

# Physical Science Laboratory Manual

## 2015-2016



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## Laboratory Regulations

- Pay close attention to the instructions given before each experiment.
- Your work in the laboratory should be done quietly and carefully. Take your time; do the work well.
- Be careful. Some of the materials which you will use are poisonous. Some might be explosive under various conditions; others are flammable. To avoid danger, follow the directions given by the instructor and those in the laboratory manual.
- Laboratory equipment should be used only for its intended purpose: completing the experiment. Misuse of equipment is not permitted.
- Be sure that you are using the materials called for and the amounts indicated in the directions. **READ DIRECTIONS AND BOTTLE LABELS CAREFULLY.**
- Original experiments (mixing chemicals “to see what will happen”) are forbidden.
- Solid waste materials and spent matches which have cooled should be placed in the trash receptacles, not in the sink or trough.
- Broken glass must be placed in the special receptacle provided for this purpose. Nothing else should be placed in this container.
- To prevent corrosion and possible accidents, flush the sink with water when liquids are poured into them.
- Look through a test tube, never into it. When heating a test tube, never point it at yourself or your fellow students.
- During chemistry experiments, laboratory aprons must be worn at all times. They should be put away neatly when instructed by your teacher.
- During chemistry experiments, safety goggles must be worn at all times. They are the first thing you put on when you enter the laboratory and the last thing you take off before leaving.

- When examining a substance, use the sense of sight always, the sense of smell cautiously, and never the sense of taste.
- Before leaving the laboratory, be sure that your apparatus and bench top are clean, dry, and ready for the next group to use. During chemistry experiments, use the sponges provided and wet them thoroughly and squeeze out the excess water. Then use the sponge to wipe down your bench. Wash and dry your hands before leaving the laboratory.
- Be sure to note the location of fire extinguishers in the laboratory.
- Be sure to note the location of the emergency eye wash sink in the laboratory.
- Be sure to note the location of the emergency shower in the laboratory.
- First aid equipment is available in the laboratory. Should an accident occur, no matter how minor it may seem, notify the instructor at once.

# Format for Physical Science Laboratory Report

*Not all instructors will require this format. Check with your instructor to determine the format required.*

Each experiment is to be handed in as a separate laboratory report. These reports are your own work. Although you will perform the experiments with a partner, the final report needs to be produced by you.

All experiments done on a particular day are to be stapled together.

Laboratory reports should be typed if possible. If they cannot be typed, they must be **neatly** hand-written. Rulers should be used to make any data tables.

Lab reports may not be submitted via email.

All heading and numbering schemes shown below are to be part of your laboratory report. All sections should fall in order and may not be attached to the back.

**Your Name**

**Report Due Date**

**Experiment Number: Experiment Title**

## **I. Purpose**

The purpose section should explain the reason for doing the experiment. You should state what physical or chemical principles or concepts are being examined. The introduction in the laboratory manual and your textbook should be of help writing the purpose. This section should not be more than 1-2 sentences. It should be written in past tense and passive voice.

## **II. Procedure**

The procedure section should **summarize** the important activities done during the experiment. This excludes cautions and tips that are provided for you in the manual. This section should **not** be copied from the manual. It should be written in past tense, passive voice, and paragraph form.

## **III. Data & Observations**

This section should contain a neat presentation of your data or measurements, preferably, in tabular form. Your data and observations should be labeled to indicate exactly what the measurement represents. Data is to be listed under each other, not in paragraph form. All measurements should include the appropriate number of significant figures and should include both the number and the unit of measurement. Any tables should have titles above them.

#### IV. Calculations & Graphs

This section should show all calculations that were needed to arrive at data reported above or data required by questions or calculations. **All calculations should be labeled to indicate exactly what was being calculated or what question was being answered.** If there are no calculations, you should include the heading for this section and under it the word NONE should appear. **Calculations should be numbered as they are in the laboratory manual.** Graphs should have titles and axis titles with units, if appropriate.

#### V. Questions

Any questions posed anywhere in the experiment should be answered in this section. Your answers are to be in complete, correct sentences. If there are no questions or problems, you should include the heading for this section and under it the word NONE should appear.

**Questions should be numbered as they are in the laboratory manual.**

#### VI. Conclusions

This section should be written in paragraph form. Below are a set of questions to guide you. A conclusion in a lab report is not simply a place to list answers to these questions. It is similar to the conclusion of an essay in that it should summarize and wrap up the whole report.

*Was the purpose achieved?*

*Briefly summarize the results of the experiment.*

*What can be concluded after doing this experiment?*

*What are sources of error that could have affected the results (during the actual experiment)?*

It is definitely acceptable to say that you did not achieve your purpose. Science does not always go as planned. If you made a mistake during the experiment, you may explain that. However, “human error” and “instrumental error” are NOT acceptable mistakes. Think about what could have happened during the experiment to adversely affect your results. Messed up calculations are not sources of error. Even if you think the experiment went perfectly, you can still propose possible errors.

**Your instructor might ask you to turn in a “mini” lab report that consists of 1 or more of these sections. Always follow given directions.**

<b>Mini Format 1:</b> Purpose, Data & Observations, Calculations & Graphs, Questions
<b>Mini Format 2:</b> Purpose, Data & Observations, Calculations & Graphs, Questions, Conclusion

# Sample Physical Science Laboratory Report<sup>1</sup>

John Doe

September 1, 2013

## Experiment 1: Determining the Boiling Point of Water

I. **Purpose:** The purpose of this experiment was to determine the boiling point of water.

II. **Procedure:**

The beaker was filled with approximately 300 mL of distilled water and then placed above the Bunsen burner. The initial temperature of the water was measured. The water was then heated by the Bunsen burner flame. The temperature of the water was recorded every two minutes until six minutes after boiling began. Observations were also made every two minutes. The flame was then turned off and the materials allowed to cool.

III. **Data & Observations:**

Table 1: Temperatures and Observations of Water while Heating

Time (min)	Temperature (°C)	Observations
0	20.0	Water is clear and still
2	41.5	No change
4	60.6	No change
6	79.4	-Water is still clear -Small bubbles appear in water
8	97.1	-Water is still clear -Large bubbles appear in water
10	99.7	Same color and bubbling continues
12	99.9	Same color and bubbling continues
14	99.9	Same color and bubbling continues

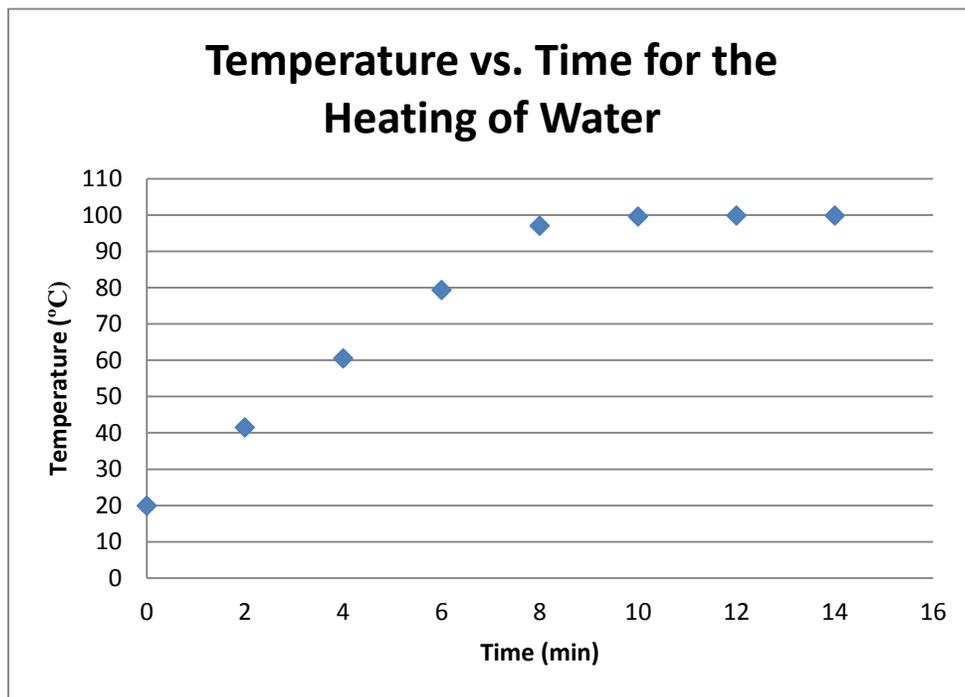
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<sup>1</sup> Adapted from Liberty High School:

<http://www-lhs.beth.k12.pa.us/departments/science/Science%20Department%20Lab%20Report%20Format.pdf>

#### IV. Calculations & Graph:

There are no calculations for this experiment.



#### V. Questions:

1. *Using your graph and observations, identify the time when boiling began and the boiling point of water.*

On a temperature vs. time graph, a section with a slope of zero (flat) corresponds to a change in state of matter. According to the graph constructed from this experiment, the boiling point of water is approximately 100 °C. This corresponds with the observations taken during the experiment. At 8 minutes, the water was bubbling quite a bit, which is a sign of boiling. These large bubbles started to appear when the temperature was 97.1 °C, which is just under the boiling point obtained from the graph.

2. *Explain the meaning of the positive slope for part of the graph and the slope of zero for the next part of the graph.*

On a temperature vs. time graph, a positive slope means that the temperature of the substance is increasing because it is absorbing energy, making the molecules move faster. In this time period, the state of matter is not changing. A flat portion (slope = 0) means that the substance is changing its state of matter. This happens because energy is still being added to it (by the Bunsen burner flame) but is now being used to break the attraction between the water molecules and make the water go from a liquid to a gas.

## VI. **Conclusion:**

The purpose of this experiment was to find the boiling point of water, which was achieved. It was determined to be 100 °C. To determine this, a temperature vs. time graph was created from data gathered during the experiment. The flat portion of this graph corresponded to the boiling of the water. When the temperature levels off, it indicates that a phase change is occurring. The temperature leveled off at 100 °C, which must therefore be the boiling point of the water. In this experiment, it is clear that energy was transferred to the water from the Bunsen burner flame throughout the period of data collection. After analyzing the graph, it can be concluded that the energy first caused the molecules of liquid water to speed up, thereby increasing the temperature of the water. This conjecture is based on the fact that temperature is a measure of average kinetic energy of the particles in a substance. Eventually, the energy from the flame was used to boiling the water, breaking the attraction between the water molecules and allowing them to escape into the gas phase. This conclusion is supported by the flat portion of the graph.

There are many possible sources of error that could have affected the results of this experiment. For example, if impure water was used, that could have affected the boiling point that was determined. When a liquid has substances dissolved in it, as might be the case with impure water, the boiling point of the liquid is elevated. The result would have been that the last set of temperatures measured would have been higher than the actual boiling point of pure water. Distilled water was used in this experiment in an effort to avoid this source of error.

# EXPERIMENT 1

## Physics Skill-Building

Throughout the course of the school year, you will learn many new techniques, skills, and approaches to analysis of scientific material. Some material you learn will pervade your career as a student of science while other parts will be specific to physics. The skills you will develop during physics experiments will serve as a foundation and a jumping point moving forward.

One concept central to any quantitative-based experiment is measurement. You will become an expert in recording measurements with the correct number of digits and the correct unit. The tools used will include meter sticks, thermometers, stopwatches, and balances, among others. Computers will also be an aid in taking some digital measurements.

Of what use would measurements be if they were not analyzed? Imagine looking at a piece of paper with Philadelphia temperatures written down from every September 1<sup>st</sup> since 1900. Without taking an average, looking at the record high or low, the 113 measurements would be overwhelming. After taking measurements, you will often perform calculations, plot graphs, or process the data in another fashion. This analysis may be performed by hand, with calculators, or with computers.

### OBJECTIVES

In this experiment, you will

- practice techniques and taking measurements with the correct number of significant figures.
- learn one way to approach error in your data.
- practice conversions and graphing.
- become comfortable and familiar with tools for future experiments.

### MATERIALS

meter sticks

balances

small weights

stopwatch

pendulum

computer for graphing

*given information for conversions, graphing, and other laboratory concepts*

## PROCEDURE

### Station 1: Measurements (Length & Mass)

#### *Length Measurement*

##### *How to Take a Measurement*

All measurements must include units. When taking a measurement with a non-digital tool, you always include all of the digits that the tool provides, plus one estimated digit.

Look at the examples below.

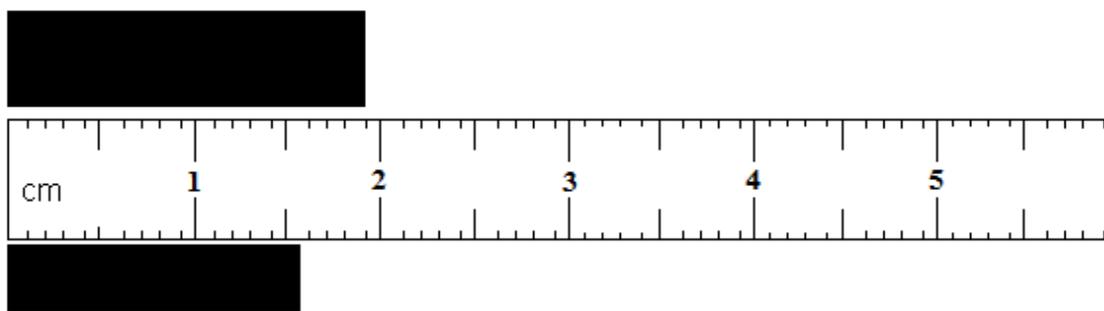


Figure 1

Each small line on the ruler represents 0.1 cm. **Each measurement recorded with this tool should have 2 decimal places – 1 more than the tool provides.** The object above the ruler falls right on the 1.9 cm line. The correct way to record that length would be **1.90 cm**. The object below the ruler falls between 1.5 and 1.6 cm. The last digit must be estimated. This measurement would be **1.56 cm**. Notice that both measurements from Figure 1 have two decimal points. **Note: Please follow your teacher's instruction on taking a measurement.**

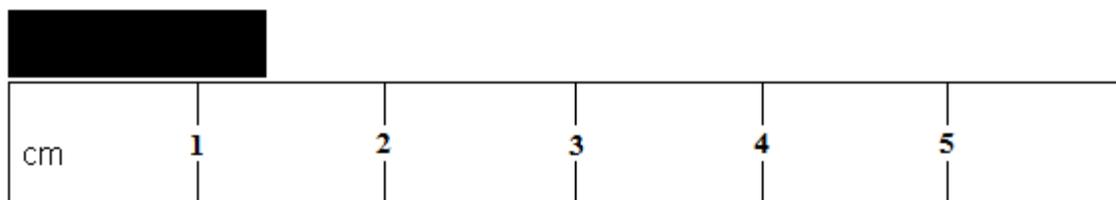


Figure 2

The ruler in Figure 2 is not as precise (exact) as the ruler in Figure 1. It only has increments of 1 cm. Therefore, each measurement recorded with *this* ruler should have 1 decimal place – 1 more digit than the tool provides. The object above the ruler is between 1 and 2 cm in length. The correct length measurement would be **1.3 cm**.

### *Practice Taking Length Measurements*

1. There are three objects at your bench and a meter stick. Examine the meter stick and right down what the smallest increment represents in the data section.
2. Measure the (longest) length of each object using the meter stick at the station. Record each value in the data section.

### *Mass Measurement*

When using a digital tool, no extra estimate is needed. The tool provides all of the precision that it can.

1. Examine the balance at your bench.
  - a. The ON/OFF button is self-explanatory. At the end of a lab period, balances should be turned off to conserve battery. You need to hold down the power button to do this.
  - b. The display should be show a 'g' for grams. If it does not, switch the mode until it does. Having the wrong unit is like stepping on a scale in Europe and thinking you weight 56 lb instead of 56 kg!
  - c. There is also a ZERO button. This sets the balance reading to zero, no matter what is sitting on it. Thus, you could set the empty balance to read zero, or place an object on it and have the balance read zero.
2. Make sure the balance is on and reads 0.0 g. If it does not, hit the ZERO button.
3. Measure the mass of the three objects at your lab bench. Record these masses in the data section.
4. Convert each of the masses to kilograms. (Note that this should go in the "calculations" section.)

### **Station 2: Error Analysis**

1. There is a pendulum at this station (like a grandfather clock). Using a stopwatch, measure the time it takes for the pendulum to go 5 complete cycles. (Say it starts on the left. It will move all the way to the right and then return to its original position. That is one cycle.)
2. Record the time in the data section. Repeat this time measurement 4 more times.
3. **The following also appears in the data analysis section:**  
The error in your measurements tells you how inconsistent they are. You can calculate the error by taking the difference between the highest and lowest time trial and dividing by 2.
4. Average the five trials in the calculations section

5. Obtain from your teacher the actual time it should take for the pendulum to complete 5 cycles. In the calculations sections, calculate the percent error in your average value.

The formula for percent error is:

$$\text{percent error} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \cdot 100\%$$

### **Station 3: Conversions**

There are several measurements written down at your station. Follow the instructions at the station for converting these measurements to different units. Record your work in the “calculations” section.

### **Station 4: Graphing by Hand**

Follow the instructions at Station 4 for constructing a graph by hand. The hand-drawn graph should be done on a separate sheet of graph paper. Insert this graph in the “calculations and graph” section of your lab report.

### **Station 5: Graphing on the Computer**

Follow the instructions at Station 4 for constructing a graph by hand. Print the graph on the lab computer. Insert this graph in the “calculations and graph” section of your lab report.

### **Station 6: Other Important Laboratory Concepts**

There are some concepts that we will use many times in the laboratory that can be easily confused. Here we will practice telling the difference between them. At your station are a series of statements. Identify them as data, calculation, observation, or conclusion, using the information below as your guide. Record your results in the data section.

#### *Data vs. Calculation*

A piece of data is very different than a calculation.

- You can use a ruler to take a length measurement, a thermometer to measure the temperature, or a stopwatch to take a time measurement. These examples would qualify as pieces of data.
- Later, you might gather your data and take an average or find a new quantity entirely. For example, if you walked 3 miles and it took 1.5 hours, you could calculate your average walking speed. You did not *measure* your speed, you *calculated* it. Calculations are a result of processing the data you obtained.

Measurements are considered data. You cannot **measure** a calculation.

*Observation vs. Conclusion*

Observations are often grouped with data. An observation is a quality that you see, hear, etc. and record. Usually data is thought of as quantitative concept (contains a number) and an observation is qualitative (e.g. the liquid is clear). This distinction is less critical than that of data vs. calculation.

Observations are sometimes confused with conclusions. An observation simply states a quality of something: its color, size, shape, etc. For example, “the liquid is clear” is an observation. A conclusion is not something you can observe. It is something that you infer based on observations and previous knowledge. For example, “the liquid is clear, *therefore it is water*” is a conclusion based on an observation and what you know about water. Not all conclusions are valid.

**DATA & RESULTS**

**Data Table for Station 1: Length Measurement**

Be sure to include units.

Number of centimeters represented by each gradation: \_\_\_\_\_

Number of decimals placed that this measurement should have: \_\_\_\_\_

Object (name)	Longest length

**Data Table for Station 1: Mass Measurement**

Be sure to include units.

Object (name)	Mass

### Data Table for Station 2: Error Analysis

Be sure to include units.

<b>Trial</b>	<b>Time for 5 Cycles</b>
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

### Table for Station 6: Other Important Laboratory Concepts

<b>Statement</b>	<b>Identification of Statement Type</b>
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

## CALCULATIONS

### Station 1: Mass Measurement Conversions

### **Station 3: Conversions**

## Station 5: Error Analysis

The error in your measurements tells you how inconsistent they are. You can calculate the error by taking the difference between the highest and lowest time trial and dividing by 2.

Difference between highest and lowest measurement: \_\_\_\_\_

Error in measurements: \_\_\_\_\_

Average the five trials in the calculations section. Obtain from your teacher the actual time it should take for the pendulum to complete 5 cycles. In the calculations sections, calculate the percent error in your average value. The formula for percent error is:

$$\text{percent error} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \cdot 100\%$$

Average time trial: \_\_\_\_\_

Percent error: \_\_\_\_\_

## QUESTIONS

1. When taking a measurement with a meter stick or a ruler, how do you know how many digits to record? How many should you record in our experiments?
2. What tool did you use to measure mass? Is that tool digital?
3. Why do you think it might be a useful skill to be able to convert between meters and centimeters? Give an example of when this conversion might be useful.
4. Name an advantage of graphing by hand. Name an advantage of graphing on a computer.
5. If there was a large difference between your highest and lowest measurements for Station 5, would you have a big or small error in your measurements?
6. Summarize the difference between data and calculations.
7. Summarize the difference between observations and conclusions.

## PRE-LAB QUESTIONS

1. What unit could you use to measure
  - a. your height?
  - b. your weight?
  - c. how long a cake needs to bake in the oven?
2. How many centimeters are in 1 meter?

## **EXPERIMENT 2**

### **Motion of a Toy Car**

Sometimes two quantities are related to each other and the relationship is easy to see. Sometimes the relationship is less evident. In either case, a graph of the two quantities often reveals the nature of the relationship. In this experiment, a graph will be constructed that represents the motion of a toy car. By keeping track of its position relative to time, you will collect the data for the graph. To do this, the car will run along the length of a strip of paper. At regular time intervals, you will mark the position of the car. This will result in several ordered pairs of data – positions at corresponding times. You can then plot these ordered pairs to make a graph representing the motion of the car.

#### **OBJECTIVES**

In this experiment, you will

- Use tools to collect data on the motion of a toy car.
- Analyze the data to draw conclusions about the speed of the car and the nature of its motion.

#### **MATERIALS**

paper  
pencil  
stopwatch  
Logger *Pro*  
computer

meter stick  
constant velocity toy car  
tape  
Vernier motion detector

#### **PROCEDURE**

1. Tape the long sheet of blank paper to the bench. It should be as flat as possible.
2. Aim the car so that it will run the length of the bench. It should face the wall so that it will not fall off the end of the table. Turn on the car and give it a few trial runs to check the alignment.
3. Using a meter stick and a pencil, draw a start line at the front tires of the toy car.
4. Practice using the stopwatch. Partner 1 will be the timer. At each one-second interval, he will call “go” and Partner 2 will mark the position of the front tires on the paper using the eraser end of a pencil. Allow the car to keep moving as you mark the intervals but stop the car before it hits the wall. Practice this until you feel comfortable with the timing.

5. **Performing the experiment:** When the car starts moving at the start line, start the stopwatch. At each one-second interval, the stopwatch operator will call “go” and the second partner will mark the position of the front tires on the paper using a pencil. Stop the car before it hits the wall. Depending on the speed of your car, you may not reach 7 seconds on your data table.
6. Measure the distances (in cm) of each point **from the start line**. (At time = 0 s, the distance was 0 cm). Record these positions on the Data Table. Be sure your measurements have the correct number of digits.

**Getting the velocity from the computer:**

7. You will use the computer and the motion sensor to get the velocity of the toy car. Open the program *Logger Pro* as instructed by your teacher.
8. Line up the toy car so that the motion detector can detect it. Turn off the car and place it near the motion detector, ready to start.
9. Click the “Collect” button. Right afterward, start the toy car. Hit the “Stop” button when the car runs out of room or is out of reach of the motion detector.
10. In the data section, write down the velocity of the toy car from the computer.

