# Chapter 13

# Static Fluids

## *13.1 Density*

### 13.1.1 Observe and find a pattern

***Lab or class:*** *Equipment per group:* graduated cylinder, water, baby oil, scale.

Use a graduated cylinder and a scale to collect data of the masses and volumes of baby oil and water (vary the volume between 50 ml and 250 ml).

| **Volume $(\text{ml} = \text{cm}^3)$** | **Mass of water (g)** | **Mass of oil (g)** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**a.** Graph mass versus volume for each liquid using the same set of axes.

**b.** Examine the two graphs and discuss with your group the similarities and differences. Come up with a name that you can use for the ratio of the mass and the volume as represented by the slope of the graph.

**c.** Choose a particular value of the volume on the $V$-axis and find the corresponding values of the mass of both liquids. Which mass is larger?

**d.** Choose a particular value of the mass on the $m$-axis and find the corresponding values of the volume for both liquids. Which volume is larger?

### 13.1.2 Design an experiment

***Lab or class:*** *Equipment:* a rock, other pieces of equipment to be determined.

Use a rock that you find outside and work with your group members to design an experiment to determine its density.

**a.** Describe the experiment and the data that you will collect.

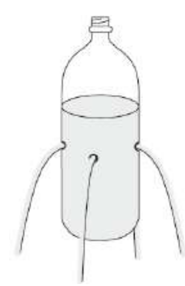
**b.** Obtain necessary equipment, collect and analyze data, and determine the value of the density.

**c.** How precise is the value you found? Write your finding as an interval.

### 13.1.3 Reading exercise

Interrogate Section 13.1 in the textbook and answer Review Question 13.1

## *13.2 Pressure inside a fluid*



### 13.2.1 Observe and explain

***PIVOTAL Lab or class:*** *Equipment per group:* plastic bottle with small holes made around the circumference, a tray to collect water.

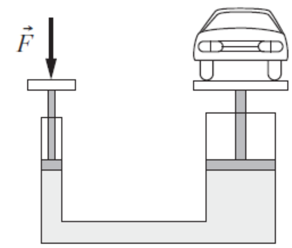
 

Use a 32-oz open plastic bottle full of water punctured in four places with thumbtacks. Hold the bottle about 1 m above the tray. Remove the thumbtacks from the bottle and observe the streams of water leave the bottle.

Explain your observation using the concept of pressure.

### 13.2.2 Reason

***Class:*** *Equipment:* none.




A hydraulic lift has a small plunger on one side of a container of liquid and another large plunger on the other side. You can push down on the small plunger, exerting a relatively small force, and lift a heavy object sitting on the other plunger. Explain how this is possible. *Hint:* Think of the cross-sectional area under each plunger, the relationship between pressure and force, and Pascal's Law.

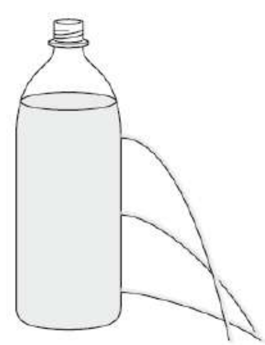
### 13.2.3 Reading exercise

Interrogate Section 13.2 in the textbook and answer Review Question 13.2

## *13.3 Pressure variation with depth*

### 13.3.1 Observe and explain

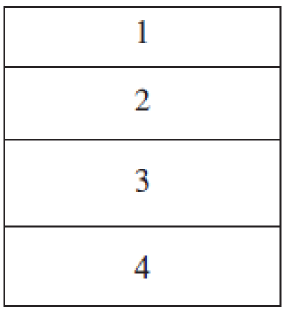
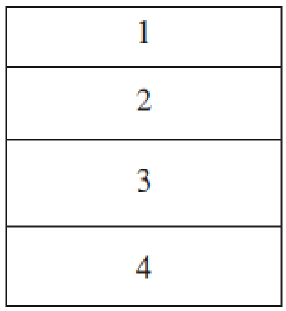
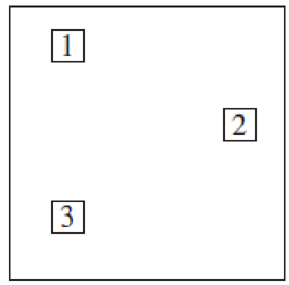
***PIVOTAL Lab or class:*** *Equipment per group:* a bottle with three holes covered with thumbtacks, tray to collect water.



