MSET Demonstration Package

Hydrostatic Pressure

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.

Hydrostatic Pressure Introduction

In this unit students will explore the hydrostatic pressure acting onto a submerge tube and will use relevant equations to calculate a theoretical pressure distribution on the tube as a function of depth submerged. Students will extrapolate data from these equations to compare back to experimentally tested data and will report on their findings. . The goal of this exercise is to prepare students and apply these concepts in an inquiry-based project.

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. Choosing correct variables when calculating theoretical pressure values.
2. Comparing theoretical values to experimentally tested values found using the MSET.
3. Recognizing the relationship between gravity, density and distance.
4. Have basic algebra knowledge of combining stress equations.
5. Have basic mechanical skills to configure MSET based on written and visual instructions.

Table of Contents

UbD Chart – Hydrostatic Pressure

<table>
<tr><th colspan="3">Desired Results</th></tr>
<tr><td rowspan="5">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:
HS-PS2-4. Use mathematical representations of Newton's Law of Gravity and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects

<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

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.</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to independently use their learning to calculate hydrostatic pressure when designing a structure, device, vehicle, etc. (i.e. masonry walls, dams, hydraulic devices, submerged vehicles, etc).</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…
1. Hydrostatic Pressure is directly proportional to water depth.
2. Forces (including gravity) are exerted from many directions when an object is submerged.
3. Computer simulations and software can help model and compute hydrostatic pressure.</td><td>ESSENTIAL QUESTIONS

1. How does depth of a submerged object affect the hydrostatic pressure exerted upon it?
2. How might a lack of hydrostatic equilibrium affect the integrity of a structure?
3. How is Newton's Law of Gravity related to hydrostatic Pressure?
4. What is the relationship between pressure and weight?
5. How can calculating and understanding hydrostatic pressure help in designing structures?</td></tr>
<tr><td colspan="2">Acquisition
</td></tr>
<tr><td></td><td>Students will know…
• Definition of hydrostatic pressure
• Newton's Law of Gravity
• The equation for calculating hydrostatic pressure</td><td>Students will be skilled at…
• Apply mathematical computations to mathematical model(s) to calculate hydrostatic pressure
• Interpret graphs to draw conclusions
• Use computer software to collect data and model hydrostatic pressure on an object
• Apply the scientific method in an experiment</td></tr>
</table>

Introductory Physics: HS-PS2-4. Use mathematical representations of Newton's law of gravitation and Coulomb's law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.		

Evidence

Assessment Evidence

PERFORMANCE TASK(S):

1. Students will use the MSET device to conduct an experiment to measure the hydrostatic pressure on an object. Students will use equations (given) to determine the hydrostatic pressure exerted on an object. The MSET device will provide a plot of the hydrostatic pressure on the object. Students will use this procedure to designing a structure in future lessons.

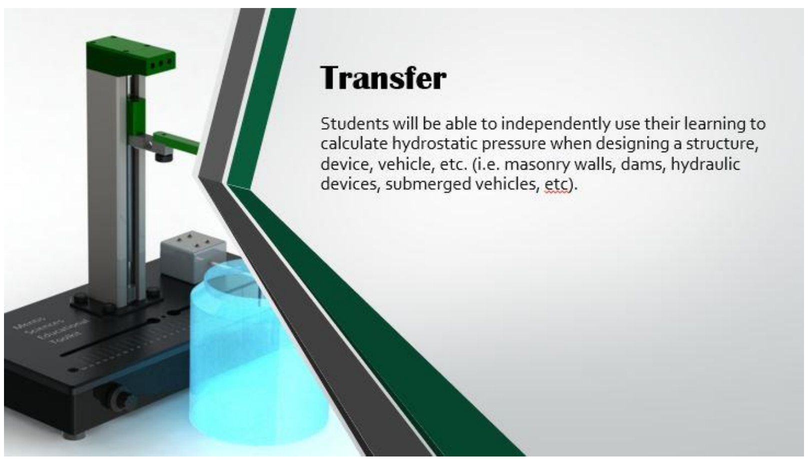
OTHER EVIDENCE:
The essential questions will be used as an entrance/exit slip to determine growth in understanding.

