Physics is FUNdamental

A Handy Guide to Constructing Explanations for All the Really Important "Stuff" in Everyday Physics

2019 EDITION

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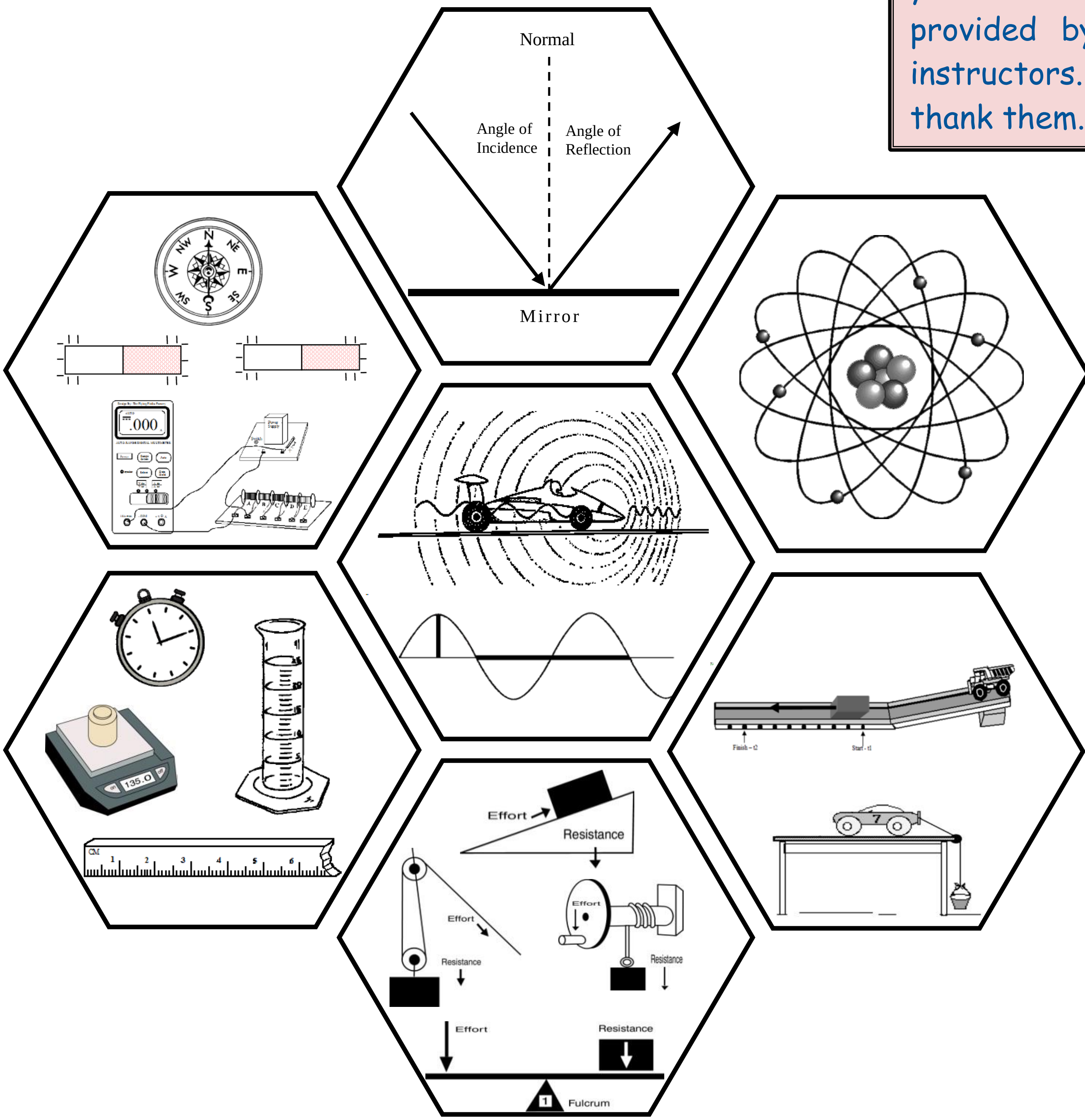

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Common Units

BASE UNITS Length - METER (m) Mass - GRAM (g) Volume - LITER (L) Temperature – CELSIUS (°C) Time = SECONDS (s)

PREFIXES kilo - one thousand hecto - one hundred deca - ten
deci - one tenth centi - one-hundredth milli - one-thousandth

RELATIONSHIPS

Value	1000	100	10	1	.1	.01	.001
Prefix	Kilo	Hecto	Deca	Base Unit	Deci	Centi	Milli

LENGTH

1 kilometer (km) = 1000 meters (m)
1 meter (m) = 100 centimeters (cm)
10 decimeters (dm) = 1 meter (m)
1 centimeter (cm) = 10 millimeters (mm)
1 micron = 10^{-4} centimeters (cm)
1 centimeter (cm) = 100,000,000 (1 x $10^{8)}$ Angstroms
1 inch (in) = 2.54 centimeters (cm) = 25.4 millimeters (mm)
1 mile (mi) = 1.61 kilometer (km)
1 meter (m) = 39.37 inches (in) = 3.281 feet (ft)

VOLUME

1 liter (l) = 1000 milliliters (mL)
1 cL = 10 milliliters (mL)
1 milliliter (mL) = 1 cubic centimeter (cc or cm^3) = .001 Liter (L)
1 quart (qt) = 2 pints (pt) = 0.25 gallons (gal) = 32 ounces (oz) = 0.946 liters (L) 1 cL = .01 L

MASS

1 kilogram (kg) = 1000 grams (g) or 100,000 (cg)
1 gram (g) = 1000 milligrams (mg)
1.0 g water = 1 milliliter of water, at Standard Temperature and Pressure
1 slug = 14.59 kg

FORCE

1 pound (lb) = 4.5 Newtons (N)
1 ton = 2000 pounds (lbs)

POWER

1 watt (W) = 1 joule / second (J/s)
1 horsepower (hp = 550 foot-pounds/second (ft lbs/s) = 746 watts (W)
1 Btu/h = 0.293 Watts (W)

TIME

1 minute (min) = 60 seconds (s)
1 hour (h) = 60 minutes (min) = 3600 seconds (s)

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Published by:

ScienceScene

12305 Lavender West, Fenton, Michigan 48430

ISBN: 0-9703732-0-1

The PHET assignments provided in this book are available from the http://phet.colorado.edu/ website. These are open source items available for anyone to use for free. Those included in this text have been modified by the authors to support the curriculum for Macomb Community College's Physical Science course.

Printed in the United States of America

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Acknowledgments

This book was written to support student centered active learning experiences in the Physical Sciences. These learning experiences are based upon laboratory activities designed to promote discovery and application of fundamental concepts. It is our belief that true understanding is based upon direct observation and manipulation of variables leading to the development of concepts which can be applied to daily life.

The laboratory experiences investigated in this book provide the opportunity to visit the most exciting world one could conceive. A world so large that galaxies fit easily inside and. yet so small. the behavior and interaction of the tiniest particles of matter become visible. This is the emerging world of today's physics. It has changed all of our lives no matter what our age. and we have only seen the beginning.

Since the first edition of this book in nineteen seventy-four, students, laboratory assistants. instructors and colleagues have contributed to the improvement and development of this book. At the end of each academic year the book is revised to include the suggested changes for that year. We wish to thank these individuals for their encouragement and useful suggestions and ideas for the improvement of this textbook.

MHS

Introduction

This textbook explores the conceptual nature of Physics and includes the structure of matter and various concepts of energy. The purpose of this textbook is to help understand how scientists use the experimental method in comparing hypotheses with reality and how the laboratory gives insights into the concepts of nature. To get the greatest benefit. regard each concept as a problem to which you are forcing nature to give an answer. From this experience. a better understanding of the process of science and the work of the scientists should result. The most usable part of all will be your own experiences discovering these processes of science.

Specifically. this book has the following goals:

1. To provide the opportunity to experience the successes, failures, certainties, uncertainties, drudgery and the rewarding achievements of scientific investigation.

2. To give practice in recording, Graphing, Interpreting, and drawing logical inferences based on empirical data.

3. To give insight into the relation between experimentation and physical concepts.

4. To give practice in developing hypotheses and using them for predictive purposes.

5. To provide the opportunity to generalize physical science concepts in order to understand and apply them to daily life.

6. To provide the opportunity to develop concepts through hands-on cooperative learning experiences.

7. To give practice in mathematically solving basic physical science formulas.

In addition to this textbook links to support materials, based upon this book, are available at the Physics Is FUNdamental Portal located at http://www.sciencescene.com or a link provided by your instructor.

MEASUREMENT

Topic 01

Objectives

1. Given the following list of terms. identify each term's correct definition. Conversely, given definitions identify their correct terms.

   Average, Centi, deci, error, Gram, kilo, liter, mas, Measurement, meniscus, meter, metric system, milli, percent of error, temperature, time, volume, unit, and density.

2. Given a piece of laboratory apparatus used for measurement, identify the smallest division on the instrument, and record measurements using the measurement rule.
3. Given a solid object, measure its length using metric units, Convert these units to all the other linear units (millimeter, centimeter, meter, kilometer).
4. Given a mass scale and various objects, measure and convert these measurements to the other units of mass (milligram, gram, kilogram).
5. Given a graduated cylinder and measure the volume of liquid and other objects. Convert these volumes to all the other metric units of volume (milliliter, liter, kiloliter).
6. Given a Celsius thermometer and an object, measure the temperature of the object, Convert the measurement to Fahrenheit. Also be able to convert from Fahrenheit to Celsius.
7. Given a set of measurements and a theoretical (accepted) value, obtain the average of the set of measurement, compute the error, and determine the percent of error.
8. Given the appropriate conversion factors and various measurements, convert the measurements from English to Metric, and Metric to English.
9. Calculate density based on volume and mass measurements.
10. Know the SI units for length, volume, and mass.

INTRODUCTION

Concept of Measurement

One of the important features of science is that it deals not only with the qualities of things (whether something is big, hot, or blue). but it also concerns itself with quantities (how big? how hot? how blue?). Quantification is accomplished using measurements. Measurements have a number with an associated unit that describes the type of measurement made, or we can say the unit defines the quantity for us. For example, the Moon is *far away*, but more precisely it is 384 million meters away from Earth, or using a different set of units the distance is 239,000 miles. It also says that atoms are *small*, but that if you could count the atoms along the edge of a table, you would find 10 billion atoms in each meter.

Why are numbers so important? Usually, there are several possible ways of thinking about things, and there may be several possible models to use in order to describe them. But if numbers are used in the descriptions, the models must also give the right numbers. With numbers we have a way of carefully checking whether an idea is right or wrong. We have a way of improving our models. It is one thing to say that hydrogen gas burns with oxygen to produce water. It means much more to say that for each kilogram of hydrogen burned 9 kilograms of water will be produced.

Our understanding of nature is based on models we hold in our minds; models of how we think things work. In science, models are much more useful when they are expressed in quantitative terms. The idea of an atom as a permanent unchanging entity came about when researchers saw that even though dissolving, burning, and boiling could change the form of materials, the total mass of the materials being analyzed did not change.

The power of science depends on the ability to make reliable predictions. Much effort has been devoted to developing measuring techniques and tools that improve our ability to make predictions. How big is something? How often or how fast does it happen? A scientific observation involves not only seeing what exists or what happens, it also involves measuring the results of definite procedures.

Every measurement is a process of comparing something to a unit of measurement. All measurements can be categorized into various dimensions. For example, there are dimensions of length, time, mass, etc.… When measuring length, we can use a measuring device that is scaled with centimeters, or a different device that is scaled with inches. Regardless of whether we indicate our measurement in centimeters or inches the measured dimension is that of length. We indicate what measuring device we have used to make the length measurement by including units with the numerical value. For example, my object may have measured 1.0 inch using an inch scaled ruler, or with a centimeter rule it will measure 2.5 centimeters. The **general** rule (there are a few exceptions) in this physical science course is that there are NO NAKED NUMBERS! They must be accompanied by a unit to have meaning. For example, if I simply say I am 5, what does this mean? The number is naked. There is no unit to identify what value the number 5 represents. It could mean 5 feet tall, 5 dollars richer, 5 dollars poorer, 5 minutes late, 5 pounds heavier, etc…. To have meaning make sure your numbers are always accompanied by a unit.

The Characteristics of Measurement

Any reported measurement must tell us three things:

1) ***units*** which tell us what type of measurement was made. (e.g. meters, grams, and liters etc. was measured)
2) an order of *magnitude (the size of the measurement which is read from your measuring device)*
3) a statement about the *uncertainty of the measurement*

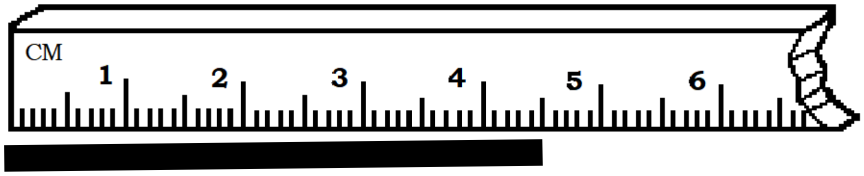
The ***units*** indicate whether the data is expressed in meters, grams, or liters of whatever quantities are being measured, (Note that usually abbreviations for the units are used instead of writing out the entire word. You will need to become accustomed to these abbreviations. They are provided in the cover of your book in parentheses.) The order of *magnitude* identifies the size of the measurement.

Uncertainty provides a statement concerning how closely (small a division) the measuring device can measure something. Suppose, for example, we are measuring the width of a door by using a meter stick having only centimeter marks on it. This means we can be reasonably certain of the door width to the nearest centimeter. Let us suppose this width to be between 71 and 72 cm. To be more accurate we need to estimate to the tenth of a centimeter between the two readings. We might write this reading as 71.<u>3</u> cm. with the <u>3</u> underlined to show that not all people would agree on the exact tenth. To write a fourth digit would require 10 times greater accuracy and would be very misleading.

Note: **Never round off your measurements when recording them!** What you write on your data sheet must accurately reflect your measuring instruments capabilities. However. after using the measurements in calculations, you may need to round off the answer.

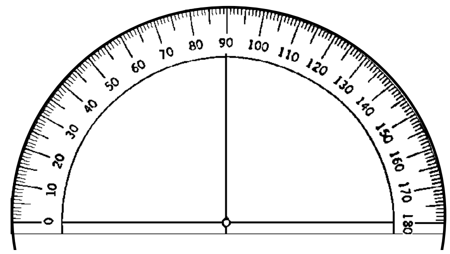
The Measurement Rule: *Determine the smallest division on the measuring device and then divide that number by 10, In general, the measurement will be written out to the number of decimal places obtained from dividing the smallest division by 10.*

Example: The smallest division on the pictured ruler on the next page is 0.1 cm. Applying the measurement rule tells us that 0.1 divided by 10 equals 0.01. When we write our measurement, we must write it out to the hundredths place. Using the same ruler below, your eye has the ability to see that the length of the line underneath it falls between 4.5 and 4.6. Some students think that they should just guess whether the measurement is 4.5 or 4.6. But, in science we can do better than just guess the $1/10^{th}$ decimal place in this situation. You can determine if the measurement is closer to 4.5 cm or closer to 4.6 cm. First, we take the difference between 4.6 and 4.5. The difference is 0.1. Now divide by 10. The result is 0.01. We should write the measured value out to the hundredths position. In this case we guess what the next decimal value should be. Doing this provides a more accurate measurement than simply ignoring the fact that the measured value falls somewhere between 4.5 cm and 4.6 cm. Let's say that the measured value is very close to 4.5. I see that the guessed position would be around 0.03. I write my measurement as 4.5<u>3</u> cm. My guessed number is in the $1/100^{th}$ position. This rule is true in general though there are many exceptions. Do not apply the measurement rule to digital instruments or any instrument where you cannot judge whether your measurement falls between two measured values or not.



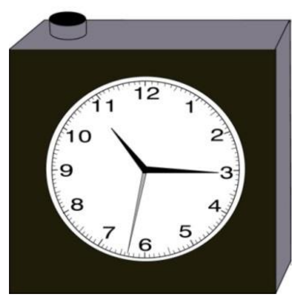
- The basic unit of measurement on this scale is the centimeter.
- Smallest division is 0.1 cm.
- Your guess must be to the nearest 0.01 of a centimeter.

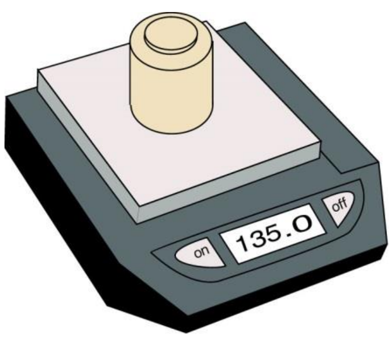
What is the smallest division of the following protractor? (1 degree) What is the smallest part of a degree that must be reported? (0.1 degree) NOTE: If a reading were to be exactly 10 degrees, it must be reported to tenths. In other words, the reading would be 10**.**0°. Writing 10° would be incorrect, Writing 10.0° is correct.



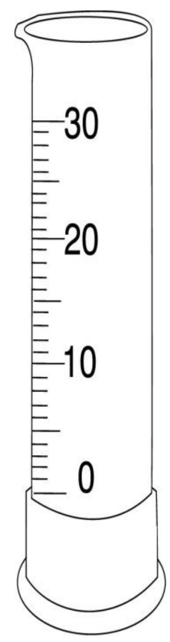
Identify the: 1) smallest unit (division). 2) correct way to record the smallest measurement applying the measurement rule for the following measuring devices.

A. (Wall Clock) 1. _______________
2. _______________





B. (Mass scale) 1. _______________
2. _______________



C. (Graduated cylinder) 1. _______________
2. _______________

Answers: **A.)** 1s, 1s (Wall clocks with second hands don't stop moving. Our eyes cannot provide a more accurate measurement than 1 second. We cannot see the second-hand fall between two 1 second positions accurately). **B.)** 0.1gram, 0.1gram (This is a digital instrument. The uncertainty in the measurement is already taken care of by the device. **C.)** 1mL. 0.1mL (We must apply the measurement rule since we have the ability to see the measurement fall between divisions.

Accuracy and Precision

When taking measurements, it is important to note that there is a difference between the accuracy of the measured values and the precision of those measured values. Accuracy compares your measured value to some predicted value. The closer your experimental measurement is to that predicted amount the more accurate your measurement is considered. Accuracy is dependent on the measuring instrument you utilize and how well you use that instrument. We usually calculate the percent error (discussed on the next page) to inform us of accuracy. Your instructor will let you know what percent errors are acceptable for your experiments throughout the semester. Precision is how consistent your measured values are. For example, if you are timing the oscillation of a pendulum you might collect the following data for 3 trials: 1.3 s, 2.2 s, and 1.5 s. We can't tell how accurate these measurements are without being informed of the expected outcome. However, we can tell that there is not good precision. The second trial time is very different than the first and third trial. It doesn't seem to fit any pattern and the discrepancy is large relatively speaking. In this course, when your experiments have poor precision you are required to repeat the measurement for the value or values that don't appear precise.

Measurement of Length

Most nations and all scientists use a method of measurement called the Metric System. Unlike the English System of measurement used in the United States, the Metric System is based on units of 10.

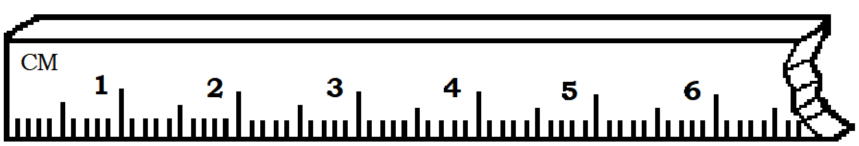
The SI unit for length is the meter (m). The meter is approximately 39.37 inches. The meter can be subdivided into 10 smaller units called decimeters. Each decimeter, in turn. is composed of 10 small units called centimeters, and each centimeter is composed of 10 millimeters. These relationships are:

1 m (meter) = 10 dm (decimeters)
1 dm (decimeter) = 10 cm (centimeters)
1 cm (centimeter) = 10 mm (millimeters)

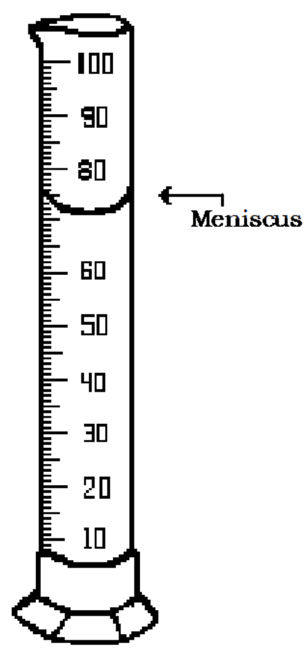
The most commonly used units of length are the meter, centimeter, and millimeter. In this system, any measurement can be expressed in any of the above units by using decimals. For example, a rod 17.0 mm long can be described in the following units:

17.0 mm **or** 1.70 cm **or** 0.170 dm or 0.017 m

Examine a meter stick in the classroom. Note that it is divided into 100 units. Each labeled unit, such as 1, 2, 3 and 4, represents the number of centimeters. Note that the meter stick is also divided into groups of 10, from 0 to 100, You can easily see heavily printed numbers such as 10, 20, 30, etc. The length from 10 to 20 represents one decimeter. The number 30 represents 30 centimeters. The smallest subdivision on the meter stick is the unit called a millimeter. One thousand of these tiny units are found on the meter stick. When using a meter stick, you should place it on its edge and avoid using the extreme left and right edges of the scale. These may be ragged from excessive use.



NOTE: When applying the measurement rule the measurement for this instrument must be recorded to the nearest 0.01 cm.



Measurement of Volume

The basic unit of volume in the Metric System is the liter (1.056 quarts). The SI unit is the Liter (L). Note that1 liter (L) = 1000 milliliters (mL). Another common unit is the cubic centimeter (cc) which is equal to 1 mL.

When working with fluids notice that the top level of the fluid being measured in the cylinder is not a flat level surface. It is a concave surface called a **meniscus**. All volume measurements are made using the bottom of the meniscus.

Measurement of Mass

Ease in conversion of units is also found in measuring mass, where the basic unit is the gram. Again all multiple units or sub units are based on 10, for example 1 kilogram = 1000 grams or 1 milligram = 0.001 gram. The kilogram, gram and milligram are the most frequently used units of mass.

To determine the mass of a sample using a balance, place the balance firmly on a level surface. Check the balance to be certain that it is reading zero when empty.

Measurement of Time

A. The proper use of a timer requires that you recognize the following about its operation.

1. It will be necessary that, upon examination of the particular timer you will be using in an experiment, you identify the button or switches that start it, stop it, and reset it.

2. Determine the units of time that you are measuring with the device. It will be necessary that you examine the scales of the timer and identify:

   a. The numbers on the scale which represents hours, minutes, and seconds

   b. Does the timer measure fractions of seconds such as a tenth of a second, a hundredth of a second, etc.….?

Measurement of Temperature

A thermometer is a device that measures temperature. Most substances expand when heated and contract when cooled. The thermometers you use are designed around this property of matter. The familiar mercury-in-glass thermometer works because mercury expands more than glass when warmed. Thus, the length of the mercury column in the glass tube provides a measure of surrounding temperature.

The metric system measures temperature on the Celsius scale. On this scale, ideally, water freezes at 0^o C and boils at 100^o C. This corresponds to 32^o F and 212^o F respectively. It is possible to convert from English to Metric and vice versa using the following mathematical statements:

$$T_{^\circ Fahrenheit} = (9/5 \text{ x } C_{elsius}) + 32$$
$$T_{^\circ Celsius} = (T_{^\circ Fahrenheit} - 32) \text{ x } 5/9$$

Notice when using these formulas that what you are looking for is on the left side of the equal sign, and what you know is entered into the right side of the equation.

Measurement of Density

The density of an object can be obtained by measuring the mass of the object and its volume.

$$Density = \frac{mass}{volume}.$$

An old trick question is what has more mass. 1 kg of bricks or 1 kg of feathers? Some students automatically say 1 kg of bricks. The real answer is they are both equal. A kg of anything = a kg of anything else. But your instincts tell you there is something different, and you are correct. The density of a kg of bricks is different than that of a kg of feathers because the volume of a kg of bricks is very different than the volume of a kg of feathers, although they both have the same mass! Why are their volumes different? Because the spacing between feathers and the spacing between the bricks is vastly different. A 1-kg bag of feathers would take up a lot more volume than a 1 kg bag of bricks, Why? Because the feathers are further apart from each other than the bricks are. The more compact an object is the higher it's density will be and vice versa. In other words objects with a higher density have molecules that are more closely spaced to each other than objects with a lower density. Objects with a density higher than that of the fluid they are placed in will sink, and those objects that have a density lower than the fluid they are placed in will float. For example a lead sinker has a higher density than water and it will sink, but oil has a lower density than water and thus is floats on water.

Determining Average, Error, and Percent Error

When conducting an experiment, measurements are repeated several times (trials), in order to minimize errors to improve the reliability of the findings. Each measurement obtained may be (even if it is only slightly) a different value. In order to find which value is most likely to be the true or the best value of your measurement we turn to the mathematical science of statistics. Statistics indicates that in order to get the best of all values obtained (in terms of being the closest to the true value), one must calculate their mean or average. To obtain an average add up all the measured values and divide by the number of trials performed. In symbols, if the values involved are x_1, x_2, x_3, ------- x_n, which means that there were a certain number of n trials performed, their average is computed by:

$$\text{average} = \frac{x_1 + x_2 + x_3 + \text{-----------} x_n}{n}$$

For Example:

1 Apple was purchased in three different markets. What is the average price?

Market 1 = 5 ¢ = x_1

Market 2 = 7 ¢ = x_2

Market 3 = 12 ¢ = x_3

Note: n = 3 since prices were obtained at 3 markets.

$$\text{average} = \frac{x_1 + x_2 + x_3 + \text{-----------} x_n}{n} \quad \text{or} \quad \frac{5 + 7 + 12}{3} \quad \text{or} \quad \frac{24}{3} \quad \text{or} \quad 8\text{ ¢}$$

You have calculated the average value which will often be the experimental value for many of the experiments in this book. The difference between your experimental value and the scientific theoretical value is the error for this set of measurements.

Error = | Experimental value **-** Theoretical value |

(Notice the absolute value bars. This means you can neglect any negative signs.)

For Example:

If you measured the width of several pieces of wood from a manufacturer to average 25.50 cm. The manufacturer indicates that the width of the wood should average 25.00 cm. Determine the error in our measurement.

Theoretical value = 25.00 cm.

Experimental value = 25.50 cm.

Error = Experimental value - Theoretical value or 25.50 cm - 25.00 cm.

Error = 25.50 cm - 25.00 cm. = 0.50 cm

It would now appear that your task has come to an end. but a problem arises when you wish to report your error to someone not involved with your experiment. To illustrate the problem, let us say that in measuring the width of an object you tell a friend that the error was 0.50 cm. That seems small enough if the total width of the object is 25.00 cm or more. In comparison we can see that 0.50 cm is indeed a small error compared to the measured value of 25.00 cm. But what if the total width of the object was only 1.00 cm? Then your error of 0.50 cm is not so small when compared to 1.00 cm. In fact, it may be too large to be acceptable.

The moral of this story is that the error is not a measure of your success or failure in performing the experiment. A better way in reporting the error is to use the percent error (% Error). Expressing your error in the form of a percentage enables one to understand accurately the magnitude of the error involved regardless of the size of the theoretical value.

$$\%\text{ Error} = \frac{100 \times \text{Error}}{\text{Theoretical value}}$$

For Example:

A) If the theoretical value of the length of the object is 25.00 cm and your error is .50 cm the

$$\%\text{ Error} = \frac{100 \times 0.50}{25.00} = 2.0\%$$

B) But, if the theoretical value of the total length of the object is 1.00 cm the

$$\%\text{ Error} = \frac{100 \times 0.50}{1.00} = 50.0\%$$

In both cases, A and B, the errors were both 0.50. The calculation of the percent of error allowed us to clearly see the difference between the two.

An Example of Average, Error & Percent Error

1. The following set of values was obtained when measuring the length of 5 different ball-point pens. According to the manufacturer the length of the pens should be 14.00 cm. Determine the average length measured, the error, and percent error.

pen 1. = 13.80 cm = x_1

pen 2. = 13.90 cm = x_2

pen 3. = 13.80 cm = x_3

pen 4. = 14.10 cm = x_4

pen 5. = 14.20 cm = x_5

Their average is obtained as follows:

1) $$x = \frac{x_1 + x_2 + x_3 + x_4 + x_5}{5} = \frac{13.80 + 13.90 + 13.80 + 14.10 + 14.20}{5} = 13.96 \text{ cm}$$

2) The error is computed as follows:

The theoretical value given in the problem = 14.00 cm.

Error = |Experimental value – Theoretical value|

Error = |13.96 - 14.00 | = 0.04 cm

3) The percent error is now computed:

$$\% \text{ Error} = \frac{100 \text{ x Error}}{\text{Theo.}} = \frac{100 \text{ x } 0.04 \text{ cm}}{14.00 \text{ cm}} = 0.3\%$$

Conversions

Converting from one unit of measurement to another can be a fairly simple procedure.