Use a bottle with three holes punctured as shown in the figure and closed with thumbtacks. Hold the bottle about 1 m above the tray. Remove the thumbtacks and observe the water streaming out of the holes. Your goal is to explain the observation.

To help explain this experiment, imagine dividing the liquid in the bottle into horizontal layers and examine the forces that the layers exert on each other. Use Newton's third law for reasoning. Work with your group members to fill in the table that follows.

| **Draw force arrows to indicate the force that layer 1 exerts on layer 2, layer 2 exerts on layer 3, and layer 3 exerts on layer 4. Indicate the relative magnitudes of the forces by the lengths of the arrows.** | **Draw force arrows to indicate the force that layer 4 exerts on layer 3, layer 3 on layer 2, and layer 2 on layer 1. Indicate the relative magnitudes of the forces by the lengths of the arrows.** | **Draw arrows representing the pressure that the liquid exerts on very small surfaces inside the liquid shown below. Remember that liquids exert pressure in all directions.** | **Use the drawings in this table to help explain the experiment with the three thumbtacks.** |
|---|---|---|---|
|  |  |  | |

## 13.3.2 Test your idea

***Lab:*** *Equipment:* same as in the activity above.

Work with your group members to predict what happens if you take the same bottle, close the lid, and then remove only the top and the bottom tacks, if the explanation you devised in the previous activity is correct.

**a.** Predict the outcome.

**b.** Explain how you made your prediction.

**c.** Perform the experiment; record the outcome.

**d.** Make a judgment about the explanation that you used to make the prediction: Was it supported or not?

## 13.3.3 Observe and explain

***PIVOTAL Lab or class:*** *Equipment per group:* whiteboard and markers.

You slowly lower a pressure sensor into a lake and measure the pressure at different depths in the water (see the table below).

| **Pressure** $\left(\mathrm{N/m^2}\right)$ | **Distance below surface (m)** |
|---|---|
| 95,000 | 0 |
| 203,000 | 10 |
| 298,000 | 20 |
| 405,000 | 30 |

**a.** Construct a graph of pressure versus depth.

**b.** Based on the graph line, write a relation between pressure and the distance below the surface of the water.

**c.** Explain the relation.

## 13.3.4 Observe and explain

***PIVOTAL*** ***Lab or class:*** *Equipment per group:* whiteboard and markers.

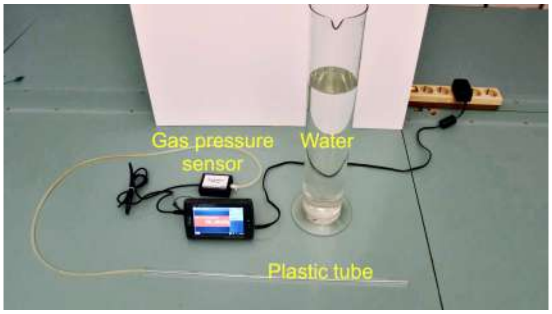
You repeat the previous experiment but this time in ocean water. The table shows the readings of the pressure sensor.

| **Pressure** $\left(\mathrm{N/m^2}\right)$ | **Distance below surface (m)** |
|---|---|
| 103,000 | 0 |
| 207,000 | 10 |
| 313,000 | 20 |
| 420,000 | 30 |

Explain why the readings are different from the readings in Activity 13.3.4.

## 13.3.5 Observe and explain

***PIVOTAL*** ***Class or lab:*** *Class equipment:* whiteboards, markers, video. Lab: pressure sensor, rubber tubing, plastic or glass tube, measuring cylinder, meter stick, water (see the photo on the right).




You connect one end of a rubber tubing to the pressure sensor and the other end to a plastic tube. You hold the plastic tube in a vertical position and lower it slowly into the water in a large cylinder. 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 graph line, 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 particular position of the tube. Indicate any assumptions that you made.