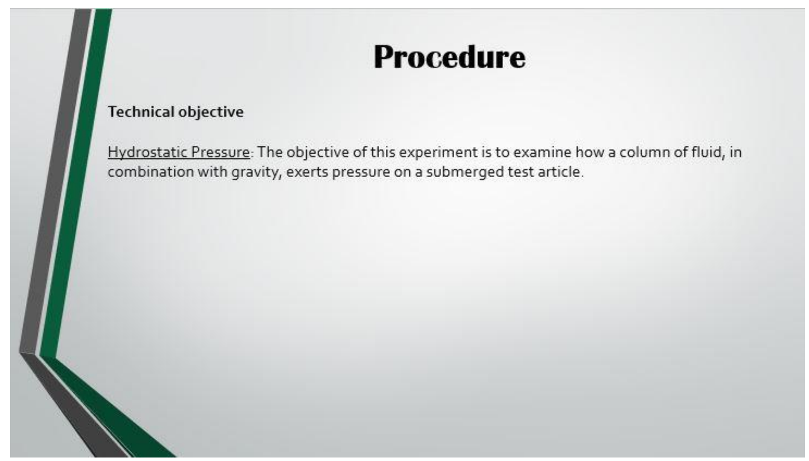
Stage 3 – Learning Plan

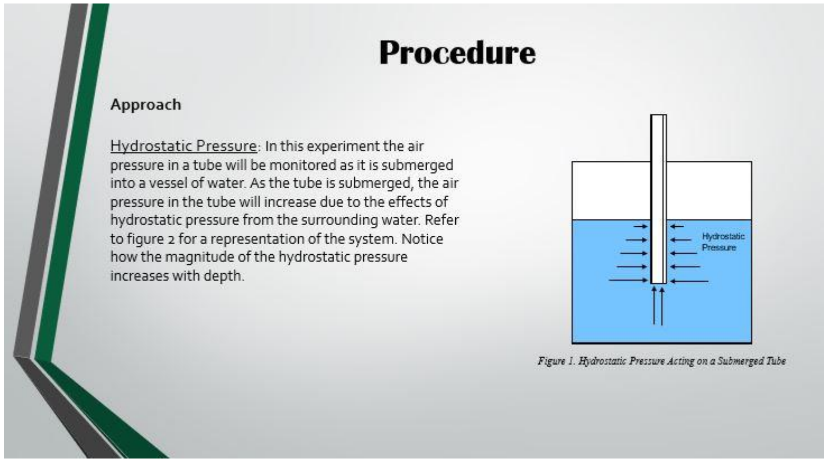
Summary of Key Learning Events and Instruction

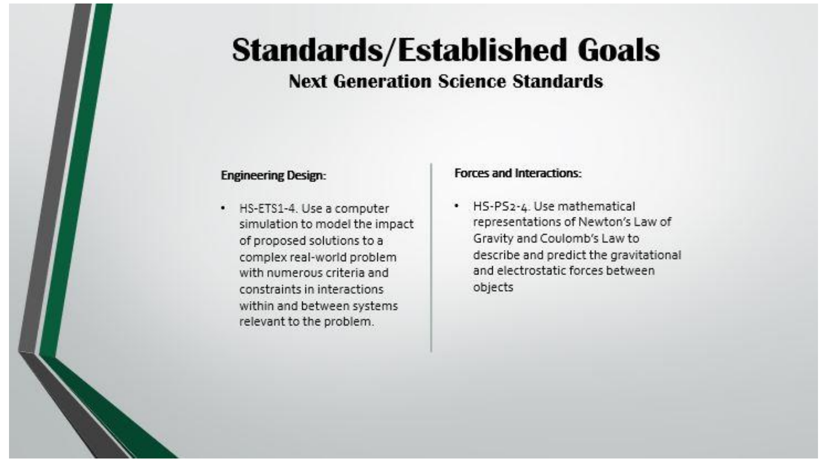
See outline of Hydrostatic Pressure experiment summary included.

