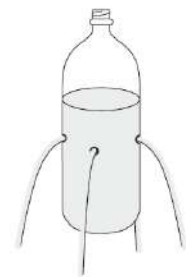
On-line activities for static fluids labs

Below is the list of experiments (real, video based and data-based) that students can perform as labs for static fluids. For each experiment we provide goals, equipment and rubrics for self-assessment. Rubrics can be found at https://sites.google.com/site/scientificabilities/rubrics

1. Observational experiment: holes in water bottle

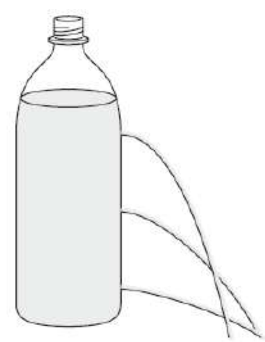
Goal: To explain an experiment using the concept of pressure.

Equipment: plastic bottle with small holes made around the circumference, a bottle with three holes covered with thumbtacks, a tray to collect water.



a. Use an opened 32-oz plastic bottle full of water that has been punctured in four places with thumbtacks (to make small holes, put pieces of Scotch tape first and then use the tacks to puncture the bottle). Hold the bottle about 1 m above the tray. Remove the thumbtacks from the bottle and observe the streams of water leaving the bottle.

Explain your observation using the concept of pressure.



b. As shown in the figure, use a plastic bottle with three punctured holes that are closed with thumbtacks. Hold the bottle about 1 m above the tray. Remove the thumbtacks and observe the water streaming out of the holes. Explain your observations.

2. Testing experiment: holes in water bottle

Goal: to make a prediction based on a hypothesis

Equipment: a bottle with three holes covered with thumbtacks, tray to collect water.

Rubrics for self-assessment: Ability to conduct a testing experiment C4, C7, C8.

If the explanation you devised in the previous activity is correct, predict what will happen when you take the same bottle, close the lid, and then remove only the top and the bottom tack at the same time.

a. Predict the outcome.

b. Explain how you made your prediction.

c. Perform the experiment; record the outcome. Sketch what you observed.

d. Do the results of your experiment allow you to reject or gain confidence in your explanation? Explain your reasoning.

3. Application experiment: drinking straw

Goal: To apply the knowledge of pressure to explain a real-life phenomenon

Equipment: cup with water, a straw.

Rubrics for self-assessment: Ability to represent information in multiple ways A5.

Fill a cup with water and insert a straw as if you are going to have a sip. Notice the level of water in the straw. Then, tightly cover the top of the straw with your finger and lift the straw from the water. Notice the amount of water in the straw. Sketch what you observe. Draw a force diagram for the water inside the straw. Use the force diagram to explain why the water does not "fall out" of the straw.

4. Observational experiment: pressure-vs-depth

Goal: to analyze data to determine how the pressure changes with depth in a liquid

Equipment: none

Rubrics for self-assessment: Ability to conduct an observational experiment B7, B8, and B9.

Watch the video of the experiment [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-13-3-5] and then proceed to the following questions.

a. Construct a graph of pressure versus depth. Describe which point on the set-up you used to determine the depth.

b. Based on the line of best fit for your graph, write a relation between pressure and the distance of the measuring point below the surface of the water.

c. Explain the relation.

d. Explain why the height of the water column inside the plastic tube increases as the tube is lowered into the water. Suggest the physical law that you can use to predict the height of the water column inside the tube for a particular position of the tube. Indicate any assumptions that you made.

5. Observational experiment: two straws

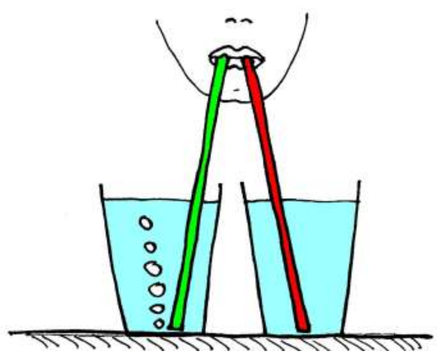
Goal: Explain the results of an experiment

Equipment: two identical transparent containers (large plastic cups, glasses or 0.5-liter water bottles with cut tops), two identical straws, sugar.

Rubrics for self-assessment: Ability to conduct an observational experiment B5, B7 and B7.

For this experiment ,you will need to prepare a sugar solution in water. The proportion is about 200 g of sugar per 1 liter of water. For the experiment, you only need about 200 ml of water therefore less sugar (do the calculation).
a. Prepare two identical containers. Pour tap water in one of them and sugar water solution in the other. Make sure the level of water in both containers is the same.

b. Hold the two straws in your mouth and lower their other ends into the water of the two containers so that both straws are almost touching the bottom (but are not in contact with it, see the figure below).