## 13.3.6 Test an idea

***Lab:*** *Equipment:* to be determined in the activity.

Two of your friends disagree on how the pressure in a liquid depends on different physical quantities. Ari thinks that the pressure depends only on the depth—the deeper you go in the same liquid, the greater the pressure. Maria thinks that the mass of liquid above the level at which one measures the pressure matters.

**a.** Discuss supporting arguments for Ari's and Maria's hypotheses.

**b.** Describe an experiment you can perform to find out whose idea can be ruled out, in words and with a sketch.

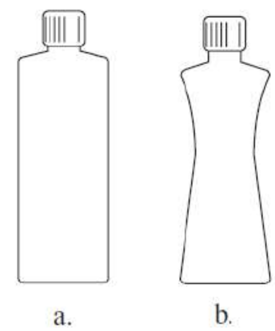
**c.** Make a list of equipment that you might need.

**d.** Predict the outcome of the experiment based on each hypothesis.

**e.** Perform the experiment; record the outcome and decide whose hypothesis can be rejected.

## 13.3.7 Reason

***Class:*** *Equipment:* none.




You drink water from a plastic bottle while traveling on an airplane. When the water is gone, you close the bottle and leave it under the seat. It looks like the bottle in part a. of the figure at right. When the plane lands you pick up the bottle and to your surprise the bottle looks like the bottle in part b. of the figure. Explain this observation by combining your knowledge of molecules, which you acquired in Chapter 12, with the new knowledge of the elevation dependence of fluid pressure that you acquired in this section.

## 13.3.8 Test an idea

***PIVOTAL*** ***Lab or class:*** *Equipment per group:* whiteboard, whiteboard markers, drinking glass, piece of smooth cardboard.

Use your understanding of atmospheric pressure to predict the outcome of the following experiment: Fill a glass with water all the way to the top. Slide a piece of smooth cardboard over the top of the glass so that no air is let in and invert the glass so that it is upside down (you are holding it upside down). Explain how you made the prediction before performing the experiment. Then perform the experiment and compare the outcome to the prediction.

## 13.3.9 Reading exercise

Interrogate Section 13.3 in the textbook and answer Review Question 13.3.

# *13.5 Buoyant force*

## 13.5.1 Observe and explain

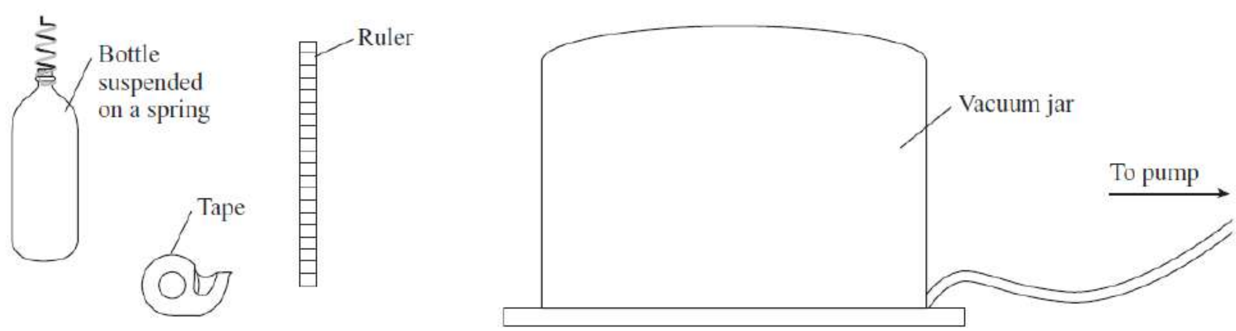
***Class:*** *Equipment:* Whiteboard and markers.

You can lift objects immersed in water that are too heavy to lift when in the air (for example, you can easily lift your friend in a pool). Draw a force diagram to support your explanation for why this is possible.

## 13.5.2 Test an idea

***Class or lab:*** *Equipment:* one set-up of the equipment shown below.

Hang a 2-liter empty plastic bottle from a spring; the spring stretches. Joshua says that the spring stretches because the air pushes down on the bottle. Taisha disagrees. She thinks that the air pushes up in a similar way to the water pushing up on a person in a pool, and the spring stretches due to Earth pulling down on the bottle. How can you test these ideas using the equipment shown below?




