Physical Science Laboratory Investigations

A real world approach to the survey of physics and chemistry for non-science majors

Version 1

Created and Written by Teresa Ciardi

Acknowledgements

John Moeller, my Dad, said this to me often, "You can do anything if you work hard”
Dr. Whitaker, at Boston University, gave me the confidence to pursue physics
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Message to Students

We begin our education as curious, inquisitive, adventurous people. Somewhere along the way, we become cautious with our answers and sometimes complacent with information. The purpose of lab is to investigate, to be curious, and to be adventurous in our efforts to observe and attain the answers we seek. Real science is a combination of intuition, failures, and successes through persistence. Never, never, give-up. All things are difficult before they are easy.

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Interpreting Errors

Systematic Error

- Measurements deviate from the correct value by the same amount each time.
- Errors have a pattern

Example: Time on a watch is always 5 minutes ahead of the true time

Random Error

- Errors have no pattern

Example: Everyone's watch shows a different time

Uncertainty in Measurement

- Number ± error
- It is the amount a number may be off from the correct value.

Example: Age ±365 days

Ratio Comparison

- Shows how two numbers compare
- Reduced fraction shows comparison

Example: $\frac{65\text{ mph}}{30\text{ mph}} = \frac{2.2}{1}$ (Means one speed is 2.2 times faster than the other)

Percent Error

- Percentage measurements are off from standard/correct value
- Absolute value

$$\text{Percent Error} = \frac{|Experimental\ Value - Accepted\ Value|}{Accepted\ Value} \times 100\%$$

Exercise 1 - Making a Hypothesis

Student Learning Objectives:
Experience making a hypothesis, taking good measurements, and developing a procedure to solve a problem.

Materials:

Pen or Pencil
Metric Ruler
Meter Stick

Introduction:
For many people, it is difficult in today's world to make a guess. People tend to prefer to look up the answer rather than use experience to attempt an answer. However, scientific theories and laws often begin with a guess based on logic and experience. Another important aspect of doing science is measurement. Good measurements and a good procedure can lead to a true answer.

Pre-lab:

A. Why is the scientific method important?
B. What does the word hypothesis mean?

Procedure:
You will use your spatial abilities, knowledge of volume, and collective reasoning skills to make hypotheses and test those hypotheses.

1. Draw a table in which you can record all the data you will be collecting. You will need the following table headings. Do not fill in data until you have read the instructions for obtaining that data.

Table		***Floor***		***Room***	
Hypothesis	**Measurement**	**Hypothesis**	**Measurement**	**Hypothesis**	**Measurement**

Table Length

2. Choose <u>one</u> pen or pencil from your team and place it on the table. Without direct measurement, make a hypothesis for the number of pen lengths your entire lab table is. Record this hypothesis.

3. Measure the table in units of pen lengths. Record this measurement.

Floor length

4. Without direct measurement, make a hypothesis for the number of pen lengths your lab floor is, in one chosen direction. Record this hypothesis.

5. Measure the floor length, in units of pen lengths. Record this measurement.

Room Space

6. How many pens do you think it would take to completely fill the classroom? Record this hypothesis.

7. Use your collective knowledge to develop a procedure for determining the number of pens required to fill the classroom. List the steps of your process under your table of data.

8. Record all measurements and calculations as you follow your process. Record your calculated number of pens to fill the room in your data table.

<u>Analysis:</u>

1. Calculate the difference between your hypothesis and measurement/calculation for each system (table, floor, and room).

2. Use a ratio to compare your hypothesis and measurement/calculation for each system (table, floor, and room).

General Questions:

1. Based on the measured floor length, in units of pen lengths, what is your hypothesis for the floor length in the other direction?

2. Think of what you observe every day. Choose one natural daily occurrence and make your own hypothesis about how or why this occurs. Then research the answer and confirm or dispute your hypothesis.

Exercise 2-Precision and Accuracy

Student Learning Objectives:

Distinguish between precision and accuracy as they are used in scientific measurement and analyze errors in measurements.

Materials:

Candle
Aluminum Foil (12x12 inch sheet - approximately)
Matches
Ruler

Introduction:

A principle objective of science is to describe the physical world through measurement. While we often begin with a hypothesis in science, it is important to make precise measurements and to determine the accuracy of these measurements. There is always some amount of error, so measurements should be made several times; the average of several measurements will lessen the amount of error introduced by the measuring process. The words precision and accuracy are often used interchangeably in common language, however, these two words have very different meanings.

Pre-lab:

A. Research and state the definition of precision.
B. Research and state the definition of accuracy.

Procedures:

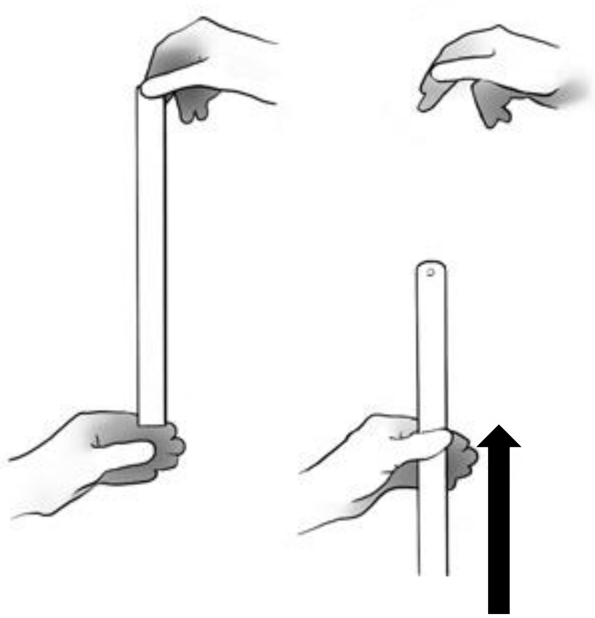
You will record measurements from three different systems and analyze errors.

Reaction Time

1. Draw a table in which to record your data for the distance a ruler falls, as you attempt to grasp it; you will need to have 5 successful trials recorded. Do not fill in data until you have read the instructions for obtaining that data.

Trial #	Distance Ruler Fell (cm)
1	
2	
3	
4	
5	

2. **Each person** will record their own data, as each person in your group attempts to grasp a ruler while it falls. One person will hold the top of a ruler so that the ruler hangs down vertically, while you place your index finger and thumb at the bottom edge of the ruler as if **you** are about to pinch the ruler. (See image on next page.)



3. The person holding the ruler should allow the ruler to drop <u>without warning</u>. **You** will then pinch the ruler as fast as you can. Record the distance the ruler falls **in centimeters**, for each of five successful trials. If the ruler falls to the floor, this not a successful trial; repeat the trial.

Burning Candle

4. Draw a table in which to record your data for the length of the candle, before and after it burns, and every 2 minutes while it burns. Read the instructions for obtaining the data.

Time (minutes)	**Length (centimeters)**
Pre-burn	
2	
4	
6	
8	
10	
Post-burn	

5. Use the aluminum foil to create a candle stand. Measure the length of the unlit wax candle **in centimeters**. Record this value as the pre-burn value.

Warning: Be careful that you do not burn yourself or the ruler during this experiment.

6. Light the candle and allow it to burn for the duration of this mini-experiment. Measure the total length of the candle + flame, **in centimeters**, measuring from the bottom of the candle to the top of the flame, every 2 minutes for a total of 10 minutes.

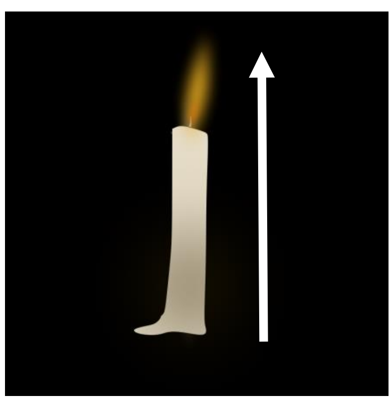


Illustration of a candle with a burning flame by chikiyo is in the public domain

7. Extinguish the candle flame. Measure the length of the unlit wax candle **in centimeters**. Record this value as the post-burn value.

Clocks

8. Look at the clock in the room and record the time. Then look at the time on your watch or cell phone and record the time. You will only have one trial for this mini-experiment.

Clean-up:

- Rinse your match and throw it away
- Throw away the foil
- Clean up any spilled wax
- Replace all items from where you obtained them

Analysis:

Reaction Time

1. Draw a table in which to record the average distance the ruler fell for each person on your team. Calculate and record the average distance the ruler fell, in centimeters, as you attempted to grasp it. Also record the average distance the ruler fell for each of your team members.

Team Averages

Team Member	Average Distance (centimeters)

2. Based on your data, who has the best reaction time? Explain.

3. List two possible sources of error in the reaction time experiment, and state whether each error was random or systematic.

Burning Candle

4. If your candle had been allowed to burn for 30 minutes, what do you predict the change in length, from pre to post burn, would have been? Explain your reasoning.

5. Describe the change in length of the candle that occurs while it is burning. Is there a steady decrease in height? Explain.

6. List two possible sources of error in the burning candle experiment, and state whether each error was random or systematic.

Clocks

7. Is it possible to measure the precision from the data you obtained in this mini-experiment? Explain.

8. List two possible sources of error in the clocks experiment, and state whether each error was random or systematic.

General Questions:

1. For which system (Reaction time, Burning Candle, or Clocks) did your team obtain the most precise measurements? Explain.

2. A systematic error will definitely affect (choose one)

    a. Precision

    b. Accuracy

    c. Both precision and accuracy

3. Teresa, Alexes, and Krystina, having received degrees in paleontology, each measure the length, in centimeters, of a dinosaur bone unearthed by their dog Bacall. Bacall, having more experience with bones, measured the bone once and obtained the correct value. Calculate the average measurement obtained by each person.

	Teresa	**Alexes**	**Krystina**	**Bacall**
	2.0	7.3	7.0	7.3
	2.1	9.1	7.3	
	1.9	5.8	7.2	
	2.0	7.0	7.1	
Average				

a. Whose measurements are accurate and precise?

b. Whose measurements are precise but not accurate?

c. Whose measurements are accurate but not precise?

d. Whose measurements are accurate, but have no measure of precision?

e. Whose measurements are probably a result of a systematic error?

f. Calculate the percent error for Teresa, Alexes, and Krystina.

	% Error
Teresa	
Alexes	
Krystina	
Bacall	

Exercise 3 - The Best Paper Towel

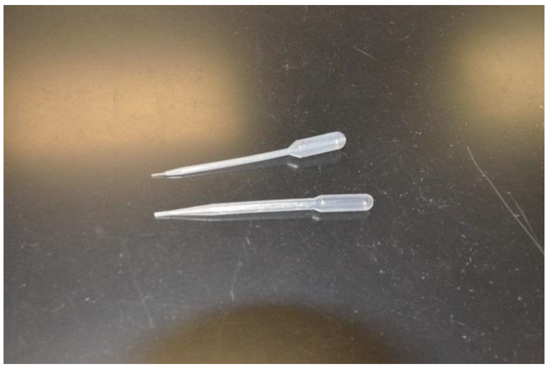
Adapted from a Lab written by Aulikki Pekkala-Flagan, with her permission

Student Learning Objectives:

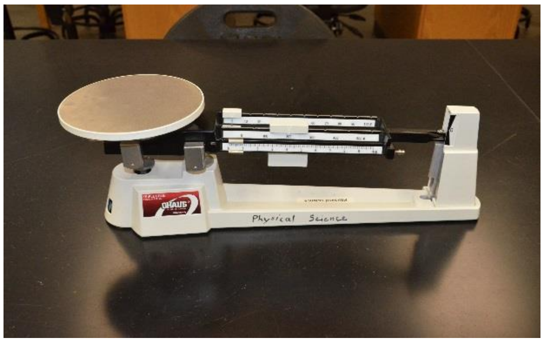
Analyze properties of different brands of paper towels and utilize a scientific approach to determine the best brand of paper towel for the money.

Materials:

4 Different Brands of Paper Towels (keep packaging details and price)
4 Index cards
Scissors
Triple Beam Balance
250 mL Beaker
24 Clothespins (per group)
Plastic Pipette
Various Masses (20-1000 grams)
Permanent Marker
Metric Ruler



Pipette by Norihiro licensed under CCO



Triple Beam Balance by Norihiro licensed under CC0

Introduction:

There are various properties that make a particular brand of paper towel appealing to a consumer which may include absorbency, durability, appearance, and/or cost. Paper towels have a variety of thicknesses and textures, and may vary in cost significantly. The question is, which paper towel is the best value? Scientists must devise a plan to answer a question, utilizing the information available and creating a process that is systemic so the same tests are applied. It is important that the scientist employs consistent measurements.

Pre-lab:

A. Name the brands of paper towels typically used in your home and state the reason(s) these paper towels are used.
B. What is the most important property to you that would promote you purchasing a particular brand of paper towel?

Procedures:

You will investigate and compare the properties of paper towels.

Absorbency

1. Choose the four brands of paper towels you will be testing and obtain 2 sheets of each. Label the sheets with the brand name.

2. Draw a table which includes the brand names of 4 chosen types of paper towels, and places to record for each the dry mass, predicted absorbency ranking, wet mass, amount of water absorbed, and resulting absorbency ranking. Do not fill in data until you have read the instructions for obtaining that data.

Paper Towel Brand	Predicted Absorbency Ranking	Dry Mass (grams)	Wet Mass (grams)	Amount of Water Absorbed (grams)	Measured Absorbency Ranking

3. List the brand names of the paper towels your team chose, in your table. Number the predicted rankings for the paper towels, in your table; give a 1 to the paper towel you expect to have the best absorbency and a 4 to the paper towel you expect to have the least absorbency.

4. Cut an equal size piece of each brand of paper towel. Label these pieces with the brand name.

5. Devise a process for testing the absorbency, which includes measurements of the dry mass and wet mass for the paper towel pieces. Follow the process and complete your table.

Clean-up:

- Throw away wet paper towel pieces
- Completely dry Triple Beam Balance
- Use classroom paper towels to dry the team table

Speed

6. Draw a table which includes the brand names of your 4 chosen types of paper towels, and places to record for each the predicted speed ranking, the measured time it takes to absorb water, and resulting speed ranking. Read the instructions for obtaining the data.

Paper Towel Brand	Predicted Speed Ranking	Time to Absorb Water	Measured Speed Ranking

7. Cut an equal size strip of each brand of paper towel; the strips should also be the same width. Label these pieces with the brand name.

8. Number the predicted rankings for the paper towels, in our table; give a 1 to the paper towel you expect to have the fastest absorbency time and a 4 to the paper towel you expect to have the slowest absorbency time.

9. Devise a process for testing the speed at which each strip absorbs water, which includes time measurements. Follow the process and complete your table.

Clean-up:

- Throw away wet paper towel pieces
- Use classroom paper towels to dry the team table

Strength

10. Draw a table which includes the brand names of your 4 chosen types of paper towels, and places to record for each the predicted strength ranking, a measurement which

indicates the strength of the paper towel, and the resulting strength ranking. Read instructions for obtaining the data.

11. Cut an equal size piece of each brand of paper towel. Label these pieces with the brand name.

12. Number the predicted rankings for the paper towels, in your table; give a 1 to the paper towel you expect to be the strongest and a 4 to the paper towel you expect to be the weakest.

13. Devise a process for testing the strength of the <u>wet</u> paper towel pieces, using the materials provided, which includes measurements. Follow the process and complete your table.

<u>Clean-up:</u>

- Throw away wet paper towel pieces and all remaining pieces of paper towels at your team table.
- Use classroom paper towels to dry the team table.
- Discard water outside (water the foliage).
- Use classroom paper towels to completely dry beaker.

<u>Analysis:</u>

1. Record information from the packaging for each of your 4 chosen types of paper towels, in a table. Use the information from the packaging and the data you collected to calculate the value of each paper towel (SQ FT per penny), and record this value in your table.

    a. Price per roll
    b. Number of square feet (SQ FT) per roll
    c. SQ FT per penny or cost per SQ FT - this is the unit price

2. Which brand of paper towel absorbed the greatest amount of water?

3. Which brand of paper towel absorbed water the fastest?

4. Which brand of paper towel is the strongest?

5. Which brand of paper towel is the least expensive (has the most SQ FT per penny)?

6. Based on your data and calculations, which brand of paper towel would be the best paper towel for the price? Use your experimental results to defend your answer.

General Questions:

1. If you were to repeat this experiment, what would you change?

2. What would you test to determine the best printer paper for the money?

Exercise 4 - Measuring a Wood Block

Student Learning Objectives:

Measure objects in inches and centimeters, and compare English and metric measurements.

Materials:

Meter Stick
Metric Ruler
Wood Block (2x4x6 inches)
Metal Cylinder (1000 grams)

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Introduction:

Measurement is an objective tool of science. When measurements utilize the same units, they may be qualitatively and objectively compared. The system of units used in the physical sciences are based on the metric system, which utilizes multiples of 10. The United States continues to use English units, such as the inch and the foot.

Pre-Lab:

A. How many centimeters are in 1 meter?
B. What is the formula for calculating the volume of a cube?
C. What is the formula for calculating the volume of a cylinder?

Procedures:

You will measure in English and metric units, and compare these measurements.

Quantifying a Wood Block

1. Draw a table for the Wood Block. Do not fill in data until you have read the instructions for obtaining that data.

Wood Block

Units	Length	Width	Thickness	Volume
Inches				
Centimeters				
Meters				

2. Measure the length, width, and thickness of your wood block in inches and centimeters, and enter these values into your table.

3. Convert all of the centimeter measurements, for your wood block, to meters.

4. Calculate the volume of your wood block, for each set of units (inches, centimeters, and meters), and enter these values into your wood block table.

Quantifying a Metal Cylinder

5. Draw a table for the Metal Cylinder. Read the instructions for obtaining the data.

Metal Cylinder

Units	Radius	Height	Volume
Inches			
Centimeters			
Meters			

6. Measure the radius and height of your metal cylinder in inches and centimeters, and enter these values into your table. Do not include the hook when you measure the height.

7. Convert all of the centimeter measurements, for your metal cylinder, to meters. 1 meter = 100 centimeters.

8. Calculate the volume of your metal cylinder, for each set of units (inches, centimeters, and meters), and enter these values into your metal cylinder table.

Analysis:

1. Use a ratio to compare wood block measurements, and reduce the fractions such that the smallest value is 1.

Example: $\frac{\text{540 inches}}{\text{15 yards}} = \frac{\text{36 in}}{\text{1 yd}}$

   a. Length centimeters and inches
   b. Width centimeters and inches
   c. Thickness centimeters and inches

2. Use a ratio to compare metal cylinder measurements, and reduce the fractions such that the smallest value is 1.

   a. Radius centimeters and inches
   b. Height centimeters and inches

General Questions:

1. Based on your analysis calculations, what is the conversion factor for inches and centimeters?

2. How many places must you move the decimal to change from meters to centimeters? In what direction must you move the decimal in this case?

3. Determine the conversion factor for changing volume from in^3 to m^3.

Exercise 5 - Walking at a Constant Speed

Student Learning Objectives:

Compare average walking speeds, and distinguish between average and constant speed.

Materials:

2 Stopwatches (you may use your phones)
Masking Tape
Measuring Tape
Mobile Phone

Introduction:

As we walk or drive, there are often distractions that may cause us to change our speed slightly. For motion in a straight line, the average speed (s) is the total distance (d) traveled divided by the time (t) it took to travel that distance. If the speed is constant, then the average speed for each time interval will have the same value.

$$\boxed{s = \frac{d}{t}}$$

Pre-Lab:

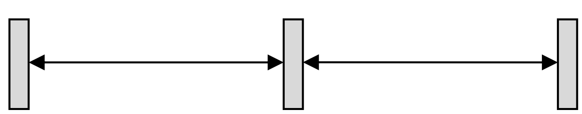
A. Define average speed.
B. Define constant speed.
C. Define instantaneous speed.

Procedures:

Each person in the group will walk a distance of 10 meters multiple times.

Just Walking

1. Use masking tape to mark a path with two equally spaced distance intervals (5 meters each) as shown below.



0 m 5 m 10 m

2. Draw a table in which to record the time for each 5 meter interval, for the first 3 trials. You will also need a place to record a calculated average time and average speed for each of the 5 meter intervals. Do not fill in data until you have read the instructions for obtaining that data.

Just Walking

Trial #	Time for 0-5 meters	Time for 5-10 meters
1		
2		
3		
Average Time		
Average Speed		

3. One team member will stand at the 5 meter mark to measure the time it takes for you to walk the first interval (0-5 meters). A second team member will stand at the 10 meter mark to measure the time it takes for you to walk the second interval (5-10 meters).

4. You will walk the full 10 meters, without pausing, while your team members collect your data, for a total of 3 trials. Record your data in your data table.

5. Repeat procedures 3 and 4 until all team members have their data. Once everyone has their own data, calculate <u>your</u> average time and speed for each interval and record these values in your data table.

Texting & Walking

6. Draw a table in which to record the time for each 5 meter interval, for 3 trials, while texting. You will also need a place to record a calculated average time and average speed for each of the 5 meter intervals. Read the instructions for obtaining the data.

7. Use your mobile phone to send a text or look through your social media while walking the 10 meters for the texting and walking trials. Record <u>your</u> data and calculations in your texting and walking data table.

<u>Clean-up:</u>

- Wind-up measuring tape before returning
- Remove all masking tape from the ground, and throw it away

Analysis:

1. Look at <u>your</u> two data tables. Did you tend to walk faster when you were just walking or when you were using your phone?

2. Look at each other's data tables and discuss any trends and/or differences your team notices.

    - Did people tend to walk faster in the first or second 5 meter interval?
    - Did everyone walk at about the same speed?
    - Did anyone wander off course while using their phone?

General Questions:

1. You calculated an average speed for each interval. Are these values also your constant speed?

2. While driving between Santa Clarita and L.A., you look at your speedometer which reads 30 mph. What form of speed are you viewing on the speedometer: average, constant, or instantaneous? Explain.

3. It is 2,790 miles from L.A. to N.Y. If you average 60 mph, how many days will it take you to travel from Las Angeles to New York by car, non-stop? Will your speed be constant?

4. If you leave L.A. on Monday at 8:00 am, stop for 7 hours of sleep each night, and stop for half an hour to eat three times a day, when (day and time) would you arrive in New York? Assume that you average 60 mph when you are driving.

Exercise 6 - Falling Objects

<u>Student Learning Objectives:</u>
Observe falling objects and compare the acceleration of falling objects in air.

<u>Materials:</u>

Bathroom Rug (about 2 feet by 3 feet)
Meter Stick
Measuring Tape
Masking Tape
g-Ball
Stop Watch (you may use your phone)
6 objects (Feather, Paperclip, Marble, Various Balls, etc.)

g-Ball image courtesy of Arbor Scientific

<u>Introduction:</u>
There is always some delay between the time an observation is made and the time it takes for a person to react and push the stop watch button, so the g-Ball will be used initially to remove the reaction time of a person from the process. Objects falling in air all experience the same acceleration due to gravity, however, the air may affect these objects differently. The average acceleration (a) of an object as it falls through air depends on the distance (d) it falls, and the time (t) it took for the object to fall.

$$\boxed{d = (1/2)at^2}$$

Pre-Lab:

A. If there was no air, what would the vertical acceleration be for each object?
B. Which do you expect to have more air resistance, something smooth or something rough?

Procedures:

You will drop the g-Ball and several objects, and compare the acceleration of these items in air.

Setting the Standard

1. Draw a table in which to record the data for the g-Ball. Do not fill in data until you have read the instructions for obtaining that data.

g-Ball

Distance (meters)	Trial 1 (seconds)	Trial 2 (seconds)	Trial 3 (seconds)	Average Time (seconds)	Average Acceleration (m/s^2)
1/2					
1					
2					
3					

2. Place the bathroom rug on the floor or ground, under the place where you will be dropping the g-Ball.

3. Practice with the g-Ball so that you know how it works prior to starting the trials for your data. Drop the g-Ball 3 times from each of the heights listed in your data table, and record the time shown on the g-Ball. This is the time it took for the g-Ball to fall to the floor once released.

4. Calculate and record the average time for each of the heights from which you released the g-Ball. Also calculate and record the average acceleration of the g-Ball in each case.

Testing Everyday Objects

5. Choose 6 objects of different masses and sizes. Determine what your process will be to compare the acceleration of these objects when they are dropped from a height. Also, consider how you will compare the data for the 6 objects to the g-Ball. Draw a data table for the data you will be collecting.

6. List your 6 objects in your data table. Indicate next to each object, the predicted rank order for these objects to fall when they are dropped from a height, from shortest time (1st) to longest time (6th).

7. Find a safe location from which to drop your 6 objects, a height of two to three stories if possible. Measure and record this distance in <u>meters</u>.

8. Proceed with dropping your 6 objects and collecting data.

<u>Analysis:</u>

1. Were the average acceleration values you calculated for the g-Ball very similar or very different?

2. Compare the acceleration of the 6 objects. Was the acceleration for your 6 objects very similar or very different?

3. Describe any differences in properties of objects which may contribute to less/more downward acceleration. How do these properties of the objects compare to the properties of the g-Ball?

4. Which object had the greatest upward acceleration from air? Explain.

5. In general, what errors in <u>your measurements</u> may have resulted in this investigation?

<u>General Questions:</u>

1. The Eiffel Tower is about 300 meters tall. Calculate the average of the values you have for the average acceleration of the g-Ball. Use the result to determine the time it would take for the g-Ball to fall from the top of the Eiffel Tower. What would be the speed of the g-Ball once it hit the ground, if it was dropped from the top of the Eiffel Tower?

2. In the absence of air, how long would it take your 6 objects to fall the measured distance from which you dropped them? What would be the final velocity of your 6 objects?

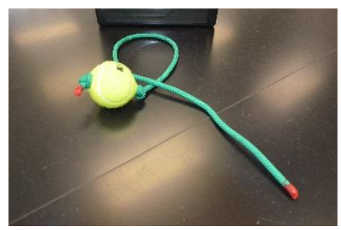
Exercise 7 - Traveling in a Circle

Student Learning Objectives:
Analyze the behavior of objects traveling in a circular path, and name some sources of centripetal force.

Materials:

Aluminum Pie Tin (with part of sidewall removed)
Marble
Approximately 1-meter Length of Rope
Soft Object (which can be secured to rope)
Triple Beam Balance

Pie Tin with Opening



Tennis Ball with Rope (Ideal)

Introduction:
Circular motion may include the orbital motion of an object, or motion that outlines part of a circular path. According to Newton's 1st law of motion, an object will maintain straight line motion unless it is pushed or pulled by some force. Any force that causes an object to travel in a circular path is a centripetal force ("center-seeking" force). The push or pull forces the object to change direction and follow a circular path. The amount of force (F) required to keep a mass (m) traveling along a circular path depends the speed (v) with which the object travels around the circle and the radius (r) of the circle.

Centripetal Acceleration	Centripetal Force
$a = \frac{v^2}{r}$	F = ma

Pre-Lab:

A. What is the radius of a circle? You may describe or sketch this.
B. What is the distance around a circle called? What is the formula for this?
C. What is the definition of acceleration?

Procedures:

You will analyze three systems involving circular motion.

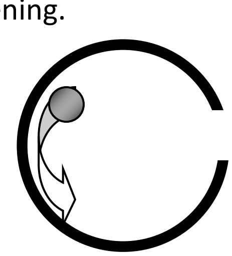
1. Draw a table in which to record the radius and mass for each system, describe or name the centripetal force and its direction. Do not fill in data until you have read the instructions for obtaining that data.

System	Mass of Object	Radius of Orbit	Centripetal Force	Centripetal Force Direction
Marble & Pie Tin				
Ball & Rope				
Spaceship & Earth				

Marble around the Pie Tin

2. Predict the path the marble will take as it leaves the opening in the pie tin. Will it continue in a circular path or will it travel in a straight line when it leaves the plate? Describe or sketch your prediction.

3. Place the pie tin on the table, and start the marble traveling along the inside edge of the pie tin. You will need to give the marble a good, fast start with your hand; the pie tin should remain on the table for this. Describe or sketch the path of the marble <u>after</u> it leaves the pie tin through the opening.



4. Name or describe the centripetal force that kept the marble traveling in a circle. State the direction of the push or pull that kept the marble circling. Record your answers.

5. Measure and record the radius of the pie tin. Also measure and record the mass of the marble. Enter these values in your data table.

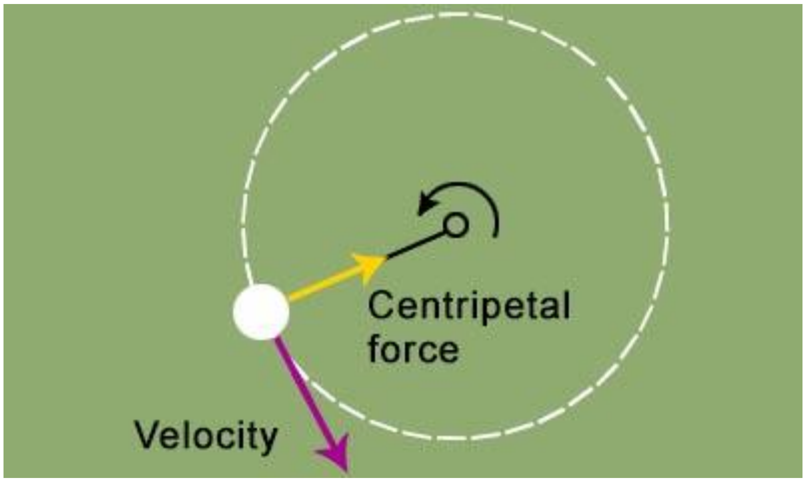
Orbiting Object

<u>**Warnings**</u>**:**

- **Be careful that no one is impacted by your orbiting object, and do not let go of it.**
- **Impact safety glasses are recommended while circling the object on the rope.**

6. Predict whether it will be more difficult to hold onto the rope when the object is circling with a slow or fast speed. Record your prediction.

7. Hold the rope firmly and circle the object at a steady rate. Then increase the speed at which your object is circling. In which case is more force required to hold onto the circling object, when it has a slow orbital speed or a fast orbital speed? Record your answer.



Centripetal-Force-Problems-Discussion-Questions by Zappys Technology Solutions is licensed under CC BY 2.0

8. Name or describe the centripetal force that caused the object to travel in a circle. State the direction of the push or pull that kept the object circling. Record your answers.

9. Measure and record the radius of orbiting object system. Also measure and record the mass of the system. Enter these values in your data table.

Space Ship

10. A spaceship is in orbit 300 km above the surface of the Earth (r = 6.378×10^6 meters). Assume the spaceship is the USS Enterprise from Star Trek, with a mass of 9.6×10^7 kg. Record the radius of the orbit and the mass of the orbiting object in your data table.

Comic-Con 2006 - USS Enterprise by *The Community - Pop Culture Geek* is licensed under CC BY 2.0

Blue Marble 2002 by NASA is in the public domain

11. Name or describe the push or pull that keeps the spaceship in orbit. State the direction of the push or pull that keeps the spaceship orbiting the Earth. Record your answers.

Analysis:

1. In general, what is the direction of the push or pull if an object is traveling in a circle?

2. Do the following quantities affect the amount of push or pull when an object is circling?

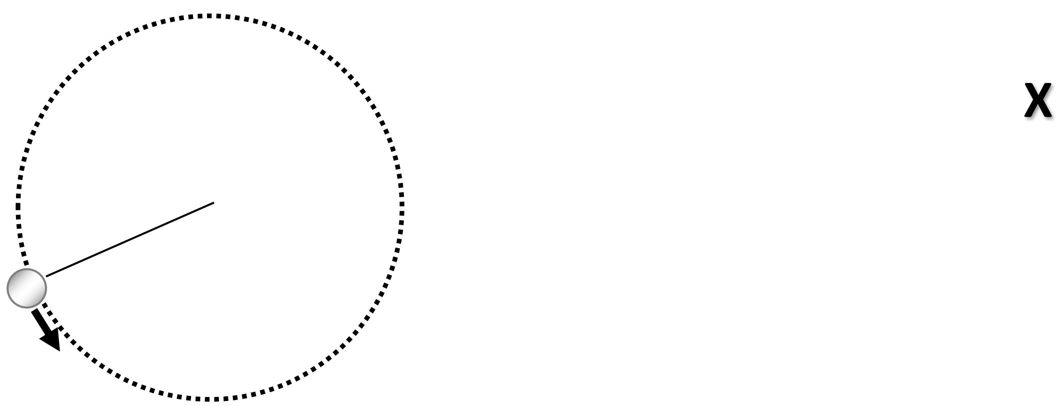
   a. Speed at which it circles. Explain.
   b. Radius of circle. Explain.
   c. Mass of the object. Explain.

3. Which object (Marble, Orbiting Object, or Spaceship) do you think had the greatest centripetal acceleration? Why?

4. Which object (Marble, Orbiting Object, or Spaceship) do you think requires the greatest centripetal acceleration to keep it circling? Why?

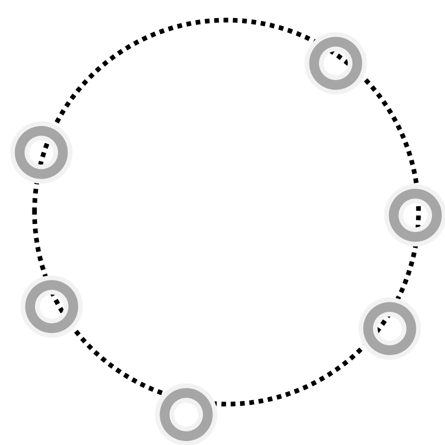
General Questions:

1. Assume that you have the object circling overhead. At which point in the orbit should you release the object if you want to hit a target directly in front of you (**X** marks the spot)? Draw a diagram. **Do not attempt to confirm this experimentally!**



2. If you maintain a constant rate of speed for the orbiting object, is there acceleration? Explain.

3. Show how the force from Earth would act on a spaceship, at each point in the orbit, by drawing arrows indicating the direction of the force keeping the spaceship in orbit.



4. Assume the spaceship has a deflector screen which makes it immune to the force from Earth. If the ship is traveling along in its orbit, and the ship turns off its engines at the same time it turns on its deflector shield, what will happen? Choose one answer and defend it.

    i. The ship will continue traveling in a circle.
    ii. The ship will travel in a straight line tangent to the circular orbit.
    iii. The ship will spiral down to the Earth.
    iv. The ship will come to a full stop, hovering above the Earth.

Exercise 8 - Firing at a Distant Target

Student Learning Objective:

Determine the optimal angle for a projectile, and calculate the range of a horizontal projectile.

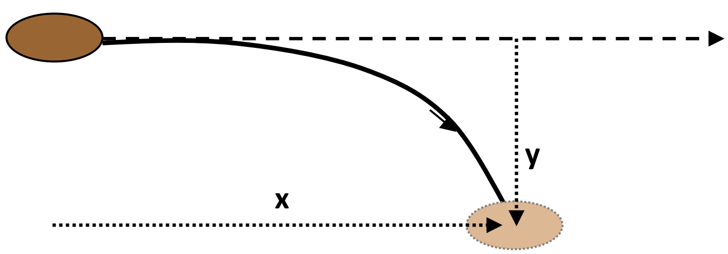
Materials:

Mini Launcher
16 mm Solid Steel Ball
Push Rod
C Clamp
Photogate Timer
Empty Soup Can
Meter Stick
Measuring Tape

Mini Launcher by Norihiro CC0

Introduction:

An object that is launched outward from a height above the ground will follow a curved path. The curved path of a projectile is a combination of the horizontal motion it is given and the effect of gravity on the object. A projectile launched horizontally, parallel to the ground, is dropping as it travels horizontally, and the result is a curved path.



