

## Experiment 2: Ratios

### Introduction

The purpose of this introductory laboratory exercise is to investigate how measurement data are simplified in order to generalize and identify trends in the data. Data concerning two quantities will be compared as a **ratio**, which is generally defined as a relationship between numbers or quantities. A ratio is usually simplified by dividing one number by another.

*Chalkboard Note: Clean up any spills, please!*

### Procedure

#### Part A: Circles and Proportionality Constants

1. Obtain three different sizes of cups, containers, or beakers with circular bases. Trace around the bottoms to make three large but different-sized circles on a blank sheet of paper.

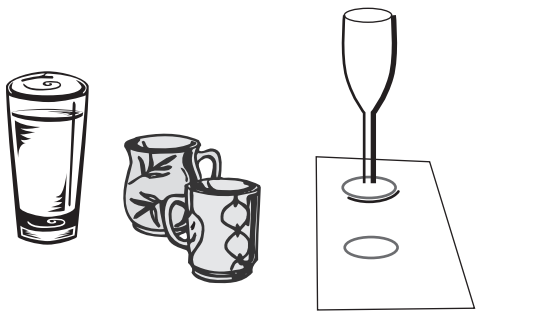


Figure 2.1

2. Mark the diameter on each circle by drawing a straight line across the center. Measure each diameter in mm and record the measurements in Data Table 2.1. Repeat this procedure for each circle for a total of three trials.
3. Measure the circumference of each object by carefully positioning a length of string around the object's base, then grasping the place where the string ends meet. Measure the length in mm and record the measurements for each circle in Data Table 2.1. Repeat the procedure for each circle for a total of three trials. Find the ratio of the circumference of each circle to its diameter. Record the ratio for each trial in Data Table 2.1 on page 23.
4. The ratio of the circumference of a circle to its diameter is known as **pi** (symbol  $\pi$ ), which has a value of 3.14... (the periods mean many decimal places). Average all the values of  $\pi$  in Data Table 2.1 and calculate the experimental error.

## Part B: Area and Volume Ratios

1. Obtain one cube from the supply of same-sized cubes in the laboratory. Note that a cube has six sides, or six units of surface area. The side of a cube is also called a *face*, so each cube has six identical faces with the same area. The overall surface area of a cube can be found by measuring the length and width of one face (which should have the same value) and then multiplying (length)(width)(number of faces). Use a metric ruler to measure the cube, then calculate the overall surface area and record your finding for this small cube in Data Table 2.2 on page 23.
2. The volume of a cube can be found by multiplying the (length)(width)(height). Measure and calculate the volume of the cube and record your finding for this small cube in Data Table 2.2.
3. Calculate the ratio of surface area to volume and record it in Data Table 2.2.
4. Build a medium-sized cube from eight of the small cubes stacked into one solid cube. Find and record (a) the overall surface area, (b) the volume, and (c) the overall surface area to volume ratio, and record them in Data Table 2.2.
5. Build a large cube from 27 of the small cubes stacked into one solid cube. Again, find and record the overall surface area, volume, and overall surface area to volume ratio and record your findings in Data Table 2.2.
6. Describe a pattern, or generalization, concerning the volume of a cube and its surface area to volume ratio. For example, as the volume of a cube increases, what happens to the surface area to volume ratio? How do these two quantities change together for larger and larger cubes?

*As the volume of a cube increases the surface area to volume ratio approaches zero.*

## Part C: Mass and Volume

1. Obtain at least three straight-sided, rectangular containers. Measure the length, width, and height *inside* the container (you do not want the container material included in the volume). Record these measurements in Data Table 2.3 (page 23) in rows 1, 2, and 3. Calculate and record the volume of each container in row 4 of the data table.

