The Great Escape! Activity Two: Forces and Pressure

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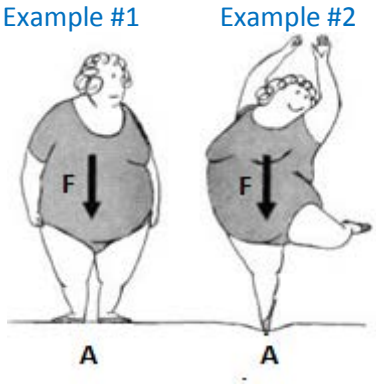
TEACHER NOTE: If Activity One: Displacement and Buoyancy has not been previously completed, see the *introductory video activities* and the common core state mathematics standards, as well as physical science and engineering standards in that activity.

Objectives:

1. Develop an understanding of the concept of pressure.
2. Differentiate the effects of pressure in solids, liquids, and gases.

Procedure Part 1:

1. Consider the image below:



2. The force "F" is represented by the vector in each image. The unit for force is a Newton or N. Compare the force in both examples.

   _____

   _____

   _____

   The force in both examples is the same indicated by the length of the vector

3. The area "A" represents the distribution of the force. The unit for area is m^2. Compare the distribution of the force in both examples.

   _____

   _____

   _____

   The force is distributed over a larger area in example #1

4. Pressure is described as a force distributed over an area. Using "P" for pressure, "F" for force, and "A" for area, write a mathematical equation for pressure.

   _____

   P = F/A

5. Based on your observations and response to the previous questions, conceptually which example has the greatest pressure acting at the surface?

   _____

   Example #2 has the greatest pressure acting at the surface

Note: For teacher use or for independent learners to check their answers to the remainder of the questions in Activity 2 Forces and Pressure Lab Parts 1, 2, and 3, see the red typed script in the section at the end of part 3 below, prior to the two final extension activities.

Math Practice:

1. A lump of cheese with a weight of 20N is placed on a table. It is a cubic lump with an area of 10 cm^2.What pressure does it exert on the table?

   _____

2. Calculate the pressure produced by a force of 800 N acting on an area of 2.0 m^2

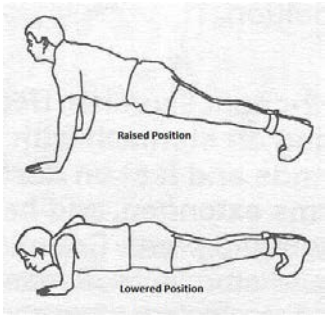
   _____

3. The pressure of a gas contained in a cylinder with a movable piston is 300 Pa. The area of the piston is 0.5 m^2. Calculate the force that is exerted on the piston.

   _____

Extension Activity 1: Push-up Challenge

1. Place your body in the raised push-up position.



2. Lower your body until you achieve the lowered push-up position.
3. Repeat the sequence using all ten of your fingertips. Continue the sequence, each time reducing the number of fingers in contact with the ground equally on each hand..
4. How would you describe the change in pressure in steps 2 and 3?

   _____

   _____

   _____

   _____

Extension Activity 2: Bed of Nails Demonstration

Materials:

1 inch thick piece of Styrofoam at least 20 cm x 25 cm (8 x 10 inches)
Several dozen nails (2 ½ inch flat head nails)
Several balloons
Piece of wood (something hard like a book) at least 20 cm x 25 cm (8 x 10 inches)

Extension Activity Setup:

1. Place several nails at one end of the Styrofoam block.
2. Place several dozen nails at the other end of the Styrofoam block.

Extension Activity Procedure:

1. Ask students: ***What do you think will happen if the balloon is pressed into the side of the Styrofoam with several nails?***
2. Place the balloon onto the side with only several nails. Place the piece of wood or other hard material on top of the balloon and apply force.

Note: Using mass cylinders will reduce variability in applying force, and will allow the students to see a quantifiable relationship between force, area, and pressure.

3. Ask students: ***Why did the balloon pop? Encourage students to identify the force vector and the area where the force is applied.***

Note: If using mass cylinders, then have students quantify the pressure applied to the nails.