The ball will travel a distance in the horizontal (x) plane while it is dropping in the vertical (y) plane.

Equation for Horizontal Motion	Equation for Vertical Motion
$x = vt$	**$y = (1/2)gt^2$**

Pre-Lab:

A. Name quantities that affect the distance a projectile travels.
B. What is the value and direction of the acceleration due to Earth's gravity?

C. Watch the video for operating the launcher:
https://www.pasco.com/prodCatalog/ME/ME-6825_mini-launcher/index.cfm

Procedures:
You will launch a steel ball at a variety of angles and parallel to the ground.

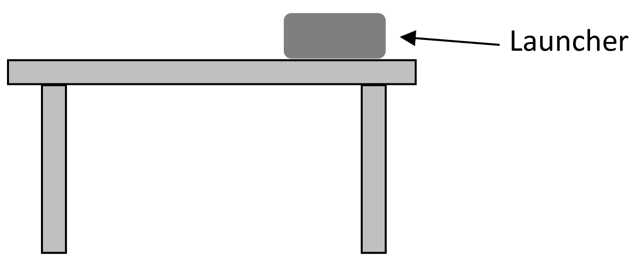
Investigating Angle

1. Draw a table in which to record three angles, and the distances the ball travels for these angles, including 3 trials per angle. Also include a place to record the average distance for each angle. Do not fill in data until you have read the instructions for obtaining that data.

Investigating Angle

Angle	Trial 1 Distance	Trial 2 Distance	Trial 3 Distance	Average Distance

2. Use the C Clamp to secure the launcher to the table, near the edge of the table.



3. Position the launcher such that it is horizontal, with a 0 angle. Use the push rod to press the ball into the launcher; pushing the piston back into the barrel will load the launcher and each click results in more force to launch your projectile. Make a couple of practice shots to familiarize yourself with the launcher.

4. Choose three non-zero angles from which you will release the ball, and record these angles in your table. Indicate the angle you think will result in the ball traveling the greatest distance.

5. Use the same number of clicks each time you load the launcher, and collect the data to complete your ***Investigating Angle*** data table. All of your distance measurements should be in meters. Once you have collected all of your data, calculate the average distances for the angles you chose.

Calculating the Range

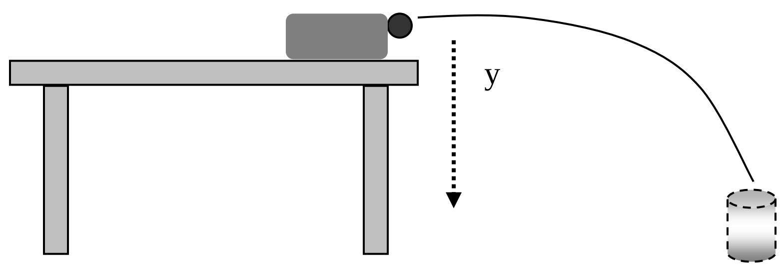
6. Place the photogate in front of the launcher such that the ball will pass through the photogate when launched.

7. Draw a ***Horizontal Range*** data table in which to record your measurements and calculations. Read the instructions for obtaining the data.

Horizontal Range

Drop Distance y	Dropping Time t	Launch Speed v	Calculated Horizontal Distance x	Actual Horizontal Distance x	% Error

8. Measure and record the vertical distance (y), in meters, the ball must drop from its release point to a can on the floor.



9. Use the *equation for vertical motion* and your measured (y), to calculate the time (t) it will take the ball to fall from the release point to the can on the floor. This will require some algebra. Record the time (t) in seconds that you calculate.

10. Position the launcher such that it is horizontal, parallel to the ground, with a 0° angle. Remove the can from the floor. Make a couple of practice shots to familiarize yourself with the photogate.

11. Load the projectile to three clicks. Launch the projectile with a 0° angle, and record the launch speed (v) of the ball shown by the photogate, in your *Horizontal Range* data table.

12. Use the *equation for horizontal motion* and the launch speed (v), to calculate the horizontal distance (x) that the ball should travel, and record this calculated horizontal distance (x) in your ***Horizontal Range*** data table.

13. Place the can on the floor where your measurements and calculations from the previous step indicate the projectile will land when released with 0° angle. Launch the projectile and measure the actual horizontal distance (x) the ball travels. It may take a couple of trials to observe exactly where the ball hits. Calculate the % error.

14. For the second set of values, calculate and record what ½ of your y distance is, in your ***Horizontal Range*** data table. Without measurement or calculation, estimate the new values (t, v, and x) for the new drop distance which is half of the initial drop distance (y). Enter these values in your ***Horizontal Range*** data table.

15. Place the can on the floor and where your estimates for ½(y) indicate the projectile will land when released at 0° angle. Load the projectile to three clicks. Launch the projectile and measure the actual horizontal distance (x) the ball travels. Calculate the % error.

Clean-up:

- Remove the tape from the floor and throw it away

Analysis:

1. Based on your data, which of the following angles would result in a football traveling the greatest distance when thrown for a long pass? (Choose one)

    a. 30°
    b. 45°
    c. 60°

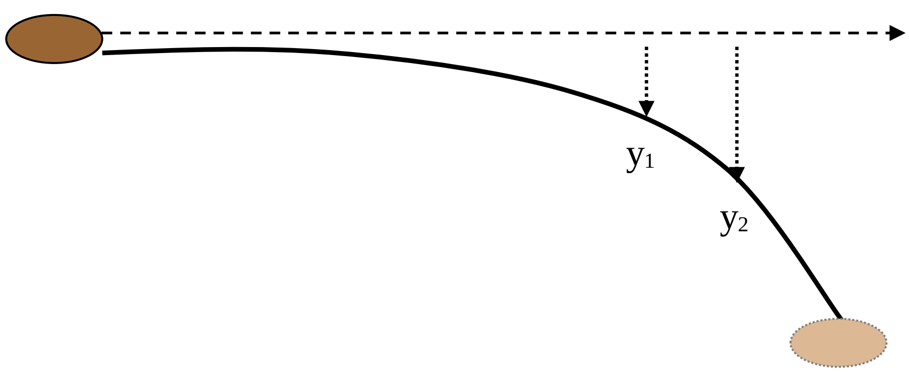
2. What errors in the process may account for missing the can?

3. In general, describe any relationship between the vertical distance (y) from which a projectile is launched and the horizontal distance (x) the projectile may be expected to travel.

General Questions:

1. A football player throws a football from 2.4 meters above the ground, with a horizontal velocity of 50 mph (22.35 m/s). Calculate the horizontal range (x) for this football.

2. In another situation, a football is in flight and falling. The football falls a distance in the vertical (y) every 1/10th of a second as indicated by the values in the chart below. Use the chart to construct graphs, and analyze the graphs. Analysis should include the relationship shown by the graph and the motion indicated by the graph.
   i. Graph 1: Distance (y) versus time (t)
   ii. Graph 2: Distance (y) versus time squared (t^2)



	Time (t) seconds	**Distance (y)** meters	t^2
y_1	0.10	0.05	0.01
y_2	0.20	0.19	0.04
y_3	0.30	0.44	0.09
y_4	0.40	0.79	0.16
y_5	0.50	1.23	0.25

Exercise 9 - Balanced & Unbalanced Forces

Student Learning Objectives:

Locate all forces acting on a system and determine whether forces are balanced.

Materials:

2 Dumbbells (equal weight)
Stop Watch
Meter Stick
Ribbon/Rope (1-2 meters in length)
Object/Pendulum Fob (such as heavy key chain)
1000 gram Mass
Masking Tape
4 meter Length Strong Rope
2 pair Work Gloves
Measuring Tape

Ribbon/Rope
Spool of String by Fcb981 is licensed under CC BY-SA 3.0

Example Key Chain
Image licensed under CC0

Dumbbells
Image by honka13 is licensed under CC0

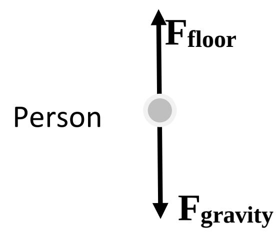
Introduction:

Usually, there are several forces acting on an object at the same time. However, the object will only change its motion if one of the forces is greater than the other(s). An object will be accelerated by a net force. A net force is the sum of all forces (both magnitude and direction) acting on an object. If all forces are balancing each other, then the object will not change its motion. Forces that are balanced are equal in magnitude, but are applied in opposite directions. A net force (F) on a mass (m) will cause an acceleration (a).

$$\boxed{F = ma}$$

A force diagram is a set of arrows showing the directions of all forces acting on an object. For example, a person standing on the floor may have a force diagram with 1 arrow up (floor force) and a 2nd arrow down (gravity force). If the forces are balanced, then the arrows will be the same size.

Force Diagram of Person Standing on Floor



<u>Procedures:</u>

You will sketch force diagrams and determining whether forces are balanced.

Dumbbells

1. Stand with one dumbbell in each hand. Lift the first dumbbell to waist height as you bend your elbow and keep your arm close to your body, and lift the second dumbbell with a straight arm until this arm is at shoulder height. Hold the dumbbells in these positions for 30 seconds. Sketch a force diagram for each situation, showing only the forces on each dumbbell. Also indicate in which position the dumbbell was more difficult to hold.

Click <u>Bent Arm Example</u> for a demonstration
Click <u>Straight Arm Example</u> for a demonstration (but use only one arm for experiment)

Mass on a Bridge

2. Make a long but stable bridge with the meter stick and 2 lab chairs. Place the 1000 gram mass in the center of the meter stick. Allow the mass to sit on the bridge for a few seconds after you let go of the mass. Sketch a force diagram, showing only the forces on the mass while it is sitting on the bridge. Record whether the meter stick moved as you placed the 1000 gram

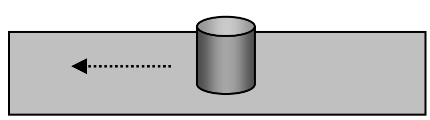
mass on it. Also record whether the meter stick continued to move while the mass was sitting on the bridge.

Pendulum

3. Remove the mass from the meter stick bridge. Make a long pendulum that hangs from the center of the meter stick bridge, using a heavy object and ribbon/rope; tie the ribbon or rope in a bow so that is may easily be untied. Start the pendulum swinging, and observe its motion. Sketch a force diagram, showing only the forces on the object at the end of the ribbon/rope, for each of the positions shown below.

Sliding

4. Place the 1000 gram mass on the table and give it a good push to send it sliding; allow the mass to slide on the table and come to a stop. Sketch a force diagram, showing all forces acting on the mass while you are pushing it. Sketch a 2nd force diagram to show the forces acting on the mass while it is sliding on its own.

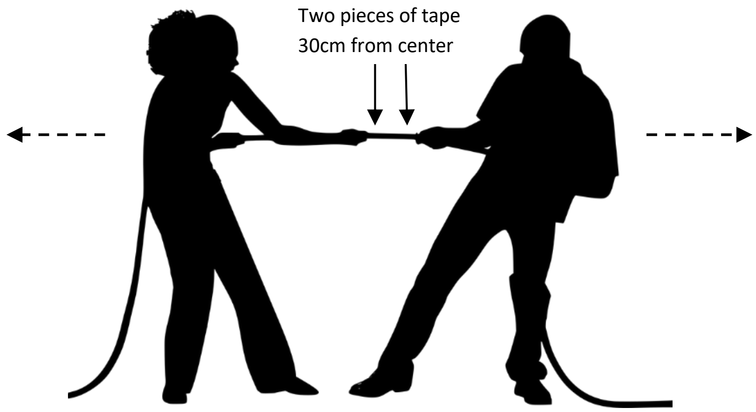


Tug of War

Warning: You should wear work gloves while grasping the rope. Do not pull so hard that you injure your classmates during the tug of war.

5. Place a strip of masking tape on the ground. Use the measuring tape to determine the center point of the rope and mark the center of the rope with a piece of tape. Measure

30 cm from the center of the rope, on each side of center, and mark these locations with tape. Observe while two people from your lab team play tug of war. Once one side's 30 cm mark on the rope crosses the tape on the floor, the game is over. Sketch a force diagram showing the forces on <u>one</u> of the challengers while they were pulling on the rope.



<u>Analysis:</u>

1. Did you feel a different force on your bent arm as compared to your straight arm while holding the dumbbells? Was the force from the 1000 gram mass different? Explain any differences in your answers.

2. Explain why the meter stick only moved a small distance and then stopped moving as you placed the 1000 gram mass on meter stick bridge.

3. Describe any differences shown by your force diagrams for the sliding mass.

4. Compare and contrast your force diagrams for the two positions of the pendulum as it is swinging. How are the force diagrams similar? How are they different?

5. Sketch or describe what the force diagram would look like for the other person playing tug of war, in comparison to the one you sketched. Would the amount force on each challenger be the same or different? Explain.

6. State whether the forces were balanced or unbalanced in the following situations.
    a) On the dumbbell being held stationary with the bent arm
    b) On the dumbbell being held stationary with the straight arm
    c) On the mass while it was being placed on meter stick bridge
    d) On the mass while it was sitting on the meter stick bridge
    e) On the object while it was swinging and was at an angle
    f) On the object while it was swinging and was vertical
    g) On the mass while you were pushing it
    h) On the mass while it was sliding on its own across the table

General Questions:

1. In general, what happens to the motion of an object if forces are unbalanced?

2. In general, what happens to the motion of an object if forces are balanced?

3. If the engine in your car is providing 500 N of force and the friction from the road is 200 N, what is the net force? Will the motion of your car change?

4. In order to maintain a constant 30 mph on a straight, flat road, you must apply pressure to the accelerator. Is there a net force on the car? Explain.

Exercise 10 - Weight of Mass

Student Learning Objectives:

Learn your weight on other planets, and differentiate between weight and mass.

Materials:

Intranet

Introduction:

Isaac Newton called mass the quantity of matter. Mass can also be thought of as a numerical measure of inertia, and exists in the absence of gravity. Weight is the pull of gravity on a mass, and depends both on the mass and on the amount of gravitational force present.

Equation for Weight
W = mg

Pre-Lab:

A. Define what is meant by a fundamental quantity.
B. Estimate your weight in pounds, here on Earth.
C. Research the standard metric units of mass and force.

Procedures:

You will analyze your weight and mass on the planets in our solar system.

1. Utilize the following website to learn your weight on other objects in our solar system, including all 8 planets, Pluto, our Moon, and our Sun. Enter your approximate weight on Earth (or some chosen weight), and choose "calculate". Your weight will be shown in units of pounds.

http://www.exploratorium.edu/ronh/weight/

2. Draw a table in which to record your weight in pounds on all 8 planets, Pluto, and our Moon. Also, include a place to record your weight in Newtons. Enter the weight values shown on the website.

3. Convert each weight in pounds to a weight in Newtons, and record these values in your data table. (**1 Newton = 0.2248 lb**)

4. Draw a 2nd table in which to record values for determining your mass. Enter the values you calculated for Newtons on Earth and Mars. Calculate your mass on Earth and on Mars, and complete the table.

Planet	**g** (m/s^2)	**W** (Newtons)	**m** (kilograms)
Earth	9.8		
Mars	3.8		

Analysis:

1. Did you calculate approximately the same mass on Mars as you calculated for your mass on Earth? What could account for any difference?

2. On which planet is your weight the greatest? Why do you think your weight is greatest on this planet?

3. Based on your data tables, which quantity is a fundamental quantity, mass or weight? Explain.

General Questions:

1. Describe what it would feel like to take a step on Mercury as compared to taking a step on Earth.

2. What would you expect your mass to be on Mercury?

3. What would you expect your mass to be on Saturn?

4. Describe any differences between weight and mass.

Exercise 11 - High Flying Bottle Rocket

Student Learning Objectives:

Analyze the flight of a rocket and apply Newton's three laws of motion to a rocket.

Materials:

Card stock colored paper
Duct Tape
Masking Tape
Clear Packing Tape
Metric Ruler
Permanent Marker
Poster Board (1 per team)
Foam Board (1 per team)
Styrofoam "Board" (1 per team)
X-Acto knife (1 per team)
Fast Drying Glue (1 per team)
Scissors
Markers
Card Stock Paper
Platform Spring Scale
Altitude Finder

Instructor Materials

2 Bottle Rocket Launchers
2 Manual Tire Pumps

Lab Team Responsibility

Empty 2-Liter Soda Bottle
Approved Materials of Choice

X-Acto Knife by Evan Amos is in the public domain

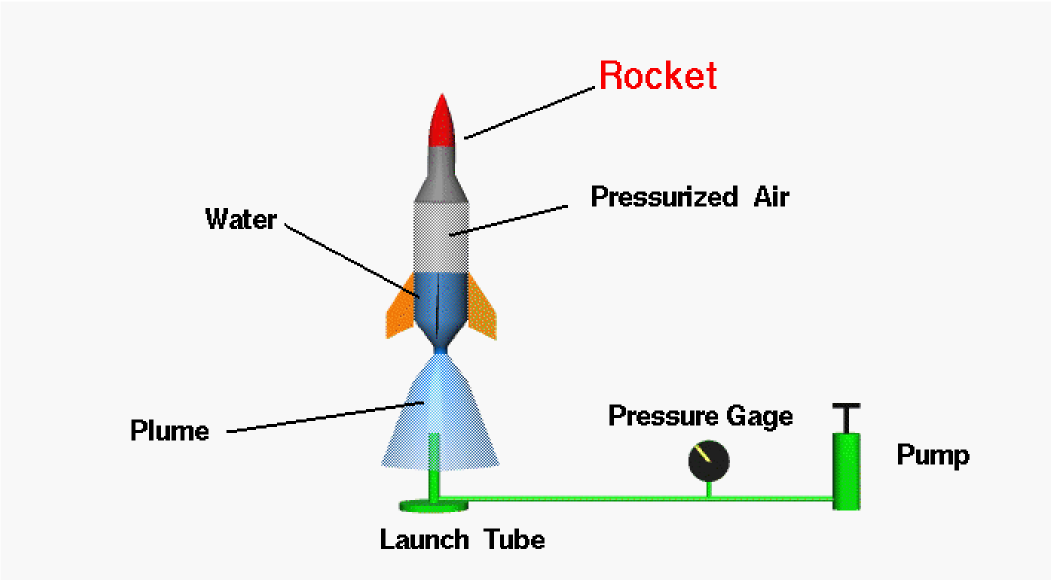
Manual Tire Pump

Lezyne bike pump & bicycle tire by Your Best Digs is licensed under CC BY 2.0

Introduction:

There are several factors that determine how well a rocket will fly. Thrust propels a rocket upward with a net force that is greater than the downward forces on the rocket. As the rocket velocity increases, it encounters increasing air resistance, or aerodynamic drag, which opposes the upward motion of the rocket. Air resistance, or drag, increases as the square of the velocity. In rocket design, it is important to minimize air resistance. Gravity works in opposition to thrust, slowing the rocket and eventually causing the rocket to fall toward the Earth.

Basic Bottle Rocket



Water Rocket by NASA is in the public domain

Pre-Lab:

Research how to build a water bottle rocket.

Plan to have at least one person bring a 2-Liter bottle.

Procedures:

You will build a bottle rocket and analyze rocket flight.

Rocket Construction

1. Check that the 2-Liter bottle your team brought will fit securely on the launcher. If it does not work with the launcher, check with your instructor.

2. Construct your rocket using the materials provided and any approved materials your team brought. Your team will have 30-40 minutes complete the construction, record initial data, and be ready to launch.

3. Use the triple beam balance to measure the mass of your completed rocket, in kilograms. Record this value as your vehicle mass.

4. Fill your bottle rocket about 1/3 full of water. Use the platform spring scale to measure the new of your rocket now that the "fuel" has been added. Record this value as your launch mass.

Warning: rockets may curve into bystanders. Impact glasses strongly recommended.

Launch Competition

Warning: Rockets may travel sideways and/or may fall toward you. Impact glasses are recommended.

5. Everyone will walk to the launch site. Each team will be allowed 10 pumps with the manual tire pump. Your instructor will count down the launch for two teams at a time, as everyone else observes and ascertains which rocket is the highest flying rocket with the altitude finder. Record the altitude of your lab team rocket.

Clean-up:

- Throw away all rocket building scraps
- Recycle 2-Liter bottle

Analysis:

1. Draw a table in which to record both the vehicle mass and the launch mass for each team rocket. Also include a column for the altitude at apogee for each rocket. Obtain the information from each team to complete your data table.

2. Describe the design features of the highest flying bottle rocket. Indicate the design feature you think may have been primarily responsible for the altitude this rocket achieved.

3. Calculate weight force of your rocket that the thrust had to overcome.

4. What would you do differently if you were to design a new rocket for the launch competition?

General Questions:

1. Use arrows to show the direction of all forces that act on a rocket as it travels upward. Note that you may have multiple words for the same force – show the direction of each.

Gravity	Thrust
Drag	Weight
Air Resistance	Friction

2. Describe how each of Newton's laws of motion were applied during the rocket launch.

Exercise 12 - The Bungee Jump

Student Learning Objectives:

Analyze the factors that contribute to momentum and impact force, and apply these to bungee jumping.

Materials:

Supersize Rubber Bands (12, 14, & 17 inches - 3 of each)
Strong String (12, 14, & 17 inches - 3 of each)
3 Masses (100-500 grams - with hook)
Masking Tape
White Butcher Paper (1 roll per team)
Permanent Markers (2 colors)
Measuring Tape
2 Meter Sticks (with hole at end)
2 Long Rubber Bands (7 inches)

Introduction:

In bungee jumping, a person may gain a lot of momentum while falling, and then be slowed gradually by the bungee. The force of impact on the person depends in part on how fast the person was traveling prior to the bungee beginning to stop the person's fall. The more momentum the person has, the harder it will be for the person to stop at the end of the bungee. How quickly the person is brought to a stop, the time in which the momentum is changed, also affects the force of impact as the person is brought to a stop.

$$\boxed{F = \frac{m\Delta v}{t}}$$

Pre-Lab:

A. Identify the variables in the impact force equation.
B. How much speed does an object gain while in free fall, each second of the fall?

Procedures:

You will visually compare momentum and impact force.

Warning: Impact from a falling mass on toes is possible.

Bungee Jumps

1. Attach a 6 foot length of butcher paper to a wall, vertically.

2. Cut each of your rubber bands so that each is one long piece, and cut pieces of string to match the lengths of the cut rubber bands.

3. Draw a table in which to record the distance each mass falls with each type of bungee. Do not fill in data until you have read the instructions for obtaining that data.

Distances

	Mass 1	Mass 2	Mass 3
Type of Bungee			
12 in Length of Rubber			
14 in Length of Rubber			
17 in Length of Rubber			
12 in Length of String			
14 in Length of String			
17 in Length of String			

4. Choose 3 masses to use as your bungee jumpers, and record these masses in your table.

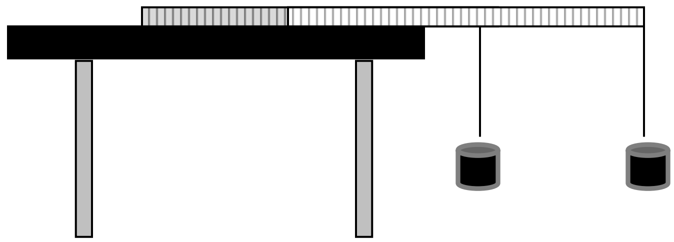
5. The top of the drop is the top of the 6 foot butcher paper. Drop each bungee system from the top of the butcher paper and mark on the paper where each bungee system stops and rebounds. Use one color marker for the cut rubber bands and the other color marker for the lengths of string. Do not re-use rubber bands or strings; each jump should have a new rubber band, a new string.

6. Measure the distances of the falls from the top of the butcher paper to the stopping point for each bungee jumper system, in meters, and record these values in your table.

From the End of the Plank

7. Attach the cut 7-inch rubber band to the ends of the meter sticks, through the holes, and the other ends of these rubber bands to equal masses. Lab teams may need to share mass sets so each team has 2 identical masses for this investigation. Place the meter sticks next to each other on your lab table. Position one meter stick such that 20

centimeters hangs over the edge of your team's lab table, and position the other meter stick such that 60 centimeters hangs over the edge.



8. The top of the drop is your table. Hold the meter sticks down on the table, align the masses with the top of the table and allow them to drop, while observing the behavior of each system. Repeat the drop a few times and then record any differences observed.

Clean-up:

- Dispose of all pieces of string and all cut rubber bands
- Remove butcher paper from wall and discard
- Remove and discard all masking tape from wall, masses and/or meter sticks

Analysis:

1. Describe any trends you see in your *Distances* data table. Relate each of the trends in your data to the sport of bungee jumping.

2. Which bungee system(s) tested would have the greatest speed at the end of the fall, prior to stopping? Why? Estimate the speed the system(s) would have prior to stopping.

3. Based on your observations, which material results in a greater force of impact, rubber or string? Explain.

4. Apply the design of the meter stick bungee systems to the sport of bungee jumping.

General Questions:

1. In which situation would you expect to feel the <u>least</u> force of impact? Choose one of the answers below and explain why.

a. You bungee jump using a relatively rigid piece of long rope
b. You bungee jump using a relatively rigid piece of short rope
c. You bungee jump using a long length of rubber band material
d. You bungee jump using a short length of rubber band material

2. Calculate the velocity at the end of a 75 foot bungee, and the impact force (first rebound) on an 800 Newton bungee jumper who takes 3 seconds to slow and rebound. How many pounds of force is this?

3. Reclaimed rubber may not be used for bungee cords. Why?

4. Natural rubber is *widely* used for bungee jumping cords. Why?

Exercise 13 - The Pressure on Your Feet

Student Learning Objective:

Ascertain the difference between pressure and force.

Materials:

Paper (2-4 sheets per person)
Metric Ruler

Introduction:

Pressure is a measure of how force is distributed. The smaller the area of contact, the greater the pressure is from the force of the object. Our body weight is distributed onto the area of our feet, or a foot as we walk. The amount of contact our foot makes with the ground determines how our weight force is distributed.

$$\boxed{P = \frac{F}{A}}$$

Pre-Lab:

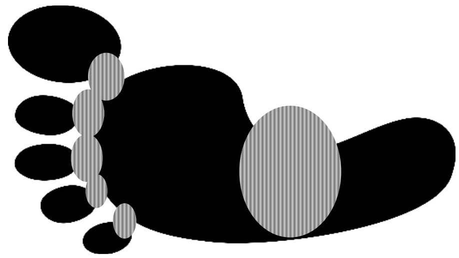
A. What is normal atmospheric pressure in units of pounds per square inch (lbs/in^2)?
B. Research and record the equation to calculate the area of a rectangle.
C. Research and record the equation to calculate the area of an oval.

Procedures:

Each person will determine the pressure on their feet.

1. Predict whether the pressure your body exerts on your foot or feet, as you walk or stand on the floor, is greater or less than normal atmospheric pressure. Record your predictions.

2. Remove a shoe and trace the outline of your foot onto the paper. You may need to place your foot diagonal or use two sheets of paper to accommodate your foot size. Shade the areas that are <u>not</u> in contact with the paper (that are not touching). You may choose whether to sketch one foot or both feet. You may also choose whether to stand as if you are in a flat shoe or a shoe with an elevated heal.



Left Footprint by bpcomp is part of the public domain

3. Draw a table in which to record the data for your foot/feet. Do not fill in data until you have read the instructions for obtaining that data.

Calculated Area 1 Foot	Net Area of Contact 1 Foot	Net Area of Contact Both Feet

4. Choose whether to use a rectangle or an oval to calculate the area of your sketched foot. Calculate and record this area as the *Calculated Area.*

5. Look at the amount of shading on your sketch and use this to estimate the percentage of the area you calculated that is actually in contact with the paper (is actually touching the paper). Unless you have completely flat feet, not all of your foot touches inside the sketched outline of your foot. Record the percentage you estimate.

6. Calculate the *Net Area of Contact* by multiplying the decimal of the percentage you estimated and the *Calculated Area* from your data table. Record the value of your *Net Area of Contact* in your table.

Example 70%: (0.7)(Calculated Area - 1 Foot)

7. Calculate the net area of contact when you stand on two feet. Record this value in your data table.

8. Draw another table in which to record the amount of pressure on your foot/feet, and how this compares to atmospheric pressure. Read the instructions for obtaining the data.

Pressure Calculations

	Pressure (lbs/in^2)	Comparison to Air
1 Foot		
Both Feet		

9. Use your approximate weight in pounds and the *Net Area of Contact* that you recorded in your first data table to calculate the pressure on one foot, as if you were taking a step. Also calculate the amount of pressure on your feet as you stand on the floor. Record these values.

10. Use a ratio to compare the pressure on your feet to normal atmospheric pressure from air. Calculate the value of the ratio and record this as the *Comparison to Air* value in your *Pressure Calculations* table.

Example: $\frac{3\ in}{7\ in} = 0.42$ (3 inches compared to 7 inches)

Analysis:

1. Explain why sketching and measuring both feet may result in more accurate results.
2. Interpret the values you calculated in your comparison of the pressure on your foot/feet to normal atmospheric pressure from air. What do the values mean?

General Questions:

1. Explain what the units of atmospheric pressure lbs/in^2 mean in terms of the "weight" of air on you.
2. Is there a difference in the amount of force exerted by you when you take a step and your full weight is on one foot as compared to when you stand and your full weight is on both feet?
3. If you or someone you know wears high-heeled shoes, placing most of the weight on the balls of the feet, does this affect the amount of force on the person's feet as compared to wearing flat shoes? Does this affect the amount of pressure on the person's feet as compared to wearing flat shoes?

4. When a ballerina goes up on point, the part of the Pointe shoe that touches the floor is about 2 inches by 1 inch. If a 110 lb ballerina has all of her weight on one Pointe shoe as she pirouettes, how much pressure is on the ballerina's toes? Use a ratio to compare the pressure on a ballerina's toes, while pirouetting, to the pressure on one of your feet as you take a step. By what factor is one pressure greater as compared to the other?

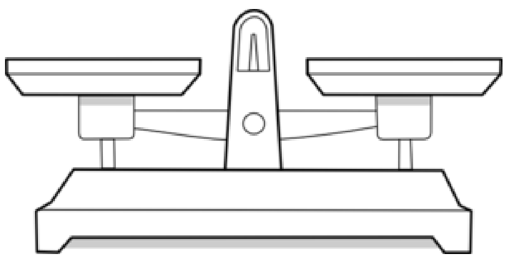
Exercise 14 - Mass vs Volume vs Density

Student Learning Objectives:

Differentiate between mass and volume, and differentiate between mass and density.

Materials:

3 Identical Empty Water Bottles
Simple Balance
Platform Spring Scale
Metric Ruler
Sand (from gallon containers)
250 mL Beaker
Funnel
Weight Boat



Balance / scale by improlux licensed in public domain

Disposable weighing boat-02 by Lilly M, licensed CC BY-SA 3.0

Introduction:

Mass is the amount of material contained in an object, while volume is the amount of space an object occupies. Different amounts of mass may take up the same amount of space. Density has a dependency on both mass and volume. An object with a relatively high density will have a relatively large amount of mass contained in a particular volume. Density is often described as a measure of how compact a material is.

$$\boxed{D = \frac{m}{V}}$$

Pre-Lab:

Research and record the equation to calculate the volume of a cylinder.

Procedures:
You will measure and calculate mass and volume, and compare densities.

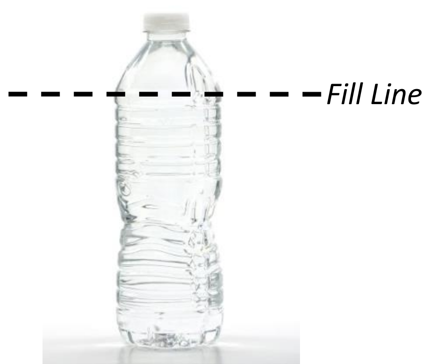
Same Mass

1. Draw a table in which to record your values for this section. Do not fill in data until you have read the instructions for obtaining that data.

Same Mass

Measured Water Height	**Predicted Sand Height**	**Measured Sand Height**	**Difference in Measured Heights**

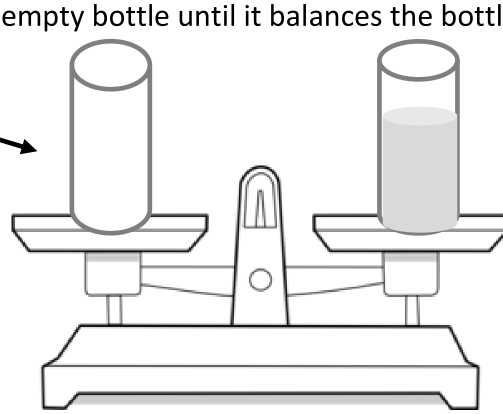
2. Fill one bottle with water, to just below the point where the bottle begins to taper. Measure and record the height, in centimeters, to which the bottle is filled with water.



3. Predict and record the height to which you will need to fill a 2nd bottle with sand in order to have the bottle of water and the bottle of sand balance each other.

4. Place the bottle with water on one side of the simple balance, and place an empty bottle on the opposite side of the simple balance. Obtain some sand in your beaker and pour sand through the funnel into the empty bottle until it balances the bottle with water.

Pour sand into this one until it balances the water on the other side of the simple balance



Balance / scale by improlux licensed in public domain

5. Remove both bottles from the simple balance. Measure and record the height to which you filled the 2nd bottle with sand. Calculate and record the difference between the measured fill height of the water and the measured fill height of the sand.

Same Volume

6. Use the funnel to continue filling the bottle with sand until it is filled to the same height as the bottle with water. Lift both of the bottles a few times, with the bottle of water in one hand and the bottle of sand in the other hand. Record any differences you notice.

7. Draw a table in which to record the mass, volume, and density of the 3 bottles containing different materials (air, water, and sand). Read the instructions for obtaining the data.

Same Volume

Type of Material	Mass in Grams	Volume (cm^3)	Density (g/cm^3)
Air			
Water			
Sand			

8. Use the platform spring scale to measure and record the mass in grams, of an empty water bottle, the bottle with water, and the bottle with sand. **Note** that we are using the mass of the empty bottle as the mass of air because we are not able to measure the mass of the air with the platform spring scale.

9. Calculate and record the volume in which you have air, water, and sand; this should be the same for each bottle. The height (h) is the measured water height from your first data table. Also calculate and record the density for each material.