**DATA**

Data Table: Motion of a Toy Car

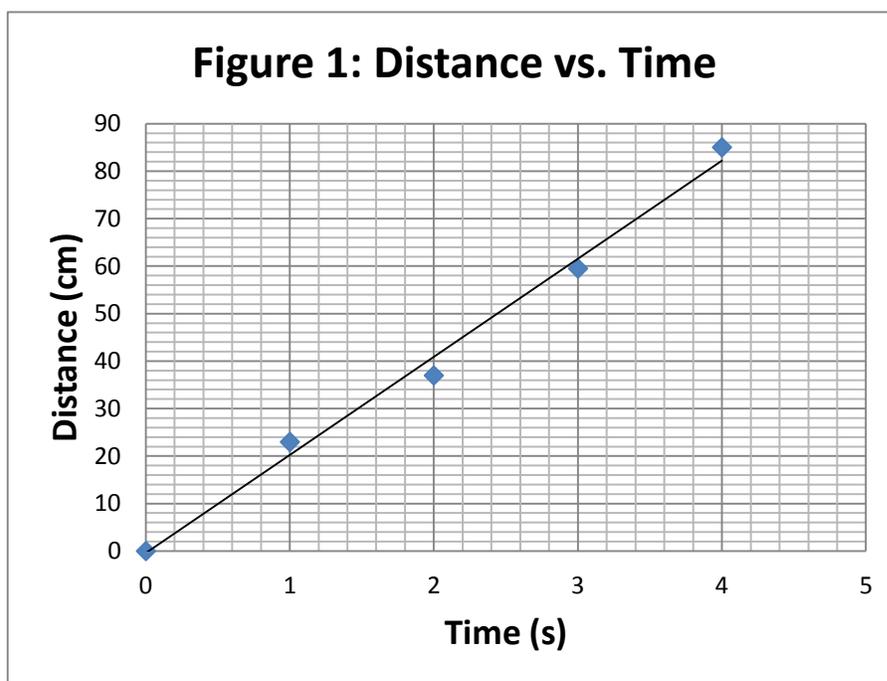
<b>Time t (s)</b>	<b>Position d (cm)</b>
0	
1	
2	
3	
4	
5	
6	
7	

Velocity of toy car from the computer: \_\_\_\_\_

## CALCULATIONS & GRAPH

On a sheet of graph paper, make a graph of position vs. time. A sample graph is shown in Figure 1.

- Title the graph “Position vs. Time.”
- Label each axis with a variable followed by a unit in parentheses. Position will be on the y-axis (in units of centimeters) because it is the dependent variable. Time will be on the x-axis (in units of seconds) because it is the independent variable. Try to fill up as much of the graph paper as possible. (Hint: Decide what range of positions or times need to fit on an axis before you start counting. Each square doesn’t have to equal 1 second or 1 centimeter.)
- Draw a line of best fit. This line does not necessarily “connect the dots.” Rather, it is a single, straight line that approximates your data. Use a ruler; place it across your data points so that your line will pass as close as possible to all of your points. The line may pass above some points and below others. Do not simply draw a line connecting the first point to the last point.



Determine the slope of the best-fit line.

- Pick two convenient points **on your line**. They should be pretty far away from each other. Convenient points are those that intersect grid lines on the graph paper. **Do not choose your own data points.**

- “Rise over run” method:

Extend a horizontal line to the right of the lower convenient point and a vertical line downward from the upper convenient point until you have a triangle as shown in Figure 2. Find and record the length of the horizontal line on your graph. This is the “run.” Do not use a ruler to measure this length. It must match the units and scale used on the x-axis.

Run: \_\_\_\_\_ s

Determine the length of the vertical line. This is the “rise.” Again, be sure the units and scale match that of the y-axis.

Rise: \_\_\_\_\_ cm

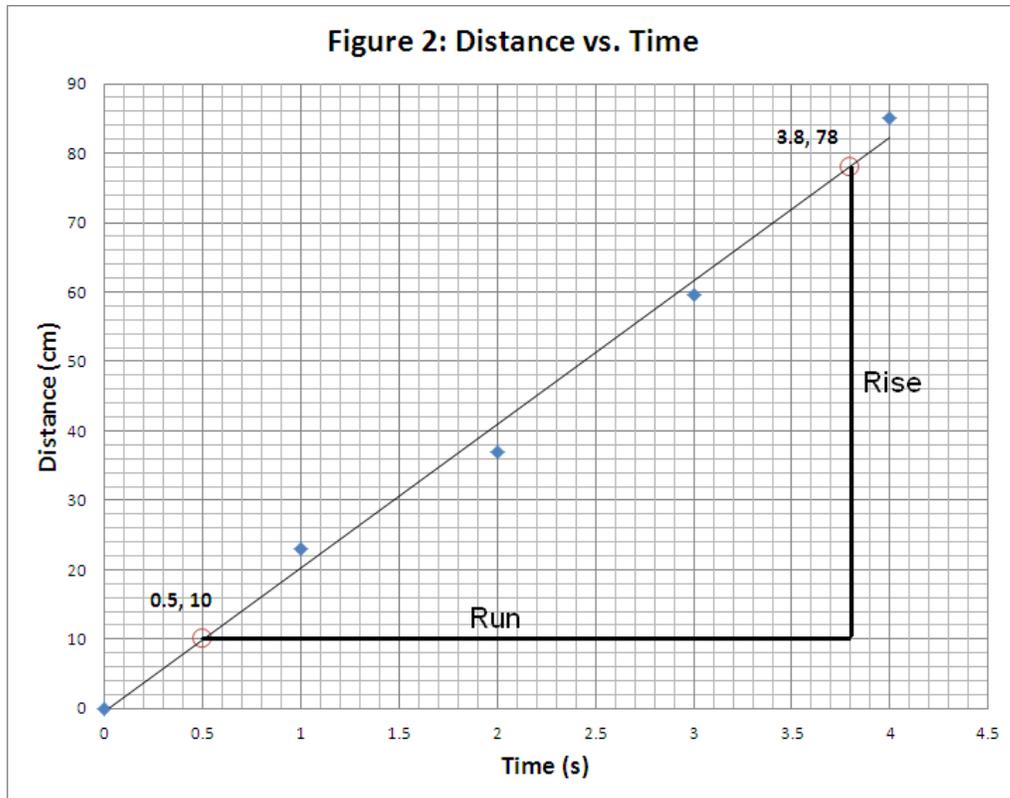
Calculate the slope by dividing the rise by the run. Show your calculation in your report.

$$\text{Slope} = \frac{\text{rise}}{\text{run}} = \text{_____ cm/s}$$

- *Formula method:*

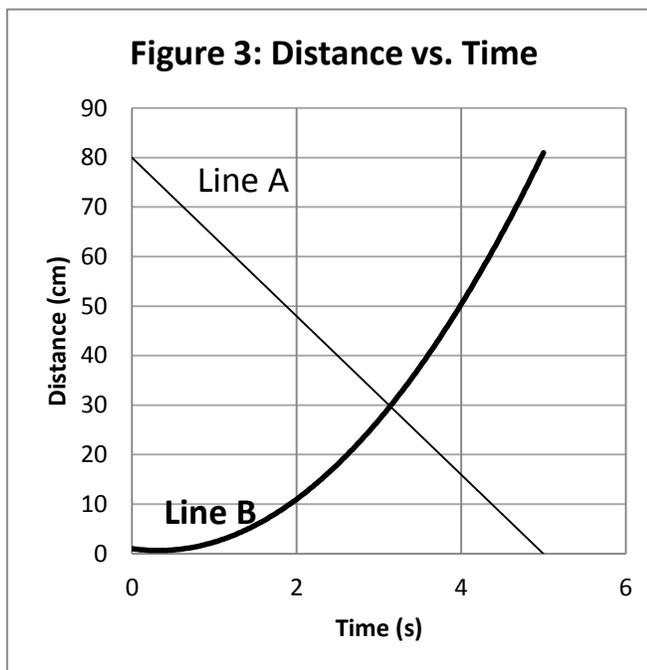
Find the coordinates of your two chosen points. They will be substituted into the formula below. For example, if one point is (3.8, 78), then  $x_1$  is 3.8 and  $y_1$  is 78. If the second point is (0.5, 10), then  $x_2$  is 0.5 and  $y_2$  is 10.

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \text{_____ cm/s}$$



## QUESTIONS

1. Look at the units for the calculated slope. What does the slope tell you about the car?
2. Suppose a faster car were used in this experiment. What would have been different about
  - a. the distance between the marks on the paper?
  - b. the number of seconds the car would have spent on the paper before reaching the edge?
  - c. the resulting position vs. time graph. (How would the slope have been different?)
3. Add a line to your graph that represents a faster car. Label it appropriately.
4. Suppose a slower car were used in this experiment. What would have been different about
  - a. the distance between the marks on the paper?
  - b. the number of seconds the car would have spent on the paper before reaching the edge?
  - c. the resulting position vs. time graph. (How would the slope have been different?)
5. Add a line to your graph that represents a slower car. Label it appropriately.
6. Suppose the car's battery ran out during the run so that the car slowly came to a stop. What would happen to the space between marks as the car slowed down?
7. What motions do the graphs in Figure 3 represent? In other words, what was the car doing to generate these motion graphs?
  - a. Line A
  - b. Line B
8. *Compare your calculated velocity to the one given by the computer.*



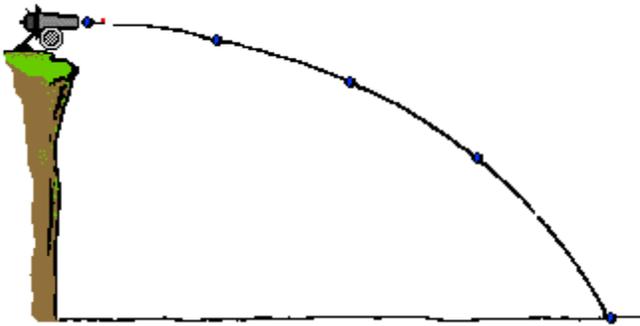
## PRE-LAB QUESTIONS

1. What two quantities will be measured in this lab? In what units, respectively?
2. Should the car be stopped after each time interval or should it be allowed to continue?
3. On a position vs. time graph, which variable is on the y-axis and which on the x?

## EXPERIMENT 3

### Projectile Motion: Bull's Eye

Projectile motion is a concept combining both vertical and horizontal motion into one problem. In this lab, a marble will serve as your “projectile”. You will be rolling it off of the lab bench and predicting, through calculations, where it will land. Vertical and horizontal motion can be considered as separate calculations, linked by a common variable: time (in this case, the time that the marble is in the air).



Without gravity, the marble you roll off the edge of the table would keep going (horizontally) forever. You know that gravity makes the marble fall to the ground, similar to the picture above. To predict where the marble will land, follow the steps outlined below. Horizontal motion will be considered the “x” direction while vertical will be the “y.” Horizontal motion will be governed by the following formula:

$$d_x = v_x \cdot t$$

where  $d_x$  is the horizontal distance travelled by the marble,  $v_x$  is the average horizontal velocity of the marble, and  $t$  is the time that the marble travels. Notice that time does not have a direction. It is simply the time that the marble is moving. You will use this equation in two different scenarios: once to calculate the velocity of the marble when it leaves the bench and once to figure out how far from the bench it will land.  $d_x$  will represent the latter.

Vertical motion will be governed by the following formula:

$$d_y = \frac{1}{2}gt^2$$

where  $d_y$  is the vertical distance travelled by the marble (a.k.a. the height of your lab bench),  $g$  is the acceleration due to gravity and  $t$  is the time that the marble is in the air. Note that the initial vertical velocity must be zero for this formula to be valid.

## OBJECTIVES

In this experiment, you will

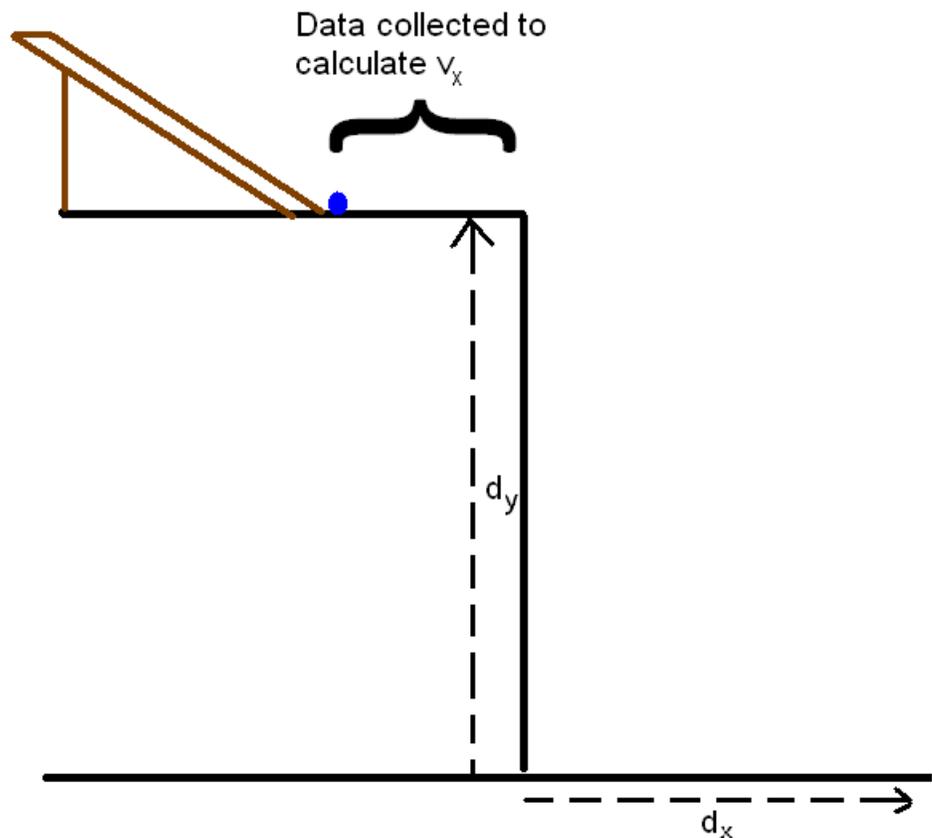
- investigate the independence of horizontal and vertical motion.
- predict the landing point of a projectile.

## MATERIALS

target paper or cup  
ramp  
Vernier photogates  
masking tape

meter stick  
marble  
Logger *Pro* and computer

## PROCEDURE



**Getting the horizontal average velocity:**

1. Be sure your ramp is set up such that the distance from the bottom of the ramp to the end of the table is about 20 cm. The whole point of the ramp is to get the marble moving, but a horizontal portion is necessary.
2. Position the Photogates so that the ball rolls through each of them while rolling on the horizontal table surface (but not on the ramp).

3. With masking tape, mark a starting position on the ramp so that you can repeatedly roll the ball from the same place. Roll the ball down the ramp through each Photogate and off the table. **Make sure you catch the marble and do not let it hit the floor.** It should also not hit the Photogates.
4. Open the file “08 Projectile Motion” in the *Physics with Vernier* folder.
5. Place the Photogates so that they are about 8-10 cm apart.
6. Measure the **exact** distance from the front of the first photogate to the front of the second photogate.
7. Enter in to the computer the distance between the photogates. This is needed in order for Logger *Pro* to calculate the velocity of the marble. The program will divide this distance by the time interval it measures to get the velocity. Carefully measure the distance from the front of the first Photogate to the front of the second Photogate. enter it into the computer.
8. Check to make sure the Photogates are working by moving your finger through the one closer to the ramp and then the one further. The red light should flash when your finger passes through. (Be sure not to move the Photogates.)
9. Click COLLECT. Roll the ball from the mark on the ramp through both Photogates and catch it immediately after it leaves the table. Repeat 9 times. Do not move the equipment. (Note: Data collection will stop after 2 minutes. If you need more time, click COLLECT to restart, choosing APPEND.) Click STOP after the 10<sup>th</sup> trial.
10. Click on the EXAMINE button and record the velocity for each trial in the data section. Click on the velocity vs. time graph and then click the STATISTICS button to get the average velocity of all the trials. Record this in Data Table 1. **This velocity will also be the marble’s average horizontal velocity while it is in the air.**

**Now that your ramp is set up and you’ve done calculations, be sure not to move it!**

**Getting information on the vertical component (FREE FALL!):**

11. Measure the height of the table, which is the vertical distance the marble will travel as a projectile. Record this height,  $d_y$ , in Data Table 2.
12. Convert  $d_y$  from centimeters to meters. Record this value in Data Table 2.
13. You know  $d_y$ , the vertical distance that the projectile travels, in meters. You can use this knowledge to figure out how long (time) the marble will be in the air. Calculate  $t$  and fill in your result in Data Table 2. Hint: Watch your units!

**Predicting where the marble will hit:**

14. You know how long the marble will be in the air ( $t$  from Step 7). You know with what horizontal velocity the marble leaves the table ( $v_x$  from Step 4). With these two pieces of information, you can calculate how far ( $d_x$ ) the marble should go from the table. In other

words, you can figure out the horizontal distance travelled by the projectile,  $d_x$ . Do so and record your result in Data Table 3.

**Testing:**

- When you are ready, ask the teacher for your target carbon paper or cup. Measure where the paper should be placed on the ground. Your goal is to hit the target! The teacher will observe your test. Measure the actual horizontal distance travelled by the marble and record your result in the data section.

**DATA**

**Data Table and In-Lab Calculations 1: Horizontal Motion on the Lab Bench**

Formula used by the computer:  $v_x = \frac{d}{t}$

Trial	Velocity (m/s)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
<b>Average</b>	

**Data Table and In-Lab Calculations 2: Vertical Information**

Scratch work:

Vertical height of lab bench ( $d_y$ ) in cm	
Vertical height of lab bench ( $d_y$ ) in m	
Formula	$d_y = \frac{1}{2}gt^2$
Rearranged formula	
Time marble is in the air	

### Data Table and In-Lab Calculations 3: Predicting Landing Point

Average horizontal velocity ( $v_x$ ) (From Table 1)	
Time marble is in the air (From Table 2)	
Formula	$d_x = v_x \cdot t$
Horizontal distance travelled by marble ( $d_x$ ) (Predicted)	

Actual result: Horizontal distance travelled by marble ( $d_x$ ): \_\_\_\_\_ cm

### CALCULATIONS (Post-experiment)

1. In your lab report, show all of the work for calculating the values that were put in the data tables. This includes how you solved for average  $v_x$ , converted  $d_y$ , time, and predicted  $d_x$ .
2. Percent error is a number that quantitatively expresses how accurate or inaccurate your experimental result is when compared to your predicted result. Check **Appendix 1** for the formula for percent error. The "experimental value" is the **actual** distance travelled by the marble and the "accepted value" is your **predicted** distance. What was the percent error for your predicted horizontal distance? Show your work.

### QUESTIONS

1. Did your marble travel too far or not far enough?
2. What would air resistance do to the motion of the marble? Be specific.

### PRE-LAB QUESTIONS

1. Identify what the following variables stand for in this experiment.  
 $d_x$     $v_x$     $d_y$     $v_y$
2. Consider the variables in #1. Which of these will be given by the computer?
3. What distance decides how long the marble will be airborne: horizontal or vertical?  
(Hint: compare the lab to a marble rolling off of a cliff.)
4. In which direction will the marble accelerate while it is in the air: horizontal or vertical?  
What causes the acceleration?
5. Rearrange the formula in Data Table 2 to solve for time. Write the rearranged form of the equation in the data table as well as on your pre-lab.

# EXPERIMENT 4

## Force

In the first part of this experiment, you will gather data to analyze the relationship between force and mass. You will use a graph to find the quantitative relationship between them. The second part of the experiment will analyze the motion of a cart, which will move by attaching it to a weight connected by a string. In this section, you will take measurement and perform calculations to eventually calculate the force acting on the cart.

### OBJECTIVES

In this experiment, you will

- investigate the relationship between force, mass, and acceleration through data collection, calculations and graphing.
- manipulate equations to calculate unknown variables using data gathered in lab.

### MATERIALS

weights  
balance  
pulley  
meter stick  
stopwatch

Force sensor  
string  
tape  
dynamics cart

### PROCEDURE

#### Part 1

1. There are five weights in front of you. Record the mass, in kilograms, of **one of the weights** in the data table below. Do not record any other masses until after Step 2.
2. **Attach that weight to the force sensor.** Read the force from the computer. Record the force required to hold the weight up in Data Table 1.
3. **Then,** repeat this for the remaining four weights.

## Part 2

- Record the mass of a dynamics cart on the data sheet.
- Attach the string to the dynamics cart as instructed by your teacher.
- Select a **small** weight from Part 1 and record its mass in Data Table 2.
- Connect the weight to the string and move the weight to the top just under the pulley. Using a piece of masking tape, mark the position of the cart when the weight is at the top.
- Slowly lower the weight to the floor. Using masking tape, mark the position of the cart when the weight first touches the floor. You have now set the distance required for the experiment. Measure the distance and record it in Data Table 2.
- Pull the cart back to the starting point and release the cart. Using a stopwatch, measure the time for the cart to move from the start to the second piece of masking tape. Record the time in Data Table 2. Repeat three times. Calculate the average of the trials and record it in the data table.

## DATA

Data Table 1: Measuring Force and Mass

<b>Weight</b>	<b>Mass</b>	<b>Force</b>
1		
2		
3		
4		
5		

Data Table 2: Motion of Dynamics Cart

Mass of dynamics cart			
Mass of small weight			
Distance travelled by cart			
Time travelled (all trials)			
Average time travelled			

## CALCULATIONS & GRAPH

### Part 1

Follow the instructions of your teacher for making the following graph and calculating its slope.

1. Make a graph of force (y-axis) vs. mass (x-axis). Note that mass must be in **kilograms** before you graph. Be sure that your graph includes a title, and labels for each axis with appropriate units.
2. Add a best-fit line.
3. Determine the slope of the graph. Show all work and give your final answer with appropriate units.

**NOTE:** If you make the graph and insert the best-fit line on the computer, it can give you the equation of the line in slope-intercept format ( $y=mx+b$ ) where  $m$ , the number in front of  $x$ , is the slope!

### Part 2

4. Calculate the weight of the dynamics cart using the following equation:

$$\text{Weight} = F_g = mg$$

5. Calculate the acceleration of the cart between the two points using the following equation. Remember, we can only use this equation because  $v_i=0$

$$d = \frac{1}{2}at^2$$

6. Calculate the force on the cart using the following formula:

$$F = (m_{\text{cart}})(a_{\text{cart}})$$

## QUESTIONS

1. In Part 1, what does the slope of the force vs. mass graph tell you? What units does it have?
2. Compare the slope that was calculated in Part 1 with the acceleration due to gravity.
3. In Part 2, what is causing the cart to accelerate?

## PRE-LAB QUESTIONS

1. In Part 1, what tool will you use to measure mass? To measure force?
2. In Part 2, a weight will pull the cart along the lab bench. Why do you think it is necessary to use a small weight?
3. For Part 2, list the variables that you will be measuring and with what units they will likely be measured.

# **EXPERIMENT 5**

## **Momentum: Egg Drop**

During this experiment, you will drop an egg from a great height and, hopefully, not damage it. The nature of this experiment is largely exploratory. You will be given limited resources with which to build a device capable of granting your egg safe passage. The pre-lab questions will help you explore what your goals should be for the device.

### **OBJECTIVE**

In this experiment, you will use your understanding of momentum to build something to carry an egg safely to the ground.

### **MATERIALS**

????????????????????

(Will be revealed in lab)

### **PROCEDURE**

1. Obtain your allocated materials from the teacher.
2. Construct your device.
3. Inform your teacher when you are finished. Follow any further instruction given.

### **OBSERVATIONS**

In flight:

Upon impact:

## **QUESTIONS**

1. Was your device successful (i.e. did your egg survive)?
  - If so, comment on what features made it so. Relate these features to concepts in physics, specifically momentum.
  - If not, comment on what flaw or lack of foresight caused the demise of your egg. Relate your comments to concepts in physics, specifically momentum.
2. No matter if your run was successful or not, how do you think you could improve your device if you were to try again?