4. Ask students: ***What do you think will happen if I do the exact same thing on the side with several dozen nails?***
5. Place the balloon onto of the side with several dozen nails. Place the piece of wood or other hard material on top of the balloon and apply force. (the balloon will not break unless a great deal of force is applied)

Note: If using mass cylinders, then have students quantify the pressure applied to the nails.

6. If you're not quantifying the pressure, then at the teacher's discretion, have several students repeat the demonstration to confirm that additional force was needed to pop the balloon on the side with several dozen nails.

7. Ask students: ***Why does the balloon not break on the bed of nails?*** **(The force is distributed over a larger area).**

8. View the following video about pressure.
   http://www.youtube.com/watch?v=vo2iE94iAoA

"Bed of Nails - Cool Science Experiment." *YouTube*. YouTube, n.d. Web. 23 July 2014.

Activity Two: Forces and Pressure Part 2 & 3; Interactives

Objective:

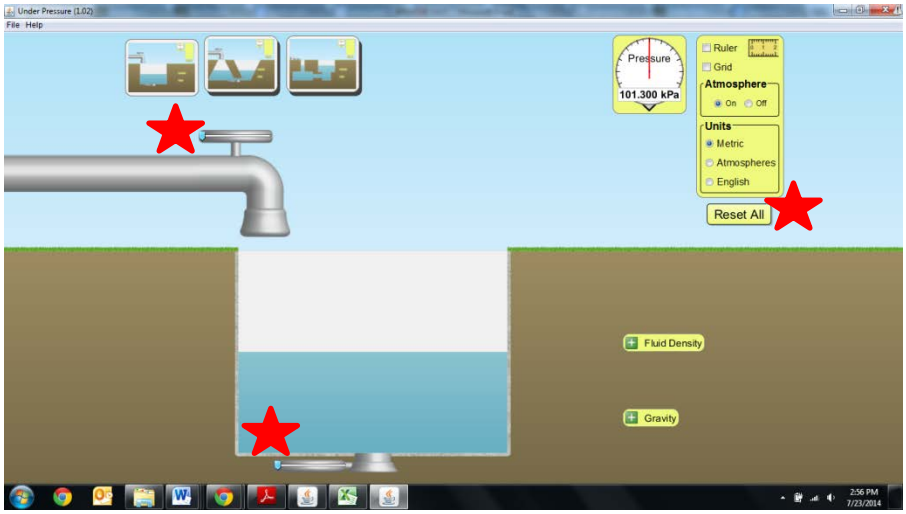
1. Differentiate the effects of pressure in solids, liquids, and gases**.**

Procedure Part 2:

Getting Familiar

1. Visit the following URL for the Phet interactive applet. http://phet.colorado.edu/en/simulation/under-pressure .
2. On the Intro screen, familiarize yourself with the applet by adjusting the volume of water by moving the faucet and drain slide.
3. Familiarize yourself with the measurement tools before beginning the activity.

Note: Before beginning the lab activity be sure to select the "reset all" button, which will return your applet to the default settings.

