buoyancy forces are useful in keeping an object from sinking in water. An example of this type of force can be seen when a boat is launched into water. Without the buoyancy force the vessel would sink.

Theory

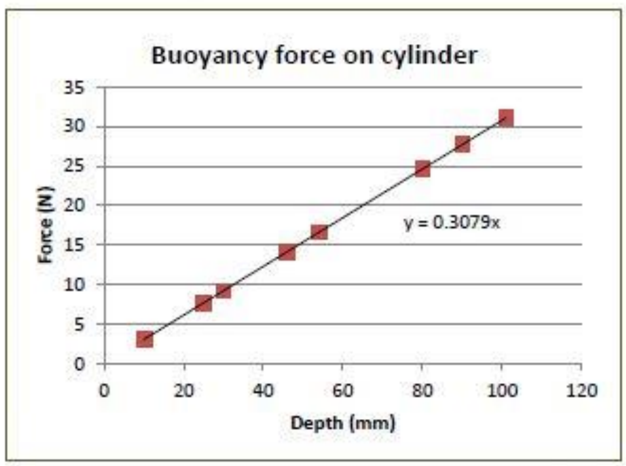
Buoyancy is a force "F" that works in the opposite direction of gravity "g" and is proportional to the volume "V" of water displaced by a body. The upward buoyancy force can be calculated using the relationship $F = \rho g V$



Setup

Results

The linear relationship between the buoyancy force and volume of water displaced will be plotted and compared to theory for a vessel of constant cross-sectional area. This relationship may also be studied for geometries that vary as a function of depth.



www.mset.info

Inquiry-Based Mini Project – Buoyancy

A raft that is 3 meters long, 1 meter wide, and 0.3 meters high is floating in fresh water. With no additional weight on the raft, it sits 3 cm under the water. A person is using the raft to transport supplies to a nearby campsite. With the weight of the person the raft sits 6 cm under the water. In order to sail on the raft safely, the water level should not exceed 22cm. Assuming that the density of water is 1000 kg/m3, determine the following: the mass of the person; the mass of the raft; and the mass of the maximum amount of supplies that you can bring onto the ship.

Using the MSET to demonstrate Archimedes' Principle, add additional weight to the buoyancy sample. Additional weight can include the addition of paperclips, additional fluid, rocks, etc. Make sure to record the empty weight of the buoyancy sample, the total weight of the buoyancy sample with the added mass, and dimensions of the buoyancy sample before performing the experiment. Make sure to follow the procedure listed below:

1.) Configure MSET in similar setup as Buoyancy setup.
2.) Attach EMPTY sample to setup and lower cross head until sample is just in contact with water.
3.) Remove sample and zero both displacement and force so the MSET is reading a zero force with no sample and zero displacement with the sample just in contact with water.
4.) Attach Sample and make sure force reading is matching the force measured earlier.
5.) Lower the sample in the water and record force as a function of displacement.
6.) Record the displacement at which the force acting on the load cell was 0.
7.) Repeat the experiment but add weight to the sample each time.
8.) Record your findings and explain how the buoyancy formulas relate to your results.
    a. Make sure to show the sum of forces and how displacement will affect the buoyancy force, remember to show how Newtons Third law applies in this section.
    b. Also report on what the 0-force reading indicates and how it relates to the raft problem that was stated above.
    c. Explain the relationship between the buoyancy force recorded, Newtons Third Law and Archimedes' Principle all relate.

Teacher Solution Key - Buoyancy

Given:

Length of raft=3 m
Width of raft= 1 m
Height of raft= 0.3 m
Underwater depth of empty raft = 3 cm
Underwater depth of raft with person= 6 cm
Underwater depth of raft with maximum load= 22 cm
Density of water= 1000 kg/m^3
Gravity= 9.81 m/s^2

Find:

F_{BER}= the buoyancy force of the empty raft
F_{BRP}= the buoyancy force of the raft with the person on it
F_P= the force of the person
$F_{B\ max}$= the buoyancy of the raft with the person and the maximum amount of supplies in it

Formula(s):

$$m = \frac{W}{g}$$

$$V = (L)(\mathrm{W})(\mathrm{H})$$

$$F_b = (V)(\rho)(g)$$

Where F_b= buoyant force and ρ=density and H = the submerged height of the raft

Solve for the mass of the person, the mass of the empty raft, and the mass of the maximum amount of supplies that the raft is able to sail safely with.