**a.** Describe your experiment in words.

**b.** Predict the outcome based on Joshua's hypothesis.

**c.** Predict the outcome based on Taisha's hypothesis.

**d.** Perform the experiment, record the outcome of the experiment, and decide whose hypothesis can be rejected.

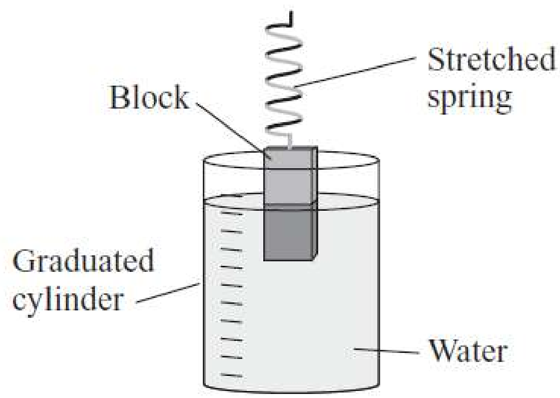
 

## 13.5.3 Observe and explain

***PIVOTAL Class or lab:*** *Equipment per group in the lab:* spring scale, two metal objects (made of aluminum and copper, same mass) to hang, graduated cylinder, water.

Read the description of the experiment below. If you have similar equipment, conduct the experiment and record your own data. If you do not have the equipment, use the data provided below.

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 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. Explain these results using the pattern that you found in part **a**.

## 13.5.4 Observe and explain

***PIVOTAL Class:*** *Equipment:* none.

The experiment described in the previous problem is repeated again, but this time the blocks are lowered into vegetable oil. Use the data recorded in the table to find a pattern in the magnitude of 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 |

## 13.5.5 Observe and explain

***PIVOTAL* *Class or lab:*** *Equipment:* none.

**a.** In Activities 13.5.3 and 13.5.4, what pattern emerges between the volume of the object in 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 partly or totally submerged in the liquid.

## 13.5.6 Test your idea

***PIVOTAL* *Lab:*** *Equipment:* spring scale, metal block, container (with water) large enough so that the block can be completely submerged in water.

Use the available equipment to predict the spring scale reading when you hang a block completely submerged in water of density 1000 $kg/m^3$.

**a.** Record the spring scale reading of the block in the air.

**b.** List the quantities that you need to measure to predict the reading of the scale when the block is submerged in water.

**c.** Write a procedure to predict the reading of the scale when the block is completely submerged.

**d.** Perform the experiment; record the actual value, and then reconcile it with your prediction.

**e.** Will the reading change if you continue lowering the block deeper into the water?

## 13.5.7 Test your ideas

***Lab or class:*** *Equipment:* Container with oil, container with water, a beaker.

Discuss with your group members what will happen when you pour water into a glass beaker partially filled with oil. Use the values for the densities of water and oil and your knowledge of buoyant force to make the prediction. Then perform the experiment and record the result. Did the prediction match the outcome?

## 13.5.8 Observe and explain

***Lab or class:*** *Equipment per group or just one set-up:* an unopened can of regular Coke® and an unopened can of Diet Coke®. Large container filled with water in which both can be submerged simultaneously, scale, graduated cylinder.

Submerge the can of Diet Coke® in water and submerge the can of regular Coke® in water.

**a.** Record your observations.

**b.** Explain your observations qualitatively.

**c.** Explain your observations quantitatively using available equipment.

**d.** List the quantities that you will measure.

**e.** List the quantities that you will calculate.

**f.** Write a mathematical procedure that will help you explain the outcome.

**g.** Collect relevant data, do the calculations, and explain the outcome of the experiment quantitatively.

## 13.5.9 Derive

***PIVOTAL Class or lab:*** *Equipment:* none.

In Activities 13.5.3–13.5.4 you found that a liquid exerts an upward force on submerged objects.

**a.** Explain *how* the liquid pushes up on a submerged object.

**b.** Explain why the liquid would be expected to exert an upward force on a submerged object that is equal to the force that Earth exerts on the liquid displaced by the submerged object. *Hint:* Think about what the liquid supports when the object is not occupying that particular volume.