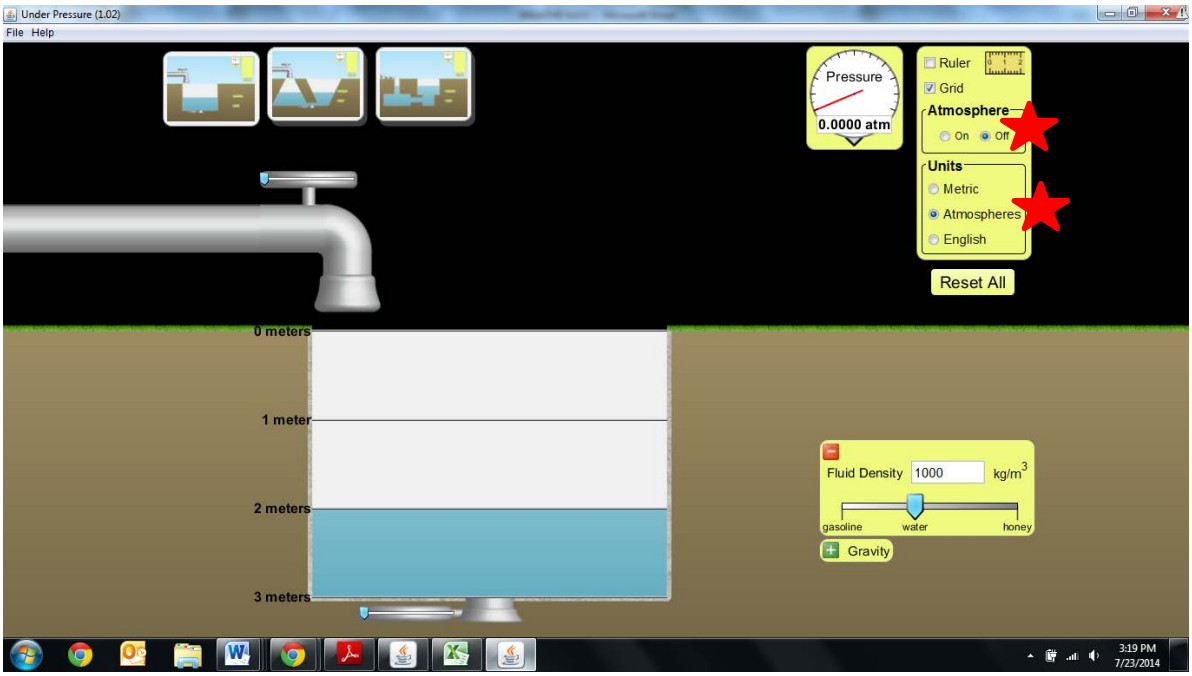


http://phet.colorado.edu/en/simulation/under-pressure

Lab Setup Part 2:

1. In this activity you will investigate pressure in liquids.
2. For this applet you need to turn “off” the Atmosphere feature
3. Be sure to set the units to “atmosphere” for the pressure gauge.

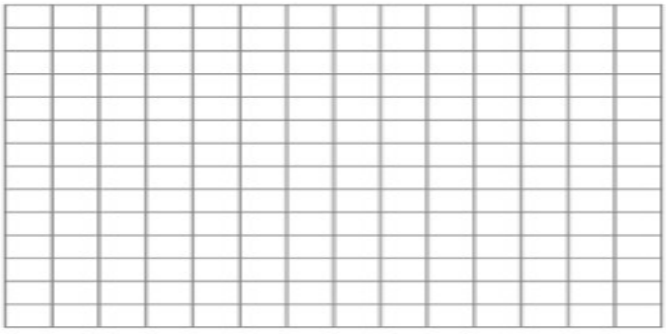
http://phet.colorado.edu/en/simulation/under-pressure



Lab Procedure Part 2:

1. Turn the atmosphere feature to the “off” position
2. Fill the pool by manipulating the faucet slide.
3. Measure the pressure at a depth of 1 meter. Record your reading in the data table.
4. Measure the pressure at a depth of 2 meters. Record your reading in the data table
5. Measure the pressure at a depth of 3 meters. Record your reading in the data table.
6. Graph your data:

Depth (m)	Pressure (atm)
1	
2	
3	



Summary questions:

1. Discuss any patterns / trends in your data. Explain your observations

   _____
   _____
   _____

2. Based on what you learned about pressure in previous activities, which variable is manipulated when you record the pressure at various depths.

   _____
   _____

3. Put the gauge at a depth of exactly 2 meters. Now change gravity to 4.9 m/s/s and then 19.6. Explain any patterns.

   _____
   _____
   _____

4. Return the gravity to 9.8 m/s^2. Put the gauge at a depth of 2 meters. Change the fluid density to 700 kg/m^3 and 1400 kg/m^3. Explain any patterns.

   _____
   _____
   _____

5. Summarize questions #1-4 by stating what factors affect pressure and whether the effects are direct or inversely related.

