Unit 4: Simple Measures

Biology in a Box

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This unit revised September 2012

Unit 4: Simple Measures
Materials List

- Graduated cylinder
- Beaker
- Bucket for water
- Funnel
- Box with volume relationship set: cube, rectangular prism, cone, pyramid, cylinder and sphere
- Balance
- Container of packing peanuts
- Box with miscellaneous items such as hickory nuts, string, acorns, sweet gum fruit (spiny seed ball), stone, cotton ball, feather, paper clips, noodles, plastic cap, felt pad, hexagonal weight, metal washer & jacks
- Box with 40 circular discs
- Box with plastic square weights: 4 1g yellow weights, 2 5g orange weights, 1 10g purple weight, 1 20g pink weight
- Box with six calibration standard weights: 1g, 2g, 5g, 10g, 20g and 50g
- Box with stop watch, cart, tape measure, string, pulley
- Board for mounting pulley
- Bag with miscellaneous shells
- Density block set
- Rhinoceros beetle
- *Morpho* butterfly

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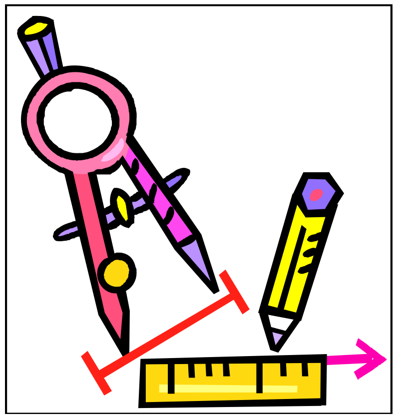


Introduction

Have you ever been measured? When you visit the doctor's office, a nurse probably measures your height and weight. Have you ever measured anything? At the grocery store, you may measure fruits and vegetables to determine how much they will cost. Scientists often measure things as a means of comparison.

In this unit, we will explore the properties of matter, including mass, volume, and density. We will learn how to measure these properties, and we will come to understand the relations that exist between them. Some of the following exercises are presented in two versions, one for lower grades, and another for higher grades: **Exercise 1: What is its mass?, Exercise 2**: **How is mass related to shape?, Exercise 3**: **Density**, and **Exercise 4: Exploring object size, shape, density and mass.**

Exercise 1: What is its mass?

The **mass** of a body is a measure of how much matter the body contains. We can measure a body's mass by measuring how strongly the body resists changes in its **velocity** (speed and direction). The more massive the body, the more difficult it is to make the body move faster, slower, or change direction. For instance, it is easier to push an empty shopping cart than it is to push a full one. Test this the next time you go to the grocery store.

Acceleration is the rate at which a body's velocity changes**.** If a body's velocity is changing, then we say that the body is **accelerating**. So, we can rephrase our previous statement about changes in velocity in terms of acceleration.

The more massive the body, the more difficult it is to accelerate.

Anything that can cause an object to accelerate is called a **force.** Gravity, magnetism, friction, and tension are examples of forces. If you hold your pencil up above your desk and then release it, the force of gravity will cause the pencil to fall to the desk. If you repeat this same experiment in outer space, beyond the reach of Earth's gravity, the pencil will simply float in place. That is, its motion will stay the same. In this exercise, we will measure how gravity changes the motions of various objects, in order to discover how massive the objects are.

In the United States, we often talk in terms of how much an object weighs, but weight is actually a measure of the gravitational pull on an object. You would have the same mass if you were standing on the surface of the moon or on the surface of the earth, but you would weigh less on the moon because the gravitational pull of the moon is less than that of the earth.

In these activities, we will consider mass. Mass is expressed in the metric system of measurement. The units of mass units and the relations that exist between them are shown in the table below.

MASS UNITS

Unit	Symbol	Relationship
milligram	mg	
gram	g	1000 mg
kilogram	kg	1000 g
metric ton	t	1000 kg

When completing scientific calculations, it is important that you keep track of all of your units, and that you are comfortable converting between units. The following example and exercises will help you learn how to convert between units.

Example: How many grams are there in one milligram?

Answer:

We start with the equation from the table that relates grams to milligrams:

$$\mathbf{1000\ mg = 1\ g}$$

Next we divide both sides of this equation by 1000 so that the left hand side of the equation is equal to 1 mg, and convert the fraction $\frac{1}{1000}$ to its decimal form:

$$\mathbf{1\ mg = \frac{1}{1000}\ g = 0.001\ g}$$

Q1. How many kilograms are there in one gram?

Q2. How many milligrams are there in one kilogram? How many milligrams are there in one metric ton?

Q3. How many kilograms are there in 800 grams?

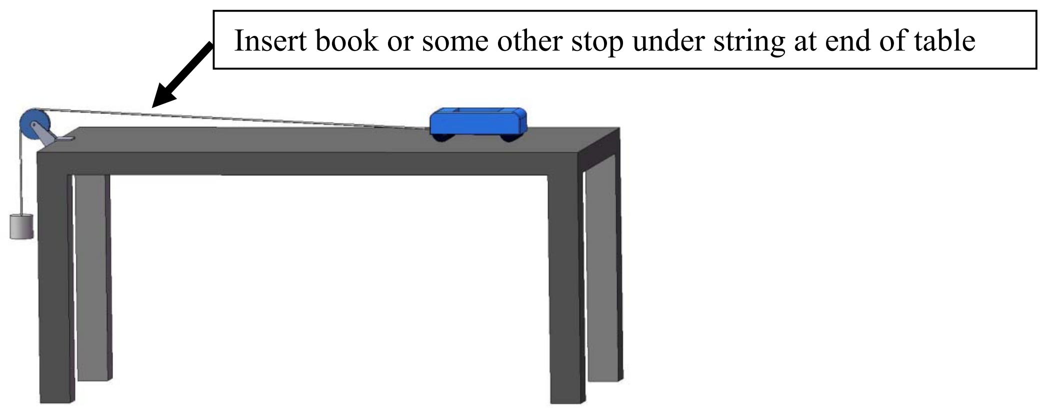
Exercise 1a: Mass & Motion

In this exercise, you will test the relationship between the mass of an object and its resistance to change in motion, using the experimental setup shown on the next page. You will complete two exercises on mass and motion: **Exercise 1a.1 & Exercise 1a.2.**

There are two versions of these exercises. The first version is intended for lower grades. The second version, intended for higher grades, is enhanced with additional mathematics.

All exercises of mass and motion utilize the set up shown on the next page.

- Locate the box labeled *Exercise 1a: Mass in Motion*. This box should contain a cart having the following characteristics: 4 wheels, a cavity to hold objects, and a hole in the front to insert a string. There should also be a measuring tape, a stopwatch, a pulley and a string with weight attached to it in the car box.
- Clear a tabletop in the room.
- You will set up the apparatus shown in the figure below, using a 50g mass.
- If your table is to too thick for the pulley clamp, attach it to the enclosed piece of dry erase board instead, and weight the dry erase board down with a book or some other heavy object.
- Place a barrier (e.g. book) under the string in front of the pulley, so that the cart does not fall off the end of the table.
- Mark a starting line at the other end of the table. At the beginning of each trial the front wheels of the cart should be even with the starting line.
- The distance between the starting line and the end barrier is your track length.
- Your track length must be less than the height of the table.



Exercise 1a.1: Items of known mass (*Methods for lower grades*)

- Find the box labeled 1a which contains a series of calibration weights**.**
- Load one calibration weight into the cart while holding it at the starting line.
- Write the mass of the calibration weight down on a sheet of paper, or on the board at the front of the room (number on weight = mass in grams).
- One person should release the cart while a second person uses the stop watch to find the time it takes the cart to travel the track (hit the stop).
- Write down the number of seconds it took for the object to travel the track.
- Repeat this process for all of the weights.
- Order the objects from the shortest time to cross the table to the longest time.

- Answer the following question.

Q1. How is the time it took the cart to travel the track related to the mass of the object in the cart?

Exercise 1a.2: Ranking items based on travel time (*Lower grades*)

- Find the box containing a number of objects of unknown mass.
- You will also need your box of calibration weights from the previous exercise.
- Find additional objects from around your room that are small enough to fit into the well of the cart.
- Repeat Experiment 1a with each of these objects.
- Order your objects in a row, from most massive to least massive, based on the time it took each one to travel the track.
- Situate your calibration weights from Exercise 1a in this same row according to the time it took each one to travel the track.
- Conclude something about the mass of each of your unknown objects. For example, you might conclude that a paper clip has more mass than the 2 gram calibration weight, but that it has a mass less than that of the 5 gram weight.
- Answer the following question.