## **PRE-LAB QUESTIONS**

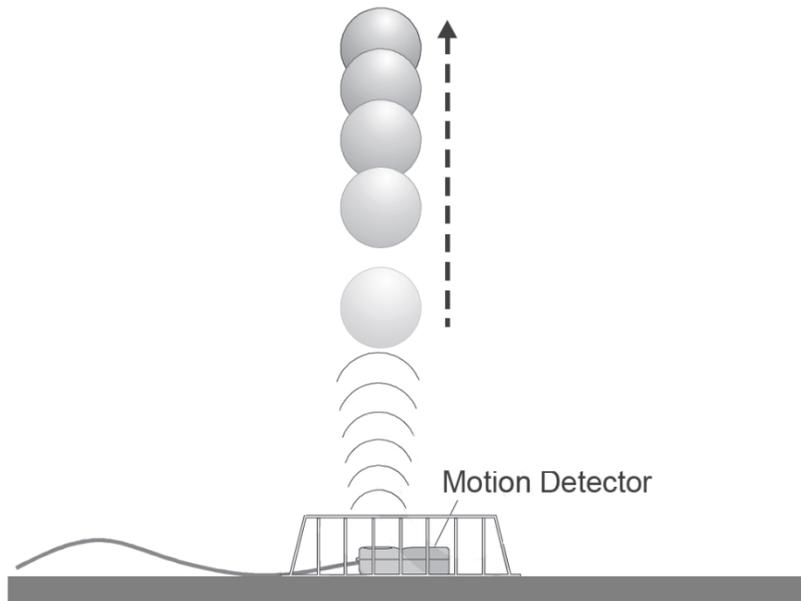
1. After reading the introduction, you are probably already thinking of ways to ensure your egg's survival. There are two main concerns to address: one while the egg falls, the other with the egg hitting the ground.
  - a. While the egg is airborne, what should the goal of your device be?
  - b. When the egg hits the ground, what should the goal of your device be?
2. In #1, you thought of two strategies to grant your egg safe passage.
  - a. How does your answer to 1(a) relate to momentum? Use the formula  $p = mv$  in your answer.
  - b. How does your answer to 1(b) relate to impulse? Use the formula  $\Delta p = Ft$  in your answer.

# EXPERIMENT 6

## Energy of a Tossed Ball<sup>2</sup>

When a juggler tosses a bean ball straight upward, the ball slows down until it reaches the top of its path and then speeds up on its way back down. In terms of energy, when the ball is released it has kinetic energy,  $KE$ . As it rises during its free-fall phase it slows down, loses kinetic energy, and gains gravitational potential energy,  $PE$ . As it starts down, still in free fall, the stored gravitational potential energy is converted back into kinetic energy as the object falls.

If there is no work done by frictional forces, the total energy will remain constant. In this experiment, we will see if this works out for the toss of a ball. We will study these energy changes using a Motion Detector.



### OBJECTIVES

In this experiment, you will

- measure the change in the kinetic and potential energies as a ball moves in free fall.
- see how the total energy of the ball changes during free fall.

---

<sup>2</sup> taken in large part from "Physics with Vernier"

## MATERIALS

computer	Vernier computer interface
Logger <i>Pro</i>	Vernier motion detector
wire basket	balance
volleyball, basketball, or other similarly heavy ball	meter stick

## PROCEDURE

1. Measure and record the mass of the ball used in this experiment.
2. Place the Motion Detector on the floor and protect it by placing a wire basket over it.
3. Turn on the computer. Open the file “16 Energy of a Tossed Ball” from the *Physics with Vernier* folder.
4. **DO NOT THROW THE BALL YET.** The ball should not exceed a height of about 1.5 m. This is less than 5 feet. Therefore, the ball should not go way over your head.
5. Hold the ball directly above and about **1.0 m** from the Motion Detector. In this step, you will toss the ball straight upward above the Motion Detector and let it fall back toward the Motion Detector. Have your partner click to begin data collection. Toss the ball straight up after you hear the Motion Detector begin to click. Use two hands. Be sure to pull your hands away from the ball after it starts moving so they are not picked up by the Motion Detector. Throw the ball so it reaches maximum height of about 1.5 m above the Motion Detector. Catch the ball close to the ground. You can stop the data collection after the ball is caught.
6. Verify that the position *vs.* time graph corresponding to the free-fall motion is parabolic in shape, without spikes or flat regions, before you continue. This step may require some practice. If necessary, repeat the toss, until you get a good graph. When you have good data on the screen, proceed to the Analysis section.
7. Click on the Examine button and move the mouse across the position or velocity graphs of the motion of the ball to answer these questions.
  - a. Identify the portion of each graph where the ball had just left your hands and was in free fall. Determine the height and velocity of the ball at this time. Enter your values in your data table.
  - b. Identify the point on each graph where the ball was at the top of its path. Determine the time, height, and velocity of the ball at this point. Enter your values in your data table.
  - c. Find a time where the ball was moving downward, but a short time before it was caught. Measure and record the height and velocity of the ball at that time.

## **DATA**

Mass of the ball: \_\_\_\_\_

Table 1: Information from Logger *Pro* on the Path of the Ball

Position	Time (s)	Height (m)	Velocity (m/s)
After release			
Top of path			
Before catch			

## **CALCULATIONS**

For each of the three points in your data table, calculate the Potential Energy (PE), Kinetic Energy (KE), and Total Energy (TE). Use the position of the Motion Detector as the zero of your gravitational potential energy. You can fill in your results in the table below for purposes of organization. Be sure to show your work in your lab report.

Table 2: Energy Calculations for a Ball Tossed in the Air

Position	Potential Energy, PE (J)	Kinetic Energy, KE (J)	Total Energy (J)
After release			
Top of path			
Before catch			

## QUESTIONS

1. How well does this experiment show conservation of energy? Explain.
2. Does the total energy of the ball remain constant? **Should** the total energy remain constant? Why? If it does not, where could the missing energy have gone?
3. What would change in this experiment if you used a very light ball, like a beach ball?

## PRE-LAB QUESTIONS

For each question, consider the motion of a ball tossed straight upward that falls down again. Assume that there is very little air resistance.

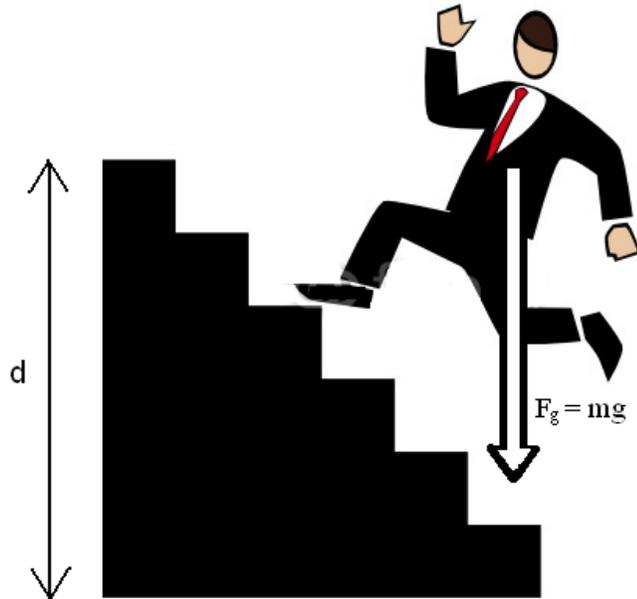
1. What form or forms of energy does the ball have while momentarily at rest at the top of the path?
2. What form or forms of energy does the ball have while in motion while moving downward?
3. Sketch a graph of velocity *vs.* time for the ball, starting when it is tossed up and ending when it is caught. (This is just qualitative: think about if it will go up/down, and when that will happen.)
4. Sketch a graph of kinetic energy *vs.* time for the ball.
5. Sketch a graph of potential energy *vs.* time for the ball.
6. If there are no frictional forces acting on the ball, how is the change in the ball's potential energy related to the change in kinetic energy?

## EXPERIMENT 7

### Work and Power

The word *work* represents a concept that has a special meaning in science that is somewhat different from your everyday concept of the term. In science, the concept of work is concerned with the application of a force to an object and the distance the object moves as a result of the force. Work ( $W$ ) is defined as the magnitude of the applied force ( $F$ ) multiplied by the distance ( $d$ ) through which the force acts.

$$W = Fd$$



You are doing work when you walk up a stairway since you are lifting yourself through a distance. You are lifting your weight (the force exerted) the vertical height of the stairs (distance through which the force is exerted). Running up the stairs rather than walking is more tiring because you use up your energy at a greater rate when running. The rate at which energy is transformed or the rate at which work is done is called power. Power ( $P$ ) is defined as work ( $W$ ) per unit of time ( $t$ ).

$$P = \frac{W}{t}$$

When the steam engine was first invented there was a need to describe the rate at which the engine could do work. Since people at that time were familiar with using horses to do their work, the steam engines were compared to horses. James Watt, who designed a workable steam engine, defined horsepower (hp) as a power rating of 550 ft·lb/s. In SI units, power is measured in Joules per second, call the Watt (W). It takes 746 W to equal 1 hp, and 1 kW is equal to about 1  $\frac{1}{3}$  hp.

$$746 \text{ W} = 1 \text{ hp}$$

$$1 \text{ kW} = 1000 \text{ W} \approx 1.33 \text{ hp}$$

### OBJECTIVES

In this experiment, you will

- identify how measurable quantities affect work and power.
- relate physical quantities to everyday activities.

## MATERIALS

staircase  
meter stick

stopwatch

## PROCEDURE

1. Both partners will perform the experiment and record the data for himself and his partner. Record both weights (in pounds) in the data table. The weight is the force (F) needed by each person to lift himself up the stairs. It will be converted to Newtons later.
2. Using a meter stick, measure the vertical height of the staircase. This can be done by measuring the height of one step and then multiplying by the number of steps in the staircase. Record this distance (d) in centimeters in the data table.
3. Measure and record the time required for each person to **walk normally** up the flight of stairs. Record the time in seconds in the data table.
4. Measure and record the time required for each person to **run** up the flight of stairs as fast as can be safely accomplished. Record the time in seconds in the data table.

## DATA

Data Table: Measurements to Calculate Work and Power

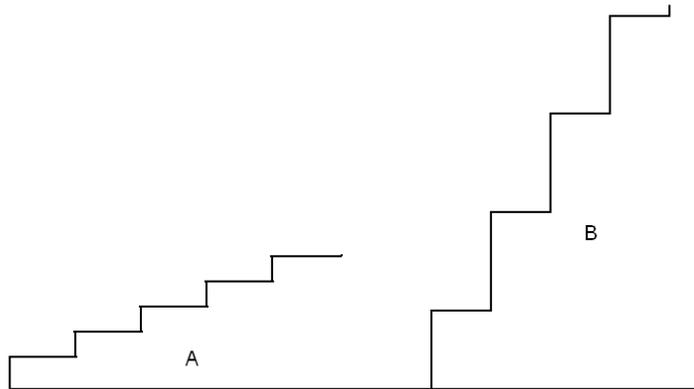
	Partner A		Partner B	
	Walking	Running	Walking	Running
Weight (F) (lb)				
Vertical height of steps (d) (cm)				
Time required to go up staircase (t) (s)				

## CALCULATIONS

1. Convert both weights to Newtons. There are 4.4 N in 1 lb
2. Calculate the work accomplished (in Joules) by both you and your partner, walking and running. (Make sure that distance is in the correct units!)
3. Calculate the power developed (in Watts) by both you and your partner, walking and running.
4. Convert the power developed by both you and your partner, walking and running, from Watts to horsepower.

## QUESTIONS

1. Explain why there is a difference in power developed while walking and running up the flight of stairs.
2. Could the power developed by a slower-moving student ever be greater than the power developed by a faster-moving student? Explain.
3. Describe an experiment that you could do to measure the power you could develop for a long period of time rather than for a short burst up a stairwell.
4. Picture two staircases, each with 10 steps. Staircase A has a gradual incline and Staircase B is very steep. How would the distance (as measured in this experiment) differ? Would force differ? Explain. Would work differ? Explain. A diagram below should help you. Note that not all of the steps are shown.



## PRE-LAB QUESTIONS

1. Using the information in the introduction, describe clearly what force and distance you will record in this experiment.
2. Summarize the origin of the unit “horsepower” and identify what variable it is used for.
3. What should not change for walking and running up the stairs: work or power? Explain.

Photo credit: <http://www.fotolia.com/id/32566257>

## EXPERIMENT 8

### Simple Machines

We use machines every day to help us accomplish tasks. They take advantage of the relationship between work, force, and distance. Simple machines can be combined to create a single, more complex machine. A way to quantify the benefit is called **mechanical advantage (MA)**. In this lab, you will explore the relationship of work, force, and distance and evaluate how various machines are of use to us.

One of the simplest machines that makes doing work easier is the incline plane, or a ramp. It is much easier to push a heavy load up a ramp than it is to lift it vertically to the same height. When it is lifted vertically, a greater lifting force is required but the distance moved is less. When it is pushed up a ramp, the distance moved is greater but the force required is less. This fact illustrates one of the most powerful laws of physics, the law of energy conservation.

Pulley systems can also be used to move loads. Sometimes, the direction of the force changes when using a pulley. Some pulleys are fixed, meaning they stay in one spot, while others are moveable. There are numerous combinations of fixed and moveable pulleys. You will be examining different pulley configurations to help you understand the concept of mechanical advantage. Simply put, the theoretical MA of a pulley system is the number of ropes pulling up on the object being lifted. (You wouldn't count the string that you pull down on.) You will also determine the observed mechanical advantage by comparing the force required to lift an object to the weight of the object.

$$\text{Observed MA} = \frac{\textit{weight of the object}}{\textit{measured force required to lift the object}}$$

### OBJECTIVES

In this experiment, you will

- investigate the force and the distance involved in moving an object up an incline.
- explore the mechanical advantage provided by different pulley systems.

## MATERIALS

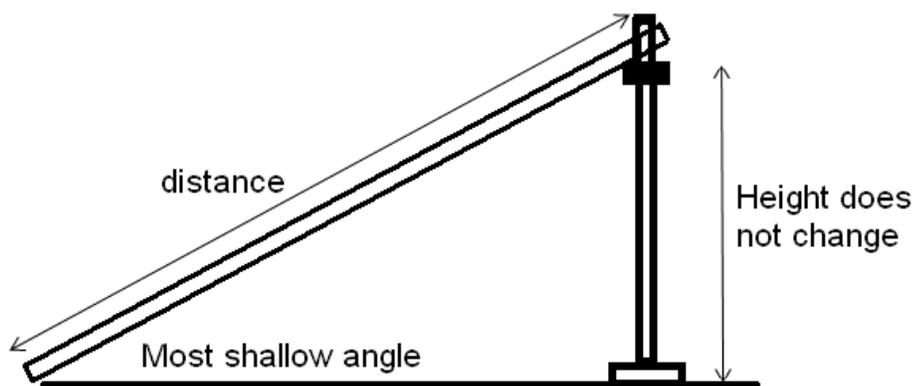
board for inclined plane  
Vernier force sensors  
Vernier computer interfaces  
clamp  
pulleys  
weight

computers  
meter stick  
pole  
cart  
string  
ruler

## PROCEDURE

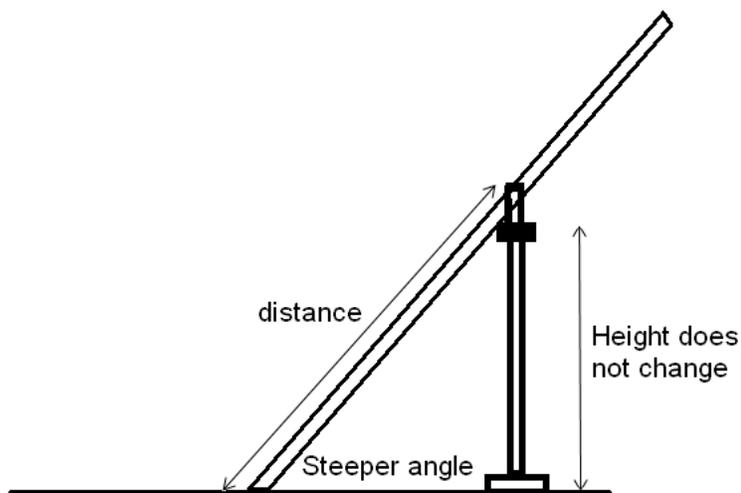
### Part 1: Inclined Plane

1. The clamp should already be on the pole. You **will not move the clamp** during the experiment. Place the board so that it is at the most shallow angle possible. (In later steps, you will slide the board so that it is at a greater incline.)



2. Attach the force sensor to the end of the cart. Pull the cart up the inclined plane with the sensor kept parallel to the plane. Read the force and record it in the data table.
3. After you measure the force, take the cart off the ramp. Measure the distance travelled by the cart, i.e. from the bottom of the board to the clamp, as indicated in the diagram. Record this distance in the data table.

- Vary the angle while keeping the height the same by sliding the board up or down along the clamp to make 3 more angles of increasing steepness. Record the force and distance each time. Use the diagram for clarification. Remember, the distance will be different every time, but not the height.

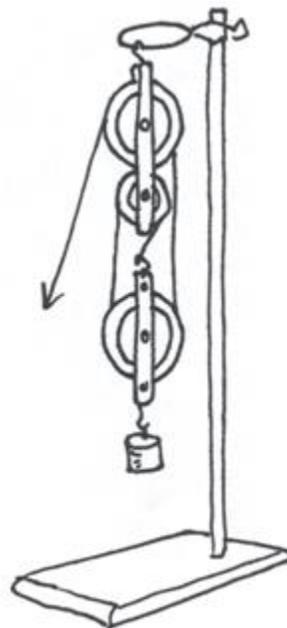
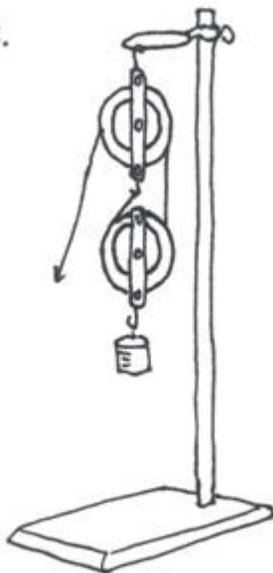
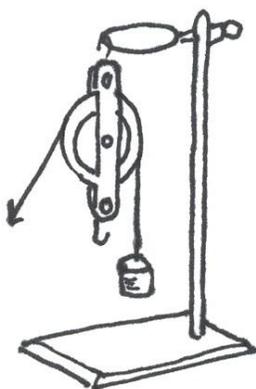


## Part 2: Pulleys<sup>3</sup>

**#1: Single Fixed Pulley**

**#2: Single Fixed, Single Moveable**

**#3: Double Fixed, Single Moveable**



- Weigh the metal weight using the force sensor by hanging it on the end. Record the weight in the data section. It is the same for all three setups.
- You will be making the three pulley configurations as shown above. If you have not already, fill in the theoretical MA for each of the three configurations.

<sup>3</sup> Pulley lab: <http://teachingphysics.wordpress.com/2009/03/19/pulley-lab-mechanical-advantage/>

3. For each configuration, you will
  - a. lift the load 20.00 cm.
  - b. measure the **force required to lift the weight** using the force sensor.
  - c. measure the **how far the string was pulled** during the same lift, using markers and measured with the ruler. (See next step.)
4. In the starting position, use a marker to color the string in a specific spot in relation to the pulley system, as instructed by your teacher. After the weight has been lifted, color the string in the same relative location. To measure the distance that the string was pulled, disassemble your pulley system and find the two colorings. Measure the distance between them. Repeat this for the other two pulley setups.

Record all of this information in the data table.

## DATA

Data Table 1: Inclined Plane

Angle (Increasing Order)	Force (N)	Distance (cm)
1		
2		
3		
4		

Data Table 2: Pulleys

Pulley Configuration	Theoretical MA	Weight of the Object	Force Required to Lift Weight	Height Lifted	Length of String Pulled
<b>Single Fixed</b>				20.00 cm	
<b>Single Fixed, Single Moveable</b>				20.00 cm	
<b>Double fixed, Single Moveable</b>				20.00 cm	

## CALCULATIONS

### *Part 1*

1. Determine the work for each of the trials.  $W=Fd$

### *Part 2*

2. Calculate the observed MA for each pulley system using the formula provided in the introduction.
3. Calculate the ratio of the length of string pulled to the height the object is lifted for each pulley system.

$$\text{Ratio: } \frac{\textit{string pulled}}{\textit{height lifted}}$$

## QUESTIONS

### *Part 1*

1. What pattern or relationship do you find between the forces and the distances?
2. How did the amount of work compare for each of the four trials? How **should** it compare?
3. Would the amount of potential energy of the cart at the **top** of the ramp (i.e. at the clamp) be different depending on the angle of the path taken to reach the top of the ramp?

### *Part 2*

4. Compare the observed MA (Calculation #2) to the theoretical MA (filled in before lab) for each pulley system.
5. Compare the ratio (Calculation #5) of string pulley/height lifted to the theoretical MA (filled in before lab) for each pulley system.
6. How does this ratio (Calculation #5) relate to the formula you learned for mechanical advantage that contains  $d_{in}$  and  $d_{out}$ ? Be specific.

## PRE-LAB QUESTIONS

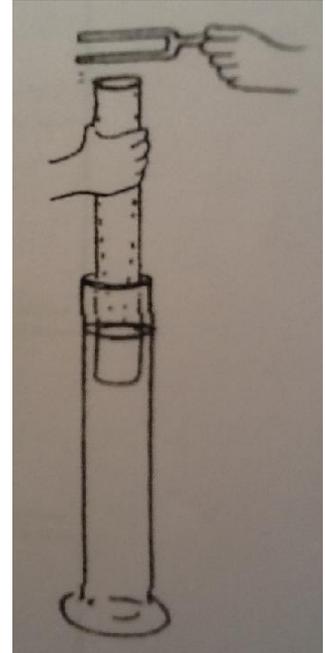
1. How does a ramp affect the force and distance that would be applied in lifting an object vertically?
2. How will you vary the distance travelled by the cart in Part 1?
3. How do machines affect the work done?
4. Explain clearly the difference between a fixed and a moveable pulley.
5. Fill in the theoretical mechanical advantage for each of the pulley systems you will be making in this experiment. You may need to read the introduction for help. Also write your answer on the pre-lab.

## EXPERIMENT 9

### Sound Waves: Mach One

You are familiar with many applications of resonance. You may have heard a vase across the room rattle when a particular note on a piano was played. The frequency of that note was the same as the natural vibration frequency of the vase. Your textbook has other examples of resonating objects.

Gases can resonate as well. A vibrating tuning fork held over an open tube can cause the air column to vibrate at a natural frequency that matches the frequency of the tuning fork. This is resonance. The length of the air column can be shortened by adding water to the tube. The sound is loudest when the natural vibration frequency of the air column is the same as (resonates with) the frequency of the tuning fork. For a tube open at one end and closed at the other, the lowest frequency of natural vibration is one for which the length of the air column is **one fourth** the wavelength of the sound wave.



In this experiment, you will use the concept of resonance to determine the wavelength of a sound wave of known frequency. You can then compute the speed of sound by multiplying the frequency by the wavelength.

### OBJECTIVE

In this experiment, you will determine the speed of sound using the concept of resonance.

### MATERIALS

resonance tube (approx. 50 cm long)  
one-liter plastic graduated cylinder  
rubber band

meter stick  
tuning forks of 256 Hz or more  
thermometer

### PROCEDURE

1. Measure and record the temperature in the laboratory.
2. Fill the graduated cylinder with water to about two thirds of its capacity. Place the resonance tube in the cylinder. You can vary the length of the air column in the tube by moving the tube up or down.

3. Select a tuning fork and record the frequency imprinted on it in the data table under "Tuning Fork 1."
4. Strike the tuning fork on the heel of your shoe (NOT on the cylinder). Hold the tuning fork about 1 cm above the open end of the tube, horizontally, with its tines one above the other. Move both the fork and the tube up and down to find the air column length that gives the loudest sound. (There are several loud spots.) Mark the water level on the tube for this loudest sound with a rubber band stretched around the cylinder.
5. Measure the distance from the top of the resonance tube to the water-level mark. This is the length of the air column. Record this measurement in the data table.
6. Measure the diameter of the resonance tube. Record this measurement in the data table.
7. Repeat Steps 2-5 for three additional tuning forks.