Start blowing into the straws until bubbles come out. In which container do the bubbles come out? Blow a little harder. Can you make the bubbles come out in the other container?

c. Explain your observations. Why do bubbles only come out in one container and not in the other container? How can your graphs explain why you cannot make the bubbles come out of the straw in the second container?

6. Application experiment: bottomless bottle

Goal: To explain complex experiments by applying the knowledge of pressure variation with depth and atmospheric pressure.

Equipment: none

In the video [https://youtu.be/7Aix6SqEi3A] the experimenter uses a 0.5 liter water bottle with the bottom cut off. In the bottle, there is a 5-mm diameter hole, about ¼ way down from the top. The hole is taped over with masking tape.
a. The bottle (without the cap) is placed into a container with water. The water level is above the taped hole). Watch the water level in the container and inside the bottle. Are they the same?

b. Now the experimenter will tightly close the bottle with the cap and lift the bottle up by holding it from the cap. The bottle does not completely leave the water. Observe what happens to the water level inside the bottle [https://youtu.be/U7d2071nsgY]. Explain. Use a pressure-vs-depth graph to justify your explanation.
c. Now, observe what happens when the experimenter removes the tape [https://youtu.be/W0tGw5eGUBI]. Explain. Justify your explanation by using the pressure-vs-depth graph.

7. Observational experiment: how does water push? Part I

Goal: Use force diagrams to explain the outcomes of an experiment.

Equipment: none

Rubrics for self-assessment: Ability to represent information in multiple ways A5 and ability to conduct an observational experiment B7 and B9.

a. Observe the experiment [https://youtu.be/_D4U-wen360] and make a list of patterns you notice.
b. Draw force diagrams for the object above water, half submerged and totally submerged at two different depths.

c. What can you conclude about the force that water exerts on the object when it is totally submerged: does it increase with depth or stay constant? Devise an explanation for your conclusion.

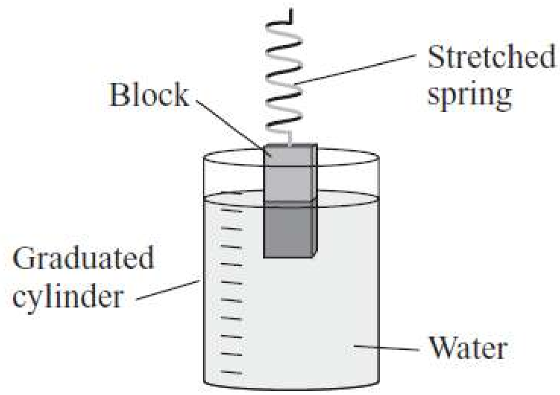
8. Observational experiment: how does water push? Part II

Goal: Find a quantitative relationship between the force exerted by a liquid on the submerged object and relevant physical quantities.

Equipment: none

Rubrics for self-assessment: Ability to conduct an observational experiment B3, B7, B8, and B9.

Experiment: A 2.0-kg block made of aluminum is attached to a Newton spring scale and is slowly lowered into a graduated cylinder filled with water. The experiment is repeated, only this time with a 2.0-kg copper block. The readings of the scales and the readings of the water level at the top surface of the water in the cylinder are shown in the table that follows.



Scale reading for the aluminum block	**Water level in the graduated cylinder**	**Volume of the aluminum block under the water**	**Scale reading for the copper block**	**Water level in the graduated cylinder**	**Volume of the copper block under the water**
19.60 N	200 ml	0	19.60 N	200 ml	0
19.10 N	250 ml	50 ml	19.10 N	250 ml	50 ml
18.60 N	300 ml	100 ml	18.60 N	300 ml	100 ml
18.10 N	350 ml	150 ml	18.10 N	350 ml	150 ml
17.60 N	400 ml	200 ml	17.60 N	400 ml	200 ml
15.60 N	600 ml	400 ml	17.36 N	424 ml	224 ml (just submerged)
13.60 N	800 ml	600 ml	17.36 N	424 ml	224 ml (deeper in water)
12.20 N	940 ml	740 ml (just submerged)	17.36 N	424 ml	224 ml (even deeper)
12.20 N	940 ml	740 ml (deeper in water)	17.36 N	424 ml	224 ml (even deeper)

a. Use the data in the table to find a pattern in the magnitude of the upward force that the water exerts on each block. *Hint:* Remember that the density of water is $1000\ \text{kg/m}^3$.

b. After the copper block is completely submerged, the scale reads 17.36 N. After the aluminum block is completely submerged, the scale reads 12.20 N. Both readings do not change when the blocks are lowered deeper under the water. Are these results consistent with the findings in Experiment 7?

