Grade 5 Dynamic Photo-Mechanics Lab Transfer Task (Teacher Guide)

The following engineering transfer tasks have been created to be used in conjunction with the URI Dynamic Photo-Mechanics Lab video. The tasks are designed to be completed in order as they build upon one another.

Teacher Notes:

- Please note printed copies will be in black and white, but projected documents will be in color.
- We suggest doing this task together as a class using a think-aloud approach. Have students turn and talk/think-pair-share/discuss their ideas as you guide them through the task.
- This is an engineering task where students will need to consider how the strength of different materials changes when an object is underwater for an extended period of time. Students will also explore how the pressure at different depths of the ocean affects the strength of these materials. It will be important to support students with discussion around explaining the relationship between pressure and depth.

Teacher Guiding Questions: You may use these guiding questions for all of the tasks, depending on how you scaffold it.

- What information did you get from the text?
- What information do we get from the diagram (Figure 1)?
- What information did you get from the graph (Figure 2)?
    - What information does the X-axis give us?
    - What information does the Y-axis give us?
- What information do we get from the data table (Figure 3)?
- How might using the graph and data table together be helpful?
- How are pressure and depth related to each other?
- What is the task?
- How do you know? How did you figure that out?
- What's your evidence?
- Does anyone have a different idea?
- Does anyone have any ideas to add?

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

Dr. Matos is a mechanical engineer at the University of Rhode Island (URI). He and his students examine the properties of materials to identify which materials are best suited for a specific task. Dr. Matos has been asked to investigate which material would make the best coating for an underwater sea vessel like a submarine. The deeper a submarine dives, the more water pressure is pushing on it. Therefore, the best coating will be one that can withstand the most pressure to help prevent the submarine from imploding, or being crushed.

Dr. Matos printed 5 models of underwater sea vessels at URI's Advanced 3D Printing Lab. The models were made out of a material called Base PLA. Four of the models were each coated with a different material. The fifth model was left without a coating. One at a time, the models were tested inside the High Pressure Implosion Facility. During each test, a vessel was placed in a tank that simulated undersea-like conditions (Figure 1). Different amounts of pressure were applied to simulate the water pressure at different depths. The researchers measured how much pressure was applied before the model imploded, or was crushed. The researchers also simulated tests to see if the materials would lose strength after being exposed to seawater over different periods of time.

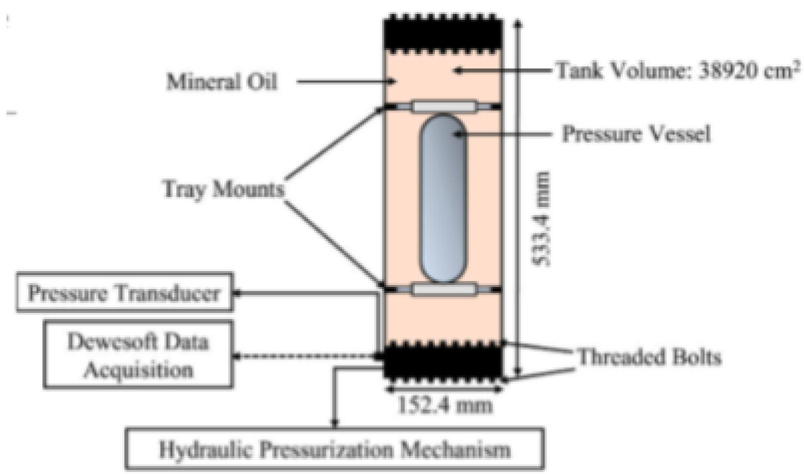

Figure 1: Schematic Diagram of High Pressure Implosion Facility

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

The graph below shows the results of Dr. Matos' investigation (Figure 2). The Analytical Collapse Pressure (MPa) indicates the amount of force the model vessel could withstand before imploding. This pressure is related to how deep the vessel can go before the risk of implosion (Figure 3). The Weathering Days shows the number of days the vessel might be expected to stay underwater.