PowerPoint Template for Instruction – Hydrostatic Pressure






Procedure
Approach
Hydrostatic Pressure: In this experiment the air pressure in a tube will be monitored as it is submerged into a vessel of water. As the tube is submerged, the air pressure in the tube will increase due to the effects of hydrostatic pressure from the surrounding water. Refer to figure 2 for a representation of the system. Notice how the magnitude of the hydrostatic pressure increases with depth.
Hydrostatic Pressure
Figure 1. Hydrostatic Pressure Acting on a Submerged Tube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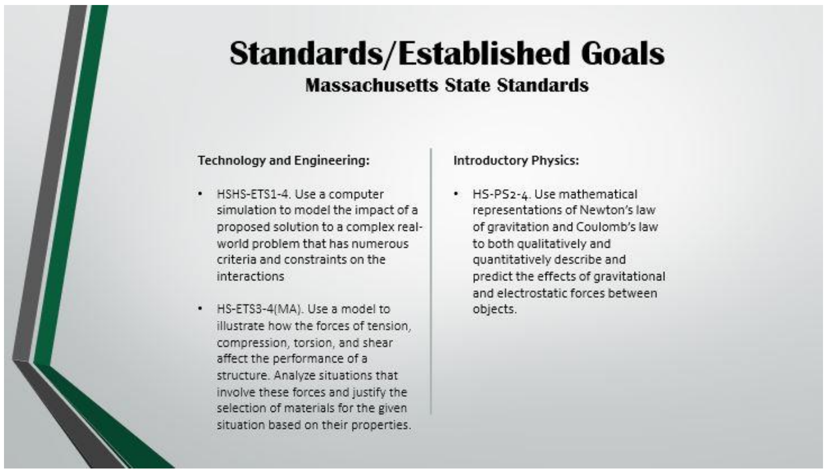
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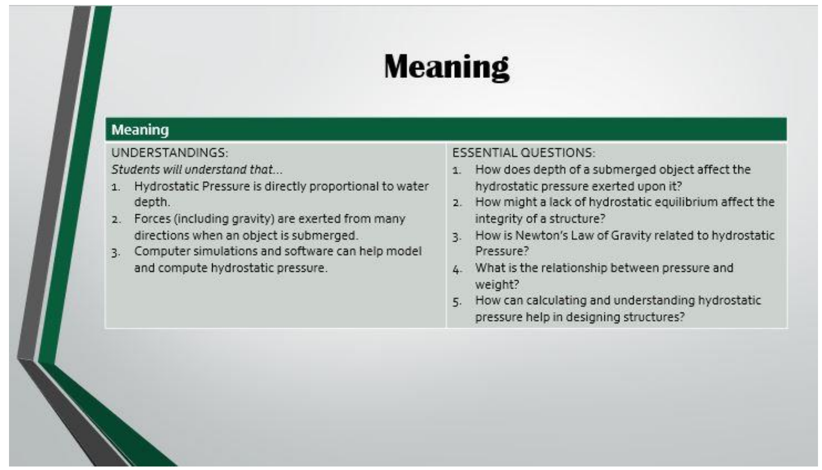
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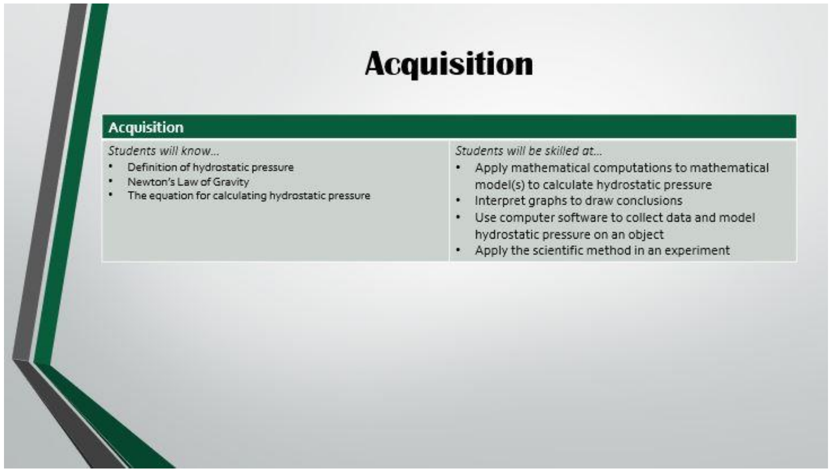
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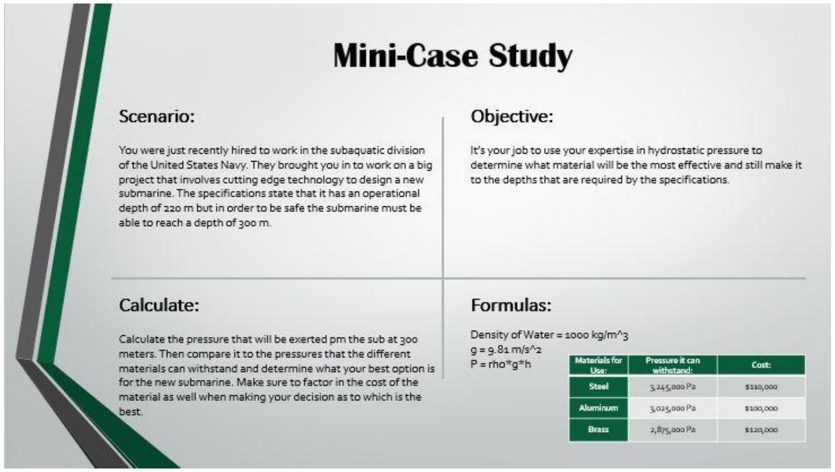
Mini-Case Study
Scenario:
You were just recently hired to work in the subaquatic division of the United States Navy. They brought you in to work on a big project that involves cutting edge technology to design a new submarine. The specifications state that it has an operational depth of 220 m but in order to be safe the submarine must be able to reach a depth of 300 m.