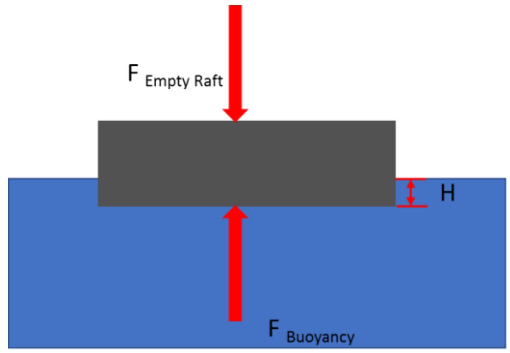


Figure 14: Free Body Diagram of the Empty Raft

$$F_{BER} = \left(9.81\,\frac{m}{s^2}\right)\left(1.0 \times 10^3\,\frac{kg}{m^3}\right)(3.0m)(1.0m)(0.030m) = 882.9N = 883N$$

$$m_{BER} = \frac{882.9N}{9.81\,\frac{m}{s^2}} = 90kg$$

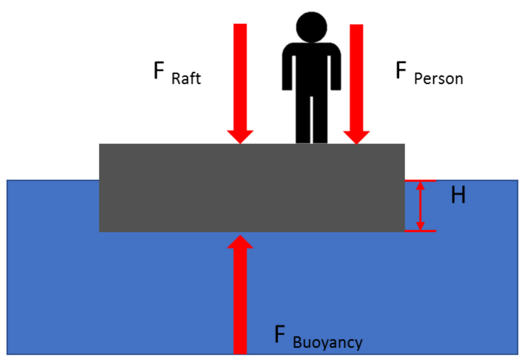


Figure 15: Free Body Diagram of Person on Raft

$$F_{BRP} = \left(9.81\,\frac{m}{s^2}\right)\left(1.0 \times 10^3\,\frac{kg}{m^3}\right)(3.0m)(1.0m)(0.060m) = 1765.8N = 1766N$$

$$F_P = F_{BRP} - F_{BER} = 1776 - 882.9 = 883N$$

$$m_P = \frac{882.9N}{9.81\,\frac{m}{s^2}} = 90kg$$

$$F_{B\,max} = \left(9.81\,\frac{m}{s^2}\right)\left(1.0 \times 10^3\,\frac{kg}{m^3}\right)(3.0m)(1.0m)(0.220m) = 6474.6N = 6475N$$

$$F_{max} = F_{B\,max} - F_B = 5592N$$

$$m_{B\,max} = \frac{5592N}{9.81\,\frac{m}{s^2}} = 570kg$$

Using MSET

Three different tests were performed:

1.) Empty Buoyancy Sample
2.) Buoyancy Sample with an additional 59 g of water
3.) Buoyancy with 16 g of steel nuts inside

Buoyancy sample was 2.25" and for each test the additional mass was placed inside of sample

Area of Sample $A = \pi * \left(\frac{D}{2}\right)^2 = \pi * (1.125\ in)^2 = 3.976\ in^2 = 25.65\ cm^2$

$$\rho_{water} = 1000\ \left(\frac{kg}{m^3}\right)$$
$$g_{atmosphere} = 9.81\ (\frac{m}{s^2})$$

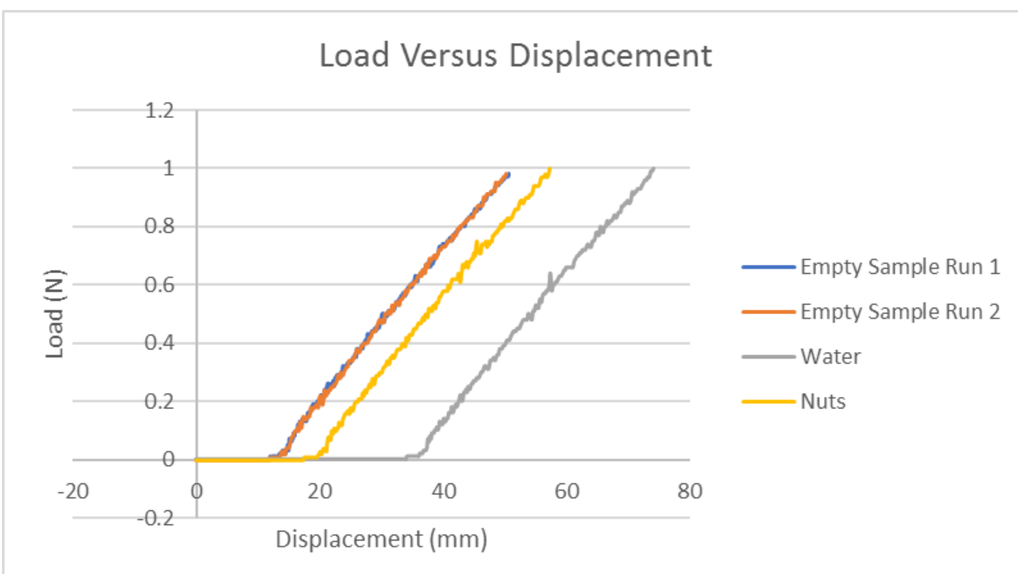


Figure 16: Load versus Displacement Buoyant Forces

a.) The load versus displacement chart of each run shows a similar trend line when the buoyant force is greater than the gravitational force and acting on the load cell.