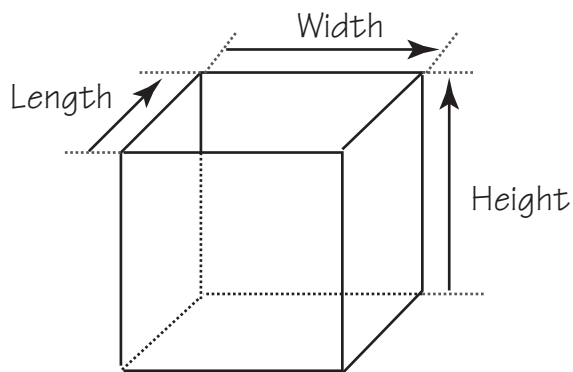


Figure 2.2

2. Measure and record the mass of each container in row 5 of the data table. Measure and record the mass of each container when “level full” of tap water. Record each mass in row 6 of the data table. Calculate and record the mass of the water in each container (mass of container plus water minus mass of empty container, or row 6 minus row 5 for each container). Record the mass of the water in row 7 of the data table.

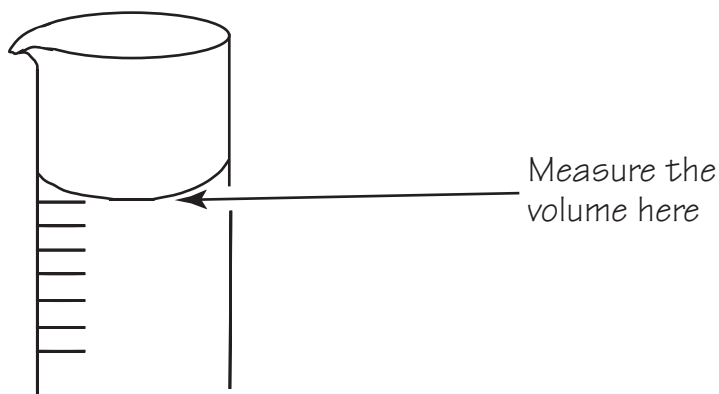


Figure 2.3

3. Use a graduated cylinder to measure the volume of water in each of the three containers. Be sure to get *all* the water into the graduated cylinder. Record the water volume of each container in milliliters (mL) in row 8 of the data table.
4. Calculate the ratio of cubic centimeters ( $\text{cm}^3$ ) to mL for each container by dividing the volume in cubic centimeters (row 4 data) by the volume in milliliters (row 8 data). Record your findings in the data table.
5. Calculate the ratio of mass per unit volume for each container by dividing the mass in grams (row 7 data) by the volume in milliliters (row 8 data). Record your results in the data table.

6. Make a graph of the mass in grams (row 7 data) and the volume in milliliters (row 8 data) to picture the mass per unit volume ratio found in step 5. Put the volume on the  $x$ -axis (horizontal axis) and the mass on the  $y$ -axis (the vertical axis). The mass and volume data from each container will be a data point, so there will be a total of three data points.
7. Draw a straight line on your graph that is as close as possible to the three data points and the origin (0, 0) as a fourth point. If you wonder why (0, 0) is also a data point, ask yourself about the mass of a zero volume of water!
8. Calculate the slope of your graph. (See appendix II on page 397 for information on calculating a slope.)

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{(800 - 400) \text{ g}}{(800 - 400) \text{ mL}} = 1.0 \text{ g/mL}$$

9. Calculate your experimental error. Use 1.0 g/mL (grams per milliliter) as the accepted value.

*You can expect less than 10 percent error, probably less than 5 percent.*

10. Density is defined as mass per unit volume, or mass/volume. The slope of a straight line is also a ratio, defined as the ratio of the change in the  $y$ -value per the change in the  $x$ -value. Discuss why the volume data was placed on the  $x$ -axis and mass on the  $y$ -axis and not vice versa.

*Because if you don't have a volume of water, you do not have a mass. Volume is the independent variable and mass is the dependent variable.*

11. Was the purpose of this lab accomplished? Why or why not? (Your answer to this question should show thoughtful analysis and careful, thorough thinking.)