Example: Convert 24 inches to feet. To accomplish this, we need to know:

1. The conversion factor from inches to feet. 12 inches = 1 foot
2. The final answer will be a smaller number of feet. (This is known by looking at the conversion factor.)

We propose two possible approaches to solve conversion problems.

Method 1: Ask and answer the following three questions:

1. What is the conversion factor?
2. Will my final answer be larger or smaller?
3. Multiply or divide to produce the results of question 2?

Example:

A. If a line was 9.5 in. long, how many centimeters would this be?

1. 2.54 cm = 1 in.
2. Larger
3. 2.54 cm / in. x 9.5 in. = 24.1 cm.

B. How many cm is 14.3 km (kilometers)? (Use the three questions.)

1. _______________
2. _______________
3. _______________

(Answer 1,430,000 cm) Can you read this number? It is 1 million 4 hundred 30 thousand centimeters.

Method 2: This approach uses a more structured set-up using fractions. The units are treated algebraically like the numbers.

Example:

A. If a line is 9.50 in long. how many centimeters would this be?

$$9.50\ \text{in} \times \frac{2.54\ \text{cm}}{1\ \text{in.}} = \frac{(9.50\ \cancel{\text{in}}) \times (2.54\ \text{cm})}{1\ \cancel{\text{in}}} = (9.50) \times (2.54\ \text{cm}) = 24.1\ \text{cm}$$

B. If the distance from your home to MCC was 4.3 km. how many miles would this be?

$$4.3\ \text{km} \times \frac{1\ \text{mi}}{1.61\ \text{km}} = \frac{(4.3\cancel{\text{km}}) \times (1\ \text{mi})}{(1.61\ \cancel{\text{km}})} = 2.7\ \text{mi}$$

Important Note: Using all of the numbers that appear on your calculator after performing a calculation does not make your answer more accurate. Your calculations cannot be more accurate than your measured values. You must evaluate your final answers and determine where the calculated answer should be rounded. There are precise methods for making these determinations in science, but these are beyond the scope of this class. For this course, rounding your answers off to match the number of decimal places in your measured values will usually be acceptable, Your instructor will let you know when it’s not. It is also very, very important to understand that it’s okay to round off calculations you make using your measured values, <u>but you should not round off your measurements</u>!!!!! For accuracy, you should always record the number of decimal places your measuring instrument provides along with the measurement rule.

Virtual Laboratory

Topic 01 – Measurement

			01
Name	Section #	Date	Topic #

I. Use the method of Unit Cancellation. or the Stair Step method to make the following metric conversions.
(dkL = dekaliter and dL = deciliter)

a) 4 dm = _________m   b) 3 mL = _________L   c) 5 g = _________ mg

d) 5 cm = _________ dm   e) 7dL = _________ dkL   f) 15 g = _________ kg

g) 12 cm = _________ m   h) 9 L = _________ hL   i) 20 dg = _________ hg

j) 30 dm = _________ m   k) 29 kL = _________ cL   l) 63 cg = _________ g

m) 0.30 cm = _________ mm   n) 0.09 hL _________L   o) 0.39 hg = _________ mg

p) 1523 mm = _________ m   q) 5.432 mL = _________ L   r) 920 g = _________ kg

II. Use the method of unit cancellation to convert the following quantities.

a) 75.6 in = _________ cm   b) 29.7 cm = _________ in   c) How many inches in 1 cm? ________

d) 6.54 mi = _________ km   e) 32.9 km = _________ mi   f) How many miles in 2.2 km? ________

g) 1.398 N = ________ lbs   h) 154 lbs = _________N   i) How many Newtons in 4.3 lbs? ________

j) 2.6 gal = _________ L   k) 92.3 L = _________ gal   l) How many gal in 2.0 L? _________

III. Convert the following temperatures.

a) 75ºF = _________ ºC   b) 75ºC = _________ ºF

c) 200ºC = _________ ºF   d) 200ºF = _________ºC

IV. Calculate the percent error for the following situations.

a) During an experiment a scientist finds the density of a rock to be 3.29 g/cm^3. The accepted value for this type of rock is 3.39 g/cm^3. Calculate the percent error. _________

b) A brick has a mass of 500 grams written on it. When the mass is measured it is found to be 489 grams. Calculate the percent error. _________

c) A student performing an experiment about the melting point of an object. After 5 trials he found the melting point to be 192 ºC. 206 ºC. 197 ºC. 199 ºC. and 202 ºC. The accepted melting value temperature is 200 ºC.
Calculate the percent error. _________

V. For each pair of units circle or highlight the smallest quantity.

a) decimeter and dekameter
b) centimeter and millimeter
c) kilogram and gram

VI. Answer the following questions.

a) How many years in a decade? _____________
b) How many years in a century? ____________
c) How many years in a millennium? _________

VII. Density calculation

a) Calculate the density of a 495 cm^3 and 1235 gram substance.
b) From your textbook. what does “No naked numbers” mean?

Hands-on Laboratory

Topic 01 – Measurement

MATERIALS

100 ml graduated cylinder
English - metric scale ruler
Marble
metric digital scale in grams'
wood block
paper clip

Bolt (.75-cm. x 5.0-cm.)
250-ml. and 1000 ml beaker
Meter stick
thermometer (ºC)
stop watch

Hot plate or stove for instructor table

PROCEDURE

Note: Read each procedure thoroughly, then perform the procedure carefully and record the data on the data sheet provided. ***Be sure to use the "Measurement Rule" in all non-digital measurements***.

Part A - Problem: How do we use metric units of length?

Section 1 - Linear Measurement

1. Use a metric ruler to measure the items listed in the data table. Convert the measurements to kilometers, meters, and millimeters.

   Pre-Lab preparation:

   How many cm in 1 m? _______

   How many m in 1 km? _______

   How many mm in 1 cm? _______

Part B - Problem: How do we measure the volume in the metric system?

1. To measure the volume of an irregular object such as a bolt:
   a. Pour water into the beaker approximately three fourths full. Repeat the process for the graduated cylinder. Measure the volume of the water and apply the measurement rule.
   b. Slide the object into the cylinder carefully to avoid any spillage or splash of water.
   c. Measure the new total volume and apply the measurement rule.
   d. Determine the volume of the irregular object by subtracting the initial volume from the final total volume and record.

2. Convert the measurements into kiloliters, liters, and centiliters.

   Pre-Lab preparation:

   How many mL in 1 cL? _______

   How many cL in 1 L? _______

   How many kL in 1 L? _______

3. Repeat steps 1 and 2 using a marble.
4. Measure the volume of a wood block using a 1000 mL beaker.
5. Compare measurements of beaker and graduated cylinder.
6. Answer the questions.

Part C - Problem: How do we determine mass in the Metric System?

1. Obtain a beaker or plastic container and determine its mass using the scale provided. Remember write all numbers provided by the digital scale. The measurement rule does not apply to digital readings.
2. Carefully measure 200-ml. of water, using the graduated cylinder, and add it to the container. Determine the mass of the container and the water.
3. Calculate the mass of the 200-ml. of water and then calculate the mass of 1-ml of water.
4. Perform all conversions indicated.
5. Measure the mass of the wood block. Perform the conversions.

Pre-Lab Preparation – What are the common units used to describe mass measurements? _________

Part D - Problem: How do we time an event?

1. Locate a distance of about 10 meters. Establish a starting line and a finish line.
2. Obtain a timer. Make sure you know how to operate it and the units involved.
3. Start the timer as you begin to walk and stop the timer when you cross the 10 meter mark. Read the time to the smallest unit available.
4. Repeat this operation for each member of your group, (At least 3 measurements are needed.)
5. Enter each recorded time on the spaces provided in the data sheet.
6. Obtain the average time by dividing the sum of all recorded times.

Part E - Problem: Measuring temperature

1. Notice where the instructor has placed a hot plate with a beaker of water on it.
2. Record temperature of water in ºCelsius. Remember to apply the measurement rule.
3. Convert the temperatures to ºFahrenheit.

Part F - Problem: Measuring angles

1. Use a protractor to measure the three angles of the drawn triangle. Use the measurement rule.

Pre-Lab Preparation – What are the common units used to describe angular measures? _________

Part G - Problem: How do we find average value, error and percentage of error?

1. Given the following data, compute the average value, error and percentage of error.

$x_1 = 61.4$ $x_2 = 62.8$ $x_3 = 67.3$ $x_{theoretical} = 61.0$

This calculation should be completed as part of your pre-lab preparation before the lab meeting.

Part H - Problem: How do we convert English to Metric and Metric to English?

Perform the conversion problems indicated in Part H on the Data Sheet. Use the conversion table in the front cover of your textbook. Make sure your answers include units. This table should be completed as part of your pre- lab preparation before the lab meeting.

Part I - Design an experiment to measure the volume of a human. The human must survive the measurement! Be detailed. What equipment will be needed and how will the measurement be accomplished? How will you insure the survival of the human? In what units will the volume be measured?

•01•
MEASUREMENT

	Section #	Kit #	Topic #
			01
			01
			01
Name			

Part A - Length

Section 1 - Linear Measurement (measure the object in centimeters and convert)

Object	Kilometer	Meters	Centimeters	Millimeters
Length of this data table				
Block length				
Block width				
Block height (or depth)				

1. How many centimeters in a 1 inch line? _____

2. What measuring instrument would be best to use to measure the chalkboard at the front of the classroom? Explain why.

3. Which is longer? Circle or highlight correct answer for each pair.
   a. 1000 millimeters or 1 kilometer
   b. 1 centimeter or 1 millimeter
   c. 1 inch or 1 centimeter

Part B – Volume (Measure volume of bolt and marble using the 250 ml beaker and the wood block using the 1000 ml beaker, and convert measurement to the other three columns. Retake the measurements using a graduated cylinder for everything but the block. Remember to apply the measurement rule. (Don't convert the graduated cylinder measurements.)

Smallest division on 250 ml beaker = _____ Smallest division graduated cylinder =_____ Smallest division 1000ml beaker = __________

Object	Kiloliters	Liters	Centiliters	Milliliters beaker	Milliliters graduated cylinder
Bolt					
Marble					
Wood block					

1. Compare the graduated cylinder measurements to the beaker measurements? Which one provides a more accurate or precise measurement? Explain. _____

2. Calculate the volume of the block (L x w x h) using your measurements from part A. Show your work and include units. Remember 1 cm^3 = 1 mL.

3. Did your calculation for determining the volume of the block agree with your beaker volume measurement? Explain your results.

4. Calculate the percent error between the volume you calculated and the volume found using the beaker.

Error = |Experimental value – Theoretical value| = | Beaker value – Calculated value from #2 | = _______________

$$\%Error = \frac{100.x.Error}{theoreticalvalue} =$$

Part C - Mass (measure the masses in grams and convert to the other two columns)

	Mass		
Object	Kilogram	Gram	Milligram
Mass of 250 ml beaker			
Mass of beaker + 200-ml water			
Mass of 200-ml water			
Mass of One milliliter of water			
Mass of wood block			

Density = mass in grams / volume in milliliters.

1. Calculate the density of water, Include units with your final answer.

2. Calculate the density of the block. **Use the volume from Part B question 2**. Include units with your final answer.

3. When the block is placed in water it floats. Based upon your density data what can you infer about the density of objects that float on water? What about objects that sink?

Part D - Time (measure the time in seconds for each person in your group to run approximately 10 meters and average the findings.)

Include units with your numbers!!

1	2	3	4	5	Average

Part E - Temperature

1. Temperature of tap water ____________°C convert to ____________°F
2. Temperature of boiling water ____________C convert to ___________°F

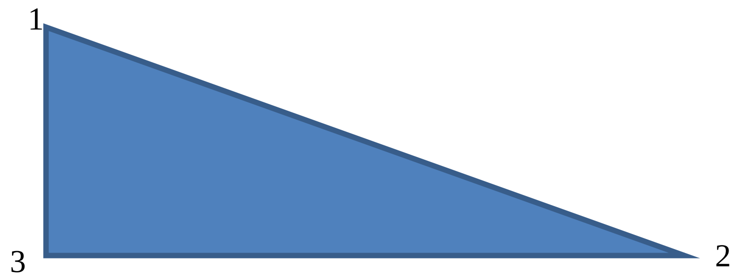
Part F – Angles

Measure the angle between the two lines at the three points using a protractor. (All 3 angles should add to 180°.)
(Don't forget to apply the measurement rule and include units!)

Angle 1: ____________

Angle 2: ____________

Angle 3: ____________



Part G – Average. Error. Percent of Error (Solve the following before the lab meeting):

x_1 = 61.4 x_2 = 62.8 x_3 = 67.3 theoretical value = 61.0

1. Average value _____

2. Error _____

3. Percentage of Error _____

Part H - Problems: Solve each of the following before the lab meeting:

Problem	Solution
1. How many cm are 3.6 in?	
2. 6.1 L are how many ml?	
3. 7.2 m are how many cm?	
4. 2.6 ft are how many cm?	
5. 5.6 m are how many mm?	
6. 2.4 hp are how many W?	
7. 10.1 lbs are how many N?	
8. 488 mi are how many km?	
9. How many kg are in 29 slugs?	

Part I – Design an experiment to measure the volume of a human. The human must survive the measurement! Be detailed. What equipment will be needed and how will the measurement be accomplished? In what units will the volume be measured? How will you insure the human survives?

MEASUREMENT

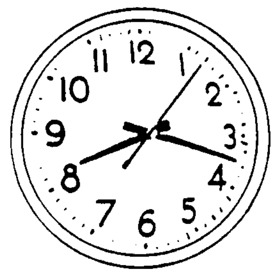
Self-Evaluation

Test 011

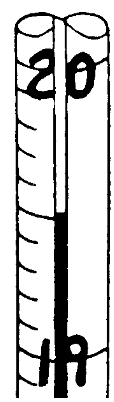
Directions: Select the best answer

1. 01.1 Indicate the metric units for volume, length, mass, and temperature, in order.
   A. liter, meter, pound, Celsius
   B. liter, meter, gram, Celsius
   C. gallon, meter, pound, Celsius
   D. liter, yard, gram, Celsius
   E. none of the above

2. 01.1 In reading a graduated cylinder we always read to the bottom of the
   A. liquid being measured
   B. meniscus
   C. nearest marking on the cylinder closest to the liquid
   D. all of the above
   E. none of the above



3. 01.2 What is the smallest measurable division on the clock pictured?
   A. 10 s
   B. 1 s
   C. 0.1 s
   D. 0.01 s
   E. none of the above



4. 01.2 To correctly apply the measurement rule to the cylinder on the right. the measurement should include a numeric value to which place?
   A. 10
   B. 1
   C. 0.1
   D. 0.01
   E. 0.001

5. 01.3 143 m are how many km?
   A. 143 km
   B. 14.3 km
   C. 1430 km
   D. 14300 km
   E. 0.143 km

6. 01.3 4.8 m are how many cm?

A. 0.48 cm
B. 48 cm
C. 480 cm
D) 4800 cm

7. 01.4 100 mg = __________ cg = _________ g = __________ kg

A. 1 cg = 10 cg = 100 kg
B. 1 cg = 0.1 g = 0.001 kg
C. 10 cg = 1 g = 0.01 kg
D. 10 cg = 0.01 g = 0.0001 kg
E. 10 cg = 0.1 g = 0.0001 kg

8. 01.4 Given a 5.25-kilogram mass determine its mass in grams.

A. 5250 g
B. 525 g
C. 0.525 g
D. 0.053 g
E. 0.00525 g

9. 01.5 12.02 liters are how many mL?

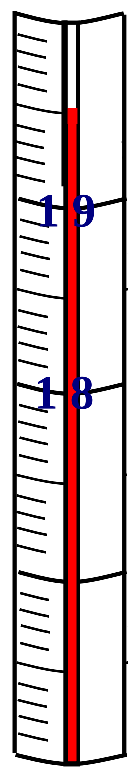
A. 0.1202 ml
B. 0 .01202 ml
C. 1.202 ml
D. 120.2 ml
E. 12020 ml

10. 01.5 6.01 liters are how many mL?

A. 60.1 ml
B. 601 ml
C. 6010 ml
D. 0.601 ml
E. 0.0601 ml

11. 01.6 Applying the measurement rule. what is the correct reading for the thermometer (shown on the right.?

A. 19.61 C^{o}
B. 19.5 C^{o}
C. 19.6 C^{o}
D. 19 C^{o}
E. 19.51 C^{o}



12. 01.6 What is the correct reading for the thermometer (shown on the right. when applying the measurement rule.

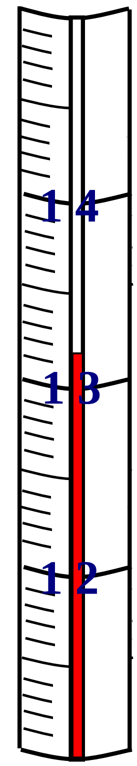
A. 13.51 C^o

B. 13 C^o

C. 13.1 C^o

D. 13.15 C^o

E. 13.05 C^o



13. 01.7 An experiment is performed three times and the following results were obtained. Find their average and compute the percent error. The theoretical value is 0.051.

TRIALS: 1) 0.053 2) 0.050 3) 0.047

A. 1.96%

B. 1.52%

C. 7.30%

D. 1.01%

E. none of the above

14. 01.7 In an experiment to determine the specific gravity of an object. the average of the results was 8.4. Calculate the percent error if the theoretical value is 6.2.

A. 60.5%

B. 23.5%

C. 35.5%

D. 0.355%

E. none of the above

15. 01.8 How many cm in 5.0 inches?

A. 1.968 cm

B. 12.7 cm

C. 15 cm

D. 10.1 cm

E. 7.54 cm

16. 01.8 254 miles are how many km?

A. 157.764 km

B. 415 km

C. 409 km

D. 40.9 km

17. 01.9 Calculate the density of a rock based on the following measurements. The volume of the rock equals 2.3 mL and the mass is 6.4 g.

A) 2.8 g/ml

B) 0.42 g/ml

C) 1.0 g/ml

D) 14.72 g/ml

18. 01.6 Convert 45.6ºC to ºF.

A) 75.5 ºF

B) 114.1 ºF

C) 42.1 ºF

D) 57.3 ºF

EXPERIMENTAL MODELS

Topic 02

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct terms.

   amplitude, constant, dependent variable, hypothesis, independent variable, law, mass, observation, oscillation, pendulum, period, prediction, scientific method, and theory.

2. Identify the independent and dependent variables given an experimental situation with a list of variables.

3. You will be expected to make a graph including a title, labeled axes with units, appropriate scales, and best fit line.

4. List or identify the steps needed in developing variables for an experimental situation that would yield the most reliable data.

5. Based upon a fictional experiment be able to identify the steps in the scientific method (examples: research question, hypothesis, and conclusion), and list the correct order of steps.

INTRODUCTION

Prior to the time of Galileo (about 1580), the progress of scientific investigation was confined to observable facts in nature and the theories of the early philosophers. As often as not, the observed facts failed to correspond in any way with the theories. Experimental results often contradicted the theories. The only measure of the theories worth was the reputation of the person who proposed them. Quite often, theories that were later disproved existed for many centuries because their author was a person of great respect.

In the 16th century, people who proposed ideas on the behavior of matter used experimental results to modify their theories. In any case, the scientific method was born, and progress was made along logical steps. Among the early proponents of the scientific method was Galileo Galilei who by a series of simple experiments was able to make several important generalizations on the nature of gravity. His methods are generally the same as those used today, namely:

1. Observations are made of some phenomena that generated a problem/question.
2. Research questions are developed to predict untested behavior.
3. Variables are identified, and, hypotheses generated to make predictions.
4. Experiments are used to examine the validity of the prediction.
5. Data is analyzed and further research identified. Theories are modified or strengthened. Theories that withstand the test of experiments of very large periods of time can become scientific laws.

Usually, once a law has been stated, further experimental work is carried on to test it. The objective is to reach a point where an explanation of all related occurrences in nature may be found in the simplest and concise law possible. It will take many years of work by many people to arrive at this ultimate end.

The Problem

The scientific method can be studied by investigating the behavior of a simple device called the pendulum. A pendulum consists of a string with a mass attached at the end. When released from some amplitude the pendulum will **oscillate** (swing back and forth). The problem is: What are the factors which affect the period of the pendulum?

Variables

The variables to be considered for the pendulum would include mass, length, amplitude, and the period of the pendulum.

Independent Variables

In an experiment there are three kinds of variables: independent, dependent and constant. The conditions which are selected to produce various results are called independent variables, For example, the mass of the string could be an independent variable. When experimenting with the pendulum, you will select a mass, conduct an experiment, and then select another mass and repeat the procedure. Until enough data was collected you would be controlling or selecting the independent variable.

Dependent Variables

The dependent variable is the result you measure. In the case of the pendulum, it is the **period** (the time to make one swing). We could change the mass of the pendulum (independent variable) and observe how the period (dependent variable) changes.

Constant Variables

It should be noted that there may be other variables which must be held constant during the described procedure to insure consistent results. These variables which are fixed are called constants. In our example while investigating mass, the length and amplitude of the pendulum must be held constant. In other words, investigate only one variable at a time while holding the other variables constant,

Research Question

All experiments try to answer a question. This question is referred to as the research question and has a very specific format that describes the effect of the independent variable upon the dependent variable. In general, the question will be of the form. ***Does the dependent variable depend upon the independent variable*?** More specifically *Does the period of a pendulum depend on mass*?

Hypothesis

When preparing to perform an experiment it's important that an educated guess as to what the answer to the question is provided. This allows us to test if we are correct or not. All hypotheses must include a very specific prediction. The general form of the hypothesis can be. **As the independent variable is increased the dependent variable will increase/decrease/remain the same/etc**…. Then we can run a test to see if our hypothesis is correct or not.

Collecting the Data

The period of a pendulum is the time (in seconds for this experiment) for the pendulum to make a complete oscillation. An oscillation is the movement of a pendulum from its one maximum position all the way over to its other maximum and back. There are three variables of the pendulum which could possibly affect the period. These are:

a. The mass of the pendulum bob.
b. The **amplitude** of the swing, i.e.. the angular distance from the vertical to maximum.
c. The length of the pendulum (distance from point of support to the middle of the mass). It is measured in centimeters for this experiment.

When there are three properties like the above, the procedure is to fix any two, and then vary the other. Thus, we would get some idea how this property affects the period. In this experiment, we will measure the period of the pendulum by recording the time for 10 complete oscillations, and then divide this number by 10 to get the period of one oscillation. This is done to reduce the experimental error of starting and stopping the pendulum by a factor of 1/10. Remember to measure and record all data to the correct number of digits indicated by the Measurement Rule discussed in Topic 1.

Data Analysis

The purpose of analyzing our data is to answer the research question. To answer the research question, we must analyze one of three conditions existing with the data. First, the data could be all the same, indicating that the dependent variable does not depend upon the independent variable. Second, the data could clearly vary in some systematic way, indicating the dependent variable depends upon the independent variable. Third, the data varies a small amount and it is unclear whether the data is really the same or is different. This variation may be a result of systematic errors, uncertainty in your measurements, errors in how the data is collected and recorded by you, or how well you performed the experiment.

Errors in experiments are an inherent part of experimental science. There's no escape! However, there is one type of error that is within your control. If you perform an experiment incorrectly, misread the measuring instruments, incorrectly record data, etc….. then you can expect to re-do the experiment or the portion that is affected by your mistakes. Many students think that writing off their mistakes as human error is acceptable. It's not. Following instructions and taking care to execute those instructions carefully is a critical part of the laboratory learning experience.

There will be systematic errors that will be out of your control. These can cause the accuracy (expected value) to be off, but these do not affect precision (repeatability of your measurements). For example, when measuring the swing of a pendulum we will be taking our measurements in a room filled with air, but the predicted value is based on measurements taken in a vacuum. The air resistance your pendulum experiences will affect the time measurements by a very small amount. Your instructor will discuss these types of errors with you before or during each laboratory.

Another type of error is the uncertainties in the measurements. Remember the *guessed* portions of your measurements from Topic 1 when applying the measurement rule? These guessed measurements will always have an effect on your results. In other words, we do not expect you to obtain zero percent errors during any lab experiment. This doesn't make the experiment invalid or somehow meaningless. Our results are controlled by the measuring instruments we have available and the design of the experiment. Your instructor will let you know the typical percent error for each experiment during the semester. If your percent error is equal to or less than this amount, then your results indicate that the uncertainty in measurements and systemic errors are what is expected. You can conclude that your results support the prediction. However, if your percent error is greater than what is expected then you should discuss this with your instructor to determine whether you incorrectly completed the experiment, performed your calculations, or recorded the data.

Example: The following represent three possible outcomes or results of an experiment and the analysis of those results. (Note: The experiment was designed to determine if the period of a pendulum depends on mass. The time in seconds for one swing (period) is recorded for 4 different masses.)

	Mass 1	Mass 2	Mass 3	Mass 4
Result 1:	1.92 s	1.92 s	1.92 s	1.92 s

Analysis: *They are the same.*

The dependent variable does not depend upon the independent variable

Result 2:	1.92 s	2.30 s	3.45 s	4.41 s

Analysis: *They are different.*

The dependent variable depends upon the independent variable

Result 3:	1.92 s	1.94 s	1.98 s	1.96 s

Analysis: *Uncertain, Statistical analysis is needed.*

There is variation but is it enough to say the data is not the same?

The variation of the data in Result 3 is obvious in terms of magnitude. However, how much variation must exist to indicate that the numbers are really different? The variation observed could be due to uncertainty in the measurements, or it could be due to the dependency of the dependent variable upon the independent variable.

When the variation is small statistical analysis is used to determine the cause of the variation. It is not the intent of this book to introduce the formal use of statistics. Our use of statistics will be based on an informal, or a common-sense approach, Our analysis will help us determine if the variation is small enough to be disregarded due to uncertainties in our measurements.

The analysis will be fairly simple and based on the variation in the data. The variation in the data is the difference between the largest and the smallest piece of data. If the variation is smaller than the size of the guessed position, then the variation would be due to uncertainties in our measurements and we can consider the data to be the same. If the variation is larger than the size of the guessed position, then we cannot conclude that the data is the same. For example:

- Sample data: 1.9<u>2</u> s 1.9<u>4</u> s 1.9<u>8</u> s 1.9<u>6</u> s
  Note: The *guessed* position is underlined. For this example, the guessed position is the hundredths position. Therefore, the size of the guessed position is 10 hundredths,
- Variation = 1.98 s – 1.92 s or 0.06 s
  Variation: difference between the highest and lowest data
- 0.06 is less than 10 hundredths therefore the variation is due to uncertainty in the measurements. We can view all 4 data points as the same,
- Since the variation is due to uncertainty (we can view all data points as equal to each other) we can conclude that the dependent variable <u>does not</u> depend upon the independent variable.

It is important to understand that this analysis will work well if we have not made any gross or large errors while making our measurements. If we have made gross errors our analysis will actually cause us to arrive at a wrong conclusion. Careful experimentation is extremely important.

Research Answer/Conclusion

The research answer is very specific. A general statement would be, *As the independent variable (increases/decreases) the dependent variable (increased. decreased, remained the same).* For our example experiments above we would write, *As the mass increased. the period of the pendulum (increased or decreased or remained the same). The period. of a pendulum depends/does not depend on the mass of a pendulum.*

Virtual Laboratory

Topic 02 – Experimental Models

			02
Name	Section #	Date	Topic #

Obtain the PHET Pendulum Simulator and notice the controls. Play with the program. Once you are comfortable using the simulator, use it and your text book to answer the following questions.

1. Does the period of the pendulum depend on Length? ____
   a) How do you know? ____
   b) What is the independent variable? ________________________________
   c) What is the dependent variable? __________________________________

2. Does the period of the pendulum depend on Amplitude? _____
   a) How do you know? ____
   b) What is the independent variable? ________________________________
   c) What is the dependent variable? __________________________________

3. Does the period of the pendulum depend on Mass? ______
   a) How do you know? ____
   b) What is the independent variable? ________________________________
   c) What is the dependent variable? __________________________________

4. What is the smallest division on the ruler? ___________________

5. What is the smallest division on the protractor? _________________

6. How should the measurement rule be applied in each case? (How many decimal places will you need to have in your answer for each measuring instrument?) Provide an example measurement for each.
   a) Ruler: ___________________________________
   b) Protractor: ________________________________

Hands-on Laboratory

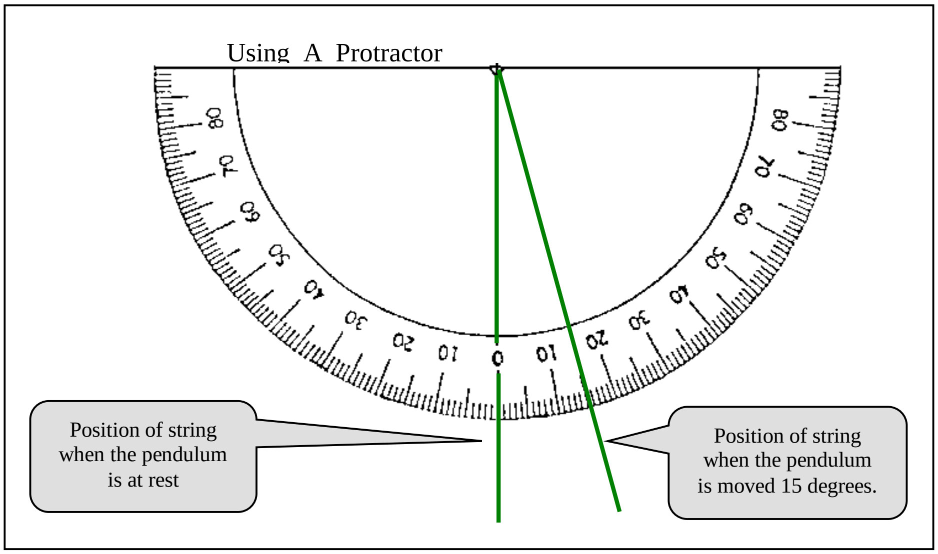
Topic 02 – Experimental Models

MATERIALS

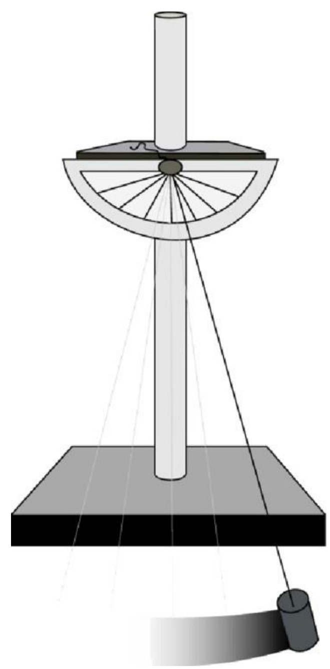
Pendulum apparatus (protractor. and string holder)
masses 10, 20, 50 g.

bar clamps	stop watch
support rods	string
Meter stick	balance (optional)

PROCEDURE



Review and apply the Measurement Rule for all non-digital measurements.