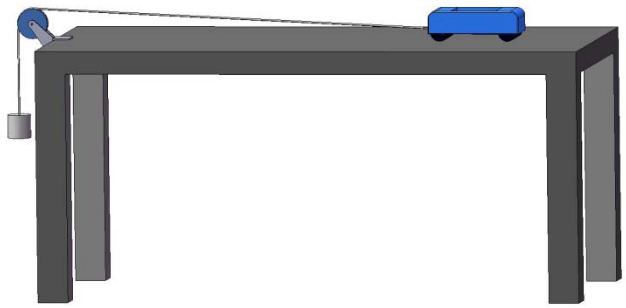
Q1. For each item below, decide which of the two animals listed is the most massive. Record your choice on the board at the front of the room.

- A meat eater that ambushes its prey or a meat eater that chases its prey
- A bird with functional wings or a flightless bird such as an ostrich
- A soaring/gliding bird (such as a vulture) or a song bird
- A beetle that bores into rotting logs and litter on the forest floor or a butterfly that visits flowers (after thinking about this pair, examine the rhinoceros beetle and *Morpho* butterfly included in this unit)
- A centipede or a millipede

- **Check your answers for Exercise 1a2.Q1 at the end of the book!**

Exercise 1a.1: Items of known mass (*Methods for higher grades*)

- Follow the directions at on page 4 to set up the apparatus shown below. Don't forget to measure the track length!



- Load the most massive calibration weight into the cart while holding it at the starting line.
- When you are ready, start the stopwatch and let go of the cart simultaneously.
- Stop the stopwatch when the cart reaches the finish line.
- For each object, record the time it takes for the cart to travel the track, and the mass of the weight used.
- Repeat with each of the remaining weights.
- Establish a qualitative relationship between the time it takes the cart to travel the track, and the mass of the object in the cart.
- Make a scatter plot of the mass, m, of the object in the cart versus the time, t, it took the cart to travel the track. Label the x-axis t and the y-axis m. Don't forget to list your units on your axes!

Exercise 1a.2: Obtaining the mass of unknowns using Newton's laws of motion (*For higher grades*)

In this exercise, you will calculate the mass of several objects using Newton's laws of motion, which are listed below:

1) The velocity (speed and direction) of a body does not change unless the body is acted on by an external force.
2) The net force acting on a body is equal to the product of the acceleration of the body and the mass of the body, that is,

$$\boldsymbol{F} = \boldsymbol{ma}$$

In this equation, mass, $\boldsymbol{m}$, is measured in kg, and acceleration, $\boldsymbol{a}$, is measured in m/s^2. The units of force, $\boldsymbol{F}$, are measured in (kg·m)/s^2

3) If one body exerts a force on a second body, then the second body exerts a force of equal magnitude and opposite direction on the first body.

Q1. Suppose two bodies have an acceleration of 8m/s^2. The mass of the first body is 3g and the mass of the second body is 10g. Find the force acting on both bodies. Which body had a greater force acting upon it? Make sure you find the answer using standard units of mass and force!

Q2. Rearrange the equation in Newton's second law to solve for a in terms of m and *F*.

Q3. Suppose that a force of $10(\text{kg·m})/\text{s}^2$ is applied to a body with a mass of 50g. What is the acceleration of the body? How much force would be needed to give a body with a mass of 100g the same acceleration? Does this agree with our previous statements relating mass and acceleration? Be careful with your units!

- Identify small objects from around the room that will fit in the cart's well and run in the same experiment you completed under **Exercise 1a** with each one.
- Record your results in a table that has the name of each object in the first column, the time it took to travel the track in the 2nd column and a blank column entitled object's mass.
- Rank these objects along with the calibration weights in a list from least massive to most massive. (The class might vote on the relative position of each item)

The following items of information are needed to determine the mass of each object.

1) The acceleration due to gravity: $9.81\ \frac{\text{m}}{\text{s}^2}$ (m = meters & s = seconds)
2) The mass of the cart: $m_c\ =\ 56\text{ g}\ =\ 0.056\text{ kg}$.
3) The mass of the calibration weight: $m_w\ =\ 0.05\text{ kg}$
4) The time, t_1, it takes the cart to travel the track. (Note: d_{track} should be measured in meters).

Now we are ready to calculate the mass of each object. First, note that since the cart and the weight are joined by a string and pulley any change in the position of the string results in an equal change in the position of the cart. As a result, the acceleration of the cart is equal to that of the string. We will call this acceleration the system acceleration and denote it as $\boldsymbol{a_s}$.

Step 1. Calculate the system acceleration, a_s.

When an object is accelerating, the relationship between the distance the object has traveled and the object's acceleration is:

$$d = v_o t + \frac{1}{2} a t^2$$

Where d is the distance traveled, v_o is the initial velocity, a is the acceleration, and t is the time it takes the object to travel the distance, d. In the cart experiment, $a = a_s$, $d = d_{track}$, and $t = t_1$. So, the relationship is

$$d_{track} = v_o t_1 + \frac{1}{2} a_s t_1^2$$

Initially the cart is at rest, and therefore the initial velocity, v_o, is zero. Thus the relationship becomes:

$$d_{track} = \frac{1}{2} a_s t_1^2$$

Q4. Rearrange the equation above to solve for a_s in terms of d_{track} and t_1.

Step 2. Calculate the gravitational force on the calibration weight.

On earth, the acceleration of a free falling body is $9.81 \frac{\mathrm{m}}{\mathrm{s}^2}$. Therefore the gravitational force, F_g, on a 5g weight is

$$F_g = m_w \times g = 0.05 \text{ kg} \times 9.81 \frac{\mathrm{m}}{\mathrm{s}^2} \approx 0.49 \ \frac{\mathrm{kg\ m}}{\mathrm{s}^2}$$

Step 3: Calculate the tension on the string.

The force of gravity on the calibration weight is opposed by the tension force, T, on the string. The net force on the calibration weight, F_w, is the difference of these two forces, that is

$$F_w = F_g - T = 0.49 \ \frac{\mathrm{kg\ m}}{\mathrm{s}^2} - T$$

Q5. Use Newton's second law to find F_w in terms of a_s and m_w.

Q6. Find T in terms of a_s.

Step 4. Use Newton's second law to find the combined mass of the cart and object, $\boldsymbol{m_{tot}}$.

The cart is being pulled by the tension, or pulling force, in the string. Therefore, the force on the cart, F_c, is equal to T.

$$F_c = T$$

By Newton's second law, F_c is also the product of the cart's mass and its acceleration.

$$F_c = m_{tot} \times a_s$$

Q7. Solve for m_{tot}.

Step 5. Find the mass of each object.

To find the mass of each object, simply subtract the mass of the cart from the combined mass of the cart and object.

$$m_{obj} = m_{tot} - m_c$$

Note that the masses m_{tot} and m_c must be in kilograms, or at least in the same units, for your answer to make sense.

- Complete your table by recording the mass of each object.
- Add the data points for the unknown objects to the graph you have made of mass versus time to travel the track.
- Test the ranking obtained from your table and graph against your original ranking of items by mass.
- Answer the following questions.

Q8 . What are some possible explanations for any differences between the first (qualitative) and second (quantitative) rankings you developed?

Q9. What objects were the heaviest? The lightest?

Q10. Can you tell by looking at the various objects which ones had more matter in them?

Q11. For each item below, decide which of the two animals listed is the most massive. Record your choice on the board at the front of the room.

- A meat eater that ambushes its prey or a meat eater that chases its prey
- A bird with functional wings or a flightless bird such as an ostrich
- A soaring/gliding bird (such as a vulture) or a song bird
- A beetle that bores into rotting logs and litter on the forest floor or a butterfly that visits flowers (after thinking about this pair, examine the rhinoceros beetle and *Morpho* butterfly included in this unit)
- A centipede or a millipede

- Check your answers for **Exercise 1a.2** at the end of this book!

Exercise 1b: What is its mass?

In this exercise we will determine the mass of various objects. Determining an object's mass allows you to answer questions like:

- Which has more mass?
- How much mass did the object gain or lose from one time to the next?
- Do objects of the same type have the same mass?

Materials needed:

- Balance
- Box with 40 circular discs/rings
- Box with colored blocks

- Locate the balance provided with this unit. Note that this balance does not allow you to directly measure an object's mass. However, you can use it to compare the masses of two objects. In this way, the balance allows you to determine or at least estimate the mass of an object with the aid of several objects of known mass.

First we will determine the mass of one of the included ring/disc masses.

- For a start, take two rings/discs out of the box. Place one ring on one tray of the balance and the other ring on the other tray. If the two trays balance (are level with one another), then the two rings are of equal mass. Take additional rings from the box and repeat this comparison to ensure that the rings are of the same mass.
- Now open the box with the colored blocks in it.

- Hold a purple block in one hand and a ring in the other hand. Which looks like it would have more mass? Which object feels heavier? Let's see which object has more mass.
- Place the purple block on the left tray of the balance and a ring on the right side of the balance. If one object has more mass than the other, the balance will be lop-sided and the more massive object will push its side of the balance down.