$$\sum Forces = F_{weight} + F_{Buoyancy}$$

Note: $F_{Buoyancy}$ is acting upwards and F_{Weight} is acting downwards.

$$F_{Buoyancy} = (V)(\rho)(g)$$

Where the Volume of the submerged sample will increase as it is submerged deeper. This is seen by lowering the sample deeper into the water and measuring the resulting force, $F_{Buoyancy}$, acting upwards. The slope of the line, N/mm, was roughly the same for each case due to the same sized sample being submerged into the water. If any of the variables changed, ex. Size of the sample submerged, density of the liquid the sample was submerged in or the gravity exerted on the sample on different testes the slope of the line would differ. This is a different experiment to show how density will affect the buoyant forces acting on a sample. Students can try submerging the sample in water, and liquids with different densities such as brine, liquid soap, oil ect. and examine the buoyant forces acting in each case.

b.) The position when the load begins to be applied, 0-force, is the point at which the buoyant force is equal to the gravitational force, or the sample is in equilibrium. In the above equation with the raft, as long as the buoyant force is equal to the gravitational force, the raft will float. If the buoyant force was greater than the gravitational force the object would rise even higher to the surface, think of a balloon that is held underwater and then released, the balloon will rise until it floats on the surface or until the buoyant force is equal to the gravitational force. The same applies if the gravitational force is greater than the buoyant force, the object will sink until it is either suspended at a certain depth due to different densities of the liquid it is suspended in or if it sinks to the bottom and is held up by the ground. An example of this type of project is pictured below.

Figure 17: Image taken from http://www.mykidsadventures.com/how-to-stack-liquids/

c.) Newton's third law states that for every force acting on an object, there is an equal and opposite reaction force that is also acting on the same object. This is seen when submerging the sample in water, the forces acting on the sample before in contact with water is gravity, F=m*g. When the object is submerged into the water, the buoyant force will begin to act in an upwards direction until the object is at equilibrium, Force reading of 0 in the upwards and negative direction, or the object is floating. Archimedes Principle states that the buoyant force acting on an object will always oppose the gravitational force acting upon the object. Buoyant force of the submerged object will increase with depth due to the displaced water weight increasing as the object is submerged deeper. When the displaced water weight equals the weight of the object, the object will float. When the displaced water weight is less than the weight of the object, example a bowling ball in a pool, the object will sink. This idea is that the displaced water weight is the buoyant force and the weight of the object is the gravitational force.

Inquiry-Based Mini Project Rubric – Buoyancy

	3	2	1	0	Score
Proper Use of Equipment	Used the MSET effectively to determine the buoyant force of an object.	Struggled with using the MSET and getting accurate data. Was able to use it to determine buoyant force but needed some assistance.	Even at the end of the experiment, struggled with the use of the MSET to accurately determine buoyant force of an object.	Didn't use the MSET	
Accuracy of Use of Terminology	Used all terms accurately including, Archimedes'' Principle, density, volume, mass, Newton's 3rd Law of Motion, and buoyant force.	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 their solution to the mini-project. Explanation included how mass, density, and volume relate to buoyant force. A detailed explanation of how Archimedes' Principle and Newton's 3rd Law	Provided a rationale for their solution, but could only briefly explain the connections between the calculations they completed and Archimedes' Principle and Newton's 3rd Law.	Provided a rationale, but their explanation was lacking the proper connections between Archimedes' Principle and Newton's 3rd Law.	Didn't provide a rationale for their solution	

	are related to the mini-project and its solution was also given.				
Use of Mathematical Computations	Accurately completed calculations and was able to use calculations to explain the reasoning behind their solution.	May have accurately calculated the mass of the maximum amount of supplies that can be loaded on the raft, however could not use it to explain the reasoning behind their solution.	Attempted to calculate the mass of the maximum amount of supplies that can be loaded on the raft, but included some miscalculations.	Did not complete calculations or calculations were incorrect for experiment.	