## 13.5.10 Reading exercise

Interrogate Section 13.5 in the textbook and answer Review Question 13.5

# *13.6 Skills for analyzing static fluid problems*

## 13.6.1 Represent and reason

***Class:*** *Equipment per group:* whiteboard and markers.

The table below provides a word description of a situation involving the pressure of liquids. Complete the table.

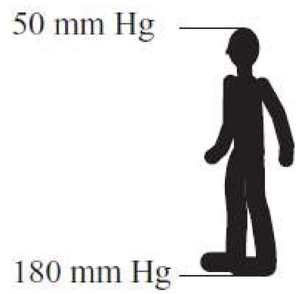
| **Word description** | **Sketch the situation (identify two points in the water).** | **Apply the relationship $P = P_0 + \rho g h$ and any other principles needed to determine the net force that the air inside and water outside exert on the window.** |
|---|---|---|
| A submarine is 100 m below the surface of the water, which has a density of $1000\ \text{kg/m}^3$. Compare the force of the water outside the submarine and the air inside (1.0 atm) on a $0.1\text{-m} \times 0.2\text{-m}$ window. | | |

## 13.6.2 Regular problem

***Class:*** *Equipment per group:* whiteboard and markers.

The pressure above atmospheric pressure of blood in a person's head and in his or her feet when standing is shown below. Explain whether these numbers make sense. *Note:* $780\ \text{mm Hg} = 1.0 \times 10^5\ \text{N/m}^2 = 1.0\ \text{atm}$.

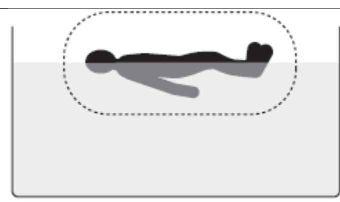
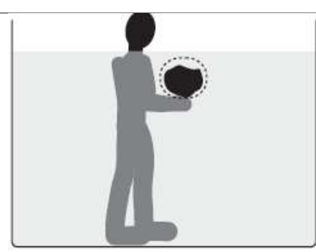
 




## 13.6.3 Represent and reason

***PIVOTAL Class:*** *Equipment per group:* whiteboard and markers.

Word descriptions and pictorial representations are provided below for two situations involving the buoyant force. Complete the table that follows.

| **Word description** | **Picture description (the system is circled)** | **Construct a force diagram for the system.** | **Apply Newton's second law in component form for the system.** |
|---|---|---|---|
| A person of density $980\ \text{kg/m}^3$ floats partially submerged in salt water of density $1030\ \text{kg/m}^3$. |  | | |
| You hold a 40-kg rock of density $2300\ \text{kg/m}^3$ that is completely submerged in water of density $1000\ \text{kg/m}^3$. |  | | |

## 13.6.4 Regular problem

***PIVOTAL Class:*** *Equipment per group:* whiteboard and markers.

Read the problem below. Then use the problem-solving strategy outlined in the table to solve it.

Suppose your mass is 70.0 kg and your density is 970 kg/m$^3$. If you could stand on a scale in a vacuum chamber on Earth's surface, the reading of the scale would be $mg = 70.0\text{ kg}\left(9.80\text{ N/kg}\right) = 686\text{ N}.$ What will the scale read when you are completely submerged in air of density 1.29 kg/m$^3$?

| | |
|---|---|
| **Sketch and translate**<br>• Make a labeled sketch of the situation and choose the system of interest. If applicable, decide on the initial and final states.<br>• Include all known information in the sketch and indicate the unknown(s) you wish to determine. | |
| **Simplify and diagram**<br>• Indicate any assumptions you are making.<br>• Identify objects outside the system that interact with it.<br>• Construct a force diagram for the system, including a vertical coordinate axis. The buoyant force is just one of the forces included in the diagram.<br>• Construct a bar chart or any other graphical representation that might help solve the problem. | |
| **Represent mathematically**<br>• Use the force diagram to help apply Newton's second law in component form.<br>• Use the energy bar chart to calculate work and energy if needed.<br>• Use the expression for the buoyant force and the definitions of pressure and density if needed; sometimes you might need the ideal gas law. | |

| **Solve and evaluate**<br>• Insert the known information and solve for the desired unknown.<br>• Evaluate the final result in terms of units, reasonable magnitude, and whether the answer makes sense in limiting cases. | |
|---|---|