Q1. Which object has more mass: the purple block or the ring?

- Consult the answer sheet at the end of the book under Exercise 1b to verify your answer if you are unsure. No cheating! You are on your honor not to peek at answers to later questions.
- Determine how many rings it takes to equal the mass of the purple block, by adding rings to the right side of the balance until the two trays appear to be level. When this occurs, the mass of the rings in the right tray is equal to the mass of the purple block**.**

Q2. How many rings did you use?

- Record the number of rings it took to balance the two trays in Data Table 1,which is located at the end of this exercise.
- Check the answer sheet under **Exercise 1b** to see if you are correct.

Let's investigate further the problem of how much mass a single ring has by repeating the comparison you made between the ring mass and the purple block with another colored block .

- Determine how many rings it takes to equal the mass of the orange square block.
- Remove all objects from the balance.
- Place an orange block in one hand and a ring in your other hand. Which block feels heavier?
- Place the orange block in one tray and the ring in the other tray.

Q3. Which has more mass?

- Check the answer sheet under **Exercise 1b** if you are unsure.
- As before, continue placing rings in the tray until the two trays are balanced.

Q4. How many rings did it take this time?

- Record how many rings in Data Table 1
- Look at the answer sheet under **Exercise 1b** to see if you are correct.

Q5. Looking at your data, what mathematical relationship can you surmise about the masses of the purple and orange blocks relative to that of the ring?

- Record this relationship in data table 1.
- Check your answers on the answer sheet under **Exercise 1b**.

Q6. Hypothesize the mathematical relationship between the yellow block and the ring. State a reason for your hypothesis on your data sheet.

- Repeat this experiment a third time.
- Compare a square yellow block to a ring. Which one looks like it would have a greater mass? Does one feel heavier than the other does?
- Place the yellow block in one tray and a ring in the other.

Q7. How many rings did it take to balance the two trays this time?

Thus far, you have been determining the relative masses of objects. Balances or scales have sets of standard masses associated with them. These objects are of known mass and are used to calibrate the scale (adjust the mechanism to ensure that it provides an accurate mass). We can use these standards to determine the absolute mass of a single object, that of the ring.

- Locate the 1gram calibration mass. Place this standard on one tray of the balance and a single ring on the other tray.
- You should now be able to answer the following questions. Record your answers in Data Table 2.

Q8. What is the mass of a ring?

Q9. What is the mass of the purple block?

Q10. What is the mass of the orange block?

Q11. What is the mass of the yellow block?

DATA SHEET for Exercise 1b: What is its mass?
Data Table 1

	Number of rings required to equal block mass	Relationship of mass of ring to mass of block
Purple block		
Orange block		
Yellow block		

Question 6: Hypothesize the relationship between the yellow block and the ring.

____

State your reason for your hypothesis.

____

____

____

Data Table 2:

Item	Mass in grams
Ring	
Purple block	
Orange block	
Yellow block	

Exercise 2: How is Volume Related to Shape?

Exercise 2a: Comparing shapes

In **Exercise 1**, we learned how to measure the mass of an object. In this exercise, we will learn how to measure an object's volume. The **volume** of an object is the amount of space it takes up. Hollow objects and containers are often described by the volume that they can hold. For example, the measuring cups and spoons in your kitchen are all labeled with the volumes that they hold.

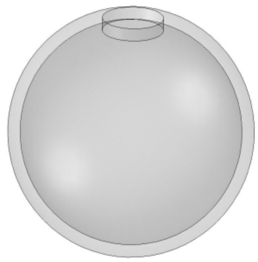
<u>Materials needed:</u>

- o Box with volume relationship set, which includes the following three-dimensional shapes:
  - cone
  - sphere
  - cylinder
  - cube
  - pyramid
  - rectangular prism
- o Beaker
- o Funnel
- o Large graduated cylinder
- o Plastic dishpan (Use this to catch any spilled water while pouring while conducting this exercise.)
- o Bucket to serve as water reservoir
- o Box containing miscellaneous objects

- Examine the six containers in the volume relationship set.
- Try to imagine which of the shapes can hold the same amount of water, or which ones look as though they take up the same amount of space (have the same volume).

Let's find out if you have guessed correctly.

- Find the round sphere pictured below, and place it in the container with its opening facing up.

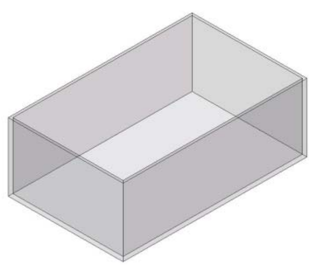


sphere

- Using the cup and funnel, fill the sphere with water. **(ALL POURING OF WATER SHOULD BE DONE OVER THE DISHPAN.)** Do this slowly to avoid spilling.

Q1. Just by looking, what container do you think holds the same volume of water as the sphere? HINT: There is only one shape that holds the same amount of water as the sphere.

- Pour the water from the sphere into the container you have chosen as being similar in volume. If you have water left in the sphere, then the container you have chosen is too small. If the new container is not filled to the top with the water from the sphere, then it has a larger volume than the sphere.
- Keep filling containers until you have found one that will hold the same volume of water as the sphere.
- Find the rectangular prism pictured below and fill it with water.



rectangular prism

Q2. Now follow the directions below to find the container that holds TWICE (2 times) the amount of water as the rectangular prism.

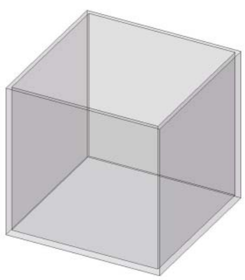
- Pour the water from the rectangular prism into the container you have chosen. You should then have an empty rectangular prism and another partially filled container.
- Fill the rectangular prism with water one more time, and pour as much of this water as you can into the container you chose.

- If you guessed the correctly, the container that you chose should be full of water and the rectangular prism should be empty.
- If this is not the case, choose another container and try again.

Look in volume relationship set box for the cylinder and cube pictured below.

cylinder

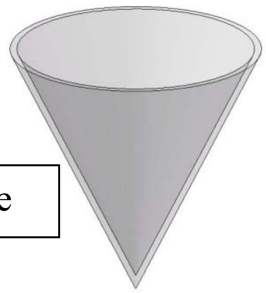
Q3. Do you think the cylinder holds as much water as the cube, or do you think one of these containers holds more than the other?



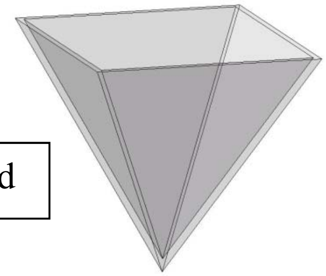
cube

- Slowly pour the water from the cube into the cylinder to learn whether your guess was correct.
- Pour the water from both containers back into the bucket.
- Turn the empty cube upside down so that the open side is facing down.
- Set the cylinder on top of the cube. Can you tell by looking down at the containers why one has a higher volume? HINT: It has to do with shape!

There are two containers left in the box that we have yet to examine. One is a cone (think ice cream!) and the other is a pyramid.



cone



pyramid

- Observe the size and shape of these containers**.** Are the containers the same height? Yes, the cone and pyramid are equally tall.

Q5. Do a cone and pyramid of equal height have equal volumes? Think carefully! If you are having trouble, look at the bases of the containers and remember the cube vs. cylinder comparison. One has a square base, and the other a circular base.

- Slide the cone into the pyramid. Now you should be able to tell which one has the greater volume.
- Fill the pyramid with water, and then pour the water into the cone. You should find that the water from the pyramid does not quite fit into the cone. Thus, shape affects volume!

Finally, let's see if we can determine the volume of each shape available to us. To do this, you will need the beaker provided and the graduated cylinder (tall thin container).

- Begin by choosing one of the shapes. Then, fill it to the top with water.
- With the aid of the funnel, carefully pour the water that filled the container into the beaker and try to read the measurement in milliliters on the side of the beaker.

Can you make a very accurate measurement of the volume of water using the beaker? Let’s see if we can get a more accurate measurement of the shape you have chosen.

- Again with the aid of the funnel, pour the water you had in the beaker into the graduated cylinder.
- Read the measurement on the side of the graduated cylinder.

Q6. What is the volume of the shape you have selected? (The answer should be in milliliters).

- Repeat this process for the rest of the shapes and compare them.

Q7. Which shape has the biggest volume? Which has the smallest volume?

- Please place the empty clear containers back into the proper boxes, and return these to the trunk.

Exercise 2b: Find the exact volume of these shapes.

There are formulas that allow you to calculate the exact volume that each of the containers holds. These formulas are listed in the table below.