## DATA

Room Temperature \_\_\_\_\_

Data Table: Tuning Fork Measurements

	Tuning Fork 1	Tuning Fork 2	Tuning Fork 3	Tuning Fork 4
Frequency (Hz)				
Length of air column (m)				
Diameter of resonance tube (m)				

## CALCULATIONS

1. Calculate the corrected length of the resonance tube **for each tuning fork trial** by adding 0.4 times the diameter of the tube to the measured length of the air column. This corrected length accounts for the air just above the tube that also vibrates. Show your work.

$$\text{Corrected length} = (\text{measured length of the air column}) + 0.4(\text{diameter of tube})$$

2. The corrected length is one fourth of the wavelength of the sound vibrating in the air column. Compute the **wavelength** of that sound **for each tuning fork trial**, showing your work.

$$4(\text{Corrected length}) = \text{sound wave's wavelength}$$

3. Using the frequency and the wavelength of the sound, compute the speed of sound in air **for each tuning fork trial**. Show your work.

$$\text{Wavespeed} = \text{frequency} \cdot \text{wavelength}$$

4. The accepted value for the speed of sound in dry air is 331 m/s at 0 °C. This speed increases by 0.6 m/s for each additional degree Celsius above zero. Compute the accepted value for the speed of sound in dry air at the temperature of your room.
5. How do your computed speeds of sound compare with the accepted value? To answer this question, compute the percent error in the experimental value **for each trial**, using your answer from Calculation #4 as the accepted value.

$$\text{percent error} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \cdot 100\%$$

### PRE-LAB QUESTIONS

1. What is resonating: the column of air or the water?
2. Why will you be calculating the “corrected” length?
3. Which is bigger: the corrected length of the resonance tube or the wavelength of the sound wave that you will hear? By what factor is it bigger (this should be a whole number)?
4. Read through the calculations. Why do you need to measure the temperature of the laboratory? In other words, what does temperature affect?
5. Which of the three calculated values *should* be the same for all trials: the corrected length of the tube, the wavelength of the sound wave, or the speed of the sound in air? Defend your answer.

## EXPERIMENT 10

### Lenses and Images<sup>4</sup>

Pretend you are an optical engineer for a camera company. You have been given a lens for which your job is to figure out the focal length. Based on the specifications you obtain by doing an experiment, a new model of camera will be designed that uses that lens.

The shape of a lens determines the size, position, and types of images that it may form. When parallel rays of light from a distant object pass through a converging lens, they come together to form an image at a point called the *focal point*. The distance from this point to the lens is called the *focal length*. In this experiment, you will find the focal length of a lens. Then, verify this value by forming images, measuring distances, and using the lens formula below.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

where  $d_o$  = object distance  
 $d_i$  = image distance  
 $f$  = focal length

### OBJECTIVES

In this experiment, you will

- observe images formed by a converging lens.
- measure the distances of objects and images from the lens.
- analyze your results to determine the focal length of the lens.

### MATERIALS

candle

screen

lens

meter stick

### PROCEDURE

#### Part 1: Determining Focal Length

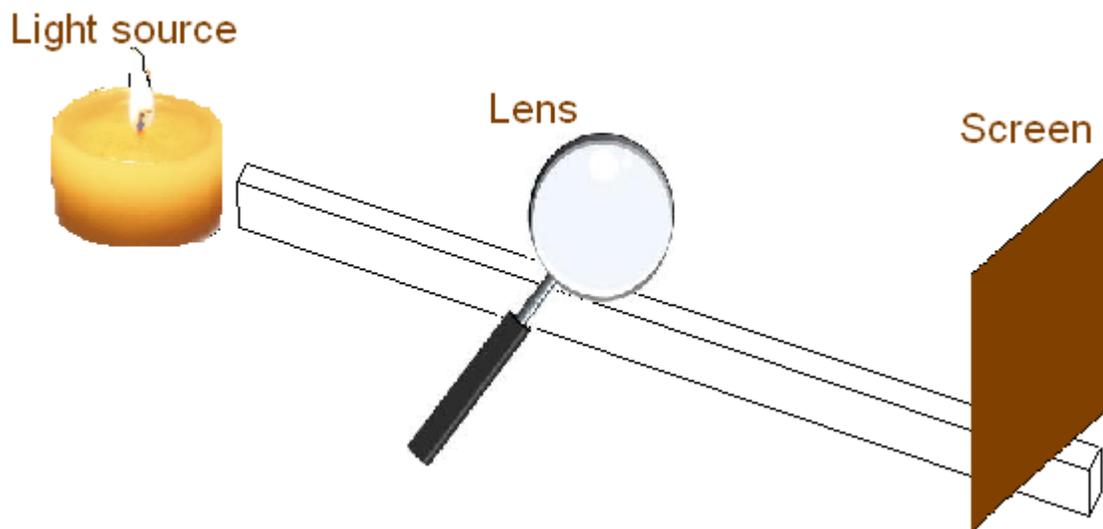
1. Stand on the side of the room closer to the windows. Point the meter stick at a tree. Hold the screen at the end of the meter stick closer to you, further from the window.
2. Slide the lens along the meter stick (between the window and the screen) until a clear image of the tree forms on the screen.
3. Measure the distance between the lens and the screen in centimeters. This distance is the focal length of the lens. Record it in the data section.

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<sup>4</sup> Experiment from Holt, *Physical Science*.

## Part 2: Forming Images

4. Set up the equipment as illustrated in the figure. Place the lens **more than twice** the focal length from the light source and keep it at that position.
5. Move the screen along the meter stick until a clear image forms. Record the distance from the light to the lens,  $d_o$ , and the distance from the lens to the screen,  $d_i$ , in centimeters as Trial 1 in the data table. Also record the height of the object and of the image in millimeters. The object in this case is the flame. Be careful not to burn the meter stick.
6. For Trial 2, place the lens **exactly twice** the focal length from the candle and keep it at that position. Slide the screen along the stick until a clear image is formed, as in Step 5. Record the distances from the screen and the sizes of the object and image as you did in Step 5.
7. For Trial 3, place the lens at a distance from the object that is **greater than** the focal length **but less than twice** the focal length. Adjust the screen and record the measurements as you did in Step 6.



**DATA**

Focal length,  $f =$  \_\_\_\_\_

**Measurements of Object and Image Distances and Sizes**

	Object distance, $d_o$ (cm)	Image distance, $d_i$ (cm)	Size of object (mm)	Size of image (mm)
Trial 1				
Trial 2				
Trial 3				

**CALCULATIONS**

1. Calculate  $\frac{1}{d_o}$  and  $\frac{1}{d_i}$ . Add your results to get  $\frac{1}{d_o} + \frac{1}{d_i}$ .
2. Calculate  $\frac{1}{f}$  using the focal length obtained in Part 1 of the procedure.

Calculation Results:

	$\frac{1}{d_o}$	$\frac{1}{d_i}$	$\frac{1}{d_o} + \frac{1}{d_i}$	$\frac{1}{f}$
Trial 1				
Trial 2				
Trial 3				

**QUESTIONS**

1. According to the formula in the introduction,  $\frac{1}{d_o} + \frac{1}{d_i}$  should equal  $\frac{1}{f}$ . How do your results compare?
2. If the object distance is greater than the image distance, how will the size of the image compare with the size of the object?

**PRE-LAB QUESTIONS**

1. What is focal length?
2. What kind of lens is used in this lab? What does it do to incoming parallel rays?
3. If the focal length of your lens happened to be 15 cm, give sample object distances that you could use for Trials 1, 2, and 3 respectively.

# EXPERIMENT 11-1

## Electricity: A Qualitative Approach

We often take our electrical devices for granted. Imagine a day without any cell phones or televisions running in the dining hall. In this experiment, you will construct circuits yourself and practice translating real-world objects into circuit diagrams using the conventions you have learned in class. By manipulating the circuits, you will see how small changes can have greater effects on the function of the circuit.

### OBJECTIVES

In this experiment, you will

- set up circuits using the guidebook.
- sketch circuit diagrams.
- manipulate the circuits to explore changes in the flow of current.

### MATERIALS

snap-circuit kit

### PROCEDURE

You may jot answers to the proposed questions within the procedure section. There is room for circuit diagrams in the observations section.

#### **Project 2**

1. Set up **Project 2**. Sketch your circuit using circuit diagram conventions.
2. Turn the switch on. Describe what happens.
3. Flick the fan. Does it fly?
4. Turn the switch off, reverse the motor, and turn it on. Flick the fan. Does it fly?
5. Examine the fan blades and offer an explanation of your results.

#### **Project 5**

6. Set up **Project 5**. Sketch your circuit using circuit diagram conventions.
7. Turn it on and describe what happens. Offer an explanation.

#### **Project 6**

8. Set up **Project 6**. Sketch your circuit using circuit diagram conventions.
9. Turn it on and describe what happens.
10. Flick the fan. Does it fly?
11. Reverse the motor, flick the fan again (you might not need to). Does it fly?
12. Rearrange your circuit so that the switch turns off only the fan, but the light stays on. Feel free to use more circuit parts. Both the light and the fan must be part of a closed circuit. Sketch your circuit using circuit diagram conventions

## **OBSERVATIONS**

### **Project 2** Circuit Diagram

#### Observations and Propositions for **Project 2**

Step 2: With switch on	
Step 3: Fan flicked	
Step 4: Motor reversed and fan flicked	
Step 5: Proposed explanation	

### **Project 5** Circuit Diagram

Observations and Propositions for **Project 5**

Step 6: With switch on. Proposed explanation.	
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**Project 6** Circuit Diagram

Observations and Propositions for **Project 6**

Step 9: With switch on	
Step 10: Fan flicked	
Step 11: Motor reversed and fan flicked	

Step 12 Circuit Diagram:

## **QUESTIONS**

1. Compare your observations for Projects 2, 5, and 6. Comment on similarities and differences. Offer explanations.
2. Including your rearrangement in Step 12 of the procedure, which of the four circuits are in series and which parallel?
3. What is the relationship between voltage, current, and resistance?
4. How does the location of the switch affect the circuit? Use your rearrangement as an example in explaining your answer.

## **PRE-LAB QUESTIONS**

1. Describe the difference between a series and a parallel circuit.
2. Draw the symbol for a light bulb, a battery, and a resistor that is used in circuit diagrams.

## EXPERIMENT 11-2

### Electricity: A Quantitative Approach

In this experiment, you will build circuits and examine how current, voltage, and resistance are related to one another. You will measure current with a device called an *ammeter*. Batteries will serve as a voltage source and light bulbs will be a part of the circuits with resistance.

Before starting the lab, assign each person in the group a job. If there are more than four people in a group, Reader/Recorder and Reporter/Lab Assistant can be split into two jobs.

#### Lab Roles:

**Group Manager** – this person is going to lead the group for the day. It is this person's responsibility to make sure that the group stays on task, completes all the tasks in the time given, and asks the teacher if there are any questions. This is the only person who can ask the teacher questions.

Name:

**Reader/Recorder** – this person will read the directions aloud to the group. This person will also be responsible for writing down the group's data and answers to questions. However, all group members' are responsible for contributing to answers and must copy answers/data after the lab is completed. Any whiteboarding that needs to be done to share out will be completed by the Reader/Recorder.

Name:

**Lab Coordinator** – this person is responsible for collecting, caring for, and returning the materials. This person will be the main experimentalist and will follow the directions given by the Group Manager and Reader. The lab coordinator will carry out the procedure.

Name:

Reporter/Lab Assistant – this person’s first duty is to aid the lab coordinator as most experiments require two sets of hands. Secondly, when sharing out, the Reporter will deliver results to the class and answers questions other classmates may raise.

Name:

## OBJECTIVE

In this experiment, you will quantitatively analyze the relationship between current, voltage, and resistance through measurements and graphs.

## MATERIALS

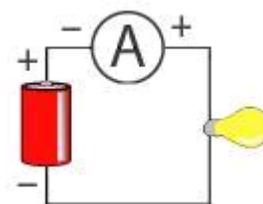
ammeter  
light bulbs  
wires

computer  
batteries

## PROCEDURE

### Part 1: Series Circuits

1. Your teacher will put on the board the voltage supplied by the batteries and resistance in one light bulb. Record those in the data section.
2. Connect a light bulb in series with an ammeter and the batteries as shown in the diagram above. Remember that an ammeter measures current. Record the current the ammeter measures in the data table.
3. Do this again, each time connecting more light bulbs in **series** until there are 4 light bulbs in the circuit. Record the current each time.



### Part 2: Parallel Circuits

4. Connect a light bulb with an ammeter and the batteries as before. Remember that an ammeter measures current. Record the current the ammeter measures in second data table.
5. Do this again, each time connecting more light bulbs in **parallel** until there are 4 light bulbs in the circuit. Record the current each time.
6. Continue to the “Processing the Data” section.

## DATA

Voltage from batteries: \_\_\_\_\_

Resistance in one light bulb: \_\_\_\_\_

Data Table 1: Series Circuits

Trial #	# of light bulbs	Total Resistance ( $\Omega$ )	Current (A)
1	1		
2	2		
3	3		
4	4		

**To get the total resistance in a series circuit, add up the resistance of each light bulb.** ( $R_{\text{tot}} = R_1 + R_2 + \text{etc.}$ )

Data Table 2: Parallel Circuits

Trial #	# of light bulbs	Total Resistance ( $\Omega$ )	Current (A)
1	1		
2	2		
3	3		
4	4		

**This time, getting the total resistance is a bit trickier. Ask your teacher for help with the calculation. The formula is below.**

$$1/R_{\text{tot}} = 1/R_1 + 1/R_2 + \text{etc.}$$

## GRAPHS

### Part 1: Series Circuits

1. On the computer, plot the Current on the y axis and the Total Resistance on the x axis.
2. Describe the curve/line that is formed by this plot. What kind of relationship exists between current and resistance? Sketch your graph below.

## Part 2: Parallel Circuits

3. On the computer, plot the Current on the y axis and the Total Resistance on the x axis.
4. Describe the curve/line that is formed by this plot. What kind of relationship exists between current and resistance? Sketch your graph below.

5. What happens if you multiply the Current and Total Resistance for any of the points on the graph? Do so for a few of the points. How does it compare to the value of the batteries' voltage?

## **QUESTIONS**

What must be true about the resistance of the ammeter if we are not considering it when we calculate the total resistance?

## **PRE-LAB QUESTIONS**

We will be connecting light bulbs, batteries, and meters in a circuit and looking at how different arrangements change the properties of the circuit.

1. Write a sentence describing current to someone who has never taken physics.
2. In our circuits, the power to light a light bulb comes from the battery. Where do most light bulbs get their power from?
3. What is Ohm's Law? Explain the relationship with words.
4. A light bulb is most nearly what kind of equipment that we draw in circuit diagrams? How do you know?
5. What does it mean to put resistors in series? What do you think will happen to brightness if we put two light bulbs in series?
6. What does it mean to put resistors in parallel?

## EXPERIMENT 12

### Chemistry Skill-Building<sup>5</sup>

Techniques used in different fields of science vary greatly. The skills you have developed during physics experiments will serve as a foundation and a jumping point for learning additional practices used in chemistry. In this experiment, you will be introduced to new equipment. You will identify its purpose and practice using some of it so that you will be more comfortable using it in future experiments.

**Volume** is a three-dimensional measurement that tells us how much space something is taking up. Some units that we will use include liters (L), milliliters (mL), and cubic centimeters (cm<sup>3</sup>). 1 mL is the same volume as 1 cm<sup>3</sup>. To measure volume, we will most frequently use a graduated cylinder.

**Mass** tells you how much matter is in an object. Early in the school year you used a triple-beam balance and a digital balance to measure mass. Both of those gave you a number with units of grams (g). When discussing the mass of a person, kilograms (kg) would be a more convenient unit.

A **Bunsen burner** is a metal device connected to a gas line via rubber tubing that provides a controlled, variable flame. By adjusting the bottom portion, the flame will become stronger or weaker. To light the burner, the gas line must be on and then a match or lighter can ignite the gas. It is important that the gas *never* be on unless the Bunsen burner is about to be lit.

Sometimes liquids contain particles of solids that are not dissolved. Fine particles or particles that settle slowly are often separated from a liquid by filtration. **Filtration** is a technique that we will use to separate a solid from a liquid or a *solution* (a kind of mixture where something is dissolved, like salt water). A piece of *filter paper* will be folded in such a way that the liquid portion can pass through but solids are left behind. The liquid or solution that passes through is called the *filtrate*.

You will also answer safety questions that will, in part, re-familiarize you with equipment in the laboratory. Because you use many chemicals in the chemistry laboratory, it is important to know something about them. Most chemicals are dangerous – e.g., poisonous when they enter the body, burn or irritate the skin, eyes and/or membranes of your digestive and respiratory tracts. Some chemicals destroy fabrics, especially synthetic or protein fibers. Chemicals can even make some things burn. Generally, most chemicals combine at a reasonable rate; however, under

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<sup>5</sup> Sections from Bolton, Ruth P., Lamphere, Elizabeth V., and Menesini, Mario. (1979). *Laboratory Experiments in ACTION CHEMISTRY*. Holt, Rinehart and Winston, Publishers, New York. p. 4-10.

certain conditions they can get out of control. Knowing these things about chemicals helps you to prevent accidents and to work safely in the laboratory. Besides safety equipment, you will also learn the names and purposes of other tools used in chemistry experiments.

## **OBJECTIVES**

In this experiment, you will

- practice techniques and taking measurements with the correct number of significant figures.
- become comfortable and familiar with safety equipment and tools for future experiments.
- understand the purpose of various safety practices.

## **MATERIALS**

graduated cylinders

sugar water solution

balances

beakers

evaporating dish

spatula

sodium chloride

Bunsen burner/matches

ring stand/iron ring

wire gauze

thermometer

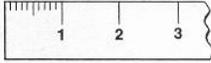
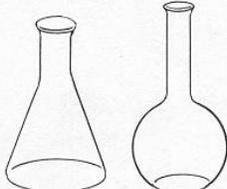
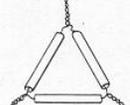
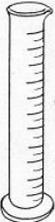
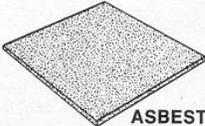
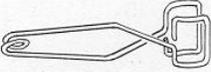
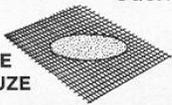
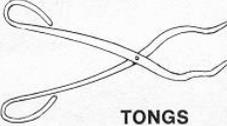
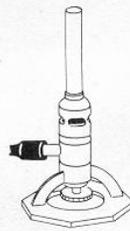
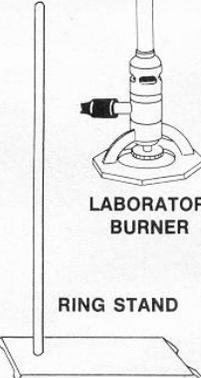
sand-water mixture

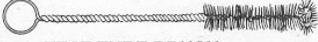
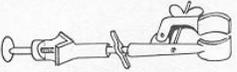
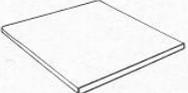
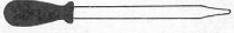
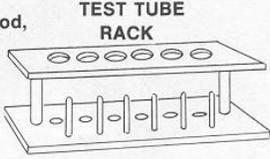
filtration setup, *including funnel, filter paper, pipestem triangle, ring stand, iron ring*

other various pieces of laboratory equipment

including tongs, stirring rod, forceps, test tube clamp, test tubes, test tube rack, test tube brush, watch glass

# LIST OF APPARATUS FOR STUDENT USE

DESCRIPTION	APPARATUS	USE	DESCRIPTION	APPARATUS	USE
glass common sizes 100 mL 250 mL 400 mL marked on the beaker	 <p>400 mL BEAKER</p>	as a container, like a cup may be heated	10 centimeter (cm) ruler, plastic divided into centimeter and millimeter (mm) divisions	 <p>10 CM RULER</p>	to measure length
glass common sizes 125 mL 250 mL 500 mL marked on the flask	 <p>ERLENMEYER FLASK      FLORENCE FLASK</p>	may be heated	triangular wire frame with clay material coverings	 <p>PIPESTEM TRIANGLE</p>	to support the crucible
glass marked with a milliliter (mL) scale	 <p>GRADUATED CYLINDER</p>	to measure volume	small porcelain dish with cover	 <p>CRUCIBLE AND COVER</p>	to heat small amounts of solid material at high temperature
size      divisions 50 mL    1.0 mL 35 mL    0.2 or 10 mL    0.5 mL 10 mL    0.1 mL	 <p>TEST TUBE</p>	many uses can be heated	hardened asbestos	 <p>ASBESTOS SQUARE</p>	to place under hot apparatus
glass several sizes	 <p>TEST TUBE CLAMP</p>	to hold a test tube	wire screen asbestos center	 <p>WIRE GAUZE</p>	to spread the heat of a flame
metal clamp with a spring handle	 <p>TONGS</p>	to pick up and hold apparatus	metal heating device connected to gas outlet with rubber tubing	 <p>LABORATORY BURNER</p>	to heat chemicals in beakers or test tubes
metal			metal rod upright heavy base	 <p>RING STAND</p>	a support with many uses

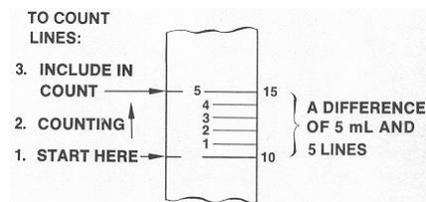
DESCRIPTION	APPARATUS	USE	DESCRIPTION	APPARATUS	USE
iron ring with screw fastener several sizes	 <b>IRON RING</b>	to fasten to the ring stand as a support for apparatus	brush with wire handle	 <b>TEST TUBE BRUSH</b>	to scrub glass apparatus
metal clamp with 1. screw fastener 2. swivel and lock nut 3. adjusting screw 4. curved clamp	 <b>BURET CLAMP</b>	to hold apparatus may be fastened to the ring stand	glass rod	 <b>STIRRING ROD</b>	to stir combinations of materials to use in pouring liquids
heavy porcelain dish with grinder	 <b>MORTAR AND PESTLE</b>	to grind chemicals to a powder	porcelain dish	 <b>EVAPORATING DISH</b>	as a container for small amounts of liquid being evaporated
may be of metal or porcelain	 <b>SPATULA</b>	to transfer solid chemicals in weighing	thick glass	 <b>GLASS PLATE</b>	many uses (should not be heated)
metal file with three cutting edges	 <b>TRIANGULAR FILE</b>	to scratch glass to file	curved glass	 <b>WATCH GLASS</b>	may be used as a beaker cover may be used in evaporating very small amounts of liquid
short length of rubber tubing	 <b>RUBBER CONNECTOR</b>	to connect parts of apparatus	glass or plastic	 <b>FUNNEL</b>	to hold a filter paper may be used in pouring
metal clamp with finger grips	 <b>PINCH CLAMP</b>	to clamp a rubber connector	glass tip with rubber bulb	 <b>MEDICINE DROPPER</b>	to transfer small amounts of liquid
rack; may be wood, metal or plastic	 <b>TEST TUBE RACK</b>	to hold test tubes in an upright position	metal	 <b>FORCEPS</b>	to pick up or hold small objects

## PROCEDURE

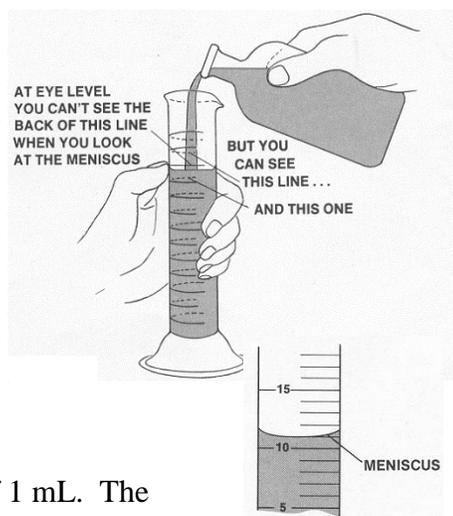
This experiment is set up in stations. You may not complete the stations in order, but you will complete all of them.

### Station 1: Volume

1. At your station, there is a graduated cylinder containing water. You will be reading the volume of the water in milliliters (mL).
2. Examine the graduated cylinder containing water. Determine how many milliliters each line represents.
3. Look carefully at the scale. Some graduated cylinders are marked differently.



4. In order to correctly read the volume, you will have to lower your eye level. You should not pick up the graduated cylinder to read it, for two reasons. First, your hand is not as steady as the bench and the level of the liquid will change. Second, there is a danger of spilling the contents, which may be harmful.