## 13.6.5 Equation Jeopardy

***Class:*** *Equipment per group:* whiteboard and markers.

Below we present mathematical descriptions of various processes in fluids. For each equation:

**a.** Sketch a situation that might be described by the equation.

**b.** Describe the situation in words.

**c.** Draw a force diagram for an object of interest (for parts **b**. and **c**. only).

Mathematical descriptions of the processes

1. $\left(1.6\times 10^5\ \text{N/m}^2\right)-\left(1.0\times 10^5\ \text{N/m}^2\right)=\left(1000\ \text{kg/m}^3\right)\times\ (9.8\ \text{N/kg})(0.0\ \text{m}-y_1)$

2. $F+\left(1000\ \text{kg/m}^3\right)\times\ (9.8\ \text{N/kg})\left(0.010\ \text{m}^3\right)-(24\ \text{kg})(9.8\ \text{N/kg})=0$

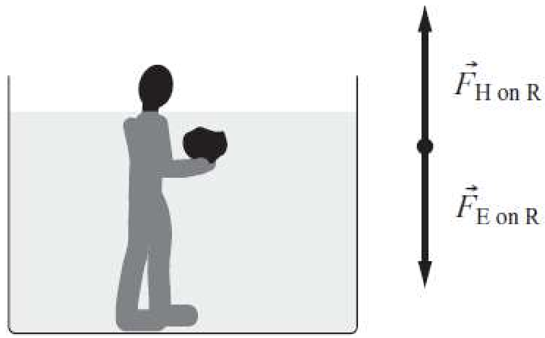
3. $\left(1000\ \text{kg/m}^3\right)\times\ (9.8\ \text{N/kg})V_{\text{displaced water}}-(24\ \text{kg})(9.8\ \text{N/kg})=0$

## 13.6.6 Evaluate the solution

***Class:*** *Equipment per group:* whiteboard and markers.

***The problem:*** You slowly lift a 20-kg rock of density $2400\text{kg/m}^3$ from the bottom of a lake near the shore. Determine the force that you must exert on the rock while lifting it when it is under the water. Assume that $g=10$ N/kg.


$\vec{F}_{\text{H on R}}$
$\vec{F}_{\text{E on R}}$

*Proposed solution:* Because you lift it slowly, the rock is not accelerating $(a = 0)$. A sketch of the situation and a force diagram for the rock (the system) are shown above. Applying the vertical component form of Newton's second law, we find:

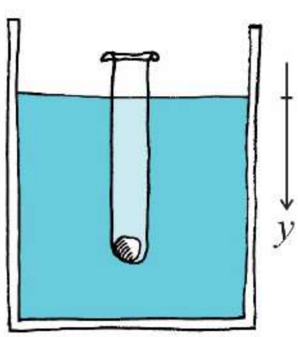
$$+F_{\text{H on R}} + (-F_{\text{E on R}}) = 0 \text{ or } F_{\text{H on R}} = F_{\text{E on R}} = mg = (20\text{ kg})(10\text{ N/kg}) = 200\text{ N}$$

**a.** Identify any missing elements or errors in the solution.

**b.** Provide a corrected solution if there are errors.

## 13.6.7 Observe and explain

Students build a simple pendulum. They put a small metal ball into a glass test tube and placed the test tube in an aquarium full of water (see figure below). When the test tube is pushed into the water and the finger is removed, the test tube oscillates up and down. The students wondered if the test tube exhibits a simple harmonic motion when it oscillates. They remembered the condition relating the force that the spring exerts on an object attached to it and the displacement of that object (Equation 10.5). To test whether the restoring force obeys this equation they conducted the following experiment: Using a force sensor, the students measured the force that they need to exert with a force sensor on the test tube, to displace it from the equilibrium position before it starts oscillating. They collected the data for the force and for the displacement that this force causes. Their measurements are in the table below (note the coordinate system in the figure). A positive $y$ value means that the tube is pushed into the water and the negative value means that it is pulled out of the water.