Part A - Problem: Does the period of a pendulum depend on Mass?

1. Prelab prep: Identify and record the independent, dependent variables, constants, the research question and hypothesis on the data page.

2. Set up a "ring-stand" near the edge of a table that has a height that will allow a pendulum length of 100-cm.

3. Obtain a string length of approximately 125-cm. Tie a loop at one end that will allow you to hook the mass. Slide the other, end of the string, in back of the adjustable clamp located in the center of the protractor. Adjust the final length of the string and mass to 100 cm. Remember the length of the pendulum is measured from pivot point to the center of the mass.

4. Obtain three different masses, 10.0, 20.0, and 50.0 grams. You will have to adjust the length to maintain 100-cm. since the masses are different lengths. Note, hook the 10 and 20 gram masses together to make a 30 gram mass.

5. Measure the period for each mass using the following method.
   a. Maintain a length of 100-cm, and amplitude of 15º, (Amplitude is measured from the at rest position to the release point)
   b. Obtain the time needed for 10 complete swings back and forth (periods).
   c. Divide the time for 10 periods by 10 to obtain the time for 1 period.

6. Does your data support your hypothesis? Explain, Show any statistical analysis.

Part B - Problem: Does the period of a pendulum depend on amplitude?

1. Pre-lab Prep: Identify and record the independent variables, dependent variables, constants, research question, and hypothesis on the data page.
2. Keep the mass fixed at 50.0-g and the length fixed at 100 cm.
3. Experiment to find the period for amplitudes of 5, 10, 15 and 20 degrees. *Remember the amplitude (given angle) is the starting point for the release of the mass and the angle (amplitude) is created by moving the mass from the resting point to the number of degrees indicated.*
4. Does your data support your hypothesis? Explain, Show any statistical analysis.

Part C - Problem: Does the period of a pendulum depend on length?

1. Pre-lab Prep: Identify and record the independent variables, dependent variables, constants, research question and hypothesis on the data page.
2. Keep the mass fixed at 50.0-g and the amplitude at 15º. Determine the period for six different lengths (10, 20, 40, 60, 80, 100 cm).
3. Does your data support your hypothesis? Explain, Show any statistical analysis.

Part D – Graph your results

1. Plot your results for **1 period** from parts A, B, and C. (See section entitled. "Notes on How to Draw a Graph".) Plot the independent variable on the x axis and the dependent variable (**time for one period**) on the y axis. Should your data start at x = 0 and y = 0? Graphs are provided at the end of the data sheets. You will have 3 separate graphs.
2. Draw a best fit line between the data points. (Do not play "Connect the Dots") If your data shows linear behavior use a ruler to draw a best fit line.
3. Title the graph Dependent variable vs. Independent variable. Label the axes and include units.
4. Identify the relationship between your dependent and independent variables for all three graphs.
   Directly Proportional relationship: Graph is a straight line that passes through the origin.
   Linear relationship: Graph is a straight line that does not pass through the origin.
   Non-linear relationship: The graph is not a straight line, but curves.
   What does the dependent variable do as the independent variable increases? Does the dependent variable increase or decrease? Does the rate of increase or decrease change or remain constant?
5. From the Period vs. Length graph determine what the period of the pendulum is for 50 cm.
6. Test this prediction by actually measuring through experimentation.
7. Determine if reading a graph provides a good method for obtaining data of this nature.

Graphing

A graph is often the easiest way to display data in a compact form which will help you analyze and interpret the data. A graph will also point out inconsistent readings. In order that a graph to be useful you should:

1. Plot **the independent variable** on the horizontal axis, and plot the **dependent variable** on the vertical axis. Choose appropriate **units** for each variable.

2. Choose the numerical range for each variable, which is necessary in order to include all of your data on the graph.

3. Decide the overall size of your graph. Determine the number of centimeters or the number of squares you are going to use for each axis. Make the graph as large as possible on the area you are using.

4. Choose appropriate numerical scales for the two axes. This is the number of units for each square on the graph paper. You must use a uniform scale along each individual axis, but of course, the two axes will usually have different scales.

5. Include along each axis the name of the variable and the corresponding unit. The scale must be labeled with the numerical value next to each second, fifth, or tenth square.

6. Plot the "points" representing your data. Avoid the use of dots (.), because dots tend to indicate absolute knowledge. Since the "points" represent the data obtained in your experiment which contains uncertainties in the measurements and hence are not measured with perfect precision. Use one of the following symbols: o, x or Δ. The symbol o is probably the best when you are going to draw only one curve on a graph.

7. Draw a best fit line/curve through your data points. If you cannot find a smooth line/curve which passes through all the points, draw your curve in the best "average" position, with some points falling on each side of the curve. If you have a straight line use a ruler to draw the line. DO NOT PLAY CONNECT THE DOTS!!!!

8. If graphing two or more functions (lines) on one graph, code them by color. For example, pencil for one, blue ball point pen for another, etc.

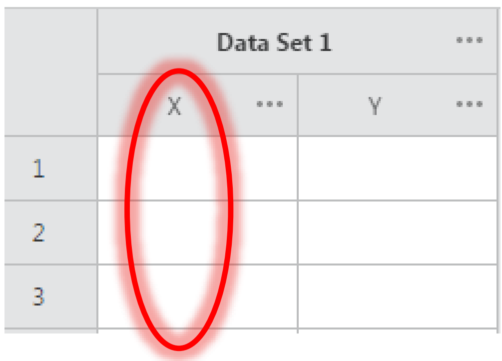
9. Title your graph with the names of the **form** Dependent variable vs. Independent variable. (Don’t title your graph with the words Dependent variable vs Independent variable!)

Graphing Using Graphical Analysis Program

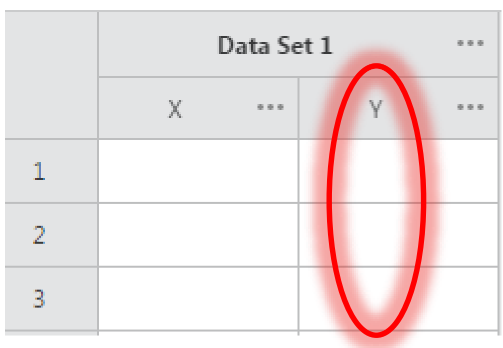
Topic 2 Graphing Make 3 separate graphs.

Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

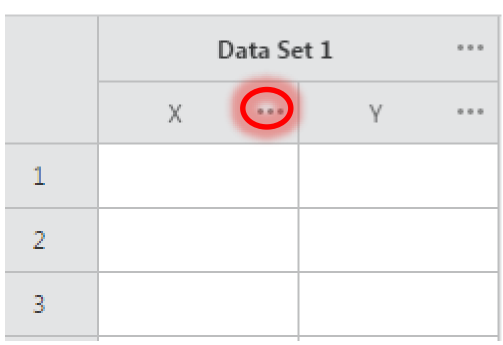
1. Enter the X data into the table; only the numbers, not the units.



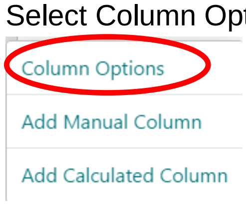
2. Enter the Y data into the table; only the numbers, not the units.



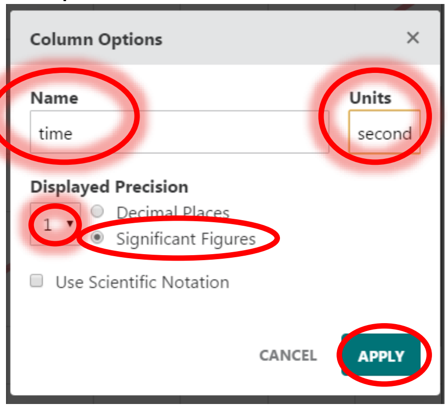
3. Click on the three dots next to X.



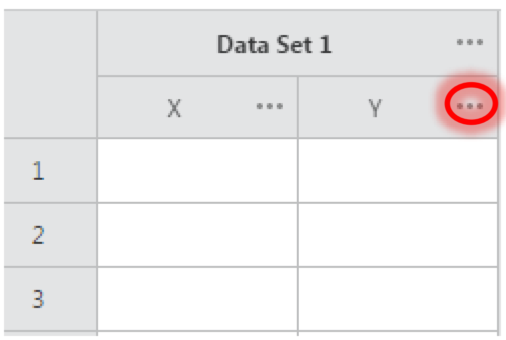
4. Select Column Options

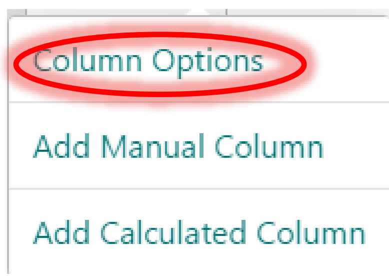


5. Type the name of the x axis (independent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



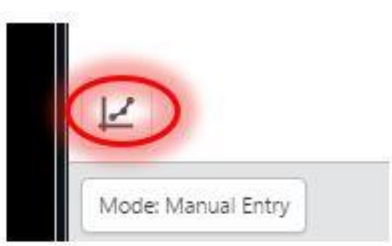
6. Repeat steps 3 – 5 for the Y axis. Click on the three dots next to Y. Select Column Options



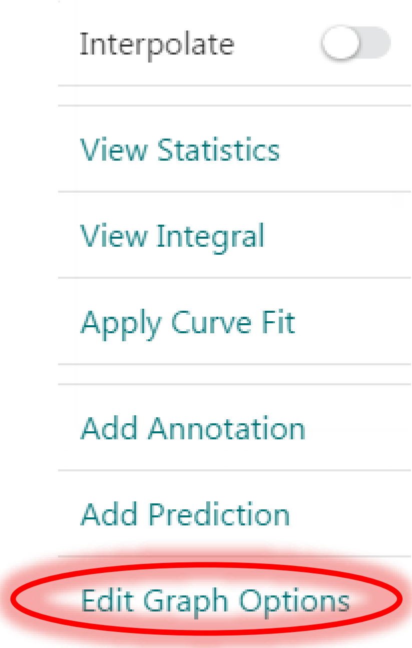


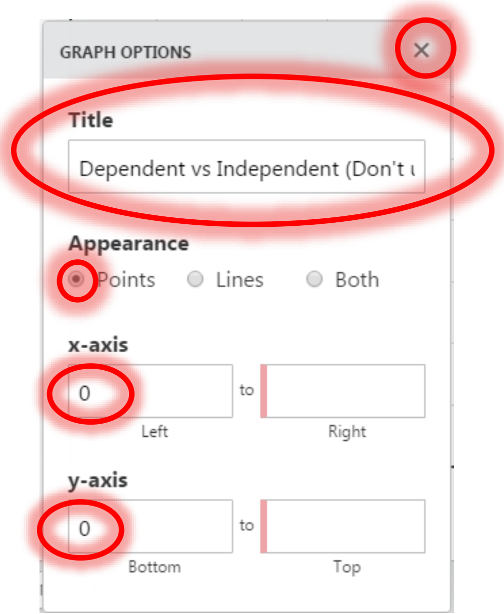
See step 5 for image. Type the name of the y axis (dependent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

7. Click on the graph icon in the lower left of the screen.



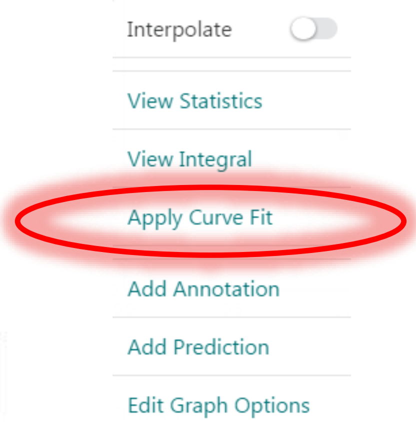
8. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to points. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.



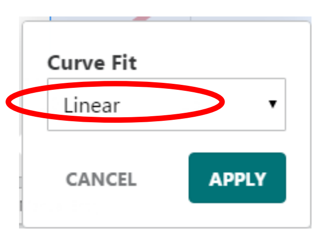


Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to insure that your graph starts with 0. 0 in the lower left corner.

9. Click on the graph icon in the lower left of the screen. Select Apply Curve Fit.

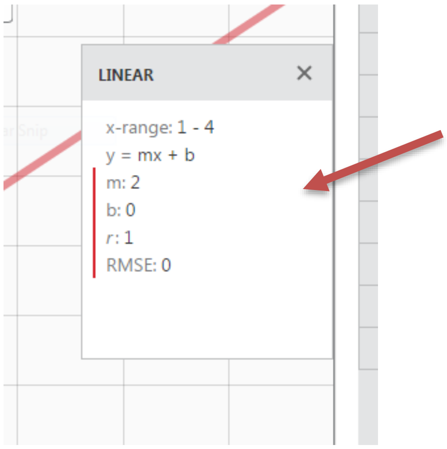


10. For the first two (parts A and B) graphs select Linear Fit as shown below. For the third graph (part C) select POWER Fit. APPLY.



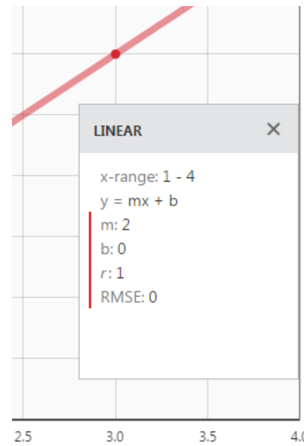
11. Uncover your best fit line or curve.

BEFORE



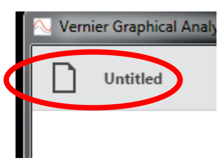
Notice the box that opens with your best fit line. If it is covering your best fit line move it so that it is not covering anything important.

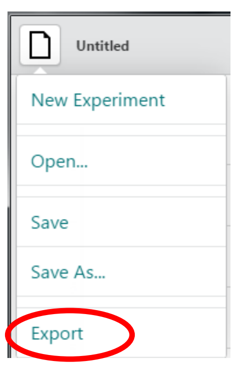
AFTER

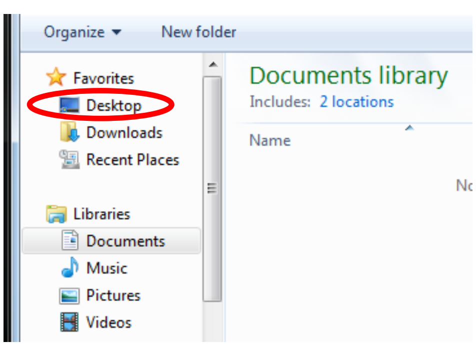


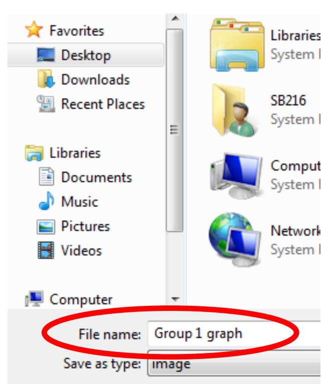
12. **Save** AND **Print** your graph(s).

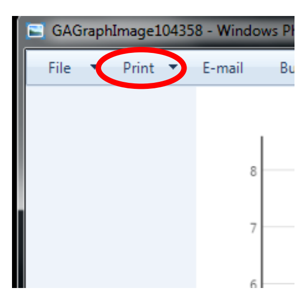
Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> Graph A, B, or C. Print.











• 02 •
EXPERIMENTAL MODEL

Report Name (ie. 019902)

Name	Section #	Kit #	Topic #
			02
			02
			02

Part A - Mass

Constant(s): Amplitude ______ degrees Length ______ cm
Independent variable ______ Dependent variable ______

Research Question: ____

Hypothesis: ____

If any of your measurements fall outside of what is expected redo the measurement(s).

Mass in grams	10	20	30	50
Time for 10 periods (s)				
Time for 1 period (s) graph				

Does your data support your hypothesis? Explain. Show any statistical analysis as required by your instructor.

____

____

Part B - Amplitude

Constant(s): Length ______ cm. Mass ______ grams
Independent variable ______ Dependent variable ______

Research Question: ____

Hypothesis: ____

If any of your measurements fall outside of what is expected redo the measurement(s).

Amplitude (degree)	5	10	15	20
Time for 10 periods (s)				
Time for 1 period (s) graph				

Does your data support your hypothesis? Explain. Show any statistical analysis.

____

____

Part C - Length

Constant(s): Amplitude _____ degrees Mass _____ grams

Independent variable _____ Dependent variable _____

Research Question _____

Hypothesis _____

If any of your measurements fall outside of what is expected redo the measurement(s).

Length (cm)	10	20	40	60	80	100
Time for 10 periods (s)						
Time for 1 period (s)$_{graph}$						

Does your data support your hypothesis? Explain. Show any statistical analysis. _____

____

____

Part D – Graphing (Make 3 graphs, Dependent variable: y axis & independent variable: x axis.)

1 **Directly Proportional relationship**: Graph is a straight line that passes through the origin.
2 **Linear relationship**: Graph is a straight line that does not pass through the origin.
3 **Non-linear relationship**: The graph is not a straight line, but curves.

(1) What is the relationship between Mass and Period (**Part A**)? _____ (select 1, 2, or 3 from above)

(2) What does the dependent variable do as the independent variable increases?
(Circle or highlight your selection between the bold choices below.)
Does the dependent variable **increase** or **decrease** or **remain the same**?

(3) What is the relationship between Amplitude and Period? (**Part B**)? _____ (select 1, 2, or 3 from above)

(4) What does the dependent variable do as the independent variable increases?
(Circle or highlight your selection between the bold choices below.)
Does the dependent variable **increase** or **decrease** or **remain the same**?

(5) What is the relationship between Length and Period? (**Part C**)? _____ (select 1, 2, or 3 from above)

(6) What does the dependent variable do as the independent variable increases?
(Circle or highlight your selection between the bold choices below.)
Does the dependent variable **increase** or **decrease** or **remain the same**?

(7) From the Period vs. Length graph determine what the period of the pendulum is for 50 cm. (Remember units!!!)

a.) L = 50 cm and P = __________

Test the graphical predictions by actually measuring the period for the 50 cm length. (Remember units!!!)

b.) L = 50 cm and P = __________

For L = 50 : Error = $|P_{\text{(from 7a.)}} - P_{\text{(from 7b.)}}|$ = ____

Calculate the percent error for L = 50 cm. (Show your work below.) ______________________.

$$\%error = \frac{100.x.Error}{TheoreticalValue}$$ (prediction from graph)

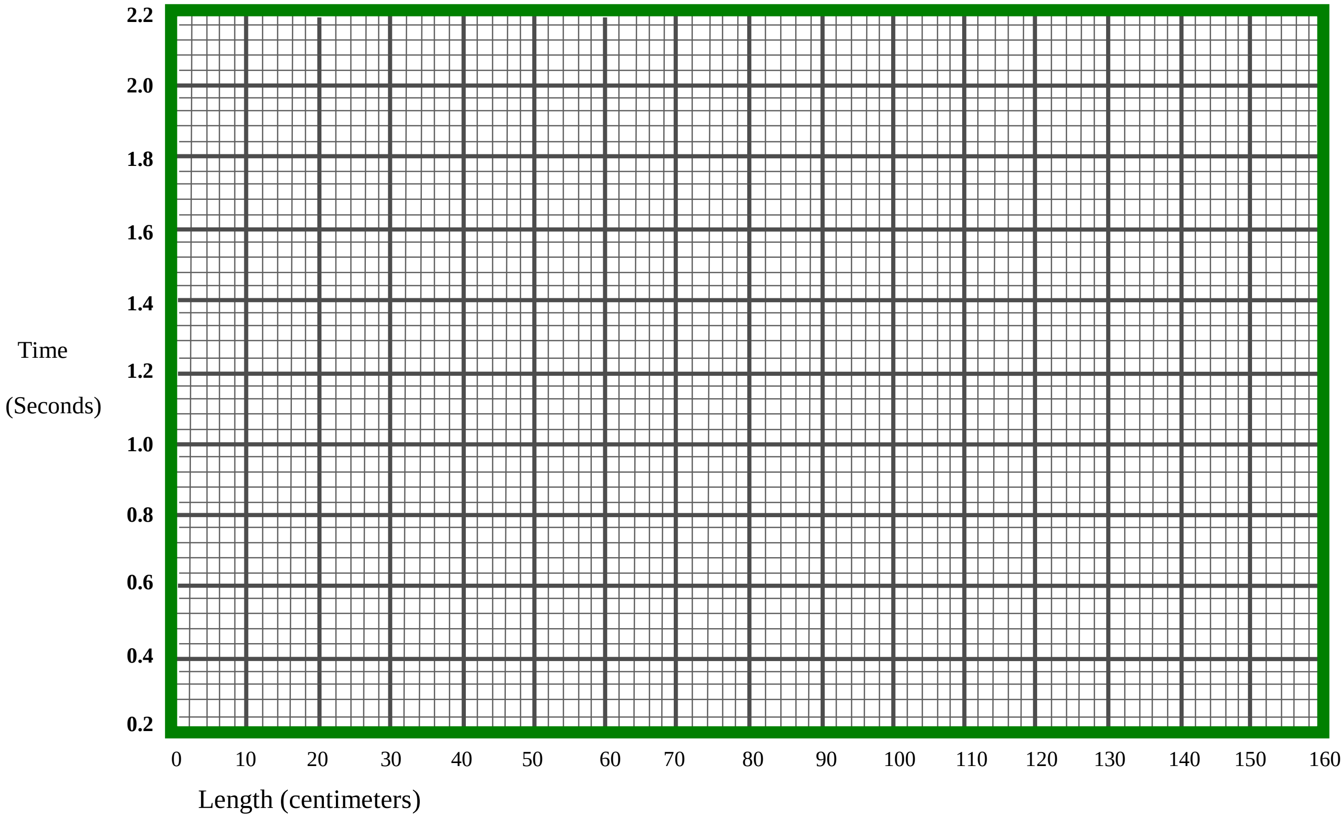
If your instructor permits you to use a graphing program, you can omit the following graphs.

Part A

Part B

Part C

Title: **Period vs Length of the Pendulum**



EXPERIMENTAL MODEL

Self-Evaluation

Test 021

Directions: Select the best answer.

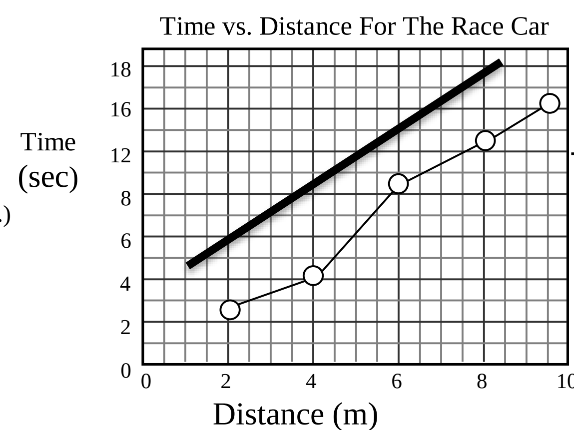
1. 02.1 In an experimental situation, the factors which are held static are called:
   A. constants
   B. dependent variables
   C. experimental group
   D. variables
   E. independent variables

2. 02.1 One complete swing of the pendulum is called:
   A. an oscillation
   B. a frequency
   C. an amplitude
   D. pendulum
   E. none of the above

3. 02.2 Given a problem such as the complete burning of a substance, the variables are: time taken for complete combustion, mass of substance, specific gravity, composition of substance, and caloric output of burning material. Identify the best measurable dependent variable.
   A. time
   B. mass
   C. experimental group
   D. composition
   E. caloric output

4. 02.2 In the experiment concerning the pendulum (involving the variables, mass, amplitude, length, and period. which was used as the dependent variable?
   A. period
   B. mass
   C. length
   D. amplitude
   E. all of the above

5. 02.3 Is the following graph correct?
   A. YES
   B. NO
   (You can ignore the connect the dot line.)

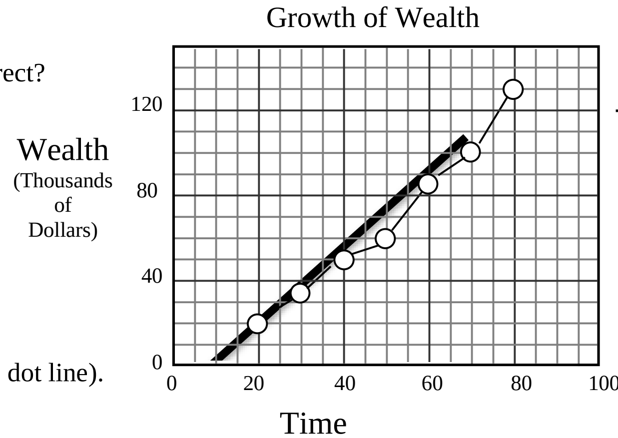


Distance (m)	Time (sec)
2.0	2.5
4.0	4.2
6.0	8.5
8.0	12.5
10.0	16.2

6. 02.3 Is the following graph correct?

A. YES

B. NO



Time (years)	wealth (Thous. dollars)
20	20.0
30	35.0
40	40.0
50	60.0
60	85.0
70	100.0
80	130.0

(You can ignore the connect the dot line).

7. 02.4 How many dependent variables do we handle at one time in our labs?

A. no more than one dependent variable at a time

B. no more than two dependent variables at a time

C. no more than three dependent variables at a time

D. all of the above

8. 02.4 An experiment is going to be developed that investigates how the amount of time students study affects their exam scores. Identify the dependent variable.

A. Study time

B. Exam scores

C. Final course grade

D. Both study time and exam scores

E. The type of exam given

9. 02.5 Arrange the following steps of scientific investigation in order.

1. develop conclusion
2. identify variables
3. conduct experiment
4. analyze data
5. identify research question
6. develop hypothesis

A. 1, 2, 3, 4, 5, 6

B. 1, 5, 3, 2, 4, 6

C. 6, 4, 3, 2, 5, 1

D. 1, 4, 3, 2, 6, 5

E. 5, 6, 2, 3, 4, 1

10.02.5 A research question asks; *Does the period of a pendulum depend on gravitational forces*? Which of the following is a correctly written hypothesis?