   _____
   _____
   _____

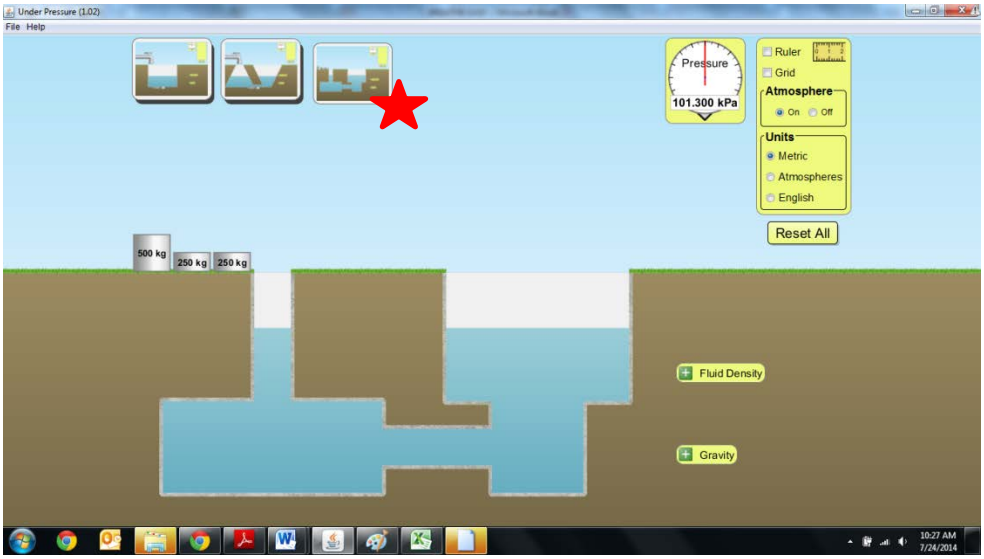
Procedure Part 3:

Getting Familiar

1. Visit the following URL for the Phet interactive applet. http://phet.colorado.edu/en/simulation/under-pressure
2. Select the 3rd display screen for this activity, it should look like the one below.
3. On the Intro screen, familiarize yourself with the applet
4. Familiarize yourself with the measurement tools before beginning the activity.

Note: Before beginning the lab activity be sure to select the "reset all" button, which will return your applet to the default settings.

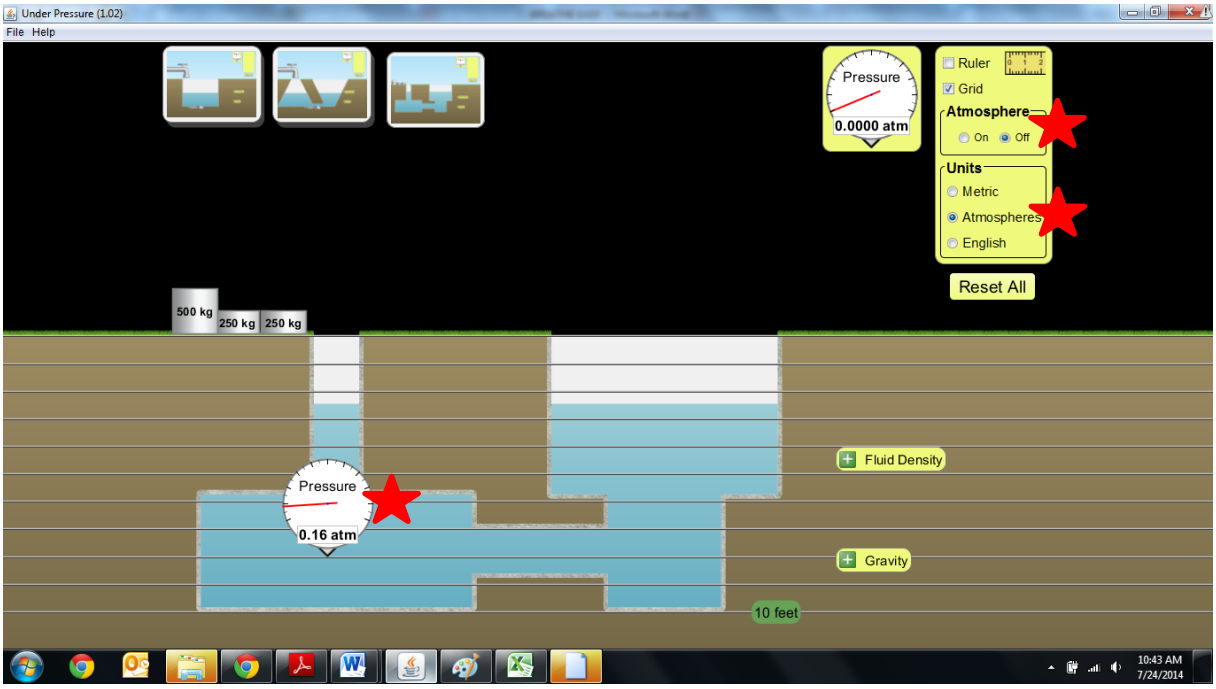
http://phet.colorado.edu/en/simulation/under-pressure



Lab Setup Part 3:

1. In this activity you will investigate pressure in liquids.
2. For this applet you need to turn "off" the Atmosphere feature
3. Be sure to set the units to "atmosphere" for the pressure gauge.