5. Read at the bottom of the meniscus (the curved surface of the liquid).
6. The meniscus diagram reading has increments of 1 mL. The bottom of the meniscus is on the 11 mL line. When taking a measurement, you always include one estimated digit. In this example, since it is right on the line, the correct reading would be **11.0 mL**. If it is between the lines, you have to *estimate* the last digit. If the increments are 0.5 mL each, then estimate to the tenths place.
7. Record your volume reading of the graduated cylinder on your bench. Write it in the data section.

8. There is a second, empty graduated cylinder at your station. Try to measure out 10 mL of the sugar water solution at your station. If you go *over* the 10 mL line, do NOT pour the sugar water back in the container. It is considered contaminated and should go down the sink (NOTE: It is safe for sugar water to go down the sink. Always check with your instructor before disposing of chemicals in this way.).
9. Record your actual volume reading for the sugar water. It's okay if it is not exactly 10 mL.

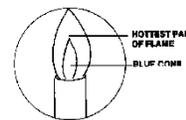
### **Station 2: Mass**

5. Examine the balance at your bench.
  - a. The ON/OFF button is self-explanatory. At the end of a lab period, balances should be turned off to conserve battery. You need to hold down the power button to do this.
  - b. The display should show a 'g' for grams. If it does not, switch the mode until it does. Having the wrong unit is like stepping on a scale in Europe and thinking you weight 56 lb instead of 56 kg!
  - c. There is also a ZERO button.
6. Often times in chemistry, we want to know the mass of a substance but we cannot directly place that material on the balance. This situation is especially true for liquids, but it is also bad practice to pour solids on the balance. The ZERO button is crucial to solving this inconvenience.
7. Make sure the balance is on and reads 0.0 g. If it does not, hit the ZERO button.
8. Place the evaporating dish on the balance and hit the ZERO button. You are essentially telling the balance not to include the mass of the beaker in the measurement.
9. Using the spatula, try to measure out 1.3 g of sodium chloride. Add slowly to the dish. If you go *over* 1.3 g, do NOT add it back to the container. The sodium chloride is considered contaminated and the extra should go in the trash can.
10. Record the reading on the balance in the data section. Since it is digital, you do not add an estimate.

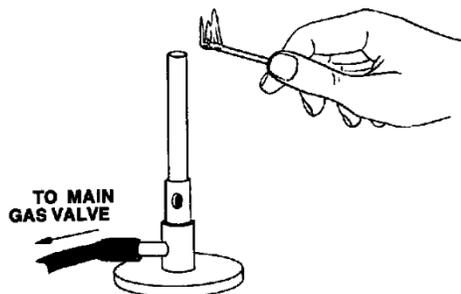
### **Station 3: Bunsen burner**

1. Fire requires three parts: (1) heat, (2) fuel, and (3) oxygen. Remove any one of these and the fire will be extinguished. There are several styles of burners available but all share the combining of heat, fuel, and oxygen. In this class, you will use a Bunsen burner.
2. Gas intake can be adjusted at the main gas valve or by a valve at the base of the burner. Oxygen intake can be adjusted at the air intake. The style of the burner and the source of heat will determine the steps you follow.

The hottest part of any flame is the tip of the inner blue cone.

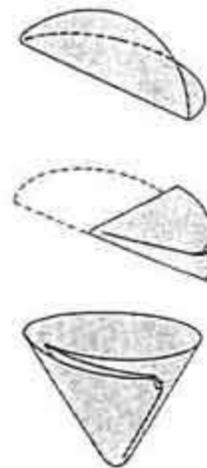


3. Rubber tubing connects the burner to the gas valve.
4. Strike match.
5. Turn on the main gas valve. The handle needs to be parallel to the rubber tubing.
6. Bring lighted match up to the chimney to ignite the gas. (If you smell gas, turn off the main gas valve and wait a couple of minutes for the odor to dissipate.)
7. Adjust the height of the flame with the main gas valve. Turn off the gas valve to turn the flame off.
8. Each partner should feel comfortable with each step. Switch roles to practice.
9. Place the Bunsen burner on the base of the ring stand so that it is right under the beaker.
10. Record the initial temperature of the water in the data section.
11. Light the Bunsen burner and heat the water up about 5 °C. Monitor the temperature with the thermometer and record the final temperature in the data section. Turn off the gas after heating the water.



#### Station 4: Filtration<sup>6</sup>

1. Fold a piece of filter paper in half. Now fold it again in quarters.
2. Hold the folded paper so that the point is facing down and look at it from above. You should be able to distinguish 4 flaps of paper.
3. Take three of the flaps to one side, separated from one of the flaps. Your filter paper should now look like a cone.
4. Place the filter paper in the funnel. (You may have to hold it there until you start pouring.)
5. Place the funnel in the pipestem triangle, which should be sitting on the iron ring.. Make sure there is a beaker under the funnel to catch the filtrate.
6. There is a mixture at your station (sand and water). Gently swirl the mixture and pour it into the filtration setup. Try to pour while the sand is *suspended* in the water. If some sand remains in the beaker, you can add water to try to flush it out. This technique gets easier with practice. Each partner should try. If sand leaks through, it means that the mixture is not being poured directly into the filter paper.



<sup>6</sup> Diagram: <http://seattlecentral.edu/faculty/ptran/pix/fold.jpg>

7. When you are finished, put as much of the filtered sand back in the filtrate (water) as you can for the next group. Discard the filter paper.

### **Station 5: Safety**

Answer the safety questions in the Questions section.

### **Station 6: Chemistry Equipment and Tools**

Try to identify the equipment on the lab bench. Then, using the equipment diagram in the Materials section, answer the equipment questions in the Questions section. Lastly, identify each of the pictures in that section.

## **DATA**

### *Station 1: Volume*

Volume measurement for water: \_\_\_\_\_

Volume measurement for sugar water: \_\_\_\_\_

### *Station 2: Mass*

Mass of the sodium chloride: \_\_\_\_\_

### *Station 3: Bunsen burner*

Initial temperature of water: \_\_\_\_\_

Final temperature of water: \_\_\_\_\_

## **QUESTIONS**

1. What unit does a graduated cylinder give volume in?
2. What does the ZERO button do on a balance?
3. How do you turn off a Bunsen burner?
4. When filtering, why do you have to put a beaker under the funnel?

*Station 5: Safety*

5. While you are working in the laboratory, why should you
  - a. wear safety goggles?
  - b. wear a laboratory apron?
  - c. use only the amounts and materials given in the directions?
  - d. use clean glassware?
6. Why are unused chemical never returned to their original containers?
7. Why are bottles of chemicals kept tightly closed except when a quantity of chemical is being removed?
8. Why should the teacher be informed if you are wearing contact lenses?
9. How should you dispose of chemicals that you used in the experiment?
10. If your skin itches, burns or appears red while you are using chemicals, what should you do?
11. What procedures should you follow to
  - a. report an accident resulting in injury to you or someone else?
  - b. report spilling a chemical or breaking equipment?
  - c. cope with a fire on your laboratory bench?
  - d. dispose of cracked or broken glassware?
12. Where are the following items located in the laboratory?
  - a. Fire extinguisher:
  - b. Fire blanket:
  - c. Shower:
  - d. Eye wash device:
13. Why is it important to work in a business-like manner, quietly, and with a minimum of distraction or migration around the classroom?

14. What is the meaning of the following words often found on the labels of chemicals?
  - a. Caustic:
  - b. Corrosive:
  - c. Hazardous:
  - d. Volatile:
15. Why are you not allowed to eat or drink anything in the chemistry classroom?
16. Why should you read the label on a bottle twice before using its contents?
17. A cap, cork, or stopper from a bottle of liquid is not put down on a desk while you are pouring out some of the liquid. Why?
18. Explain the statement: "*You are only as safe as the LEAST safe person in the laboratory.*"

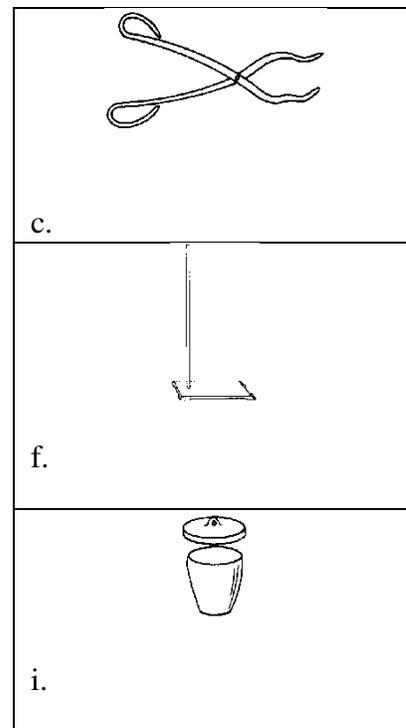
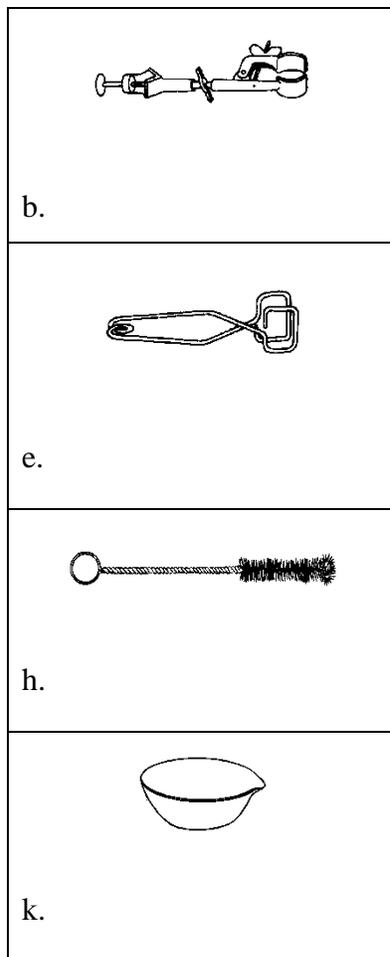
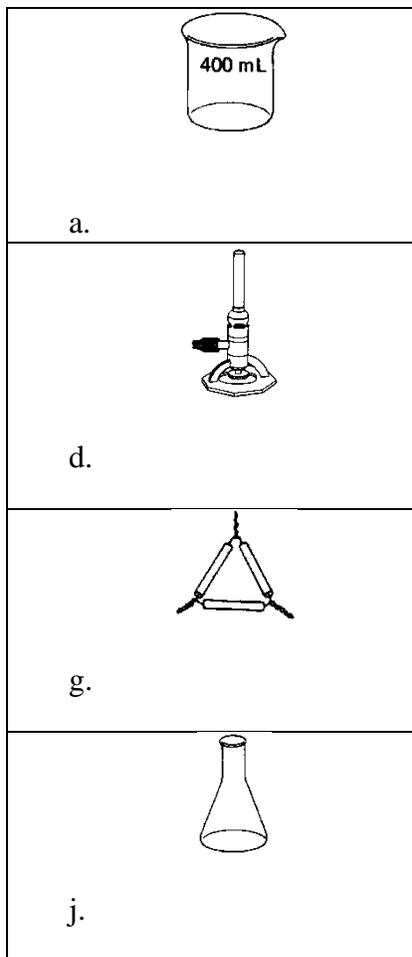
*Station 6: Equipment*

19. Name the apparatus or glassware that is used.
  - a. to pick up and hold apparatus?
  - b. to clean glassware?
  - c. as a cover for a beaker?
  - d. to transfer solid chemicals in massing?
  - e. as a container for small amounts of liquid being evaporated?
  - f. to grind chemicals to a powder?
  - g. to measure a volume of a liquid?

h. to measure length?

i. to measure mass?

20. Identify each of the following items.



## **PRE-LAB QUESTIONS**

1. Define the following terms:

Volume, Mass, Bunsen burner, Filtration, Filtrate

2. Give two reasons why safety in the laboratory is important.
3. Familiarize yourself with the equipment diagrams provided in this experiment.

## EXPERIMENT 13

### Thermal Energy from Foods

You use food as fuel for your body. Food contains the stored energy you need to walk, run, think, and so on. To keep your body process going, your body must release the energy stored in food by digesting the food.

You cannot directly measure the energy contained in food. However, you can determine the amount of thermal energy *released* as a sample of food is burned by determining the thermal energy *absorbed* by water heated by the burning sample. The water absorbs the energy released by the burning sample. By measuring the temperature change of a given mass of water, you can calculate the energy released from the food sample. Raising the temperature of 1 gram of water by 1 degree Celsius requires 4.19 joules of energy. This information can be expressed as the specific heat of water:

$$c_{\text{water}} = 4.19 \frac{J}{g \cdot ^\circ C}$$

It is easier to measure information about water than about the unfamiliar food sample. You will use your knowledge of water to figure out the energy released by the food sample. Since the energy released by the food should be absorbed by the water, the absolute values of energy absorbed and released are equal:

$$|\text{energy released}| = |\text{energy absorbed}|$$

You can use the following equation to determine the value of the heat ( $Q$ ) released when a food sample is burned:

$$Q = m_w c_w \Delta T = m_w c_w (T_f - T_i)$$

where  $Q$  is the energy absorbed by the water,  $m_w$  is the mass of the water,  $c_w$  is the specific heat of water, and  $\Delta T$  is the change in temperature of the water.

### OBJECTIVES

In this experiment, you will

- calculate a change in thermal energy.
- determine the heat absorbed per gram of food burned.
- relate chemical concepts to nutritional information on the foods you eat.

## MATERIALS

flask  
ring stand/iron ring  
food samples  
evaporating dish  
matches  
graduated cylinder

paper clip  
wire gauze  
thermometer  
wood splint  
balance

## PROCEDURE

1. Straighten the paper clip and insert it through the first food sample. Balance the paper clip across the evaporating dish. Measure the mass of the sample, paper clip, and evaporating dish and record it as  $m_{is}$  (initial mass of the sample) in the data section.
2. Place the clean, dry flask on the balance and hit the “zero” button.
3. Measure 50 mL of water using the graduated cylinder.
4. Pour the water into the flask on the balance. Record the reading on the balance, which is the mass of the water, in the data section as  $m_w$ .
5. Place the flask on the wire gauze as shown by your instructor. Measure the temperature of the water. (Remember, your measurement should include all of the digits that the tool provides plus one estimated digit.) Record this temperature as  $T_i$ .
6. Light the wood splint with a match. Use the burning splint to ignite the food sample. Once the food sample is burning, safely extinguish the splint. Position the evaporating dish under the flask. The water in the flask should absorb most of the energy released by the burning food.
7. Gently stir the water with the temperature probe and closely observe the temperature rise.
8. Blow out the flame of the burning food after about 2 minutes. (Your sample might take more or less time: try to burn as much of it as possible.) Record the **highest** temperature of the water during the 2 minutes as  $T_f$ .
9. Allow the evaporating dish and its contents to cool. Determine the mass of the dish, paper clip, and remaining food sample. Record this value as  $m_{fs}$  (the final mass of the sample).
10. Repeat **Steps 1-9** for a different food sample. Wipe off the paper clip so that no residual food from the first trial remains. Be sure to clean out the evaporating dish and get new water for the flask.

## DATA

Food Sample	Mass of Sample Set-up (g)		Mass of water (g)	Temperature of Water (°C)	
	$m_{is}$	$m_{fs}$	$m_w$	$T_i$	$T_f$

## CALCULATIONS

Remember to label each calculation and to show all work, including formulas and units.

1. Calculate the change in temperature,  $\Delta T$ , for each trial.
2. Use the equation given in the introduction to calculate the energy absorbed by the water for each trial. Be sure to use the mass of the water, NOT the mass of the food sample set-up.
3. Calculate the mass of the food that was burned by subtracting the final mass from the initial mass. (Note that this calculation, ‘initial – final,’ is a bit “backwards” because we want a positive answer.  $(m_{is} - m_{fs})$  will tell us the mass of food burned.)
4. Calculate the heat absorbed **per** gram of food burned by dividing the energy absorbed by the water by the mass of food burned. Don’t forget a unit! It will become evident when you do the calculation.

$$\text{heat absorbed per gram of food burned} = \frac{Q}{m_{is} - m_{fs}}$$

5. Suppose 20.0 g of your first food sample is burned completely. Use your result from #4 above to calculate the value of energy released in this situation. (You know the heat released PER ONE GRAM of food burned. How much will be released if you burned 20.0 g?)

## QUESTIONS

1. In order to calculate the amount of energy released or absorbed by a substance, what information do you need?
2. What measurement did you take that proves energy is being transferred in this experiment?
3. Did you **measure** information to directly calculate the energy released by the food sample or the energy gained by the water?
4. Most of the energy of the burning food was absorbed by the water. What do you think happened to the small amount of energy that was not absorbed by the water?
5. Look at the results of your calculations. Which food sample released
  - b. the most energy?
  - c. the most energy per gram of food burned?

## **PRE-LAB QUESTIONS**

1. Why does the temperature of the water increase? Be very specific.
2. Consider the specific heat of water. How much energy would it take to raise the temperature of **2 g** of water by 1 °C? You can do the full calculation or you could try to figure it out intuitively.
3. Why is it important to position the evaporating dish right below the flask of water?

# EXPERIMENT 14

## Properties of Matter

Everything that has mass and takes up space is called matter. Matter exists in four different states: solid, liquid, gas, and plasma. This paper, your hand, water, and the air you breathe all consist of matter. Even the planets and stars are made of matter.

Scientists use two types of properties to describe matter. Physical properties depend on the nature of the matter. They are observed when there is no change in chemical composition. The physical properties of water describe it as a colorless, nonmagnetic liquid between the temperatures of 0 °C and 100 °C with a density of 1.0 g/mL. Chemical properties describe the change in chemical composition of matter due to a chemical reaction. A chemical property of water is its reaction with iron to form rust.

Matter is constantly changing. A physical change involves a change in shape, size, state, and so on. When a material changes composition, a chemical change occurs.

### OBJECTIVES

In this experiment, you will

- find the density of salt water and of solid samples.
- classify materials by states of matter.
- identify physical and chemical properties.
- distinguish between physical and chemical changes.

### MATERIALS

table salt (sodium chloride, NaCl)  
beaker  
stirring rod  
copper strip  
iron sample  
magnet  
matches  
chalk  
iodine solution

graduated cylinder  
balance  
funnel  
wood sample  
rubber sample  
sugar solution  
test tubes  
starch solution  
hydrochloric acid, HCl

## PROCEDURE

### **Part 1: Density of Salt Water**

1. Measure approximately 10 g of table salt into the beaker.
2. Measure 50 mL of water and pour it into the beaker. Stir the mixture thoroughly so that all of the salt dissolves.
3. On the balance, “zero” the mass of the clean, dry graduated cylinder.
4. You are going to measure the mass and volume of five amounts of the salt water. Using the funnel placed in the graduated cylinder, pour a small amount of the mixture (no more than 15 mL) into the graduated cylinder.
5. Remove the funnel. Measure and record the mass and volume of this first sample in Data Table 1.
6. Add some more salt water to the graduated cylinder. Measure and record the mass and volume again. Do this three more times (a total of five samples).

### **Part 2: Density of Solids**

7. There are two solids at your bench. Start with the cube and measure its mass. (Make sure you have reset your balance.) Record the mass in Data Table 2.
8. Measure the dimensions of the cube so that you can calculate its volume. (Volume = length\*width\*height). Record the information in the data table.
9. Measure and record the mass of the cylindrical solid.
10. To measure the volume of the cylinder, you will see how much water it displaces. Put 30 mL of water in the graduated cylinder. (It is not essential to have exactly 30 mL, but be sure to note the exact amount of water you have on your data table). **Slide** the metal cylinder along the side of the graduated cylinder into the water (to avoid water splashing out or **breaking the glass**). Record the new volume of both the water and metal cylinder. The difference is the volume of the cylinder.

### **Part 3: Physical Properties of Four Samples**

11. Examine the samples of iron, wood, rubber, and copper. In Data Table 3, describe the physical properties listed and any other properties you can readily observe.
12. Test each sample for its attraction to a magnet. Record your observations in Data Table 3.
13. Use each sample to complete the circuit provided. Record whether the sample conducts electricity in the data table.

### **Part 4: Chemical Properties**

14. Organize three clean, dry test tubes in your test tube rack.
15. One partner should be ready to light a match. Add about half an inch of hydrochloric acid to the first test tube.
16. Make observations of the appearance of both hydrochloric acid and chalk, before they are mixed.
17. Place a small amount of chalk in the acid and observe what happens. Light the match and hold it directly inside the mouth of the test tube (without dropping it in). Record all of your observations in Data Table 4.
18. In the second test tube, add 10-15 drops of **starch** solution.

19. Make observations of the appearance of both starch and iodine, before they are mixed.
20. To this test tube, add 2 drops of iodine solution and record observations in Data Table 4.  
(Record the initial observations, i.e. before mixing, as well.)
21. In the third test tube, add 10-15 drops of **sugar** solution.
22. Make observations of the appearance of both sugar and iodine, before they are mixed
23. To this test tube, add 2 drops of iodine solution and record observations in Data Table 4.  
(Record the initial observations, i.e. before mixing, as well.)
24. Clean and dry all of your equipment.

## **DATA & OBSERVATIONS**

Table 1: Density of Salt Water

<b>Sample</b>	<b>Mass (g)</b>	<b>Volume (mL)</b>
1		
2		
3		
4		
5		

Table 2: Density of Solids

<b>Sample</b>	<b>Mass (g)</b>	<b>[Other Measurements]</b>	<b>Calculated Volume (cm<sup>3</sup> or mL)</b>
Cube		Length: Width: Height:	
Cylinder		Initial Volume: Final Volume:	

Table 3: Physical Properties of Four Samples

<b>Sample</b>	<b>Color</b>	<b>Shape</b>	<b>State of Matter</b>	<b>Other Properties</b>	<b>Attracted to magnet?</b>	<b>Conducts electricity?</b>
iron						
wood						
rubber						
copper						

Table 4: Observations of Chemical Properties

*Remember that observations are much more informative when there is an “initial observation,” i.e. what the materials looked like before they were mixed together. Record this information as well.*

Material Reacting	<u>Observations</u>	
	Before	After
hydrochloric acid + chalk		
starch solution + iodine solution		
sugar solution + iodine solution		

## **CALCULATIONS & GRAPH**

### **Part 1**

1. Make a graph of Mass (y) vs. Volume (x) and plot the data points. Be sure to label the axes and title the graph. Draw a line of best fit. Calculate the slope (with appropriate units). The slope is the density of salt water. Follow any instructions your teacher might give.

### **Part 2**

2. Calculate the density of the cube and that of the cylinder.

## **QUESTIONS**

### **Part 1**

1. Do you think the density of salt water should be greater than or less than that of water? Explain. Is your value greater than or less than that of pure water? (It’s okay if your result doesn’t match what you think it should be. Defend your answer choice).
2. Using your graph, determine what the mass of 60 mL of salt water would be.
3. Would salt water float on water? Why or why not?

### **Part 2**

4. Compare the density of the two solids. They are made of the same metal. Should the densities be the same or different? Comment on your results (i.e. if the densities match or not).
5. What would happen to the density of the metal cylinder if it were cut in half?

### **Part 3**

6. What are two physical properties that iron and copper have in common?

### **Part 4**

7. When you added the chalk to the hydrochloric acid, what type of change took place? How do you know?
8. Which solution do you think had a chemical reaction with iodine: starch or sugar? Why?

## **PRE-LAB QUESTIONS**

1. Is density a physical or chemical property?
2. What is the formula for density? Give sample units for each part of the formula.
3. Distinguish between a physical and a chemical property.
4. Your younger sibling really likes orange juice but drinks so much that the acid is a problem. Your parent adds water to the juice so it's not too strong.
  - a. What happens to the color of the orange juice if a lot of water is added?
  - b. Is mixing orange juice and water a chemical reaction?
5. In Part 1, what equipment are you using to get the volume?
6. In Part 2, name the two ways (tool/technique) you will use to get volume.