A. Gravity depends on the period of the pendulum.

B. The period of a pendulum depends on gravity.

C. The gravity changes as the period of the pendulum increases.

D. The period of the pendulum increases the gravitational forces.

E. As the gravitational force increases the period of the pendulum will decrease.

STRUCTURE OF MATTER

Topic 03

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct term.

   acid, anion, atomic number, atomic weight, atoms, base, cation, catalyst, compounds, covalent bond, dissociation, electrolyte, electrons, elements, gas, groups, heterogeneous, homogeneous, indicator, inorganic, ion, ionic bond, isotopes, liquid, litmus, matter, metals, mixtures, molecules, neutrons, non-metals, non-pure substance, organic, period, phenolphthalein, pHydrion, protons, pure substance, salt, energy levels or orbits, solid

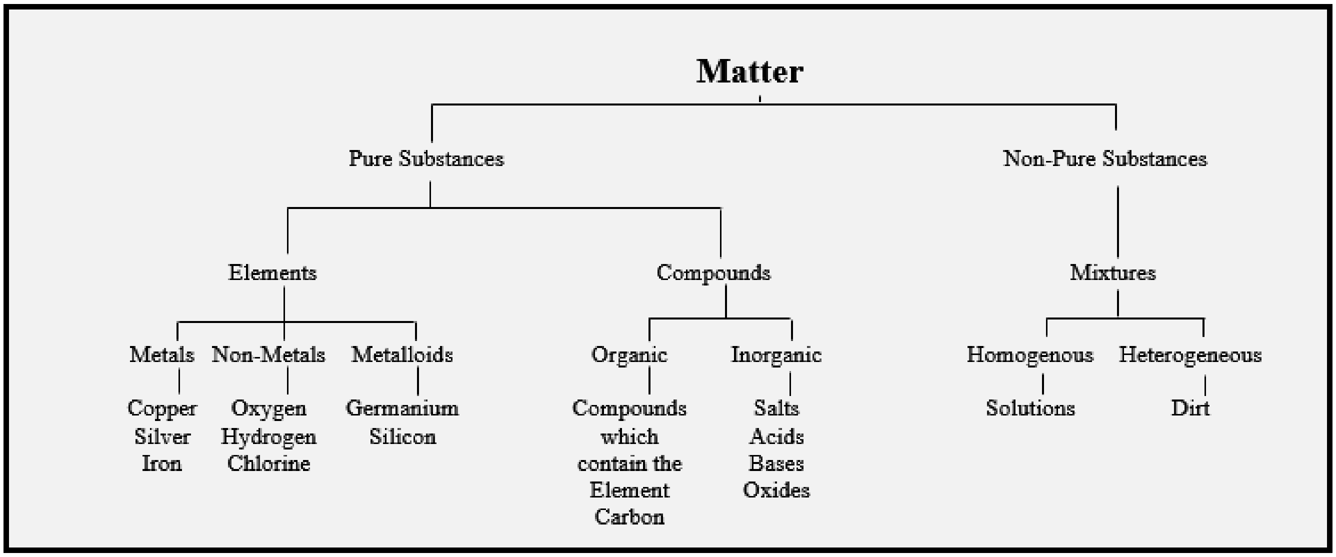
2. Identify or describe the major components of the atomic theory as stated in this unit.
3. Identify and describe the degree of chemical activity, and the arrangement of the elements in the Periodic Table.
4. Identify and describe the characteristics of compounds having either covalent or ionic bonds.
5. Identify or describe a model that can be used to depict the structure of an element or a molecule.
6. Identify whether elements will produce ionic or covalent bonds in a molecule.
7. Identify or describe the four states of matter (solids, liquids, gas, and plasma), and rank them according to the energy of their component atoms or molecules. Identify the fifth state of matter.
8. Identify or describe the properties of metals and non-metals, as outlined in this unit.
9. Identify or describe the importance of the Law of Definite Proportions.
10. Given a specific indicator and an unknown solution, identify whether the solution is an acid or base, and determine the pH level.

INTRODUCTION

Classification of Matter

Matter is defined as any substance which takes up space and has mass. Looking at the materials which make up our world, shows us that they can be easily classified based on their physical properties. They can be further divided into finer subparts until we have different subdivisions, each containing substances which possess common physical properties. A classification system used by many scientists begins by dividing matter into pure, and non-pure substances.

Pure substances are composed of the same molecule such as water (H_20). The rock, granite, is classified as a **non-pure substance**, because it is made up of quartz, mica and feldspar, each of which is composed of several elements. This classification scheme further divides pure substances into elements and compounds and classifies non-pure substances into homogeneous mixtures and heterogeneous mixtures.



Elements are such materials as hydrogen, helium, lithium, neon, sodium, and others that make up the Periodic Table of Elements. Elements are divided into metals, non-metals, and metalloids. Examples of non-metals are oxygen, hydrogen, and chlorine. Examples of metals are copper, silver, and iron. The general properties of non-metals and metals are:

GENERAL PROPERTIES OF NONMETALS:

1. Little luster.
2. Insulators or nonconductors.
3. If solid, they are brittle.
4. May be solid, liquid, or gaseous at room temperature.
5. Non-metals tend to acquire negative charge particles (electrons), and thereby form negatively-charged bodies, (anions).

GENERAL PROPERTIES OF METALS:

1. High luster, therefore they reflect light and heat.
2. Good conductors of heat and electricity.
3. Machinable, ductile, malleable, not brittle.
4. Normally solid at room temperature.
5. Metals tend to lose negative charged particles (electrons) and form positively-charged bodies, (cations).

Catalysts are chemicals used to speed up a reaction without becoming affected by the reaction.

Compounds are pure substances formed by the chemical combination of two or more different elements in definite proportions by weight. The new compound has entirely different properties from the original elements from which it is formed. The chemist's shorthand for a compound is called a formula. It consists of two or more symbols, which represent one molecule of an element or a compound. Compounds are such things as sodium chloride (table salt), ammonium chloride, silver nitrate, and potassium sulfate--- materials in which the elements that form the compound conform to the ***Law of Definite Proportions***. For example, one atom of sodium always combines with one atom of chlorine, in a definite proportion ---one to one to form salt. Different compounds may have a different ratio of one element to another, but whatever it is, it is fixed or a definite proportion (small. whole numbers). Compounds are divided into two categories, organic and inorganic, Organic compounds are those that contain the element carbon. Inorganic compounds are those made up of salts, acids, bases, and oxides. Inorganic materials could be represented by the combination of oxygen with other materials. such as Iron oxide (Rust).

Mixtures are formed when substances of any kind are physically mixed, with no chemical activity taking place thus no new substances are formed, and each substance retains its original properties. These substances may be mixed in any proportion. **Homogeneous** mixtures are such things as gases dissolved in liquids, gases dissolved in solids, etc.
In homogeneous mixtures the molecules are distributed throughout the materials uniformly. Dirt is a **heterogeneous** mixture because the components of the dirt are mixed randomly, and not according to a fixed proportion. Muddy water could also be considered a heterogeneous mixture.

States of Matter

Matter exists as **solids, liquids, gases**, and **plasma**. We know that solids are substances which have a definite shape, and a definite volume. Liquids can take the shape of the portion of the container in which they are placed (but unlike gases don't fill the volume of the container unless there is enough fluid to do so), and also have a definite volume. Enclosed gases spread out in all directions and take the shape of a container. They have neither definite shape, nor definite volume, Plasma is a high temperature gas made of ions which contain both negatively and positively charged particles. The vast majority of our universe is in the plasma state. If we take a solid, and add enough energy, it can be converted to a liquid. If more energy is added to the material, it is changed to a gas. The addition of more energy produces the plasma state. A fifth state of matter has recently been discovered in a laboratory called a Bose-Einstein condensate.

Atomic Theory

All matter is composed of atoms. You are surrounded by matter. Examples include the air you breathe, the blood in your veins, every cell in your body, your neurons, the textbook, the chair you are sitting on, the food you eat, vitamin supplements, the water in lakes and oceans, the helium that fills balloons, etc…. A molecule is when two or more atoms are bonded together. Individual atoms and molecules are extremely tiny and cannot be seen with the naked eye. A water molecule consists of two atoms of hydrogen and one atom of oxygen (H_2O). You can easily learn these structures by studying atomic models. An atomic model helps explain the behavior of substances in terms that are understandable.

The following is a list of the basic properties of atoms:

1. The atomic number is the number of protons in the nucleus of the atom. The number of protons defines the chemical element. (1 proton = Hydrogen, 2 protons = Helium, 3 protons = Lithium, etc….)

2. Atoms always contain at least one or more protons. Most atoms also have neutrons and electrons. The simplest atom is a Hydrogen atom. It has one proton and one electron.

3. Electrons are negatively-charged particles, protons are positively-charged particles, and neutrons carry no electrical charge.

4. Neutral atoms contain equal numbers of electrons and protons.

5. Changing the number of neutrons produces an isotope of that chemical element. For example if we add a neutron to hydrogen, it is still a hydrogen atom, but it is now an isotope of hydrogen.

6. Changing the number of electrons produces ions of that chemical element. Helium typically has two protons, two neutrons, and two electrons. If we remove (or add) one or more electrons, we still have a helium atom, but we now call it a helium ion. Or we can say it is ionized.

7. The atom consists of a dense nucleus surrounded by electrons, which are arranged in various energy levels, or orbits, The energy levels are quantized (the electrons can only be in one energy level or another and not in between).

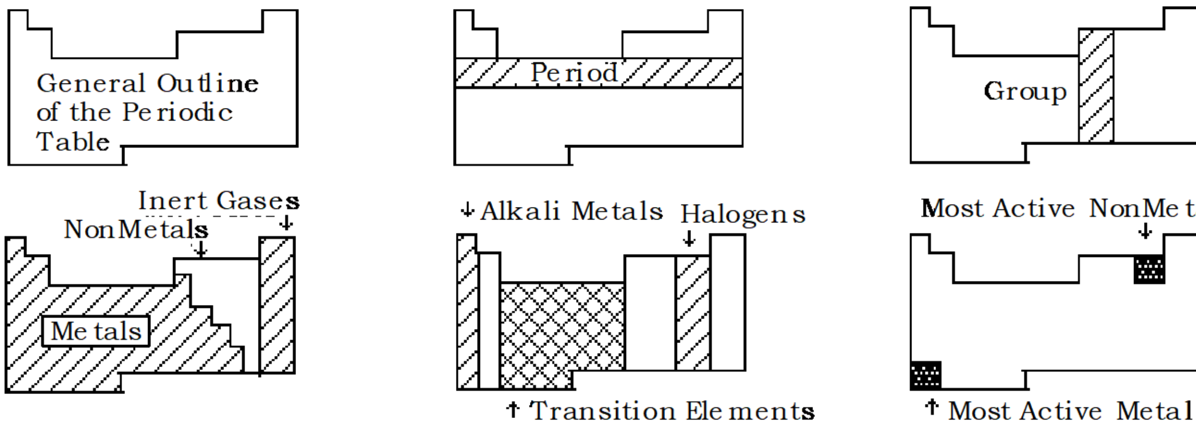
8. The nucleus of an atom contains the heavier particles; protons and neutrons. The atomic weight of an atom is equal to the sum of the protons and neutrons in the nucleus of the atom.

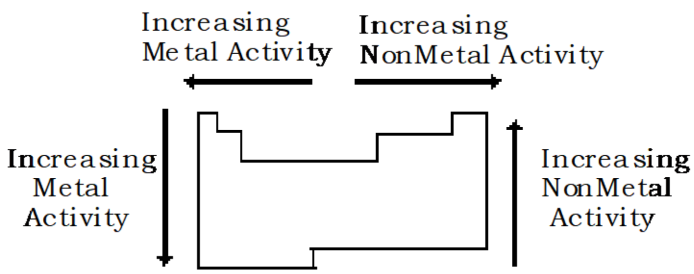
9. There are a specific maximum number of electrons that can be contained in each electron energy level. The K energy level, which is the energy level nearest the nucleus, has a maximum of 2 electrons. The L energy level contains a maximum of 8; and the M energy level, 18. This holds true in all cases, except when M is the outermost energy level of an atom, in which case it may contain no more than 8 electrons. Electrons move successively to fill the lowest energy levels (energy levels or orbits), as their number increases.

The Periodic Table

The construction of the first true periodic table of the elements is credited to Dmitri Mendeleev in about 1869. Dmitri was a chemist in the Russian Czar's employ, and his aim was to group the known 63 elements into families with common characteristics. His table had many gaps, but it allowed for the inclusion of elements then undiscovered, which, when found, would usually possess the characteristics that Mendeleev had predicted. Today, some 118 chemical elements are known, though not all are naturally occurring. These are arranged in the periodic table. (See a copy of the Periodic Table included in this topic after the lab instructions.)

In the periodic table, the vertical columns are known as ***groups,*** or *families*. Each group contains only elements that have physical, electrical, and chemical characteristics in common. In each group, atomic weight increases from top to bottom. Each horizontal row is called a **period**. The elements in each period are related by similarities in the way the electrons of the atoms are arranged around the nucleus.





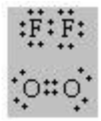
How quickly a chemical element responds to the presence of another chemical element is called reactivity. For example. sodium is highly reactive with water and other substances, and helium is not. The most reactive elements in the periodic table are to be found in two groups, the first group, and the seventh. The elements of the first group are the **alkali metals**, and the seventh group is the **halogens**. The alkali metals typify the method of reaction of the metals in general. Atoms of the **metallic elements** have one to three loosely-held electrons orbiting around the stable nucleus. These atoms located in the outermost energy level are called **valence electrons**. These loosely-held valence electrons are easily lost to other atoms, leaving behind an electrically-charged metal ion.

Non-metals, like the **halogens**, are elements whose atoms have an almost complete layer of outer electrons. usually 5-8 valence electrons. Halogens have 7 valence electrons. When a metallic atom loses an electron, it is the atoms of the non-metals, like the halogens, which pick up these electrons to complete their outer electron layer. As these extra electrons are acquired, the non-metal atoms take on an electrical charge, and become ions. Because of these tendencies to give up electrons to become ions, the metal elements are known as electron donors. The non-metal elements are known as electron acceptors because they tend to receive the electrons. This type of reaction forms a bond between the atoms known as an **ionic bond**. In these compounds, metal and non-metal ions are held together by their attraction for each other due to the electrical charge each carries. Ionic compounds will often dissolve in water. When ionic compounds are dissolved in water the ionic bonds are broken producing charged ions that are capable of conducting electricity. Even though pure distilled water will not conduct electricity, a solution of an ionic compound in water will. Ionic compounds often have very high melting points, and are not usually flammable, except when exposed to great heat.

A **covalent bond** occurs if one or more pairs of electrons combine to share electrons to form a valence of 8 electrons. For example, two fluorine atoms (each has 7 valence electrons) will share one electron from each other. One electron from each atom combines to form one pair that is shared by both fluorine atoms creating a stable valence of 8 electrons for each atom. Two oxygen atoms (each has a valence of 6 electrons) will share two pairs of electrons (one pair from each atom) to form a stable molecule. See the **Lewis Dot Structures** in the figure in the next section.

Lewis Dot Structures

Lewis Dot Structures, also known as Electron Dot Structures are diagrams that show the bonds between atoms and molecules. These are drawn using the chemical symbol for the elements involved in the bond. (A list of chemical elements and their symbols is provided in this topic after the lab instructions.) The chemical symbol is surrounded by dots that represent the valence electrons that the element has. The number of valence electrons is obtained from the periodic table provided in this topic (just after the lab instructions). Notice to the left of the chemical symbol there is a narrow column that contains a list of numbers. The very last number on the list informs us how many valence electrons this element has. For example, Sodium, chemical symbol Na and atomic number 11, has a list of numbers to the left that reads 2, 8, and 1. The last number 1 represents the number of valence electrons. In this week's lab you will work with a relaxed form of the Lewis Dot Structure. The figure on the left shows dot structure diagram for covalent bonds in fluorine and oxygen gases, and the one on the right is the dot structure diagram for the ionic bond in sodium chloride.



Formation of Compounds

As mentioned previously, some chemical elements tend to participate in chemical reactions in which they share their electrons with other atoms. When these elements form a chemical bond in which electrons from atoms are shared, then the resulting bond is called **covalen**t. Covalent compounds are often not soluble in water. Even when one does dissolve in water, like sugar, the solution will not conduct electricity. When ranked according to frequency of occurrence, covalent compounds are most frequently gases, then liquids, and least often found to be solids. When elements form a chemical bond in which electrons from one atom are taken by another atom, the resulting bond is called **ionic**. Ionic compounds are most frequently solids, then liquids, and lastly gases, when ranked in the same manner.

Covalent   Ionic

Gases   Liquids   Solids

Where a material is composed of two or more elements joined by some kind of chemical bond, that material is called a **compound**. Some compounds can have both of the types of bonds at separate points in their structures. Sometimes, the type of bond involved in a compound can be successfully predicted by seeing which elements are involved. In many cases, however, we can only discover whether a bond is ionic or covalent by finding out some of the electrical, physical, and chemical characteristics of the compound. There are definite characteristics of ionically-bonded compounds, which are quite different than those for covalently- bonded compounds.

As you look at the way two different elements combine, note that the structure of valence electrons will always involve 8 electrons. If two different elements combine in the following ratios: 7 electrons to 1 electron, 6-to-2, or 5-to-3, the resulting compound will tend to be ionic. Examples include sodium chloride and potassium oxide. If the ratio is 4-to-4 the resulting compound will tend to be covalent. Carbon atoms tend to participate in many covalent bonds. Examples include methane and carbon dioxide. Methane contains 1 carbon atom that has 4 valence electrons and 4 hydrogen atoms that each has 1 valence electron. Carbon dioxide has 1 carbon atom that has 4 valence electrons, and 2 oxygen atoms that have 6 valence electrons each. Only 2 pairs (4 electrons) from the oxygen participate in the covalent bond.

Ions

When certain compounds such as sodium hydroxide. NaOH, are put in water, we say it dissolves. Water is a solvent that dissolves the material and the material dissociates, leaving positive and negative ions moving about in the water. Sodium lends its outermost (valence) electron, leaving an electron-proton imbalance. This imbalance leaves sodium with a +1, or a positive charge. When this situation occurs, the sodium is said to be an ion; specifically, a **cation**. In other words, it has a charge associated with it, and is no longer electrically neutral. When atoms gain electrons becoming negatively charged they are also ions, specifically **anions.**

When a solution has an equal number of positive and negative ions, it is called an electrolyte. The larger the number of ions in a given volume of a solution, the better it will conduct electricity. The presence of an electrolyte can be measured by measuring its electrical conductivity. This measurement, however, will only give an apparent degree of ionization. The strength of an electrolyte is determined by its degree of ionization. A strong electrolyte is one which is ionized almost completely. Weak electrolytes are those that produce few ions. The terms strong and weak are not to be confused with diluted and concentrated. Strong and weak refer to the degree of ionization. Diluted and concentrated refer to the amount of solute, dissolved material. dissolved in a solvent.

Ionic solutions conduct electric current. We find ionic solutions in all living things to conduct nerve impulses. We also find them in the battery of our car to conduct electricity.

Acids, Bases and Salts

Acids are compounds that contain hydrogen, turn litmus paper red, and have a sour taste. The three most common acids used in the chemical laboratory are hydrochloric acid, nitric acid, and the "king" of all acids, sulfuric acid. Each of these has many important commercial uses, Lemons, oranges, grapefruit, and limes have characteristic sour tastes because they contain citric acid. Other important acids are acetic acid (vinegar), tartaric acid (found in grapes), and boric acid.

A **base** is a compound made up of a metal that is united with a group of elements containing oxygen and hydrogen, known as the hydroxide group. (OH-). The two strongest bases in common use are lye, (sodium hydroxide) and potash (potassium hydroxide). They are employed in soap making, the manufacture of dyes, paper, and many other important products. Household ammonia (ammonium hydroxide) is a mild base that is used for laundering and cleaning.

If an acid and a base are added to each other, EXTREME CAUTION SHOULD BE TAKEN, When the two are combined, if there are an equal number of positive and negative ions present, neutralization will take place which results in the formation of a salt and water.

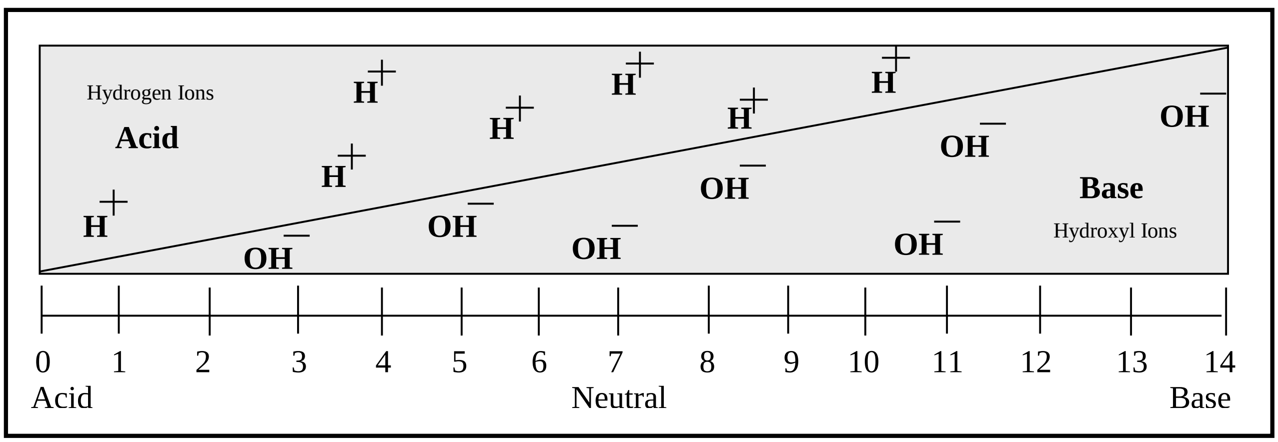
Sodium Hydroxide + Hydrochloric Acid ⟶ Sodium Chloride + Water

$$Na^{+}OH^{-} + H^{+}Cl \longrightarrow \underset{\text{Salt}}{Na^{+}Cl^{-}} + \underset{\text{Water}}{H_2O}$$

A **salt** is a compound whose water solution contains positive ions other than hydrogen ions, and negative ions other than hydroxide ions. Common table salt (NaCl), is a member of a large class of compounds which chemists call salts,

pH Scale and Indicators

The strength or concentration of an acid or base is indicated by a number referred to as the pH. The **pH** scale indicates the concentration of hydrogen ions in a solution. The scale ranges from 0 to 14. Neutral solutions have a pH of exactly 7. A pH number less than 7, indicates the presence of an acid while a number greater than 7 indicates the solution is a base. You may have used the pH scale if you have a swimming pool or used certain hair shampoos or deodorants. A pictorial representation of the pH scale is found in the following diagram.



Indicators are chemicals that reveal the presence of an acid or a base. They can change color, depending upon the presence of hydrogen ions, or hydroxyl ions. Selected indicators and their color changes are listed in the table below.

Indicator	Acid	Neutral	Base
Red Litmus	Red/Pink	Red/Pink	Blue
Blue Litmus	Red/Pink	Blue	Blue
Phenolphthalein	Colorless	Colorless	Red/Pink
pHydrion - Indicates pH value by color for acids and bases. Neutral is typically yellow/green.			

Virtual Laboratory

Topic 03 – Structure of Matter

	Section #	Date	Topic #
Name			**03**

1. Draw the dot structures for the following 6 elements using the periodic table in the textbook.

H **O** **N** **S** **Cl** **F** ○ ●

2. Draw the dot structures for the following molecules:

Formula	Name	Dot Structure **(Covalent bonds)**
H_2	dihydrogen	
F_2	Diflourine	
Cl_2	dichlorine	
NH_3	ammonia	
H_20	water	
H_2S	Hydrogen sulfide	

3. Draw the dot structures for the following 8 elements using the periodic table in the textbook.

Mg **Br** **K** **Al** **Cl** **Na** **S** **O**

4. Draw the dot structures for the following molecules:

Formula	Name	Dot Structure **(Ionic bonds)**
NaCl	Sodium chloride	
$MgBr_2$	Magnesium Bromide	
K_2S	Potassium sulfide	
Al_2O_3	Aluminum oxide	

Hands-on Laboratory

Topic 03 – Structure of Matter

MATERIALS

pHydrion paper
blue litmus paper
red litmus paper
conductivity tester with Power Supply
Vinegar (Acetic Acid)
Dry Sodium Chloride
Sodium Chloride Solution
Sugar Solution
Tap Water
Soap
Anti-freeze
Lemon Juice (citric acid)
Baking soda solution
Ammonia
Bleach
Milk of Magnesia
Isopropyl Alcohol (rubbing alcohol)
Distilled water

PROCEDURE

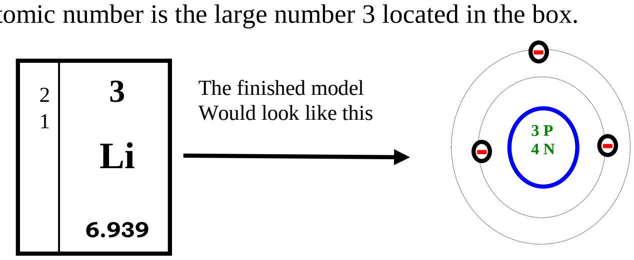
Pre-lab prep: Complete all of Parts A, B, and C on the provided data pages prior to the lab meeting. There is also a pre-lab prep for parts D and E and data table predictions.

Part A - Problem: How do we build atomic models of atoms?

1. Using the Periodic Table and the steps a-d draw atomic models for Hydrogen, Helium, Beryllium, Boron, Carbon, Nitrogen, Oxygen, Fluorine, Neon, Sodium, Magnesium, and Copper on a sheet of plain paper.
   a. Drawing a circle to represent the nucleus of an atom.
   b. Place in the circle the atomic number, (number of protons) followed by a P.
   c. Place the number of neutrons in the nucleus circle, followed by the symbol for neutron, N. Remember to find the number of neutrons, subtract the number of protons from the atomic weight. (Round off to the nearest whole number.)
   d. Draw large circles representing the electron orbits. Place the correct number of electrons represented by smaller circles with a minus sign.

      Example: For Li

      1) Using "The Elements", find the name of the element you are looking for. Across from the name, find the atomic number. Look up the number in the Periodic Table.
      2) The atomic number is the large number 3 located in the box.



Lithium

3) The 2 represents the number of electrons in the first energy level, and the 1 represents the number of electrons in the second energy level.
4) The Li is the symbol for Lithium.
5) 6.939 is the atomic weight.

2. Compare your drawings to drawings of atomic models, on the data sheet, in order to name each model pictured on the data sheet. The drawings you made are for your reference only.

***Note**: The open and solid dots are used to indicate where the electrons came from and have no structural meaning*.

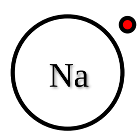
Part B - Problem: How do we construct an electron-dot model to represents an element?

1. Draw Electron-dot models for Hydrogen, Helium, Beryllium, Boron, Carbon, Nitrogen, Oxygen, Fluorine, Neon, Sodium, Magnesium, Silicon, Chlorine, Potassium, Tin and Copper by:
   a. Draw a circle and place the element's symbol in the circle. The circle represents everything in the atom except the electrons in the outermost energy level. (see Periodic Table.)
   b. Place a tiny circle with a minus sign (or dash) inside of it to represent each of the outermost electrons,

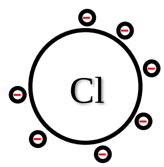
2, Using the Periodic Table and the models pictured in the data sheet, select the correct model for each of the elements listed. Please note that we have not included the symbol as part of the model. You are just considering the outermost electrons for your selection.

Part C - Problem: How do you draw models to represent molecules?

1. To draw molecules of atoms. Using sodium chloride. NaCl, as an example:
   a. Using the Periodic Table, obtain the number of electrons in the outer energy level of sodium and draw an electron-dot model of the elements:

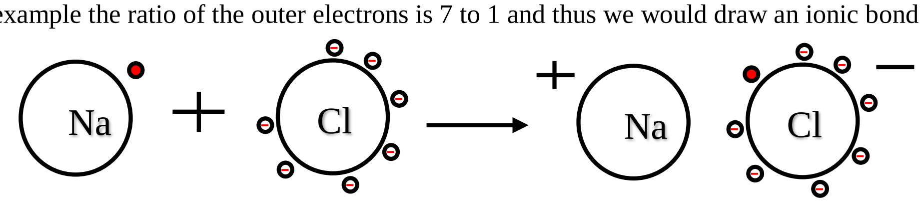


b, Next obtain the number of electrons in the outer energy level of chlorine, If you were to draw an electron-dot model it would look something like:

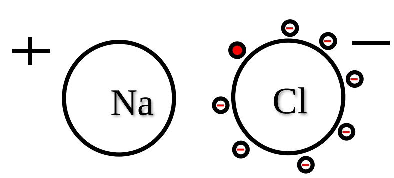


c. If the sum of outer electrons provided by the elements is eight a compound will be formed. If sodium is added to chlorine a chemical reaction will occur and the atoms are bonded together forming the compound sodium chloride. By observing the ratio of outer electrons, we can determine the type of bond. If the electrons combine in the ratio of 7 electrons to 1 electron, 6-to-2, or 5-to-3, the resulting compound will tend to be ionic. If the ratio is 4-to-4 or contains carbon, the resulting compound will tend to be covalent.

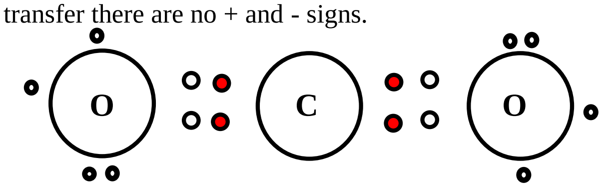
d. In our example the ratio of the outer electrons is 7 to 1 and thus we would draw an ionic bond for our molecule.



e. The resulting model, indicated below, should be drawn on your data sheet. Ionic molecules are indicated by showing the transfer of electron(s). The + and - signs are used to indicate the transfer of electrical charge. (When more than one charge is transferred it is indicated by using multiple + or – signs)

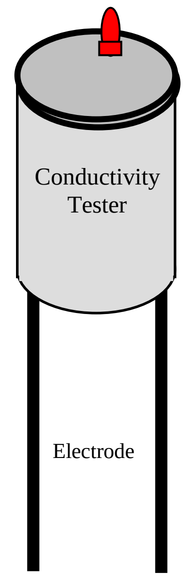


2. Models of covalent molecules show shared electrons, which are spaced at equal intervals between the elements. Note: since there is no electron transfer there are no + and - signs.