Note: Using psi or kPa will yield greater precision and be easier to quantify changes in pressure.



http://phet.colorado.edu/en/simulation/under-pressure

Lab Procedure Part 3:

1. Place two pressure gauge in the left pool until the gauge reads 0.16 atm (see image)
2. Drop a 250 kg mass into the hole
    a. Does the water exert a force on the 250 kg mass? Explain how you know

    _____

    _____

    _____

    _____

    b. Did the pressure change? By how much?

    _____

    _____

    _____

    c. Remove the mass. Place a second pressure gauge at a depth equal to the first gauge in the other pool of water. Drop a 250 kg mass into the hole. Did the pressure change? By how much? Compare this to your response to question 2b.

    _____

    _____

    _____

    _____

    _____

    d. What happens to the gauges if you <u>add 500 kg</u> of mass?

    _____

    _____

    _____

e. Select the “ruler tool”, and try dropping the 250 kg mass into the hole again. Observe the movement of the water carefully. Measure the height of the water on both sides. Based on your observations do you think liquids can be compressed? Explain your reasoning.

_____
_____
_____
_____

f. Turn on the atmospheric pressure. What happened? Explain your observations using what you have learned about pressure in previous activities.

_____
_____
_____

Check your answers to the questions in Activity 2 Forces and Pressure Lab Parts 1, 2, and 3, in the red typed script for the questions repeated below.

Math Practice Answers:

1. A lump of cheese with a weight of 20N is placed on a table. It is a cubic lump with an area of 10 cm^2.What pressure does it exert on the table?

   _____
   $P = (20\ N) / (10\ cm^2) = 10\ N/cm^2$
2. Calculate the pressure produced by a force of 800 N acting on an area of 2.0 m^2

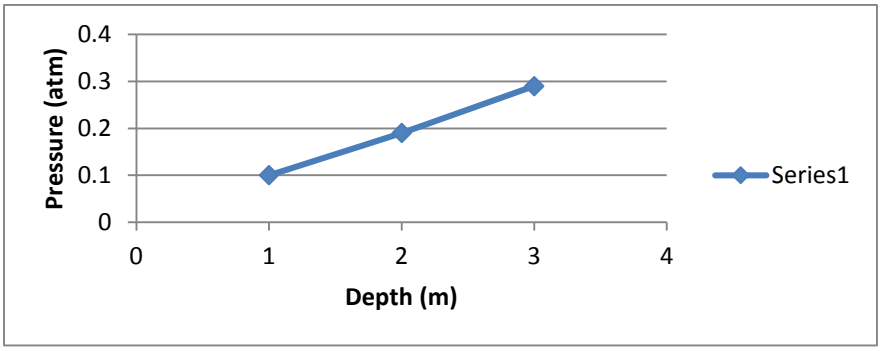
   _____
   $P = (800\ N) / (2.0\ m^2) = 400\ N/m^2$
3. The pressure of a gas contained in a cylinder with a movable piston is 300 Pa. The area of the piston is 0.5 m^2. Calculate the force that is exerted on the piston.

   _____
   $F = PA,\ F = (300\ Pa)\ (0.5\ m^2) = 150\ N$

Activity 2, Lab Procedure Part 2 Answers

6. Graph your data

Depth (m)	Pressure (atm)
1	0.10
2	0.19
3	0.29



Summary questions:

1. Discuss any patterns / trends in your data. Explain your observations

   _____

   _____

   _____

   The pressure increases with depth
2. Based on what you learned about pressure in previous activities, which variable is manipulated when you record the pressure at various depths.

   _____

   _____

   The force applied is increased with depth
3. Put the gauge at a depth of exactly 2 meters. Now change gravity to 4.9 m/s/s and then 19.6. Explain any patterns.