Objective:
It's your job to use your expertise in hydrostatic pressure to determine what material will be the most effective and still make it to the depths that are required by the specifications.
Calculate:
Calculate the pressure that will be exerted pm the sub at 300 meters. Then compare it to the pressures that the different materials can withstand and determine what your best option is for the new submarine. Make sure to factor in the cost of the material as well when making your decision as to which is the best.
Formulas:
Density of Water = 1000 kg/m^3
g = 9.81 m/s^2
P = rho*g*h
Materials for Use:
Pressure it can withstand:
Cost:
Steel
3,245,000 Pa
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Aluminum
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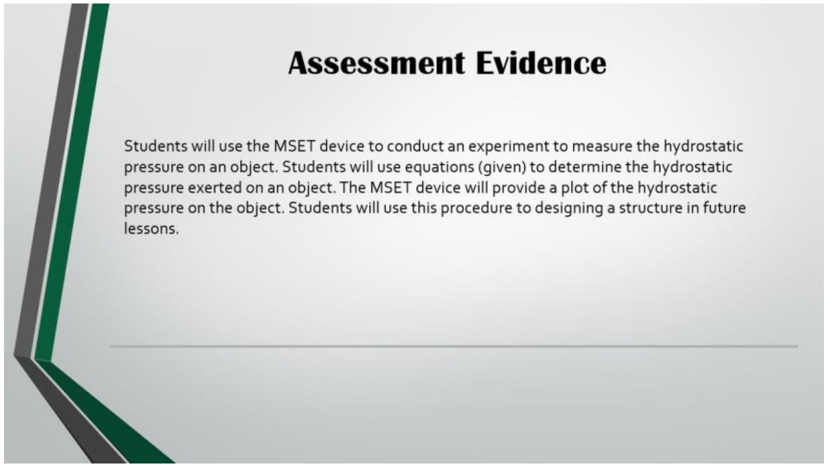

Assessment Evidence
Students will use the MSET device to conduct an experiment to measure the hydrostatic pressure on an object. Students will use equations (given) to determine the hydrostatic pressure exerted on an object. The MSET device will provide a plot of the hydrostatic pressure on the object. Students will use this procedure to designing a structure in future lessons.