*(Student answers will vary.)*

## Results

1. What is a ratio? Give several examples of ratios in everyday use.

*A relationship between numbers or quantities.*

*Examples: 100 cents per dollar, 60 seconds per minute, 365 days per year.*

2. How is the value of  $\pi$  obtained? Why does  $\pi$  not have units?

*By taking the ratio of the circumference of a circle to the diameter.*

*Both circumference and diameter are measured in the same units and when you divide the circumference by the diameter the units cancel out.*

3. Describe what happens to the surface area to volume ratio for larger and larger cubes.

Predict if this pattern would also be observed for other geometric shapes such as a sphere.

Explain the reasoning behind your prediction.

*Surface area to volume ratio approaches zero for larger and larger cubes.*

*This pattern would also be true for other shapes because surface area is proportional to length squared and volume is proportional to length cubed so surface area/volume is proportional to  $1/\text{length}$  which goes toward zero as the object gets larger.*

4. Why does crushed ice melt faster than the same amount of ice in a single block?

*There is more surface area for the smaller pieces of ice than the single block, the air is in contact with more of the ice, so it melts faster.*

5. Which contains more potato skins: 10 pounds of small potatoes or 10 pounds of large potatoes?

Explain the reasoning behind your answer in terms of this laboratory investigation.

*The 10 lbs of small potatoes have more potato skins. There is more total surface area for the same smaller potatoes than the larger potatoes.*

6. Using your own words, explain the meaning of the slope of a straight-line graph. What does it tell you about the two graphed quantities?

*The slope of a straight-line graph tells you how one quantity changes when the other variable changes. In this case, the slope equals  $1.0 \text{ g/mL}$ . This tells me that the mass of water in grams equals the volume of the same water in milliliters.*

7. Explain why a slope of mass/volume of a particular substance also identifies the density of that substance.

*Density is mass/volume. The slope equals the change in mass divided by the change in volume. This is the same as density.*

## Problems

An aluminum block that is  $1\text{ m} \times 2\text{ m} \times 3\text{ m}$  has a mass of  $1.62 \times 10^4$  kilograms (kg). The following problems concern this aluminum block:

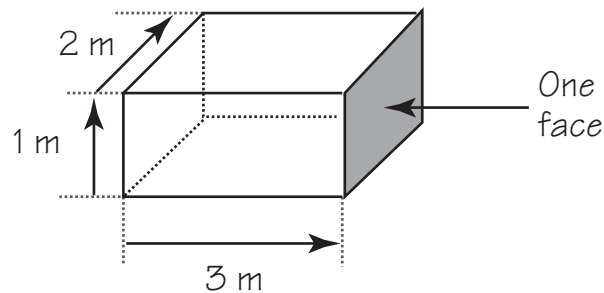


Figure 2.4

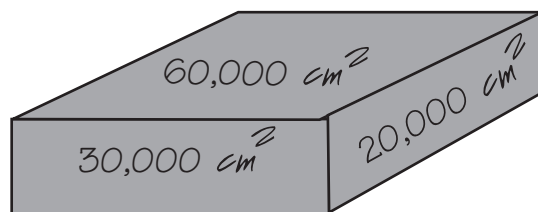
1. What is the volume of the block in cubic meters ( $\text{m}^3$ )?

$$\text{Volume} = (\text{length})(\text{width})(\text{height}) = (3\text{ m})(2\text{ m})(1\text{ m}) = 6\text{ m}^3.$$

2. What are the dimensions of the block in centimeters (cm)?

*300cm by 200cm by 100cm*

3. Make a sketch of the aluminum block and show the area of each face in square centimeters ( $\text{cm}^2$ ).



4. What is the volume of the block expressed in cubic centimeters (cm<sup>3</sup>)?

$$(300\text{ cm})(200\text{ cm})(100\text{ cm}) = 6,000,000\text{ cm}^3.$$

5. What is the mass of the block expressed in grams (g)?

$$1.62 \times 10^4\text{ kg} \times 1000\text{ g}/1\text{ kg} = 1.62 \times 10^7\text{ g}$$

6. What is the ratio of mass (g) to volume (cm<sup>3</sup>) for aluminum?

$$\text{mass/volume} = 1.62 \times 10^7\text{ g}/6 \times 10^6\text{ cm}^3 = 2.7\text{ g/cm}^3$$