   _____

   _____

   _____

   When the gravity is increased the pressure increases. The increase in the gravity generates a greater downward force
4. Return the gravity to 9.8 m/s^2. Put the gauge at a depth of 2 meters. Change the fluid density to 700 kg/m^3 and 1400 kg/m^3. Explain any patterns.

   _____

   _____

   _____

   When the density is increased the pressure increases. The increase in the density increases the mass of the same volume of fluid, therefore creating a greater downward force.
5. Summarize questions #1-4 by stating what factors affect pressure and whether the effects are direct or inversely related.

   _____

   _____

   _____

   Pressure is directly related to the force that is applied, but inversely related to the area that the force is distributed over.

Activity 2, Lab Procedure Part 3 Answers

1. Place two pressure gauge in the left pool until the gauge reads 0.16 atm (see image)
2. Drop a 250 kg mass into the hole

    a. Does the water exert a force on the 250 kg mass? Explain how you know

    The object does not sink, so the water must exert a buoyant force on the object that is equal to the weight of the object

    b. Did the pressure change? By how much?

    The pressure changed from 0.16 atm to 0.17 atm

    c. Remove the mass. Place a second pressure gauge at a depth equal to the first gauge in the other pool of water. Drop a 250 kg mass into the hole. Did the pressure change? By how much? Compare this to your response to question 2b.

    The pressure change that occurred in 2b was identical to the pressure measured on the 2nd gauge

    d. What happens to the gauges if you add 500 kg of mass?

    The pressure gauge in both pools read 0.18 atm

    e. Select the "ruler tool", and try dropping the 250 kg mass into the hole again. Observe the movement of the water carefully. Measure the height of the water on both sides. Based on your observations do you think liquids can be compressed? Explain your reasoning.

    No, the water level in both pools is identical. This illustrates that the pressure is distributed throughout the liquid, indicating the general incompressibility of liquids.

f. Turn on the atmospheric pressure. What happened? Explain your observations using what you have learned about pressure in previous activities.

_____
_____
_____
_____

Turning on the atmospheric pressure illustrated that the weight of the air contributes to the weight of the water acting on a submerged object.

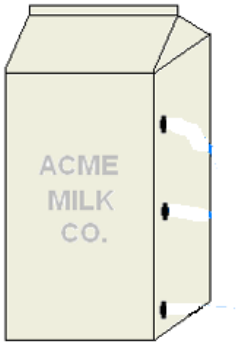
Extension Activity 3: Bottle Fountain

Materials:

1 plastic bottle or other available container
Water
Tool to drill at least three holes

Extension Activity Setup:

1. Drill 3 holes in the bottle in a vertical arrangement. Place the holes at least 2.54cm (1 inch) apart



Extension Activity 3 Procedure:

1. Plug the holes with your fingers
2. Fill the bottle and place the cap on the bottle.
3. Expose the holes and observe the water flow from each hole.

Extension Activity 3 Questions, answers in red:

Note: You can quantify the activity by using a ruler to measure the initial contact points of the water flow from each hole.

1. Observe the flow of water through the holes. What are your initial observations?
   _____
   _____
   _____
   _____
   The water spout at the bottom is longer than the spout at the top.
2. What appears to happen to the flow over time?
   _____
   _____
   _____
   All three water spouts begin to decrease in length over time
3. Use what you learned in previous activities to explain why there are variations in the length of the water spout from each of the three holes.
   _____
   _____
   _____
   _____
   The weight of the water provides the force. The weight of water over moving through the bottom hole is the greatest; therefore the spout on the bottom travels the furthest.

Extension Activity 4: Water Balloon

Materials:

1 balloon
Water
Needle, or something to poke holes in balloon with

Extension Activity 4 Setup:

1. Fill balloon with water

Extension Activity 4 Procedure:

1. Tie off balloon so there is very little air trapped inside.

2. Quickly poke several holes around the perimeter of the balloon and squeeze.

3. Observe the flow of water through the holes in the balloon. What are your initial observations?

   _____
   _____
   _____
   _____

   The water flows from each of the holes

4. How would you describe the flow of water from hole? Explain your observations.

   _____
   _____
   _____
   _____

   The water flows equally from each hole. This suggests that the force is originating from the center. It also suggests that the water is not able to be compressed, and the pressure is transmitted