9. Observational experiment: how does oil push?

Goal: Find a quantitative relationship between the force exerted by a liquid on the submerged object and relevant physical quantities.

Equipment: none

Rubrics for self-assessment: Ability to conduct an observational experiment B3, B7, B8, and B9.

Experiment 8 is repeated again, but this time the blocks are lowered into vegetable oil. Use the data recorded in the table below to find a pattern in the magnitude of the upward force that the oil exerts on each block. *Hint:* Remember that the density of oil is $900\ \text{kg/m}^3$.

Scale reading for the aluminum block	**Oil level in the graduated cylinder**	**Volume of the aluminum block under the oil**	**Scale reading for the copper block**	**Oil level in the graduated cylinder**	**Volume of the copper block under the oil**
19.60 N	200 ml	0	19.60 N	200 ml	0
19.16 N	250 ml	50 ml	19.16 N	250 ml	50 ml
18.70 N	300 ml	100 ml	18.70 N	300 ml	100 ml
18.26 N	350 ml	150 ml	18.26 N	350 ml	150 ml
17.80 N	400 ml	200 ml	17.80 N	400 ml	200 ml

a. In Experiments 7, 8, and 9 what pattern emerges between the volume of the object in the liquid and the effect of the liquid in supporting the object?

b. Use this pattern to devise an expression for the lifting force exerted by a liquid on an object that is partly or totally submerged in the liquid.

10. Testing experiment: containers and scales

Goal: To make predictions of the outcome of an experiment using the idea under test

Equipment: none

Rubrics for self-assessment Ability to conduct a testing experiment C4 and C8

You place a plastic container with water on a scale and observe the reading (see the figure on the left below). Then, you hang a 1-kg object from a string and submerge it in the water so that the bottom of the object does not touch the bottom of the container (see the figure on the right below). You notice that the scale reading increases and the water level goes up. Your friends suggest the following explanations for the increase in the scale reading:

Scale reading: 620 g

Scale reading: 750 g

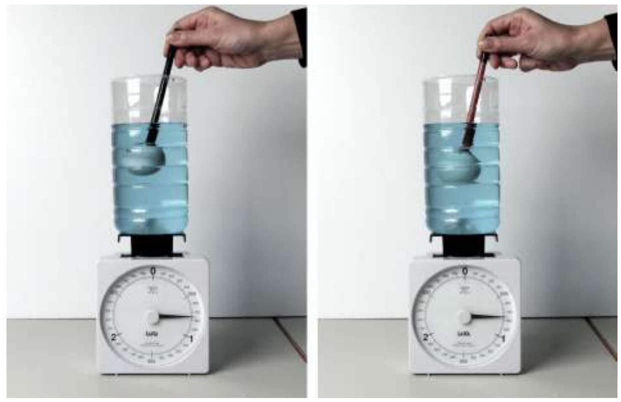
Finn: The water exerts an upward force on the submerged object. According to Newton's third law, the object consequently exerts a force on the water that is an equal in magnitude and opposite in direction (downward). This force makes the water press harder on the container and the container press harder on the scale.

Dimitry: Some mass of the immersed part of the object adds to the mass of the water. As a result, the force exerted by the container on the scale increases.

Alex: The immersed object exerts no force on the water, but it does make the water rise. The higher the level of the water, the more pressure on the bottom surface of the container. Consequently, this causes a larger the force to be exerted by the container on the scale.

While testing their explanations, your friends designed the following testing experiments:

Testing experiment 1



Testing experiment 2

<u>Testing experiment 1</u>: Squeeze the container to achieve the same increase in water level as when immersing the 1-kg object. Record the reading of the scale.

<u>Testing experiment 2:</u> Submerge in the water a ping-pong ball fixed on the end of a thin stick and record the change in the scale reading. Then, repeat the experiment with a ping-pong ball filled with sand.

a. Before reading on, make predictions for the outcome of each testing experiment based on each explanation proposed by your friends.

The outcomes of the testing experiments are as follows:

<u>Outcome of TE1</u>: The scale reading is 620 g (note: the cardboard “squeezers” were also on the scale in the original experiment)

<u>Outcome of TE2:</u> In both cases, the scale reading increases by 30 g.

b. Compare the outcomes of the testing experiments with your predictions and decide which explanation(s) you can reject and which you cannot reject.

c. Based on the explanation(s) that you were not able to reject, draw a force diagram for the water-container object. Draw another force diagram for the 1-kg object in the case when the 1-kg object is immersed in the water (as is the case in the figure on the right at the beginning of this activity).