Shape	Volume formula	Explanation
sphere	$V = \frac{4}{3}\pi r^3$	$r = radius\ of\ sphere$ $(r = \frac{1}{2} diameter)$
rectangular prism	$V = l \times w \times h$	$l = length\ of\ base$ $w = width\ of\ base$ $h = height$
cylinder	$V = \pi r^2 h$	$r = radius\ of\ base$ $h = height$
cube	$V = l \times w \times h$	$l = length\ of\ base$ $w = width\ of\ base$ $h = height$
right cone	$V = \frac{1}{3}\pi r^2 h$	$r = radius\ of\ base$ $h = height$
square pyramid	$V = \frac{1}{3} w^2 h$	$w = width\ of\ base$ $h = height$

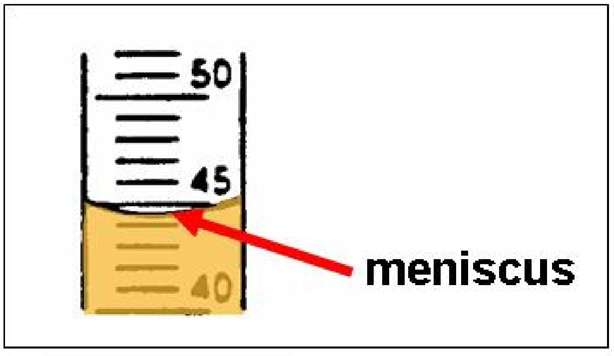
- Use the correct formula to determine the volume of each container. Measure as carefully as possible for the most accurate results.

Exercise 2c: **Finding the volume of irregular solids using displacement**

Some solids, like the shells included in this unit, have irregular shapes and cannot easily be measured with a meter stick or ruler to accurately calculate their volumes. However, there is another method to find the volumes of irregular solids. In order to use this method, you will need to accurately measure the volume of a liquid in a cylinder.

When a liquid is put into a cylinder, it does something unusual. It curves. This curve is caused by a quality that liquids have called surface tension.
When you read the graduated cylinder, you read it at the **bottom of the curve**. This is called the **meniscus**.

- Place the graduated cylinder on the table for an accurate reading
- Place some water in the graduated cylinder (approximately 90 ml) and note the meniscus.
- Be sure to get down to eye level with the meniscus in order to read the exact volume in ml present.



- Write down the *exact* amount of water you have in the graduated cylinder. This is your ***Initial Volume.***
- Now place your shells in a row from smallest to largest based on visual inspection. Each shell has a letter on it.
- Record your shell ranking on the board at the front of the room.

Now let's measure the volume of the shells so we can see how our **qualitative** ranking based on estimation by sight compares to our **quantitative** ranking based on measurement.

- Place a shell into the water without splashing any water out of the cylinder.

- Read the new level of water in the graduated cylinder (again to the bottom of the meniscus). Write down the new level of the water. This is your ***Final Volume.***
- Subtract the initial volume from the final volume. This difference is the ***volume of the shell.***
- Repeat these steps for each of the different shells to practice determining the volume of irregular solids.
- Now rank the shells from lowest volume to greatest volume, and record your ranking on the board. Compare your two ranking systems.

Using your volume measurements, you can actually determine how much larger (greater in volume) each shell in the ranking is than the previous shell. This is done by completing ratios.

Example:

Let's suppose you had the following set of quantitative data

Shell #	Volume	Size relative to next lower shell
1	1.2 ml	
2	2.4 ml	2 times greater than #1
3	3.3 ml	1.375 times greater than #2
4	3.9 ml	
5	4.6 ml	

Then, to find how much more volume shell 2 has than shell 1, we calculate the ratio,

$$\frac{volume\ of\ shell\ 2}{volume\ of\ shell\ 1} = \frac{2.4}{1.2} = 2$$

That is, shell 2 has twice as much volume as shell 1. Similarly, we can find how much more volume shell 3 has than shell 2.

$$\frac{volume\ of\ shell\ 3}{volume\ of\ shell\ 2} = \frac{3.3}{2.4} = 1.375$$

That is, shell 3 has 1.375 times the volume of shell 2.

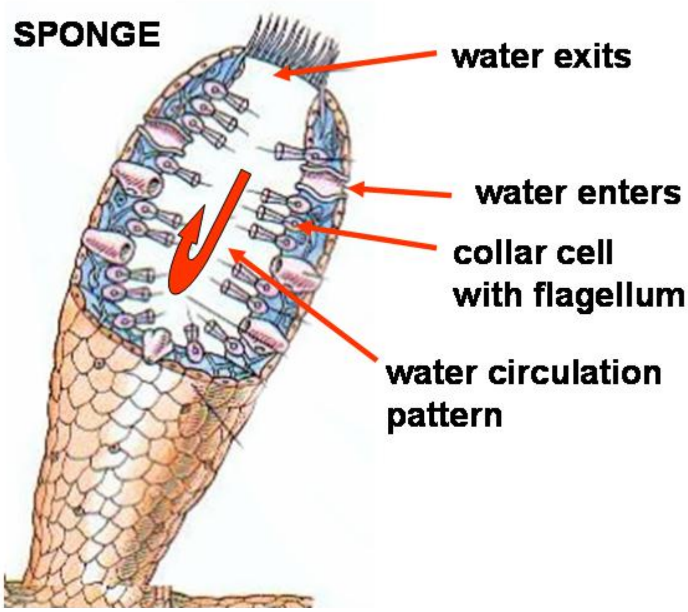
- Finish the table above.

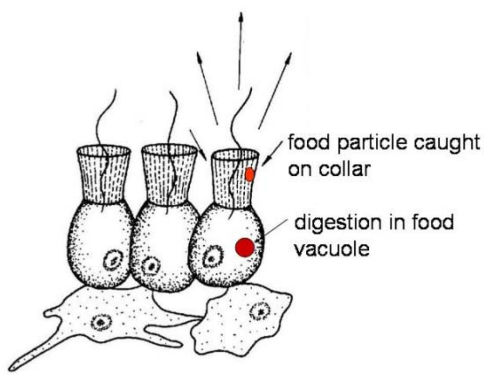
- Complete a similar table for your shell sample.

Shell #	Volume	Size relative to next lower shell
1		
2		
3		
4		
5		

Now see if you can answer the following ***"Super Solver"*** questions.

Q8. The sponge is a filter-feeder: it circulates water through an internal cavity to obtain oxygen and gather food particles (bacteria and dead organic matter) on its collar cells. Wastes are also eliminated, as the beating of flagella generates the flow of water through the sponge's central cavity**.** What volume of water does a filter-feeding sponge cycle through its cavity per day if its flagella create a current flow of 75 liters of water per hour?

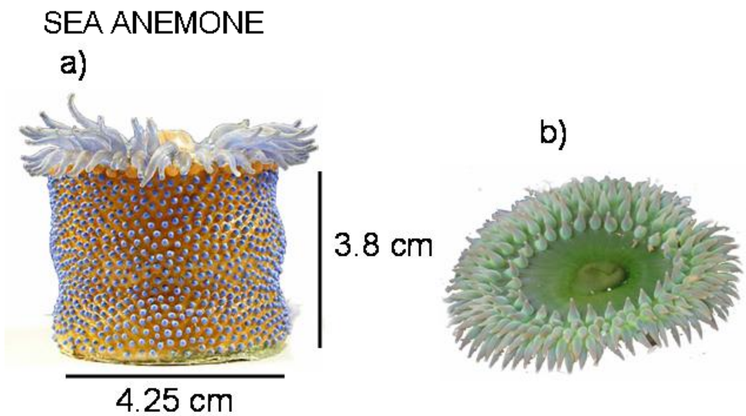




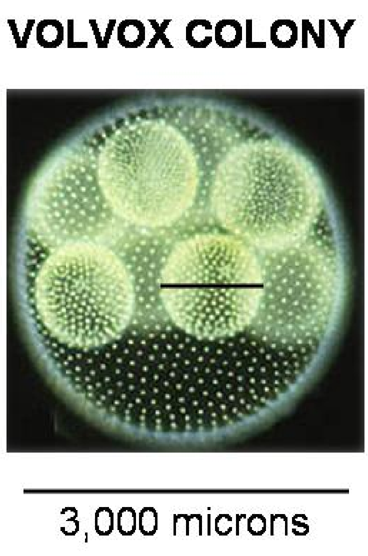
Q9. Since the typical sponge pumps a volume of water per minute equal to about 5 times its body volume, what is the volume of the sponge under **Q8**?