MSET Experiment Procedure– Hydrostatic Pressure

Technical objective

The objective of this experiment is to examine how a column of fluid, in combination with gravity, exerts pressure on a submerged test article.

Background

Hydrostatic pressure "*Hp*" is generated when fluid is placed on top of a body that is submerged in it. As the depth of fluid is increased, there is a proportional increase in pressure on the body. As an example, a person swimming on the surface of a lake, pond, or ocean has a force pushing down on them due to their weight. As the swimmer descends to a deeper depth, they encounter increased amounts of fluid on top of them and an increased pressure on their body shown in Figure 1.

Approach

In this experiment the air pressure in a tube will be monitored as it is submerged into a vessel of water. As the tube is submerged, the air pressure in the tube will increase due to the effects of hydrostatic pressure from the surrounding water. Refer to Figure 1 for a representation of the system. Notice how the magnitude of the hydrostatic pressure increases with depth.

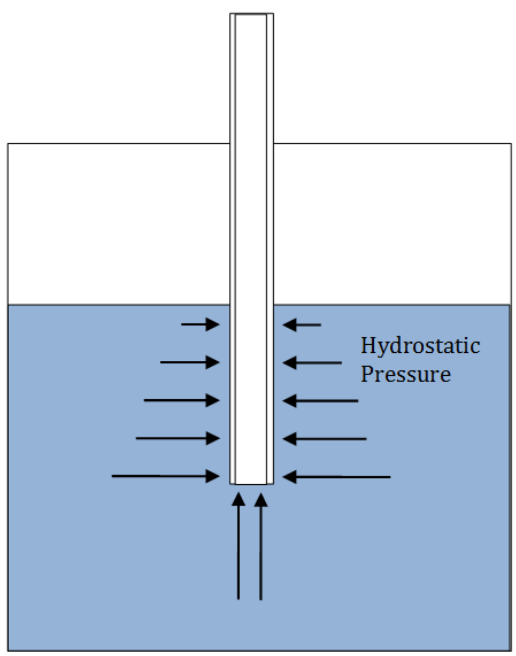
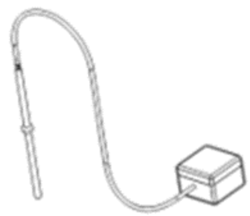
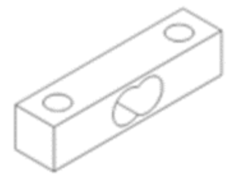
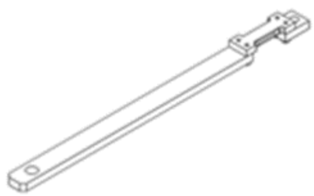
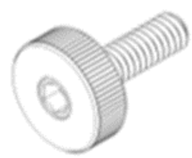


Figure 1: Hydrostatic Pressure Acting on a Submerged Tube

Experiment Setup

1. Gather the following components:

Pressure Tube and Sensor Assembly 	Water Vessel 	5kg Load Cell 
100g Load Cell Assembly 	5/8" Thumbscrew 	4 mm Hex Wrench 

2. 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.** Attach the tower to the base plate as shown in the Quick Setup Guide.

3. Position the carriage so its top is level with the 6cm mark on the tower scale.
4. Carefully place a container, filled with 500ml of water, in front of the MSET base.
5. Slide the pressure tube assembly through the unthreaded hole in the load cell extension until the two o-rings rest on the extension.