Clean-up:

- Pour sand back into original container
- Rinse out the sand bottle
- Wash and completely dry your beaker
- Discard water outside (water the foliage)
- Place wet water bottles on the drying rack

Analysis:

1. Use ratios to compare the densities. Include all possible comparisons.

2. Explain why the same mass of sand and water had different fill heights.

General Questions:

1. Is it possible to have different amounts of mass fit into the same volume?

2. If two different objects have the same volume, they will also have the same mass. (True or False)

3. If two different objects have the same volume, they will also have the same density. (True or False)

4. Gold has a density of 19.3 g/cm3. Explain what the units mean.

5. Explain how density affects the weight of an object.

Exercise 15 - Sinking & Floating

Student Learning Objectives:

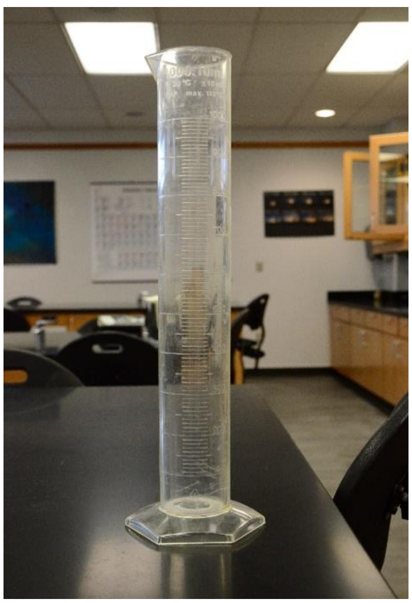
Analyze relative density in relation to layers of liquids, and sinking & floating.

Materials:

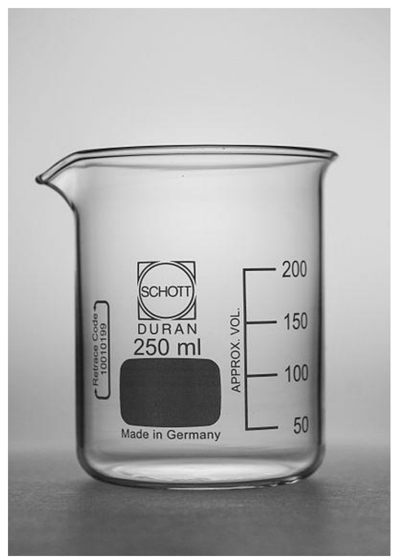
1000 mL Graduated Cylinder
2 250 mL Beakers
2 Colors Food Coloring
Clear Corn Syrup (200 mL per group)
Vegetable Oil (200 mL per group)
91% Isopropyl Alcohol (350 mL per group)
Variety of Small Objects
Ice Cubes (from ice cube tray)

Sample Small Objects

Rubber band
Metal paperclip
Coated paperclip
Popcorn
Pencil eraser
Bouncy ball
Marble



1000 mL Graduated Cylinder



Schott Duran Beaker low form 250ml by Lucasbosch licensed under CC BY-SA 3.0

Introduction:

Sometimes fluids will remain separated such that one type of fluid is floating on top of another type of fluid. We see this if we add oil to water; the oil floats on the water. Whether a particular material will float may depend on relative density. An object that is less dense than the fluid will float. An object that is more dense than the fluid may float under certain circumstances.

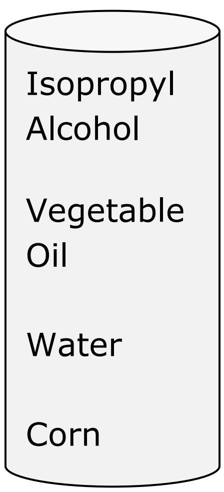
Pre-Lab:

A. Describe what a fluid is.
B. What are some differences between a graduated cylinder and a beaker?

Procedures:
You will a variety of objects for whether they sink or float. The first activity may be completed as a class.

Density Gradient

1. Choose whether to sketch a diagram of the system and indicate the level at which objects settle, or draw a chart in which to record results. Sketch a cylinder with the layers of liquids, or draw a chart in which to list the level at which each object settles.



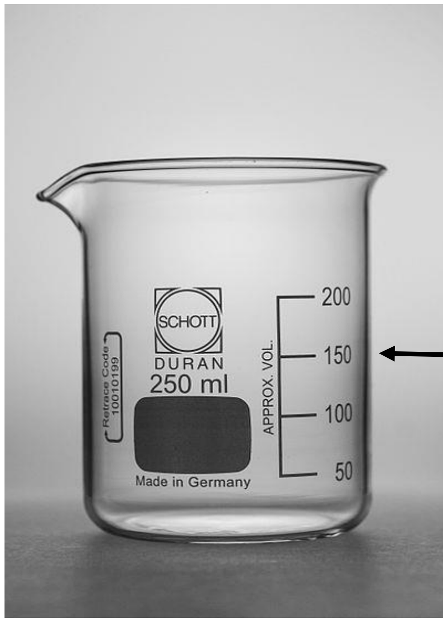
Top of Alcohol	Top of Oil	Top of Water	Top of Syrup	Bottom

2. Obtain 200 mL of each liquid (corn syrup, water, vegetable oil, isopropyl alcohol), or observe as your instructor obtains these materials; the liquids must be added to the graduated cylinder in the correct order. The corn syrup may be poured directly into the graduated cylinder. The water may be obtained with a 250mL beaker, and 1-2 drops of food coloring may be added to allow the liquid to be more easily seen. Vegetable oil may be slowly poured into the graduated cylinder. The alcohol may be obtained with a 250mL beaker, and 1-2 drops of food coloring may be added to allow the liquid to be more easily seen.

3. As each small object is chosen for testing, predict in your mind where the item will settle. Share your predictions among your lab team. Then observe and record the position at which each item settles when dropped into the graduated cylinder.

Ice & Fluids

4. Fill one beaker with 150 mL of water and the other beaker with 150 mL of 91% isopropyl alcohol.



Fill <u>up</u> to the 150 mL line

Schott Duran Beaker low form 250ml by Lucasbosch licensed under CC BY-SA 3.0

5. Predict whether the ice will be able to float in the water and/or the isopropyl alcohol. Record your predictions.

6. Obtain 2 ice cubes and place one ice cube in each of the beakers. Record your observations for both the water and the isopropyl alcohol.

<u>Clean-up:</u>

- Pour the ice and liquids from the 250 mL beakers down the sink
- Clean and dry your beakers
- Follow instructor directions for clean-up of graduated cylinder materials

Analysis:

1. Why is it important to add the liquids to the graduated cylinder in the correct order? Why do the liquids remain layered in this order?

2. Write a sentence which explains the locations small objects settled in the layers of liquids.

General Questions:

1. Based on your observations, which has a lower density, alcohol or water?

2. Ice and water are H_2O molecules in different states. Why do you think ice (frozen H_2O) floats in water (liquid H_2O); why are the densities different?

Exercise 16 - Two Wood Rafts

Student Learning Objectives:
Apply Archimedes Principle, and compare two rafts made from different wood.

Materials:

Pine Wood Raft (about 10x20 cm)
Oak Wood Raft (about 10x20 cm)
Plastic Container (about 6x12 inches)
Triple Beam Balance
Metric Ruler

*Wood rafts should be same size
**Any two types of wood will work

Introduction:
Whether an object will float may depend on density. However, ships made of metals are able to float, and metals have a higher density than water. Archimedes Principle explains how an object with greater density than a fluid, such as a steel ship in water, is able to float in the fluid. An object may float if the object is able to displace an amount of fluid equal to its weight. The depth of water to which a ship sinks, determines the amount of water that is displaced by the ship, and the amount of water displaced determines the amount of buoyancy force from the water. When an object is floating in a fluid, the objects pressure down and the fluid pressure up must balance which means the pressure up from the water must equal the pressure down from a boat.

$$\mathcal{P}_{Boat} = \mathcal{P}_{Fluid}$$

Pressure of Object	Pressure from Fluid
$\mathbf{P = \frac{F}{A}}$	$\mathbf{P = Dgh}$

Pre-lab:

A. Define what a fluid is.

B. Research what Archimedes Principle is, and state this principle.

C. Research and record the density of fresh water in units of kg/m^3.

Procedures:

You will determine the height of the water line required for a raft to float.

Warning:

- **Do not place wood blocks into the water until specifically instructed.**

1st Wood Block

1. Choose one of the wood blocks to be your 1st wood raft. Use this raft for the following procedures.

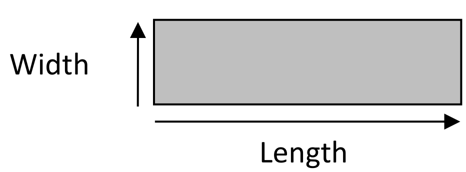
2. Draw a table in which to record physical quantities for the raft you chose, including mass in kilograms, weight in Newtons, length in meters, width in meters, and bottom area in square meters. Do not fill in data until you have read the instructions for obtaining that data.

Physical Quantities

	Mass (kg)	Weight (N)	Length (m)	Width (m)	Bottom Area (m^2)
Raft 1					

3. Measure and record the mass of the wood raft. Calculate and record the weight of the wood raft in Newtons. The weight in Newtons is the force the raft will apply to the water.

4. Measure and record the length and width of the wood raft, in meters. Use these measurements to calculate the bottom area of the raft, and record this value. This is the area of the raft that will be pushing on the water, applying pressure to the water.

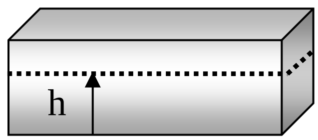


5. Draw a 2nd table in which to record the predicted water line height, calculated water line height, and measured water line height for the wood raft. Also include a place to record the percent error. Read the instructions for obtaining the data.

Water Line Height

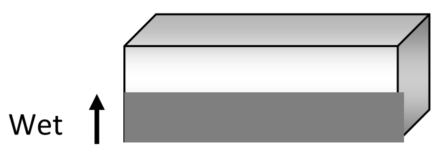
	Predicted	Calculated	Measured	% Error
Raft 1				

6. Hold the wood raft in your hand and predict the level to which the raft will need to sink in order to float. Measure and record this height in meters, as the predicted water line height.



7. Set the two equations for pressure, the pressure up from the water and the pressure down from the boat, equal to each other. Calculate the height, h, of the water for the wood raft. Record this value as the calculated water line height.

8. Fill the plastic tub about half full of water. Gently place the wood raft into the tub of water, carefully remove it, and measure the amount of the raft thickness that is wet, in meters. Record this value as your measured water line height.



9. Calculate and record the percent error for this investigation, using your calculated value as the standard value.

2nd Wood Raft

10. Draw a table in which to record the predicted water line height and measured water line height for the 2nd wood raft.

11. Hold both wood blocks in your hands. Discuss and predict the level to which the 2nd wood raft will need to sink in order to float. Measure and record this height in meters, as the <u>predicted</u> water line height for your 2nd wood raft.

12. Gently place the wood raft into the tub of water, carefully remove it, and measure the amount of the raft thickness that is wet, in meters. Record this value as your <u>measured</u> water line height for your 2nd wood raft.

<u>Clean-up:</u>

- Discard water outside (water the foliage)
- Thoroughly dry everything used in the experiment

<u>Analysis:</u>

1. Describe any differences you noticed when holding the two wood rafts.

2. Compare the <u>measured</u> water lines in a ratio, and explain the value you obtain.

3. Use Archimedes Principle to explain why one wood raft would be able to hold more cargo than the other.

4. Use the data about your **raft 1** to estimate the amount of cargo in kilograms that this raft could carry. Explain your rationale for this estimate.

<u>General Questions:</u>

1. Would the wood rafts float <u>higher or lower</u> in the isopropyl alcohol (810 kg/m^3) as compared to in water (1000 kg/m^3)? Explain.

2. Why is so much of a steel cargo ship under water? Use principles of floating to justify your answer.

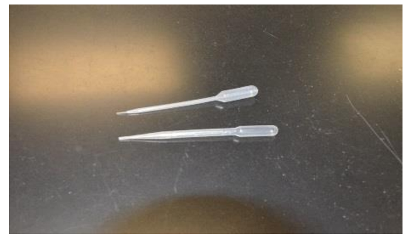
Exercise 17 - Magic Coins & Paperclips

Student Learning Objectives:

Observe the effects of surface tension, and apply the scientific method to refine predictions.

Materials:

2 Pennies (must be clean and dry)
2 Nickels (must be clean and dry)
Plastic Pipette (small tip)
250 mL Beaker
3 oz Paper Cup
1 Box Small Metal Paperclips
1 Container Liquid Dish Soap



Pipette by Norihiro

Introduction:

Sometimes, if a person is very careful, a glass can be overfilled such that a bubble of water rises above the lip of the glass. The bubble of water is an example of surface tension. Water has molecular characteristics which allow the molecules to be strongly attracted to each other, and the molecular attractions are strongest at the surface. The water molecules and the glass molecules are also attracted to each other.

Pre-Lab:

A. Define cohesion.
B. Define adhesion.
C. Describe surface tension.

Procedures:

You will test the properties of surface tension.

Two Sides to a Coin

1. Place the coins on the table such that each coin has a "heads" facing up and a "tails" facing up. Discuss which one each person thinks will hold the most drops of water.

2. Draw a table in which to record your 1st prediction, adjusted prediction, and actual number of water droplets, for each coin surface. Do not fill in data until you have read the instructions for obtaining that data.

Two Sides to a Coin

Coin	Surface	1st Predictions	Adjusted Predictions	Actual Number of Droplets
Penny	Heads			
Penny	Tails			
Nickel	Heads			
Nickel	Tails			

3. Fill the beaker about half full of water. Place the pipette in the beaker, and draw some water into the pipette by first squeezing the bulb and then allowing it to expand. The pipette will not be completely full. Place a single drop of water on the table from the pipette. Based on the size of the water droplet, predict how many water drops can be placed on each coin surface before the water will spill over the edge. Record your 1st predictions. Each person on the team may have different predictions.

4. Add one drop of water at a time to the top of your first coin surface, counting the number of drops, until the water spills over. Record the actual number of droplets. Discuss whether any changes to the original predications should be made based on your first result. Record your adjusted predictions for the other three surfaces.

5. Test each of the remaining coin surfaces, and record the results.

Magic Paper Clip

6. Fill the 3 oz paper cup to over the brim with water, such that there is a “bubble” of water above the top of the cup. Gently place a small metal paper clip on top of the water, so that it floats. If the paperclip sinks, use another paperclip from the box. This is possible, so do not give up.

7. Once the paperclip stays on top of the water, add drops of liquid soap to the water until the paperclip sinks. Then make at least 3 attempts to float another paperclip on the top of the water. Record your observations.

Clean-up:

- Discard water outside (water the foliage)
- Thoroughly dry each coin, and your beaker
- Retrieve the paperclips from the paper cup, thoroughly rinse and dry
- Dispose of the paper cup
- Squeeze as much water as you can out of the pipette and place on drying towel

Analysis:

1. Write the differences you notice between your 1st predictions and your adjusted predictions from the mini-experiment of adding water droplets to coins.

2. Explain why the paperclip was able to float on top of the water. What exactly provides the upward force to balance the weight of the paperclip?

3. Was a paperclip able to float on top of the soapy water? Explain why.

General Questions:

1. Sketch or describe where cohesion occurs when there is a bubble of water on a surface. Also, sketch or describe where adhesion occurs when there is a bubble of water on a surface.

2. Based on the density of a metal and the density of water, should the paperclip be able to float on water? Explain.can

Exercise 18 - Weight Lifting

Student Learning Objectives:
Compare and contrast work and energy, and determine when mechanical work occurs.

Materials:

Dumbbells (different weights – i.e. 2 lbs and 4 lbs)
Meter Stick
Measuring Tape

Introduction:
When lifting weights at the gym, you use energy to move a weight. Mechanical work occurs when energy is used to move an object a distance. Mechanical work and energy have the same units of Joules, which indicates that they are closely related. The use of energy does not always result in mechanical work; an object must be moved for there to be mechanical work done on an object.

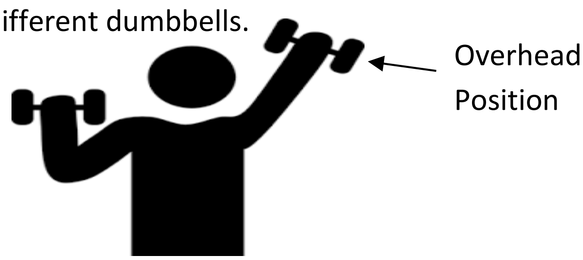
$$\boxed{W = Fd}$$

Pre-Lab:

A. Is weight a force? Is mass a force?
B. Research and write down the conversion factor for pounds to Newtons.

Procedures:
Two different masses will be lifted, held, and lowered.

1. Hold one dumbbell in each hand. Lift both dumbbells such that they are overhead, hold them there for 10 seconds, and then lower both dumbbells. Then lift the dumbbells one at a time. Each person in the group should try this. Discuss as a team, what was noticed regarding the amount of energy needed lift, hold, and lower the different dumbbells. Capture the team discussion in a written statement that states what was observed about energy required to lift, hold, and lower the different dumbbells.



2. While standing with one of the dumbbells overhead, have someone measure the distance from the overhead position to your toe. Each person in the group will need to record their own distance.

3. Draw a table in which to record the force in Newtons for each dumbbell, and the mechanical work done lifting, holding, and lowering, each dumbbell.
   i. Convert the weight of each dumbbell from pounds to Newtons, and record these values in your data table.
   ii. Calculate and record the amount of mechanical work, in Joules, done to lift each dumbbell 0.75 meters.
   iii. Determine the amount of mechanical work, in Joules, done on each dumbbell while held overhead for 10 seconds.
   iv. Determine the amount of mechanical work, in Joules, done to lower each dumbbell 0.75 meters.

Analysis:

1. Was the amount of energy you used to lift versus to lower different for either dumbbell?

2. Was the amount of mechanical work done to lift versus to lower different for either dumbbell?

3. Calculate and record the amount of mechanical work, in Joules, each dumbbell may do on *your* toe **if** it were to fall from the overhead position to your toe.

4. View each person's calculations for the dumbbells falling on their toe. Write a general statement regarding the relationship between the height from which an object falls and the mechanical work that may result.

General Questions:

1. Is mechanical work done on a mass, while it is held overhead?

2. Is energy expended while a mass is held over head?

3. Explain why it is more difficult to lift a weight than it is to lower the same weight?

Exercise 19 - Rolling Down a Hill

Student Learning Objectives:

Relate height to mechanical work and stopping distance, and analyze incline angle relationships to velocity and acceleration.

Materials:

Activity 1

Ramp (metal wall corner)
Metric Ruler
Meter Stick
Ring Stand with Adjustable Clamp
Solid Steel Ball
Measuring Tape
Length of Carpet (4-6 meters)
Styrofoam Cup (with cut out)
Masking Tape
Triple Beam Balance
Weight Boat
Extra meter sticks to use as bumpers (optional)

Activity 2

Adjustable Ramp
6ft Track
Friction Motor Car
Photogate Timer

Introduction:

When a car rolls or slides down a hill, it gains speed and may do mechanical work on anything that is at the end of its path. This is an example of conservation of mechanical energy, the transfer of energy. Height gives an object gravitational potential energy and this energy is transformed into kinetic energy as the object travels downward. At the bottom of a hill, mechanical energy may be transformed into mechanical work when braking or when impacting anther object.

Gravitational Potential Energy	Kinetic Energy	Mechanical Work
$GPE = mgh$	**$KE = (1/2)mv^2$**	**$W = Fd$**

Pre-Lab:

A. Define gravitational potential energy
B. Define kinetic energy

Procedures:

You will analyze the motion of objects that travel down ramps from different heights.

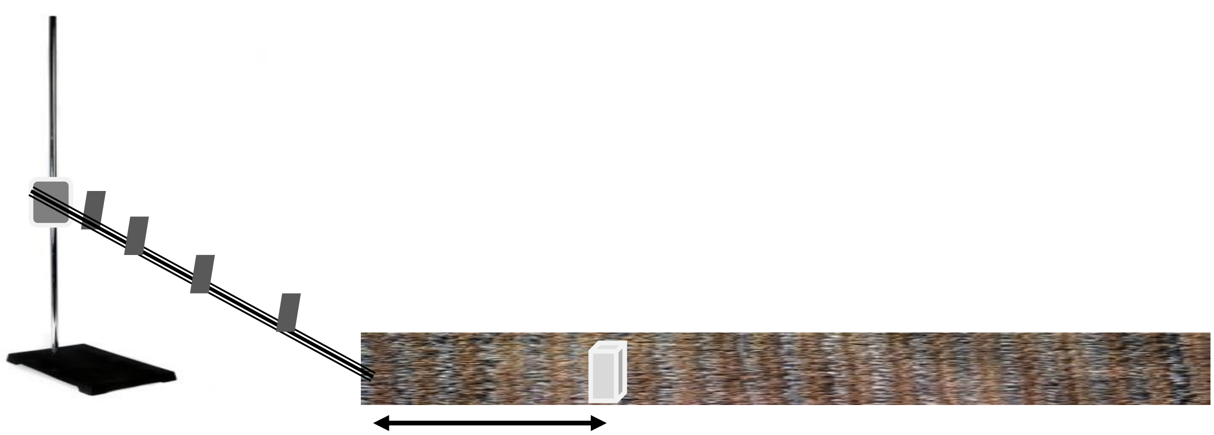
Activity 1

1. Find a flat location that will allow you to utilize the full length of carpet.

2. Assemble ring stand with a clamp and place the metal ramp such that the low end of the ramp is sitting on one edge of the carpet. The high end of the ramp will balance on the clamp, at a height that you choose.

3. Discuss as a team where you predict the ball will stop when released from the high end of the ramp. Stand next to the carpet at the predicted stopping point while another team member releases the ball from the top of the ramp. If the ball continues past the end of the carpet your ramp is too high. Lower the ramp and repeat this process until the ball stops on its own before reaching the end of the carpet, when released from the high end of the ramp.

4. Measure and record the mass of the solid steel ball, and the mass of the pencil box.



5. Choose four locations on the ramp from which to release the ball, and mark each location with a piece of tape. Place the pencil box <u>1 meter</u> from the low end of the ramp.

6. Draw two tables, one for steel ball information and one for pencil box information. Do not fill in data until you have read the instructions for obtaining that data.

Steel Ball

	Ball 1	**Ball 2**	**Ball 3**	**Ball 4**
Initial Height (meters)				
GPE (Joules)				

Pencil Box

	Box 1	**Box 2**	**Box 3**	**Box 4**
Distance Moved (meters)				
Mechanical Work (Joules)				

7. Measure and record the distance in meters from the floor to each piece of tape; these are the initial heights for your steel ball. Use these heights and the measured mass of the steel ball to calculate the GPE in Joules for each height, and record these values in your *Steel Ball* table.

8. Release the ball from each of the heights. Measure and record the distance the pencil box moves from the 1 meter mark for each release location. Use these distances and the weight force of your pencil box to calculate the Mechanical Work done in Joules, to move the pencil box. Record these values in your *Pencil Box* table.

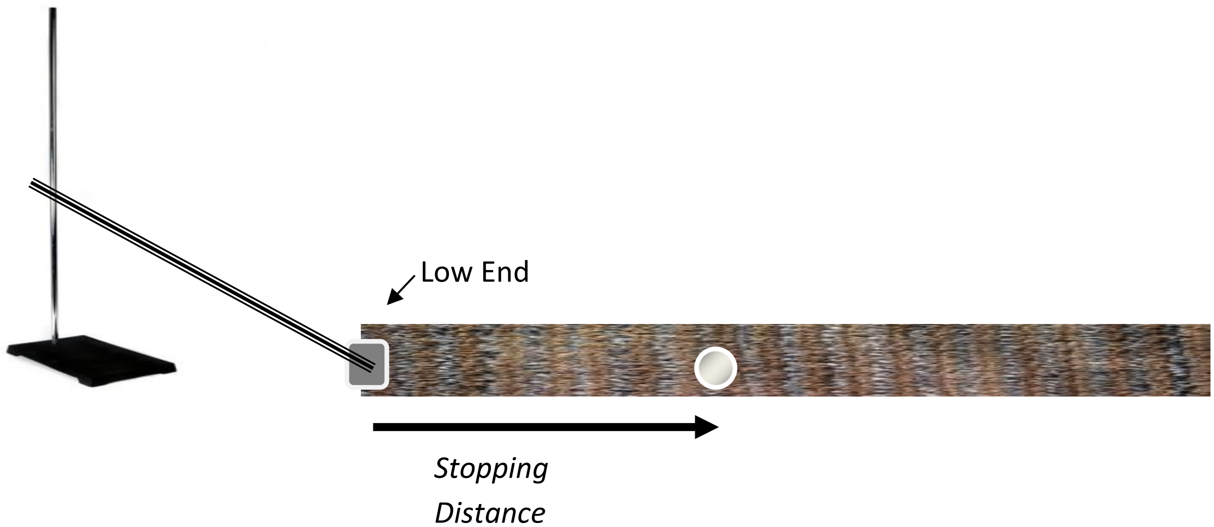
9. Remove the pencil box from the system.

10. Draw another table in which to record stopping distance data and add the initial heights for the steel ball to this table.

Stopping Distance

	Ball 1	Ball 2	Ball 3	Ball 4
Initial Height (meters)				
Trial 1 Stopping Distance (meters)				
Trial 2 Stopping Distance (meters)				
Average Stopping Distance (meters)				

11. Release the ball and observe where the ball stops. Measure and record the distance in meters from the low end of the ramp to the ball, for each height, and complete two trials for each height. If the ball leaves the carpet, the trial does not count and must be redone. Calculate the average stopping distance for each height and record these values in your table.

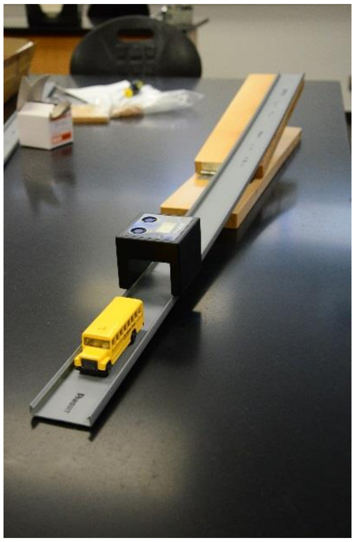


Clean-up:

- Remove and dispose of all tape
- Return all items from *Activity 1* to appropriate locations

Activity 2

12. Set up the adjustable ramp with the 6 foot track on the floor, and position the Photogate Timer as shown in the image. Send the car down the ramp a few times and familiarize yourself with the photogate; it should be set to measure velocity.



Car on track by Norihiro licensed under CC0

13. Draw a table in which to record the initial height and velocity for the three different angles (10^o, 20^o, and 30^o) of incline for the ramp.

Angle	Initial Height	Velocity
10^o		
20^o		
30^o		

14. Position the ramp at the first angle, position the car for release from the top, and hold it there. Measure and record the initial height of the car. Then release the car from the top of the ramp and observe the velocity shown by the photogate. Record the velocity car had at the bottom of the ramp. Repeat this process for the other two angles.

Clean-up:

- Make sure photogate is off
- Return all items from *Activity 2* to appropriate locations

Analysis:

Activity 1

1. Use the steel ball and pencil box tables to construct a graph of distance the pencil box moved versus height from which the steel ball was released. How does the height from which the ball is released affect the amount of work done on the cup?

2. Was all GPE of the steel ball converted into mechanical work on the pencil box? Explain.

3. Construct a graph using your stopping distance and initial height data. Use the graph to determine how the data sets are related (linearly, quadratic, etc.). Write a sentence which describes what your graph shows.

Activity 2

4. Construct a graph using your angle and velocity data. How does this graph compare to your stopping distance and initial height graph?

General Questions:

1. In general, as height increases, which of the following increase? (record all correct choices)
    a. GPE
    b. Mechanical Work possible
    c. Stopping distance
    d. KE
    e. Velocity

2. In which case is more kinetic energy gained along an incline, when it has a relatively small incline angle or a relatively large incline angle? Explain.

3. The mass of an object does not contribute to the velocity at the bottom of a hill when energy is conserved within the system. Explain why?

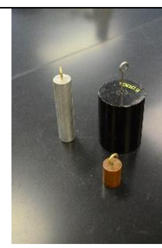
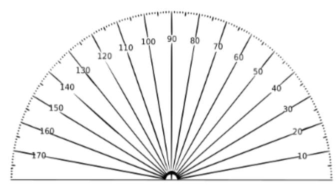
Exercise 20 -The Swing

Student Learning Objectives:

Ascertain the variable that determines the period of a swing through use of the scientific method, and apply conservation of energy to the motion of a swing.

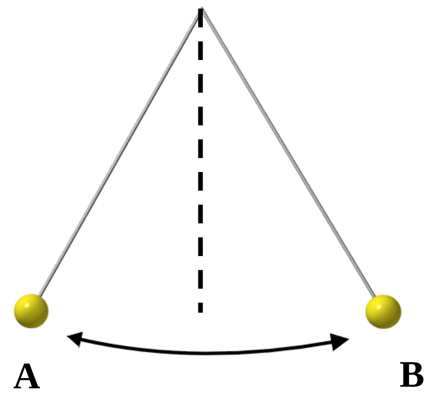
Materials:

Metal Rod (from ring stand)
2 Lab Chairs
Key Chain
Length of Ribbon/String (2 meters)
Triple Beam Balance
Protractor
Stop Watch
1 Mass with Hook

			
Ribbon/Rope Spool of String by Fcb981 is licensed under CC BY-SA 3.0	*Example Key Chain* Image licensed under CC0	*Mass with Hook by Norihiro*	*A Protractor by yamachem licensed under public domain*

Introduction:

A swing at the park is an example of a pendulum. **The period** of a swing, or pendulum, is the time required for the pendulum to circle back to its beginning point, after traveling outward and then returning to the beginning point (from **A** to **B** back to **A**).



Conservation of energy maintains the motion of the pendulum, as Gravitational Potential Energy (GPE) is converted to Kinetic Energy (KE), and KE is converted back into GPE. A swing at the park is just a pendulum with a length, and you are the mass. As you swing, the angle with respect to vertical changes.

Procedures:

You will determine which variable affects the period of a pendulum.

1. Discuss as a team which variable will affect the period of the pendulum, angle, mass, length, or all of these. Record your prediction.

2. Make a bridge with the metal rod and chairs, such that only the ends of the rod are on the chairs. You may want to secure the rods with masking tape.

Long Pendulum

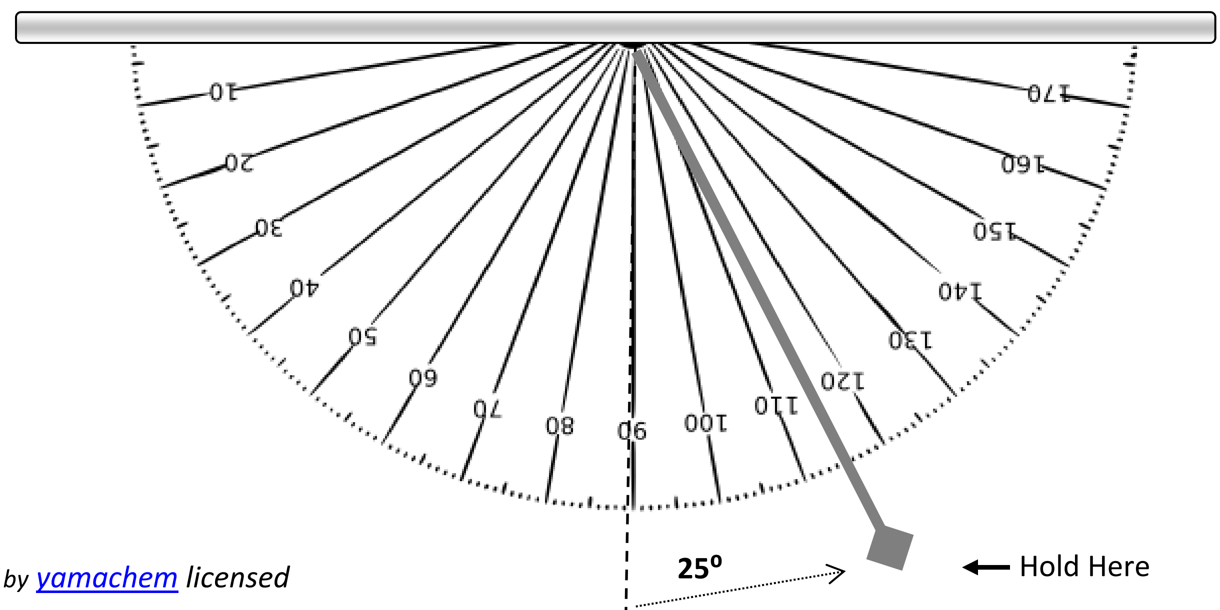
3. Draw a table in which to record data for the 1st pendulum. Do not fill in data until you have read the instructions for obtaining that data.

Length of String	Angle	Time for 5 Cycles 1st Mass	Period 1st Mass	Time for 5 Cycles 2nd Mass	Period 2nd Mass

4. Secure the pendulum fob to the center of the ribbon with a double knot (this may already be done). Then tie the ends of the ribbon <u>in a bow</u> at the middle of the rod, such that the longest possible pendulum hangs from the center of the rod. Measure the length of this pendulum in meters. You will need to decide your end points of measurement and then be consistent with how you measure the length of each pendulum system during the investigation. Record your length measurement, which will remain the same.

5. Choose two angles from which to release the pendulum (i.e., 20^{o} and 40^{o}). Record these angles in your data table.

6. Place the protractor at the bottom of the metal rod, and use the protractor to release the pendulum from your first chosen angle; measure from vertical outward. Hold the pendulum from the bottom so that the ribbon/string remains straight. Release the pendulum. Measure and record the time for **5** complete cycles. Calculate and record the period for one cycle. Repeat this process for your second angle.



A Protractor by yamachem licensed under public domain

7. Add a hooked mass to your pendulum, and repeat the processes in step 6 for this system with the added mass. Record all of your values in your data table.

Short Pendulum

8. Draw a 2nd table in which to record all of the same data as you recorded for the long pendulum.

9. Untie the ribbon. Then re-tie the ribbon in a bow such that it is about half the length of what your long pendulum was. Also, remove the hooked mass that you had added. Measure the length of this pendulum in meters. Record your length measurement, which will remain the same.

10. Use the same angles as you chose for the long pendulum, and repeat the same processes to acquire your data for the short pendulum.

<u>Analysis:</u>

1. Use your data to determine which quantity affected the period of the pendulum the <u>most</u>: angle, mass, or length?

2. Based on your observations, at which point in the swing did your pendulum have maximum KE? You may describe or sketch this.

<u>General Questions:</u>

1. Would a small (20^o) angle or a large (40^o) angle result in the greatest gravitational potential energy? Explain

2. Is it possible for you and a person who is half your mass to swing with the same period on park swings? Why?

Exercise 21 - Balancing a See-Saw

Student Learning Objectives:

Analyze the effects of mass and distance on a lever, and compare forces at different distances from a fulcrum.