For animation of sponge feeding, go to
http://www.biology.ualberta.ca/courses.hp/zool250/animations/Porifera.swf

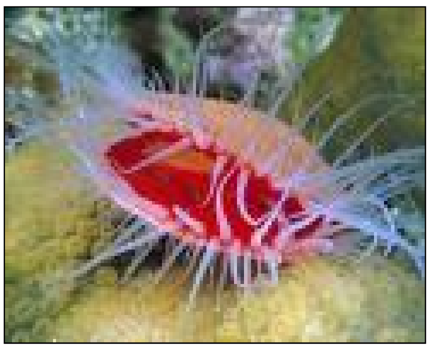
Q10. The sea anemone pumps water into its body to assume its feeding form, see **Figure a** below). When it is frightened by a predator, it contracts strong longitudinal muscles and flattens to the form shown in **Figure b** below. If the anemone contracted to 10% of the height of its feeding form, with no changes in diameter, what volume of water did this anemone force out?

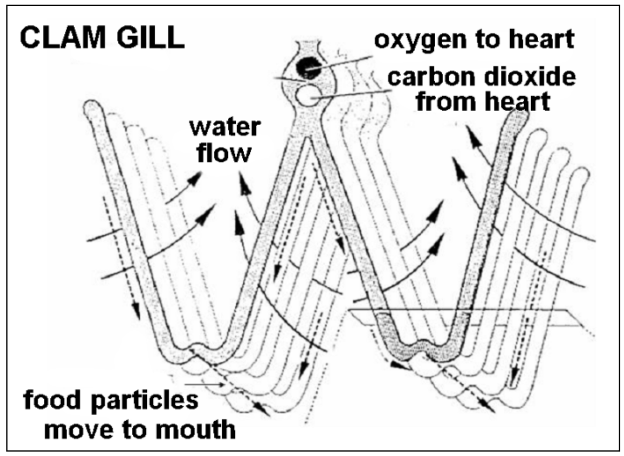


Q11. *Volvox* is found in freshwater ponds, puddles, and ditches. It is a chlorophyte (algal protist) that forms spherical colonies. a) What is the volume of the large *Volvox* "mother colony" in microliters? b) What is the volume, in microliters, of the "daughter colony" indicated with a black bar across its diameter?
HINT: 1 micron = 1×10^{-6} m, and 1 microliter (µl) = 1 mm^3 = 1×10^{-9} m^3.



Q12. Clams use gills for gas exchange and in the collection of food particles, just as sponges pump water through collar cells. Researchers predict that clams at deeper depths will have much larger gills than individuals of the same species would have in shallow waters. Why might this be the case, and how could they quantitatively test this hypothesis a) in living specimens, and b) in collected specimens from which the gills have been dissected?





Exercise 3: Density

Often, you judge how much mass an object has by its volume. For example, you think of a refrigerator as being more massive than a toaster because it has a greater volume. You may also have guessed the purple block was heavier than the orange block in **Exercise 1b**, because it appeared to be taller than the orange block.

Size can often be used as an indication of mass, but sometimes appearance can be deceiving. This is because the material from which an object is made also influences its mass. Materials have different densities. The **density** of a material is a measure of how tightly the matter making up the material is packed together (Figure 1 below). If the matter is loosely packed, then the density of the material is low. An object made of low density material may seem light for its size. If the matter is tightly packed, then the density of the material is high. An object made of high density material may seem heavy for its size. Take, for example, a china dinner plate and a paper picnic plate of the same size (volume). The china plate will be heavier than the paper plate, because bone china is denser than paper. That is, because the matter in the china plate is more tightly packed, there is more matter in the china plate, and thus it is heavier.

Low density liquids rise to the top of a column, while the more dense liquids move to the bottom: they separate as shown in the picture below (Figure 2).

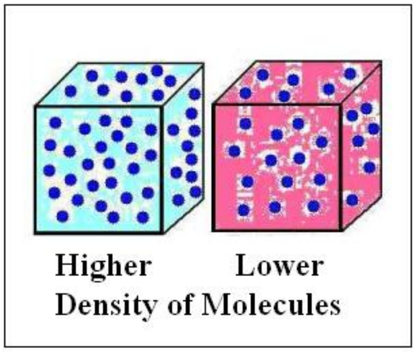


Figure 1

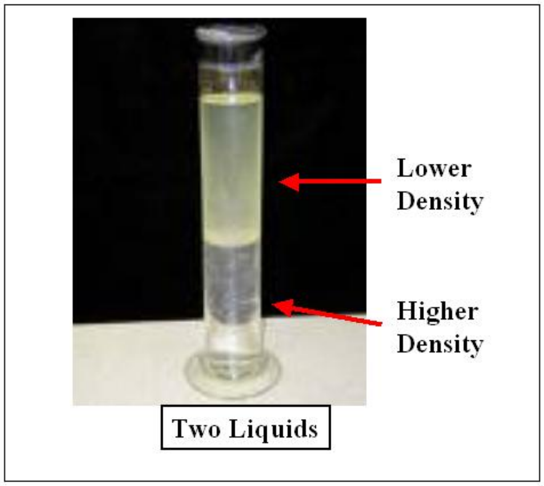


Figure 2

The density of an object is a function of its mass and volume:

Density = mass ÷ volume OR $\boldsymbol{D = \frac{M}{V}}$

In **Exercise 3a**, we will experiment with the relationship between the material an object is made of and the object's mass. <u>However, first you will need to set up your balance and calibrate it.</u>

- Find the balance and make sure the pans are centered on either side.
- Before you take any measurements, you need to calibrate your balance. **You will need to calibrate the balance frequently as you go through the following exercises to assure the accuracy of your data.**

<u>How to calibrate your balance:</u>

- Take out the box with the calibration masses, and remove the set of masses. Contained in this box are multiple masses. Take out two of the masses with the number 20 printed on the top.
- Place one 20g mass on each tray. If the scale is calibrated, the trays should be level and the center needle (pointer) should point to the largest center line, as shown in the picture below. Get down to eye level with the needle for the most accurate reading.

- Adjust the black knob above the needle until the needle comes to rest on the center line, as shown in the figure below.
- Your balance is calibrated!

Exercise 3a: Estimating the densities of cubes composed of different materials

In this exercise, you will compare the densities of a number of different materials used in daily life.

- Remove the poplar cube from the blue box containing the set of density blocks, and place it in one of the trays of your balance. Place the numbered masses on the other tray until you can determine the mass of the block. You will have to round out the mass estimate for the cube to the nearest gram, as there are no masses of less than one gram available.
- Record the mass in the Data Table 1.
- Repeat this procedure until all blocks are measured.
- Find the volume of each cube by measuring the length of one of its sides and using the formula from Exercise 2b:

$$\boldsymbol{V = l \times w \times h}$$

- Remember, for a cube, the measurements for length, width, and height are the same!
- Record the volumes of the cubes in the table.
- Using your data for mass and volume, complete the column labeled measured density in the data table by using the density formula:

$$\boldsymbol{D = \frac{M}{V}}$$

Data Table 1 for Exercise 3: Density Blocks

Material	Mass	Volume	Measured Density	True Density	Measurement Error (%)
Poplar					
Oak					
Pine					
Aluminum					
Steel					
Nylon					
Acrylic					
PVC					
Brass					
Copper					

Exercise 3b: Calculating percent error

Remember that the masses in your table are only approximations, because our smallest mass standard was 1g. Errors in measurement result not only from the limitations of our tools, but the limitations of our senses.

- In the answer sheets under **Exercise 3a**, you will find the density of each material from which the cubes from Exercise 3a are made. We will consider these values to be the true densities of the wood. NO PEEKING until you are ready to begin this exercise.
- Record the true densities in your table.

Now you are ready to determine the percent error of your measurements. Percent error will tell you the accuracy of your measurements.

$$\boldsymbol{percent\ error = \frac{measured\ density - true\ density}{true\ density} \times 100}$$

- Using the formula, calculate the measurement error for each of the blocks.
- Since some of the values listed in the table list a range of densities for particular materials, use the midpoint of the range of density values of those materials as the true value when making your calculations.
- Fill in the final column of your table.

- Your percent error can reflect an overestimate (>0) or an underestimate (< 0) of true density.
- Was there a trend in the error of your estimates? That is, did you tend to overestimate the density, or to underestimate it? If so, what might be some reasons for this trend?

Exercise 3c: Density in Biology and Technology

- Now that you understand the concept of density, see if you can answer the following biological and technological questions

Q1. Poplar, aspen and many pine tree species have wood that is low in density, while maple and beech trees are at the high end of wood density. What are some differences in the habits and life histories of these trees that would explain the differences in their wood densities?

Q2. Use the wood densities listed on below to match each tree species with its use. A given tree species may have more than one purpose, and the same object might be made from different woods. **Uses**: wood sculptures, pallets, paneling, flooring, matchsticks, bats, furniture, plywood, composites, paper.