## EXPERIMENT 15

### Physical and Chemical Changes

Matter undergoes many changes. You are familiar with both physical and chemical changes. A **physical change** is one that does not alter the identifying properties of a substance. It can be a change in form, state, or energy level, but no “permanent” change occurs in the properties of the substance, i.e. no change in the bonding. A piece of paper torn into two parts, for example, still has the properties of the original paper and no new substance has been formed. Thus tearing a piece of paper into two parts is a physical change. Evaporation, condensation, melting, freezing, and dissolving are all examples of physical changes.

A **chemical change** is one that produces new substances with new properties. A piece of paper that burns produces gases and ash that have different properties than the original paper, so this is an example of a chemical change. Heat, light, and electricity often produce chemical changes. Chemical changes occur as (1) atoms combine to form new compounds, (2) compounds break down into simpler substances, and (3) compounds react with other compounds or elements to form new substances. In short, chemical bonds are broken and/or formed.

### OBJECTIVES

In this experiment, you will

- determine if certain changes in matter are physical or chemical changes.
- support your determinations with evidence.

### MATERIALS

sodium chloride, NaCl  
evaporating dish  
nichrome wire  
magnesium ribbon  
dilute hydrochloric acid (HCl) solution  
funnel  
ring stand/iron ring  
copper(II) chloride (CuCl<sub>2</sub>) solution  
aluminum foil  
stirring rod  
watch glass

graduated cylinder  
Bunsen burner  
tongs  
small test tube  
silver nitrate (AgNO<sub>3</sub>) solution  
filter paper  
clay triangle  
beakers (100 mL and 250 mL)  
balance  
wire gauze

## **PROCEDURE**

### **Part 1: Sodium chloride solution**

1. Measure 2.0 g of sodium chloride in a clean, dry evaporating dish. Pour the NaCl into a **small**, clean, dry beaker.
2. Measure 50 mL of water in the graduated cylinder. Pour the water into the beaker. Use the stirring rod to help dissolve the NaCl. Note the approximate level of the solution in the beaker (for later comparison).
3. Continue dissolved 2 g samples of NaCl until a total of 10 g are dissolved. Watch the level of the solution after each addition. Be sure to stir so that all of the salt is dissolved.
4. Record your observations of the level of the solution in the observations section. (Does it change? How?)
5. Clean out your evaporating dish.
6. Measure about 5 mL of the sodium chloride solution in the graduated cylinder. Pour the sample of the solution into the evaporating dish. Make observations of the sample.
7. Place the evaporating dish above the Bunsen burner on the wire gauze. Light the burner.
8. Heat the solution until a dry solid remains. Record observations of the heating process and of the solid.

### **Part 2: Heating wires**

9. Carefully examine the nichrome wire sample, noting the color, luster, flexibility, and other properties you can observe in the observations section.
10. Light the Bunsen burner. Hold the wire with tongs and heat it strongly in the flame of the burner until it glows brightly. **After the wire cools**, again examine the wire, recording the properties as you did before.
11. Carefully examine the magnesium ribbon sample, noting the color, luster, flexibility, and other properties you can observe in the observations section.
12. Hold the ribbon with tongs and ignite the end in the flame of a burner. **CAUTION:** Do not look directly at the magnesium while it is burning. Afterward, again examine the magnesium, recording the properties as you did before.

### **Part 3: Silver nitrate and hydrochloric acid**

13. Carefully pour silver nitrate solution into the small test tube so that is about one-third to one-half full. Record the color of both this solution and the hydrochloric acid, before mixing.
14. Add several drops of dilute hydrochloric acid solution, gently swirling the mixture with the addition of each drop. Record your observations.
15. Filter the solid that forms (the precipitate), using small amounts of water as necessary to flush all the precipitate from the test tube.
16. Record your observations of the precipitate.

17. Discard the filtered liquid (the filtrate) and place the filtered precipitate on the watch glass. Place the watch glass on a sunny part of your lab bench. Allow it to sit for two or three minutes and then make another observation (you can move on in the meantime).

**Part 4: Copper(II) chloride and aluminum foil**

18. Place a piece of crumpled aluminum foil in a large, clean, dry beaker.
19. Record observations of both the aluminum and the copper(II) chloride solution before mixing.
20. Pour enough copper(II) chloride solution in the beaker so that it is contact with aluminum foil. Your teacher will show you how much is needed.
21. Observe the results.

## OBSERVATIONS

Table: Observations of Physical and Chemical Changes

Action	Observations
Part 1: Dissolving sodium chloride (level of solution)	
Part 1: Heating NaCl solution and observing the solid	Before:  After:
Part 2: Heating nichrome wire	Before:  After:
Part 2: Heating magnesium ribbon	Before:  After:
Part 3: Silver nitrate + hydrochloric acid	Before:  After:
Part 3: Precipitate in sunlight	Before:  After:
Part 4: Aluminum foil + copper(II) chloride	Before:  After:

## QUESTIONS

1. What **kind** of change (physical or chemical) occurs when sodium chloride dissolves in water? Give an explanation for your answer.
2. What **kind** of change (physical or chemical ) occurs when the salt water solution was heated? What change was it, specifically (give the name)?
3. Use your observations to state whether a new substance was formed after heating each of the following:
  - a. the nichrome wire.
  - b. the magnesium ribbon.
4. What evidence indicates if new substances with new properties were or were not formed when hydrochloric acid was added to silver nitrate solution?
5. Did the precipitate exposed to sunlight undergo a physical or chemical change? Give an explanation for your answer.
6. What **kind** of change occurred when the aluminum foil was in the copper(II) chloride solution? Give an explanation for your answer.

## PRE-LAB QUESTIONS

1. State whether the following observations/changes would indicate a physical or chemical change.
  - a. Sugar dissolves in water
  - b. Bread left in the sunlight turns green
  - c. A piece of paper turns brown when lit on fire
  - d. An ice cube melts
  - e. A piece of metal has rusted
  - f. A nail left in copper(II) sulfate develops a red-brown coating
2. Give an example of a physical and chemical change that could occur to a tree branch.
3. Predict what will happen in Part 1 when the solution is heated. (You will need to read carefully.)
4. Copper(II) chloride solution is blue. What color is copper metal? Give an example of where a person could find copper metal.

# EXPERIMENT 16

## Separating a Mixture

A mixture is formed when substances combine without changing chemically. Each component or ingredient of a mixture retains its own identity and properties. Physical changes are used to separate the components of a mixture.

### OBJECTIVES

In this experiment, you will

- describe the characteristics of mixtures.
- identify the substances in a mixture by their physical properties.
- separate these substances according to physical properties.

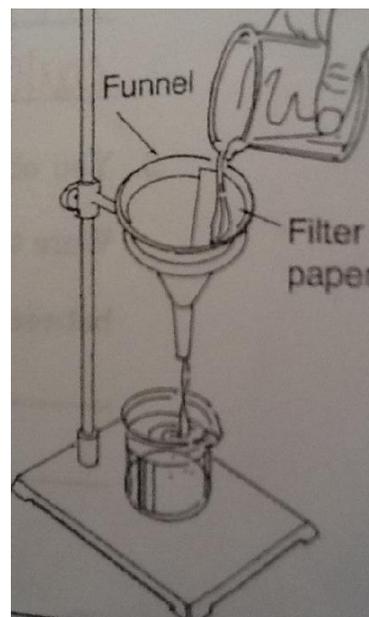
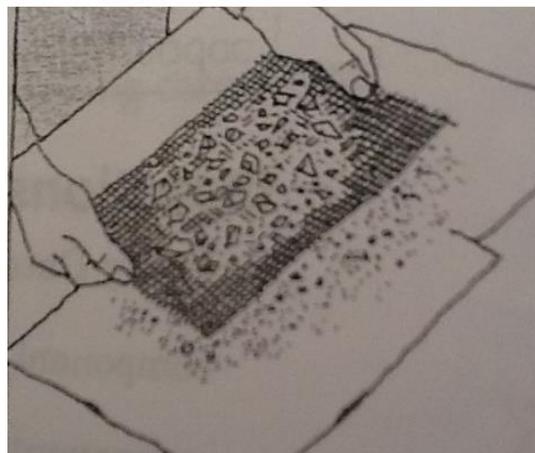
### MATERIALS

beakers (100 mL, 250 mL)  
clamp  
filter  
filter paper  
paper towels  
ring stand  
wire gauze  
pipestem triangle

funnel  
graduated cylinder  
magnet  
mixture  
plastic bag  
stirring rod  
water

### PROCEDURE

1. Examine your mixture. Estimate the number of components making the mixture. (You do not need to record this.)
2. Unfold a paper towel and put it on your lab bench. Holding the wire gauze over the paper towel, filter the large pieces from the mixture. (See right.) Place the **large pieces** aside on a second paper towel and label them **Component A. Set this component aside.**
3. Place another paper towel, labeled Component B, on your lab bench. Use a magnet wrapped in a plastic bag to separate the metal filings from the rest of the mixture. Remove the magnet from the bag to release the **metal filings** on to the paper towel. **DO NOT** let the metal filings get stuck to the magnet itself. Set aside **Component B.**
4. Place the remaining mixture in a 250-mL beaker. Add about 25 mL of water and stir the mixture. Filter the mixture (as demonstrated by your instructor and shown to the right), collecting the **filtrate** in another beaker. Place the beaker with the filtrate on a paper towel, labeled **Component C**, and place it aside.
5. Allow the **component on the filter paper** to dry on another paper towel. Label it **Component D.**
6. Complete the table below by making observations of the physical properties of the various components. There should be *at least* three observations for each component. Some examples could be the color, state of matter, if it is dissolved in anything, etc.



## OBSERVATIONS

Table 1: Observations of Separated Components

Component	Physical Properties
A	
B	
C	
D	

## QUESTIONS

Table 2: Physical Properties of Known Substances

<b>Component</b>	<b>Physical Properties</b>
sand	does not dissolve in water, small grains, many colors including orange/brown/tan, not attracted to magnet
iron	metallic, attracted to a magnet, small, black filings
marble chips	large rock pieces, many colors including white and pink
copper(II) sulfate	dissolves in water, blue when dissolved, not attracted to magnet

1. Using the table above and your in-lab observations, identify each of the components of your mixture. Note that it is not necessary to include Table 2 in your lab report.
2. Explain how you know that the combination of substances you began with was a mixture and not one compound.
3. You observed several changes while separating the components of the original mixture. Were these changes physical or chemical?
4. Name the specific change(s) that occurred in each of the following procedure steps. An example of a “specific change” would be *evaporation*, although that did not occur in this experiment.
  - a. Step 2 (identify 1 change)
  - b. Step 4 (identify 2 changes)
5. Explain the differences between physical and chemical changes and how this lab furthered your understanding.

## PRE-LAB QUESTIONS

1. When doing a filtration, what is the filtrate?
2. Identify the physical **property** in Procedure Steps 2, 3, and 4, respectively, which is essential to that point in the separation. In other words, in each of those steps, what property of a component allows you to separate it from the rest of the mixture?

# EXPERIMENT 17

## Chemical Structures

In your notebook or on the whiteboard, it can be hard to picture what a molecule or an ionic network really “looks” like. Very powerful microscopes are needed to probe these structures but we can also use macroscopic models to wrap our head around the three-dimensional nature of matter.

In class, you have practiced drawing structures of molecules such as H<sub>2</sub>O or CO<sub>2</sub> and have seen diagrams of ionic compounds. On the atomic level, however, substances exist in three dimensions. This concept will be explored hands-on.

### OBJECTIVES

In this experiment, you will

- use model kits to create three-dimensional structures of various molecules.
- use model kits to discover the structure of more complex molecules.
- investigate the three-dimensional nature of ionic lattices.

### MATERIALS

model kits

ionic lattice models

### PROCEDURE

#### Part 1: Molecules

H<sub>2</sub>   H<sub>2</sub>O   CO<sub>2</sub>   NH<sub>3</sub>   CCl<sub>4</sub>   C<sub>2</sub>H<sub>6</sub>   C<sub>2</sub>H<sub>4</sub>   C<sub>2</sub>H<sub>2</sub>   C<sub>6</sub>H<sub>14</sub>

1. You will use the model kits and the provided guide to construct each of the molecules above. First, put together the **first** molecule. **Proceed to Step 2.**
2. Next, draw the structure of the molecule. You may have only used one “bond” from the kit, but think about whether that must represent a single, double, or triple bond. Include the correct number of bonds in your structure.

3. **For C<sub>6</sub>H<sub>14</sub>**, construct the molecule at least three different ways. Draw the structures for each. Check with your teacher to make sure your three answers are actually different.

### **Part 2: Ionic Lattice**

4. Look at the ionic lattice model. Try to decide the chemical formula based on the model. You can use X for the cation and Z for the anion.

### **DATA**

**Part 1:** Draw your molecular structures below. After you draw the molecule, include lone pairs of electrons where appropriate. Label each structure with the appropriate chemical formula.

**Part 2:** Chemical formula of the ionic compound \_\_\_\_\_

## **QUESTIONS**

1. Is H<sub>2</sub>O a linear molecule?
2. Using the chemical formula for the ionic compound, which of these is the possible identity? NaCl, BaI<sub>2</sub>, K<sub>2</sub>O, Mg<sub>2</sub>O<sub>2</sub>
3. What have you learned from this experiment? What have you found interesting? Do you view chemical structures in the same way as you did before the experiment?
4. Define the word *isomer*. How is it relevant to this experiment?

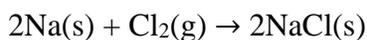
## **PRE-LAB QUESTIONS**

1. If the following elements were to form covalent bonds, how many bonds would each element need?
  - a. Carbon
  - b. Hydrogen
  - c. Chlorine
  - d. Oxygen
  - e. Nitrogen
2. What is the difference between an ionic and a covalent bond?

## EXPERIMENT 18

### Chemical Reactions

The changes that occur during a chemical reaction are represented by a *chemical equation*. An equation uses chemical symbols to represent the reactant and products. An arrow stands for the word “yield” or “produce.” The reactants are the substances that react. The products are the substances that are formed from the reaction. For example, the reaction of the elements sodium and chlorine to produce sodium chloride is given by the following chemical equation.



*Reactants*                  *product*

In a *synthesis reaction*, two or more substances react to form a new, more complex substance. You may think of a synthesis reaction as putting substances together to produce a single new substance. The synthesis reaction of hydrogen peroxide is given by the equation below.



A *decomposition reaction* produces several simpler products from the breakdown of a single compound. This process takes one compound and breaks it down into several compounds and/or elements.



In a *single displacement reaction*, two or more reactants change to form two or more products. More specifically, one element replaces another in a compound. In the following reaction, carbon displaces the hydrogen in water and elemental hydrogen is released as hydrogen gas.



Chemical reactions often take place between two reactants in the same solution. When the reaction occurs, solid particles may form within the container. These products, called *precipitates*, are insoluble solids. For example, look at the following reaction.



AgCl is a precipitate, while the soluble product, NaNO<sub>3</sub>, remains in solution. Silver and sodium cations are exchanged in this reaction. Such a reaction is called a *double displacement reaction*. The formation of the precipitate is a visible indication that the reaction has occurred.

### OBJECTIVES

In this experiment, you will

- recognize the reactants and products of a chemical reaction.
- identify the type of chemical reaction you observe.
- learn how chemical equations can more simply represent the reaction occurring.
- observe several double displacement reactions and distinguish when there is no reaction.

## MATERIALS

aluminum foil/tray	matches
tongs	steel wool (Fe source)
test tubes	wood splint
baking soda (sodium bicarbonate, $\text{NaHCO}_3$ )	Bunsen burner
beaker	copper(II) sulfate solution ( $\text{CuSO}_4$ )
iron nail (Fe)	barium chloride solution ( $\text{BaCl}_2$ )
sodium carbonate solution ( $\text{Na}_2\text{CO}_3$ )	sodium hydroxide solution ( $\text{NaOH}$ )
iron(III) chloride solution ( $\text{FeCl}_3$ )	potassium sulfate solution ( $\text{K}_2\text{SO}_4$ )

## PROCEDURE

### Part 1: Synthesis Reaction

1. Protect the table with a sheet of aluminum foil or a tray. Place the **unlit** Bunsen burner in the center of the foil/tray.
2. Observe the color of the steel wool. Record your observations in the observations section.
3. Remember that the steel wool is the source of iron for the reaction. Predict if there will be any changes in the steel wool if it is heated in a flame (and what they might be). Write your prediction in the observations section.
4. Light the burner. Be sure to stay clear of the flame.
5. Hold the steel wool with the tongs over the flame. As it burns, record the changes it goes through. Turn off the flame after you observe the changes.

### Part 2: Decomposition Reaction

**Read all of the steps in Part 2 before you begin!**

6. Place a small scoop of baking soda (containing sodium bicarbonate,  $\text{NaHCO}_3$ ) in a test tube.
7. In the data section, write your prediction of what will happen to the baking soda as it is heated. Also write your observations of the baking soda before it is heated.
8. Make sure the Bunsen burner is still on the foil/tray. Light the burner. Be ready to do steps 9 and 10 before you continue.
9. Use the test-tube holder to heat the test tube in the flame, as shown by your instructor. The bottom of the test tube should be in the flame. Angle the test tube slightly so that your hand is not directly above the flame. Do not point the mouth of the test tube at anyone.
10. After the test tube has been heated for a few moments, test for the presence of  $\text{CO}_2$ . Light a match or wooden splint. Hold the flaming splint in the mouth of the test tube. If the flame of the splint goes out,  $\text{CO}_2$  is present. Record your observations of the test.
11. Record a description of the product formed inside the test tube.

### Part 3: Single Displacement Reaction

12. Predict what change will occur when a nail sits in copper(II) sulfate solution.
13. Gently place a nail in a clean, dry beaker. Record its initial color.
14. Pour just enough copper(II) sulfate solution in the beaker so that the nail is submerged. Note the initial color of the solution. *Caution: The  $\text{CuSO}_4$  solution is toxic. Handle with care.*

15. Allow the mixture to sit for a few minutes. Once you see some changes, record the color on the nail and of the solution.

#### Part 4: Double Displacement Reactions

16. Put a paper towel under the test tube rack. Place 5 test tubes in the test tube rack. Label 5 test tubes A through E. Place 10 drops of the solutions in the test tubes as outlined below.

Test Tube A:	BaCl <sub>2</sub>	+	Na <sub>2</sub> CO <sub>3</sub>
Test Tube B:	Na <sub>2</sub> CO <sub>3</sub>	+	K <sub>2</sub> SO <sub>4</sub>
Test Tube C:	CuSO <sub>4</sub>	+	NaOH
Test Tube D:	FeCl <sub>3</sub>	+	NaOH
Test Tube E:	NaOH	+	K <sub>2</sub> SO <sub>4</sub>

17. For each test tube, record whether or not you see a precipitate. (The presence of a precipitate indicates that a chemical reaction has occurred.) If you do, record observations of the precipitate.

#### OBSERVATIONS

Table 1: Synthesis Reaction

Prediction of changes in heated steel wool	
Color of steel wool before burning	
Color of steel wool after burning	

Table 2: Decomposition Reaction

Prediction of changes in heated baking soda	
Description of baking soda before heating	
Description of deposits inside heated test tube	
Observations of flaming splint in test tube	

Part 3: Prediction of changes in nail and CuSO<sub>4</sub> solution \_\_\_\_\_

Table 3: Single Displacement Reaction

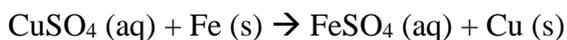
Observation Time	Color of nail	Color of CuSO <sub>4</sub> solution
before reaction		
after reaction		

Table 4: Double Displacement Reactions

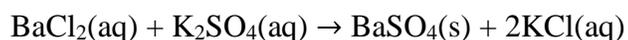
Test Tube	Reactants	Precipitate? If yes, observations of it
A	BaCl <sub>2</sub> + Na <sub>2</sub> CO <sub>3</sub>	
B	Na <sub>2</sub> CO <sub>3</sub> + K <sub>2</sub> SO <sub>4</sub>	
C	CuSO <sub>4</sub> + NaOH	
D	FeCl <sub>3</sub> + NaOH	
E	NaOH + K <sub>2</sub> SO <sub>4</sub>	

## QUESTIONS

- In Part 1, when you burn the steel wool, what metallic element is reacting? With what molecule in the air is it reacting?
- What chemical is decomposing in Part 2 (give the formula)? With respect to chemistry, what does it mean to decompose?
- In Part 2, offer an explanation for the observation you made about the flaming splint.
- Explain how Part 3 is a single displacement reaction and not a double displacement reaction. Here is the reaction:

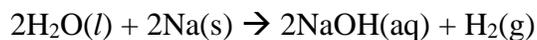


- Look at the reaction above in Question #4. Using what you know about the **products**, **explain** the colors that you observed in Part 3. (What colors correspond to what product?)
- In the pre-lab, you listed all of the cations and anions used in Part 4. For each reaction in which you **observed a precipitate**, predict the products. (Remember, for a double displacement reaction, the cations switch places.) **Important:** The products must be neutral! Pay attention to the charges on each ion. Simply switching the letters will not necessarily work.
- In the reaction below, identify which product is the precipitate.



## PRE-LAB QUESTIONS

1. What is a chemical equation?
2. Label the reactants and products in this reaction.



3. What metallic element is in steel wool?
4. What is the chemical formula for baking soda?
5. What will  $\text{CO}_2$  do to a flame?
6. What is a precipitate?
7. What does aqueous mean? (abbreviated *aq*)
8. For Part 4, list the six compounds being used. Then, for each compound, separately list the cation and anion **with their charges**. Here is an example for aluminum chloride,  $\text{AlCl}_3$ , which is *not* in Part 4.

Compound:	$\text{AlCl}_3$
Cation:	$\text{Al}^{+3}$
Anion:	$\text{Cl}^-$

## EXPERIMENT 19

### Striking it Rich!

In this experiment you will explore the meaning of the word alloy. In class, you have learned that it is a type of mixture. Recall that, in general, a mixture consists of multiple elements or compounds combined physically but not chemically. Experiment 16 was about separating a mixture. Separation as well as creation of a mixture involves physical changes. In the laboratory, you will be creating an alloy.

### OBJECTIVES

In this experiment, you will

- investigate the meaning of the word alloy.
- observe changes in the color of a penny
- conjecture what is happening at the atomic level.

### MATERIALS

3 pennies  
graduated cylinder (25 mL)  
ring stand  
tongs  
watch glass  
iron ring

beaker (250 mL)  
balance  
wire gauze  
Bunsen burner  
zinc/zinc chloride mixture  
spatula

*Caution: Zinc chloride is toxic. If you get any on your skin, wash it off. Do not put your face directly over the heated beaker. Do not touch hot glassware!*

### PROCEDURE

**The following has already been done for you:**

*Weight 2.0 g of zinc powder and place it in a 250 mL beaker. Measure 25 mL of zinc chloride ( $ZnCl_2$ ) solution in a graduated cylinder and add it to the beaker.*

**Begin here:**

1. Obtain 3 pennies per group. Use steel wool to clean each penny until it is shiny.
2. Set aside one penny to serve as the control (an untreated sample). Record the appearance of the control in the first part of the table.

3. Place two pennies on the bottom of the beaker containing the zinc/zinc chloride mixture.
4. Place a watch glass over the beaker as instructed by your teacher. Place the beaker on top of the wire gauze on the ring stand. Heat the solution over a Bunsen burner until it boils.
5. Once boiling, turn off the burner. **Wait 5 minutes.**
6. Take the beaker off the gauze and use a spatula to flip the coins over.
7. Put the beaker back over the burner, light the flame and turn it off again once the solution is boiling. **Wait 5 minutes.**
8. Carefully put the beaker on the table. Remove the pennies with a spatula/tongs and rinse them in cold water. Make and record observations of the pennies in the second part of the table. For the rest of the experiment, you only need 1 of these 2 pennies.
9. Light the Bunsen burner again. Hold 1 of the pennies from Step 8 with the tongs by the edge. Waft the penny back and forth in the flame for about 20 seconds. **DO NOT OVERHEAT!** Observe closely. Something should happen.
10. Quickly rinse the penny in cold water. Make and record observations of the penny in the last part of the table.
11. During cleanup, do not discard the zinc/zinc chloride mixture. Leave it for the next group. Be sure to wash your hands.