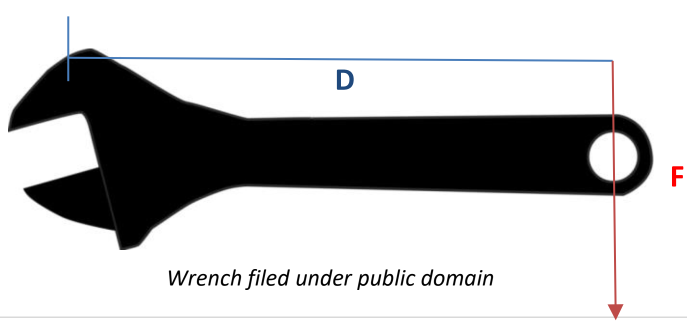
Materials:

Meter Stick (width must accommodate knife edge clamps)
Fulcrum
Set of Slotted Masses (with hanger)
3 Objects of Unknown Mass (keys, sunglasses, etc.)
3 Knife Edge Clamps
Triple Beam Balance
Masking Tape
String

		
Fulcrum	Slotted Masses	Knife Edge Clamp

Introduction:

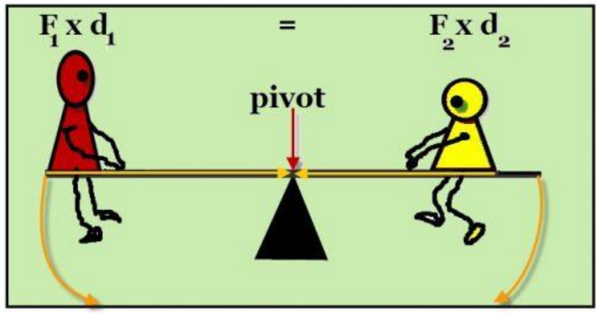
Torque is force acting at a distance, tending to cause rotation around a point. The point about which the object rotates, the pivot point, is called the fulcrum. When force is applied perpendicular to a lever arm, the amount of torque depends on the perpendicular force (F) applied and the length of the lever arm (d) through which the force acts.



Wrench filed under public domain

$$\boxed{\tau = \text{Force x distance}}$$

The amount of torque on one side of a fulcrum is equal and opposite to the amount of torque on the other side of the fulcrum. This can allow a see-saw to be balanced if the two people sit at the correct distances from the pivot point.



$$\boxed{\tau_1 = -\tau_2}$$

Although the torque on each side of the pivot point is equal, the amount of force on each side of the pivot can be very different.

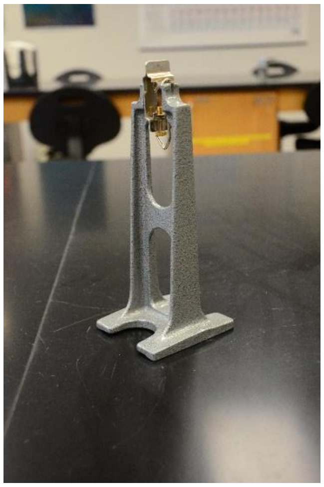
Pre-Lab:

A. If you are given a mass, how do you determine the force?
B. What is meant by mechanical advantage?

Procedures:
You will analyze a see-saw system to determine mass and torque.

Center of Mass

1. Place one knife edge clamp at the center of the meter stick and place the knife edge clamp on the fulcrum. Adjust the position of the knife edge clamp until the meter stick balances horizontally on the fulcrum; you are finding the center of mass of the meter stick. Record the center of mass for the meter stick, in centimeters (cm). The center of mass will not necessarily be 50 centimeters.

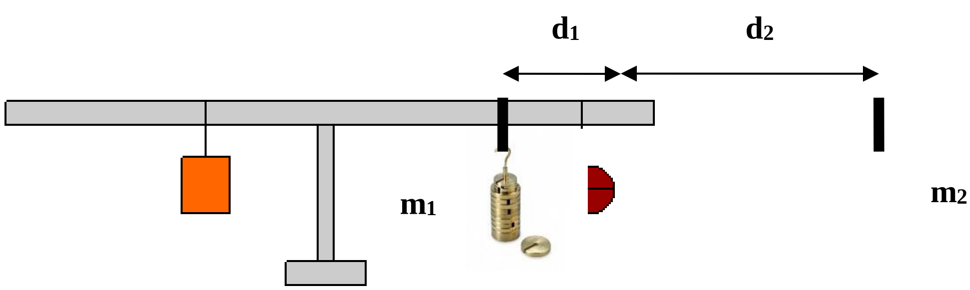


Unknown Mass

2. Draw a table in which to record data for three systems. Do not fill in data until you have read the instructions for obtaining that data.

Object	Known Mass	Distance 1	Distance 2	Calculated Unknown Mass	Measured Unknown Mass

3. Attach an object of unknown mass to a knife edge clamp. You may use tape or string to secure the object to the clamp if necessary. Place this clamp somewhere on one side of the meter stick. Place another clamp on the other side of the pivot. Add individual slotted masses until you have balanced the system, and record the amount of slotted mass in grams that you have added as the <u>known mass</u>. As you add the slotted masses, you may need to adjust distances to balance the meter stick. Record the final distances in centimeters from the fulcrum to each respective mass.



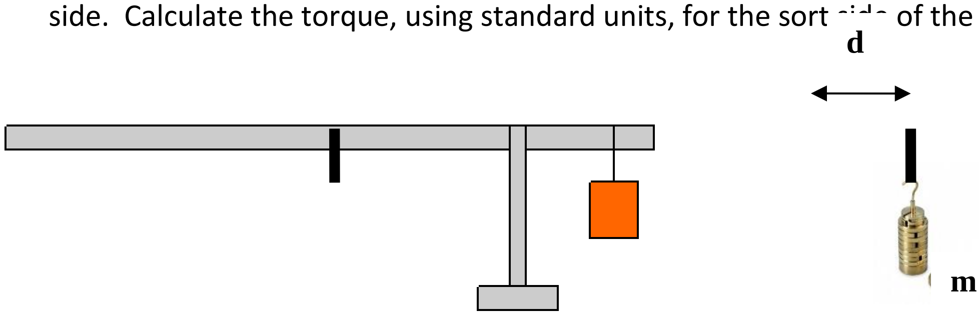
4. Repeat the process in step 3 for the other two additional objects of unknown mass, choosing different distances for each unknown mass.

5. Use your data to calculate the unknown mass for each of your objects, and record these values as your <u>calculated unknown mass</u>.

6. Use the triple beam balance to measure the mass of each object. Record these values as your <u>measured unknown mass</u>.

Off Center

7. Adjust the meter stick so that the 75 centimeter mark is located at the fulcrum. Place a knife edge clamp near each end of the meter stick. Each clamp should be the same distance from the end. Add the slotted masses to short end of the meter stick until the meter stick is balanced. You may need to adjust the fulcrum position slightly in order to balance the meter stick. Once the meter stick is balanced, record the distances (**d**) from the fulcrum to the slotted masses. Also record the amount of slotted mass (**m**) you added to the short side. Calculate the torque, using standard units, for the sort side of the meter stick.



<u>**Analysis:**</u>

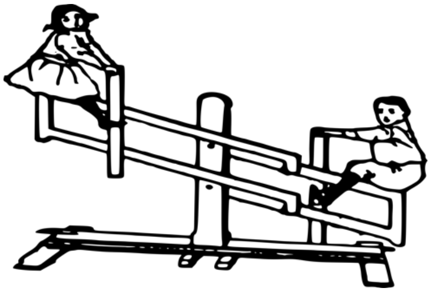
1. Consider the system in which you had 3 unknown masses. On which side did there tend to be <u>less distance</u> between the fulcrum and the mass, the side with the most mass or the side with the least mass?

2. Describe any errors that may have resulted in a difference between your calculated mass and the measured mass for your unknown objects.

3. What is the torque on the long side of the meter stick, in the *Off Center* system? This is a conceptual question.

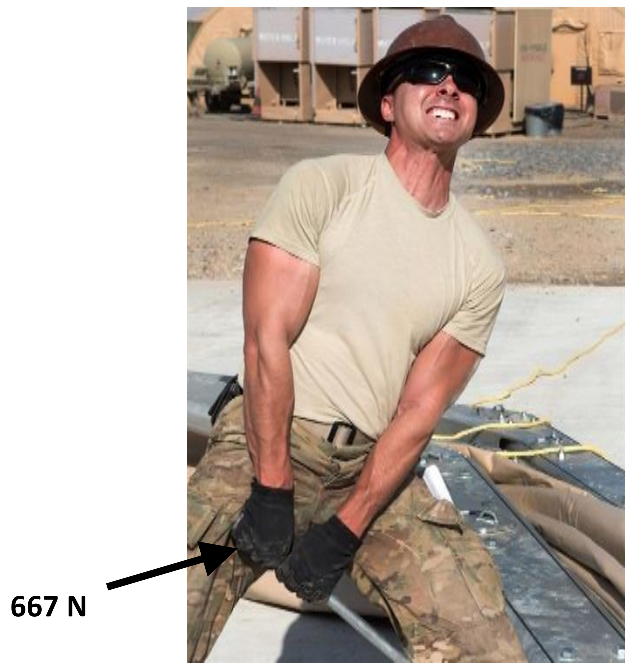
General Questions:

1. If you weigh twice as much as your little sister, where should you sit with respect to the pivot point, in order to balance the see-saw? Should you sit closer to the pivot or father from the pivot? How much closer/farther should you sit?



Kids on a Seesaw by j4p4n available in Public Domain

2. A person pulls on the long end of a crowbar with 150 lbs (667 Newtons) of force perpendicular to the lever arm, in an effort to open a crate. The long end of the crowbar measures 90 centimeters. The short end that is under the top edge of the crate measures 5 centimeters from the pivot.



Pry bar work licensed under public domain

Calculate the amount of torque on the long end of the crowbar.

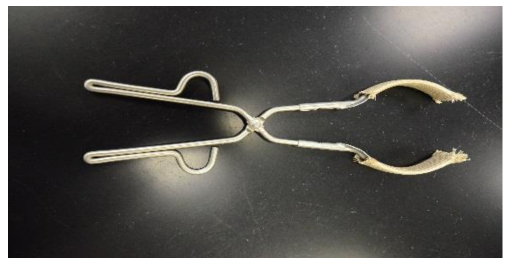
a. What is the torque on the short side of the crowbar?
b. Calculate the amount of force applied to the crate.
c. What is the mechanical advantage gained by using the crowbar?

Exercise 22 – The Temperature of a Molecule

Student Learning Objectives:
Observe the difference of molecular movement in hot and cold water, and predict the equilibrium temperature.

Materials:

Heat Source (Bunsen Burner or Hot Plate)
2 Thermometers
2-250 mL Beakers
1 400-500 mL Beaker
Food Coloring (2 colors)
Aluminum Foil (for a lid)
Heat Gloves
Beaker Tongs



Beaker Tongs

Introduction:
The amount of kinetic energy, the amount of movement, is what determines how hot or cold something seems to be. If atoms / molecules have a relatively high average kinetic energy, then the material will feel hot. If atoms / molecules have a relatively low average kinetic energy, then the material will feel cold. We may not be able to see the movement, but even solid objects have atoms / molecules that are vibrating and may have translational motion. When two material with different temperatures come into contact, they will come into thermal equilibrium.

Pre-Lab:

A. Does something that feels hot have a relatively high or low average kinetic energy?
B. Define thermal equilibrium.

Procedures:
You will observe the movement of molecules in hot and cold water.

1. Add 100 mL of water to each 250 mL beaker. Place one of the beakers of water on the heat source, cover it with the foil, and heat until it boils. Once the water is boiling, turn off the heat source and remove the foil lid.

2. Add 2 drops of food coloring to each beaker (cold and hot) <u>at the same time</u>. Record your observations.

<u>Warning</u>: Do not place a thermometer in a beaker while the beaker is on the heat source.

3. Remove the beaker of hot water from the heat source. Place a thermometer in each beaker and record the temperature of the water in each beaker.

4. Predict what the temperature will be when the water from the two beakers (cold and hot) is combined. Record your prediction.

5. Remove the thermometers, and pour the water from the two small beakers into the large beaker. Place <u>both</u> thermometers into the large beaker and determine the average "final" temperature; this should be an average of the temperature shown on each thermometer after the thermometers have settled. Record the final temperature of the combined liquids.

<u>Clean up:</u>

- Wash and dry all glassware
- Wash and dry thermometers

<u>Analysis</u>:

1. In which beaker of water was more movement observed when the food coloring was added?

2. Do hot or cold water molecules have a higher average kinetic energy? What is the evidence for this?

3. Calculate the difference between your predicted and measured temperatures for the combined water. Describe any factors that could account for the difference.

4. What is the purpose of using 2 thermometers to measure the temperature of the combined water?

General Questions:

1. Describe what happened to the kinetic energy of the cold molecules and the kinetic energy of the hot molecules when the water from the two beakers was combined.

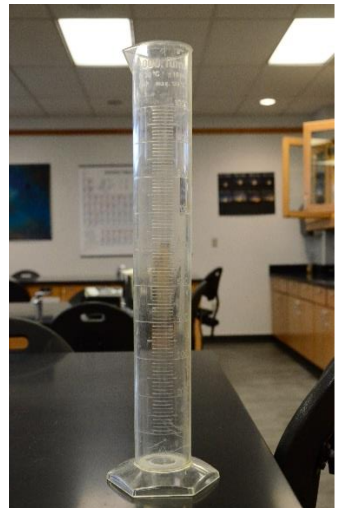
2. Would you expect the hot or cold water to have a higher density? Why?

Exercise 23 - Heat Energy Transfer

Student Learning Objectives:
Analyze heat energy transfer and measure specific heat capacity.

Materials:

- Heat Source
- 250 mL Beaker
- 2 large Styrofoam Cups
- 2 Thermometers
- Triple Beam Balance
- 3 Solid Metal Samples
- Beaker Tongs
- Heat Gloves
- Tongs (for removing metal sample)
- Aluminum Foil (for lid)
- Graduated Cylinder



Graduated Cylinder

Introduction:
The specific heat capacity of a material is the amount of heat required to change the temperature of the material. The higher the heat capacity, the more energy the material must gain or lose to have a change in the temperature of that material. A material that has a relatively high specific heat capacity will tend to resist temperature change. Objects and materials that are placed into contact will reach thermal equilibrium after a time. The heat lost by one material is gained by the other material until both materials are at the same temperature. While the heat energy exchanged may be equal, the temperature changes may be very different if the two materials have very different values of specific heat capacity. If a system is isolated, all energy lost by one material will be gained by the other material.

Heat Energy Equation	Transfer of Energy
$Q = cm\Delta T$	$Q_{lost} = Q_{gained}$

Pre-Lab:

A. Identify the variables in the heat energy equation.
B. When hot metal is placed in cold water, identify which material (metal, water) will be the Q_{lost} and which will be the Q_{gained}.

Procedures:

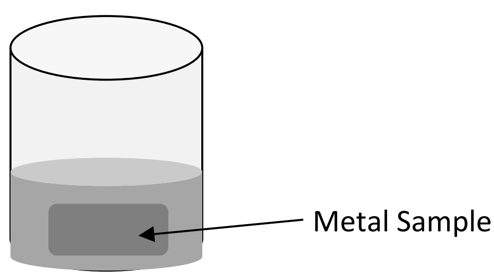
You will analyze the results of placing hot metal samples into cold water.

1. Draw a table in which to collect all of your data. Do not fill in data until you have read the instructions for obtaining that data.

Sample	Mass Metal Sample (grams)	Mass Cold Water (grams)	T_i of Water (Celsius)	T_i of Metal (Celsius)	T_f of Both (Celsius)	ΔT Metal	ΔT Water

2. Choose three metal samples and measure the mass in grams. Record these values in your data table.

3. Place your first metal sample into the beaker and add water until your metal is completely submerged in water. Place the beaker on the heat source, cover with a foil lid, and heat until boiling. While you are waiting for the water to boil, read the procedures that follow so you are ready for the transfer.



4. Use the graduated cylinder to measure an amount of cold water that you think will completely cover your metal sample when placed into one of the Styrofoam cups. Add this cold water to one of the Styrofoam cups, while your metal is heating in the beaker. Record the total mL you add to the Styrofoam cup as the *mass of cold*, in grams. (**1 mL = 1 gram of water**)

5. Use the thermometer to poke a hole through the bottom of the 2nd Styrofoam cup, place the cup with the thermometer onto the cup with cold water to create an isolated system. Measure the temperature in Celsius of the cold water that is in the bottom Styrofoam cup. Record this value as the initial temperature for the cold water (T_i *of Water*).

Warning: Do not place a thermometer in a beaker while the beaker is on the heat source.

6. Once the water in the beaker has boiled for at least 2 minutes, to ensure that the metal sample is hot, follow the next steps as quickly and as you safely can.

   a. Remove the top Styrofoam cup with the thermometer
   b. Transfer the metal sample from the beaker and to the Styrofoam cup with cold water
   c. Isolate the system with the 2nd Styrofoam cup that has the thermometer (make sure the thermometer is down in the water)
   d. Remove the beaker with hot water from the heat source
   e. Place the 2nd thermometer into the hot water

6. Observe both thermometers, the one in the Styrofoam cup system and the one in the beaker with hot water. When it looks like the temperatures have stopped changing, record the temperatures in the appropriate places, in your data table.

   - The temperature of the hot water is the assumed initial temperature for the hot metal sample. (T_i *of Metal*)

   - The temperature in the Styrofoam cup system with the water and metal sample is the final temperature of both the water and the metal. (T_f *of Both*)

7. Repeat the process to obtain data for your other metal samples. You may re-use the hot water in the beaker to heat your second metal sample; make sure there is enough water to

completely cover your next sample. You will need to obtain new cold water in the Styrofoam cup system for each sample.

8. Calculate and record the change in temperature for the cold water and for the metal, for each of your samples.

Analysis:

1. Use the specific heat of water (4186 J/kg^{o}C) and your data to calculate the specific heat of the metal, for each metal sample. Assume all heat energy was transferred from one material to the other.

2. Describe any possible sources of error in your investigation process.

3. Use the table of specific heat capacities to calculate the percent error in your measurements.

Material	Specific Heat Capacity (J/kg°C)
Aluminum	900
Brass	380
Copper	387
Iron or Steel	452
Lead	128
Tungsten	134
Zinc	390
Water	4186

4. In general, which showed the greater temperature change when combined and isolated: the metal samples or the cold water?

Clean-up:

- Wash and dry metal samples and beaker
- Wash and dry thermometers before replacing them in protective containers
- Completely dry Styrofoam cup that had water
- Dispose of Styrofoam cup with hole

General Questions:

1. Based on the specific heat capacities of metals, which 20 gram mass metal sample would you expect to change temperature the most when submerged and isolated in 100 °C water?

2. Your hot water temperature was probably lower than the boiling point for water. Explain what may contribute to water boiling at a lower temperature than the standard boiling point for water.

3. Use a ratio to determine how many times greater the specific heat capacity of water is compared to the specific heat capacities of your metal samples.

Exercise 24 - Rates of Heat Conduction

Student Learning Objectives:
Compare the thermal conductivity of different materials and examine properties of conductors versus insulators.

Materials:

Wire & Flame	*Conduction & Containers*
4-inch Length of Steel Wire	Heat Source
4-inch Length of Copper Wire	A 400-500 mL Beaker
Stop Watch	250 mL Beaker
Matches	Empty Metal Soup Can
Candle	Small Styrofoam Cup
Aluminum Foil	3 Stick-on Thermometers
	Masking Tape
	Heat gloves
	Beaker Tongs
	Aluminum Foil (for a lids)

**Both wires should be the same gauge and should be new*
**The Glass Beaker, Metal Can, and Styrofoam Cup should be about the same diameter*

Introduction:
The ability to conduct heat depends on the mobility of the electrons, how free the electrons are to meander and have collisions. The more free electrons are to move independent of the nucleus, within a material, the faster the material will conduct (move) heat energy. A substance in which electrons are not able to move freely will slow or impede the flow of heat energy. Substances which slow the transfer of heat energy are called insulators. The thermal conductivity of a material is a measure of the Joules per second which can be transferred through the material.

Pre-Lab:

A. Predict which wire will be the best conductor.
B. Predict which container will be the best insulator.
C. What does gauge mean as it pertains to wire?

Procedures:

Warning: Be careful not to burn yourself during this investigation.

Wire & Flame

You will hold two different types of wire in a candle flame.

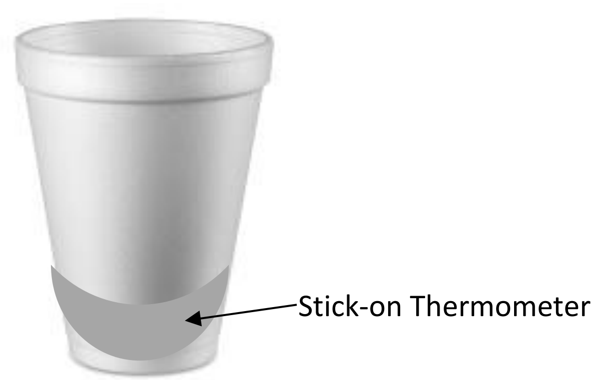
1. Use the aluminum foil to create a candle stand. Light the candle and leave it lit.

2. Hold one wire in each hand such that about 2 inches of the length extends from your grasp. Place the ends of both wires into the flame at the same time (one person should be holding both wires) while another person begin timing the experiment. **As soon as a wire becomes too hot to hold, let go of it.** Record which wire became hot 1st and the time it took for this wire to conduct heat to your hand.

Conduction & Containers

You will be measuring the change in temperature on the outside of three different containers.

3. Obtain 300 mL of water in the 400-500 mL beaker. Place the beaker on the heat source, cover the beaker with a foil lid, and bring the water to a boil. While you are waiting for the water to boil, add a stick-on thermometer around the bottom of each container you will be testing (Beaker, Can, & Cup). If the thermometer is not making good contact with the container, use masking tape to secure it.



4. Draw a table in which to record the <u>initial temperature</u>, <u>final temperature</u> and <u>change in temperature</u> for each container. Do not fill in data until you have read the instructions for obtaining that data.

5. After the temperatures on the thermometers have settled, record the initial temperature of each container in your data table.

6. Once the 300 mL of water is boiling, use either heat gloves or beaker tongs to pour about 100 mL of boiling water into each container. Cover each container with foil. Observe the thermometers until the temperatures have peaked and then record the final temperature of each container in your data table.

7. Touch the outside of each container near the bottom of the container where the hot water is. Rank the order of the containers from most conductive to least conductive, based on what you feel with your hand.

8. Calculate and record the change in temperature for each container.

<u>Clean-up:</u>

- Rinse the wires you used under cold water and throw away
- Dispose of all used foil
- Remove thermometers and throw away unless reusable
- Completely dry all containers

<u>Analysis:</u>

1. Which wire was the best conductor?

2. Which container (Glass Beaker, Metal Can, or Styrofoam Cup) was the best conductor?

3. Which container (Glass Beaker, Metal Can, or Styrofoam Cup) was the best insulator?

<u>General Questions:</u>

1. Which wire has a higher specific heat capacity, copper or steel? What is your evidence?

2. Does an insulator add heat or trap heat?

Exercise 25 - Phase Change of Water vs Salt Water

<u>Student Learning Objectives</u>:
Determine whether adding salt to water makes it boil and change phase faster than regular water.

<u>Materials:</u>

- 2-100 mL beakers
- Triple Beam Balance
- 3 oz Paper cup
- 100 mL Graduated Cylinder
- 10 grams Salt
- Plastic Spoon
- Hot Plate
- 2 Thermometers
- Heat Gloves
- 2 Stop Watches

<u>Introduction:</u>
Latent heat of vaporization is the amount of energy it takes to have a substance change phase between a liquid and a gas. The amount of energy required to change the phase of a substance depends on the amount of mass and the type of material. Once the boiling point is achieved for the substance, it will begin to phase change.

<u>Pre-Lab:</u>

Research and record the specific heat capacity and latent heat of vaporization for both water and salt water.

<u>Procedures:</u>
You will boil water and salt water.

1. Use the graduated cylinder to add 50 mL of water one beaker and 40 mL of water to the second beaker.

2. Obtain 10 grams of salt and add it to the beaker that has 40 mL of water. Stir for 2 minutes or until the salt has completely dissolved, whichever comes first.

3. Draw a table in which to record initial water line level, final water line level, and number of mL vaporized, and the peak temperature for each substance.

4. Use the grease pencil to carefully and accurately mark the level of the water line on each beaker. Record the initial number of mL in each beaker.

5. Place both beakers on the heat source. You will need to closely observe the two beakers so that you are able to determine which substance begins to boil first. Your team will need to decide what constitutes boiling and apply this to both beakers. As soon as the first substance begins to boil, start the first stop watch. Start the 2nd stop watch when the 2nd substance begins to boil. Record which substance boiled first. Allow the 1st substance to boil for ten minutes and remove it from the heat source; measure and record the temperature of this substance. Allow the 2nd substance to boil for ten minutes and remove it from the heat source; measure and record the temperature of this substance.

6. View the level of the water line on each beaker, and record the final number of mL in each beaker.

7. Calculate the number of mL vaporized by finding the difference between the initial water line level and the final water line level. Enter these values in your table.

Clean-up:

- Wash and dry beakers
- Wash and dry thermometers before replacing them in protective containers
- Dispose of 3 oz paper cup
- Place graduated cylinder on drying rack

Analysis:

1. Were the initial water lines the same for each substance? Explain any differences in the number of mL in each beaker initially.

2. Based on your observations, which substance has the <u>higher</u> specific heat capacity, fresh water or salt water? Describe the proof you have for this. Do your observations agree with your pre-lab research?

3. Based on your experiment, which has a <u>higher</u> latent heat of vaporization, regular water or salt water? Describe the proof you have for this. Do your observations agree with your pre-lab research?

<u>General Question</u>:

1. Based on your investigation, does it matter when you add the salt for the cooking time?

Exercise 26 - Magically Moving Objects

Student Learning Objective:
Observe the interactions of charge and determine the method of charging.

Materials:

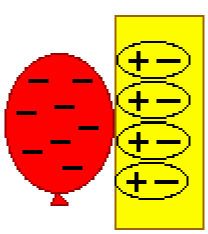
- Balloons (6-7)
- String
- Ring Stand
- 2 Ring Clamps
- 2 Empty Soda Cans
- Kleenex Tissue
- Small Container Ground Black Pepper
- Scissors
- Sheet of White Paper
- Measuring Tape
- Various types of Cloth (Silk, Wool, Etc.)
- 2 Magnets

2 Ring Clamps

Introduction:
A material with a higher concentration of electrons than protons is negatively charged. A material with fewer electrons than protons is positively charged. Some materials give up electrons easily and some materials accept electrons easily, causing each object to become charged. Opposite charges attract each other and any charged object may electrically attract a neutral object. Coulomb's Law can be used to calculate the force between two charged objects.

$$\boxed{F = \frac{k(q1)(q2)}{d^2}}$$

A charged object can force particles to rearrange in a neutral object, leaving one side of the neutral object positive and the other side of the neutral object negative.



Pre-Lab:

A. List the ways in which objects may become charged.
B. What is the charge in Coulombs for 1 electron? For 1 proton?

Procedures:

You will charge various objects and observe the effects of charge.

Hanging Balloon Bounce

1. Set up your ring stand, and place the clamps as close to the same height as possible. The clamps should face opposite each other.

2. Inflate two balloons and tie one to each ring such that the balloons hang at the same height. Adjust the position of the clamps until the balloons are separated by about 2 inches when they hang from the ring clamps.

3. Charge one balloon using hair or clothing, and then allow the balloons to hang. Observe the motion of the balloons and record your observations. Charge both balloons and repeat the process.

Testing Magnetic Attraction

4. Choose a balloon. Each person on the team will need a balloon.

5. Test the magnets to make sure they are able to attract and repel each other.

6. Charge your balloon and investigate whether either pole of a magnet is attracted or repelled by a charged balloon. Record your findings.

Rolling Soda Can Race

7. Find a clear path for two soda cans to travel side by side. Choose two "runners" from your team. Lay the empty soda cans on their sides, at a starting line. The runners will need to inflate their balloons. Allow the runners 2 minutes to charge their balloons, and then race their cans to the end of your team's path using only static electricity. Without touching the soda can, runners will use the balloon to make it move. Measure and record the distance of your team path.

Sticky Tissue Competition

8. Tear the tissue into several small pieces and spread them on your team table. Everyone will need to have an inflated balloon. Choose how long you will charge your balloons, and then compete for the tissue pieces. Record the number of pieces each team member was able to attract and/or steal with their balloon.

Jumping Pepper

Warning: Pepper can sting the eyes.

9. Lay the piece of paper on a table and sprinkle about a spoonful of ground black pepper onto the paper. Choose one team member to charge their balloon. Position the charged balloon about 12 inches above the pepper and then slowly lower it while the rest of the team observes. Record your observations.

Clean-up:

- Use the scissors to cut a small hole where balloons are tied so the air will escape quietly (or wash off the pepper if you want to keep your balloon
- Untie or cut string from ring clamps
- Dispose of the balloon, string, pepper, and pieces of tissue

- Wash your table

Analysis:

1. Explain the result of having only one hanging balloon charged. Why did the balloons behave the way that they did?

2. Explain the result of having both hanging balloons charged. Why did the balloons behave the way that they did?

3. How was each object charged? (friction, contact, or induction)

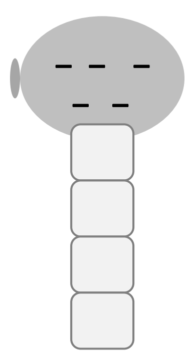
    a) Balloons
    b) Soda can
    c) Tissue paper
    d) Pepper

4. Discuss and describe what was used to win the sticky tissue competition and any products that may have prohibited other members from winning.

5. In general, does static electricity exhibit force at a distance?

General Questions:

1. Show the charges on pieces of tissue in a chain, hanging from a negatively charged balloon. Does each piece of tissue have a charge or is each piece neutral?



2. Assume 10,000 electrons were transferred from your hair to the balloon. If the balloon is then held 1 centimeter from your hair, what is the magnitude of the force between your hair and the balloon.

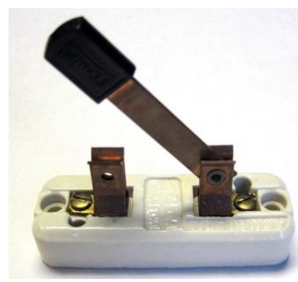
Exercise 27 - Holiday Lights

Student Learning Objectives:

Construct, compare, and contrast series and parallel circuits.

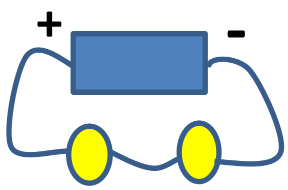
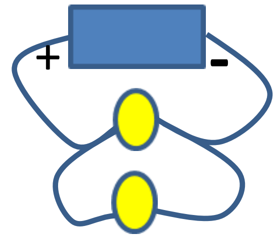
Materials:

4 D-size Batteries
2 Battery Holders (2 D-Size Batteries)
1 6-inch Length of Insulated Conducting Wire
12+ Electrical Leads (short length)
6 Flashlight Bulbs
6 Bulb Sockets
2 Electrical Switches
Electrical Tape

		
Electrical Leads (Crocodile Clip Cables by Suyash Dwivedi licensed under CC 4.0)	*Flashlight Bulb by Rainer Bielefeld is licensed under Public Domain*	*Electrical Switch (knife switch by Ayl~commonswiki licensed under CC 3.0 BY-SA*

Introduction:

An electric circuit provides a complete path through which electrons may flow. There are two basic types of circuits: series and parallel. Devices in a series circuit are connected in one continuous loop while devices within a parallel circuit are connected in multiple loops. Electrical switches create a break in the path, preventing the flow of electrons. A short circuit is a path of least resistance in the electrical circuit which bypasses the devices the circuit is intended to operate. Circuit diagrams show how devices are connected together. The lines in a circuit diagram represent wires.

Series Circuits	*Parallel Circuits*
	

The resistance is added differently in each type of circuit because of how current flows across each device in series versus parallel circuits.

Series Circuit Resistance	Parallel Circuit Resistance
$\mathbf{R = R_1 + R_2 + R_3}$	$\mathbf{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

<u>Pre-Lab:</u>

View series and parallel circuit diagrams on the internet.

<u>Warnings</u>:

- **Exposed ends of wires can burn you.**
- **Wires will become hot if a short circuit is created.**

<u>Procedures:</u>

You will construct a variety of circuits.

1. Your first task is to construct a simple circuit using a single wire, a single battery, and a single light bulb (no socket). This circuit may be used to test whether light bulbs are broken as you progress through the lab. **You must have this circuit checked by your instructor before you continue.**

2. Predict which type of circuit will result in brighter bulbs, series or parallel. Record your prediction.

3. Draw a data table in which to record working/not working results for 8 circuit permeations.

Series Circuit

4. **You will need to have this circuit checked by your instructor once it is working.** Construct a series circuit using 1 battery holder, 1 electrical switch, 2 batteries, 2 bulbs, 2 sockets, and as many pieces of electrical leads as you need. If the bulbs do not light, test each light bulb with a battery and a wire. Once you have a working circuit, and it has been checked by your instructor, remove one bulb by unscrewing a bulb from a socket, and record working / not working in your data table. Replace the bulb, make sure your circuit is working, and open the switch. Record whether the circuit is working/not working with the switch open.

5. Add a 3^{rd} bulb with a socket to your series circuit. Record whether the brightness changed when the 3rd bulb was added to your series circuit. Test and record working/not working with one unscrewed bulb, and with the electrical switch. Detach the batteries and set this circuit aside; do not disassemble it.

Parallel Circuit

6. **You will need to have this circuit checked by your instructor once it is working.** Construct a parallel circuit using 1 battery holder, 1 electrical switch, 2 batteries, 2 bulbs, 2 sockets, and as many pieces of electrical leads as you need. If any of the bulbs do not light, test them with a battery and a wire. Once you have a working circuit, and it has been checked by your instructor, remove one bulb by unscrewing a bulb from a socket, and record working/not working in your data table. Replace the bulb, make sure your circuit is working, and open the switch. Record whether the circuit is working/not working with the switch open.

7. Add a 3^{rd} bulb with a socket to your parallel circuit. Record whether the brightness changed when the 3rd bulb was added to your parallel circuit. Test and record working/not working with one unscrewed bulb, and with the electrical switch. Detach the batteries and set this circuit aside; do not disassemble it.

Comparing Series & Parallel

8. Re-attach the batteries to each of your circuits, series and parallel. Once you have both circuits operating, compare the overall brightness of the bulbs in each. Note that some bulbs may be brighter than others as a function of age. Record which type of circuit, in general, has the brightest bulbs.

Combination Circuit

9. Construct a combination circuit such that part of your circuit is wired in series and part of your circuit is wired in parallel. Sketch this circuit and indicate where you have series connections and where you have parallel connections.

Analysis:

1. Compare and contrast series and parallel circuits, based on your observations.

2. What is similar about removing a bulb and opening a switch? What does this do?

3. Calculate the resistance for each of your 3 bulb circuits. Assume each bulb has a resistance of 2 Ohms and neglect any resistance provided by the rest of the system.

4. How were you able to verify that you had both series connections and parallel connections in your combination circuit?