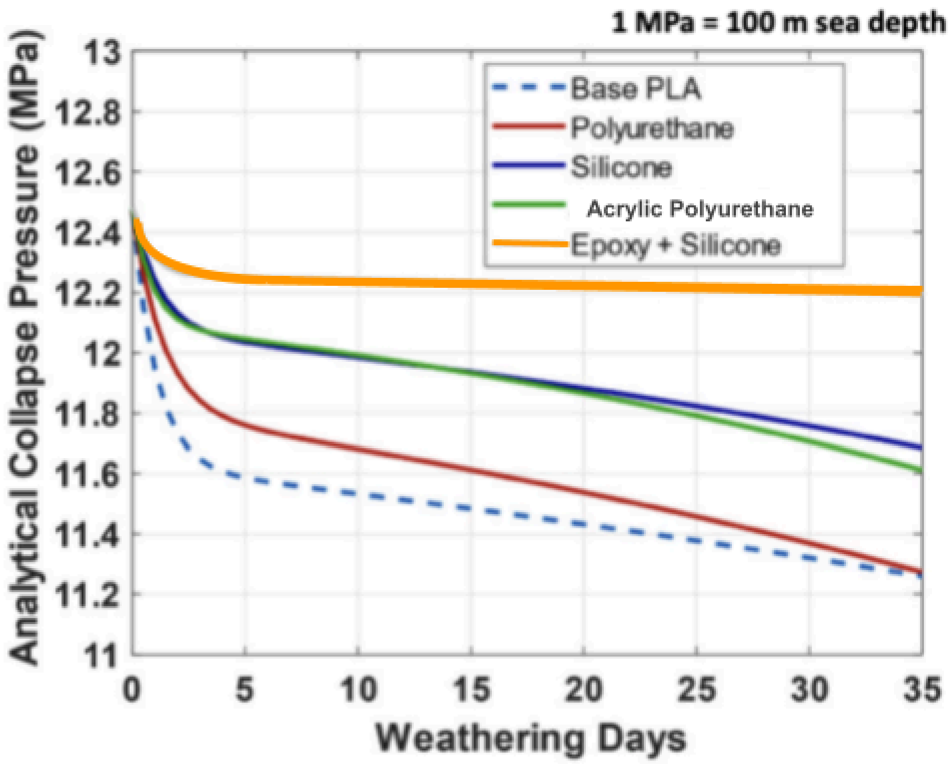

Figure 2: Analytical Collapse Pressure & Weathering Days

1 MPa = 100 Meters

Analytical Collapse Pressure (MPa)	Depth (meters)
11	1,100
11.2	1,120
11.4	1,140
11.6	1,160
11.8	1,180
12	1,200
12.2	1,220
12.4	1,240
12.6	1,260
12.8	1,280
13	1,300

Figure 3: Analytical Collapse Pressure (MPa) and Sea Depth (meters)

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

Teacher Notes:
PLA (polylactic acid) is a type of polymer (or plastic)

- All of the materials that are used as coatings are also different types of plastics (polymers) in thin coatings
- “The Analytival Collapse Pressure (measured in megapascals - MPa)”
- 1 MPa = 1 N / m2
  (1 mega pascal equals 1 Newton per meter square)
  (It is the force applied to an area on the outside of a submarine for example)

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

Task 1: Based on the research from the Dynamic Photomechanics Lab, use the graph and table above to answer the following questions:

1)
   a. At Day 35, what is the maximum amount of pressure a vessel coated with Acrylic Polyurethane could withstand before imploding?

Based on the graph, the maximum amount of pressure a vessel coated with Acrylic Polyurethane could withstand before imploding on day 35 is 11.6 MPa

Teacher Note: Answers may vary between 11.6-11.7 MPa due to the Acrylic Polyurethane line ending slightly above the 11.6 MPa mark.

   b. What depth does that amount of pressure represent?

11.6 MPa is equivalent to 1,160 meters of sea depth

   c. On a 35 day trip, would 1,140 m be a safe depth for a vessel coated in Acrylic Polyurethane to dive without the risk of implosion? Be sure to provide evidence to support your thinking.

Yes. According to the graph, 1,140 meters would be a safe depth for a vessel coated in Acrylic Polyurethane to dive without risk of implosion, because that depth is equivalent to 11.4 MPa of pressure, and the Acrylic Polyurethane coating can allow a vessel to withstand up to 11.6 MPa of pressure before risking implosion after spending 35 days underwater.