3. Using the procedures indicated in this topic determine the molecular models of: **NaI, KC1, HCl, $ZnCl_2$, CS_2, and CH_4**. Then select the model, provided in the data chart, and supply the appropriate information (name, Ionic or Covalent, elemental symbol, and charge). The 2 in $ZnCl_2$ means to draw 2 atoms of Cl and 1 atom of Zn.

   a) NaI b) KC1 c) HCl d) $ZnCl_2$ e) CS_2 f) CH_4



Part D - Problem: Ionic and Covalent Bonds

Prelab Prep: The Research Question is: ____

Prelab Prep: Your hypothesis is (including a general prediction): _____

Use the same samples for part D and E of the laboratory.

1. Obtain several small cups to hold the test materials listed in the data sheet, Part D. Pour enough solution to fill the little cup ¼ full. For each of the powders add a small amount, approximately 0.5 teaspoon to a cup and mix with distilled water.

2. Write the name of the material on each cup.

3. Obtain a conductivity tester. A conductivity tester is a device that has a light bulb that will light when a conductive material is placed between the two electrodes. We will use this device to determine the conductivity of a solution. The brightness of the light bulb lights indicates the presence of ions in the solution which originated from an ionic bond.

4. Test each material by placing the electrodes into the solution in each container. The level of conductivity or ionization is indicated by the brightness of the light. A brighter light indicates a greater degree of ionization and thus a solution with greater conductivity. Test several different materials so that you can judge the range of the brightness level of the tester.

5. **Put distilled water in one of the containers to wash the electrodes after each test.** ***Be sure to change this water after every two tests. Wipe electrodes off with paper towel.***

6. Indicate which compounds are ionic and which compounds are covalent.

   Ionic

   Good conductor- a bright light.
   Fair conductor- a moderately bright light.
   Poor conductor- a dim but discernible light.

   Covalent

   Non-conductor - no light.

   Save all the samples for the next part of the laboratory.

Part E – Acids and Bases

Prelab Prep: The Research Question is: ____

Prelab Prep: Your hypothesis is (including prediction for each item in the data table provided):

____

1. Using the test substances from the preceding part. (excluding the dry compounds), test each with the indicators.
2. For red litmus and blue litmus conduct a test by placing the indicator in the solution and observing any color change. You will notice that any material when it is wet will look darker. You should look for an actual color change.

   Note: • The pHydrion paper changes color. Match the color to the color scale on the vile and record the corresponding number.

   • **red litmus tests for bases by turning blue**. Record – is a base or not a base.

   • blue litmus tests for acids by turning red. Record – is a acid or not a acid.

   If neither litmus changes color. then the item being tested is neutral.

Part F - Data Analysis Answer the questions asked at the end of the Data Sheets.

The Elements

Element	Symbol	Num.	Element	Symbol	Num.
Actinium	Ac	89	Mercury	Hg	80
Aluminum	Al	13	Molybdenum	Mo	42
Americium	Am	95	Neodymium	Nd	60
Antimony	Sb	51	Neon	Ne	10
Argon	Ar	18	Neptunium	Np	93
Arsenic	As	33	Nickel	Ni	28
Astatine	At	85	Niobium	Nb	41
Barium	Ba	56	Nitrogen	N	7
Berkelium	Bk	97	Nobelium	No	102
Beryllium	Be	4	Osmium	Os	76
Bismuth	Bi	83	Oxygen	O	8
Boron	B	5	Palladium	Pd	46
Bromine	Br	35	Phosphorus	P	15
Cadmium	Cd	48	Platinum	Pt	78
Calcium	Ca	20	Plutonium	Pu	94
Californium	Cf	98	Polonium	Po	84
Carbon	C	6	Potassium	K	19
Cerium	Ce	58	Praseodymium	Pr	59
Cesium	Cs	55	Promethium	Pm	61
Chlorine	Cl	17	Protactinium	Pa	91
Chromium	Cr	24	Radium	Ra	88
Cobalt	Co	27	Radon	Rn	86
Copper	Cu	29	Rhenium	Re	75
Curium	Cm	96	Rhodium	Rh	45
Dysprosium	Dy	66	Rubidium	Rb	37
Einsteinium	Es	99	Ruthenium	Ru	44
Erbium	Er	68	Samarium	Sm	62
Europium	Eu	63	Scandium	Sc	21
Fermium	Fm	100	Selenium	Se	34
Fluorine	F	9	Silicon	Si	14
Francium	Fr	87	Silver	Ag	47
Gadolinium	Gd	64	Sodium	Na	11
Gallium	Ga	31	Strontium	Sr	38
Germanium	Ge	32	Sulfur	S	16
Gold	Au	79	Tantalum	Ta	73
Hafnium	Hf	72	Technetium	Tc	43
Helium	He	2	Tellurium	Te	52
Holmium	Ho	67	Terbium	Tb	65
Hydrogen	H	1	Thallium	Tl	81
Indium	In	49	Thorium	Th	90
Iodine	I	53	Thulium	Tm	69
Iridium	Ir	77	Tin	Sn	50
Iron	Fe	26	Titanium	Ti	22
Krypton	Kr	36	Uranium	U	92
Lanthanum	La	57	Vanadium	V	23
Lead	Pb	82	Xenon	Xe	54
Lithium	Li	3	Ytterbium	Yb	70
Lutetium	Lu	71	Yttrium	Y	39
Magnesium	Mg	12	Zinc	Zn	30
Manganese	Mn	25	Zirconium	Zr	40

Activity Series Of The Metals

1. Potassium
2. Calcium
3. Sodium
4. Magnesium
5. Aluminum
6. Manganese
7. Zinc
8. Chromium
9. Iron
10. Cadmium
11. Cobalt
12. Nickel
13. Tin
14. Lead
15. Hydrogen
16. Copper
17. Silver
18. Platinum
19. Gold

PERIODIC CHART OF THE ELEMENTS

Each cell: electron shells (in parentheses), atomic number, symbol, atomic weight.

LIGHT METALS		TRANSITION HEAVY METALS										NON METALS					INERT GASES
(1) 1 H 1.00797																	(2) 2 He 4.0026
(2,1) 3 Li 6.939	(2,2) 4 Be 9.0122											(2,3) 5 B 10.811	(2,4) 6 C 12.01115	(2,5) 7 N 14.0067	(2,6) 8 O 15.9994	(2,7) 9 F 18.9984	(2,8) 10 Ne 20.183
(2,8,1) 11 Na 22.9898	(2,8,2) 12 Mg 24.312											(2,8,3) 13 Al 26.9815	(2,8,4) 14 Si 28.086	(2,8,5) 15 P 30.9738	(2,8,6) 16 S 32.064	(2,8,7) 17 Cl 35.453	(2,8,8) 18 Ar 39.948
(2,8,8,1) 19 K 39.102	(2,8,8,2) 20 Ca 40.08	(2,8,9,2) 21 Sc 44.956	(2,8,10,2) 22 Ti 47.90	(2,8,11,2) 23 V 50.942	(2,8,13,1) 24 Cr 51.996	(2,8,13,2) 25 Mn 54.9380	(2,8,14,2) 26 Fe 55.847	(2,8,15,2) 27 Co 58.9332	(2,8,16,2) 28 Ni 58.71	(2,8,18,1) 29 Cu 63.54	(2,8,18,2) 30 Zn 65.37	(2,8,18,3) 31 Ga 69.72	(2,8,18,4) 32 Ge 72.59	(2,8,18,5) 33 As 74.9216	(2,8,18,6) 34 Se 78.96	(2,8,18,7) 35 Br 79.909	(2,8,18,8) 36 Kr 83.80
(2,8,18,8,1) 37 Rb 85.47	(2,8,18,8,2) 38 Sr 87.62	(2,8,18,9,2) 39 Y 88.905	(2,8,18,10,2) 40 Zr 91.22	(2,8,18,12,1) 41 Nb 92.906	(2,8,18,13,1) 42 Mo 95.94	(2,8,18,13,2) 43 Tc (99)	(2,8,18,15,1) 44 Ru 101.07	(2,8,18,16,1) 45 Rh 102.905	(2,8,18,18) 46 Pd 106.4	(2,8,18,18,1) 47 Ag 107.870	(2,8,18,18,2) 48 Cd 112.40	(2,8,18,18,3) 49 In 114.82	(2,8,18,18,4) 50 Sn 118.69	(2,8,18,18,5) 51 Sb 121.75	(2,8,18,18,6) 52 Te 127.60	(2,8,18,18,7) 53 I 126.9044	(2,8,18,18,8) 54 Xe 131.30
(2,8,18,18,8,1) 55 Cs 132.905	(2,8,18,18,8,2) 56 Ba 137.34	57-71 See Lanthanide Series	(2,8,18,32,10,2) 72 Hf 178.49	(2,8,18,32,11,2) 73 Ta 180.948	(2,8,18,32,12,2) 74 W 183.85	(2,8,18,32,13,2) 75 Re 186.2	(2,8,18,32,14,2) 76 Os 190.2	(2,8,18,32,15,2) 77 Ir 192.2	(2,8,18,32,17,1) 78 Pt 195.09	(2,8,18,32,18,1) 79 Au 196.96	(2,8,18,32,18,2) 80 Hg 200.59	(2,8,18,32,18,3) 81 Tl 204.37	(2,8,18,32,18,4) 82 Pb 207.19	(2,8,18,32,18,5) 83 Bi 208.980	(2,8,18,32,18,6) 84 Po (210)	(2,8,18,32,18,7) 85 At (210)	(2,8,18,32,18,8) 86 Rn (222)
(2,8,18,32,18,8,1) 87 Fr (223)	(2,8,18,32,18,8,2) 88 Ra 226	89-100 See Actinide Series															

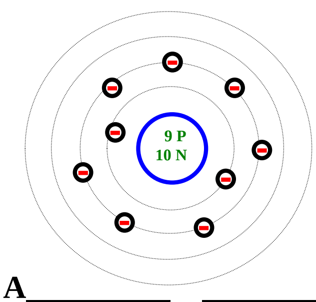
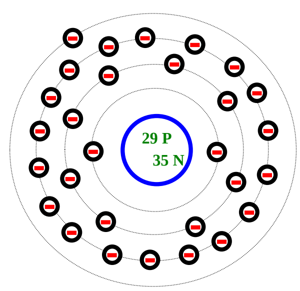
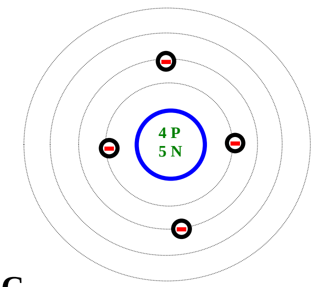
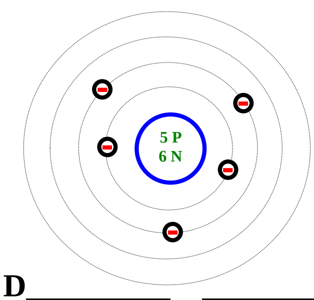
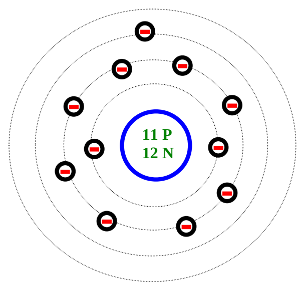
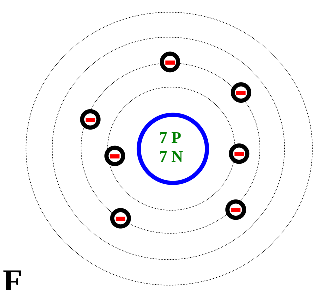
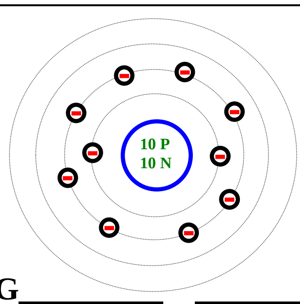
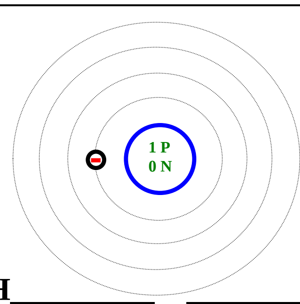
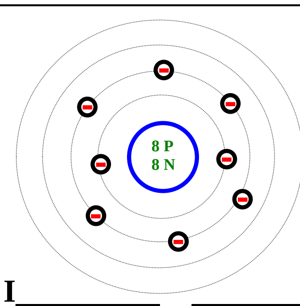
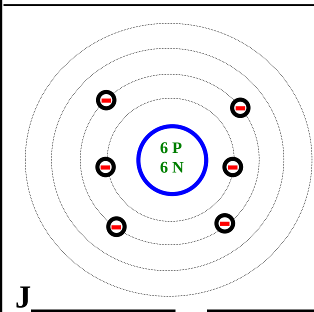
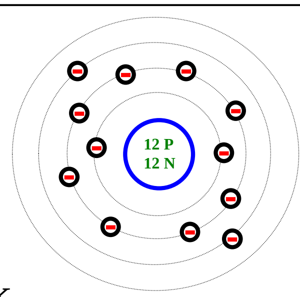
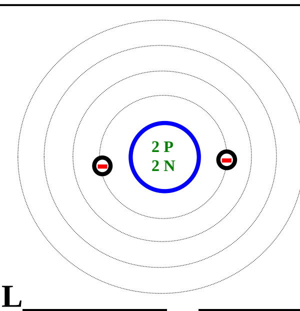
LANTHANIDE SERIES (Rare Earth Elements)	(2,8,18,18,9,2) 57 La 138.91	(2,8,18,19,9,2) 58 Ce 140.12	(2,8,18,21,8,2) 59 Pr 140.907	(2,8,18,22,8,2) 60 Nd 144.24	(2,8,18,23,8,2) 61 Pm (147)	(2,8,18,24,8,2) 62 Sm 150.35	(2,8,18,25,8,2) 63 Eu 151.96	(2,8,18,25,9,2) 64 Gd 157.25	(2,8,18,26,9,2) 65 Tb 158.924	(2,8,18,28,8,2) 66 Dy 162.50	(2,8,18,29,8,2) 67 Ho 164.930	(2,8,18,30,8,2) 68 Er 167.26	(2,8,18,31,8,2) 69 Tm 168.934	(2,8,18,32,8,2) 70 Yb 173.04	(2,8,18,32,9,2) 71 Lu 174.97
ACTINIDE SERIES	(2,8,18,32,18,9,2) 89 Ac (227)	(2,8,18,32,18,10,2) 90 Th 232.038	(2,8,18,32,20,9,2) 91 Pa (231)	(2,8,18,32,21,9,2) 92 U 238.03	(2,8,18,32,22,9,2) 93 Np (237)	(2,8,18,32,23,9,2) 94 Pu (244)	(2,8,18,32,24,9,2) 95 Am (243)	(2,8,18,32,25,9,2) 96 Cm (247)	(2,8,18,32,26,9,2) 97 Bk (247)	(2,8,18,32,27,9,2) 98 Cf (251)	(2,8,18,32,28,9,2) 99 Es (254)	(2,8,18,32,29,9,2) 100 Fm (253)	(2,8,18,32,30,9,2) 101 Md (256)	102 No (254)	103 Lw (257)

• 03 •
STRUCTURE OF MATTER

Name	Section #	Kit #	Topic #
			03
			03
			03

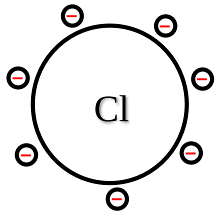
Part A: Atomic models of atoms (the tiny circles represent electrons)

Identify the name of each of the elemental models and record the name next to its assigned letter in each square. Next to that indicate the chemical symbol. For assistance review the periodic table of the elements. Each element is identified by the number of protons in the nucleus.

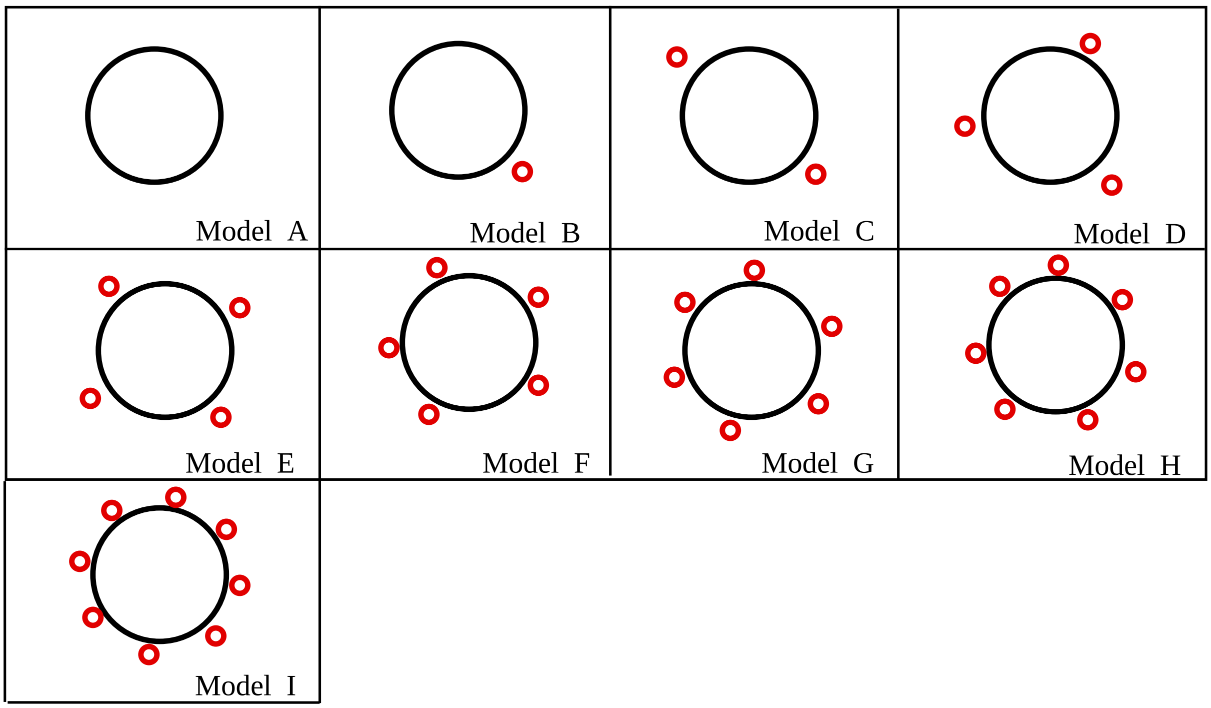
 A__________ __________	 B__________ __________	 C __________ __________
 D__________ __________	 E __________ __________	 F__________ __________
 G__________ __________	 H__________ __________	 I__________ __________
 J__________ __________	 K__________ __________	 L__________ __________

Part B: Electron-dot models that represent atoms

Using the Periodic Table and the models pictured. select the correct model for each of the elements listed. Please note that we have not included the symbol as part of the model. You are just considering the electrons for your selection. The tiny circles represent the valence electrons.



Chlorine



Fill in the table below based upon the pictures above. Use the Periodic Table to determine the number of valence electrons for each element listed below, and then select the picture above that represents the number of valence electrons.

	Element	Model
1.	Hydrogen	
2.	Helium	
3.	Beryllium	
4.	Boron	
5.	Carbon	
6.	Nitrogen	
7.	Oxygen	
8.	Fluorine	

	Element	Model
9.	Neon	
10.	Sodium	
11.	Magnesium	
12.	Silicon	
13.	Chlorine	
14.	Potassium	
15.	Copper	
16.	Tin	

Part C: Drawing Models that represent atoms

From the following list. **Sodium Iodide, Potassium Chloride, Hydrochloric (one Hydrogen and one chlorine), Zinc Chloride, Methane (Carbon and four Hydrogen), or Carbon Disulfide**, complete the electron dot models in the spaces provided below. Indicate the compounds name, type of bond (Ionic or Covalent), its symbol, and charge where appropriate.

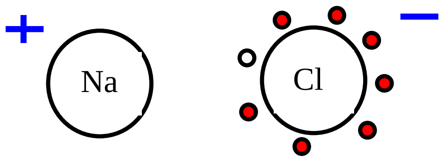
If working online perform the following, (otherwise just handwrite the required information):

To place the symbol on the drawing. copy and paste one of the following: Na, I, K, Cl, H, Zn, C, and S,

To place the name on the drawing, copy and paste one of the following: **Sodium Iodide, Potassium Chloride, Hydrochloric, Zinc Chloride, Methane,** or **Carbon Disulfide**.

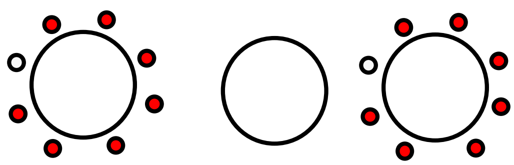
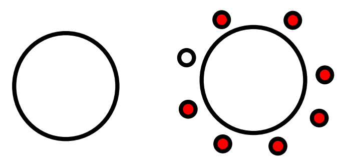
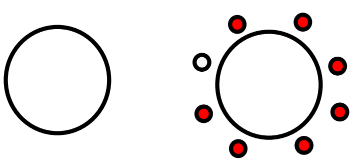
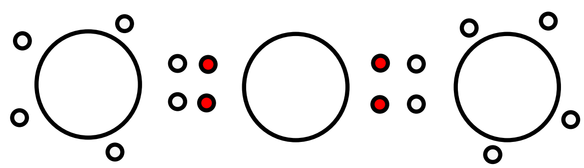
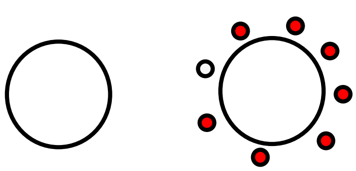
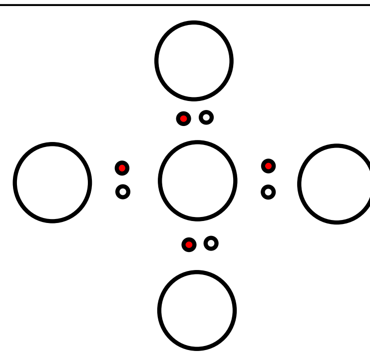
To place the positive and negative signs for the ionic bonds copy and paste: − +

Example:



NaCl Sodium Chloride

Hint: Determine number of valence electrons for each chemical element listed above.

 Name Bond:	 Name Bond:
 Name Bond:	 Name Bond:
 Name Bond:	 Name Bond:

The data for Parts D and E are entered into the same data table provided below.

Part D: Ionic and Covalent Bonds: Prelab Prep: The Research Question is:

____

Prelab Prep: Your hypothesis is (including **general** prediction):

____

Conducting the test: Place a check mark in the appropriate column to identify if your conductivity test is **E** = Excellent**,** **G** = Good, **P** = Poor, or **N** = Nonconductor. If the light turns on during the test then indicate that the material is **I** = Ionic, and if it does not light then place a C = Covalent.

Part E: Acids and Bases - Prelab Prep: The Research Question is

____

____

Prelab Prep: Your hypothesis is (including prediction for each item in the column below):

____

For the litmus tests place a **B** for is a base. **A** for is an acid and a **N** for **N**ot a base or **N**ot an acid. Indicate the number for the PHydrion test. **Only use distilled water to make solutions**! Take special care to avoid contaminating your samples!

Be careful of contamination! Watch for actual color change. Wet paper gets dark but is not a color change.

Substance tested	Conductivity Test				Analysis	Your Prediction	RED Litmus	Blue Litmus	Phydrion
	E	G	P	N	I / C	A. B. or N	B or N	A or N	0-14
Tap Water									
Distilled Water*									
Sodium Chloride (Table salt) (Dry)									
Sodium Chloride (Table salt) Solution									
Sugar Solution									
Vinegar (acetic acid)									
Anti-Freeze (**dispose of properly**)									
Dish Soap									
Lemon Juice (citric acid)									
Isopropyl Alcohol (rubbing alcohol)									
Baking Soda (Solution)									
Ammonia									
Milk of Magnesia									
Mouthwash									
*Verify the label indicates the water is distilled.									

Part F: Data analysis (Use litmus test results when making the lists.)

1. List any acids that are non-conductors _____

2. List any acids that are conductors _____

3. List any acids that have an ionic bond _____

4. List any acids that have a covalent bond _____

5. List any bases that are non-conductors _____

6. List any bases that are conductors _____

7. List any base that has an ionic bond _____

8. List any base that has a covalent bond _____

For part **D** (Bonds): Do your results support your hypothesis? Explain your results.

___

___

___

For part **E** (Acids and Bases): Do your results support your hypothesis? Explain your results.

___

___

___

STRUCTURE OF MATTER

Self-Evaluation

TEST 031

1. 03.1 Isotopes of the same kind of element differ in their number of:
   A. protons
   B. neutrons
   C. electrons
   D. charges

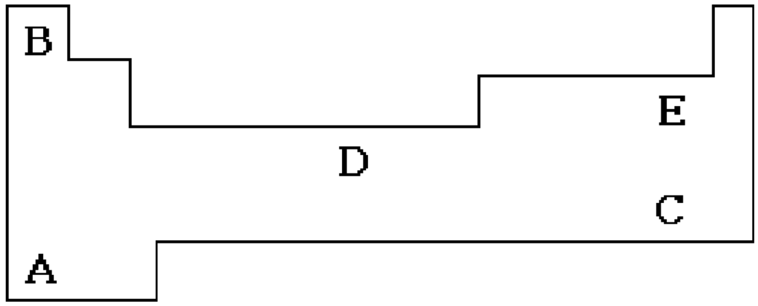
2. 03.1 An atom that has acquired an additional electron(s) is called a(n):
   A. cation
   B. electrolyte
   C. anion
   D. catalyst
   E. isotope

3. 03.2 Aluminum has an atomic weight of 27, and an atomic number of 13. Which of the following indicates electron placement?
   A. 2-7-4
   B. 2-8-17
   C. 2-8-3
   D. 2-8-8-8-1
   E. none of the above

4. 03.2 Which of the following is part of the atomic theory?
   A. An atom always contains electrons, protons, and neutrons.
   B. Atomic weight is the sum of protons and electrons.
   C. An atom of an element contains the same number of electrons as protons, and is electrically neutral.
   D. Atoms consist of a dense nucleus, surrounded by protons, which are arranged in various energy levels known as energy levels or orbits.
   E. None of the above.

5. 03.3 Which of the following is most correct. concerning the organization of elements in the periodic table?
   A. elements progress horizontally with the addition of one proton
   B. elements progress vertically with the addition of one neutron
   C. elements progress vertically with the addition of one electron
   D. elements progress horizontally with the addition of one neutron

6. 03.3 Using the following diagram of the periodic table, which *metal* would be most active? (Choose A, B, C, D, or E).



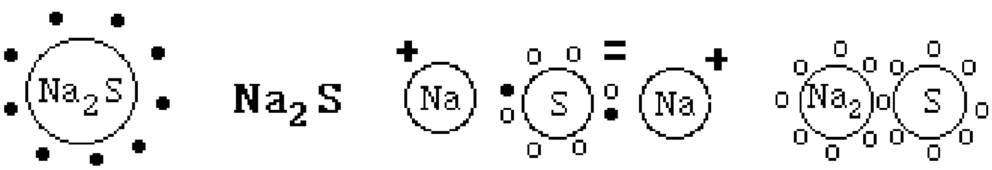
7. 03.4 Covalent compounds are materials which tend to be __________ at room temperature:

A. solids
B. solids and liquids
C. liquids and gases
D. ionic solutions
E. solids and gases

8. 03.4 When forming molecules by either ionic bonding or by covalent bonding, the atoms seem to:

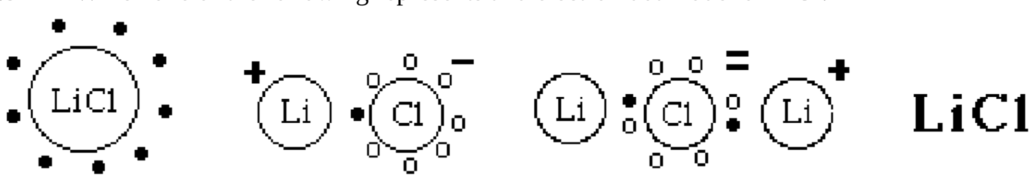
A. take 8 electrons
B. share 8 electrons
C. attain the outer structure of inert gases
D. none of the above

9. 03.5 Which one of the following represents an electron dot model of Na_2S?



A. B. C. D. E. none of them

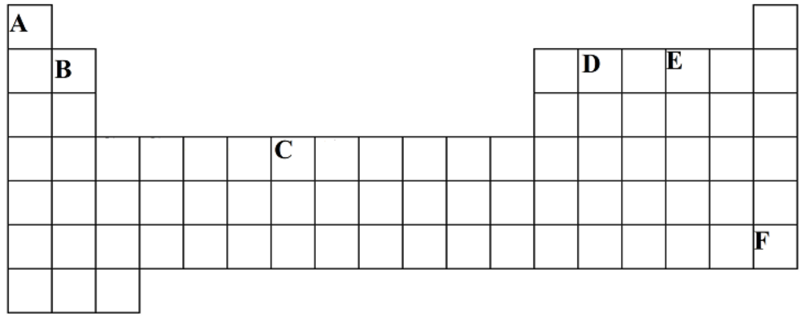
10. 03.5 Which one of the following represents and electron dot model of LiCl?