## **OBSERVATIONS**

Table: Observations of Three Pennies

<b>Condition</b>	<b>Observations</b>
Untreated penny	
Penny heated in Zn/ZnCl <sub>2</sub> mixture	
Penny heated in Zn/ZnCl <sub>2</sub> mixture and then in Bunsen burner flame	

## **QUESTIONS**

1. Do the treated pennies *appear* to be made from a metal other than copper? Explain why (or why not). Base your answer solely on the appearance of the pennies.
2. If someone claimed that a precious metal was created in this experiment, would you agree? Why (or why not)? Base your answer on your knowledge of chemical principles and reactions.
3. Explain two practical uses for the techniques demonstrated in this experiment.
4. In your pre-lab, you defined the term *alloy*. Restate its meaning. How does it apply to this lab? Did you successfully make an alloy? If so, which one do you think you made (name)?
5. At an atomic level (meaning on the very small scale of atoms), what do you think happened in this experiment? Re-read the introduction and think about what was made in lab.

## **PRE-LAB QUESTIONS**

1. What is the difference between a mixture and a compound?
2. What do you think the purpose of having a control penny is?
3. What is an alloy?

## EXPERIMENT 20

### Analysis of the Reaction between $\text{AgNO}_3$ and $\text{NaCl}$

In this experiment, you will use laboratory and mathematical techniques you have been mastering in order to design, conduct, and evaluate your own experiment. You will be answering the following question: how do the amounts of reactants we use affect how much product is made?

#### **OBJECTIVES**

In this experiment, your goals will be

- to predict products for a reaction between silver nitrate and sodium chloride.
- to predict which product is the precipitate, given that all compounds containing nitrate are soluble in water.
- to determine the limiting reagent.
- to predict how much solid product will be produced.
- to analyze whether or not your predictions were accurate.

#### **MATERIALS**

beakers  
filtration equipment  
balance  
spatula  
 $\text{AgNO}_3(\text{s})$   
 $\text{NaCl}(\text{s})$

#### **PROCEDURE**

1. Write out the equation for the double displacement reaction between silver nitrate and sodium chloride.
2. Discuss with your partner how much of each reactant you should use.
3. How should you start the reaction? (Hint: When we mix two reactants together, what state are they often in?)

4. Get your plan approved by your teacher. Record the actual masses used and notes about what procedure you chose to follow.
5. Start the reaction and record observations of it.
6. Filter the result.
7. Set aside the solid product to dry.

**DATA/OBSERVATIONS:**

Mass of silver nitrate:

Mass of sodium chloride:

Description of procedure & reaction:

Mass of dry product:

## CALCULATIONS (ANALYSIS)

While your product is drying, complete each of the following:

1. Determine which product is the precipitate.
2. Calculate how much product could have been made from each of the reactants, determining the limiting reagent.

3. How much solid product should you have made?

When your product is dry, get its mass by zeroing a second piece of filter paper and scraping the solid onto it. Put the mass of the dry product in the data section your report.

4. Calculate the percent yield using the formula below.

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} * 100\%$$

## **QUESTIONS/CONCLUSION**

In your lab report, discuss the accuracy of your predictions, accounting for any discrepancies. Describe how the techniques of this lab may be applicable in other situations.

## **PRE-LAB QUESTIONS**

1. Define *limiting reagent*.
2. Hypothesize why it is necessary to let the solid product dry before weighing it.

# EXPERIMENT 21

## pH

Acids and bases are classes of chemical compounds and each class has certain properties in common. Acids have characteristic properties of reacting with active metals to release hydrogen gas, neutralizing bases to form a salt, and changing the color of certain substances such as litmus. Bases, on the other hand, have characteristic properties of converting plant and animal tissues to soluble substances, neutralizing acids to form a salt, and reversing the color changes that were caused by acids.

Some chemical compounds are acidic, such as vinegar, and other compounds are basic, such as lye; but the terms acidic and basic are very general and inexact. The **pH scale** is a concise and quantitative way of expressing the acidity or basicity of a solution. pH depends on *both* the strength of an acid/a base (strong vs. weak) as well as the concentration of that acid/base. On this scale a neutral solution (neither acidic nor basic properties) has a pH of 7.0. Acidic solutions have pH values below 7; a smaller number means greater acidic properties. Basic solutions have pH values above 7; a greater number means greater basic properties. The pH scale is logarithmic (not linear) so a pH of 2 is 10 times more acidic than a pH of 3. Likewise, a pH of 8 is 10 times 10, or 100 times more basic than a pH of 6.

Many plant extracts and synthetic dyes change colors when mixed with acids or bases. Such substances that change color in the presence of acids or bases can be used as an **acid-base indicator**. Litmus, for example, is an acid-base indicator made from a dye extracted from certain species of lichens. The dye is applied to paper strips, which turn red in acidic solutions and blue in basic solutions. This is only a “ball park” indicator, however, since it only indicates on which side of the pH scale a solution lies. Other indicators are available that can be used to estimate the pH to about half a pH unit – for example, a pH of 3.5. There are also electrical instruments that measure pH by measuring the conductivity of a solution.

### OBJECTIVES

In this experiment, you will

- determine the characteristics of several commercial indicators.
- summarize how each indicator behaves in an acidic vs. basic solution.
- test an unknown to determine its acidic or basic properties.

## MATERIALS

watch glass

test tubes

glass stirring rod

### *Solutions*

0.1 M hydrochloric acid, HCl

0.1 M sodium hydroxide, NaOH

unknown

0.1 M acetic acid, HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>

diluted ammonia

### *Indicators*

red litmus paper

bromthymol blue

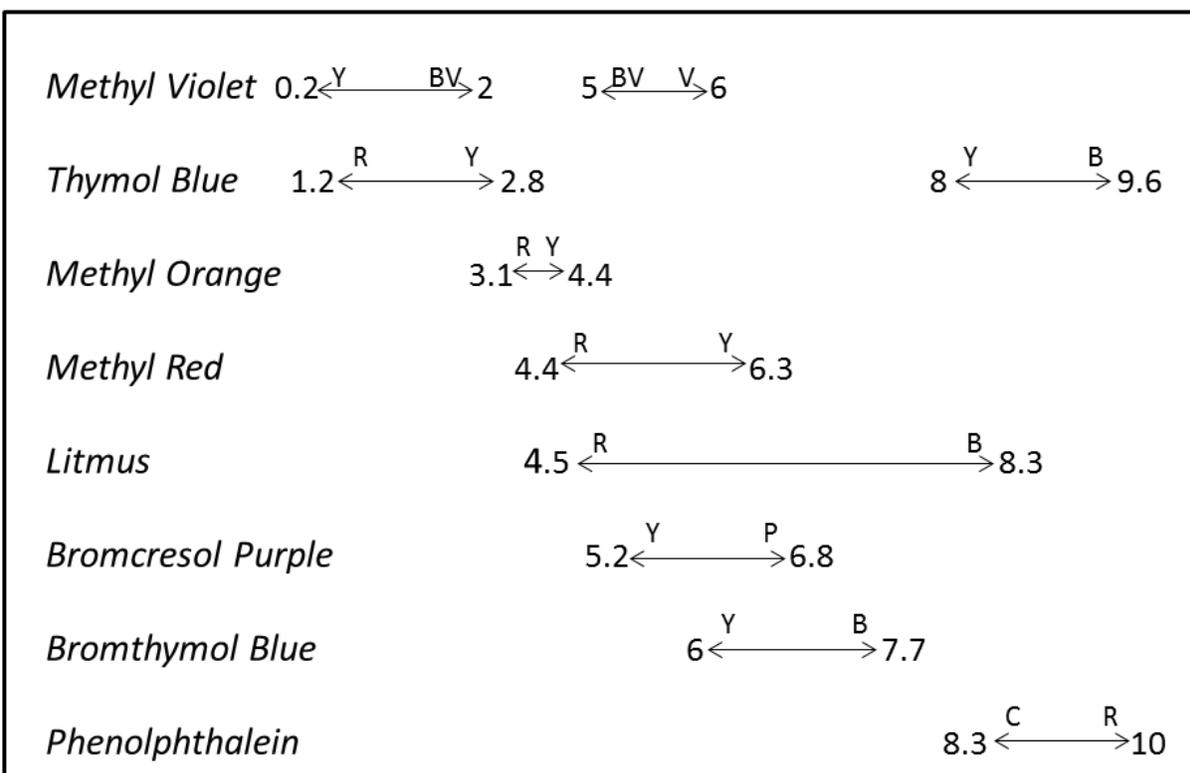
methyl red

blue litmus paper

methyl orange

phenolphthalein

### pH Ranges and Color Changes for Selected Indicators



NOTE: This figure is not drawn perfectly to scale. The letters stand for colors. For example, between a pH of 8.3 and 10, a solution containing phenolphthalein turns from clear to red.

## PROCEDURE

1. Start with hydrochloric acid. Record the color of the solution in the observations section.
2. Pour hydrochloric acid into five clean test tubes so that each is about 1/3 full. From left to right, these are Test Tubes 1-5.
3. Place **half** of one strip of red litmus paper and **half** of one strip of blue litmus paper on the watch glass. Describe the color of each strip in the observations section. Save the other halves for future trials.
4. Dip the clean glass stirring rod in Test Tube 1 so that a drop of the solution is on the end. Touch the end of the stirring rod to the red litmus paper. Record your observations of the paper.
5. Dip the stirring rod in Test Tube 1 again and touch it to the blue litmus paper. Record your observations of the paper.
6. Take the dropper out of the bromthymol blue indicator to examine the color. Record your description of its color. Put two drops of the indicator into Test Tube 2. Record your observations of the mixture.
7. Do the same actions as Step 6 for
  - a. methyl orange in Test Tube 3
  - b. methyl red in Test Tube 4
  - c. phenolphthalein in Test Tube 5
8. Clean out all of your test tubes. Repeat Steps 1-7 for
  - a. acetic acid
  - b. sodium hydroxide
  - c. ammonia
  - d. the unknown solution

## OBSERVATIONS

Table 1: Results of Indicator Tests for Acid Solutions

<b>Indicator</b>	<b>Hydrochloric Acid</b> Color: _____	<b>Acetic Acid</b> Color: _____
red litmus Color: _____		
blue litmus Color: _____		
bromthymol blue Color: _____		
methyl orange Color: _____		
methyl red Color: _____		
phenolphthalein Color: _____		

Table 2: Results of Indicator Tests for Base Solutions

<b>Indicator</b>	<b>Sodium Hydroxide</b> Color: _____	<b>Ammonia</b> Color: _____
red litmus Color: _____		
blue litmus Color: _____		
bromthymol blue Color: _____		
methyl orange Color: _____		
methyl red Color: _____		
phenolphthalein Color: _____		

Table 3: Results of Indicator Tests for Unknown Solution

<b>Indicator</b>	<b>Unknown</b> Color: _____
red litmus Color: _____	
blue litmus Color: _____	
bromthymol blue Color: _____	
methyl orange Color: _____	
methyl red Color: _____	
phenolphthalein Color: _____	

## QUESTIONS

1. Based on your observations, summarize what an acid solution and what a base solution will do to each indicator:
  - a. red litmus
  - b. blue litmus
  - c. bromthymol blue
  - d. methyl orange
  - e. methyl red
  - f. phenolphthalein
2. A popular noncarbonated beverage turns *thymol blue* to yellow and methyl orange to red. Use the figure in the introduction to predict the approximate pH of this soft drink. Is it acidic or basic?
3. What is the approximate pH of an acidic beverage that turns methyl orange to a yellow color?
4. Does phenolphthalein change colors in an acidic or basic pH range? Would it be helpful in identifying **how acidic** a substance is (very acidic vs. a little acidic)? Explain why or why not.
5. In lab, you analyzed an unknown solution. Do you think it was an acid or a base? Why? Your test results should provide support in your answer.

## PRE-LAB QUESTIONS

1. Acetic acid is  $\text{CH}_3\text{COOH}$ . Where can you find this acid in your kitchen?
2. There are two solutions of sodium hydroxide in front of you. One has a pH of 8 and the other has a pH of 10. Which is more basic? Which do you think has a higher concentration of hydroxide? Explain your answers. (Remember, concentration is how much base there is per unit volume.)
3. Would litmus paper help you differentiate between the two solutions mentioned in #2? Explain.

## EXPERIMENT 22

### Titration

A neutralization reaction occurs between an acid (low pH) and a base (high pH) to produce a salt and water. This reaction type can be used to figure out the concentration of either the acid or the base if one of them is unknown. To find the unknown concentration of the acid, we will perform a procedure called a *titration*. During a titration, the neutralization point is when the moles of acid equal the moles of base. In this experiment, that means all of the acid will have been neutralized by the base. Since we will know how much base has been added, we can figure out the moles of acid at this point. At the end, we will calculate the concentration of the acid.

We will first make a standard solution of a base, sodium hydroxide, or NaOH (known concentration). We will add the NaOH solution one milliliter at a time to a measured volume of the acid and monitor the pH with a computer probe. We will construct a graph of our data and use the graph to find the neutralization point.

### OBJECTIVES

In this experiment, you will

- monitor the pH during a neutralization reaction.
- construct a neutralization curve.
- calculate the concentration of a sample of hydrochloric acid.

### MATERIALS

evaporating dish  
balance  
beakers/Erlenmeyer flask  
stirring rod  
computer

sodium hydroxide, NaOH  
hydrochloric acid, HCl  
phenolphthalein  
pH probe  
graduated cylinder

## **PROCEDURE**

### **Creating a standard solution of NaOH**

1. You will be given NaOH solid pellets by your instructor. Get the mass of the evaporating dish before you ask your instructor for the chemical. **Caution:** Do not touch the sodium hydroxide with your hands. Do not allow the NaOH to sit too long in the evaporating dish.
2. Measure and record the mass of the NaOH in the data section
3. Transfer the NaOH to a clean, dry beaker.
4. Measure out 50 mL of water and add it to the beaker. Stir the solution with a clean, dry stirring rod until all of the solid is dissolved. Get a piece of paper, label it, and place the beaker on top of it.
5. Clean the graduated cylinder.

### **Setting Up and Performing the Titration**

**CAUTION: You must be very careful not to cross-contaminate your solutions by using equipment, such as a stirring rod, in both of them.**

6. Measure 20 mL of the hydrochloric acid solution (provided) and pour it into a beaker or an Erlenmeyer flask (whichever is at your station).
7. Log into the computer and open the Logger Pro program.
8. Put the pH probe into the HCl solution in the beaker/flask.
9. Wait until it becomes steady, and then note the reading in Data Table 1.
10. Add 4 drops of phenolphthalein to the HCl solution.
11. Use a clean dropper to add **1 mL** of the NaOH solution to the HCl solution and stir. (To stir, you may use a clean stirring rod.) **Do not allow the dropper to touch the HCl solution.** Record the pH in Data Table 1.
12. Continue adding NaOH solution, 1 mL at a time. Stir and record the pH after each addition. **Also record any observations you make of the solution (pH is not an observation) in Data Table 2.**



Data Table 2: Qualitative Observations of the Titration

Observations of changes in the solution	Volume of base added (mL)

Note: You may need more or fewer spaces than are provided, depending on your observations. Feel free to edit the table as necessary. The column for volume is so that you know how far along you were in the titration when you made a given observation.

### **CALCULATIONS & GRAPH**

1. Construct a graph of pH vs. volume of NaOH (aq) added. Label the axes with units, if appropriate. These graphs are called titration curves. Give your graph a title.
2. Calculate the concentration of your standard solution of sodium hydroxide using the following formulas. Make sure that you use the correct volume and convert it to liters first.

$$\frac{\text{mass}}{\text{molar mass}} = \text{moles}$$

$$\frac{\text{moles}}{\text{volume}} = \text{molarity}$$

3. Use your graph to locate the neutralization point of the titration. What volume of the NaOH solution was needed to neutralize the 20 mL of HCl solution?
4. **Calculating the concentration of the acid solution:**
  - a. Rearrange the equation below to solve for  $M_a$

$$V_a M_a n_a = V_b M_b n_b$$

$a$  and  $b$  stand for acid and base, respectively.  $V$  is volume,  $M$  is molarity, and  $n$  is moles.

- b. Using the equation above, your result from Calculations #2 and #3, and your knowledge of the neutralization point, calculate the concentration of the acid.

5. **Calculating concentration another way:**

- a. Using your result from Calculation #2 & 3, calculate the moles of base added **at the neutralization point**. Make sure that you use the correct volume and it is in liters. The formula is below.

$$\text{moles} = \text{molarity} * \text{volume}$$

- b. How many moles of HCl were in the 20 mL of HCl solution? (Hint: No additional calculation is necessary. Think about what is true of moles at the neutralization point.)
- c. Since you know the **volume** of the acid initially used and the **moles** of acid, you can calculate the concentration of the acid using the **molarity** equation. Use the equation below to find the molarity of the acid. Make sure the volume is in liters.

$$\text{molarity} = \frac{\text{moles}}{\text{volume}}$$

## QUESTIONS

1. Compare the two results you got for the calculation of the acid's concentration (Calculations #4b and #5c).
2. Summarize your observations made in Data Table 2. Why do you think it happened? Remember that you added phenolphthalein before the titration began.
3. If the concentration of your standard NaOH solution was much higher...
  - a. Do you think you would need more or less of it to neutralize all of the acid? Explain.
  - b. What would happen to your graph? (Describe how it would change.)

## PRE-LAB QUESTIONS

1. In this experiment, what acid is used? What base?
2. What is a neutralization point?
3. Write the chemical equation for this neutralization reaction, predicting the products.
4. What do you think the purpose of the phenolphthalein will be? Your answer should be specific to a titration experiment.

## Appendix 1: Percent Error

Percent error tells you how far your experimentally obtained value is from the accepted value.

The experimental value could be a measurement or a calculation. It is obtained either directly (via measurement) or indirectly (calculated as a result of values obtained during the experiment).

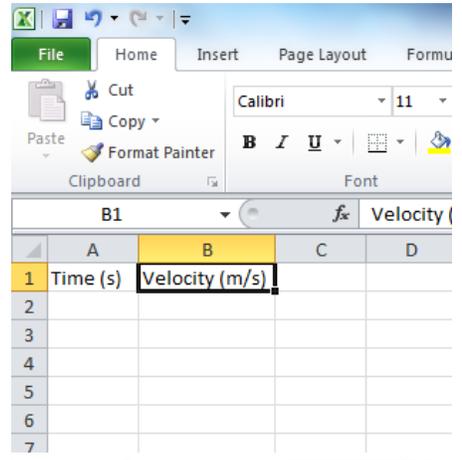
The accepted value is what “everyone” (the scientific community) agrees is the actual, accurate value for the topic at hand. For example, the accepted value for the speed of light is  $3.0 \cdot 10^8$  m/s. Since it is considered the “true” value, it is good to compare the result from your experiment to it.

$$\text{percent error} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \cdot 100\%$$

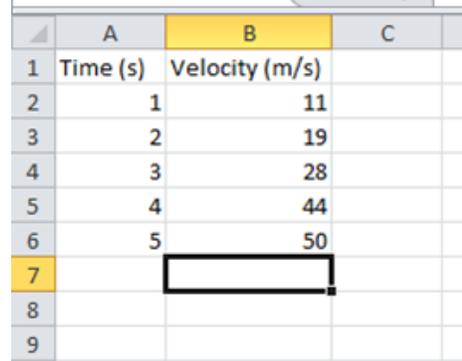
Sometimes the numerator of this fraction can be considered as an absolute value (making the difference positive, no matter what). If not, a positive vs. negative result for percent error simply indicates whether your experimental value was above or below the accepted value. For the form of the equation shown, if the experimental value is greater than the accepted value, the percent error will be positive. If it is less, the percent error will be negative.

## Appendix 2: Graphing in Microsoft Excel PC Instructions

1. Type your headers into cells A1 and B1 with units in parentheses. Whatever you type in Column A will become your  $x$  coordinates and Column B your  $y$ .

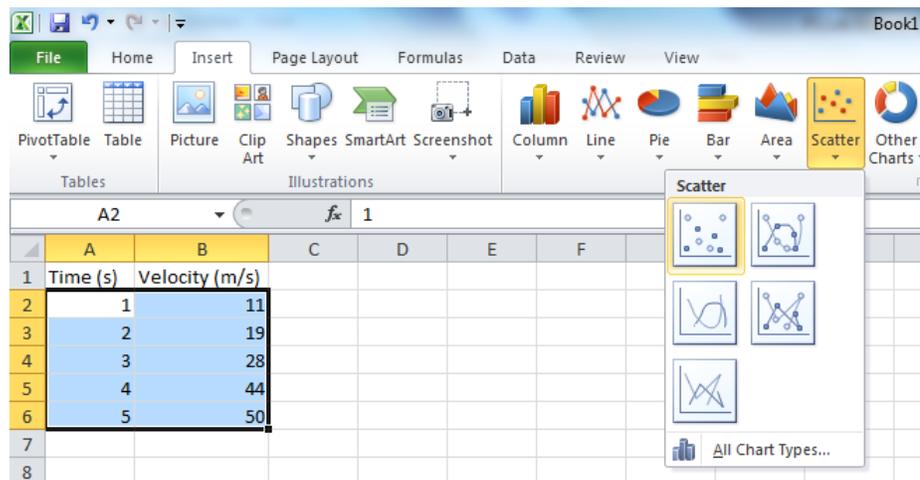


2. Fill in your numbers (no units) in the cells below each header (just like a data table).

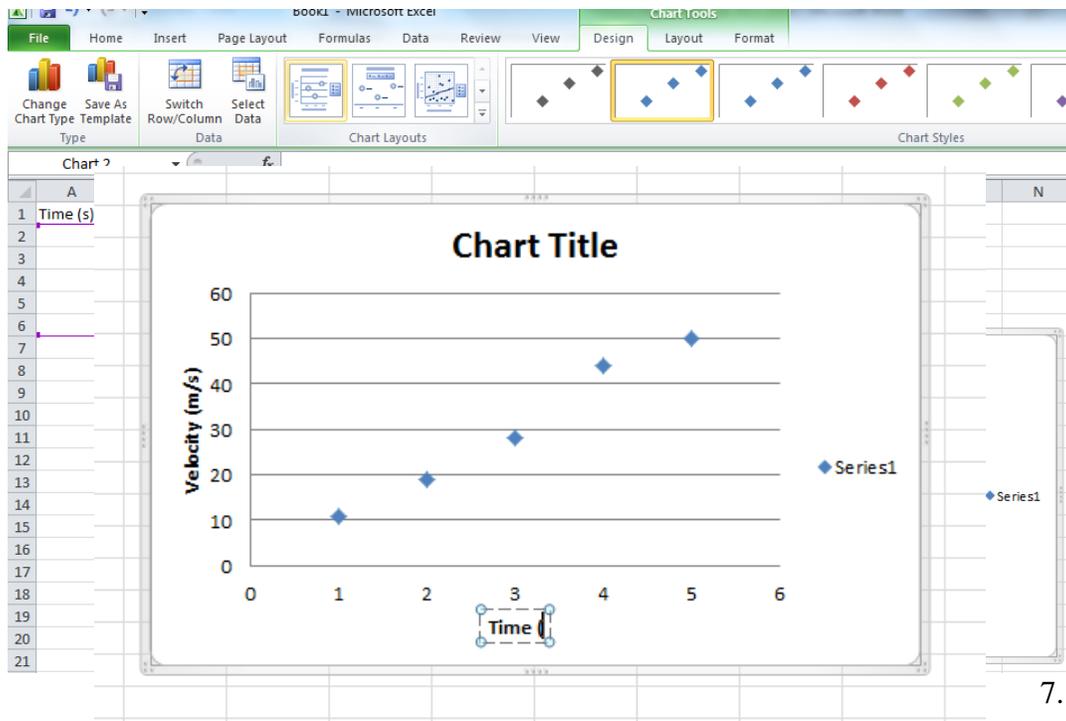


3. Click and drag to highlight just the numbers. (Click on Cell A2 and drag down to the bottom right of your data.) Both the  $x$  and  $y$  values should be highlighted.