| $y$(m) | $F_{\text{FS on T}}$(N) |
|---|---|
| -0.020 | -0.060 |
| -0.015 | -0.045 |
| -0.010 | -0.030 |
| -0.005 | -0.015 |
| 0 | 0 |
| 0.005 | 0.015 |

| | |
|---|---|
| 0.010 | 0.030 |
| 0.015 | 0.045 |
| 0.020 | 0.060 |

**a.** Draw a force diagram for the test tube for 3 selected positions of the tube. What are the forces that provide the "restoring force" when that tube is pushed down? When it is pulled out of the water?

**b.** Analyze the data (it is best to graph it) to find a pattern. Describe the pattern in words and mathematically.

**c.** Explain why the pattern provides evidence that the test tube undergoes a *simple harmonic motion* when displaced from the equilibrium position.

**d.** Determine the period of the tube vibration, knowing that the total mass of the tube and the metal ball is 50 g.

## 13.6.8 Design an experiment

***PIVOTAL* Lab:** *Equipment:* to be determine in the activity.

You have an object of unknown material that floats in water. Design and carry out two independent experiments that will allow you to determine its density. Reconcile any discrepancy in the two values you obtain.

## 13.6.9 Predict

***Lab:*** *Equipment:* a rectangular block of wood, a large container with water—big enough for the block to fit into it—a ruler, and a scale.

Work with your group members to predict how much of the block will be above water if you place the block into the container. Then perform the experiment and compare your prediction to the outcome.

**a.** Describe the procedure that will help you make your prediction.

**b.** List quantities that you will need to measure and record the measurements.

**c.** Use the measured quantities and the procedure to make the prediction. Take into account experimental uncertainties.

**d.** Perform the experiment and record the experimental value of the height of the block above the surface.

**e.** Discuss whether the predicted and experimental values agree.

## 13.6.10 Test different explanations

***Class:*** *Equipment per group:* whiteboard and markers.

You place a plastic container with water on a scale and notice 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 scale reading:

**Scale reading: 620 g** **Scale reading: 750 g**

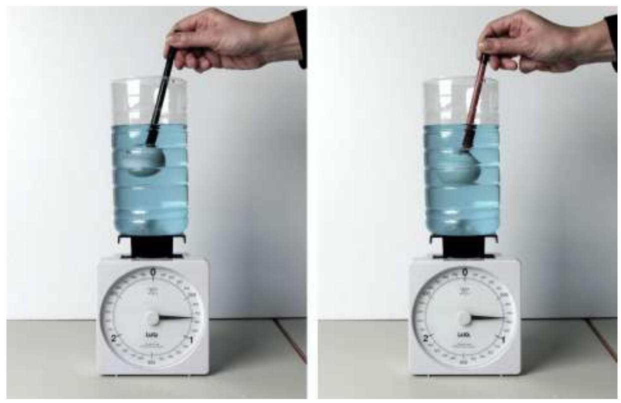
Finn: The water exerts an upward force on the submerged object, and thus the object exerts an equal in magnitude and downward force on the water, according to Newton's third law. This force makes the water press harder on the container and the container on the scale.

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 makes the water rise. The higher the level of water, the more pressure on the bottom surface of the container and consequently the larger the force exerted by the container on the scale.

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

**Testing experiment 1**



**Testing experiment 2**

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

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

Outcome TE1: scale reading is 620 g (note: the cardboard "squeezers" were also on the scale in the original experiment)

Outcome of TE2: 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 you can reject and which you cannot reject.