General Questions:

1. Can you unscrew a bulb from a series circuit without affecting the flow of electrons?

2. Can you unscrew a bulb from a parallel circuit without affecting the flow of electrons?

3. How do you think most of the circuits in your home are wired, in series or in parallel? What evidence do you have?

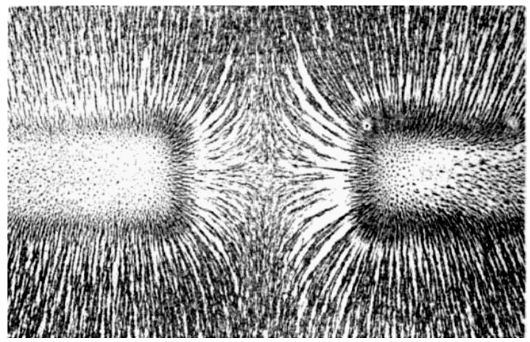
Exercise 28 - Magnetic Field Patterns & Interactions

Student Learning Objectives:

Observe magnetic field patterns, and observe interactions between magnetic fields.

Materials:

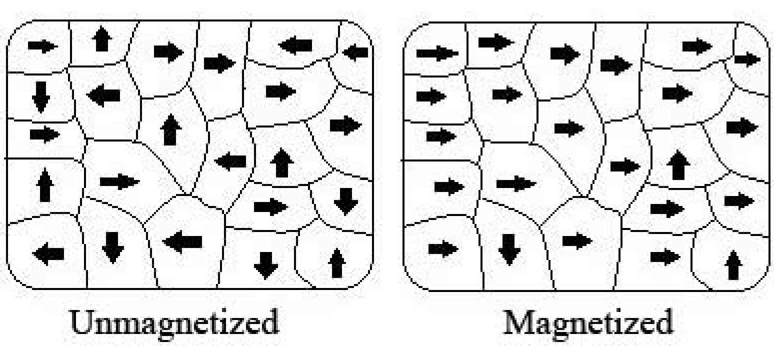
Box Small Paper Clips
1 Large Paper Clips
1 Container of Iron Filings
1 Piece of White Paper
4 Magnets (various sizes and shapes)
2 Strong Bar Magnets
1 Magnetic Compass
1 Magnetic Field Observation Window



Magnetic field of bar magnets attracting is licensed under public domain

Introduction:

A material exhibits magnetic properties when electrons align in a particular way within the material. Each electron is basically a tiny magnet and when the magnetic fields of the electrons are aligned within a material, the magnetic moments of the electrons add together making the entire material magnetic. All magnets have both a north seeking pole and a south seeking pole which are based on the magnetic moment positioning of the electrons. Opposite poles are attracted together, while like poles repel. A magnet can induce magnetism in a ferromagnetic material. Iron filings exhibit magnetic effects when they are near a magnet, and align themselves with the magnetic field of the magnet.



Pre-Lab:

A. Research and describe what a ferromagnetic material is.

B. Predict whether magnetic attraction is possible through materials, like a glass window.

<u>Procedures:</u>

You will observe several magnetic field patterns, and test magnetic attraction.

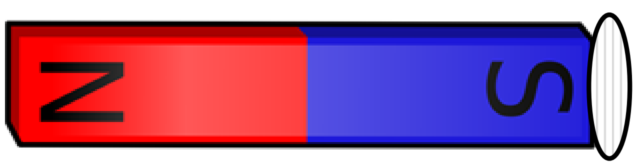
Please use the piece of paper as a barrier between the magnets and the iron filings. Iron filings will not wash off a magnet.

Patterns

1. Choose your first magnet and place it on <u>top</u> of the piece of paper. Move the *Magnetic Field Observation Window* around to evenly distribute the iron filings in the solution, and then place it on top of the magnet. Observe the pattern. Remove the Magnetic Field Observation Window and place the magnet <u>under</u> the piece of paper. Lightly sprinkle a thin layer of iron filings from the container of iron filings onto the paper, like you are seasoning your food, until a pattern emerges. Describe or sketch the pattern for this magnet. Pour the iron filings from the paper back into the container. Repeat this process for each of your 4 magnets.

Magnetic Metal

2. Choose one of the bar magnets and place a paperclip such that it extends out from the top surface of the magnet. Repeat the Magnetic Field Observation Window and the iron filings processes for this system. Describe or sketch what you observe.



Bar Magnets by torisan is in the public domain

Strongest Magnet

3. Spread the small paperclips onto the table. Have each team member choose a magnet. Have a team competition to determine which magnet is the strongest. Describe the properties of this magnet, like its shape and what it was able to do to win the competition.

Multiple Fields

4. Orient the bar magnets such that the <u>opposite poles</u> attract. Repeat the Magnetic Field Observation Window and the iron filings processes for this system. Describe or sketch what you observe.

5. Re-orient the bar magnets such that the <u>like poles</u> face each other. Repeat the Magnetic Field Observation Window and the iron filings processes for this system. Describe or sketch what you observe.

6. Use a combination of magnets, or combinations of magnets and paperclips, to create two new patterns. Describe or sketch what you observe happening to the magnetic fields when they are brought close to each other.

Mapping the Field

7. Place a strong bar magnet on the table. Slowly move the magnetic compass around the magnet and observe the compass needle. Sketch the direction the arrow points at various locations to produce a map of the field surrounding this magnet.

Magnetic Materials

8. Draw a table in which to list 3 magnetic and 3 non-magnetic materials/objects in your classroom.

9. Choose a strong magnet and test items in your classroom to complete your table of magnetic and non-magnetic materials/objects.

Extension of the Field

10. Choose two strong magnets. Determine if the magnets are strong enough to attract each other through the items listed below. Record your results.
    a. A sheet of paper
    b. A wood door
    c. The thickness of the edge of your table
    d. The seat of your chair
    e. A glass window

Clean-up:

- Clean up all iron filings
- Throw away the piece of paper
- Wash your team table

Analysis:

1. Explain what must take place in a paperclip for it to produce a magnetic field.

2. Describe evidence from your observations that prove opposite poles attract and like poles repel.

3. Magnetic fields may extend through materials/objects in the vicinity of the field. (True/False)

General Questions:

1. Are all metals magnetic? What is your evidence?

2. Is it possible to have a magnet with only one pole? Explain.

3. "One pole of the magnet is negative and the other pole of the magnet is positive." Is this statement true or false?

Exercise 29 – The Electromagnetic Connection

Student Learning Objectives:

Test the induction of a magnetic field from electricity, and the strength of an electromagnet.

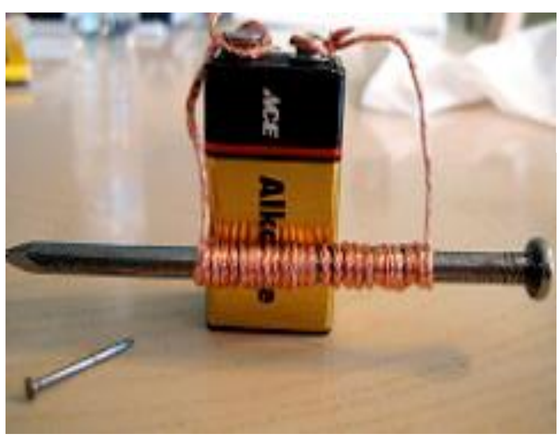
Materials:

Large Iron Nail (such as 10d 3")
5 feet Insulated Conducting Wire (small gauge 28 AWG)
Single D Battery Holder
1 D Battery
1 Container of Iron Filings
1 Piece of White Paper
1 Box Small Paperclips
1 Magnetic Compass
Masking Tape
Electrical Switch
3 Electrical Leads
Sand Paper or Wire Strippers (depending on type of insulation)
Phone compass app

*Kits available through miniscience.com/kits/electromagnet

Introduction:

An electromagnet is basically a coil of conducting wire encircling an iron core that becomes a magnet when electric current is present in the wire. The iron core strengthens the magnetic effect. Electromagnets have a north magnetic pole and a south magnetic pole as long as there is electric current in the coil of wire.



Pre-Lab:

A. What is Maxwell's Law?
B. Do opposite magnetic poles attract or repel?

Procedures:

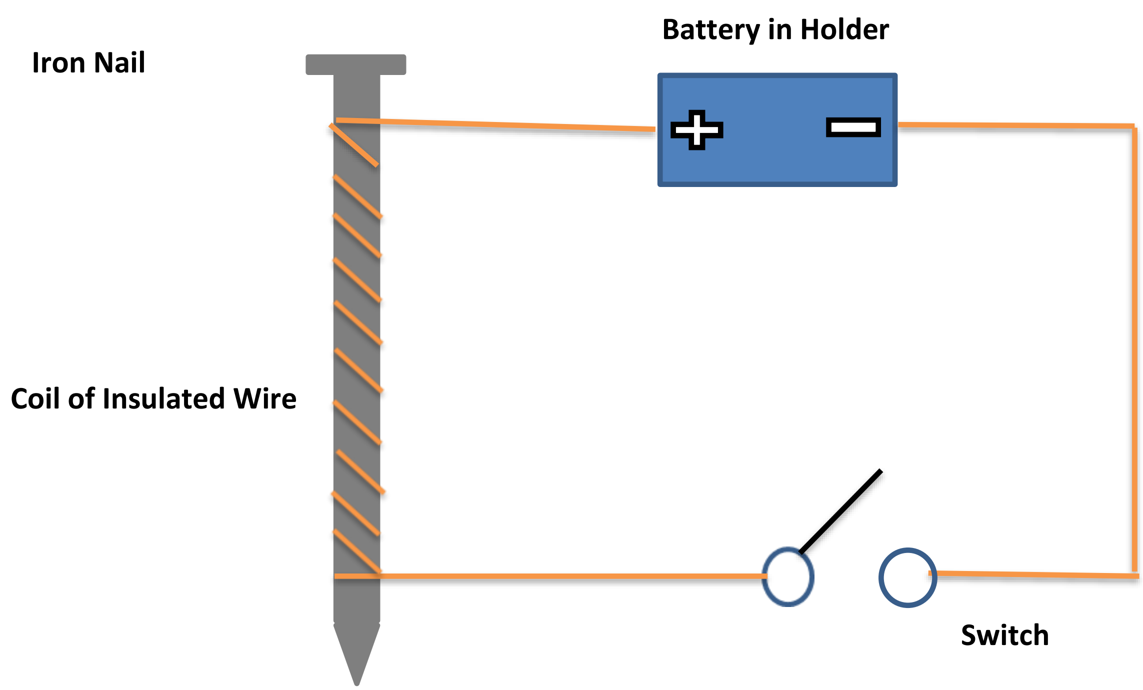
You will make an electromagnet and investigate its properties.

Making the Electromagnet

1. Wrap the nail in masking tape to prevent direct contact between the nail and the wire.

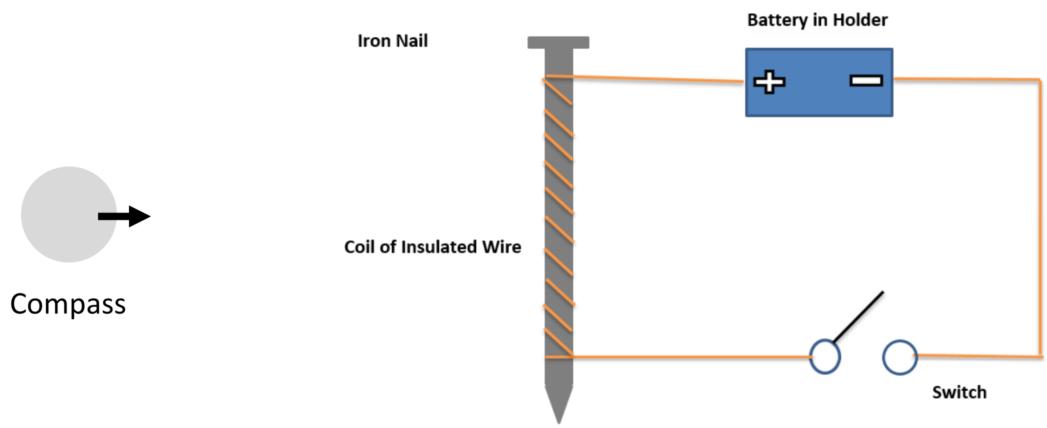
2. Leave about 6 inches of wire loose at one end and wrap most of the rest of the wire around the nail. Try not to overlap the wires. Leave enough wire so that there is about 6 inches of wire loose at the other end of the nail.

3. Remove about 1 inch of insulation from both loose ends of the wire. Make sure the switch is open and use the electrical leads to create the circuit shown below. Your battery should be in a battery holder. NOTE: An electromagnet uses up a battery quickly and the battery may get warm, so open the switch or remove the battery whenever you are not using the electromagnet.



Testing Your Magnet

4. Close the switch, with the battery in the battery holder. Bring the magnetic compass near the side of your electromagnet and observe the compass needle. What did the compass needle do? Record your answer.



5. Open the switch. Disconnect the battery and turn the battery around. Close the switch and record any change in the behavior of the compass needle. Then re-open the switch.

Determining the Poles

6. Use your phone compass app to determine which end of the magnetic compass needle is the north seeking end. Place the magnetic compass at the end of your electromagnet that is the tip of the nail. Close the switch. Record whether the end with the tip of the nail is the south magnetic pole or north magnetic pole of the electromagnet.

7. Move the magnetic compass to the other end of your electromagnet and observe the magnetic compass needled; record your observation. Then re-open the switch.

8. Sketch your electromagnet and label the poles you identified.

Magnetic Field Pattern

9. Place your electromagnet under the piece of paper. Close the switch. Lightly sprinkle iron filings onto the paper. Describe or sketch your observations.

10. Pour the iron filings back into their container and re-open the switch.

Testing Strength

11. Spill the small paperclips onto the table. Close the switch and record the number of paperclips you are able to pick up with our electromagnet. Then re-open the switch.

12. Unwrap about 1/3 of the wire from your nail. Close the switch and record the number of paperclips you are able to pick up with our electromagnet. Then re-open the switch.

Clean-up:

- Clean up all iron filings
- Throw away the piece of paper
- Wash your team table
- Unwrap all wire and remove tape from nail

Analysis:

1. Explain why the compass needle moves in the vicinity of the electromagnet. How is this possible when the two objects are not in direct contact?

2. Sketch or describe how changing the direction of a current effects magnetism.

3. Describe any correlation between number of coils and magnetic strength.

General Questions:

1. Electric current can induce magnetism. (True or False)

2. The more turns of wire there are in an electromagnet, the stronger the magnet is. (True or False)

3. Was the electromagnet you made most similar to a bar magnet or a button magnet? Explain.

Exercise 30 - Energy of Sound & Speed of Light

Student Learning Objectives:

Verify that sound is a wave which carries energy and propagates through a variety of materials; observe that sound begins as a vibration, and detect the difference between the speed of sound and the speed of light.

Materials:

Drum
Box of Paperclips
Tuning Fork
400-500 mL Beaker
Metal Fork
Metal Spoon
2 Wood Stakes
Firm Grip Work Gloves

		
Drum	*Tuning Fork*	

Introduction:

All waves begin as a vibration. For the vibration to produce sound, there must be a material through the vibration may travel. The vibrations of atoms and molecules in air create compressions and rarefactions in the air. Sound travels at an average speed of 343 m/s in air; this speed varies because it depends on the atmospheric pressure and temperature of the air. It takes time for the sound wave to travel.

$$\boxed{s = \frac{d}{t}}$$

Pre-Lab:

What is a longitudinal wave? Describe and/or sketch it.

Procedures:

You will observe sound producing systems.

1. Draw a table in which to record your data. Do not fill in data until you have read the instructions for obtaining that data.

System	**Vibration** (yes or no)	**Sound** (yes or no)	**Energy** (yes or no)
Drum Energy			
Sound in Water			
Fork & Spoon			

Drum Energy

2. Place several paperclips on your drum. Then tap on the drum a few times and observe both the drum surface and the paperclips. Did the surface of the drum vibrate (vibration)? Did you hear sound from the drum (sound)? Was energy transferred to the paperclips (energy)? Enter all of your answers for this system in your data table.

3. Tap on the drum softly and then harder. Record any changes you see and/or hear when you tap on the drum with different amounts of force.

Sound in Water

4. Fill the beaker ¾ full with water.

5. Gently strike the tuning fork against your hand or soft pad, and then place the tuning fork in the water. Did you see the tuning fork vibrate (vibration)? Did you hear sound from the tuning fork (sound)? Was energy transferred to the water (energy)? Enter all of your answers for this system in your data table.

Fork & Spoon

6. Hit the fork with the spoon (be careful not to hit your hand). Observe the tines on the fork. Hit the fork with the spoon again and then bring the fork close to your ear. Each person on the team may want to try this. Did you see the fork vibrate (vibration)? Did you hear sound

from the fork (sound)? Was energy transferred, did you feel something (energy)? Enter all of your answers for this system in your data table.

Sound versus Light

Note: This experiment must take place in a large outdoor space.

7. Walk to a location where there is ample space and the ground is relatively flat. Have one person put on the gloves, hold the two wood stakes, and walk 100 paces (regular steps) from the rest of the team. Observe as the person hits the stakes together. Record whether your team observed a difference in the travel times for the light wave and the sound wave.

8. Increase the separation to 200 paces and repeat the process. Record any difference observed at this separation as compared to the 100 paces separation.

Clean-up:

- Completely dry beaker and tuning fork before returning them

Analysis:

1. What was required to start each vibration, to make the system vibrate?

2. What were the mediums (solids, liquids, gases) though which the waves traveled in each case?

3. Which systems produced an audible sound in the lab?

4. Assume that 100 paces equals 122 meters.

   a. Calculate the time for the sound wave to travel from the stakes to the observers, for 100 paces. The average speed of sound is 343 m/s.
   b. Calculate the time for the light wave to travel from the stakes to the observers, for 100 paces. The speed of light in air is 3×10^8 m/s.
   c. Use a ratio to calculate how much faster one wave arrives before the other.

General Questions:

1. When you speak, how is the sound produced? What must happen?

2. Why does a person typically see lightening before hearing thunder when both the lighting and the thunder travel the same distance from the same cloud?

3. As a storm cloud approaches, you count 5 seconds between the lightning and the thunder. How far away is the storm cloud? Provide mathematical proof for your answer.

Exercise 31 - Waves on a Very Long Spring

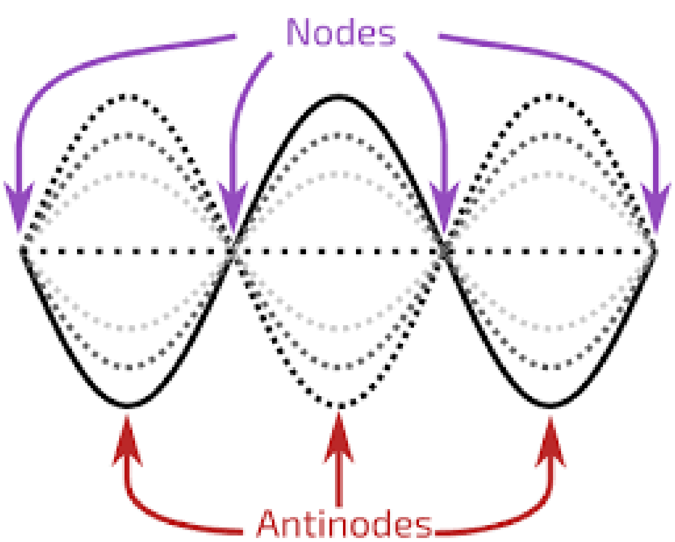
Student Learning Objectives:

Analyze waves on a spring, and ascertain relationships between wave properties.

Materials:

- Long Spring (2 meters long - when un-stretched)
- Strong Metal Clamp
- Masking Tape
- Measuring Tape
- Impact Glasses (recommended)

A wave is a disturbance in a medium (material). All waves begin as a vibration, and this vibrational energy is carried from one location to another by the wave. The basic properties of waves include wavelength (λ), frequency (f), period (T), wave speed (v), and amplitude. A standing wave occurs when one end of the medium is fixed; this allows the wave to make reflections of itself. In certain places the vibrations will add to produce maximum amplitude and in other places the vibrations will cancel each other resulting in no vibration.



Frequency & Period	Speed & Frequency	Speed & Period
$f = \frac{1}{T}$	$v = \lambda f$	$v = \frac{\lambda}{T}$

Pre-Lab:

A. Define each wave property (wavelength, frequency, period, wave speed, and amplitude).
B. Describe or sketch what a transverse wave is.

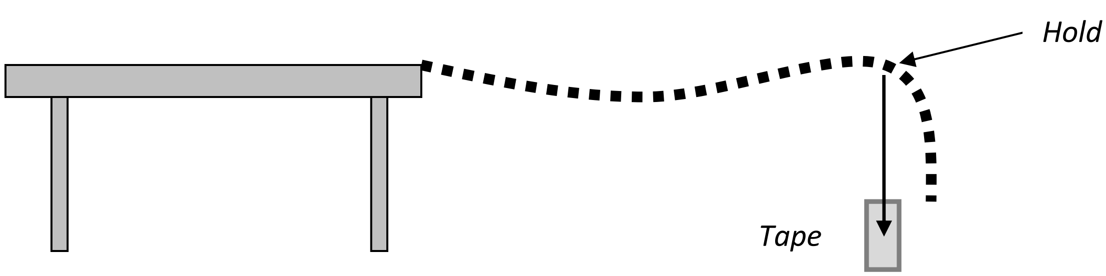
Procedures:
You will create different standing waves along the spring.

Warning:

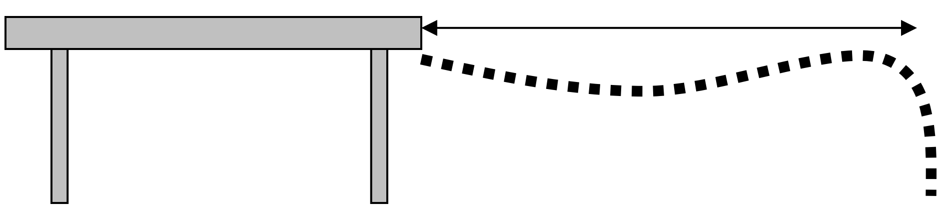
- **Each person must pay attention and be ready in case the spring comes loose from the clamp.**

1. Use the clamp to securely fasten one end of the spring to a table.

2. Stretch the spring out so that it does not touch the ground and is as close to horizontal as is possible, however, do not overstretch the spring! You do not have to use all of the spring, but you should have at least 2-3 meters of horizontal spring. Any remaining length of spring may be coiled and held in your hand. Place a piece of tape on the spring where you intend to hold it, and place a piece of tape on the floor directly below your hold on the spring. Maintain this position for the entire experiment to ensure that the spring length is maintained.



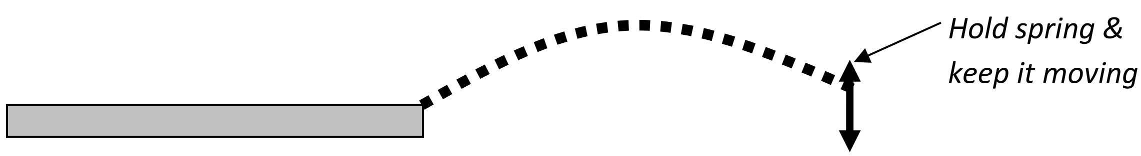
3. Measure and record the length of the horizontal spring in meters, from the clamp to where you are holding the spring. This measurement will be used to determine the wavelength of the waves you produce.



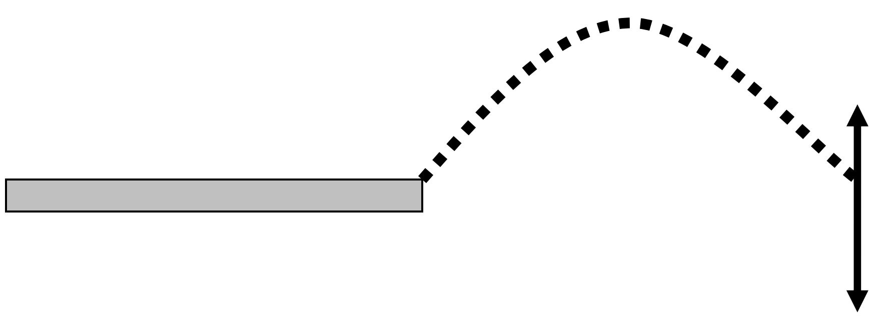
4. Draw a table in which to record your data. Do not fill in data until you have read the instructions for obtaining that data.

	Time for 10 Cycles (seconds)	**Period** (seconds)	**Frequency** (Hertz)	**Wavelength** (meters)	**Wave Speed** (m/s)
1 bump					
1 high bump					
2 bumps					
2 high bumps					
3 bumps					

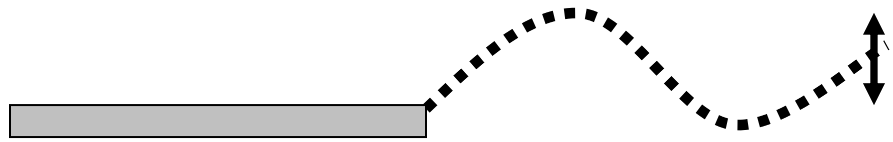
5. Create a wave on the spring by continuously moving your hand up and down in a maintained rhythm that sustains one bump. Be careful to maintain your positioning such that your hand remains aligned with the tape on the floor. While the one bump standing wave is sustained, measure the time it takes for 10 complete cycles. One cycle requires that the spring return to the start position, for example, begins at top and returns to top. Record the total time for 10 complete cycles in your data table.

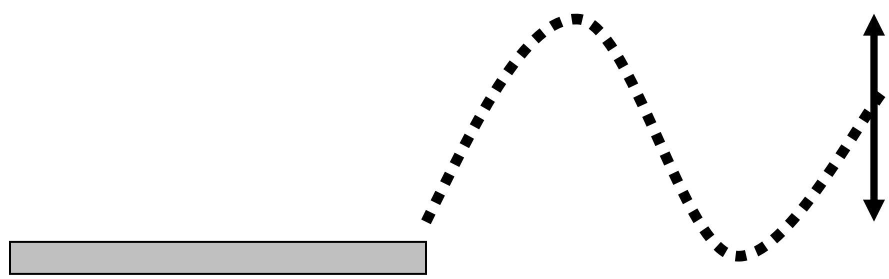


6. Create a wave on the spring by continuously moving your hand up and down in a maintained rhythm that sustains one "high" bump. Be careful to maintain your positioning such that your hand remains aligned with the tape on the floor. Measure and record the time for 10 complete cycles of this wave.

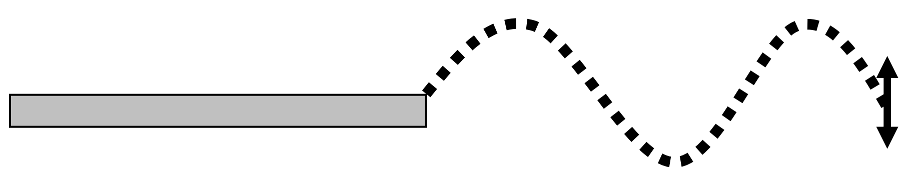


7. Repeat the one bump process for a two bump wave. Measure and record the time for 10 complete cycles of both the regular two bump wave and the "high" two bump wave.





8. Repeat the one bump process for a three bump wave. Measure and record the time for 10 complete cycles of the regular three bump wave; you do not need to acquire data for a "high" three bump wave. The "high" three bump wave is very difficult to sustain.



Clean-up:

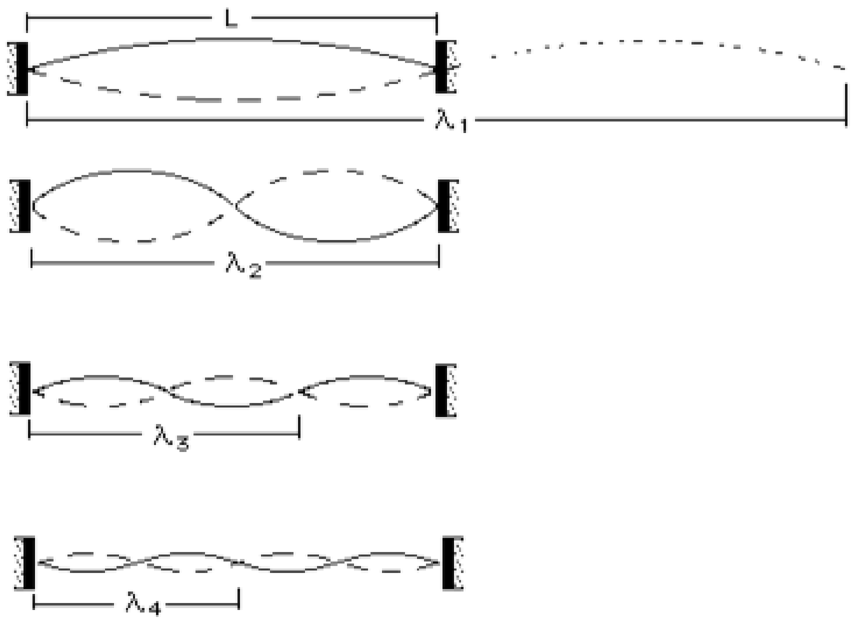
- Remove tape from spring and floor, and throw tape away in the trash

Analysis:

1. You have the time for 10 cycles for each of your waves. Determine the time for one cycle, the period, for each of your waves. Record these values in your data table.

2. Calculate the frequency for each of your waves and record these values in your data table.

3. Use the length of the spring when it was horizontal to determine the wavelength for each of the waves you created. You will need to consider the number of wavelengths you are producing, in the measured length of the spring, for each wave. Record the wavelength for each wave in your data table.



4. Did changing the height of the wave significantly change any of the properties of the wave? If yes, which properties were significantly changed?

5. What was the medium through which the waves travelled?

6. What type of wave did you create, transverse or longitudinal?

7. Based on your experiment, what does increased amplitude require?

General Questions:

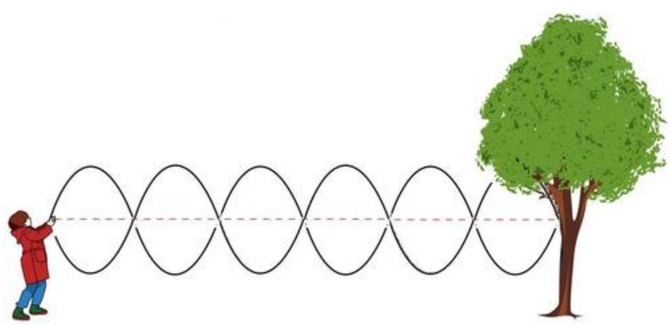
1. Sketch the original wave and its reflection for the two bump wave. Indicate locations on the spring where you would place a bell, while the two bump wave is sustained, if you wanted the bell to ring as quietly as possible. Are these locations nodes or antinodes?

2. Sketch the original wave and its reflection for the three bump wave. Indicate locations on the spring where you would you place a bell, while the three bump wave is sustained, if you wanted the bell to ring as loudly as possible. Are these locations nodes or antinodes?

3. Explain why the bell would ring quietly in certain locations on the spring, and loudly in certain locations on the spring, while a standing wave is sustained.

4. Standing waves of air molecules are produced in some wind instruments. Do you think the holes of a wind instrument are placed at the nodes or antinodes? Defend your answer.

5. How many nodes does the standing wave in the following image have? How many anitnodes does this wave have?



Standing Wave in a rope by Adrignola licensed CC BY-SA 3.0

Exercise 32 - Bouncing Light

Student Learning Objectives:
Observe the law of reflection in different systems, compare reflective surfaces, and view reflections from curved mirrors.

Materials:

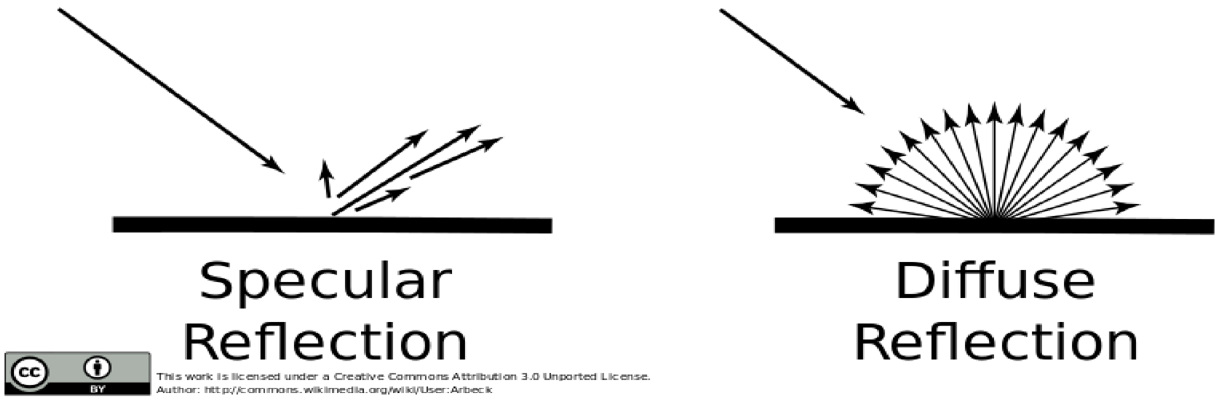
Law of Reflection
Flashlight
Flat Mirror (single plane)
Masking Tape
Meter Stick
Ramp (metal wall corner)
Ring Stand with Adjustable Clamp

The Bounce
Small Basket or Box
Your Lab Chair
Tennis Ball
Milk Crate (uneven surface)

Comparing Reflectivity
Sheet White Paper
Sheet Smooth Foil
Sheet Crinkled Foil
Wood Block
Flat Mirror
Flashlight

Mirrors
2 Flat Mirrors
Hand Held Concave/Convex Mirror
Metal Spoon
Candle
Matches
Concave Mega Mirror
Convex Mega Mirror

Introduction:
Incoming light rays and outgoing light rays interacting with a reflective surface are at the same angle from what is called a normal line. The normal line is a line that is drawn perpendicular to the surface where the light is hitting the surface. The law of reflection states that the angle of incidence and the angle of reflection are equal with respect to the normal line. If the surface is smooth and flat, the light rays will leave the surface parallel to each other. However, if the surface is irregular, the light rays will leave in various directions.



<u>Pre-Lab:</u>

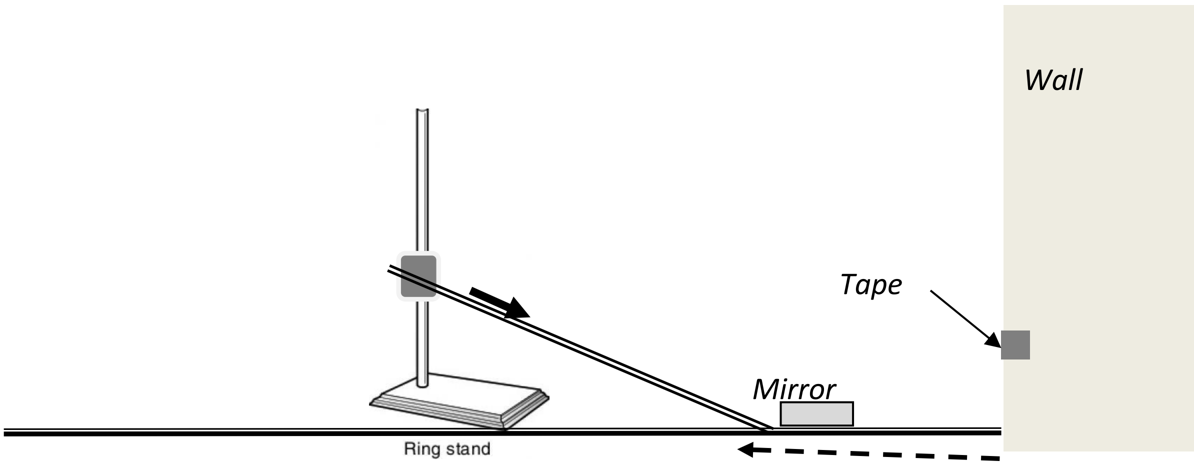
A. What is a photon?
B. Explain or sketch the curve of a concave mirror and the curve of a convex mirror.