4. Go to the Insert tab and click on the Scatter drop down. Select the first option (the one with just dots).

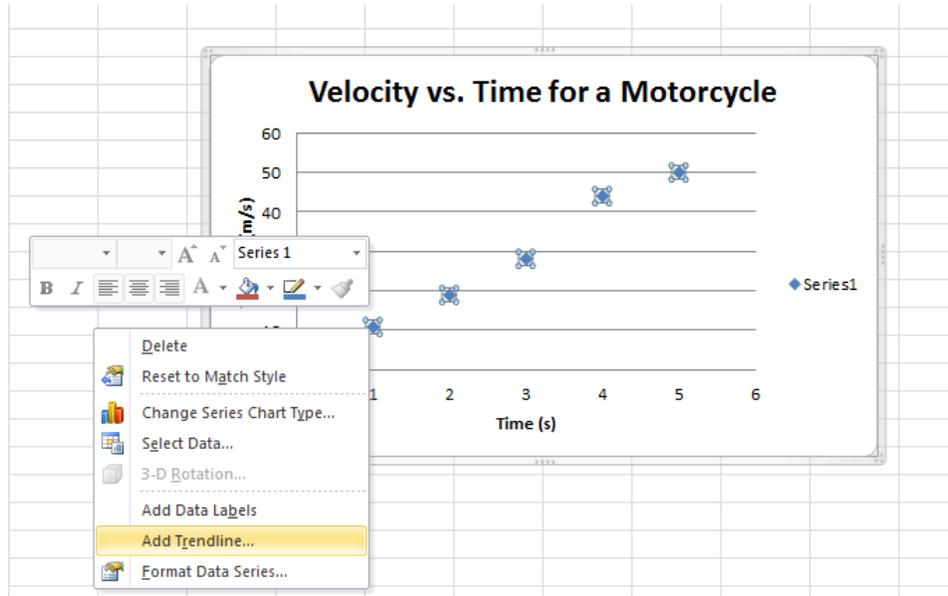


- Once you select that option, a graph will pop up and you will automatically be in the Chart Tools Design tab.
- Within Chart Layouts, click on the first layout option.

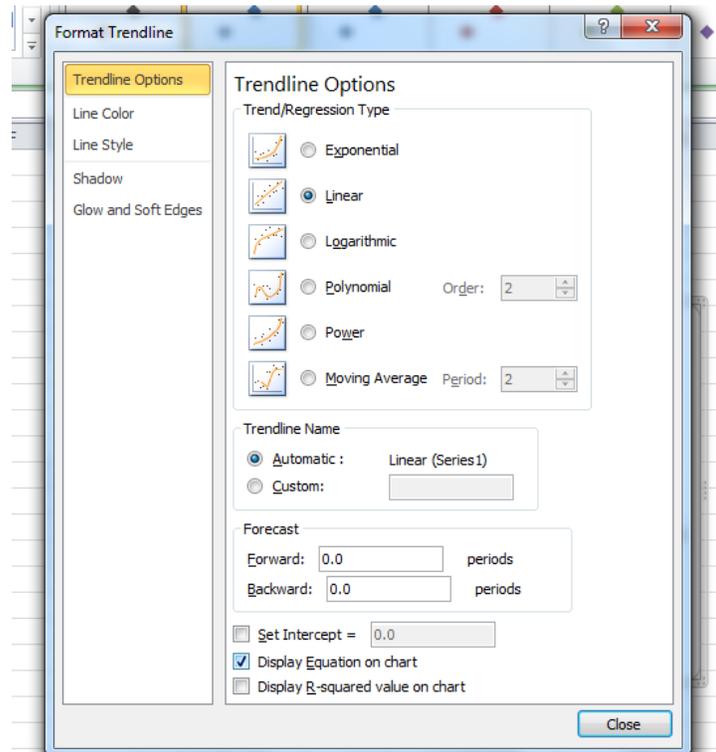


- Your graph should now have a title and axis labels. These three fields act like textboxes. You can click in them to edit the title of the graph and of the axes.

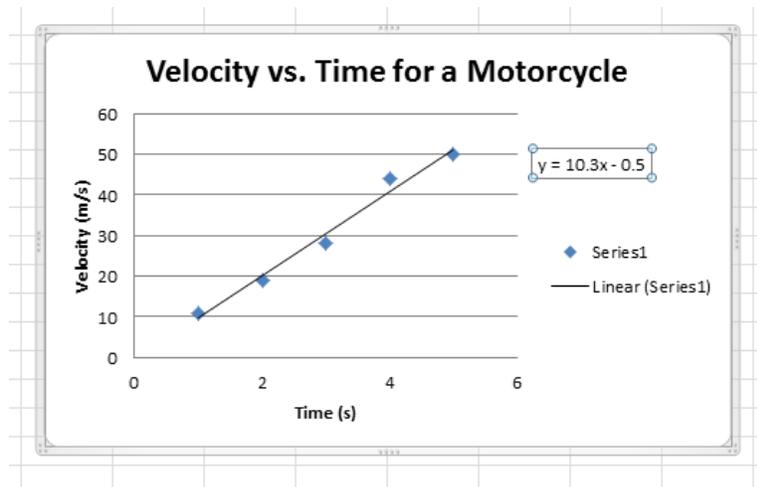
8. If instructed by your teacher to create a best fit line, right click on one of your data points. Select “Add Trendline.”



9. In the window that pops up, make sure linear fit is selected and then click the box to display the equation on the “chart” (graph).



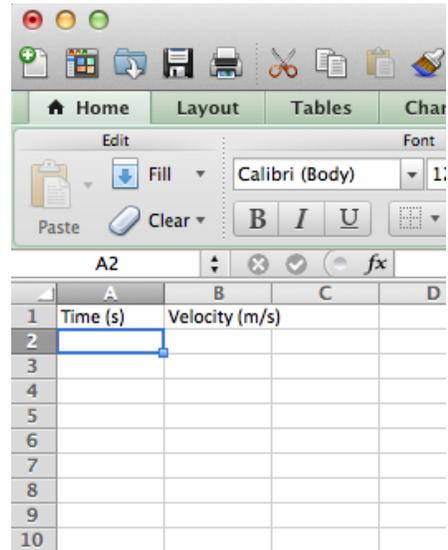
10. Click “Close.” You can move around the equation of the best fit line to make it more easily visible. Notice that the line may not go through any/all of your data points. The equation displaced is in “ $y=mx+b$ ” format and is the equation of the best-fit line.



11. To print, click on the white space in the corner of the graph window. Then go to File→Print and it will print a full-page version of your graph. Alternatively, you could copy and paste the graph into a Word document, as you would a picture, for use in your lab report.

## Mac Instructions

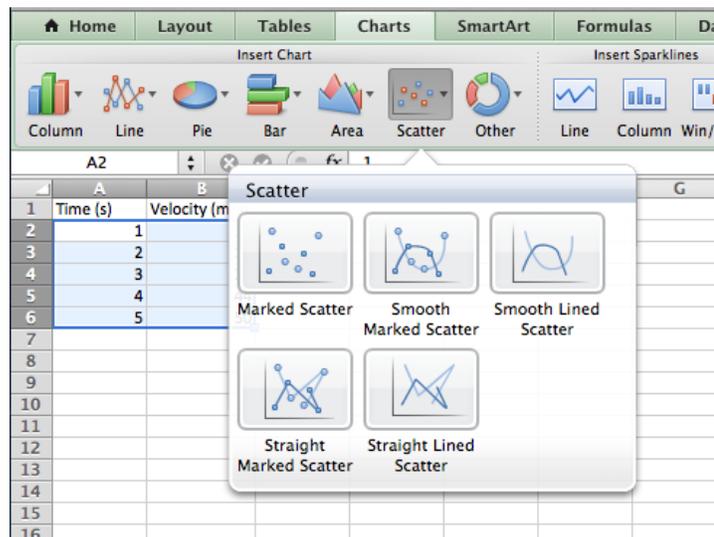
1. Type your headers into cells A1 and B1 with units in parentheses. Whatever you type in Column A will become your  $x$  coordinates and Column B your  $y$ .



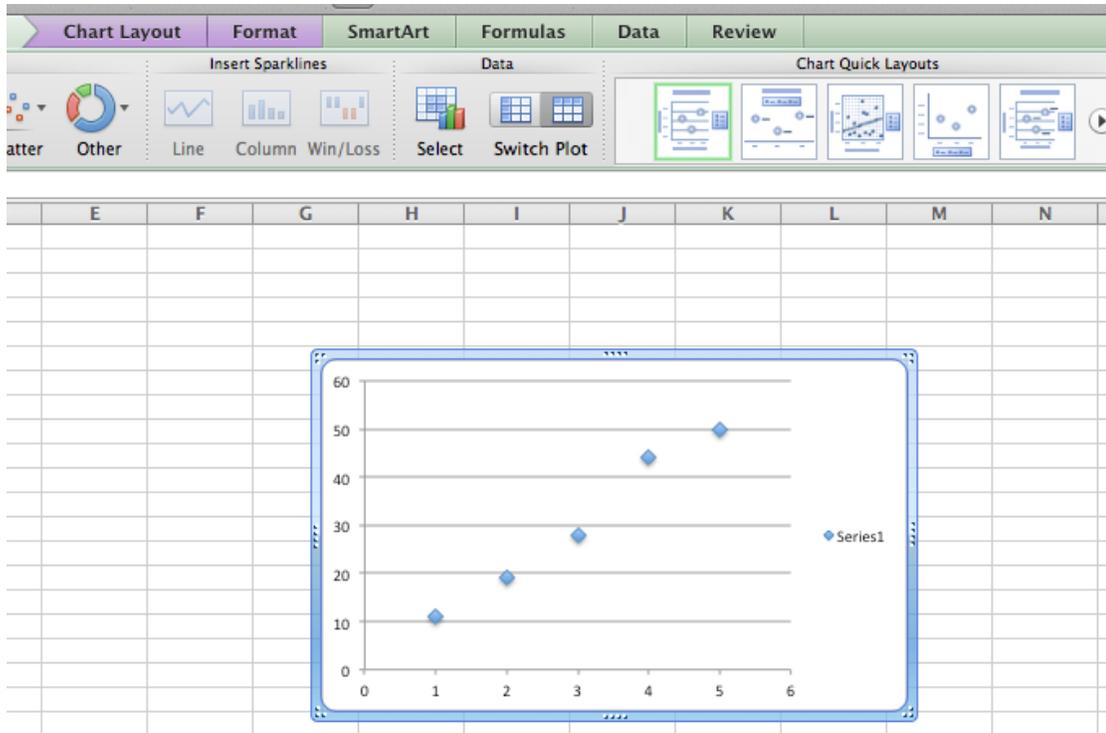
2. Fill in your numbers (no units) in the cells below each header (just like a data table).

	A	B	C
1	Time (s)	Velocity (m/s)	
2		1	11
3		2	19
4		3	28
5		4	44
6		5	50
7			
8			
9			
10			

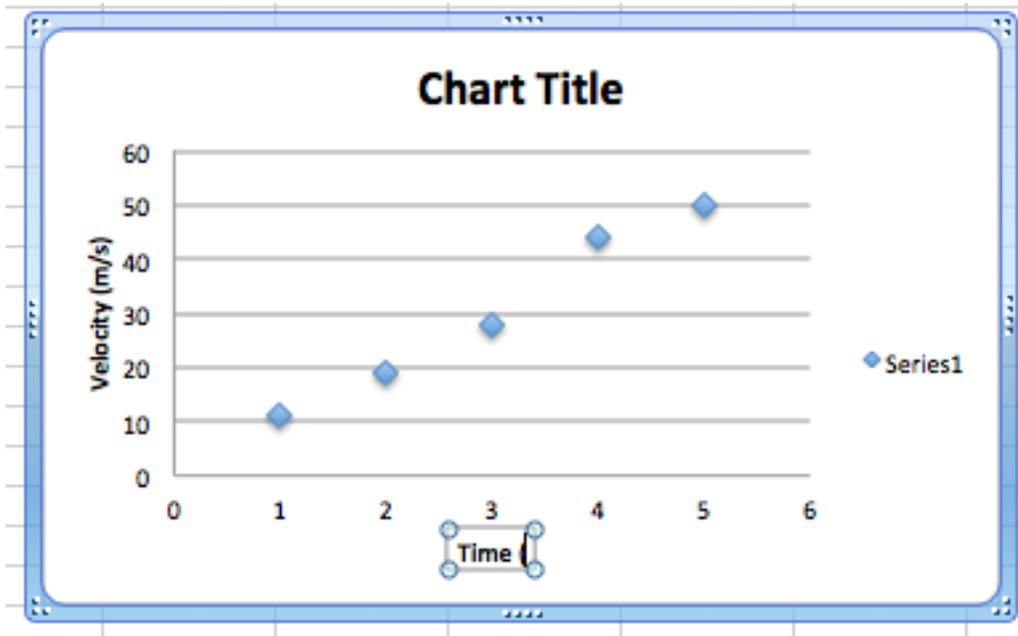
3. Click and drag to highlight just the numbers. (Click on Cell A2 and drag down to the bottom right of your data.) Both the  $x$  and  $y$  values should be highlighted.
4. Go to the Charts tab and click on the Scatter drop down. Select the first option called marked scatter.



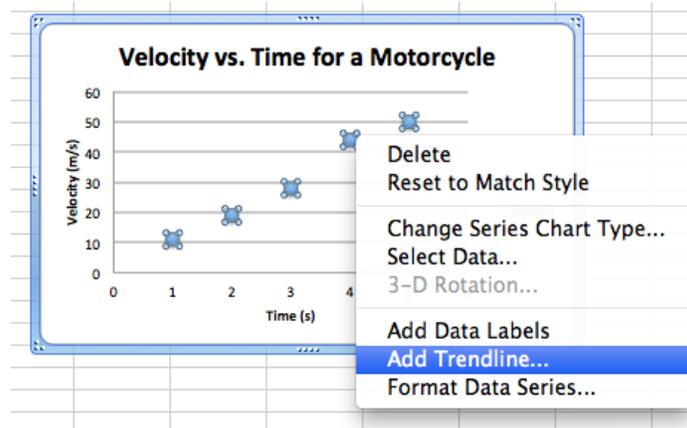
- Once you select that option, a graph will pop up and you will automatically be in the Chart Layout/Format tabs.
- Within Chart Quick Layouts, click on the first layout option.



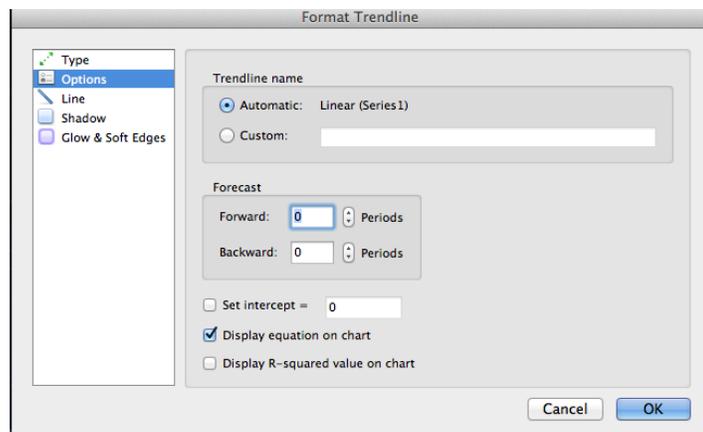
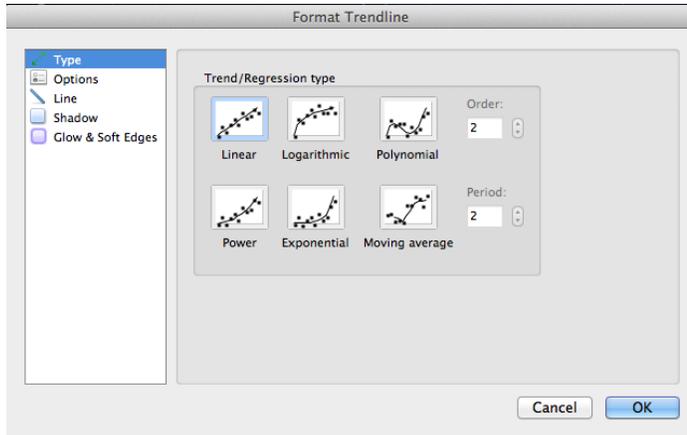
7. Your graph should now have a title and axis labels. These three fields act like textboxes. You can click in them to edit the title of the graph and of the axes.



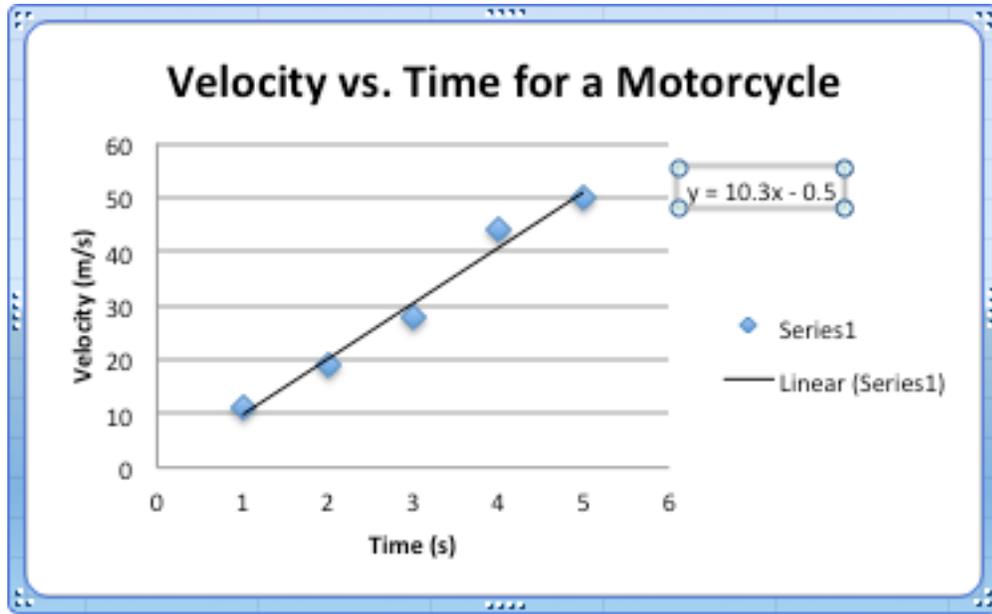
8. If instructed by your teacher to create a best fit line, right click on one of your data points. Select “Add Trendline.”



9. In the window that pops up, make sure linear fit is selected. Then, in the same window, go to Options. Click the box that says “Display equation on chart” (graph).



10. Click "OK." You can move around the equation of the best fit line to make it more easily visible. Notice that the line may not go through any/all of your data points. The equation displaced is in "y=mx+b" format and is the equation of the best-fit line.

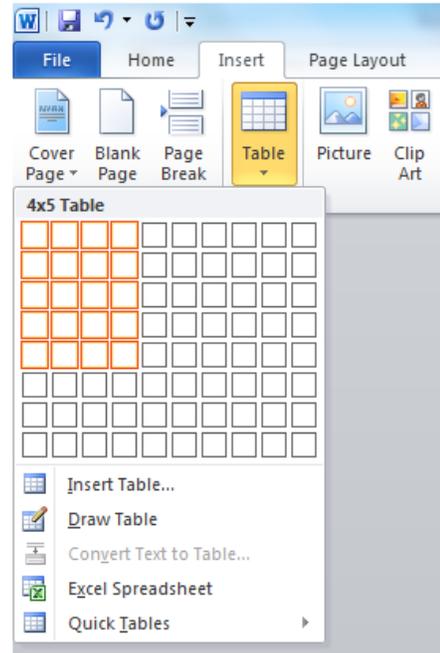


11. To print just the graph, click on the white space in the corner of the graph window. Then follow normal printing procedures. Alternatively, you could copy and paste the graph into a Word document, as you would a picture, for use in your lab report.

## Appendix 3: Some Basic Tools in Microsoft Word PC Instructions

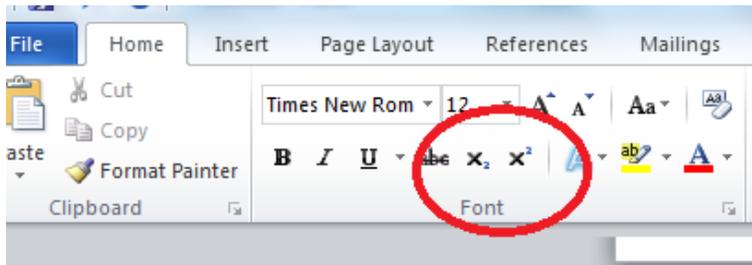
### Tables:

Go to the Insert Tab and click on Table. You can select how many columns and rows you want by moving the mouse around.



### Superscripts and Subscripts:

On the Home tab, in the Font section, you will see little icons like these:



If you want to make some text into a superscripts or subscript, highlight those letters/numbers and then click on the appropriate icon. Here is the difference:

Expressing “x squared”

Wrong: x2

Right: x<sup>2</sup>

Expressing the chemical formula for water

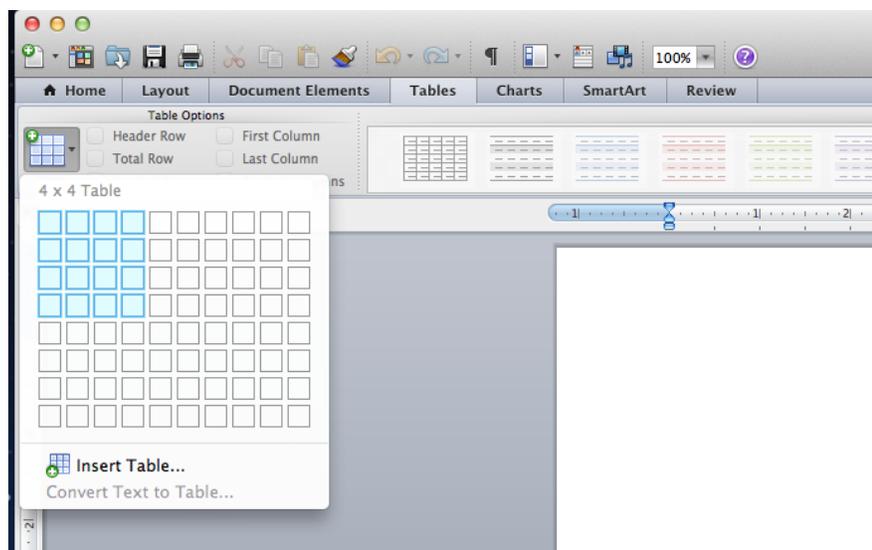
Wrong: H2O

Right: H<sub>2</sub>O

## Mac Instructions

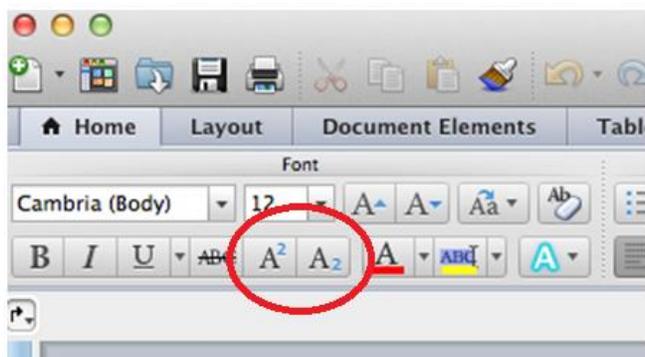
### Tables:

Go to the Tables Tab and click on New. You can select how many columns and rows you want by moving the mouse around.



### Subscripts & Superscripts:

On the Home tab, in the Font section, you will see little icons like these:



If you want to make some text into a superscripts or subscript, highlight those letters/numbers and then click on the appropriate icon. Here is the difference:

Expressing “x squared”

Wrong: x2

Right: x<sup>2</sup>

Expressing the chemical formula for water

Wrong: H2O

Right: H<sub>2</sub>O