A. B. C. D. E. none of them

11. 03.6 Using the following diagram of the periodic table, which two elements could be predicted to form a covalent bond?

A. A and D
B. D and E
C. B and F
D. C and A



12. 03.6 Covalent compounds will most likely form between two neutral elements having the following number of valence electrons?

A. 2 and 1
B. 1 and 7
C. 4 and 4
D. 3 and 1

13. 03.7 Which one of the following best represents a model of liquid?

A. Atoms which are very tightly bound to each other and organized.
B. Atoms are loosely bound and conform to the shape of whatever volume contains them
C. Atoms that are constant random motion and exert weak forces on each other
D. Atoms are tightly bound and arranged in a random fashion.

14. 03.7 Which one of the following best represents a model of a solid?

A. Atoms are tightly bound and arranged in a random fashion.
B. Atoms are loosely bound and arrange themselves to take on the shape of whatever vessel contains them.
C. Atoms that are constant random motion and exert weak forces on each other
D. Atoms which are very tightly bound to each other and organized.

15. 03.8 Which of the following is not a property of a nonmetal?

A. forms cations in solutions
B. insulator
C. brittle
D. forms anions in solutions
E. none of the above

16. 03.8 The general properties of metals are:

A. brittle
B. high luster
C. form anions
D. A and C
E. B and C

17. 03.9 The Law of Definite Proportions indicates:

A. the number of atoms of one element to another in a molecule
B. the way a molecule reacts
C. the way an element reacts
D. Periodic Law is incorrect
E. that all matter is electrically neutral

18. 03.9 The statement which describes the way the number of atoms of one element combine with the atoms of another element to form a molecule is called:

A. Periodic Law
B. Atomic Theory
C. Law of Molecular Structure
D. Law of Definite Proportions
E. none of the above

19. 03.10 The following indicators will turn pink in a base:

A. red litmus
B. blue litmus
C. phenolphthalein
D. pHydrion
E. C and D

20. 03.10 This indicator will be yellow/green if it is neutral:

A. red litmus
B. ions
C. electrolytes
D. pHydrion
E. salts

M O T I O N

Topic 04

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct term.

   acceleration, constant acceleration, constant velocity/speed, kinetic energy, linear motion, mass, momentum, speed, time, velocity, and weight.

2. Given the formula v = d **/** t, be able to calculate the speed (v), distance traveled (d), or time of travel (t) of some object.
3. Given the formula $a = (v_{final} - v_{initial})$ / time, compute the acceleration of a moving object.
4. Given the formula momentum = m x v, calculate the momentum of an object with a mass, (m), moving with a speed (v),
5. Given the formula KE = ½ m x v^2, calculate the kinetic energy of an object.
6. Identify and describe the speed and acceleration of an object from a position vs time graph and a speed vs time graph.

INTRODUCTION

Motion occurs when an object changes position. Motion is a relative rather than an absolute term. An object may be in motion in relation to another object. and yet two moving objects can be stationary with respect to one another. For example, we may go for a ride and pass a person standing by the side of the road. To the person standing by the side of the road we will be in motion, and in regards to the friend on the seat next to us we will be at rest.

The study of motion is of great significance because it involves every single object in the universe. When investigating motion, there are some basic concepts that are indispensable:

(1) the distance traveled by an object in a specific amount of time (speed).

(2) the changing speed or velocity of an object during a specific amount of time (acceleration).

Average Speed

When discussing how fast an object moves, we usually use the term speed.

The speed (v) of an object traveling a distance (d) in a period of time (t) is described by the following formula

v = d / t

Example: Consider a person walking a distance of ten meters at a steady pace (d = 10 m), in five seconds (t = 5 s). This person's speed would be calculated like this:

v = d / t or **(**10 meters**)** **/** **(**5 seconds**)** **=** 2 m/s

This result means that the person will walk (in a straight line) 2 meters every second if they maintain a constant speed (no acceleration). If they start at position zero, the person will have walked two meters in the first second. After two seconds the person will have walked four meters, and after three seconds the person will have walked six meters.

The dimensions of speed are length over time. The SI **unit for speed is m/s**. The formula permits us to use other units as well. We can find speed in units of kilometers per hour, inches per minute, miles per year, etc…..

Average Acceleration

An object is accelerating if it speeds up or slows down. Acceleration is the measure of how much the speed changes during a certain period of time. An object moving in a straight line with constant speed has no acceleration. Think about it. The object is not speeding up or slowing down.

You are familiar with the changing speed of your car in traffic as you push the accelerator to pass the slow moving vehicle in front of you. In order to find the rate of acceleration of a moving object you need the following information:

(1) the original speed of the moving object (v_1).

(2) the final speed of the moving object (v_2).

(3) the time (t) that it took for the object to change from v_1 to v_2.

To find the acceleration (a) divide the change in speed ($v_2 - v_1$) by the corresponding time (t) needed to affect such change.

$$\mathbf{a = (v_2 - v_1) / t}$$

Let's try one example to make sure you understand the idea. An ant is clocked moving at a speed of 0.03 m/s (v_1), before being disturbed. When disturbed, it is observed that in a period of 2 seconds (t), it quickly changes its speed to 0.08 m/s (v_2). What was its rate of acceleration during this 2-second period?

Solution: $a = (v_2 - v_1) / t = (0.08\text{m/s} - 0.03\text{ m/s}) / 2\text{ s} = 0.025\text{ m/s/s}$.

The acceleration is read as 0.025 meters per second squared. What does this answer mean? It means that the speed of the ant increases 0.025 m/s every second. If the ant starts with zero speed it will attain a speed of 0.025 m/s after one second assuming its acceleration remains constant. After two seconds its speed will be 0.050 m/s, after three seconds it's speed will be .075 m/s. What will the speed be after four seconds?

Please note that if v_1 (the initial speed) is greater than v_2 (the final speed) that the object is decelerating (slowing down). The formula remains the same whether an object speeds up or slows down. Using the above formula yields a negative sign in the final answer indicating that the object is decelerating.

The SI unit for acceleration is m/s^2. The above formula is flexible with the units you can use. For example, miles/hour^2. inches per minute^2, kilometers/day^2 all have dimensions of length over time squared which describes the dimensions of acceleration.

Momentum

Any object that is in motion has momentum. A very massive object moving slowly has a large momentum, as does a very low mass object moving at a great speed.

momentum = mass x speed or momentum = m x v

When using the momentum formula, the unit of mass must be kilograms and the unit of speed must be m/s. The **unit for momentum** is kg m/s.

Mass and Weight

Have you noticed that the formula for momentum uses the mass of an object and not its weight? You will also find that this is true when calculating the energy of an object associated with its motion. It is important to note that mass and weight do not mean the same thing. Mass is how much of the object there is. Weight is the amount of gravitational force between two objects that have mass. We will discuss weight in more detail in the next seminar. If you were to magically transport to the Moon right now your weight would change, but your mass would not. For now, make sure not to confuse mass with weight though we will find that there is a relationship.

Energy

When an object has momentum, it also has kinetic energy called the energy of motion. The kinetic energy of an object is one-half of its mass multiplied by its speed squared. The **unit for energy** is the Joule (J).

$$\mathbf{KE = {}^1/_2\, m \times v^2}$$

This energy is changed into work when one object strikes another. For example, the energy of an automobile at 60 km an hour (16.7 m/s) is approximately nine times as large as at 20 km an hour (5.6 m/s). [Note: since mass is constant, the difference depends upon the square of the velocity, or $16.7^2 = 16.7 \times 16.7 = 279$ and $5.6^2 = 5.6 \times 5.6 = 31.4$, 279 is almost nine times larger than 31.4.] This helps explain why an object hit by a car traveling at 60 km. per hour sustains much more damage than an object hit at 20 km per hour. We will discuss energy in more detail in Topic 06.

Virtual Laboratory

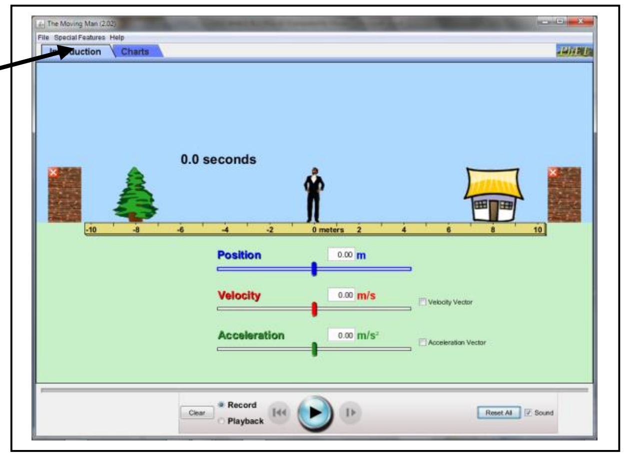
Topic 04 – Motion

			04
Name	Section #	Date	Topic #

Motion Simulation - The Moving Man   Constant Velocity

Today you will learn how to get information from a simulation program. Our goal is to play with the simulation to find the rules that it follows. Simulations are designed to follow the rules that govern the rest of the universe.

You will use the simulation called **PHET**: **The Moving Man**. Just google for the link. Click on the play button to start the program.



Part 1 – Introduction

Notice the two tabs at the top left of the screen. For now, leave it on Introduction. We will investigate only position and velocity for the first part. We will investigate the Acceleration (green) slider later.

1. How does the Moving Man react when you adjust the blue position slider? (You can also type a number into the box).

   ____

2. How does the Moving Man react when you adjust the red Velocity slider? (You can also type a number into the box).

   ____

3. How does time relate to velocity?

   ____

Part 2 – Charts

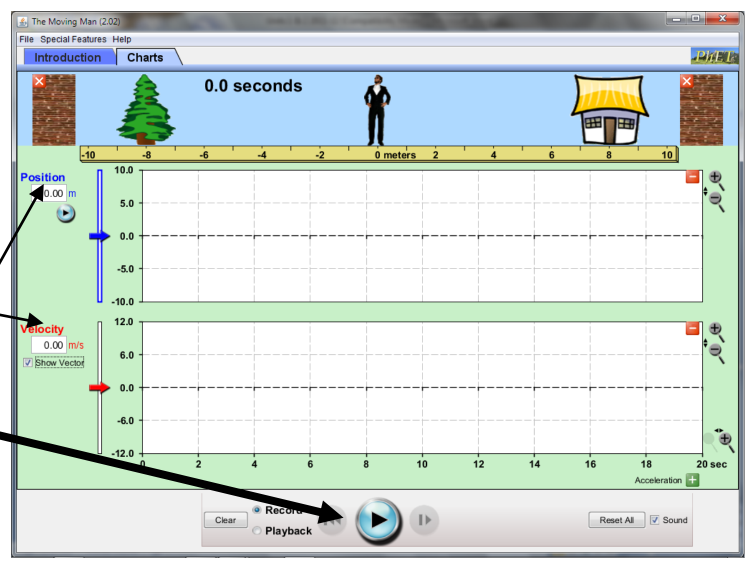
Now click on Charts at the top left.

Click on the red Minus button on the top right of the bottom (acceleration) graph to remove it.

Now investigate the simulation by typing (or dragging the arrow) different numbers into the position or velocity boxes and pressing the Play button.

Notice the timer in the blue-sky area.

Notice where positive and negative numbers are located on the charts.



Create simulations so that you can answer the following questions: (The following questions are asking you to describe the speed of the man and his direction of travel (e.g. moving Right, moving left, standing still, etc…)

4. The position graph line is on the positive side when the moving man is doing what? ______________________________
5. The position graph line is on the negative side when the moving man is doing what? ______________________________
6. The position graph line has a positive slope when the moving man is doing what? ________________________________
7. The position graph line has a negative slope (this means the line is below the zero on the y axis – notice the numbers are negative there) when the moving man is doing what? ____

8. The position graph line has a slope of zero when the moving man is doing what? ___________________________________

9. The velocity graph line is on the positive side when the moving man is doing what? _________________________________

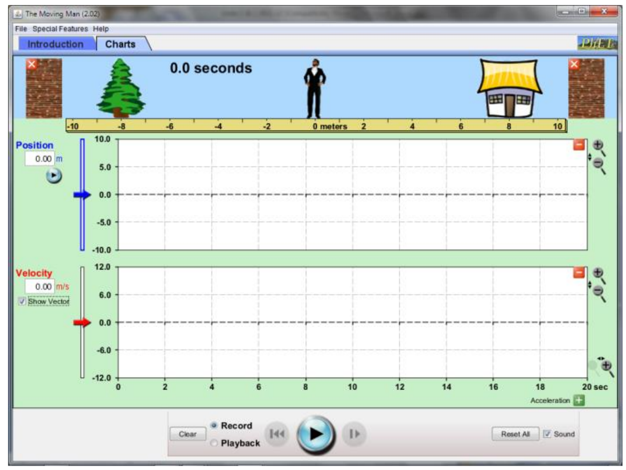
10. The velocity graph line is on the negative side when the moving man is doing what? ______________________________

11. The velocity graph line is on zero when man is doing what? ____

12. The line on the velocity graph is closer to zero when the moving man is doing what? ______________________________

13. The line on the velocity graph is far from zero when the moving man is doing what? _______________________________

14. Draw an example (on the image provided on the right) of The Moving Man moving forward from 0 meters at a velocity of 2m/s for 4 seconds.



a. Calculate how far he would move? Show your work.

____

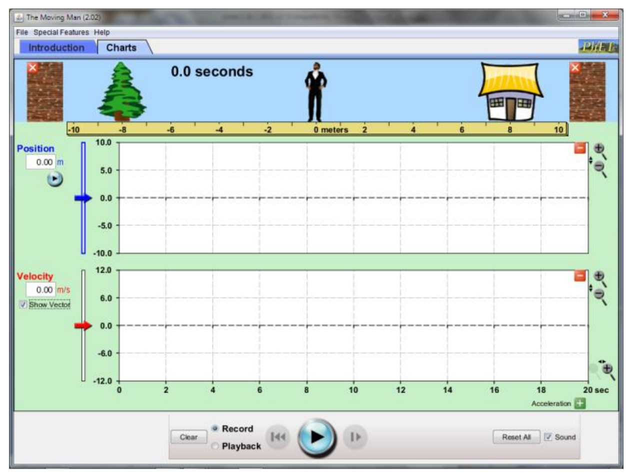
b. How far would he move if he went twice as fast? Show your work.

____

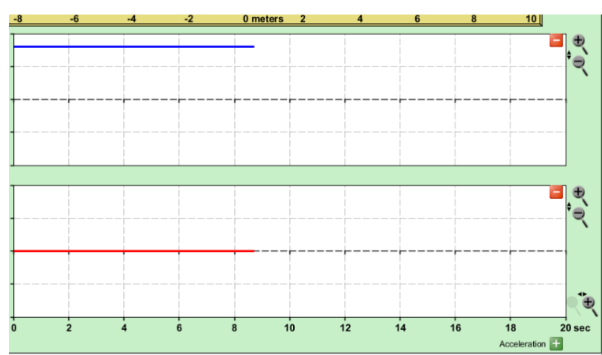
c. Calculate how far would he move if he went for twice as long from part a? Show your work.

____

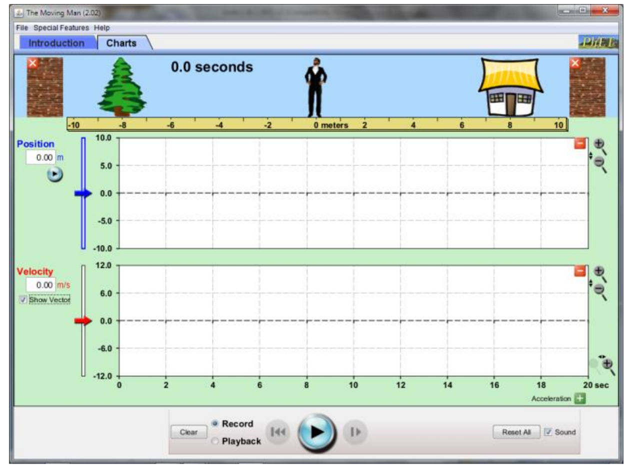
15. Draw an example of The Moving Man moving left from zero at a velocity of -5m/s.



16. What is The Moving Man doing according to this graph?



17. Click on the Clear button at the bottom. Make sure the program is paused. Type into the Position box **-10,** and **+4** into the Velocity box.



Draw what you think both graphs will look like in the picture.

Calculate how long it will take for the Moving Man to get to the other side. Show your work

____

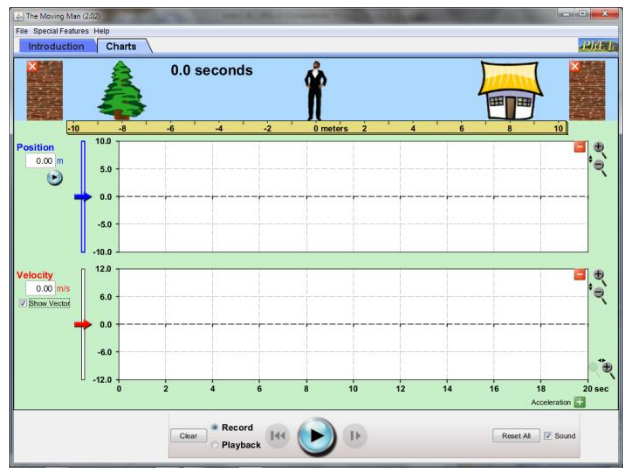
18. Now, click on the play button, What happened?

Draw the results on the diagram on the right.

Was your answer to 17 correct? ____________________

What physically could not happen to the man with these settings?

____

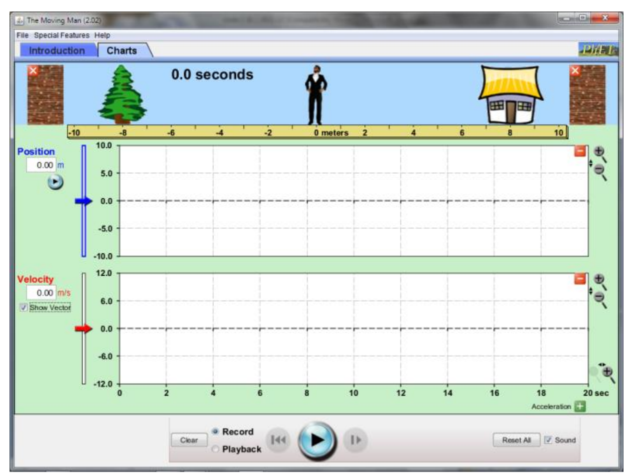


19. Click on the Clear button at the bottom. Make sure the program is paused. Type into the Position box **8,** and **-2** into the Velocity box.

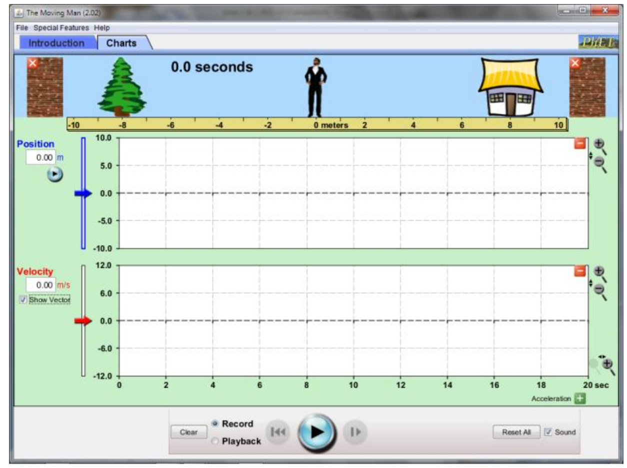
Draw what you think both graphs will look like in the picture on the right?

Calculate how long it will take for the Moving Man to get to the other side. Show your work.

____



20. Now. click on the play button. What happened? Draw the results here on the diagram.



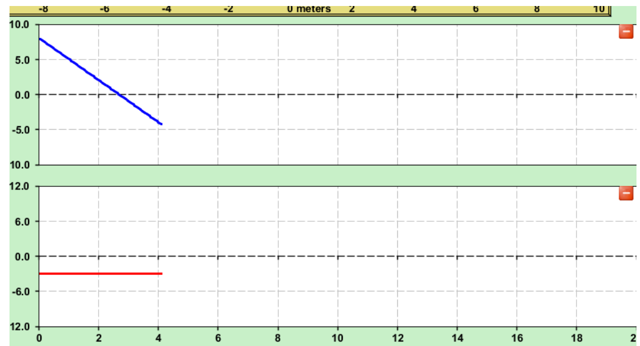
Is your answer to 19 correct?

____

What cannot happen with these settings?

____

21. Describe what happened to make this graph:



Starting Position: ______________________

Direction: __________________________

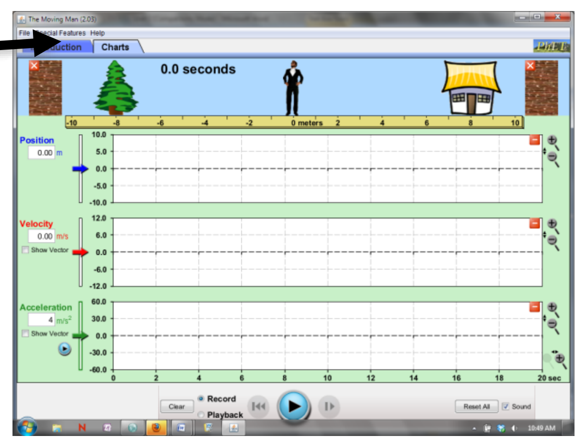
Velocity: ____________________________

Time interval: _________________________

Distance traveled: _________________________

The Moving Man with Uniform Acceleration (acceleration that stays constant)

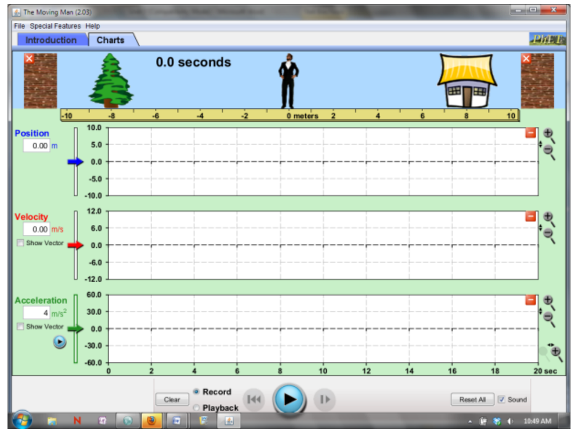
Click on the Charts tab at the top of the screen.



This works better if you type numbers into the box instead of moving the man with your mouse.

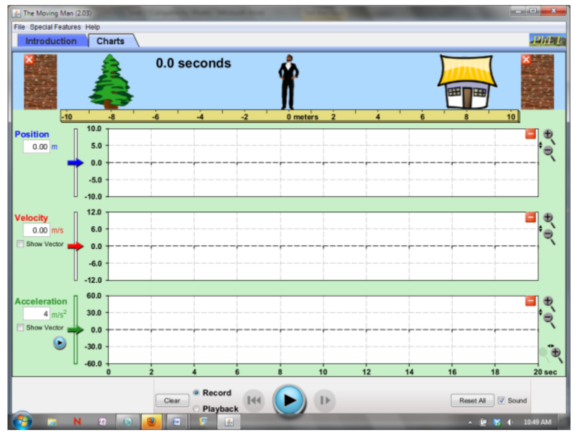
For all questions. answer **<u>with both a sentence and a graph</u>**.

22. How do you know from the graphs if you have constant velocity? (What will the position, velocity, and acceleration graphs look like? Draw this on the graphs provided.)



23. How do you know if the moving man is moving left or right?

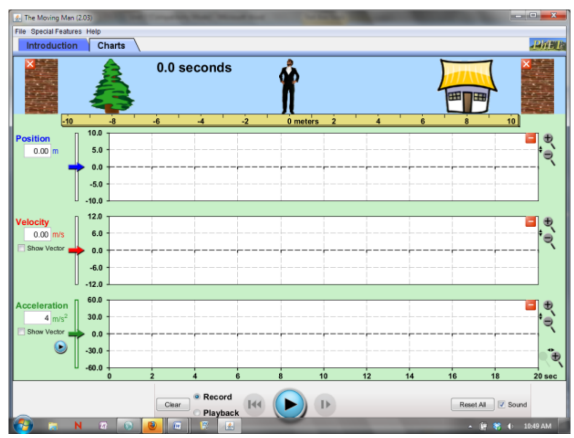
____



What will the position, velocity, and acceleration graphs look like? (Draw this on the graphs provided.)

24. How do you know on a velocity vs. time graph if the acceleration is positive or negative?

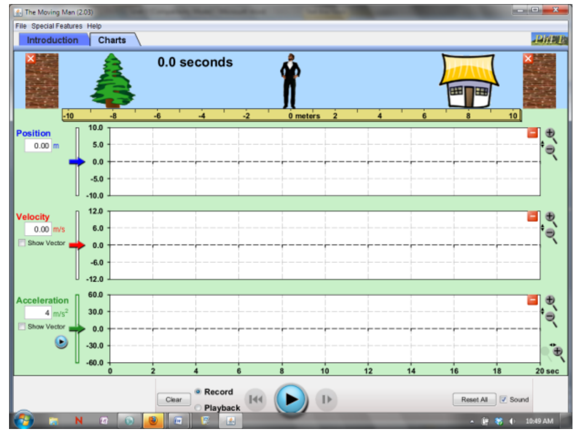
____



What will the position, velocity, and acceleration graphs look like? (Draw this on the graphs provided.)

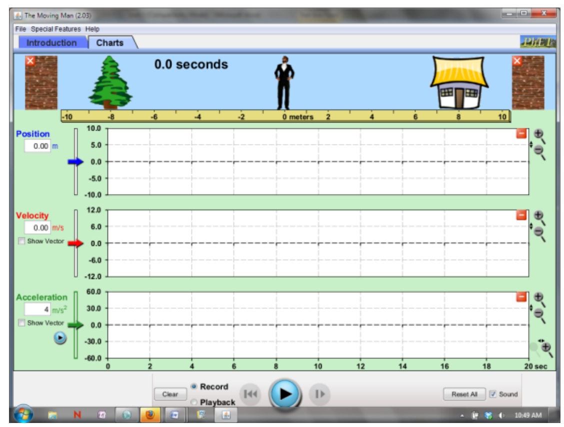
25. How do you know which way the position vs. time graph will curve? (What will the moving man be doing? Draw this on the graph provided.)

____



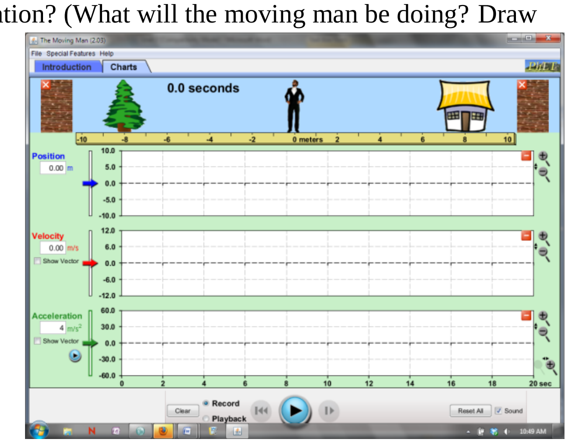
26. What happens when you have a positive velocity and a negative acceleration? (What will the moving man be doing? Draw this on the graph provided.)

____



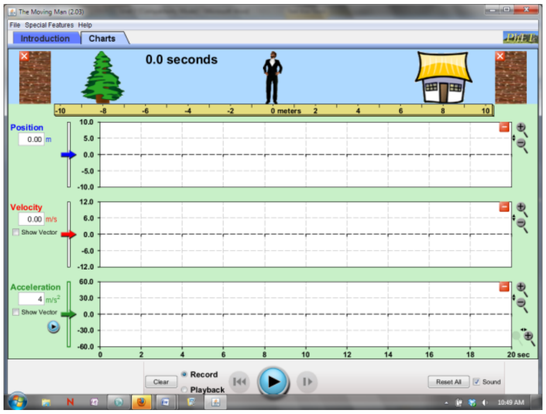
27. What happens when you have a negative velocity and a positive acceleration? (What will the moving man be doing? Draw this on the graph provided.)

____



28. CHALLENGE: There are two ways to get positive acceleration. What are they? (How must he move? Draw this on the graph provided.)

____



Hands-on Laboratory

Topic 04 – Motion

MATERIALS

2 battery powered toys
English - metric scale
stop watch
photogate
clock or wristwatch with a second hand
measurement of sound device
clock
Optional: Trolley (for suspension on a slanted wire) of truck and ramp

PROCEDURE

Note: All measurements must be in meters and kilogram.

The **pre-lab prep** this week is to complete the listed problems from the Self Evaluation on a separate sheet of paper **that shows your work** for mathematically solving the problems, including your final answer. Submissions that only provide an answer and not the work will not receive any credit! The self-evaluation is located at the end of this topic. **Complete problem numbers 3, 6, 7, 9 and 10**. Make sure your name is written at the top of your assignment.