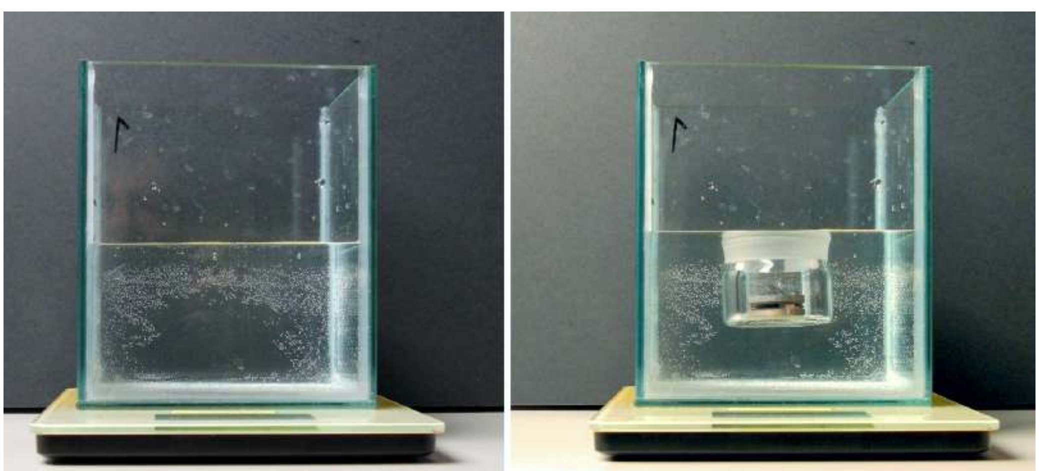
d. Try to explain the outcome of testing experiment 1. (*Hint:* draw the forces that the water in the container exert on different parts of the container's walls.)

11. Application experiment: beakers and scales

You have a scale, a small glass beaker, a metal object, and a square glass container (base 130 mm × 130 mm, height 150 mm) with water (see the figure below, from left to right).

First, you zero the scale. Then you put an empty small glass beaker on the scale and record the mass: $m_{\mathrm{GB}} = 33\ \mathrm{g}$. Then you put the square glass container including water on the scale and record the mass: $m_{\mathrm{CW}} = 1851\ \mathrm{g}$ (see the next figure, photo on the left).

Then you put the metal object on the bottom inside the small glass beaker and carefully place them both on the surface of the water. When you release the beaker, it floats with its upper edge just aligned with the water surface but no water enters the beaker (see the next figure, photo on the right). At this point, you record a new scale reading $m_{\mathrm{CWBO}} = 1927\ \mathrm{g}$.

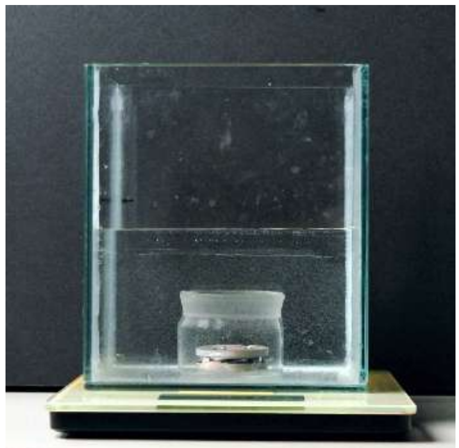


a. Estimate the volume of the small glass beaker based on the measured masses. How else can you estimate the volume of the glass beaker? Describe a second method. Indicate any assumptions that you made. Compare the results from the two methods. Are the results of these two methods consistent with each other?

b. Estimate the mass of the metal disk.

c. Estimate the volume of the water in the glass container.

d. You slightly push the small glass beaker that is floating so that the water fills the beaker and it sinks to the bottom (see the figure below). Predict the final reading of the scale.



12. Application experiment: crazy test tube

Goal: to use force diagrams and energy bar charts to explain the outcome of an experiment

Equipment: none

Rubrics for self-assessment: Ability to represent information in multiple ways A5 and A8

Observe the video of a test tube with some ball bearings in water
[https://youtu.be/VxTkQTFVvzk]

a. Describe what you observe. What kind of motion does the test tube undergo? How do you know?

b. Draw two motion diagrams for the upward motion of the tube (one when the test tube starts moving up and the other one when the test tube approaches the top of the upward motion). Then draw corresponding force diagrams for one point of each motion diagram.

c. Repeat part **b** for the downward motion (the beginning and before the test tube stops and reverses direction).

d. When does the test tube have its maximum kinetic energy? Where does the kinetic energy of the moving test tube come from? Explain using a bar chart. State your chosen system and describe the initial and final states

e. Use the data in the video to determine the period and amplitude of vibrations. The video is recorded in real time at 30 frames per second.