Tree Type		
Common Name	**Scientific Name**	**Density g/ml**
Poplar	*Liriodendron tulipifera*	0.30-0.39
Aspen	*Populus sp.*	0 .42
White pine	*Pinus strobus*	0 .42
Maple	*Acer sp.*	0 .70
Oak	*Quercus sp.*	0 .74
Ash	*Fraxinus sp.*	0 .75

Q3. Because density influences mass, would you expect bone density to differ between terrestrial mammals and birds? If so, what pattern would you expect to exist between the two?

Q4. How would you expect the densities of marine mammals to compare to the densities of terrestrial mammals?

Q5. When it comes time to prepare the gravy to accompany the turkey that has been baking in the oven all day on Thanksgiving, the cook attempts to remove as much fat as possible from the juices that have accumulated in the bottom of the roasting pan. How can this be done?

- Check your answers under the Answer Sheet for **Exercise 3c**.

Exercise 4: Exploring object size, shape, density, and mass (*Lower grades***)**

- Locate the box containing several miscellaneous items.
- This box contains several each of the following items:
    - hickory nuts
    - acorns
    - stones
    - cotton balls
    - paper clips
    - noodles
    - plastic caps
    - sweet gum fruits (spiny seed balls)
    - felt pads
    - feathers
    - metal washers
    - jacks
- The objects in this box vary in size, shape, and density. In this exercise, you will explore how these properties are related to mass.
- The questions below will aid you in this exploration. Use different combinations of weights to answer as many of the questions as possible.
- Then develop and answer your own questions about these objects and others that you have in your room.
- Be sure to put all materials back in the appropriate boxes when you are finished.

1. What is the approximate mass of three hickory nuts?

2. Do different hickory nuts have the same mass?

3. If not, why might they differ in mass?

4. Do acorns differ in mass?

5. How does the mass of an acorn cap compare to the mass of an acorn nut?

6. Is the mass of a hickory nut greater than that of an acorn?

7. What is the approximate mass of two spiral noodles?

8. If you know the mass of two noodles, can you estimate the mass of one noodle without using the balance?

9. Why might two noodles be more similar in mass than two nuts?

10. Which has a smaller mass: two pieces of string or two paperclips?

11. Which has greater mass: a feather, a ball of cotton, or a polystyrene peanut?

12. Is the mass of a stone equal to the mass of three hickory nuts?

13. Is there an item in from the box of miscellaneous items with a mass of approximately five grams? If so, what is it?

Super-Solver Problem

- Rank the following objects from most to least massive: acorn, cotton ball, feather, felt pad, hickory nut, metal washer, plastic cap, polystyrene peanut, sweet gum fruit (the spiny seed ball), and stone.
- Now rank the same set of objects according to volume. You can estimate the volume of each object by estimating the product of each object's length, width, and height, that is, $length \times width \times height$.
- How do the two rankings compare? What contributes most to the difference between the two rankings (shape, size, or type of material)?

UNIT 4: Simple Measures
ANSWER SHEETS

Answers for Exercise 1

Q1. How many kilograms are there in one gram?

$$0.001 \text{ kg} = 1 \text{ g}$$

Q2. How many milligrams are there in one kilogram? How many milligrams are there in one metric ton?

$$1{,}000{,}000 \text{ mg} = 1 \text{ kg}$$
$$1{,}000{,}000{,}000 \text{ mg} = 1 \text{ metric ton}$$

Q3. How many kilograms are there in 800 grams?

$$0.8 \text{ kg} = 800 \text{ g}$$

Answers for Exercise 1a.1: Items of Known Mass (*Lower grades*)

Q1. How is the time it took the cart to travel the track related to the mass of the object in the cart? The greater the mass of the object in the cart, the longer it should have taken for the cart to travel the track.

Answers for Exercise 1a.2: Mass and Motion Answers (*Lower grades*)

Q1. For each item below, decide which of the two animals listed is the most massive.

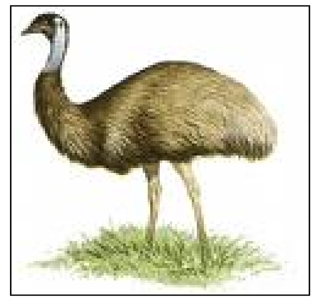
- **A meat eater that ambushes its prey or a meat eater that chases its prey**

An active chasing predator is lighter (less massive) than an ambush predator.


Less massive Cheetah **More massive Panther**

- **A bird with functional wings or a flightless bird such as an ostrich**
  Flightless birds are of greater mass than birds with wings used for flight. Lower masses make it easier for birds to obtain loft at lower wind speeds. The flightless, fully terrestrial birds are the most massive of all bird species. Some soaring birds may be of larger mass than the swimming flightless penguins, but penguins have more mass for their size than vultures, condors, and eagles.





Ostrich (Africa) **Rhea (South America)** **Emu (Australia)**
Massive Flightless Birds

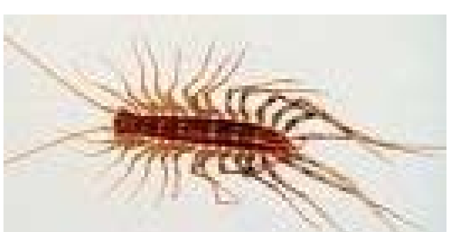
- **A soaring bird (such as a vulture) or a song bird**
  Birds of large mass have difficulty getting off of the ground. They require fairly high wind speeds to do so, and thus usually start flight from perches. These birds soar/glide on warm thermal updrafts of air with wings spread to keep aloft. The largest of the soaring birds is the condor, which roosts where it can easily launch itself into flight with just a few wing beats. Roost sites include large trees, snags, cliffs, and rocky outcrops. The song bird below has a mass of about 50g: the condor has a mass of 11,350g. The mass of a condor is thus 227 times greater than that of a typical song bird.


Soaring: Condor **Active flight: song bird**
Greater mass **Less mass**

- **A beetle that digs into rotting logs and litter on the forest floor or a butterfly that visit flowers.**
  Forest beetles, such as rhinoceros beetles are often quite massive, and flight is mostly restricted to searching for mates. They are, in fact, unable to change direction in flight, and thus must crash into something and fall to the ground to change course. Scientists believe that the rhinoceros beetle is the strongest animal on earth for its size, something that permits it to be able to forage through heavy litter on the forest floor and dig underground, where it is safe from predators. Butterflies are active flyers that visit flowers. They definitely have less mass than the detritus-boring beetles. **Find the rhinoceros beetle and butterfly in your trunk**.

Rhinoceros Beetle Greater mass **Butterfly less mass**

- **A centipede or a millipede.**
  Though centipedes and millipedes are closely related animals belonging to the Class Myriapoda, the centipedes are active predators that chase down their prey in high gear locomotion. They are of much less mass than the millipedes, which are detritivores, feeding on rotting logs. The millipede is a low gear animal that has two pair of legs per segment compared to the centipede, which has only one pair of legs per body segment. The millipedes use their greater mass in generating digging power.



Less massive centipede **More massive millipede**

Answers for Exercise 1a.2: Mass and Motion Answers (*Higher grades*)

Q1. Suppose two bodies have an acceleration of 8m/s^2. The mass of the first body is 3g, and the mass of the second body is 10g. Find the force acting on each body. Which body has a greater force?

The force on the first body is $8\frac{\mathrm{m}}{\mathrm{s}^2} \times 0.003\mathrm{kg} = 0.024\frac{\mathrm{m{\cdot}kg}}{\mathrm{s}^2}$.
The force on the second body is $8\frac{\mathrm{m}}{\mathrm{s}^2} \times 0.01\mathrm{kg} = 0.08\frac{\mathrm{m{\cdot}kg}}{\mathrm{s}^2}$.
The force on the second body is greater.

Q2. Rearrange the equation in Newton's second law to solve for *a* in terms of m and *F*.

$$a = \frac{F}{m}$$

Q3. Suppose that a force of 10(kg·m)/s^2 is applied to a body with a mass of 50g. What is the acceleration of the body? How much force would be needed to give a body with a mass of 100g the same acceleration? Does this agree with our previous statements relating mass and acceleration?

The acceleration of the first body is

$$a = \frac{10\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}}{0.05\mathrm{kg}} = 200\frac{\mathrm{m}}{\mathrm{s}^2}$$

If a 100g body has an acceleration of $200\frac{\mathrm{m}}{\mathrm{s}^2}$, then the force on the body is

$$F = 0.1\mathrm{kg} \times 200\frac{\mathrm{m}}{\mathrm{s}^2} = 20\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}$$

Therefore, it takes twice as much force give a 100g body an acceleration of $200\frac{\mathrm{m}}{\mathrm{s}^2}$ as it does to give a 50g body an acceleration of $200\frac{\mathrm{m}}{\mathrm{s}^2}$. This agrees with our previous statement that the more massive a body is, the more difficult it is to accelerate.