Note: This lab activity must be done in a darkened room.

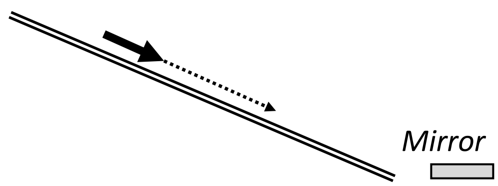
<u>Procedures:</u>
You will mimic the reflection of a photon and observe reflective properties of materials.

Law of Reflection

1. Set-up the ramp such that the bottom end of the ramp is about one meter from a wall. The height of the ramp at the top end is not important. Hold the flashlight at the top of the ramp and position the mirror on the floor where the light beam is shining. The light should be reflected from the mirror to the wall. Use a piece of masking tape to mark the center of the light circle on the wall.



2. Slide the flashlight down along the ramp, closer to the mirror, while observing the light circle on the wall. Make sure the light from the flashlight continues to hit the mirror as you slide the flashlight down the ramp, and adjust the position of the mirror if needed. Record whether the light circle continues to be centered on the tape. Also record how the size of the light circle changes.



3. Change the height of the clamp on which your ramp is balanced, to change the angle of incidence. Repeat processes you completed for the lower ramp. Record whether the light circle continues to be centered on the tape. Also record how the size of the light circle changes.

The Bounce

4. Place the basket or box on a chair. Stand about 2 meters from the chair, and make 3 attempts to bounce the tennis ball from the floor into the basket or box that is on the chair while you observe the motion of the ball. Record the general direction the ball appears to bounce, toward the basket or box or in some random direction.

5. Place an uneven surface, like a milk crate, on the floor between you and the chair, and make 3 attempts to bounce the tennis ball from the milk crate into the basket or box that is on the chair while you observe the motion of the ball. Record the general direction the ball appears to bounce, toward the basket or box or in some random direction.

Comparing Reflectivity

6. Place each of the reflective surfaces (see list) on your on your table. Bounce light from each surface to the ceiling and observe the amount of reflected light on the ceiling, from each surface. List the reflective surfaces from most reflective to least reflective.

7. Stand about 2 meters from a wall and turn on the flashlight. Shine the flashlight through the air toward the wall. Observe the light from the flashlight and compare the light in the air to the light on the wall. Record where the most light is seen, in the air or on the wall.

Mirrors

8. Draw a table in which to record information about each mirror image. Do not fill in data until you have read the instructions for obtaining that data.

	Image Apparent Size	**Image Apparent Distance**	**Image Orientation**
Flat Mirror			
Concave Mirror			
Convex Mirror			
Spoon-Concave side			
Spoon-Convex side			

9. Use your aluminum foil to create a candle stand and place your candle on the table. Light the candle with a match. Use each of the hand held mirrors and both sides of the spoon to view an image of the candle; you will need to position the candle between you and the reflective device. Record data for each device.
   - Size of the image (same, smaller, or larger) compared to the size of the candle
   - Apparent image distance (same, nearer, further) from the mirror as compared to the candle distance from the mirror

- Orientation of the image (same or upside down)

10. Position the two flat mirrors near the candle and determine the angle at which the most images of the candle, the most reflections, are created. Record the number of reflections you were able to create with your "infinity mirror" system. Also sketch your system.

11. Locate where the Mega Mirrors are set up in your classroom, and utilize them to view an image of yourself. Record which mirror (concave or convex) produces a larger image of you and which mirror (concave or convex) produces a smaller image of you. Investigate whether the image size changes at a particular distance from one of these mirrors and record your observation.

Clean-up:

- Remove tape from the wall and throw it away
- Dispose of all aluminum foil

Analysis:

1. Based on your observations of the tape on the wall, does distance between light source and mirror affect the angle at which the light is reflected?

2. In which case was diffuse reflection modeled when you were bouncing the tennis ball, when bounced from the floor or the milk crate?

3. Describe how the surfaces of the most reflective and least reflective items are different.

4. When the flashlight is shown through the air toward the wall, is more light seen in the air or on the wall? Explain why this happens.

5. Which type of mirrored surface tends to produce an image that appears <u>smaller</u> than the object?

6. Which type of mirrored surface tends to produce an image that appears <u>larger</u> than the object?

<u>General Questions:</u>

1. When light is bounced off a rough surface, not much light seems to be reflected from the surface. Why? Does the law of reflection apply to these surfaces? Explain.

2. Do photons follow the law of reflection?

Exercise 33 - Bending Light

Student Learning Objectives:

Observe the effects of light refraction, and investigate the images produced by different lenses.

Materials:

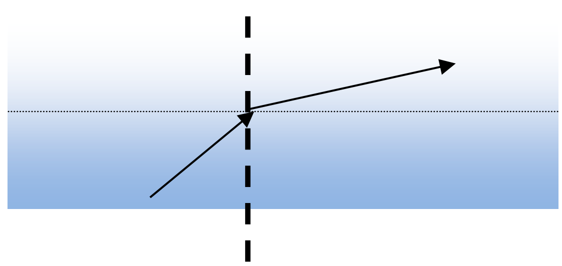
Explorations with Air and Water	*Images with Lenses*
Plastic Rectangular Tub	Plano-Convex
2 Pennies (clean and shiny)	Plano-Concave
2-250 mL Beakers	Double Convex
Wide Plastic Straw	Double Concave
Wood Skewer	Candle
Masking Tape	Matches
Metric Ruler	Sheet Aluminum Foil
Measuring Tape	
White Sheet of Paper	
Laser Refraction Tank	

Introduction:

Light travels in a straight line at a constant speed, unless it interacts with a material. When light travels from one medium to another, one material to another, the light's velocity changes where the two mediums meet. The apparent location of an object may not be the actual position of the object if it is being viewed through more than one material, for example if the light from the object passes through both air and water as it travels to you. If light passes from one material to another at some angle from the normal line, then the path of the light will change. The indices of refraction of the two different mediums will determine whether the light will bend toward or away from the normal line as it travels from one material into a different material.

Normal Line

Shown as a dashed line perpendicular to the boundary between air and water



Boundary

Additionally, a curved lens alters the light paths causing an object to appear either smaller or larger because of how the light ray paths are altered.

Pre-Lab:

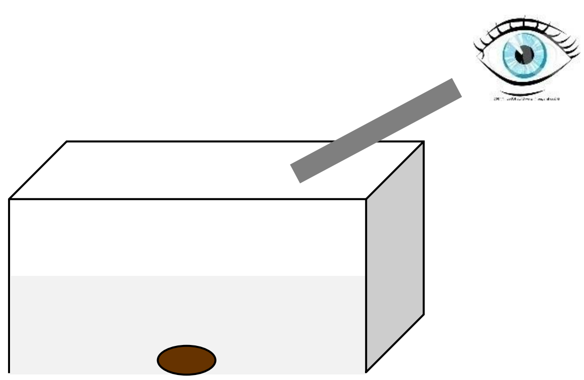
A. Define refraction.
B. Research and record the index of refraction for air and for water.
C. Explain or sketch the curve of a concave lens and the curve of a convex lens.
D. Define total internal reflection.

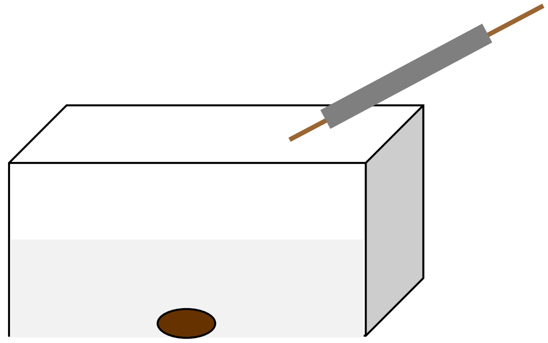
Procedures:
You will observe the effects of refraction in several systems.

Spear the Penny

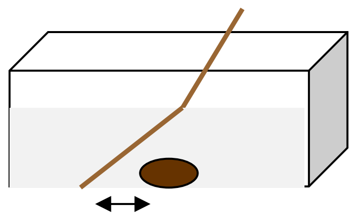
1. Place one penny on the bottom of the plastic tub; it should be near the center. Fill the tub about half full with water.

2. Balance the straw at the edge of the tub, keeping the entire straw in air, and use it as a sighting tool to see the penny. Do not allow the straw to go into the water. When you see the penny through the straw, tape or hold the straw in place. Use your fingers to send the wood skewer through the straw in an attempt to spear the penny. If you repeat shooting a skewer through the straw, obtain and use a dry skewer. Record whether you successfully speared the penny.



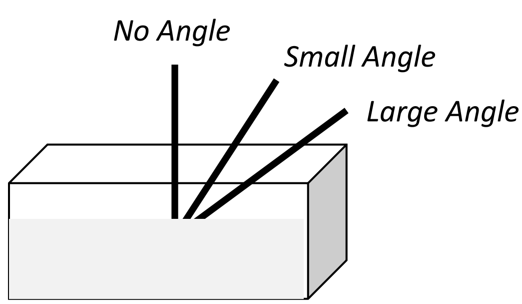


3. After the attempt, record an estimate in centimeters of the distance between the skewer and the penny. Then remove the straw, skewer, and penny from the tub of water.



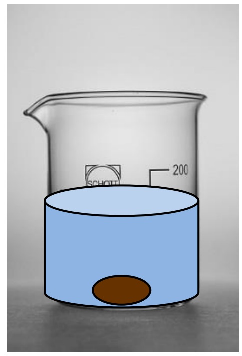
Bending Ruler

4. Place about half of the ruler into the water, vertically. Then slowly move the ruler such that the angle from vertical is increased. Record the angle (small or large) from vertical at which the ruler appears most bent at the air/water line, and sketch the system. Then remove the ruler from the tub of water.

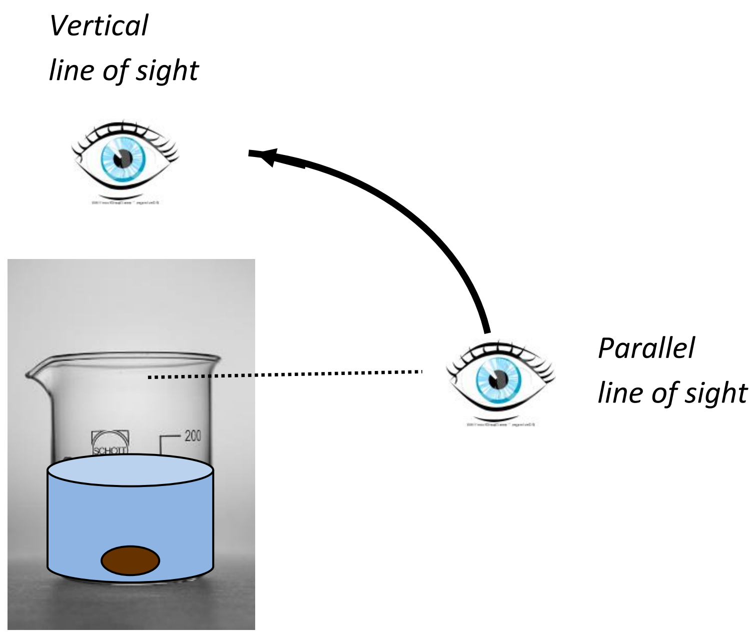


Where is the Penny

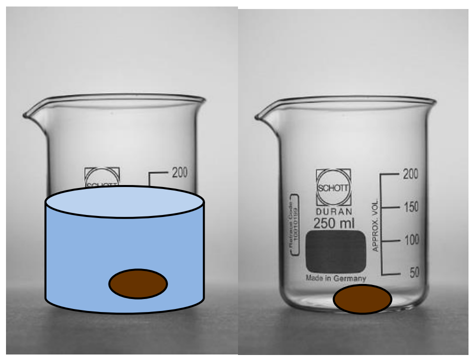
5. Add 150 mL of water to the 250 mL beaker. Place the white sheet of paper on the table close to you, and set the beaker on the paper. Place one penny on the bottom of the beaker, and position the penny so that it is in the center; you may want to use the skewer to center the penny.



6. Position yourself such that you are eyelevel with the surface of the water in the beaker. While looking at the surface of the water, slowly change your angle of observation, moving from a parallel line of sight to a vertical line of sight. Record your observations, the changes that occurred in the appearance of the penny as your line of sight changed. Also record the greatest number of penny images you were able to see.



7. Place the 2nd penny in the center of the empty 250 mL beaker. Find a location where you can place the beakers side by side on the piece of paper near eye level, when you are standing. You will need to have several meters behind you so that you can back away from the beakers. Make sure each penny is in the exact center of each beaker.



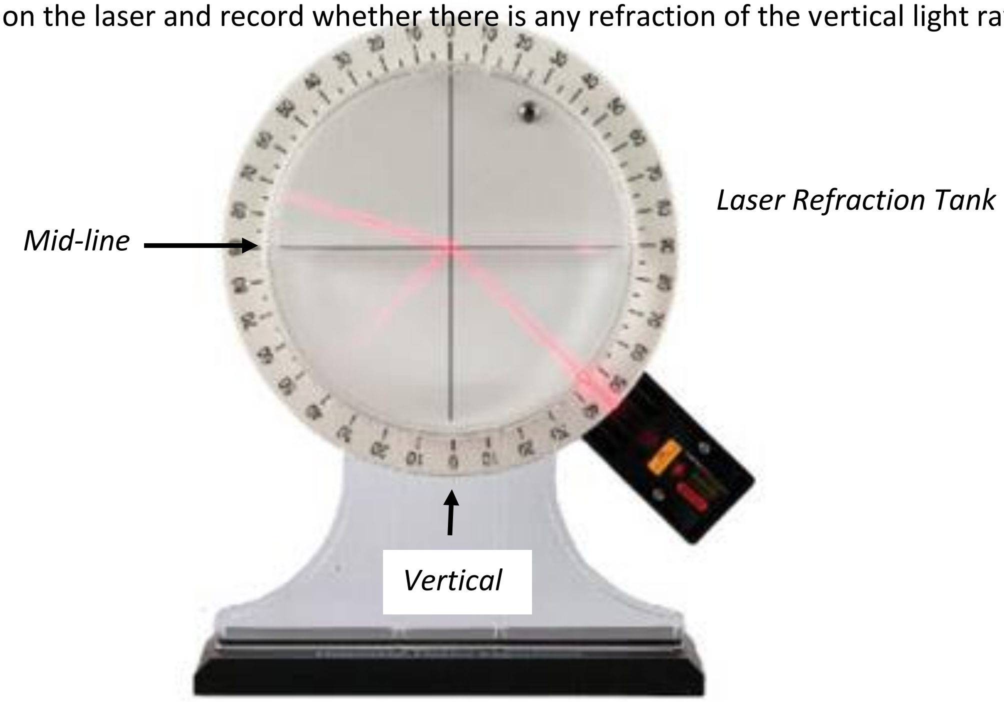
8. Draw a table in which to record distances for each person on your team. These will be the distances at which one of the pennies disappears. Also include a place to record which penny disappeared.

9. Position yourself so that your eyes are level with the beakers, and look at the pennies through the sides of the beakers such that the light is traveling from the penny through water/air to you. Take a few steps backwards, away from the beakers, and then position yourself so that your eyes are level with the beakers again. Continuing taking steps backwards and observing the pennies until one of the pennies has disappeared. Measure and record the distance in meters it took for one of the pennies to disappear from your view, and record which penny disappeared. Repeat the process for each person on the team.

Angles of Refraction

10. Draw a table in which to record the angle of incidence and the angle of refraction for <u>six</u> positions/angles.

11. Add water to the midline of the Laser Refraction Tank. Position the laser at the bottom such that a vertical beam of light may travel from the bottom of the tank to the top of the tank. Turn on the laser and record whether there is any refraction of the vertical light ray.



12. Position the laser at 20º for the angle of incidence. Determine and record the angle of refraction in your table. Choose five additional angles and repeat the process.

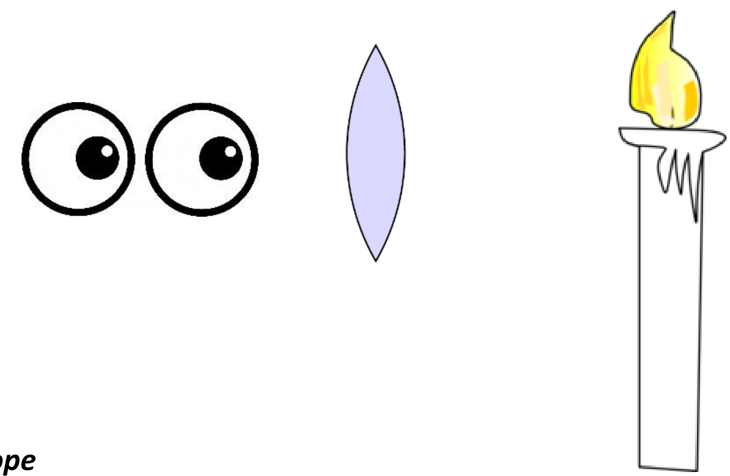
13. Determine and record the angle of incidence required for total internal reflection.

Images with Lenses

14. Draw a table in which to record information about each lens image. Do not fill in data until you have read the instructions for obtaining that data.

Lens/Combination	Image Apparent Size	Image Orientation
Plano Concave Lens		
Double Concave Lens		
Plano Convex Lens		
Double Convex Lens		

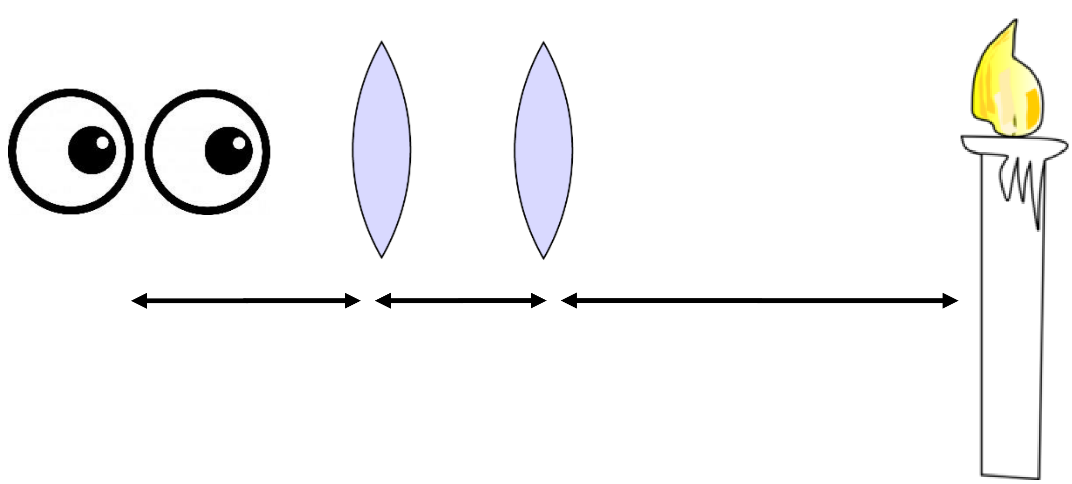
15. Use your aluminum foil to create a candle stand and place your candle on the table. Light the candle with a match. Use each of the hand held lenses and four different combinations of lenses to view an image of the candle; you will need to position the lenses somewhere between you and the candle such that you have a clear, focused image. Record data for each system.
    - Size of the image (same, smaller, or larger) compared to the size of the candle
    - Orientation of the image (same or upside down)



The Telescope

16. Choose one of the convex lenses. View the candle on your table while you are relatively close to the candle. Then adjust the lens-candle distance and your eye-lens distance as you back away from the candle flame. Record the orientation of the image once it is focused at the larger distance.

17. Add a second convex lens to the system and adjust the positions of the lenses until you have an enlarged image of the candle that is upright. Have someone measure all of the distances in this system.



Clean-up:

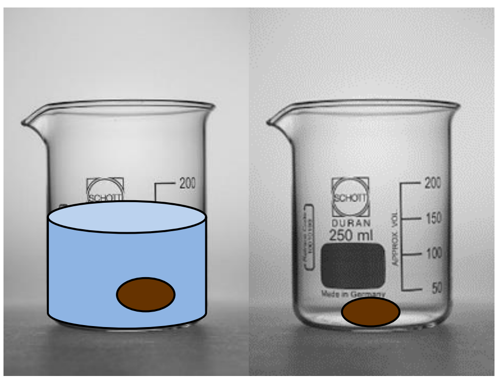
- Discard water outside (water the foliage)
- Wash and completely dry your beakers
- Completely dry any other wet items used

Analysis:

1. Based on your attempt to spear the penny, how should you aim if you are viewing an object that is in water while you are standing in air viewing the object from an angle?

2. Explain why the ruler appears to be bending at the boundary between air and water.

3. Sketch a light ray that travels from each penny, is transmitted through the side of the beaker, and travels toward you some distance away. Use your sketch to explain why one penny disappears (or should disappear) as you walk backwards.



4. How does the image from a ***concave*** <u>lens</u> compare/contrast with the image from a ***concave*** <u>mirror</u>?

5. How does the image from a ***convex*** <u>lens</u> compare/contrast with the image from a ***convex*** <u>mirror</u>?

6. Use your data from the Laser Refraction Tank to describe, in general, how changes in angle relate to the refraction of light.

General Questions:

1. Does light always travel in a straight path?

2. In general, the greater the angle of incidence, the (more/less) bending there appears to be when an object is partially in one medium and partially in a second medium. Choose one.

3. In general, when light travels from one medium to another, the light always changes _______ (speed/direction) and may change _______ (speed/direction). Fill in the blanks.

4. If you see a sea shell in the ocean, and you are viewing it from an angle in the air, how should you adjust your aim? Give specific alterations that should be made.

Exercise 34 - The Atomic Spectra of Neon Lights

Student Learning Objectives:
Compare atomic spectra from various elements, and relate color to wavelength and energy.

Materials:

Spectrum Tube Power Supply
6-8 Different Gas Emission Tubes
Heat Gloves
Diffraction Grating Slides (2-4 per group)
Hand-held Spectrometers (2-4 per group)
Colored Pencils

This lab must be done in the dark

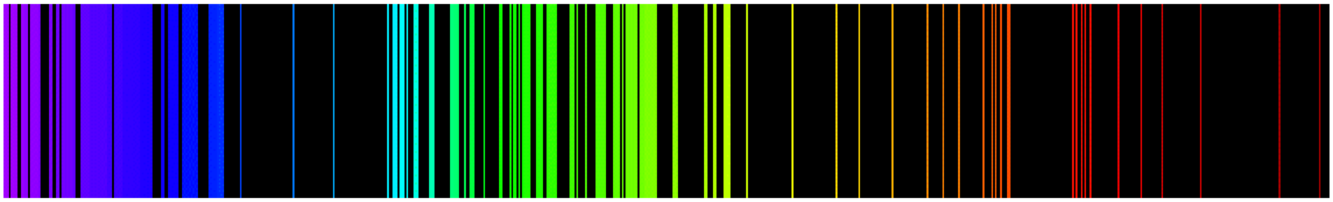
Spectrum Tube Power Supply
*(**High Voltage!**)*

Hand-held Spectrometer

Introduction:
As electrons jump from one energy state to another within an atom, the atom absorbs and emits a quantum of energy specific to the jump. The emitted energy is in the form of photons. Since light exhibits both particle and wave properties at the same time, each photon is associated with a particular wavelength. Every atom in the periodic table has unique energy levels, and thus, emits a unique pattern of photons. The pattern of emission lines produced by photons when a gas is excited, is called an atomic spectrum.

Energy per Photon	h	c
$E = \frac{hc}{\lambda}$	6.626×10^{-34} J s	3×10^{8} m/s

Example Atomic Spectrum



Emission Spectrum is under public domain

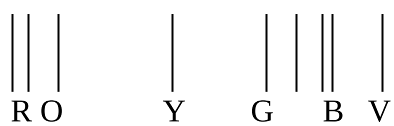
Procedures:

You will view the atomic spectra of various elements.

Warnings:

- **Do not touch the high voltage connections on the Spectrum Tube Power Supply**
- **Gas emission tubes become very hot**

1. Start a list in which to record the element, the dominant color, and the pattern of colored lines (atomic spectrum). See example below for your list.

Element	**Dominant Color**	**Atomic Spectrum**
Hydrogen	*Red*	

2. Make sure the voltage source is off. Place a gas emission tube into the voltage source. Turn on the voltage source and observe the dominant color being emitted from the center of the emission tube. Record the element contained in the gas tube and the dominant color.

3. When the lights are turned off, view the atomic spectrum produced through both the diffraction grating slide and hand-held spectrometer. Observe and remember the pattern of colored lines. Once the lights are turned back on, sketch the pattern of colored lines, labeling each line or set of lines with the color. Note that you may see a pattern that has red to violet or violet to red, depending on how you are holding your spectrometer. Make sure you orient your spectrometer the same for each viewing.

4. Observe all available elements and complete your list.

Analysis:

1. Explain why each element has a different dominant color.

2. Based on your data, is an atomic spectrum unique to the element?

3. Calculate the energy for each wavelength in the atomic spectrum of hydrogen and match energies to the colors of the lines produced. You will need to convert each wavelength to meters before you calculate the energy in Joules.

Wavelength (nm)	**Wavelength** (m)	**Energy** (J)	**Color**
397			
410			
434			
586			
656			

General Questions:

1. Hydrogen has one energy level available when it is in the ground state. However, hydrogen is able to emit multiple lines of color. Explain how this is possible.

2. In which case must an atom lose more energy, when it emits a color of light that has a shorter wavelength or when it emits a color of light that has a longer wavelength?

Exercise 35 - Modeling Radioactive Half-Life

Student Learning Objectives:

Simulate radioactive decay, and use half-life to determine the age of model samples.

Materials:

Rolling the Dice
Graph paper
Colored Pencils
25 small multi-colored cubes per group
(1 side red, 2 sides black, 3 sides white)

Dating the Beans
4 Different Bean Samples

Introduction:

Radioactive decay is the process of an atom changing into a different type of atom; it is a change in the number of protons. Half-life is the time it takes for one half of a sample of radioactive atoms to decay, so that half of the original number of atoms have decayed. There will still be the same total number of atoms after each half-life, but the types of atoms in the sample change. Each radioactive isotope has its own half-life. The half-life of an isotope of carbon may be used to determine the age of a fossil. Carbon-14 has a known half-life of **5,730 years**. The amount of carbon-14 remaining in a sample indicates the approximate age of the sample. Carbon-14 decays into nitrogen during the decay process.

Radioactive Isotope	Half-life
$^{239}_{94}Pu$	2.44×10^4 years
$^{238}_{92}U$	4.51×10^9 years
$^{214}_{84}Po$	0.00016 seconds
$^{210}_{83}Bi$	5 days
$^{210}_{82}Pb$	20.4 years
$^{14}_{6}C$	5.73×10^3 years

Pre-Lab:

Define what an isotope is.
Based on the half-life, which of the radioactive isotopes in the table above would release the most radiation during a 30 day exposure? Explain.

Rolling the Dice

Each color on the wood cube represents a different isotope. As an isotope's color turns face up when the cubes are rolled, it is considered to have decayed and is removed from the pile.

1. Predict and record the number of throws it will take to reach the half-life for each color, to have half of a particular color removed from the set.

2. Start your first list for the red cubes.

Throws	Cubes Remaining	Red Cubes Decayed
0	*25*	-
1		

3. Assume that all cubes are starting as one isotope. Shake all cubes and roll them onto a table, this counts as throw number 1. Remove record the number of cubes that are red side up and set them aside (they have decayed). Count and record the number of cubes remaining; the ones that were not red side up. Continue this process until all of the cubes have rolled such that they are red side up. Track each throw, including throws for which none of the cubes decayed to red.

4. Start a new list for the black cubes, and use the same method of tracking throws for the black cube decay process.

5. Start a new list for the white cubes, and use the same method of tracking throws for the white cube decay process.

Dating the Beans

The colored beans represent atoms. Assume the black beans are carbon atoms and the red beans are nitrogen. Assume the white beans are all of the other types of atoms in the sample.

5. Draw a table in which to record the number of black beans, red beans, and white beans in each sample. Also include a column in which to record the total number of beans in each sample. Your team should have a set of 4 different bean samples.

Sample	Black Beans	Red Beans	White Beans	Total
1				
2				
3				
4				

6. Count and record the total number of beans, the number of black beans, and the number of red beans in each sample. Check the counts with your instructor to ensure that your samples have the correct numbers of beans.

7. Assume that each sample started with 64 black beans. Determine the fraction of carbon remaining in each of your samples, based on your counts. Record your answers.

Analysis:

1. Construct a graph of your data for the red side up data from *rolling the dice*. You will need to decide whether the number of **throws** or the number of **cubes remaining** is the independent variable. Also construct graphs for the black side up data and the white side up data. You may use a different colored pencil to graph the results for each of the colored sides, and graph all three sets of data on the same graph, or you may construct three separate graphs. Estimate and sketch a best fit line for each data set.

2. Do the graphed sets of data indicate a constant or non-constant rate of decay?

3. Determine the half-life, in units of throws, for each color (red, black, white) on the wood cube.

4. Assume the black beans are carbon-14 atoms and that each sample started with 64 black beans. Follow and document the decay process to track the fractional amount of beans that would remain after each decay, and follow the decay process until you have numbers that match your bean counts.

Amount	**Fraction**	**Time**
64	-	-
32	*1/2*	*5730 years*

5. Use the decay process for your black beans, and the half-life of carbon-14, to carbon date your fictitious samples.

Age of Fictitious Samples

Sample	Age
1	
2	
3	
4	

General Questions:

1. Based on the half-life's for each color on the cubes, which of these substances, red, black, or white, would be the most harmful? Why?

2. The abundance of Carbon-14 in our atmosphere is 1 atom of Carbon-14 per Trillion (10^{12}) atoms. Calculate the abundance of carbon-14 (black beans) a living fictitious sample would have.

3. Calculate the percentage change in abundance of nitrogen (red beans), in our fictitious samples, from sample 1 to sample 4.

4. Two rocks are found at different levels in the Earth. Both contain the isotope $^{210}_{82}\mathbf{Pb}$. However, one rock contains 1/128th the amount of this isotope as the other rock. What is the difference in the age of these rocks? The half-life of $^{210}_{82}\mathbf{Pb}$ is 20.4 years.

Exercise 36 - Identifying Chemical Changes

Student Learning Objectives:

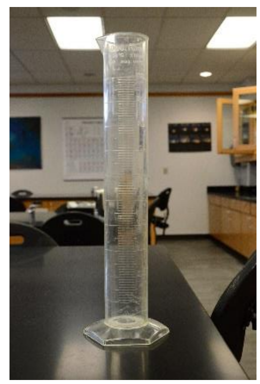
Identify the indicators of chemical change, and determine whether the reaction was spontaneous.

Materials:

Red Water
Red Food Coloring
Plastic Spoon
25 mL "fresh" Bleach
250 mL Beaker
Thermometer

Old Colors by [Anniesortega]() CC BY SA 3.0

Inflating Balloon
16-18 oz. Plastic Bottle (empty, clear)
Graduated Cylinder
Balloon (9-12 inch diameter)
Baking Soda
White Vinegar
Plastic Spoon
Funnel
Thermometer


Graduated Cylinder

Dr. Foamy
1 Package Dry Active Yeast
400-500 mL Beaker
200 mL Hydrogen Peroxide
Dish Soap
Plastic Spoon
250 mL Beaker
Thermometer

Package Dry Yeast

Professor Flame
Box of Matches

Notes:

- Bleach must be new and fresh (chlorine will escape over time)
- Red food coloring must be grocery store grade (other red food colorings will not work)

- Yeast must be fresh each term (aged yeast is no longer active)
- There may be 4 stations for the 4 sets of materials

Safety:

- **Rubber gloves and safety goggles are recommended for this lab.**

Introduction:

When two substances chemically react, a new substance is formed. The new substance may have a different color or temperature than the original substances, or may be in a different phase. There are several indicators that a chemical change has occurred, and multiple indicators may occur in a single reaction. If no added energy is required to start the reaction, then it is a spontaneous reaction, even if the reaction takes a while to progress. Stirring is not typically regarded as adding energy. A spontaneous chemical reaction does not mean the reaction happens quickly, but rather that the atoms will naturally react when placed into contact.

Warnings:

- **Bleach and hydrogen peroxide can irritate eyes and skin**
- **Bleach and food coloring can stain clothing**
- **Notify your instructor of any spills**

Pre-Lab:

A. List indicators of chemical change.
B. Research the chemicals present in the matchstick.
C. Review Laboratory Safety Guidelines, specifically guidelines pertaining to chemicals.

Procedures:

You will observe indicators of chemical change in four reactions.

Red Water

1. Start a list in which to record your data.

Reaction	ΔT	Touch	Spontaneous	Indicator(s)
Red Water				

2. Obtain 100 mL of water in the 250 mL beaker. Add 25 mL of bleach to the water. Add 2 drops of the red food coloring to the water/bleach solution, return to your lab table, and gently stir until mixed. Measure and record the initial temperature of this solution. Gently touch the outside of the beaker, and notice how it feels (cold, warm, etc.).

3. While the beaker sets on your table, occasionally check the water/bleach solution for **30-60 minutes**. Once it appears there has been a chemical change, measure temperature and record any temperature change. Gently touch the outside of the beaker; record what you feel (cold, warm, hot, or same). Also record whether the reaction is a spontaneous reaction (yes or no) and the indicator(s) that a chemical change has occurred.

Inflating Balloon

4. Use the graduated cylinder to measure 40 mL of vinegar into the empty water bottle.

5. Use the funnel and a plastic spoon to add 4 spoonful's of baking soda to the balloon. This should be done over a paper towel to minimize the mess.

6. Return to your lab table with the water bottle and balloon. Carefully, seal the water bottle by stretching the opening of the balloon over the opening of the bottle; make sure it is well sealed and be careful not to allow any baking soda into the bottle yet. Record the approximate initial temperature of this solution as measured from the outside of the bottle. Gently touch the outside of the beaker, and notice how it feels (cold, warm, etc.).

7. Tip the balloon up and empty the contents of the balloon into the bottle. Measure the temperature outside of the bottle and record any temperature change. Gently touch the outside of the bottle; record what you feel (cold, warm, hot, or same). Also record whether the reaction is a spontaneous reaction (yes or no) and the indicator(s) that a chemical change has occurred.