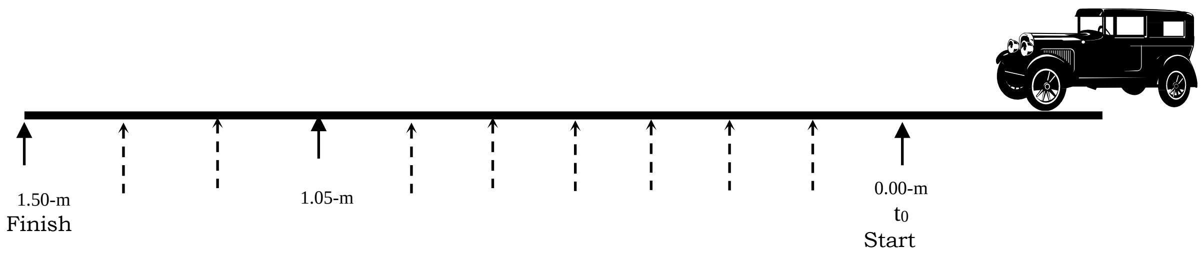
Part A – Measuring speed.

1. Measuring the speed of a battery powered car (tumble buggy).
    a. Obtain a small toy, which is the moving object to be used in this experiment.
    b. Make a race track. Mark a starting line, and 1.00 meter from that a finish line. Call this distance d, measure it with the meter rule, and record this exact distance.
    c. Release the moving object approximately 0.25 meter in front of the starting line. Begin timing when the car passes over the starting line, and clock the time that it takes to travel the distance d. Call this time (t).
    d. Repeat this procedure several times, until you are satisfied about two ideas: (the car should be moving when it passes the two points.)
        1) that the vehicle is indeed traveling with a velocity that can be reasonably called constant. (uniformly, steadily, in a straight line)
        2) that the time for each run is about the same. (not unusually high or low).
    e. Compute the velocity of the moving object, using the ratio $v = d / t$ and record.
    f. Repeat for the second car.

2. Measure the speed of a runner.
    a. Mark off a distance of 10 m in the hallway.
    b. Measure the amount of time it takes a member of your group to run this distance.
    c. The speed of the runner is $v = d/t$.
3. Calculate the momentum and kinetic energy of each item.
   Mass must be in kilograms and velocity must be in (meters / second)

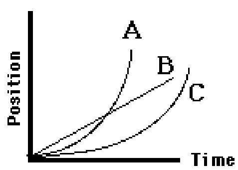
   momentum = mass x velocity K.E. = $\frac{1}{2} m \times v^2$

Part B – Speed, Acceleration, and Graphing (*Do only section B1a or B1b as assigned by instructor)*



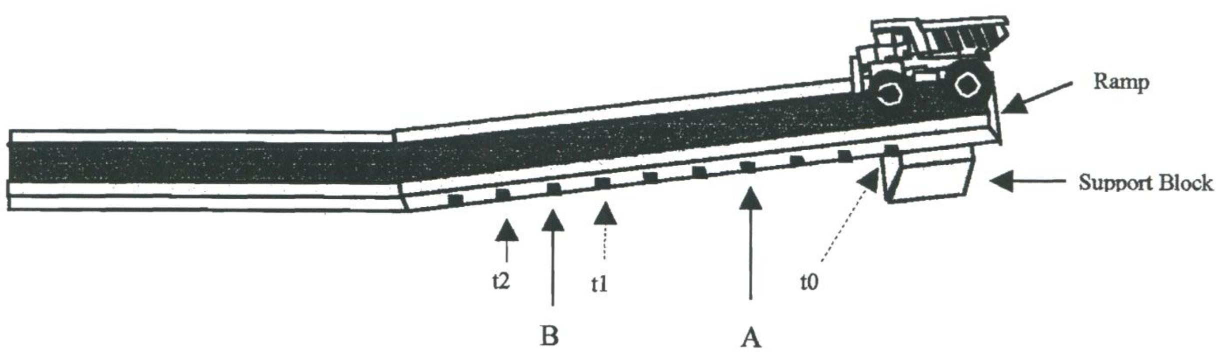
1a. Measuring Distance and Time:

1. Mark a starting line (release point), and points every 15 cm along the path. There should be a total of 11 marks.
2. Consult with your partners to determine the best method of measuring the time from the start position to each marked position. Take 3 trials of data.
3. Average the times for each position.
4. Graph the distance (d) on the y axis and the avg. time (t) on the x axis. (Normally we plot the dependent variable on the y axis and the independent variable on the x axis. We are intentionally plotting the dependent variable on the x axis and the independent variable on the y axis this time. Doing so allows us to see how the position changes with time. We can also obtain the slope of this graph that will inform us of the speed of the vehicle. Remember that the slope of the line on a graph is the rise divided by the run, or in other words $\Delta y/\Delta x$.) What is the shape of your graph, A, B, or C? B indicates that the car is moving with constant speed, and A and C show that the car is accelerating.



5. If your graph looks like B, draw a best fit line and calculate the slope. This is the velocity of your car.
6. Plot a graph of speed (v) vs Time (x axis) and calculate the slope. The slope of this line is the acceleration of your vehicle.

<u>OPTIONAL</u> Your instructor may or may not include the following lab exercises:



.

1b. Measuring the acceleration of a toy truck.

1. Obtain the two-piece ramp, stopwatch, support block, small truck with a magnet attached, and electronic sensors. Connect the two pieces of the ramp together and place the support block in the 6-cm position under the starting position. Connect the electronic sensor to the stopwatch and insert one of the sensors into the slot nearest the truck (T_0) and the second sensor in the seventh slot (T_1) or .300-meters from the first sensor. When the truck is released the magnet will activate the first sensor, turning on the stopwatch, and when the truck passes over the second sensor the stopwatch will be turned off.

2. Release the truck at the starting line to obtain the time for .300-meters. Repeat this activity and record the time three times. These times should be consistent, if they are not, repeat until they are. The time to travel from t0 to t1 is equal to t1-t0.

3. Insert one of the sensors into the slot nearest the truck (T_0) and the second sensor in the ninth (T_2) slot or .400-meters from the first sensor. Release the truck at the starting line to obtain the time for .400-meters. Repeat this activity and record the time three times. The time to travel from t1 to t2 is equal to t2-t1.

4. Determine the averages for the t_0, t_1, t_2 and the time to travel ($t_1 - t_0$) and ($t_2 - t_1$).

5. The velocity at position A labeled V_1, between t_0 and t_1, is equal to distance/time or .300-m / ($t_1 - t_0$).
   The velocity at position B labeled V_2, between $t_1$and t_2, is equal to distance/time or .100-m / ($t_2 - t_1$).

6. Compute the change in velocity (Δv), using: $\Delta v =$ (velocity B – velocity A)

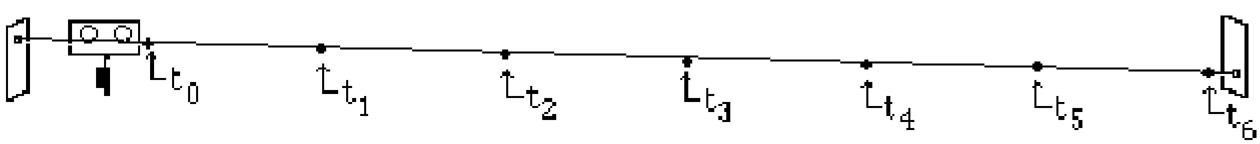
7. Compute the time (Δt) between point B and point A.
   Time at point A: $T_1 = t_1 / 2$
   Time at point B: $T_2 = (t_1 + t_2) / 2$
   Time interval between A_{time} and B_{time} $\Delta t = T_2 - T_1$

8. Calculate the acceleration of your car, between point A and point B, and repeat the experiment to verify your results.
   $a = \Delta v / \Delta t$

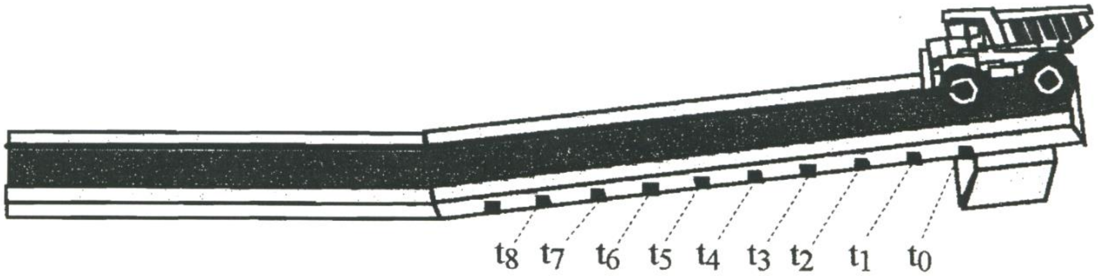
9. Calculate the acceleration of your car, between the starting point and point B.

2- Acceleration A More Complete Picture (_Do only section B2a or B2b as assigned by instructor)_

2a. Measuring the acceleration of a trolley.



1. This is a large group *cooperative* activity.
2. Timers will be placed at each interval marked on a suspended wire.
3. Start the trolley and all the timers at t_o. When the trolley passes each interval, the timers at that interval must stop their stopwatches.
4. The timers will average their times, and record that average as a single trial. Repeat to obtain a total of three trials.
5. Calculate the accelerations of your trolley using the procedures indicated in the data table.
6. After calculating the accelerations of your truck load the spreadsheet "Motion.xls" and verify your calculation. Make sure to include a copy of the spreadsheet in your report.



2b. Measuring the acceleration of a truck.

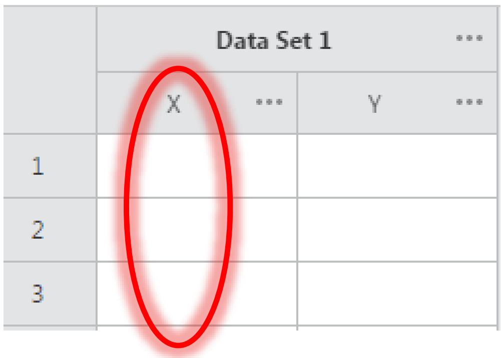
1. Obtain the two-piece ramp, stopwatch, support block, small truck with a magnet attached, and electronic sensors. Connect the two pieces of the ramp together and place the support block in the 6-cm position under the starting position.
2. Connect the electronic sensor to the stopwatch and insert one of the sensors into the slot nearest the truck and the second sensor in the second slot or .050-meters from the first sensor. When the truck is released the magnet will activate the first sensor, turning on the stopwatch. and when the truck passes over the second sensor the stopwatch will be turned off.
3. Release the truck at the starting point to obtain the time for .050-meters. Repeat this activity and record the time (t1) three times. These times should be consistent, if they are not, repeat until they are.
4. Move the second sensor (.050-m) one slot forward (t2) and obtain the time for this new distance.
5. Collect the time for each of the distances using the positions (t0 -> t8) while keeping the first sensor at t0.
6. Calculate the accelerations of your truck using the procedures indicated in the data table.
7. *After* calculating the accelerations of your truck load the spreadsheet “Motion -Trolley.xls OR
   Motion -Truck.xls “and verify your calculation. Make sure to include a copy of the spreadsheet in your report.

Graphing Using Graphical Analysis Program

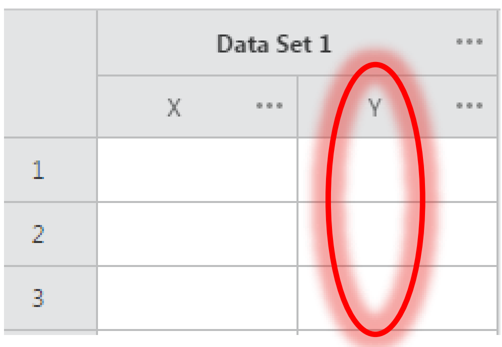
For Topic 4 you will make 2 separate graphs.

Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

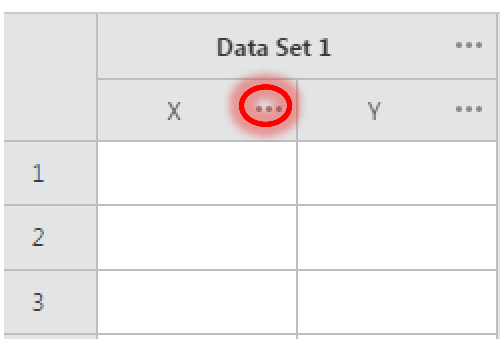
1. Enter the X data into the table; only the numbers, not the units.



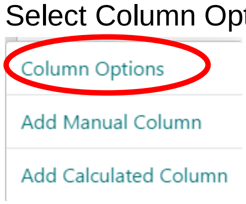
2. Enter the Y data into the table; only the numbers, not the units.



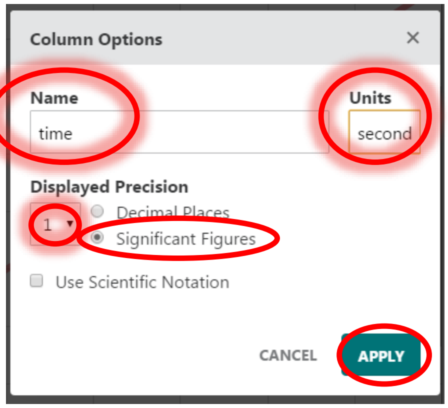
3. Click on the three dots next to X.



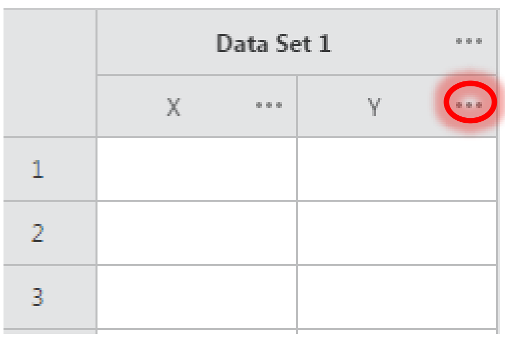
4. Select Column Options

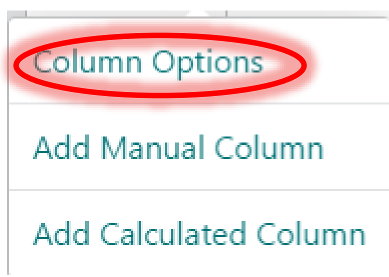


5. Type the name of the x axis (independent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



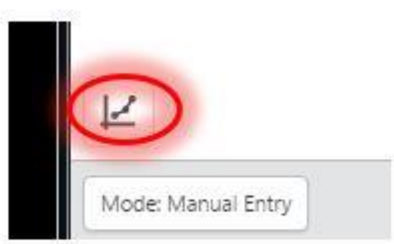
6. Repeat steps 3 – 5 for the Y axis. Click on the three dots next to Y. Select Column Options



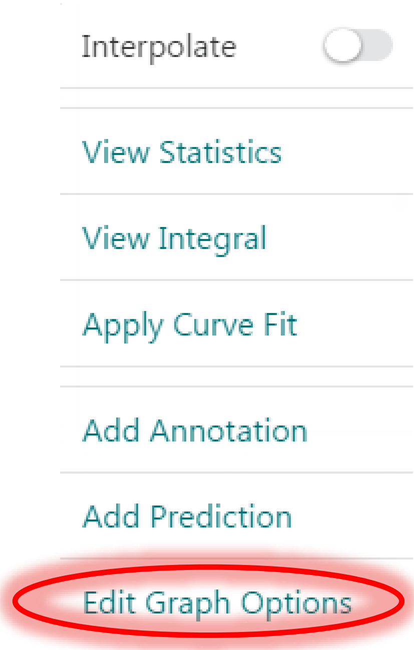


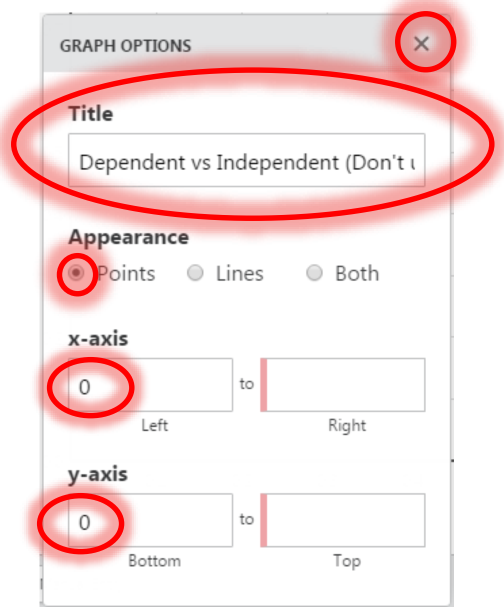
See step 5 for image. Type the name of the y axis (dependent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

7. Click on the graph icon in the lower left of the screen.



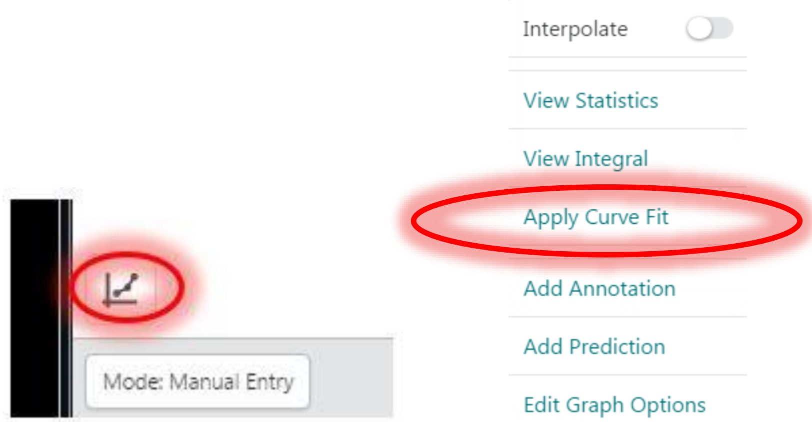
8. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to points. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.



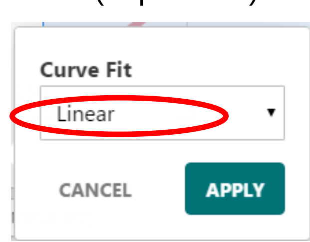


Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to ensure that your graph starts with 0 in the lower left corner.

9. Click on the graph icon in the lower left of the screen. Select Apply Curve Fit.

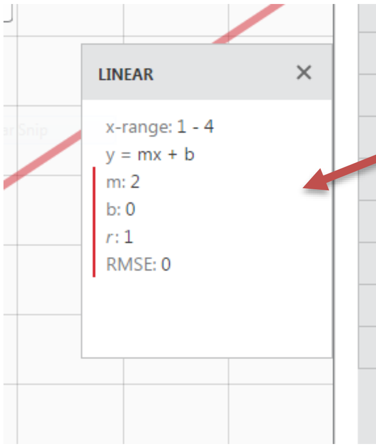


10. For the first two (parts A and B) graphs select Linear Fit (or power fit) as shown below.



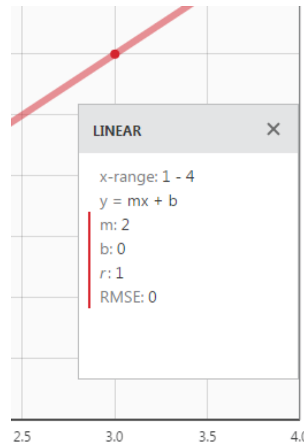
11. Uncover your best fit line or curve.

BEFORE



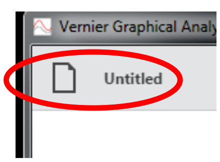
Notice the box that opens with your best fit line. If it is covering your best fit line move it so that it is not covering anything important.

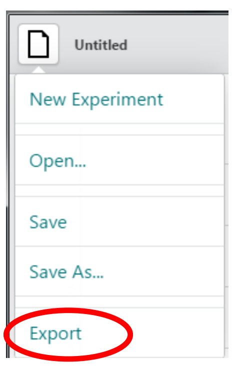
AFTER

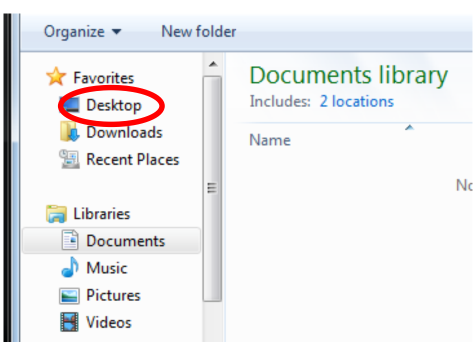


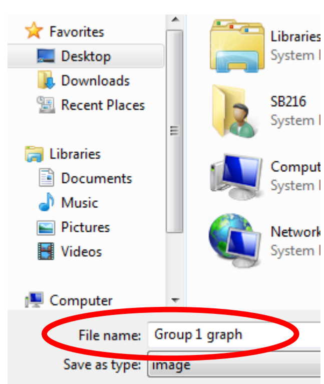
12. **Save** AND **Print** your graph(s).

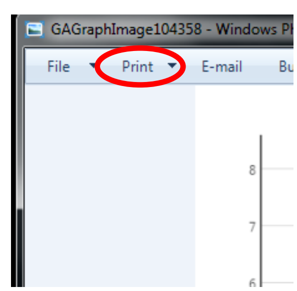
Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> *Motion Graph X*. Print.











• 04 •
M O T I O N

Name	Section #	Kit #	Topic #
			04
			04
			04

Name Section # Kit # Topic #

Part A - Speed

Object	Distance traveled (meters)	Time (seconds)	Speed (m/s)	Mass (grams)	Mass (kg)
Tumble Buggy	1.0				
Pullback Car	1.0				
Runner	10.0				

Mass must be in kilograms and velocity must be in (meters / second) to use the following formulas:

momentum = mass x velocity K.**E.** = $^1/_2$ **m x v**^{2}

Calculate the following: **(Don't forget the units!)**

Energy	Tumble Buggy	Pull back car	Runner
Momentum			
Kinetic Energy			

1. Which object had more momentum? Explain why.

____

____

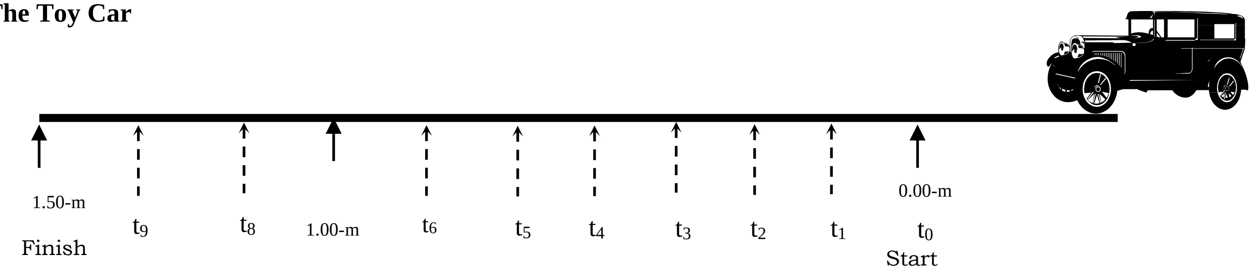
2. Which object had more kinetic energy? Explain why.

____

____

Part B- Speed and Acceleration Data (Do only section 1a or 1b as assigned by instructor)

1a. The Toy Car



Start car as far from 0 m as possible. Students must stand directly in front of position being timed. Make a few practice runs before collecting data.

	t_o	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Trial 1 Time (seconds)	0										
Trial 2 Time (seconds)	0										
Trial 3 Time (seconds)	0										
Average time (seconds)	0										
Distance (m)	0	0.15	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1.35	1.50
Speed (m/s)											

Graph the distance on the y axis, and average time on the x axis. <u>Make sure to include the distance = 0 at time = 0 for this graph only.</u> (Should be linear.)

1. Should you select a Best Fit Curve or a Best Fit Line for your graph? ________

2. Reading your graph, did your car travel with constant speed? ____

3. How do you know based on your graph? ____

4. The slope of the line from your graph (if it is a straight line) is the speed: _______________ (don't forget to include units!)

Make a graph with speed on the y axis and average time on the x axis. Select Linear Fit. (Do not include 0.0.)

5. The slope of the line from your graph is the acceleration: ________________ (don't forget to include units!)

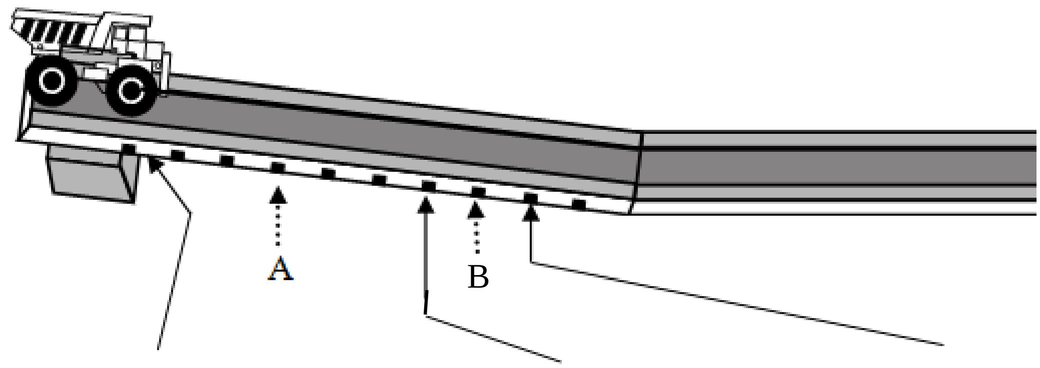
The answers to the following questions are **<u>not</u>** based on your graphs. Answer using complete sentences.

6. What is the difference between speed and acceleration? This question is testing your understanding of the definitions of these two concepts.

____

____

1b. The Truck



	t_0	t_1	t_2
First time trial	0		
Second time trial	0		
Third time trial	0		
Average Time	0		

Time to travel the distance	$T_1 = t_1 - t_0$	$T_2 = t_2 - t_1$
Average velocity $v = d/t$	Position A $v_A = .300/T1$	Position B $v_B = 0.100/T2$
Time velocity actually occurred	Time at Position A or $T_A = t_1 / 2$	Time at Position B or $T_B = (t_1+t_2)/ 2$

ΔT = change in time between adjacent velocity	$\Delta T = T_B - T_A$
Δv = change in adjacent velocity	$\Delta v = v_B - v_A$
$a = \Delta v / \Delta T$ (acceleration between points A and B)	$a = \Delta v / \Delta T$

What is the acceleration from the starting point (t_0) to point B? ______

M O T I O N

Self-Evaluation

Test 041

Directions: Select the best answer. The Pre-Lab prep problems are highlighted.

1. 04.1 The shortest length between two points located on the same plane is:
A. average speed
B. distance
C. acceleration
D. acceleration of gravity

2. 04.1 A fundamental characteristic of matter, which causes an object to occupy space and gravitationally attract other bodies is:
A. force
B. weight
C. distance
D. mass

3. 04.2 After walking steadily for 3 hours, you find yourself 9.6 kilometers away from your point of departure. What was your walking speed?
A. 4.5 km/hr
B. 2.3 km/hr
C. 5.4 km/hr
D. 3.2 km/hr

4. 04.2 An airplane is observed to travel a distance of 300 kilometers in two hours without changing its rate of speed. What is its speed?
A. 100 km/hr
B. 45 km/hr
C. 50 km/hr
D. 150 km/hr

5. 04.3 A sports car goes from zero to 120 km/hr (33.33 m/s) in 6 seconds. Assuming constant acceleration, what was the rate of acceleration for this run?
A. 55.6 m/s^2
B. 5.56 m/s^2
C. 2.025 m/s^2
D. 556 m/s^2

6. 04.3 What is the acceleration of a bird which changes its speed by 5 m/s every 4 seconds of time?
A. 1.25 $meter/sec^2$
B. 1.025 $meter/sec^2$
C. 2.025 $meter/sec^2$
D. 1.045 $meter/sec^2$

7.04.4 A football player with mass of 95 kg is running down the field with a speed of 0.94 m/s. What is his momentum?
A. 10.1 kg m/s
B. 89.3 kg m/s
C. 94.0 kg m/s
D. 95.9 kg m/s

8. 04.4 If car A had a mass of 150 kg and a velocity of 65 m/s, and car B had a mass of 25 kg and a velocity of 695 m/s, which car would have the most momentum?

A. car A
B. car B
C. neither
D. they are equal

9.04.5 Calculate the kinetic energy of a 1259 kg car traveling at 55 m/s.

A. 2.29 J
B. 69.000 J
C. 6295 J
D. 1.904.238 J

10.04.5 Which car has the most Kinetic Energy? Car A with a mass of 1250 kg and a speed of 2.4 m/s or Car B that has a mass of 1300 Kg and a speed of 2.0 m/s.

A. car A
B. car B
C. neither
D. they are equal

FORCES and SIMPLE MACHINES

Topic 05

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely. given the definition identify the correct term.

   Force, Impact, Impulse, Weight, Actual Effort, Actual Mechanical Advantage, effort, fulcrum, Ideal Effort, Ideal Mechanical Advantage, inclined plane, lever, pulley, resistance, screw, wedge, and wheel and axle.