Q4. Rearrange the equation above to solve for a_s in terms of d_{track} and t_1.

$$a_s = \frac{2d_{track}}{t_1^2}$$

Q5. Use Newton's second law to find $\boldsymbol{F_w}$ in terms of $\boldsymbol{a_s}$ and $\boldsymbol{m_w}$.

$$F_w = m_w \times a_s = 0.05\ \frac{\text{kg m}}{\text{s}^2} \times a_s$$

Q6. Find $\boldsymbol{T}$.
Because

$$F_w = 0.49\ \frac{\text{kg m}}{\text{s}^2} - T$$

and

$$F_w = 0.05\ \text{kg} \times a_s$$

we see that

$$0.05\ \text{kg} \times a_s = 0.49\ \frac{\text{kg m}}{\text{s}^2} - T$$

which implies that

$$T = 0.49\ \frac{\text{kg m}}{\text{s}^2} - (0.05\ \text{kg} \times a_s)$$

Q7. Solve for $\boldsymbol{m_{tot}}$.

$$m_{tot} = \frac{0.49\ \frac{\text{kg m}}{\text{s}^2} - (0.05\ \text{kg} \times a_s)}{a_s}$$

Q11. See Q1. Under Exercise 1a.1. (*Lower grades*)

<u>Answers for Exercise 1b</u>

Q1. Which object has more mass: the purple block or the ring? The square purple block has the higher mass.

Q2. How many rings did you use? It takes 10 rings to equal the mass of the square purple block.

Q3. Which has more mass? The orange block has the higher mass.

Q4. How many rings did it take this time? It takes 5 rings to equal the mass of the orange block.

Q5. Judging from how many rings you used to equal the masses of purple and orange blocks, what conclusions can you make about the mass of each block

relative to that of the rings? The purple block is ten times the mass as one ring and the orange block is five times the mass of a ring.

Q6. Hypothesize the mathematical relationship between the yellow block and the ring. The ring and yellow block are equal in mass.

Q7. How many rings equal a yellow block? 1 ring

Q8. What is the mass of a ring? 1 gram

Q9. What is the mass of the purple block? 10 grams

Q10. What is the mass of the orange block? 5 grams

Q11. What is the mass of the yellow block? 1 gram

<u>Answers for Exercise 2</u>

Q1. Just by looking, what container do you think holds the same volume of water as the sphere? You should have chosen the rectangular container**. Was this easy to tell just by looking at the containers?**

Q2. Which container holds TWICE the amount of water as the rectangular box? You should have determined that the cube container holds twice the volume of water that the rectangle holds. This can also be stated as the rectangle has half the volume of the cube.)

Q3. Do the cube and cylinder have the same volume?
You should have answered "no". The cube container has a higher volume than the cylinder. It holds more water.

Q4. Can you tell by looking down at the containers why the cube has a higher volume? HINT: It has to do with shape!
Though the formulas for calculating the volume of a cube and a cylinder look different, they both are essentially the product of the area of the base times the height. A cylinder with a base that has the same perimeter as a cube's base would have greater volume, if the two shapes were of equal height. However, a cylinder with a base with a diameter equal to the length of the side of a cube (and the same height) would have less volume, since the corners of the cube add extra space. You can check this yourself through comparisons of the formulas for the volume of

each shape, substituting ***x*** for the length of the side of a cube (also the cube's height!), and ***x/2*** as the radius of the cylinder (with the height of the cylinder also being ***x***).Thus, an object's shape can determine its volume. Once again, looks can be deceiving!

Q5. Do a cone and pyramid of equal height have equal volumes? The pyramid has a slightly higher volume than the cone because it has a square instead of a circular base. (The corners allow room for more water). Again, however, the volume of each also depends on the area of the base, as well as the height!

Q6. What is the volume of the shape you have selected? (The answer should be in milliliters (ml)).

Cube: Approximately 1000 ml.
Rectangular prism: approximately 450 ml.
Sphere: approximately 450 ml.
Pyramid: approximately 400 ml.
Cone: approximately 370 ml.
Cylinder: approximately 800 ml.

Q7. Which shape has the biggest volume? Which has the smallest volume? The cube has the biggest volume (1000 ml) and the cone has the smallest volume (370 ml).

Q8. What volume of water does a filter-feeding sponge cycle through its cavity per day if its flagella create a current flow of 75 liters of water/ hr? 1800 liters (*l*) or 1.8 kiloliters (*kl*).

Q9. Since the typical sponge pumps a volume of water per minute equal to about 5 times its body volume, what is the volume of the sponge under Q8? The volume of this sponge is 0.25 *l* or 250 cubic centimeters (cm^3).

Q10. What volume of water did the anemone force out? The anemone is a cylinder in shape with a height of 3.8 cm and a diameter of 4.25 cm.
The volume of a cylinder is given as $V = \pi r^2 h$, where the radius r = ½ of its diameter. The volume of this anemone is approximately $3.14(2.13^2)(3.8) = 54.2$ cm^3 or 54.2 *ml*. If the anemone contracted to 10% its height, this would mean that it forced out approximately 48.8 ml of water.

Q11a. What is the volume of the *Volvox* colony in microliters? The *Volvox* colony and individual cells within it are spherical in shape. The equation for the volume of a sphere is

$$\boldsymbol{\frac{4}{3}\pi r^3}$$

$$\frac{4}{3}\pi(1500\mu\text{m})^3 = \frac{4}{3}\pi(1500 \times 10^{-6}\text{m})^3 = 1.41 \times 10^{-8}\text{m}^3$$

Since a microliter is equal to $1.0 \times 10^{-9}\text{m}^3$, the volume of the colony in microliters is

$$1.41 \times 10^{-8}\text{m}^3 \times \frac{1\mu\text{l}}{1.0 \times 10^{-9}\text{m}^3} = 1.41 \times 10^1\mu\text{l} = 14.1\ \mu\text{l}$$

b) What is the volume of the indicated daughter colony in microliters?
In measuring the two lines in the *Volvox* figure, we learn that the indicated daughter colony within the mother colony has a diameter of approximately 0.327 of the 3000 micron diameter of the colony, or a diameter of the daughter colony = 981 microns. Its radius is 490.5 microns. The volume of the daughter colony

$$= \tfrac{4}{3}\pi(490.5\mu\text{m})^3 = \tfrac{4}{3}\pi(490.5 \times 10^{-6}\text{m})^3 = 4.94 \times 10^{-10}\text{m}^3$$

Since a microliter is equal to $1.0 \times 10^{-9}\text{m}^3$, the volume of the colony in microliters is

$$4.94 \times 10^{-10}\text{m}^3 \times \frac{1\mu\text{l}}{1.0 \times 10^{-9}\text{m}^3} = 4.94 \times 10^{-1}\mu\text{l} = 0.494\ \mu\text{l}$$

Q12. Clams use gills for gas exchange and in the collection of food particles, just as sponges pump water through collar cells. Researchers predict that clams at deeper depths will have much larger gills than individuals of the same species would have in shallow waters. Why might this be the case, and how could they quantitatively test this hypothesis.
There would be less oxygen available in the depths of the ocean, because photosynthesis, which releases oxygen, occurs only in the photic zone receiving light. Shallow waters layer will also gain additional oxygen through gas exchanges occurring at the surface. Therefore, clams at deeper depths might be expected to have larger gills to be able to obtain their oxygen requirements from the less oxygenated habitats. To quantitatively test this hypothesis **in living specimens,**

biologists release a known volume of water containing dye (e.g., food coloring) at the incurrent syphon of test clams where water is pulled in by the action of cilia.

They then time the release of the dye as the water containing it is expelled from the clam. Using this method, they can quantitatively compare pumping rates (the volume of water moved through the gills per unit time) in clams. The larger the gill volume, the greater the pumping rate. **In dissected specimens**, water displacement would be a good approach to comparing the relative size of gills collected from clans at the two depths.

Answers for Exercise 3

Exercise 3a:

Material	True Density (g/ml)
Poplar	0.35 - 0.50
Oak	0.60 - 0.90
Pine	0.35 - 0.60
Aluminum	2.70
Steel	7.60
Nylon	1.13
Acrylic	1.16 - 1.19
PVC	1.39 - 1.42
Brass	8.00
Copper	8.90

Exercise 3c:

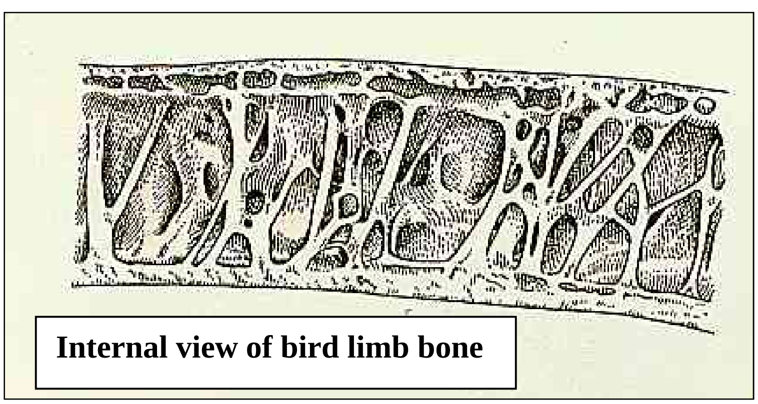
Q1. Balsa, aspen, poplar, and many pines have wood that is low in density, while maple and beech trees are at the high end of wood density. What is the difference in the habits and life histories of these trees that would explain the differences in their wood densities?