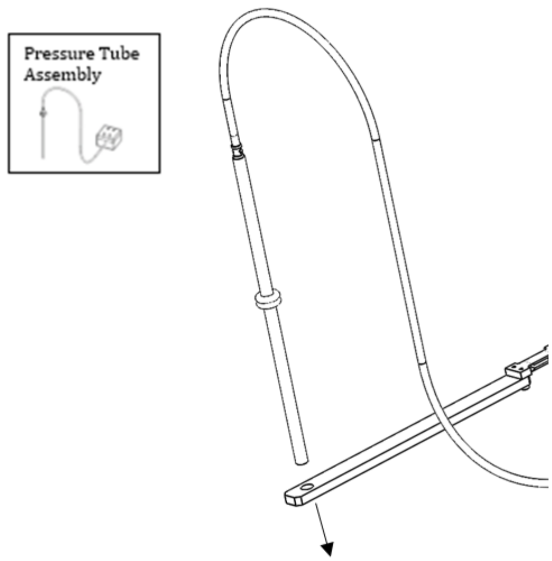


Figure 2: Assembly of Pressure Tube and Load Cell Extension

6. Connect the load cell extension to the load cell with the 4mm Hex Wrench as pictured in Figure 3. **Handle the 100g loadcell carefully. It is fragile and can be easily damaged.**