Dr. Foamy

8. Add 200 mL of hydrogen peroxide to the 250 mL beaker. Add a "squirt" of dish soap to the hydrogen peroxide and gently stir until mixed. Measure and record the initial temperature of this solution. Gently touch the outside of the beaker, and notice how it feels (cold, warm, etc.).

9. Set the 400-500 mL beaker in a sink. Pour one packet of active dry yeast into the large beaker. Then add the 200 mL of hydrogen peroxide/soap mixture to the large beaker in the sink, and gently stir to mix. Observe the reaction for a few seconds. Measure the temperature and record any temperature change. Gently touch the outside of the beaker; record what you feel (cold, warm, hot, or same). Also record whether the reaction is a spontaneous reaction (yes or no) and the indicator(s) that a chemical change has occurred.

Professor Flame

10. Obtain a box of matches, return to your lab table, and strike a match. Record whether you think there was a temperature change. Record whether the reaction is a spontaneous reaction (yes or no) and the indicator(s) that a chemical change has occurred.

Clean-up:

- Dispose of bleach, vinegar and hydrogen peroxide solutions as directed by your instructor
- Wash, rinse, and completely dry, all glassware, spoons, and thermometers
- Thoroughly rinse the graduated cylinder and place it on a drying rack
- Thoroughly rinse the water bottle and place it on a drying rack
- Rinse the match and discard it
- Discard the balloon in trash
- Thoroughly clean the surface of your lab table

Analysis:

1. Which reaction occurred most rapidly?

2. Explain why some reactions feel cold and some reactions feel hot in terms of heat energy transfer.

3. Explain why we must strike a match in order for the combustion reaction to occur.

General Questions:

1. What happens when bleach comes into contact with stains on clothing? Is this a physical or chemical change?

2. What is the possible chemical product when to household cleaners are combined? Why is this practice dangerous?

3. What happens when hear is added to liquid water? Is this a physical or chemical change?

4. What is the basic difference between a physical change and a chemical change?

Exercise 37 - Mixing Solids & Liquids

Student Learning Objectives:
Compare the solubility of different substances under different conditions, and classify mixtures.

Materials:

Comparing Solutes
Salt Substitute (KCl)
Salt (NaCl)
Granulated Sugar ($C_{12}H_{22}O_{11}$)
Baking Soda ($NaHCO_3$)
4 3-oz Paper Cups
4 Thermometers
4 250-mL Beakers
4 Plastic Spoons
Grease Pencil
Triple Beam Balance

Comparing Solvents
Granulated Sugar
3 3-oz Paper Cups
3 Plastic Spoons
3 250-mL Beakers
Vegetable Oil
Isopropyl Alcohol
Water

Hot vs Cold
Granulated Sugar
2 3-oz Paper Cups
2 Plastic Spoons
2 250-mL Beakers
Heat Source
Beaker Tongs
Heat Gloves
2 Thermometers
Aluminum Foil (for lid)

Notes:
- There may be 3 stations for the 3 sets of materials
- The paper cups, thermometers, and beakers are to be re-used for each mini-experiment

Introduction:
Solubility is a measure of how well a particular solvent is able to dissolve a particular solute, to break existing chemical bonds. The solubility of a solute depends on several factors. If a solute is successfully dissolved in a solvent to form a stable solution, which has the same appearance throughout, then the solute/solvent combination is classified as a homogeneous solution. If

particles of solute remain visible in the solution, then the solute/solvent combination may be classified as a heterogeneous suspension unless the incomplete dissolving is a result of saturation. What appears as a heterogeneous suspension may simply be a saturated solution.

Pre-Lab:

A. Describe the appearance of a homogenous solution.
B. Describe the appearance of a heterogeneous suspension.
C. Define concentration of a solution.
D. Explain what it means for a mixture to be saturated.

Safety:

- **Rubber gloves and safety goggles are recommended for this lab.**

Warning:

- **Salts and isopropyl alcohol can irritate eyes and skin**

Procedures:

You will combine a variety of substances.

Comparing Solutes

1. Record which solid solute you predict will be the most dissolved, and which one you predict will be the least dissolved.

2. Draw a table in which to record the initial temperature, final temperature, and classification for each of your four mixtures. Do not fill in data until you have read the instructions for obtaining that data.

Comparing Solutes

Solid	Initial Temperature	Final Temperature	Classify
KCl			
NaCl			
Sugar			
Baking Soda			

3. Use the grease pencil to label each beaker with the name of the solute you intend to add to the beaker. Measure 100 mL of cold water into each of the 250 mL beakers. Measure and record the initial temperature of the water in each beaker.

4. Label the paper cups: “KCl”, “NaCl”, “Sugar”, and “Baking Soda”. Then add 5 grams of each solid solute into the corresponding paper cups.

5. All 4 team members will be needed in this step. At exactly the same time, add each solid solute to each corresponding beaker of water and begin stirring each solution with a plastic spoon, while holding the thermometer steady; **do not use the thermometer for stirring**. All team members should attempt to stir at the same rate. Stir the contents in the beakers for 2 minutes; then stop stirring and allow the contents in the beakers to settle while you measure and record the final temperature of the mixtures in each beaker.

6. Once the contents in the beakers have been allowed to settle for at least 1 minute, classify each substance.

Clean-up:

- Pour contents from beakers into a sink and thoroughly flush sink with water
- Wash the beakers, spoons, and thermometers
- Use a dry paper towel to remove any residue from each paper cup

Hot vs. Cold

7. Record which water (hot or cold) you predict will dissolve the sugar fastest.

8. Draw a table in which to record the temperatures and times needed to dissolve sugar for the cold and hot water.

Hot vs. Cold

Cold Water Temperature	Hot Water Temperature	Cold Water Dissolving Time	Hot Water Dissolving Time

9. Measure 100 mL of cold water into two of the 250 mL beakers. Measure and record the temperature of the water in one of these beakers as the cold water temperature.

10. Place one beaker on the heat source, cover the beaker with a foil lid, and bring the water to a boil. While this water is heating, use 2 of the paper cups and measure 5 grams of the granulated sugar into each paper cup.

11. Once the heated water is boiling, turn off the heat source, remove the foil lid, and use the beaker tongs or heat gloves to set the hot beaker on the table. Measure and record the hot water temperature.

12. At exactly the same time, add sugar to each beaker, start a stopwatch, and begin stirring each mixture with a plastic spoon. Team members should attempt to stir at the same rate. Observe in which beaker the sugar is dissolved first and record the time it took for the sugar to dissolve, while continuing to stir the contents in other beaker. Stop stirring the contents in the 2nd beaker either when the sugar has completely dissolved or it has been 2 minutes, and record the time the 2nd beaker was stirred.

Clean-up:

- Pour contents from beakers into a sink and thoroughly flush sink with water
- Wash the beakers, spoons, and thermometers
- Use a dry paper towel to remove any residue from each paper cup

Comparing Liquid Solvents

13. Record which liquid solvent you predict will dissolve the most sugar and which solvent you predict will dissolve the least amount of sugar.

14. Draw a table in which to record the initial temperature, final temperature, and classification for each of your three mixtures. Do not fill in data until you have read the instructions for obtaining that data.

Comparing Solvents

Liquid	Initial Temperature	Final Temperature	Classify
Vegetable Oil			
Isopropyl Alcohol			
Water			

15. Use the grease pencil to label each 250 mL beaker with the name of the solvent you intend to add to the beaker. Measure 100 mL of each liquid solvent into the corresponding beaker. Measure and record the initial temperature of the liquid in each beaker.

16. Use 3 of the paper cups and measure 5 grams of granulated sugar into each paper cup.

17. At exactly the same time, add the sugar to each beaker of liquid and begin stirring each solution with a plastic spoon, while holding the thermometer steady; **do not use the thermometer for stirring**. All team members should attempt to stir at the same rate. Stir the contents in the beakers for 2 minutes; then stop stirring and allow the contents in the beakers to settle while you measure and record the final temperature of the mixtures in each beaker.

18. Once the contents in the beakers have been allowed to settle for at least 1 minute, classify each substance.

Clean-up:

- Dispose of bleach, vinegar and hydrogen peroxide solutions as directed by your instructor
- Thoroughly wash and completely dry all beakers, thermometers, and plastic spoons
- Discard paper cups in trash
- Clean your laboratory table top

Analysis:

1. Which mixture, if any, demonstrated the greatest temperature change in *comparing solids*?

2. Which solid, if any, decreased the temperature of water the most in *comparing solids*? Which solid, if any, increased the temperature of water the most?

3. Use your data from *hot vs. cold* to describe the effect of temperature on solubility.

4. Which mixture, if any, demonstrated the greatest temperature change in *comparing solvents*?

5. In each case, you added 5 grams of solute to 100 mL of solvent. Calculate the concentration of each of these mixtures in grams per liter. Also calculate the percentage of solute in each of these mixtures.

General Questions:

1. In general, what does a change in temperature indicate?

2. Does a single solvent (cleanser) remove all solutes (stains)? What is your hypothesis for why this happens?

Exercise 38 - Pattern in the Periodic Table

Student Learning Objectives:
Practice use of the shell model, and document the patterns in the periodic table.

Materials:

Periodic Table
Drawing Compass (optional)

Introduction:
The shell model identifies the number of electrons in each main energy shell of an atom, when the atom is in the ground state. Each element in a vertical group of the periodic table has similar physical and chemical characteristics because all elements in a vertical group have the same electron configurations. The electron configuration also determines the reactivity of an element. By accounting for electrons in the main energy levels, and recognizing that electrons begin to pair-up once a shell is half full, this model can be used to predict chemical bonds.

Pre-Lab:

A. According to the shell model, what is the maximum number of electrons allowed in each main energy shell?

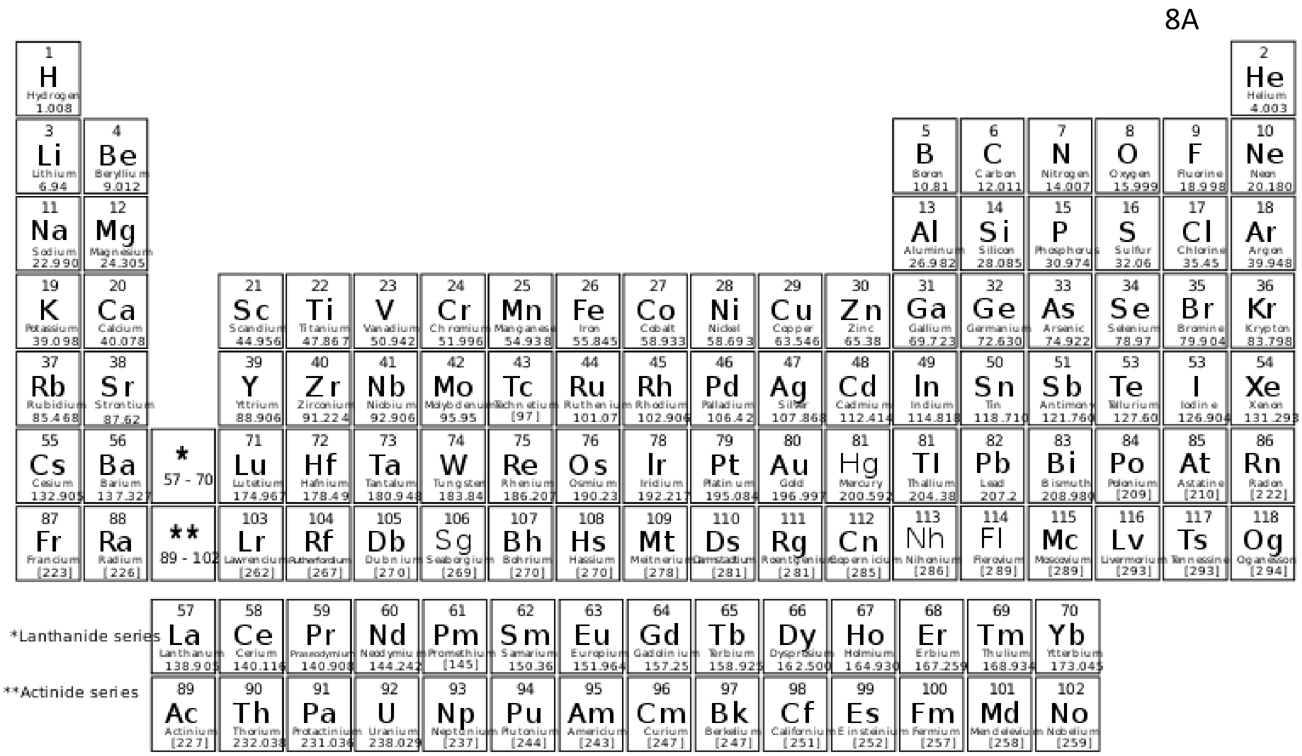
Shell	Maximum Number Electrons Allowed
1	
2	
3	
4	
5	
6	
7	

B. How do we know the number of energy shells elements have available in the ground state?

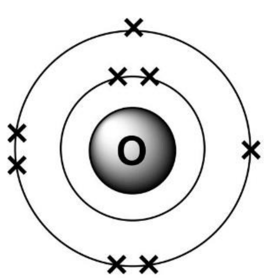
Procedures:

You will sketch the main energy shell electron configurations for model for group A elements.

1. Choose one Group A set of elements for which you will be responsible. Each person on the team should have one Group A column. We will not be working with the Group B elements.



2. Draw the main energy shell electron configurations for the first 5 elements in your chosen Group A column. Remember to begin by adding only half of the electrons allowed in the shell as single marks or dots, and then add electron pairs until you have accounted for all electrons the regular atom would have. Determine and record your Group A trend of unpaired electrons.



3. Once each team member has completed the main energy level electron configurations for a Group A column, choose another Group A column that has not been completed and repeat the process of drawing electron configurations and determining the trend. Each team member should complete at least two of the Group A columns.

4. Collaborate with your team to obtain and list the trends for each Group A column (IA, IIA, IIIA, IVA, VA, VIA, VIIA, VIIIA). See example below for listing trends.

Group	**Trend**
IA	*Mostly empty with 1 unpaired electron*

Analysis:

1. As you move from left to right along a period (row), what happens regarding the number of electrons in the outermost shell?

2. Describe how the number of unpaired valence/outer shell electrons is related to the group number either directly or by the octet rule.

3. What is periodic in the periodic table?

4. Assuming the goal is to be like a noble gas, a Group 8A element, determine the number of electrons elements in each particular group/column would tend to gain or lose. Create list that shows your answers. See example below for your list.

Group	**Number of electrons element will gain/lose**
IA	*lose 1*

General Questions:

1. What makes the noble gases non-reactive?

2. Some materials tend to gain electrons and some materials tend to lose electrons. If all elements are attempting to be like the noble gasses, would magnesium (Mg) tend to become a positive or negative ion? What would the charge be on a magnesium (Mg) atom? Defend your answer.

Exercise 39 - Building Models of Molecules

Student Learning Objectives:

Build models of molecules, and analyze the structure of these molecules for polarity.

Materials:

Molecular Models Kit
Colored Pencils

Figure 1 Molymods by Sonia licensed under CC BY 3.0

Introduction:

Atoms that are attracted together because they share or exchange electrons are in a chemical bond. In a covalent bond, atoms share 1-3 pairs of electrons. There are specific ways atoms bond within a particular molecule; some molecules have a straight-line structure while others have a more 3-dimensional structure. The structure of the molecule is responsible for some physical and chemical properties of the molecule. Polarity is a measure of how the electrons are shared. If electron pairs spend more time around one nucleus than the other, a molecule may have slightly negative and slightly positive ends. Additionally, if the distribution of atoms is not symmetric, then the molecule may exhibit polarity. In general, if the molecule is symmetric with the same types of atoms in the outer structure, then the molecule will be non-polar.

Molecular Models Kit:

- Spheres represent the nucleus of an atom
- Different colors represent different atoms
- Each spring connector represents a pair of shared electrons
- Holes in the spheres represent missing electrons needed by the atom

Element	Symbol	Color of Sphere
Bromine	Br	Orange
Hydrogen	H	Yellow
Carbon	C	Black
Nitrogen	N	Light Blue
Oxygen	O	Red
Chlorine	Cl	Green
Iodine/Fluorine	I or F	Purple

Pre-Lab:

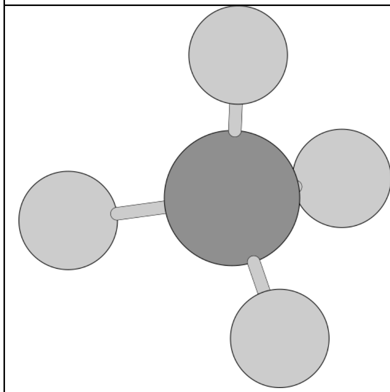
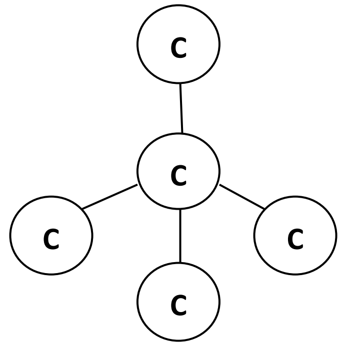
A. How many electrons are shared?
   a. Single bonds
   b. Double bonds
   c. Triple bonds

B. Determine the number of unpaired electrons for each element contained in the kit.

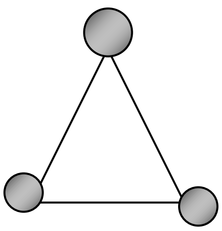
Element	Symbol	Number Unpaired Electrons
Bromine	Br	
Hydrogen	H	
Carbon	C	
Nitrogen	N	
Oxygen	O	
Chlorine	Cl	
Iodine/Fluorine	I or F	

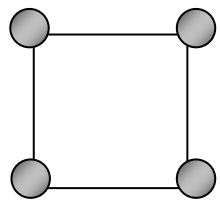
Procedures:

You will build and sketch several models of molecules.

Actual Model	Sketch
 *Methane molecule* CC SA 4.0	

Notes: Molecules that contain carbon may have more than one structure possible. Triangle and square structures are usually not valid.





1. Complete all tasks for each of the molecules listed. You may use colored pencils as long as you include a key for the colors you choose. Each atom must be identified in each molecule.

→ Build the molecule
→ Check that every hole is filled
→ Sketch the model of the molecule (attempt to show any three-dimensional structure)
→ Analyze the structure and record whether the molecule is polar or non-polar

2. *Molecules containing Single Bonds*

a. Hydrogen, H_2
b. Bromine, Br_2
c. Carbon Monoxide, CO
d. Water, H_2O
e. Hydrogen Chloride, HCl
f. Hydrogen Bromide, HBr
g. Hydrogen Peroxide, HOOH
h. Iodine Chloride, ICl
i. Methane, CH_4

j. Dichloromethane, CH_2Cl_2

3. *Molecules containing at least one Double Bond*

a. Oxygen, O_2
b. Ethylene, C_2H_4
c. Nitroxyl, HNO
d. Nitrous Acid, HONO
e. Formaldehyde, H_2CO
f. Formic Acid, HCOOH
g. Chloroethene (vinyl), C_2H_3Cl
h. Carbon Dioxide, CO_2
i. CycloPropene, C_3H_4

4. *Molecules containing at least one Triple Bond*

j. Nitrogen, N_2
k. Acetylene, C_2H_2
l. Cyanic Acid, HOCN

5. *Some common substances*

m. Ozone, O_3
n. Ammonia, NH_3
o. Ethanol, C_2H_6O
p. Acetic acid, $C_2H_4O_2$

Analysis:

1. Look at the models for methane and dichloromethane. How are they similar? (choose one)

   a) Same structure
   b) Same elements
   c) Polarity
   d) Same chemical formula

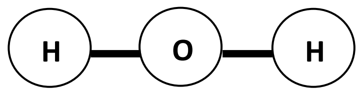
2. Explain the symmetry plays in polarity. Provide an example.

3. Organic compounds are those that contain carbon. What percentage of the models you constructed are organic?

General Questions:

1. Describe or sketch the different structures possible for C_3H_4. Do you expect these substances to have the same or different properties?

2. The structure of a water molecule causes it to be polar. If the water molecule had the structure illustrated below, would it still be polar? Explain.



Exercise 40 - Melting Wax & Cooking Sugar

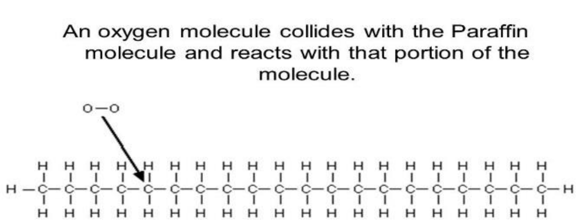
Student Learning Objectives:
Observe thermal decomposition of two compounds, and analyze chemical equations to determine the products.

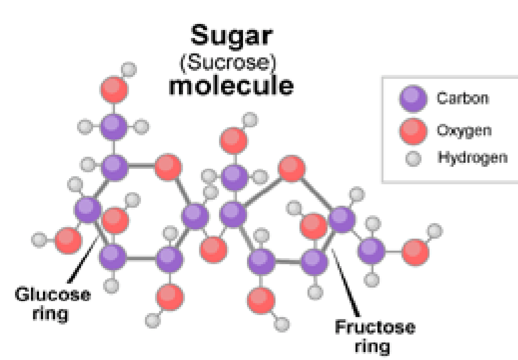
Materials:

- Paraffin Wax Candle
- 3 Ice Cubes
- 2 Aluminum Pie Tins
- Heat Source
- Metal Tongs
- Heat Gloves
- Matches
- Aluminum Foil
- Granulated Sugar
- Plastic Spoon

Note: the thermal decomposition of sugar should be performed in a chemistry hood if possible to avoid setting off a fire alarm.

Introduction:
Most of the substances you see around you are a combination of elements; they are compounds. Many compounds contain similar elements, and 90% of compounds contain carbon. When energy is added to a substance, the compounds can be broken into new products; this is a chemical reaction. As a candle ($\mathbf{C_{25}H_{52}}$) burns in the oxygen ($\mathbf{O_2}$) provided by air, new substances will result. When sugar ($\mathbf{C_{12}H_{22}O_{11}}$) is heated, the molecule will split into three products. Both wax and sugar contain the same base elements of carbon and hydrogen, so thermal decomposition of these two substances results in the same products.





Pre-Lab:

A. Compare the wax molecule and sugar molecule and describe at least two differences.
B. Define condensation.

Warnings:

- **Be careful not to burn yourself**
- **Excessive heating of the sugar may result in a fire alarm**

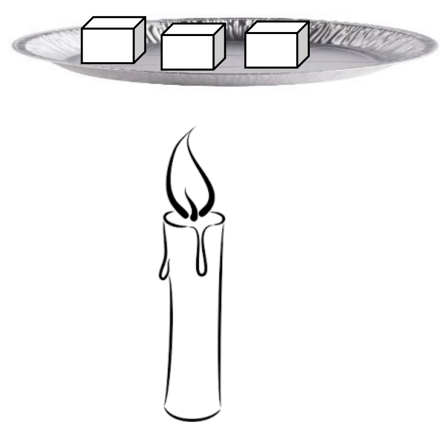
Procedures:
You will burn a candle and heat sugar.

Melting Wax

1. Place 3 ice cubes in one aluminum pie tin, and add a "splash" of water. Your goal is to have a little ice water in the pie tin.

2. Use the aluminum foil to create a candle stand.

3. Light the candle (**$C_{25}H_{52}$**) and use the metal tongs or heat gloves to hold the pie tin containing the ice water above the flame of the candle; the pie tin should be held about 1 centimeter above the flame for 2 minutes. Remove the pie tin from above the candle and hold it such that you are able to see the bottom of the pie tin. If there is nothing on the bottom of the pie tin, re-position the pie tin above the candle for another 2 minutes. After 2-4 minutes, record whether a liquid has condensed on the bottom of the pie tin. Also record whether there is a black soot on the bottom of the pie tin.

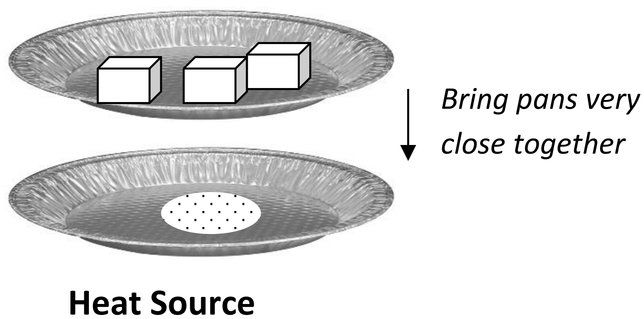


4. Use a paper towel to remove any substances from the bottom of the ice water pie tin. Keep the ice water; you will need to use it again.
Cooking Sugar

5. Set up your heat source.

6. Add 1 spoonful of sugar (**$C_{12}H_{22}O_{11}$**) to the second aluminum pie tin.

7. Use tongs and/or heat gloves to position the pie tin containing sugar in direct contact with your heat source. Once the sugar begins to change color and a gas is observed leaving the sugar, position the ice water pie tin 1 centimeter above the sugar pie tin, with the pie tins as close together as possible but not touching. After a few seconds, check the bottom of the ice water pie tin for moisture. If there is nothing on the bottom of the pie tin, re-position the pie tin above the candle for another few seconds, unless the sugar is beginning to burn. As soon as you see moisture on the bottom of the ice water pie tin, stop the experiment and remove the sugar from the heat source. Prolonged cooking of the sugar may set-off the fire alarm.



8. Turn off the heat source. Record whether a liquid has condensed on the bottom of the ice water pie tin pan. Also record the appearance of the contents in the sugar pie tin.

Clean-up:

- Rinse and dry the ice water pie tin
- Rinse the sugar pie tin and discard it in the trash
- Clean your laboratory table top
- Throw away foil used as a candle stand

Analysis:

1. The gas that is released from the candle is carbon dioxide (CO_2). Analyze the chemical equation and determine what the liquid is that condensed on the bottom of the pie tin, and what the black soot is that may have been viewed on the bottom of the ice water pie tin.

$$\mathbf{C_{25}H_{52} + 26O_2 \rightarrow 12C + gas + liquid}$$

2. Analyze the chemical equation for thermal decomposition of sugar, and determine the products.

$$\mathbf{C_{12}H_{22}O_{11} \rightarrow solid + liquid}$$

3. List common product(s) from the two reactions.

General Questions:

1. If no ice was used, no liquid would condense on the bottom of the ice pie plate. Why?
2. Explain why energy is required for the compounds to become new products. What does the energy do?

Exercise 41 - Dozens & Moles

Student Learning Objectives:

Practice the relationship between dozens and moles, and practice stoichiometry.

Materials:

36 Small Metal Paperclips
36 Large Metal Paperclips
36 Small Metal Nuts
36 Large Metal Nuts
Triple Beam Balance

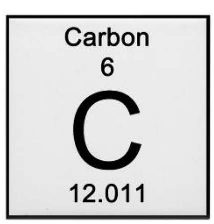
Introduction:

There is a relationship between moles, grams, and molecules that is similar to the relationship between miles, feet, and inches. One mole of any substance has the same number of particles, just as one dozen of any item has the same number of pieces. There are the same number of molecules in any mole, just as there are the same number of pieces in any regular dozen.

Substance	Molecules
1 mole H_2O	6.02×10^{23}
1 mole CO	6.02×10^{23}
1 mole H	6.02×10^{23}
1 mole O_3	6.02×10^{23}

Item	Pieces
1 dozen Cookies	12
1 dozen Roses	12
1 dozen Eggs	12
1 dozen Paperclips	12

The mole is central to stoichiometry like the meter is central to the metric system. If the number of moles are known, then the amount of grams and the number of particles may be calculated. The atomic mass on the periodic table indicates the amount of grams that one mole of a particular type of atom would contain. Avogadro's number is the number of atoms or molecules 1 mole of *any* substance would contain.

	$N_A = \dfrac{6.02 \times 10^{23}\ \text{particles}}{1\ \text{mole}}$
1 mole of Carbon has 12.011 grams	*1 mole of Carbon has 6.02×10^{23} atoms*

Pre-Lab:

A. Define stoichiometry.

Procedures:

You will dozens of items to visualize moles of atoms and molecules.

Dozens

1. Draw a table in which to record your data for dozens, grams, and pieces. Do not fill in data until you have read the instructions for obtaining that data.

Item	Mass per Dozen	Dozens in 15 Grams	Calculated Mass of 3 Dozen	Measured Mass of 3 Dozen	Dozens per 36 Pieces	Mass of 1 Piece
Small Paperclips						
Large Paperclips						
Small Metal Nuts						
Large Metal Nuts						

2. <u>Measure</u> and record the mass in grams of one dozen small paperclips, one dozen large paperclips, one dozen small metal nuts, and one dozen large metal nuts.

3. <u>Calculate</u> how many dozens a 15 gram sample would contain, for each type of item. Record these values in your data table.

4. <u>Calculate</u> and record the mass of 3 dozen for each type of item. Then use the triple beam balance to <u>measure</u> the mass of 3 dozen for each type of item.

5. <u>Calculate</u> and record the number of dozens in a 36 piece sample, for each type of item.

6. <u>Calculate</u> and record the average mass in grams of one piece, for each type of item. Use the triple beam balance to check your answer; if there is significant error, redo the calculation.

Moles

7. Draw a table in which to record your data for moles, grams, and particles.

Element	Mass per Mole	Moles in 15 Grams	Calculated Mass of 3 Moles	Moles per 1.806 x 10^{24} Atoms	Mass of 1 Atom
Aluminum					
Iron					
Helium					
Carbon					

8. Use the periodic table to determine the mass in grams of one mole of atoms, for each type of atom listed in the table. Record these values in your table.

9. <u>Calculate</u> how many moles a 15 gram sample would contain, for each type of atom. Record these values in your table.

10. <u>Calculate</u> and record the mass of 3 moles for each type of atom listed.

11. <u>Calculate</u> and record the number of moles in a sample that contains 1.806 x 10^{24} particles, for each type of atom.

12. <u>Calculate</u> and record the average mass in grams of one particle, for each type of atom.

<u>Clean-up:</u>

- Check that none of your paperclips or metal nuts were mixed

<u>Analysis:</u>

1. Compare the "dozens per 36 pieces" to the "moles per 1.806 x 10^{24} atoms". Describe any similarity in these sets of numbers.

2. Choose true (T) or false (F) for each statement about dozens, grams, and pieces.

   a) Three dozen small paperclips and three dozen large paperclips have the same amount of mass.
   b) Three dozen small metal nuts and three dozen large metal nuts have the same number of pieces.

c) A 15 gram sample of anything would contain the same number of pieces.

3. Choose true (T) or false (F) for each statement about moles, grams, and atoms.

   a) Three moles of aluminum and three moles of iron have the same amount of mass.
   b) Three moles of helium and three moles of carbon have the same number of atoms.
   c) A 15 gram sample of anything would contain the same number of pieces.

General Questions:

1. A typical water bottle contains 16.9 mL of water, which is 16.9 grams of water.

   a) Calculate the number of water bottles you would have if you had 3 dozen water bottles.
   b) Calculate the mass of water you would have if you had 3 dozen water bottles.

2. A water molecule (H_2O) contains two hydrogen atoms and one oxygen atom.

   a) Calculate the number of water molecules in 3 moles of water.
   b) Calculate the mass of water in 3 moles of water.

3. How many moles of calcium (C) has the same mass as 6 moles of helium (He)?

4. What mass of sodium (Na) has the same number of atoms as 24 grams of carbon (C)?

Exercise 42 - Rates of Reactions

Student Learning Objectives:

Analyze factors that affect the rate at which a chemical reactions progress, and determine whether the combined substances result in a chemical reaction or a mixture.

Materials:

Apple & Air

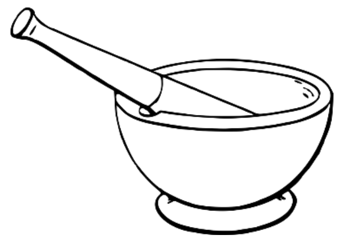
1 Fresh Red Apple (per group)

1 Kitchen Knife

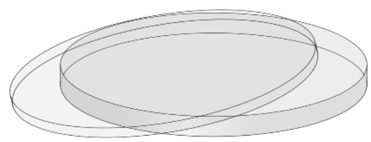
1 Vitamin C Tablet (ascorbic acid)

Mortar and Pestle

Petri Dish



Mortar & Pestle licensed under CC0



Petri Dish licensed under CC0

Bubbling Potato

Hydrogen Peroxide (H_2O_2)

Slice Potato (1/2 inch thick)

Graduated Cylinder

Better Faster

2 Alka-Seltzer Tablets

Mortar and Pestle

2 Thermometers

Making Kool-Aid

Heat Source

Beaker Tongs

Heat Gloves

Aluminum Foil (for lid)

2 Sugar Cubes

2 Packages Dry Kool-Aid

Weak or Strong

Baking Soda

2 3-oz paper cups

Vinegar (acetic acid)

Triple Beam Balance

Grease Pencil

Notes:

- Use a Red Delicious apple
- Each team will need a total of four 250 mL beakers
- Each team will need two plastic spoons
- Materials for each mini-experiment may be placed together in stations

Introduction:

Chemical reactions may occur seemingly instantly, or may take some time to progress. There are several factors that determine the rate at which a chemical reaction occurs. In general, the more energetic and numerous collisions are between reactants, the faster reactions occur. Sometimes reaction rates are intentionally slowed or inhibited. Factors that may affect reaction rates include nature of reactants (complexity), temperature, concentration, surface area, and use of a catalyst.

Pre-Lab:

What is a catalyst?
Which has more surface area, a solid tablet or a crushed one?

Warning: Please be careful with the knife and be aware at all times of its location.

Procedures:

You will witness a variance in reaction rates related to differing chemical factors.

Apple & Air

1. Start a list in which to record your observations.

Experiment	Fastest Rate	Indicator(s)
Apple & Air		

2. Use the mortar and pestle to crush a vitamin C tablet. Transfer the crushed contents to the petri dish and add enough water to make a paste, using a plastic spoon to mix the water with the vitamin C.

3. Cut open the apple, and immediately cover the entire surface of one half with the vitamin C paste. Leave the other half of the apple uncovered in the open air. Set both halves of the apple aside for **30-60 minutes**, and proceed with the other mini-experiments while you are waiting.

4. After 30-60 minutes have passed, rinse off the vitamin C, and compare the apple halves. Determine and record the apple that exhibited the fastest rate of reaction. List any

indicators of chemical change; if there were no indicators of chemical change then write "none".

Clean-up:

- Wash and dry your mortar and pestle, petri dish, and plastic spoon

Bubbling Potato

5. Obtain two 250-mL beakers, and use the graduated cylinder to add 100 mL of hydrogen peroxide to each of the beakers.

6. Add a 1/2 inch thick slice of potato to one of the beakers of hydrogen peroxide. Set the beakers side-by-side and view the beakers every few minutes for **30-60 minutes**. Hydrogen peroxide (H_2O_2) will naturally decay to water, and your goal is to observe if the potato alters the natural reaction rate. The beaker which shows more gas bubbles is releasing oxygen atoms at the faster rate. Proceed with the other mini-experiments while you continue to check the reaction rates of the hydrogen peroxide.

7. After 30-60 minutes have passed, determine and record which hydrogen peroxide exhibited the fastest rate of reaction. List any indicators of chemical change; if there were no indicators of chemical change then write "none".