Pines, poplars, aspen, and balsa are fast growing pioneer, or weedy tree species. As they are among the first trees to invade a grassland or disturbed habitat, there is little competition for sunlight. In producing rapid growth in height, cell density is sacrificed**.** On the other hand, maples and beech are late succession tree species that grow slowly under the shade of a forest canopy. Rather than emphasizing height, these species put more energy into cell density. There is a greater energetic cost to producing high density wood, but there is greater stem longevity associated with higher cell densities. Thus, maples and beeches will live longer than the pioneer species.

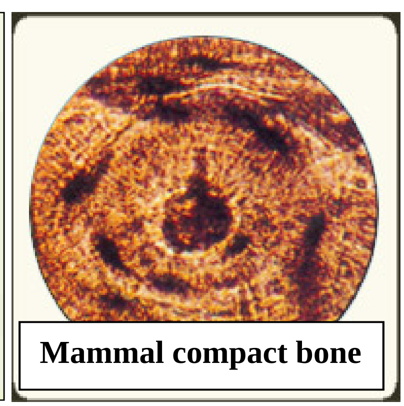
Q2. Given that you know that tree species have the following wood densities, match each tree species with its corresponding use. A given tree species may have more than one purpose, and the same object might be made from different woods. Uses: wood sculptures, pallets, paneling, flooring, match sticks, bats, furniture, plywood, composites, paper.

Tree Type	**density (g/ml)**	
Poplar	0.30-0.39	wood composites (plywood)
Aspen	0.42	matchsticks, paper
White pine	0.42	paneling, pallets
Maple	0.70	floors, bats furniture
Oak	0.74	floors, furniture
Ash	0.75	bats

Q3. Because density influences mass, would you expect bone density to differ between terrestrial mammals and birds? If so, what pattern would you expect to exist between the two?
Birds have much less dense bones then mammals because they need to have as little mass as possible to obtain lift. As you have learned from wood, the more dense the material, the stronger it is. Birds use a strut framework within their hollow tubes to supply the strength they have lost through low bone density.



Internal view of bird limb bone



Mammal compact bone

Q4. Extend the question above to consideration of mammals in the seas relative to terrestrial mammals. This is a complex problem, typical to biology. Since sea water provides support, one would expect that there would not be selection pressure for less bone mass. However, sea mammals are adapted from terrestrial relatives, and there is evidence that greater bone density has been selected for in mammals that occupy shallow waters. The greater density provides ballast that aids the mammal in maintaining position in the water. Marine mammals in deep water, however, have reduced bone density with cross sections of their bones resembling a case of osteoporosis.

Q5. When it comes time to prepare the gravy to accompany the turkey that has been baking in the oven all day on Thanksgiving, the cook attempts to remove as much fat as possible from the juices that have accumulated in the bottom of the roasting pan. How can this be done?

Fat (lipids) are lower in density than the flavored water (juices) released from the turkey as it roasts in the oven. Cooks use a spoon to skim off the fat from the remainder of the gravy. There are also special containers that complete this task.

Biologists use a similar technique in determining the lipid content of animal tissue. A tissue sample is homogenized in a blender and allowed to settle following spinning in a centrifuge. The relative volume of the lipid layer floating to the top of a graduated cylinder to other tissue fluids is determined, and each layer present in the homogenate is separated from the others for use in further tests.

SUGGESTED READING

<u>Grades K-3</u>

What Is the World Made Of? All About Solids, Liquids, and Gases - Kathleen Weidner Zoehfeld and Paul Meisel
Solids, Liquids and Gases - Ontario Science Centre and Ray Boudreau
Gravity Is a Mystery - Franklyn M. Branley and Edward Miller
What is Gravity? - Lisa Trumbauer
Simple Machines - Deborah Hodge and Ray Boudreau
What's the Matter in Mr. Whiskers' Room? - Michael Elsohn Ross and Paul Meisel (Illustrator)
Forces Make Things Move - Kimberly Brubaker Bradley and Paul Meisel

<u>Grades 4-7</u>

Matter (Discovery Channel School Science) - Gareth Stevens Publishing
Can You Feel the Force? - Richard Hammond
Fatal Forces (Horrible Science) - Nick Arnold
The Spinning Blackboard and Other Dynamic Experiments on Force and Motion - Paul Doherty and Don Rathien
Forces and Movement - Peter D. Riley
Forces and Motion - Alvin Silverstein, Virginia B. Silverstein, and Laura Silverstein
Isaac Newton and Physics for Kids: His Life and Ideas with 21 Activities - Kerrie Logan Hollihan

<u>Grades 7+</u>

Eyewitness Visual Dictionary of Physics - DK Publishing
Sports Science Projects: The Physics of Balls in Motion - Madeline P. Goodstein
Isaac Newton and the Scientific Revolution - Gale E. Christianson

<u>Scientific Journal Articles (included on Teacher CD)</u>

Bisbee, G.D. and C.A. Kaiser. 1997. Milkweed seed dispersal: A means for integrating biology and physics. *The American Biology Teacher* 59(7):426-427.

Magnusson, W.E., A.P. Lima, W. Alves da Silva, and M. Carmozina de Araújo. 2003. Use of geometric forms to estimate volume of invertebrates in ecological studies of dietary overlap. *Copeia* 2003(1):13-19.

Ryser, P. 1996. The importance of tissue density for growth and life span of leaves and roots: A comparison of five ecologically contrasting grasses. *Functional Ecology* 10(6):717-723.

LINKS

Mass and Matter - website from Kennesaw State University; provides numerous links to information on matter, mass, atoms, and molecules.

http://edtech.kennesaw.edu/web/matter.html

Physical Science Interactive Web Sites - A quite comprehensive list of interactive physics websites compiled by Jerrie S. Cheek at the Educational Technology Training Center at Kennesaw State University. Divided into subject-specific sections such as matter, force and motion, atoms, radioactivity, the periodic table, atomic and molecular motion, transformations and flow of energy, waves, and electricity and magnetism.

http://edtech.kennesaw.edu/physicalscience/physicalscienceinteractivesites.htm

PhysicsCentral - Learn how your world works! A website by the American Physical Society. Be sure to check out **Physics@Home**, which presents several physics experiments easily completed both at home and in the classroom!

http://www.physicscentral.com/

http://www.physicscentral.com/experiment/physicsathome/index.cfm

Shape and Space (Measurement) - Website from British Columbia's Ministry of Education providing activities and resources regarding measurement of shape and space for grade levels K-1.

http://www.bced.gov.bc.ca/irp/mathk7/k1sasme.htm

Physics4Kids.com: Motion - Great introductory website presenting information on forces, vectors, laws of motion, energy of motion, velocity, momentum, friction, gravity, and work.

http://www.physics4kids.com/files/motion_intro.html

What is Matter? - An 8th grade "sci-ber text" from the Utah State Office of Education, which includes information and experiments on physical and chemical changes. Also features clickable "bookmarks" leading to similar sections on energy, forces, machines, and an earth science section, as well.

http://www.schools.utah.gov/CURR/science/sciber00/8th/forces/sciber/intro.htm

Forces and Motion - Cool website from Cislunar Aerospace (funded by NASA) that offers beginner, intermediate, and advanced activities on forces and motion, complete with checklists of skills/techniques utilized by each.

http://wings.avkids.com/Curriculums/Motion/motion_links.html

Exploratorium: Sport Science - Great website for getting athletic types interested in science! Presents the physics and biomechanics behind numerous sports.

http://www.exploratorium.edu/sports/

IBEAM (Integrating Biology Experimental Activity Modules) with Introductory Physics – Another great website from Kennesaw State. Contains activities illustrating opposing forces, acceleration due to gravity, center of mass, and several other physics concepts, and how they relate to biological systems.

http://ibeam.kennesaw.edu/index.htm

Light and Matter - Open source physics textbooks!

http://www.lightandmatter.com/

Insultingly Stupid Movie Physics - An amusing site that highlights examples of bad physics in movies. Even has a section on how to use movie physics in the classroom, including lists of movie scenes with activities based on corresponding physical principles.

http://www.intuitor.com/moviephysics/

http://www.intuitor.com/moviephysics/mpclassroom.html