7. Under what topic would you look in the index of a reference book to check your answer to question 6? Explain.

*Check the value of mass density for aluminum.*

## Invitation to Inquiry

If you have popped a batch of popcorn, you know that a given batch of kernels might pop into big and fluffy popcorn. But another batch might not be big and fluffy and some of the kernels might not pop. Popcorn pops because each kernel contains moisture that vaporizes into steam, expanding rapidly and causing the kernel to explode, or pop. Here are some questions you might want to consider investigating to find out more about popcorn: Does the ratio of water to kernel mass influence the final fluffy size of popped corn? (Hint: measure mass of kernel before and after popping). Is there an optimum ratio of water to kernel mass for making bigger popped kernels? Is the size of the popped kernels influenced by how rapidly or how slowly you heat the kernels? Can you influence the size of popped kernels by drying or adding moisture to the unpopped kernels? Is a different ratio of moisture to kernel mass better for use in a microwave than in a convention corn popper? Perhaps you can think of more questions about popcorn.





Data Table 2.1      Circles and Ratios									
	Small Circle			Medium Circle			Large Circle		
Trial	1	2	3	1	2	3	1	2	3
Diameter (D)	<u>5.5</u>	<u>5.4</u>	<u>5.5</u>	<u>8.7</u>	<u>8.5</u>	<u>8.6</u>	<u>12.5</u>	<u>12.4</u>	<u>12.3</u>
Circumference (C)	<u>18.0</u>	<u>18.3</u>	<u>17.8</u>	<u>24.7</u>	<u>27.1</u>	<u>27.6</u>	<u>38.9</u>	<u>38.6</u>	<u>38.7</u>
Ratio of C/D	<u>3.27</u>	<u>3.39</u>	<u>3.24</u>	<u>3.15</u>	<u>3.19</u>	<u>3.21</u>	<u>3.11</u>	<u>3.11</u>	<u>3.15</u>
Average $\frac{C}{D} =$ <u>3.20</u> Experimental error: <u>2% from <math>\pi</math></u>									

Data Table 2.2      Area and Volume Ratios			
	Small Cube	Medium Cube	Large Cube
Surface Area (cm <sup>2</sup> )	<u>24.4</u>	<u>96</u>	<u>386</u>
Volume (cm <sup>3</sup> )	<u>8</u>	<u>64</u>	<u>512</u>
Ratio of Area/Volume	<u>3.0 (cm<sup>2</sup>)/(cm<sup>3</sup>)</u>	<u>1.5 (cm<sup>2</sup>)/(cm<sup>3</sup>)</u>	<u>0.75 (cm<sup>2</sup>)/(cm<sup>3</sup>)</u>

Data Table 2.3      Mass and Volume Ratios

Container Number	1	2	3
1. Length of container	<u>6 cm</u>	<u>10 cm</u>	<u>20 cm</u>
2. Width of container	<u>4 cm</u>	<u>5 cm</u>	<u>7.5 cm</u>
3. Height of container	<u>8 cm</u>	<u>4.5 cm</u>	<u>6.5 cm</u>
4. Calculated volume	<u>192 cm<sup>3</sup></u>	<u>225 cm<sup>3</sup></u>	<u>975 cm<sup>3</sup></u>
5. Mass of container	<u>200 g</u>	<u>250 g</u>	<u>400 g</u>
6. Mass of container and water	<u>392 g</u>	<u>475 g</u>	<u>1375 g</u>
7. Mass of water	<u>192 g</u>	<u>225 g</u>	<u>975 g</u>
8. Measured volume of water	<u>192 mL</u>	<u>225 mL</u>	<u>975 mL</u>
9. Ratio of calculated volume to measured volume of water	<u>1.0 cm<sup>3</sup>/mL</u>	<u>1.0 cm<sup>3</sup>/mL</u>	<u>1.0 cm<sup>3</sup>/mL</u>
10. Ratio of mass of water to measured volume of water	<u>1.0 g/mL</u>	<u>1.0 g/mL</u>	<u>1.0 g/mL</u>