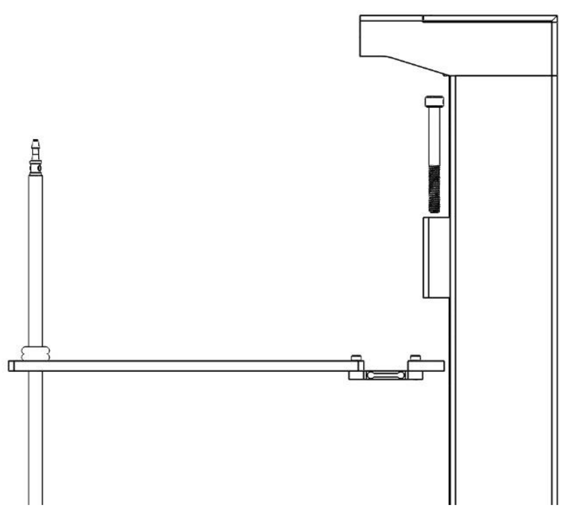


Figure 3: Attachment of the Load Cell Extension to the Load Cell

7. Plug the pressure sensor into port 3 of the SIM.

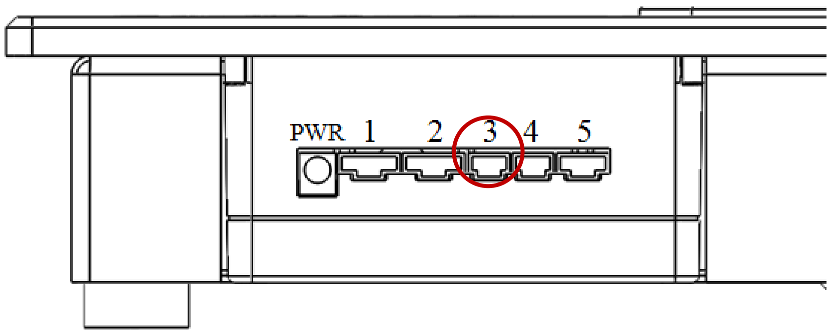


Figure 4: Port 3 on SIM

8. The MSET should now look as picture in Figure 5.

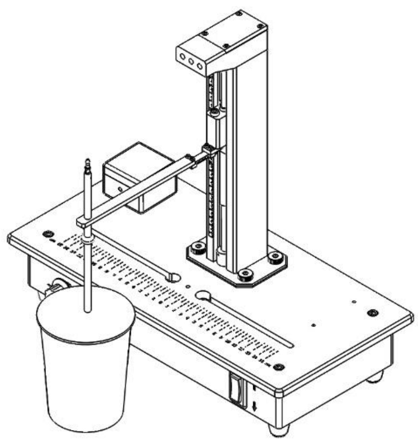


Figure 5: Completed Hydrostatic Experiment Setup

Experimental Procedure

1. In the MSET software, double click “Hydrostatic Pressure” to launch the hydrostatic experiment.

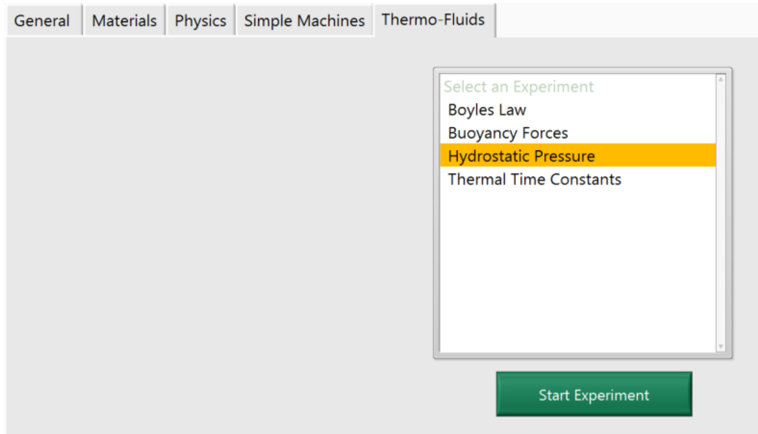


Figure 6: Location of Hydrostatic Pressure Experiment

2. If the tube is not just touching the surface of the water, slide the two o-rings up or down the pressure tube until it does.
3. Click **Start Measuring** to begin reading the pressure sensor.
4. Press and hold **Zero Readings** on the MSET program to zero the pressure readout
5. Click **Log Data** to begin collecting data.
6. Displace the carriage downward 80mm.
7. When the final displacement is achieved, release the direction control switch and click **Stop Data Logging** then **Stop Measuring**.
8. 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.

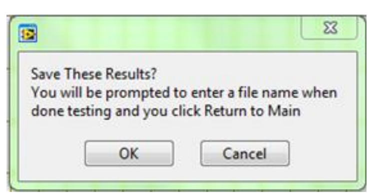


Figure 7. Save Results Prompt

9. Press **Return to Main**.

10. Input a suitable file name and press “ok”.
11. The data collection portion of this experiment is now complete. Continue to the data analysis portion.

Data Analysis

1. Calculate the theoretical hydrostatic pressure over the depth range measured.

2. Retrieve the raw data set by navigating to the C: drive then MSET > Thermo-Fluids

   Determine the average error from theory and experimental measurements.

3. Discuss potential errors between theoretical and experimental results.

4. Would the results differ if ocean water was used? Explain.

5. How much pressure would be exerted by a column of water on a vessel submerged to 100 meters?

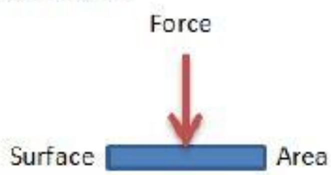
MSET – HYDROSTATIC PRESSURE

Purpose

Introduce pressure measurements and the concept of hydrostatic pressure showing that it increases as the depth of a fluid increases.

Pressure

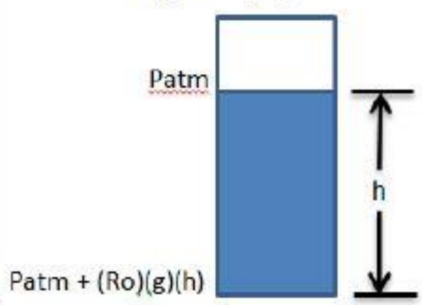
Pressure is defined as a force acting on a surface of an object. The pressure applied to a person is called atmospheric pressure and is 14.7 lbs. for every square inch of surface area.