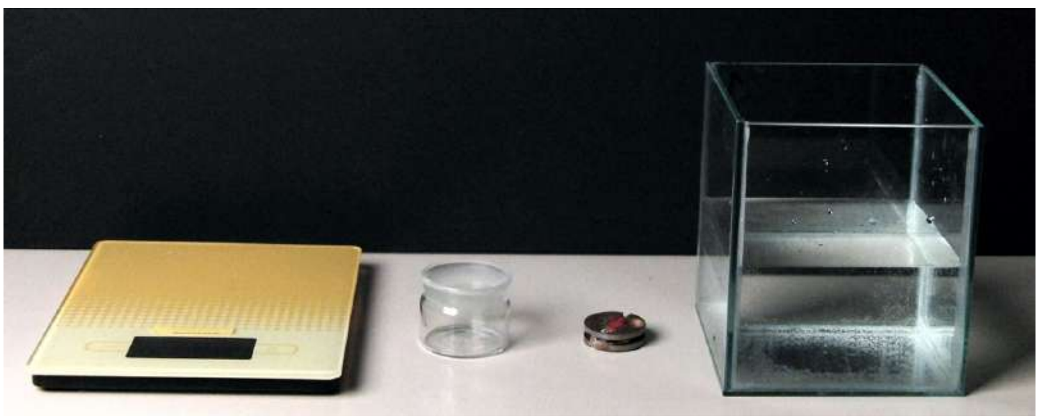
**c.** Based on the explanation that you were not able to reject, draw a force diagram for the water-container object and another force diagram for the 1-kg object in the case when the 1-kg object is immersed in the water (as in the figure on the right at the beginning of this activity)

**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 wall.)

## 13.6.11 Analyze

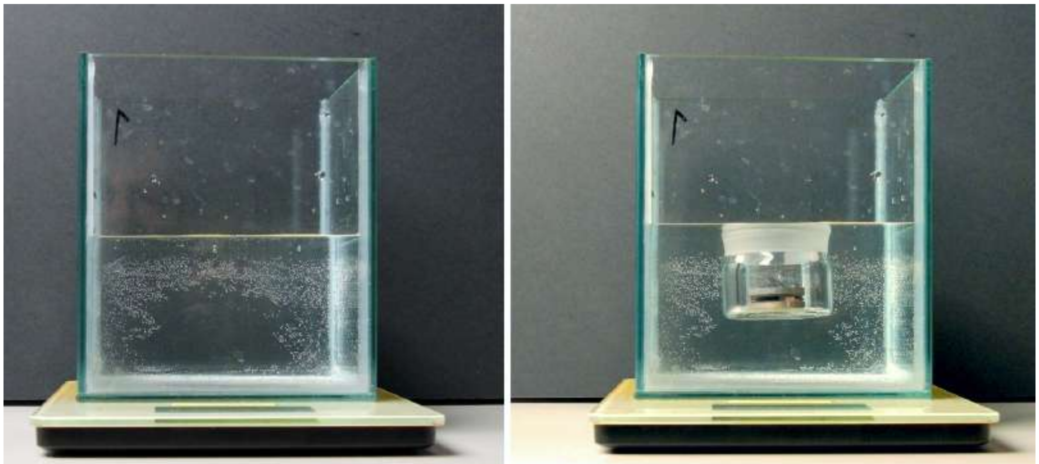
***Class:*** *Equipment per group:* whiteboard and markers.

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

Then you put the metal object on the bottom inside the small glass beaker and place them both carefully on the surface of 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 $m_{\text{CWBO}} = 1927$ g.

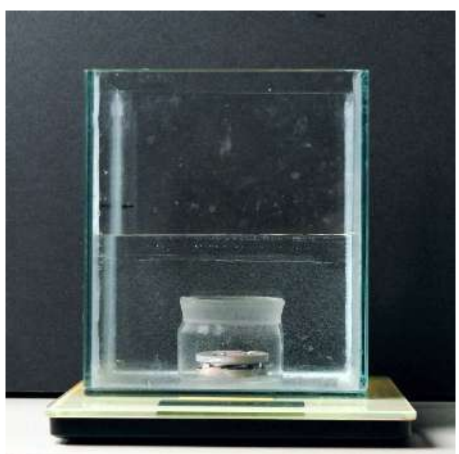


**a.** Estimate the volume of the small glass beaker based on the measured masses. How else can you estimate the volume of the glass beaker? Describe the second method. Indicate any assumptions that you made. Compare the results from the two methods. Do they reasonably match?

**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.



## 13.6.12 Reading exercise

Interrogate Section 13.6 in the textbook and answer Review Question 13.6.