Teacher Note: Students may state that it would not be safe to dive that deep because of the narrow margin between the analytical collapse pressure after 35 days of weathering (11.6MPa) and the amount of pressure acting against the vessel (11.4 MPa). Credit for this question should be given to the students that justify their answers with proper reasoning based on the given data.

2) How many days could you expect a vessel coated in Polyurethane to stay at a depth of 1,160 meters without risk of imploding? Be sure to support your thinking with evidence from the graph.

According to the graph, a vessel coated in Polyurethane could stay at a depth of 1,160 meters for 15 days without risk of imploding.

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

3) Dr. Matos tested the model with no coating, called Base PLA, so he could compare its strength to the vessels that do have a coating. Based on the data, overall, do the coatings allow the vessels to withstand more pressure than they would without a coating? Be sure to support your thinking with evidence from the graph.

Yes. According to the graph, all of the vessels with coating were able to withstand more pressure, each day weathered, than the vessel without coating.

4) Write a letter to Dr. Matos, recommending which of the tested materials is best suited for coating a robotic under-water vessel that will be exploring the ocean floor for over a month at depths between 1,180 m and 1,210. Be sure to include evidence to support your thinking.

Teacher Note: Answers will vary. See sample response below for guidance.

Dear Dr. Matos,

If you are sending a robot underwater to explore the ocean floor for more than a month at depths of up to 1,210 meters, I suggest using a vessel coated with Epoxy + Silicone. After a month underwater (about 30 days), the Epoxy + Silicone coating can withstand 12.2 MPa which means it can travel to a depth of 1,220 meters. Based on the graph, the Epoxy + Silicone coating showed the highest resistance to pressure across all days of weathering.

Sincerely,
Rebecca Robinson

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

Task 2: Dr. Watwood is a biologist who is conducting research on seasonal migration patterns of Beaked whales. To do so, she tags (attaches an indicator) Beaked whales with GPS trackers. The data from the trackers can be downloaded after they detach from the whales and float to the surface. Dr. Watwood expects the whales to dive up to 1180 meters, into very cold waters.

1) If Dr. Watwood is planning to collect the data from the trackers after two weeks, which materials can she consider using to coat the equipment without the risk that the equipment will implode? Use evidence from the data to explain your thinking.

If Dr. Watwood is planning to collect data from the trackers after two weeks, she should consider coating her equipment with either Silicone, Acrylic Polyurethane, or Epoxy + Silicone. Either of these three coatings will allow her equipment to withstand more than 11.8 MPa of pressure, which is equivalent to 1,180 meters of sea depth, for more than two weeks, or fourteen days.

2) Which one of the following additional criteria would you recommend Dr. Watwood consider to help her make a final decision about which coating material to use? Explain your reasoning.

<u>Additional criteria to consider for coating material selection</u>

- Cost
- Ability to withstand extremely high heat
- Ability to withstand high winds

Of the mentioned additional criteria, I'd recommend Dr. Watwood to consider the cost of materials to help her make a final decision because the temperature in deeper waters is very cold, so the ability to withstand extremely high heat is irrelevant, and there will be no winds once the materials are below the surface, so the ability to withstand high winds will also be unnecessary.

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

3) Consider the depth the whales will dive, the amount of time the equipment will be in the water, and the cost of the materials shown in the table below. What coating material would you recommend to design the most affordable equipment that can perform the job effectively? Explain your thinking.

Coating Material	Cost
Epoxy and Silicone	Highest
Silicone	↕
Acrylic Polyurethane	
Polyurethane	Lowest

Teacher Note: Answers will vary. See sample response below for guidance.

Because Silicone, Acrylic Polyurethane, or Epoxy + Silicone can all withstand the 11.8MPa of pressure that 1,180 meters of sea depth will act on the equipment for the two weeks Dr. Watwood wants to monitor the whales for, I would recommend designing the equipment to be coated with Acrylic Polyurethane because it will withstand the pressures, but cost her the least.

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

This task supports students in working toward:

NGSS Matter and Its Interactions

5-PS1-3
Make observations and measurements to identify materials based on their properties.

NGSS Engineering Design

3-5-ETS1-1
Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016