Clean-up:

- Rinse the graduated cylinder and set aside

Better Faster

8. Fill two 250-mL beakers with 150 mL of cold water, and measure the temperature.

9. Use the mortar and pestle to completely crush one Alka-Seltzer tablet; leave the other tablet whole. At exactly the same time, add the crushed tablet to one beaker and the whole tablet to the other beaker. Stir each beaker at the same rate until the contents are dissolved, while holding the thermometer steady; **do not use the thermometer for stirring**.

10. Record whether the crushed tablet or the whole tablet exhibited the fastest rate of reaction. Determine whether there was a temperature change and list any indicators of chemical change; if there were no indicators of chemical change then write "none".

Clean-up:

- Wash and dry your mortar and pestle, beakers, thermometers, and plastic spoons

Making Kool-Aid

11. Fill two 250-mL beakers with 150 mL of cold water.

12. Place one of the beakers on the heat source and heat the water to nearly boiling; you may use foil as a lid to speed up the heating process. Turn off the heat source once the water is hot, and use beaker tongs or heat gloves to set the hot beaker on the table.

13. Simultaneously add one sugar cube to each beaker. Stir each beaker at the same rate until all sugar is dissolved. Record whether the hot or cold water exhibited the fastest rate of reaction. List any indicators of chemical change; if there were no indicators of chemical change then write “none”. Then simultaneously add one package of Kool-Aid to each beaker and observe; **do not stir**. Record whether the hot or cold water exhibited the fastest rate of reaction. List any indicators of chemical change; if there were no indicators of chemical change then write “none”.

Clean-up:

- Wash and dry your beakers and plastic spoons

Weak or Strong

14. Label one beaker 100% and the other beaker 50%, with the grease pencil.

15. Use the graduated cylinder to add 100 mL of vinegar to the “100%” beaker. Then add 50 mL of vinegar and 50 mL of water to the “50%” beaker.

16. Measure 5 grams of baking soda into each paper cup.

17. Place both beakers in a sink. Then simultaneously add 5 grams of baking soda, from the paper cups to each beaker. Record whether the “100%” or “50%” solution exhibited the fastest rate of reaction. List any indicators of chemical change; if there were no indicators of chemical change then write “none”.

Clean-up:

- Throw away apple, potato, and paper cups

- Thoroughly wash and completely dry all glassware, plastic spoons, and other re-usable items (place graduated cylinder on drying rack to air dry)
- Clean your lab table

Analysis:

1. In which case was the reaction rate slowed or inhibited?

2. What item or substance was added to be a catalyst?

3. In general, does a high temperature or a low temperature increase the reaction rate?

4. What is the purpose of crushing a tablet, what factor in reaction rates does this increase?

5. How did the dissolving of the sugar cube compare to the Kool-Aid? Why did this happen?

6. Write a general statement regarding concentration and reaction rates.

General Questions:

1. Some labels on medications warn against braking and/or crushing tablets. Explain why crushing certain medications could be dangerous in terms of chemical reaction rates.

2. Do other fruits and vegetable turn brown when left open in the air? What do you think the brown substance is? Hint: Red Delicious apples contain a lot of iron which reacts with oxygen in the air.

Exercise 43 - Magic Colors

Student Learning Objectives:

Observe color changes as substances are mixed, and use the colors to determine whether the resulting solution is an acid or a base.

Materials:

Acid Colors & Base Colors
4 250-mL Beakers
Universal Indicator Solution
Vinegar
4 Plastic Pipettes
Ammonia
Grease Pencil
Graduated Cylinder
600-mL Beaker

> ***Safety 1st***
> **Always read the label and make sure you are obtaining the correct chemical**

Looks like Kool-Aid
Phenolphthalein Solution
Sodium Carbonate
Vinegar
3 Plastic Pipettes
5 250-mL Beakers
600 mL Beaker
1/8th Teaspoon Measurer
Plastic Spoon

Invisible Ink
Phenolphthalein Solution
100 mL Beaker
Q-tip (one per person)
Windex/Ammonia (one spray bottle per group)
White Paper (1 sheet per person)

Notes:

- It is very important to use correct glassware
- If measurements are not exact, the process will not work
- Each team will need a total of five 250 mL beakers

- Each team will need <u>one</u> 600 mL Beaker

<u>Introduction:</u>

When two substances chemically react, a new substance is produced. One indication that a new substance has been produced is a color change. The universal indicator is a chemical that changes color in the presence of certain levels of acids and bases. *Acids turn the indicator red, pink, orange, and yellow*, while <u>bases turn the indicator green, blue, and purple</u>. The purple color may look more like a deeper pink, as compared to the pink you will see when the solution is acidic. Phenolphthalein is also an acid/base indicator; however, this substance will only change color in the presence of a base.

<u>Pre-Lab:</u>

A. What is the definition of an acid?
B. What is the definition of a bas?

<u>Safety</u>:

- **Do not re-use pipettes! Pipettes are intended for single use only so chemicals are not mixed unintentionally.**
- **Never obtain chemicals directly from storage container to avoid cross contamination. Use a beaker.**
- **Rubber gloves and safety goggles are recommended for this lab.**

<u>Warnings</u>:

- **Some chemicals used in this experiment can be hazardous if misused!**
- **Phenolphthalein Solution is harmful if ingested.**

<u>Procedures:</u>

You will observe color changes as your solution changes acid/base levels.

Acid Colors & Base Colors

1. Draw a table in which to record your observations.

Acid Colors & Base Colors

Stage of Experiment	Color	Acidic or Basic
1st Beaker added to 2nd Beaker		
2nd Beaker added to 3rd Beaker		
3rd Beaker added to 4th Beaker		

2. Use the grease pencil to label your 250 mL beakers, 1st, 2nd, and 3rd. Label the 600 mL beaker as 4th.

3. Add 25 drops of the universal indicator into the 1st 250-mL beaker, and then use the graduated cylinder to add 200 mL of water to this beaker.

4. Obtain a full pipette of vinegar; note that it will not be completely full. Add the vinegar to the 2nd 250-mL beaker.

5. Obtain a full pipette of ammonia, and add the ammonia to the 3rd 250-mL beaker.

6. Use the graduated to add 100 mL of vinegar to the 600 mL beaker; this is your 4th beaker.

7. Now it is time to pour.

   a. Slowly pour the contents from the 1st beaker into the 2nd beaker and record the color that results in your table.
   b. Then pour all contents from the 2nd beaker into the 3rd beaker and record the color that results in your table.
   c. Finally, pour all contents from the 3rd beaker into the 4th beaker and record the color that results in your table.

8. Determine and record whether the solution was acidic or basic at each stage, based on the color.

Clean-up:

- Dispose of final solution as directed by your instructor
- Discard all used pipettes as directed by your instructor
- Thoroughly wash and dry all beakers, and set aside for next mini-experiment
- Thoroughly wash graduated cylinder and place on drying rack to air dry
- Clean your laboratory table top

Looks like Kool-Aid

9. Draw a table in which to record your observations.

Looks like Kool-Aid

Stage of Experiment	"Color"	Basic
4 Beakers		
5 Beakers		

10. Use the grease pencil to label your 250 mL beakers, 1st, 2nd, 3rd, 4th and 5th.

11. Add exactly 1/8th teaspoon of sodium carbonate into the <u>1st</u> 250 mL beaker. Use a pipette to add enough water to make a paste, and stir with the plastic spoon until the sodium carbonate is somewhat dissolved in the paste.

12. Use another pipette to add 6 drops of phenolphthalein solution to the <u>2nd</u> 250 mL beaker.

13. Add 3 full pipettes of vinegar to the <u>3rd</u> 250 mL beaker.

14. Fill the 600 mL beaker with 500 mL of water.

15. Now it is time to pour.

    a. Fill all 5 of the 250 mL beakers to the 100 mL line.
    b. Set aside the beaker <u>3rd</u> beaker that contains vinegar.
    c. Pour the contents from the beakers labeled <u>1st</u>, <u>2nd</u>, <u>4th</u>, and <u>5th</u> into the 600 mL beaker, then pour the liquid from the 600 mL beaker back into the <u>1st</u>, <u>2nd</u>, <u>4th</u>, and <u>5th</u> beakers, filling each to the 100 mL line.
    d. Record the color of the liquid in the four beakers, in your *Looks like Kool-Aid* table; this is the *4 beakers stage* of the experiment.

16. Now it is time to pour for the next stage of the experiment.

    a. Pour all five 250 mL beakers of liquid into the 600 mL beaker
    b. Then pour the liquid from the 600 mL beaker back into the five 250 mL beakers, filling each to the 100 mL line.
    c. Record the color of the liquid in the five beakers, in your *Looks like Kool-Aid* table; this is the *5 beakers stage* of the experiment.

18. Determine in which stage(s) the liquid was basic based on the color, and record yes/no for basic in your *Looks like Kool-Aid* table.

Clean-up:

- Dispose of final solution as directed by your instructor
- Discard all used pipettes as directed by your instructor
- Thoroughly wash and dry all beakers
- Clean your laboratory table top

Invisible Ink

18. Obtain 10 mL of phenolphthalein solution in a clean 100 mL beaker.

19. Dip a Q-tip into the phenolphthalein solution and use it to write your own choice of message on your sheet of white paper. Let it completely dry.

20. After your message is completely dry, spray the paper with Windex/ammonia. Record the color of your message. Determine and record whether the color indicates an acid or a base.

Analysis:

1. Use the following scale for the universal indicator to assign pH values to your solutions. Record the pH value next to the table for each solution.

Red	Pink	Orange	Yellow	Green	Blue	Purple
1	3	5	6	8	12	14

2. Explain how we may know that the "appearing" invisible ink process is a chemical reaction.

General Questions:

1. Name an acidic item that you have at your house. How do you know it is acidic?

2. Name a basic item that you have at your house. How do you know it is basic?

Exercise 44 - Acids & Bases around the House

Student Learning Objectives:
Analyze household products for acid/base level, and determine types of products that tend to be acidic/basic.

Materials:

pH Test Strips (1 box per group)
Digital pH Sensor
6 100-mL Beakers
2 3-oz Paper Cups
Household Products & Food Items (4 per group)
Bottled Water (2 brands per group)

pH Test Strips

Notes:

- The goal is to have 36 different items available to test.
- Each lab group should have 2 household cleaners, 2 edible products, and 2 brands of bottled water to test at their lab table.

Introduction:
Many products that are found in a typical household may be acidic or basic. The pH value indicates the strength of the acid or base. The pH scale ranges from 0 to 14 with 0 being the most acidic and 14 being the most basic. Warnings on certain products may be due to the fact that the product is a relatively strong acid or base. Strong acids and bases completely ionize when brought into contact with water, providing numerous acid ions or base ions to the solution. For a substance to be neutral, it must have a pH of exactly 7. Although pure water (pure H_2O) is neutral, some sources of water may have a pH other than 7.

Pre-Lab:

A. What is the pH range for an acid?
B. What is the pH range for a base?

Warning: Some household products may irritate skin and can damage the eyes.

Safety:

- **Safety glasses and rubber gloves are recommended for this experiment.**
- **Do not ingest any of the test materials!**

Procedures:

You will test the pH level of household items.

1. Start a list in which to record the pH values and the classification (acid/base) for each item in the lab.

Item	pH (Test Strip)	pH (Sensor)	Acid or Base
Laundry Soap			

2. Obtain a small amount of your first item in one of the 100 mL beakers, in order to avoid cross contamination.

3. Touch the multi-colored end of one pH test strip on your first item, placing the multi-colored end of the strip in direct contact with item for a brief moment. The test strip will react immediately upon contact. Then match the colors on the strip to the color guide on the box. Record the pH value according to the test strip. Set aside the used pH test strip; it is trash.

4. Use the digital pH sensor to measure the pH value and record the number in your list. Rinse the pH Sensor.

5. Identify the item as an acid or a base.

5. Complete the pH testing and classification (acid or base) for all of your items, recording your data in your list.

6. Label one of the 3-oz paper cups “acid” and fill this cup about 1/4 full with your strongest acid. Label the other 3-oz paper cup “base” and fill this cup about 1/4 full with your strongest base. Place both cups on a paper towel. Allow the cups to set for a few minutes while you obtain the rest of your data.

7. While you wait for your acid and base to interact with the paper cup, collaborate with the other lab teams to exchange data and complete your list.

8. When you return to your table, observe your two 3-oz paper cups. Then walk to the other lab tables and observe their 3-oz paper cups. Record your general observations.

Clean-up:

- Thoroughly wash and completely dry beakers used
- Throw away used pH test strips
- Clean your lab table
- Throw away any pieces of fruit tested

Analysis:

1. Which item was the strongest acid?

2. Which item was the strongest base?

3. Are there similarities among the substances that are acids? Explain.

4. Are there similarities among the substance that are bases? Explain.

5. Describe how your pH values from the test strips and the pH sensor compared. Which do you think is more accurate, the pH test strips or the pH sensor? Why?

General Questions:

1. What do you think something acidic may do to your teeth?

2. If one of your 3-oz paper cups began to disintegrate, what does this indicate about the items people may have in their home?

3. In general, what goes together?

    a) Some Food Items = (acids or bases)
    b) Cleaning Products = (acids or bases)

Exercise 45 - Chemistry in a Ziploc Bag

Student Learning Objectives:

Investigate combinations that result in a reaction, and analyze acid-base reactions.

Materials:

Baking Soda ($NaHCO_3$)
Calcium Chloride ($CaCl_2$) (in 2-3 mm pellets)
Phenol Red ($C_{19}H_{14}O_5S$) Solution (or Phenol Blue)
3 Plastic Pipettes (Small Tip)
4 Ziploc Bags (Gallon Size)

> ***Safety 1st***
> **Always read the label and make sure you are obtaining the correct chemical**

Notes:

- Set-up each chemical on its own tray with its own pipettes/plastic spoons.
- There should be a solid waste container for this lab.

Introduction:

Acids contribute hydrogen ions (H^+) into a solution during a chemical reaction, and are known as **proton donors** as a result. Bases contribute hydroxide ions (OH^-) into a solution during a chemical reaction or bond with a proton making them **proton accepters**. Phenol solution turns yellow in acidic solutions and remains red in basic solutions. There are many indicators that a chemical reaction has occurred, some of which include color change, temperature change, and production of a gas.

Pre-Lab:

A. Explain what it means to be a proton donor, what does the molecule do?
B. Explain what it means to be a proton acceptor, what does the molecule do?
C. Research and record the molecular formula for phenol blue.

Warnings:

- **Some chemicals used and produced in this experiment may irritate skin, can damage the eyes, or may be hazardous to your health if inhaled.**
- **This reaction may form sodium hydroxide (NaOH) which can cause severe chemical burns.**

Safety:

- **Safety glasses and rubber gloves are recommended for this experiment.**
- **Do not open any Ziploc bag in which a gas is produced, unless you are releasing the gas into an operating chemistry hood!**

Procedures:

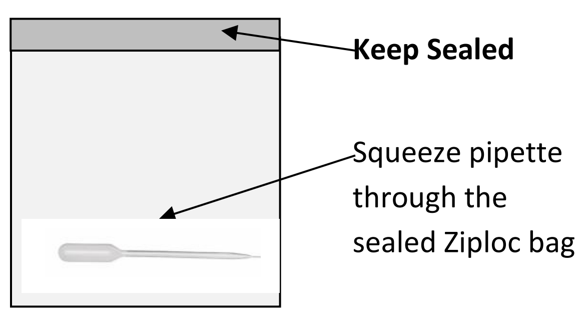
You will investigate various combinations of the three chemicals.

All Together

1. Add 1 spoonful of baking soda and 2 spoonful's of the calcium chloride into a Ziploc bag, and seal the bag. Gently mix the two substances without crushing the pellets of calcium chloride; the mixing can be accomplished by simply moving the outside of the bag in various directions with your hand.

2. Fill the pipette with phenol solution. Note that the pipette will not be completely full. Carefully place the pipette into the Ziploc bag so that no phenol solution is released into the solid mixture yet. Gently smooth as much air as possible from the bag, without releasing the phenol solution or crushing any pellets, and then seal the bag.

3. Keep the Ziploc bag sealed. Squeeze the pipette from outside of the sealed Ziploc bag to release the phenol solution. Gently mix the contents in the bag, without crushing the calcium chloride pellets. Touch the outside of the Ziploc bag to determine if there has been a temperature change and/or a gas produced.



5. Record any indicator(s) that a chemical reaction has occurred. Also record the color of the product.

6. If a gas was produced, release the gas from the Ziploc bag into an operating chemistry hood. If there is not a chemistry hood available, then place the sealed Ziploc bag in the container provided by your instructor.

Other Combinations

7. Determine all possible combinations for the three substances, excluding all of them together which you have already tested.

8. Utilizing the same amounts of particular chemicals (1 spoonful baking soda, 2 spoonful's calcium chloride, 1 pipette phenol solution), test each of your combinations in sealed Ziploc bags. Record any indicator(s) that a chemical reaction has occurred, for each combination. Also record the color of any product, for each combination. **If a gas is produced, do not open the Ziploc bag** unless releasing it in a chemistry hood. If there is not a chemistry hood available, then place the sealed Ziploc bag in the container provided by your instructor.

Analysis:

1. Based on your observations, which combinations result in the specific chemical change indicators (excluding the *all together* combination)?

    a) Color change?
    b) Temperature change?
    c) Gas produced?

2. The reaction that occurs in the Ziploc bag, when all three chemicals are added together, occurs in a multi-step process. Is the bolded substance in step 3 of the process an acid or a base? Explain.

    Step 1: $HCO_3^- \rightarrow H^+ + CO_3^{2-}$
    Step 2: $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$
    Step 3: $H^+ + \underline{\mathbf{HCO_3}}^- \rightarrow H_2O + CO_2$
    Step 4: $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$

General Questions:

1. Classify each substance in the chemical equations as an acid or base, by determining for each substance whether it is a proton donor or a proton acceptor.

   a) NH_3 + H_2O ←→ NH_4 + OH
   b) H_2O + HCO_3 ←→ H_3O + CO_2

2. In a reversible reaction, is there a trend for determining the acid and base when the reaction is reversed? Explain.

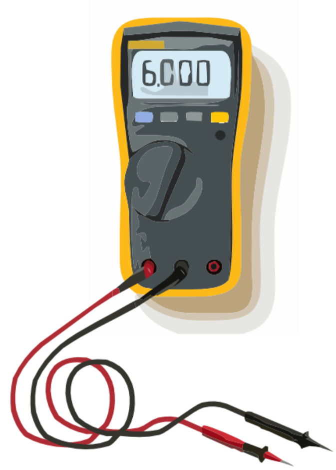
Exercise 46 - Fruit & Veggie Current

Student Learning Objective:

Test produce for oxidation/reduction properties, and compare any current produced to the current needed by a light bulb.

Materials:

- Multi-meter
- 3 Produce Items (per Group)
- 1 Copper Metal Strip
- 1 Zinc Metal Strip
- pH Indicator Strips
- Small L.E.D.
- 2 Leads with Alligator Clips
- Kitchen Knife



Multi-meter licensed under CCO

Notes:

- The goal is to have 18 different types of produce available to test per section.
- The multi-meter must be able to measure milliamps.

Introduction:

Copper is a material that easily accepts electrons while zinc is a material that easily gives up electrons. This promotes a flow of electrons. When two different types of metal strips are placed into an acidic solution, a chemical reaction may take place between the solution and the metals. A chemical reaction in which electrons are accepted by one material and given up by another material is called an oxidation-reduction reaction, and results in the flow of electrons. The process of chemical reactions using or producing electricity is electrochemistry.

Pre-Lab:

A. Research and record the current needed for a small L.E.D.
B. Research how to use a multi-meter.
C. Which metal will be oxidized and which metal will be reduced in this experiment?

Warnings:

- **Please be careful with the knife and be aware at all times of its location.**
- **The metal strips can cut your hand, so be careful.**

Safety:

- **Juices from produce may squirt, and can irritate the eyes.**
- **Safety goggles are recommended for this lab.**

Procedures:

You will test a variety of produce items for electric current production.

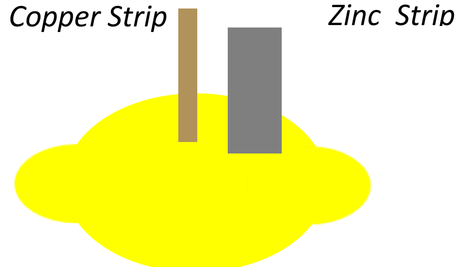
1. Draw a table in which to list your produce items and record your data.

Produce	**Prediction** (yes/no)	**Amount of Current** (milliamps)	**Operates L.E.D.** (yes/no)	**pH**

2. Choose 3 produce items to test, and list these items in your table. Be specific when you list the produce items; there are many varieties of apples.

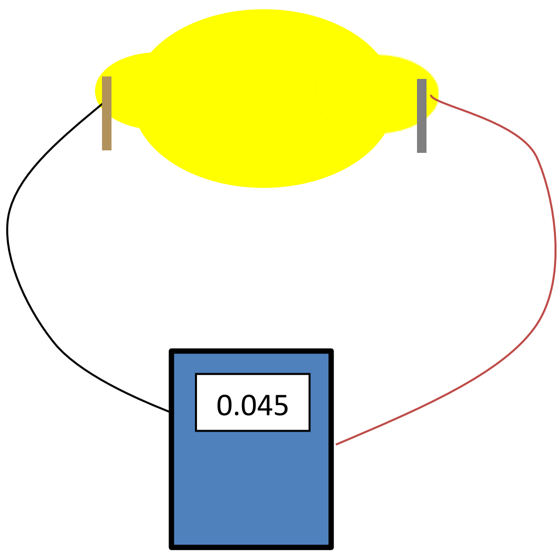
3. For each piece of produce in your list, predict whether you think there will be any current produced. Record your predictions in your table.

4. Use the knife to make a small cut for each piece of metal in the outer skin. Insert the copper and zinc strips into the first produce item, about 2 centimeters (1 inch) apart, such that the flat sides are parallel to each other and about 1/3 of the metal strips are inside the produce.

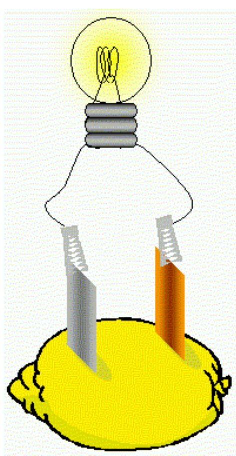


5. Turn on your multi-meter, and adjust the dial to measure in milliamps (mA). Attach the accompanying cords to the appropriate holes in the multi-meter, the ones that will allow you to measure milliamps. Each multi-meter is different.

6. Assemble a series circuit with your multi-meter, the leads from the multi-meter, and the metal diodes in your produce item. Record the peak current shown by the multi-meter, in your table. Note that a negative reading is simply showing you the direction electricity is flowing; it is not a negative amount of current. If you have no reading, wiggle the metal diodes and make sure the metal ends of the multi-meter leads are in full contact with the metal strips.



7. Replace the multi-meter with the L.E.D. and use the leads with the alligator clips to complete your series circuit. Record whether the produce item is able to light the L.E.D.



8. Remove and thoroughly rinse the metal strips before you insert them into your next produce item. Also rinse the knife prior to using it for the next produce item.

9. Test each of your produce items, recording the peak current for each, and whether the item is able to light the L.E.D. Remember to rinse the metal strips each time before inserting them

10. Use the pH test strips to determine the pH of each produce item, by placing the multi-colored end into one of the holes made by the metal strips. Record the pH values in your table.

Analysis:

You will need to collaborate with other teams to determine the answer to some of these questions.

1. Did each fruit and vegetable tested produce current?

2. Which piece of produce generated the most current?

3. Which piece of produce had the highest level of acidity?

4. Which piece of produce has the highest water content?

5. Are there any general trends that relate properties of produce to amount of current? Expain.

6. A 60 Watt lightbulb requires 0.55 amps to operate. For the produce items you had at your table, calculate the number of each it would take to operate the 60 Watt light bulb.

General Questions:

1. If you were to see a You Tube video of someone powering their cell phone with three pieces of produce, would you believe this was possible? Explain.

2. Which metal is the negative diode, the one that is oxidized or the one that is reduced?

3. In which direction does electricity flow?

    a. Oxidized metal to Reduced metal
    b. Reduced metal to Oxidized metal

Appendix I - The Physical Science Tool Box of Units

Student Learning Objectives:
Familiarize yourself with the metric system, and practice converting from one set of units to another set of units.

Materials:

Scientific Calculator

Introduction:
The system of units used in the physical sciences is based on the metric system. Numbers that describe physical quantities range from the very large to the very small, so a set of standard prefixes are used to designate convenient-sized units that differ by multiples of ten. Every step in the metric system is a multiple of 10.

Multiple	Prefix	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{1}	deca	da
10^{0}		

Multiple	Prefix	Symbol
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	▯
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

The United States continues to use English units. Conversion factors utilize equivalent sized measurements. For example, 1 inch and 2.54 centimeters measure the exact same length.

English to Metric
1 inch = 2.54 centimeter
1 mile = 1609 meters
0.2248 lb = 1 Newton

To convert from set of units to another, simply multiply the measurement by the appropriate conversion factor.

[Measurement] x [Conversion Factor]

Example

12 ~~inches~~ x $\frac{2.54 \text{ centimeters}}{1\ \cancel{\text{inch}}}$ = 30.48 centimeters

The inches in the numerator and the inches in the denominator cancel.

Practice:

Thinking about Prefixes

1. Use the table of prefixes to complete an ordered list of the most common multiples used in physical science: **mega**, **kilo**, **centi**, **milli**, **micro**, and **nano**. List these prefixes in order by powers of ten, from largest to smallest. Then write the scientific notation and the standard notation for the prefix word.

Example
giga = 10^9 = 1,000,000,000

2. Think about what the words "Mega Millions" means. If you won 300 Mega Millions, how many millions of dollars would you have won?

Metric to Metric

3. Utilize differences in powers of ten or a number line to "move" within the metric system of units.

   a. 5 centimeters = ___________ meters
   b. 2,000 meters = ___________ kilometers
   c. 650 nanometers = ___________ meters
   d. 20 millimeters = ___________ meters
   e. 20 grams = ___________ kilograms

Time

4. Use your knowledge of seconds minutes and hours.

1 hour = ___________ seconds
1 hour = ___________ nanoseconds

1 day = __________ seconds

5. There are 365 days in a standard calendar year. Write your current age in years and convert this to seconds.

6. If you were able to blink every nanosecond for an hour, how many times would blink?

English to Metric & Metric to English

7. Use conversion factors to convert from one system of units to another.

65 mph = __________ kph
65 mph = __________ m/s
60 inches = __________ centimeters
60 inches = __________ meters
20 m/s = __________ mph
20 cm = __________ inches

Common American Quantities

8. Write your approximate weight and convert this to Newtons.

9. Cargo ships carry many megatons of consumer products. How many pounds are in 500 Megatons of cargo? (1 ton = 2000 lbs)

10. The length of an American Football field is 100 yards. How many meters are in 100 yards?

Measurements in 2D and 3D

11. An accent rug measures 4 feet by 6 feet. Calculate the area of the rug in square feet, and then convert the units to square meters.

12. A gift box measures 12 inches by 8 inches and is 3 inches tall. Calculate the volume, and then change the units from inches to centimeters.

Appendix II - Constructing & Interpreting a Graph

Student Learning Objectives:
Construct scientific a graph, determine the relationship shown by a graph, and interpret what the graph shows.

Materials:

Ruler
Graph Paper

Introduction:
Graphs allow us to visualize the relationship between two sets of numbers. Scientists often graph sets of numbers looking for a correlation, or a mathematical relationship. When constructing a graph of physical quantities, the independent variable is placed on the horizontal (x-axis), and the dependent variable is placed on the vertical (y-axis). A best fit line is utilized to represent the data; it is a smooth line or curve which is the average of the data points. The graph can be used to develop an equation relating the two sets of data.

Independent & Dependent Variables

Independent variables do not depend on the measurement of another quantity. They are fundamental quantities. A change in location or direction will not affect a fundamental quantity. (*Example: time*)

Dependent variables depend on the measurement of another quantity. A change in location or direction will affect/change this type of quantity. (*Example: acceleration*)

Rules for Construction of a Good Graph

- Draw the axes of the graph such that the graph will fill the space provided, leaving just enough room for labeling.

- Determine the independent and the dependent variables, and label your axes accordingly. Include the units in your axes labels.

- Determine the minimum and maximum values for each axis. Then choose a scale with equal increments which will accommodate all of the data for each axis.

- Plot the data and draw a smooth line or curve that best fits the data points.

Linear or Direct Relationship

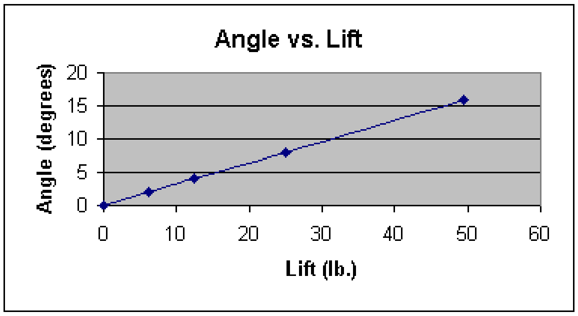


Image Credit: NASA

Graph shows a relationship of the form $y = x$

y depends directly on x

Quadratic Relationship

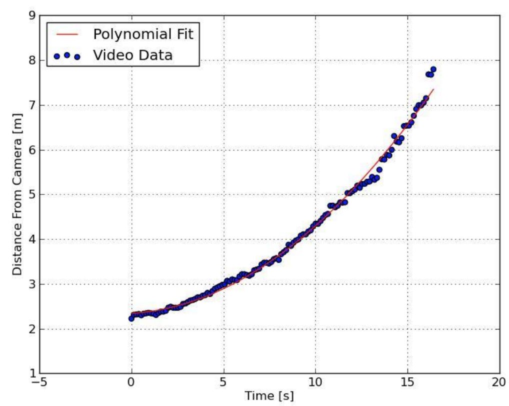


Image Credit: ESA

Graph shows a relationship of the form $y = x^2$

y depends directly on the squared value of x

Inverse Square Relationship

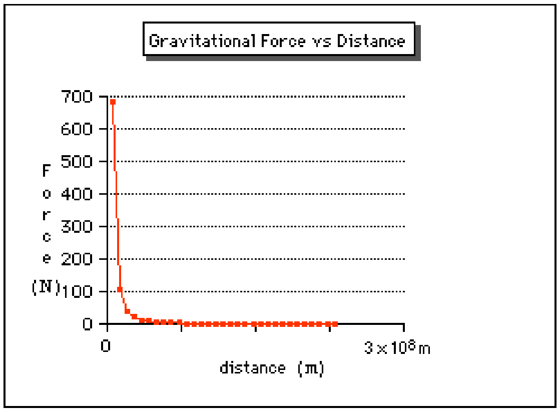


Image Credit: NASA

Graph shows a relationship of the form $y = \frac{1}{x^2}$

y depends on the inverse of the squared value of x

Practice:

1. Construct a graph using the data in Table 1 and determine whether the graph shows a linear, quadratic, or inverse square relationship. Describe the motion shown by the graph.

2. Construct a graph using the data in Table 2 and determine whether the graph shows a linear, quadratic, or inverse square relationship. Describe the motion shown by the graph.

Table 1

Distance (meters)	**Time** (seconds)
7.06	1.2
19.62	2.0
47.13	3.1
90.69	4.3
122.62	5.0
188.50	6.2
240.35	7.0

Table 2

Speed (m/s)	**Time** (seconds)
5.9	1.2
15.7	2.0
25.0	3.1
51.4	4.3
45.6	5.0
54.9	6.2
64.8	7.0

3. Look at the data table containing football player statistics. Determine which data set is the independent variable and which data set is the dependent variable. Construct a graph using the football player data and determine whether the graph shows a linear, quadratic, or inverse square relationship. Interpret the "Football Player" graph by describing how height and weight are related to each other.

Football Player Height	**Football Player Weight (lbs)**
5 ft 8 in	168
5 ft 9 in	178
5 ft 10 in	186
5 ft 11 in	177
6 ft	201
6 ft 1 in	196
6 ft 2 in	230
6 ft 3 in	205
6 ft 4 in	222
6 ft 5 in	228
6 ft 7 in	259

Appendix III - Manipulating Numbers in Scientific Notation

Student Learning Objectives:

Practice changing between standard notation and scientific notation, and practice calculations with scientific notation.

Materials:

Scientific Calculator

Introduction:

Scientific notation indicates the number of 10's multiplied or divided. A negative exponent indicates the number of 0's in front of the coefficient. A positive exponent indicates the number of 0's after the coefficient. Numbers in the physical sciences can be very large or very small, making it cumbersome to write the entire number in standard notation, so powers of ten are used as a shorthand. When two numbers with powers of 10 are multiplied, the coefficients are multiplied, and then the powers of 10 exponents are added. When two numbers with powers of 10 are divided, the coefficients are divided, and then the powers of 10 exponents are subtracted.

The Meaning of Powers of 10

Standard	Scientific	Powers of Ten
540,000,000,000	5.4×10^{11}	5.4 x [10x10x10x10x10x10x10x10x10x10x10]
0.00000101	1.01×10^{-6}	$\frac{1.01}{[10\times10\times10\times10\times10\times10]}$

Standard	Scientific	Decimal Places
540,000,000,000	5.4×10^{11}	10^{11} means move the decimal 11 places to the right
0.00000101	1.01×10^{-6}	10^{-6} means move the decimal 6 places to the left

How to Multiply & Divide

$10^6 \times 10^2 = 10^8$	exponents: $6 + 2 = 8$
$10^6 \times 10^{-2} = 10^4$	exponents: $6 + (-2) = 4$
$10^6 \div 10^2 = 10^4$	exponents: $6 - 2 = 4$
$10^6 \div 10^{-2} = 10^8$	exponents: $6 - (-2) = 8$

How to Multiply & Divide with Coefficients

$(2 \times 10^3) \times (4 \times 10^5)$	$(2 \times 4) \times 10^{3+5} = 8 \times 10^8$
$(2 \times 10^3) \div (4 \times 10^5)$	$(2 \div 4) \times 10^{3-5} = 0.5 \times 10^{-2}$

Practice:

1. Write the following numbers in scientific notation; keep only 3 significant figures.

    9,876,543
    1,000
    1,000,000,000
    0.000009876543
    0.000000001000

2. Multiply and divide the following numbers.

    10^8 times 10^{-3}
    10^8 divided by 10^{-3}
    14×10^{15} times 2×10^{-12}
    14×10^{15} divided by 2×10^{-12}
    $(9 \times 10^9)(1.6 \times 10^{-19})(1.6 \times 10^{-19})$ divided by (5×10^{-5})

3. A wavelength of blue light is 450 nanometers or 450×10^{-9} meters. What is this wavelength in standard notation?

4. Our sister galaxy, the Andromeda galaxy is 250 Million light years, or 250 x 10^6 light years from us, and 1 light year is 9.46 x 10^{15} meters. Calculate the total distance in meters to the Andromeda Galaxy, in standard notation.