Theory

Hydrostatic pressure "HP", applied to the surface of a vessel that is submerged in a liquid of density "Ro", at some depth "H" can be calculated with the following equation:

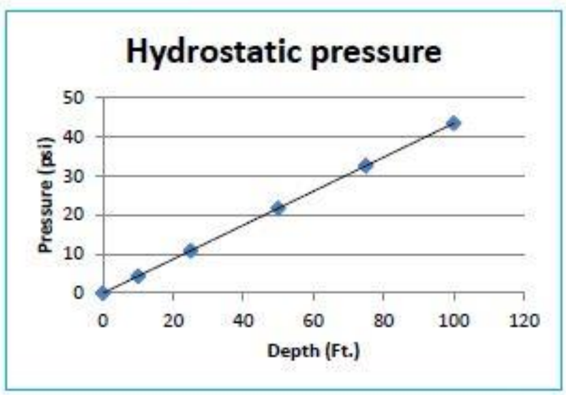
$$Hp = \rho g h$$



Setup

Results

Results will show that the hydrostatic pressure follows a linear relationship and that the pressure at a depth can be calculated accurately using the theoretical equation defined. Plots pressure versus depth will be generated, and used to predict the pressure at various depths with liquids other than water.



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Inquiry-Based Mini Project – Hydrostatic Pressure

You were just recently hired to work in the subaquatic division of the United States Navy. They brought you in to work on a big project that involves cutting edge technology to design a new submarine. The specifications state that it has an operational depth of 220 m but in order to be safe the submarine must be able to reach a depth of 300 m. It's your job to use your expertise in hydrostatic pressure to determine what material will be the most effective and still make it to the depths that are required by the specifications.

Density of Water = 1000 kg/m^3
g = 9.81 m/s^2
P = rho*g*h

Materials for Use:	Pressure it can withstand:	Cost:
Steel	3,245,000 Pa	$110,000
Aluminum	3,025,000 Pa	$100,000
Brass	2,875,000 Pa	$120,000

Calculate the pressure that will be exerted pm the sub at 300 meters. Then compare it to the pressures that the different materials can withstand and determine what your best option is for the new submarine. Make sure to factor in the cost of the material as well when making your decision as to which is the best.

Teacher Solution Key – Hydrostatic Pressure

Relevant Equations:

$$P = \rho * g * h$$

Where P is the Hydrostatic Pressure, ρ is the density of water (kg/m^3), g is the gravitational acceleration on earth (m/s^2) and h is the distance the object is submerged in water.

Find:

Pressure exerted on the submarine at a depth of 300m.

Calculations:

Materials fo Use	Calculated Pressure (Pa)	Maximum Pressure (Pa)	Cost ($)
Steel	2943000	3245000	110,000
Aluminum	2943000	3025000	100,000
Brass	2943000	2875000	120,000

Both the Aluminum and Steel can survive the maximum calculated pressure seen on the submarine at the depth of 300m. Aluminum is a lower cost and would be a suitable material for design of the submarine.

Inquiry-Based Mini Project Rubric – Hydrostatic Pressure

	3	2	1	0	Score
Proper Use of Equipment	Used the MSET effectively to determine hydrostatic pressure.	Struggled with using the MSET and getting accurate data. Was able to use it to determine hydrostatic pressure but needed some assistance.	Even at the end of the experiment, struggled with the use of the MSET to accurately determine hydrostatic pressure of an object.	Didn't use the MSET	
Accuracy of Use of Terminology	Used all terms accurately including, Archimedes'' hydrostatic pressure, density, atmospheric pressure, and Newton's Laws of Motion.	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 why a particular material was chosen as the most effective while also taking cost into consideration. The explanation also	Provided a rationale for their solution, but could only briefly explain why they chose a particular material and how depth, density, weight, and Newton's Laws played a part in their solution.	Provided a rationale, but their explanation was lacking the proper connections between their solution and depth, density, weight, and Newton's Laws.	Didn't provide a rationale for their solution	

	included a description of how depth, density, weight, and Newton's Laws may have affected the pressure on the submarine and therefore the solution to the mini-project.				
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 pressure exerted on the submarine, however could not use the calculations to explain the reasoning behind their solution.	Attempted to calculate hydrostatic pressure exerted on the submarine, but included some miscalculations.	Did not complete calculations or calculations were incorrect.	