2. Given the formula F = m x a, for a given object calculate the force acting on it, the mass, or its acceleration.
3. Given w = m x 9.8 be able to determine the weight and mass of an object on Earth.
4. Identify and apply Newton's three Laws of Motion.
5. Identify and give examples of the six types of simple machines.
6. Identify and give examples of the three types of levers.
7. Given IMA = D_E / D_R be able to calculate the Ideal Mechanical Advantage (IMA), Effort Distance (D_E), and the Resistance Distance (D_R) of a simple machine.
8. Given IE = Resistance R / IMA be able to calculate Ideal Effort (IE), the resistance (R), or the Ideal Mechanical Advantage (IMA) of a simple machine.
9. Given appropriate data or equipment determine Actual Effort (E) of a simple machine.
10. Given AMA = R / E be able to calculate Actual Mechanical Advantage (AMA), Resistance (R), and Effort (E) of a simple machine.

INTRODUCTION

Forces

Now that you are familiar with accelerated motion. in which we analyzed the motion of an object without any concern for its mass, we can bring into the picture a new element, the mass of the object. A man of great genius, Isaac Newton, concerned himself with this problem of motion with mass involvement, and he was able to associate three ideas together: the mass (m) of the object, its acceleration (a) during motion, and the force (F) needed to produce such motion. As you can see, the inclusion of mass into the picture has introduced another very important element, the force acting on the object to produce motion. In order to deal with these three elements, let's first examine their meaning:

1. acceleration (a), was found to be the ratio of the change of speed of an object and the time involved: $a = (v_2 - v_1) / t$
2. mass (m), can be understood to be the amount of matter contained in an object.
3. force (F), is anything that can potentially accelerate an object. (It doesn't have to accelerate it, but it must have the capability to do so).

How are these three factors related? Let's do what Newton did to answer this question. Think of any object with a mass (m) for the duration of this explanation. If you were to pull the object with particular force (which we will call F_1), and measure its corresponding acceleration (a_1), you could divide F_1 by a_1 to obtain the ratio F_1/a_1. If you repeat this operation using another force (F_2), and measure its corresponding acceleration (a_2), [if the force is different. expect the acceleration to be different], you could then obtain the new ratio, F_2/a_2. Let's continue this procedure for other forces in order to obtain the ratios: F_3/a_3, F_4/a_4, F_5/a_5, etc. A very interesting conclusion can be drawn from the above results. All the ratios (F/a) obtained are equal! It appears that as one increases the force, the acceleration increases correspondingly in such a way that the F/a ratios are equal for a particular mass. Therefore, F / a = m, or as it is more commonly written: **F = m x a**, which constitutes the third big idea of motion.

When using this formula, the unit of mass must be in kilograms, the unit of acceleration must be m/s^2, and the **unit of force** is the Newton. N is the abbreviation for the Newton unit.

Impulse

A change in momentum, of an object, indicates that the mass, or the velocity, or both of these have changed. Change in acceleration is produced by a force. The greater the force that acts on a body, the greater the change in speed will be with a corresponding change in momentum. One way to change the momentum of a moving body is to increase or decrease its speed. A simple way to increase speed is to have a force act upon the moving body for the longest possible time. To change the momentum of an object, both force and time are important. The quantity *force x time* is called the impulse. A good tennis player or golfer knows that the follow-through is important to carry the ball any distance. When following through the club or racket acts upon the ball for the longest possible time. Therefore, the ball travels farther.

Sir Isaac Newton's Laws of Motion

The great scientist, Sir Isaac Newton identified three laws that describe the actions of motion,

Newton's First Law states that any object moving uniformly in a straight line with constant velocity, or at rest. will remain in uniform motion or at rest, unless acted upon by some outside force. The property of matter that tends to keep it in motion (when in motion), or at rest (when at rest), is called inertia. Inertia is a measurement of an object's ability to resist a change in its motion. Inertia is not a force! The mass of an object is a measure of that object's inertia. A 50 kg child has more inertia than 25 kg child.

Newton's Second Law describes what happens when a force is applied to a moving body. The change which any force makes in the motion of an object depends upon the size of the force, and the mass of the object. The greater the force acting on the body the greater its acceleration will be. The greater the mass of the object the smaller its acceleration will be. The change of motion takes place in the same direction in which the force acts.

Newton's Third Law indicates that for every action, there is an equal and opposite reaction. This is the principle which explains how the jet propulsion engine works. Another example is the rotating lawn sprinklers that spin when water squirts from their nozzles. Such sprinklers have two or four arms, and as the water emerges from the nozzles. the arms are pushed around in the opposite direction spraying water over the lawn.

Gravitational Force

Newton wasn't finished after he developed the three Laws of Motion. He also developed what we now call the Universal Law of Gravitation. What this law tells is that any two objects that have mass are gravitationally attracted to each, and that this force of attraction diminishes rapidly with increasing distance. When an object is at the surface of a planet we can calculate this gravitation attraction with a simple formula **weight = mass x acceleration due to gravity = m x 9.8 m/s^2**. The acceleration due to gravity is the acceleration an object has at the surface of a planet if it is in free fall. On Earth the acceleration due to gravity is 9.8 m/s^2. On the Moon the acceleration due to gravity is 1.6 m/s^2. A 10 kg object weighs (10 x 9.8) 98 N on Earth but on the Moon only weighs (10 x 1.6) 16 N. Recall that the mass of an object is how much of it there is, but the weight is the gravitational attraction between two objects. Weight is a force and mass is not.

Frictional Force

Motion around us is almost always affected by friction. Friction is the resistance to motion. One of the most common things that creates friction is the air. Automobiles and airplanes are streamlined in order to reduce some of this resistance to the air.

Friction is also helpful because, unless friction existed between our feet and the Earth. we would not be able to walk. We could not nail two boards together if it were not for friction because friction holds the nail in place. When we apply the brakes while driving an automobile, friction stops the car.

One way in which we reduce friction is through the use of lubricating oil. Friction between liquid substances is much less than between solid substances. There are many ways of combating friction. Friction may be greatly reduced by the use of wheels, ball bearings, roller bearings, and lubricants. Because of these modifications of the effects of friction, one person can push an automobile, and six people can push a locomotive.

A practical way to develop an understanding of forces is through simple machines. Trucks, railroads, and ships are machines used to haul goods to and from markets. Without machines, the residents of our cities would find it more difficult to live, and farmers could not raise enough food to feed us. According to many experts without machines we would still be an agrarian society. Almost every activity of our daily life depends in some way on machines. We have constructed a wide variety of machines to satisfy our needs. Early people made stone axes that served as weapons. The machines that we gradually developed gave us great control over our environment (physical surroundings). To operate our improved machines, we harnessed the energy of falling water and of such fuels as coal, oil, and the atom. Today, since we use so many machines the age we live in is often called the machine age.

Principles of Machines

A machine produces force and controls the direction and the motion of force. But it cannot create energy. A machine can never do more work than the energy put into it. In other words, a machine can change the relationship between force and distance (Work = F x d) but the total amount of work done is constant. It only transforms one form of energy such as electrical energy to another form of energy such as mechanical energy. The ability of a machine to do work is measured by two factors. These factors are known as efficiency and mechanical advantage. These are concepts we will study further when we investigate the next topic 06 Energy. For now, we will focus on the forces produced by the machines and the forces we apply to them.

Ideal Mechanical Advantage (IMA) can be demonstrated with a crowbar, which is a type of lever. When one end of the crowbar is directly under the resistance a part of the crowbar must rest on a fulcrum (support). The closer the fulcrum is to the resistance, the less effort there is required to raise the resistance by pushing down on the handle of the crowbar; and the greater the mechanical advantage of the crowbar. For example, if the resistance is 200 kilograms, and the distance from the resistance to the fulcrum is one fourth of the distance from the handle to the fulcrum, the mechanical advantage will be four to one. Therefore, it will take 200/4 = 50 kilograms of effort to raise the resistance. But the distance the resistance will be moved will be only one-fourth of the distance through which the effort is applied.

IMA = Distance effort moved / Distance resistance moved = D_E / D_R

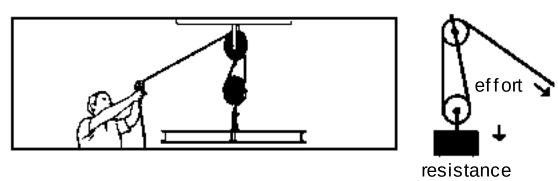
This sounds very good but we understand that machines are not one hundred percent efficient. This affects the mechanical advantage of our machine. This means that IMA may not be the best way to describe our machine. In fact, the *Actual Mechanical Advantage* (AMA) that is the ratio of the force exerted by the machine (resistance) to the force applied to the machine (effort), may be the best way to describe our machine.

AMA = Resistanc / Effort = R / E

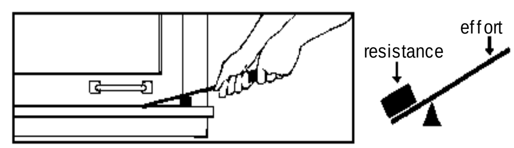
Six Simple Machines

Most machines consist of a number of elements, such as gears and ball bearings that work together in a complex way. But no matter how complex they are, all machines are based in some way on six types of simple machines: the pulley, the lever, the wheel and axle, the inclined plane, the wedge, and the screw.

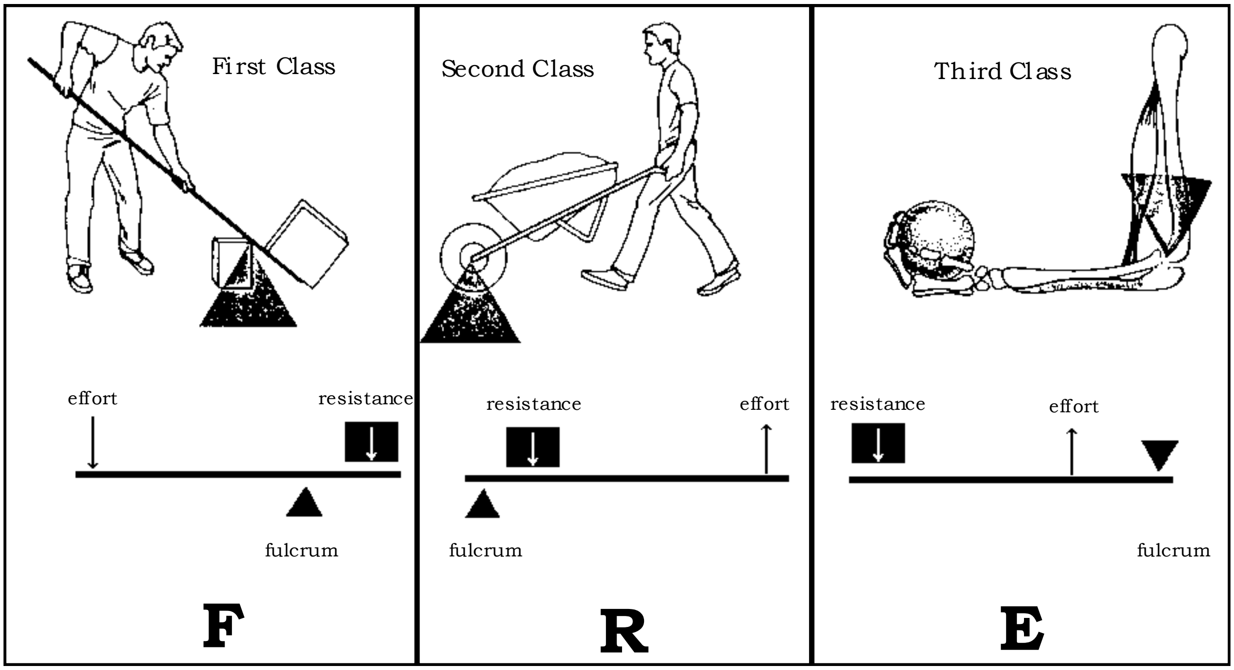
A ***pulley*** is a wheel over which a rope or belt is passed. It is a form of the wheel and axle. The mechanical advantage of a single pulley is one, because the downward effort exerted on the rope equals the resistance at the other end of the rope that passes over the pulley. The advantage of the single pulley is that it changes the direction of the force. For example, to lift a resistance, a person can more conveniently pull down on a rope thus using the entire weight of their body. When one pulley is attached to a support and a second pulley is attached to the resistance a definite mechanical advantage is obtained.



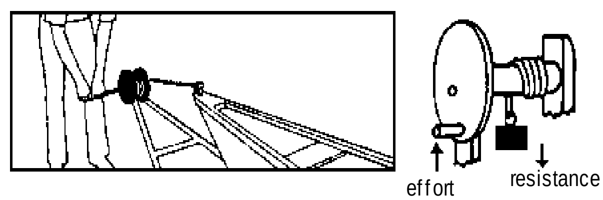
A ***lever*** consists of a rigid body, typically a metal bar, pivoted on a fixed **fulcrum** (pivot point). There are three basic types of levers. Which type of lever we have depends upon the position of the Fulcrum (F), Resistance (R), and Effort (E). The three types of levers may seem a bit confusing at first but the word FRE (F-Fulcrum, R-Resistance, and E-Effort) can help us remember the types of levers. The order of the letters (FRE) refers to the class (1st, 2nd, and 3rd) of the levers.



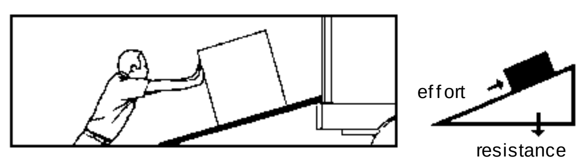
In a first-class lever (represented by the F in FRE) the Fulcrum (F) is between the Resistance (R) and the Effort (E). A crowbar is an example of a first-class lever. In a second-class lever (represented by R in FRE) the Resistance (R) is between the Fulcrum (F) and the Effort (E). A wheel barrow is an example of a second-class lever. In a third-class lever (represented by the E in FRE) the Effort is between the Fulcrum (F) and the Resistance (R). An example of a third-class lever occurs when a person lifts a ball in the palm of the hand. The Resistance (R) is at the hand, the Fulcrum (F) is at the elbow, and the forearm supplies the Effort (E) to lift the ball.



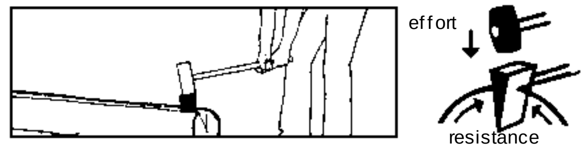
The ***wheel and axle*** is essentially a modified lever, but it can move a resistance further than a lever can. In a windlass, or winch, used to raise water from a well, the rope that carries the resistance is wrapped around the axle of the wheel. The effort is applied to a crank handle on the side of the wheel. The center of the axle serves as a fulcrum. The mechanical advantage depends upon the ratio between the radius of the axle and the distance traveled by the crank handle. The wheel and axle machine has important applications when it is used to transport heavy goods by rolling rather than by sliding. The wheel itself is regarded as one of the most important inventions of all time. It is widely used in all types of machinery and motor vehicles.



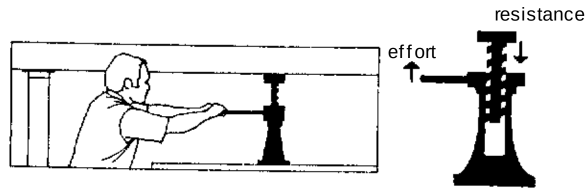
The ***inclined plane*** allows the average person to raise a 200-pound box up 2 feet into the rear of a truck. By placing a 10-foot plank from the truck to the ground. a person could raise the resistance easily. If there were no friction, the force required to move the box would be exactly 40 pounds. The mechanical advantage of an inclined plane is the length of the incline divided by the vertical rise. The mechanical advantage increases as the slope of the incline decreases. But the resistance will then have to be moved a greater distance.



The ***wedge*** is an adaptation of the inclined plane. It can be used to raise a heavy resistance over a short distance or to split a log. The wedge is driven by blows from a mallet or sledge hammer. The effectiveness of the wedge depends on the angle of the thin end. The smaller the angle, the less the force required to raise a given resistance.



The ***screw*** is actually an inclined plane cut in a spiral around a shaft. The mechanical advantage of a screw is approximately the ratio of the circumference of the screw to the distance the screw advances during each revolution. Wood or machine screws are common examples of the screw.



In the following laboratory, we will investigate the pulley. lever, inclined plane, and the wheel and axle. We will not investigate the wedge and the screw because they are considered extensions of the inclined plane. Thus, through the study of the inclined plane, we will gain an understanding of the screw and wedge.

In the laboratory, we will collect the same type of data for each machine and use it to evaluate the machine. For each machine we will measure the:

- resistance — R
- effort needed to move the resistance — E
- distance effort moved — D_E
- distance the resistance moved — D_R

From this data you will calculate:

- Actual Mechanical Advantage — $AMA = R / E$
- Ideal Mechanical Advantage — $IMA = D_E / D_R$
- Ideal Effort — $IE = R / IMA$

<u>Notice that only four variables are measured</u>; resistance, effort. effort distance and resistance distance for each of the simple machines.

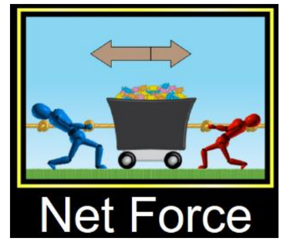
Virtual Laboratory

Topic 5 – FORCES and SIMPLE MACHINES

Name	Section #	Date	Topic #
			05

GETTING STARTED: Google **PHET Forces and Motion: Basics**

NOTE: Sum of Forces = Net Force



A. TUG OF WAR: (Notice 4 choices on the page. Select Net Force.)

Make sure all of the boxes in the upper right-hand corner are checked.

1. Create a scenario on the rope in which the forces are **BALANCED** by clicking on and dragging the men to the rope positions. Click on the Go button.

   a) What is the **NET FORCE** on the cart?______________________________
   Explain how Newton's First Law applies to the **cart** this situation.
   ____

Comparing the Red Team's Force to the Blue Team's force: (circle the appropriate answer)

b) The direction and strength of the RED force is: **RIGHT** or **LEFT** and **SMALLER** or **LARGER or EQUAL**?

c) The direction and strength of the BLUE force is: **RIGHT** or **LEFT** and **SMALLER** or **LARGER or EQUAL**?

d) The NET force is in which direction? **RIGHT** or **LEFT or Not applicable**

2. Click **the orange reset button.** Create a scenario on the rope pull in which the forces are **UNBALANCED**. Click on the Go button.

   a) What is the **NET FORCE** on the cart? ____

   b) Describe how Newton's First Law applies to the cart in this scenario.
   ____

   c) Does Newton's second apply **to the cart** in this scenario?
   ____

   Explain why or why not. ____

Comparing the Red Team's Force to the Blue Team's force: (circle the appropriate answer)

d) The direction and strength of the RED force is: **RIGHT** or **LEFT** and **SMALLER** or **LARGER or EQUAL**?

e) The direction and strength of the BLUE force is: **RIGHT** or **LEFT** and **SMALLER** or **LARGER or EQUAL**?

f) The NET force is in which direction? **RIGHT** or **LEFT or Not applicable**

g) Explain how Newton's Third Law applies **to the cart** in both situations.
____

B. MOTION: Click on the Motion Icon. Play around with the simulation so that you know how to use it. You can click on the objects below the track and drag them to the skate board. Change the applied force by typing the amount in the white box below the Applied Force slide or sliding the slider. Make sure that all of the boxes in the upper right-hand corner are checked (Force, Value, Masses, Speed) *There is **no FRICTION** in this scenario.

1. Place the refrigerator on the skateboard. **Calculate** the acceleration of the Skateboard/Refrigerator if a PUSH force of 100 N is applied to it, ________________, (Don't forget the units!) Will the Skateboard/Refrigerator continue accelerating if the PUSH force is removed? (highlight the answer) **YES** or **NO**

2. Apply a **PUSH** force of approximately 100 N, Click the play button. Once the skateboard is moving remove the **PUSH** by changing the force to 0 quickly. Answer the following questions. *You might need to do this a couple of times to get the feel of removing the force without stopping the skateboard. **All of your answers below** are based on the situation where you have stopped pushing the skateboard.*

3. What happens to the **SPEED** of the Skateboard/Refrigerator when there is no longer a Push force? (Highlight the appropriate answer.) **Increase** **Decrease** **Stays the Same** **Zero**

4. Are the forces acting on the Skateboard/Refrigerator **BALANCED** or **UNBALANCED**?

5. What are the horizontal **FORCES** acting on the Skateboard/Refrigerator?

6. Will the Skateboard/Refrigerator ever stop moving? **Yes** or **No** Why or why not? **EXPLAIN using the appropriate Newton's Laws**!

7. Reset the simulation and click all of the boxes again. Place the refrigerator on the skateboard and **APPLY** a force of approximately 100 N. This time **DO NOT** remove the **PUSH** force from the refrigerator/skateboard. Answer the following questions.

8. What happens to the **SPEED** of the Skateboard/Refrigerator when the **FORCE** is continuously applied? (Highlight the appropriate answer.) **Increase** **Decrease** **Stays the Same** **Zero**

9. Are the forces acting on the Skateboard/Refrigerator **BALANCED** or **UNBALANCED**?

10. Will the Skateboard/Refrigerator speed ever stop changing? **YES** or **NO** Why or why not? **EXPLAIN using the appropriate Newton's Laws**!

    ____

C. FRICTION: Click on the **FRICTION** Icon at the bottom of the simulation. Play around with the simulation so that you know how to use it. Make sure that all of the boxes in the upper right-hand corner are checked (Forces, Sum of Forces, Values, Masses, Speed). Notice you can control the amount of friction using the slider bar labeled Friction in the box on the upper right. Leave it in the middle to start with. Drag a 50 kg box to the track. Apply a **PUSH** force of 100 N to the box (type 100 into the box). Press the Play button. Notice the play button is going but the box is not moving. Notice the direction of the force arrows for the **PUSH** (applied force) and the Friction force. Now begin to slide the Friction bar to the left very slowly. Observe. Then move the Friction bar to the right very slowly. Observe. (Hold mouse button in to continuously apply force or click on arrow to hold force.)

Circle the appropriate answers below:

a) How does the presence of **FRICTION** affect the movement of the objects in the simulation?
The object: **SPEEDS UP** **SLOWS DOWN** **IT'S NOT AFFECTED**

b) **BEFORE** the object starts moving, what do you notice about the **FRICTION FORCE** and the applied **PUSH FORCE?** Are the forces **BALANCED** **or** **UNBALANCED**

c) **AFTER** the object starts moving**,** what do you notice about the **FRICTION FORCE** and the applied **PUSH FORCE?** Are the forces **BALANCED** **or** **UNBALANCED?**

d) Place a 50 kg box on the ground. Slide the Friction slider to approximately ¼ from the left (this equals around 50 N of friction). How much **Applied FORCE** is required to just put the box in **MOTION**? _____________ Newtons.
What is the **NET FORCE** acting on the box? ________________

e) Keep the previous friction setting and place the 2nd 50 kg box on top of the 1st. **PREDICT** how much **FORCE** will be required to just put the boxes in **MOTION.**____**Newtons**

Now try it using the simulator.

f) What was the **ACTUAL FORCE REQUIRED**? ______________________________________Newtons

g) Can you use this to **PREDICT** how much force is required to just move the **REFRIGERATOR**?

h) **PREDICTION**______________________**ACTUAL**_____________________ **(Don't forget units!)**

i) **This is Not required - CHALLENGE:** Determine the **MASS** of the PRESENT? Mass = ________________kg.

j) **EXPLAIN** how you got your answer. ___

Hands-on Laboratory

Topic 05 – Forces and Simple Machines

MATERIALS

mass (approximately 5N)	20 Newton scale
2 single pulleys	10 Newton scale
2 double pulleys	5 Newton scale
short string	small chain
long string	wheel and axle device
1 lever	
1 inclined plane	1 meter stick
simple machine device	

PROCEDURE

Part A - Friction

A. How much static friction force is there between wood and 4 other surfaces?

Obtain the multi surface friction board and place it near the end of the table. You will need to place a heavy weight (found in the kit) on it to prevent sliding. Cut a piece of string approximately 60 cm long. Make a loop at each end of the string. Place one end of the loop on the hook of a wood block. Place the other end of the loop over the edge or pulley connected to the edge of the table. Place the block on one of the surfaces. Begin by hanging a 10-gram mass from the loop that is dangling. Does it cause the block to slide? Determine the maximum amount of weight that can be hung from the string without causing the block to slide. **<u>This hanging weight is equal to the static force of friction between the block and surface it is on.</u>** (Remember weight is a force.)

How to calculate weight: weight = hanging mass (in kg) x 9.8 m/s^2.

Example: What does a 33.32-gram mass weigh? First convert from grams to kg.

Mass = 33.32 grams = 0 .03332 kg. **weight = 0.0332 x 9.8 = 0.33 N.**

Perform the experiment again but this time place a mass (as indicated on the table) on the wood block.

Mass of wood block ___________grams = _____________kg. Weight of wood block = ________N

Helpful Hints:

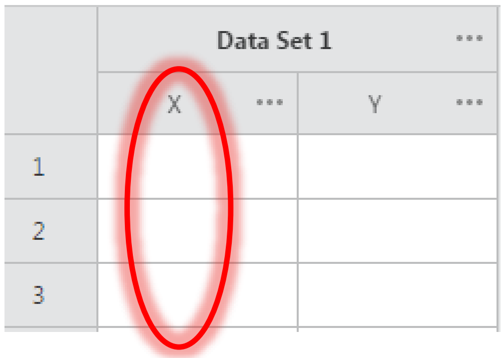
- **Place heavy weight on surface board to prevent slipping.**
- **Look for data pattern while taking measurements to see if you need to re-do a data point.**
- **If using the chain, the weight of the chain must be included with the hanging weight.**
- **Only use string, and not the chain for the cardboard surface.**

Graphing Using Graphical Analysis Program

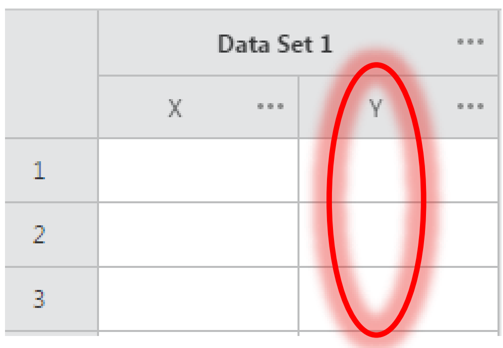
For Topic 5 you will plot 4 sets of data on one graph.

Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

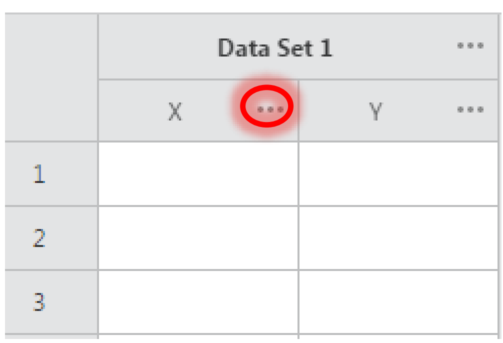
1. Enter the X data into the table; only the numbers, not the units.



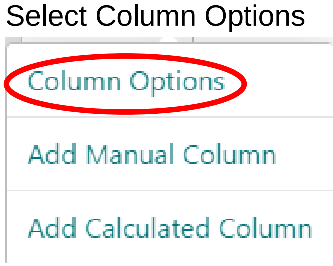
2. Enter the Y data into the table; only the numbers, not the units.



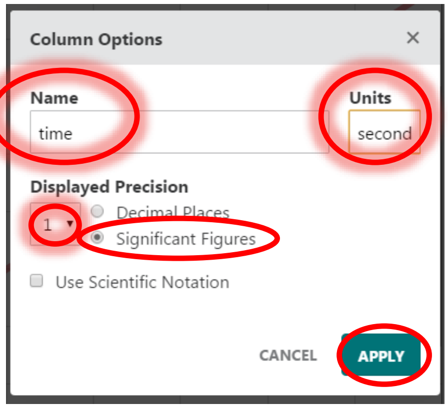
3. Click on the three dots next to X.



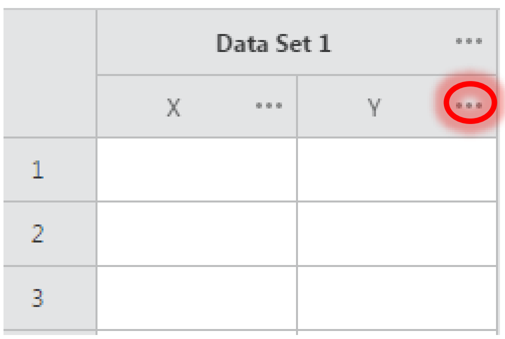
4. Select Column Options

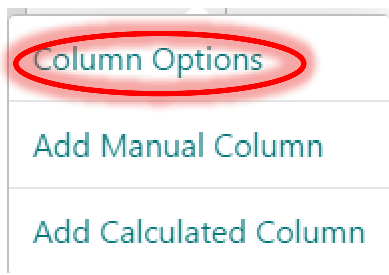


5. Type the name of the x axis (**Weight of block + additional mass**) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



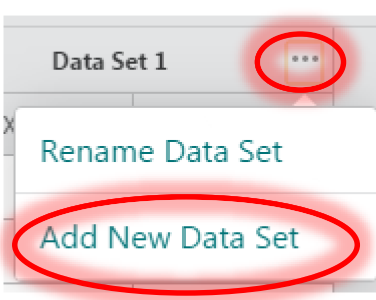
6. Repeat steps 3 – 5 for the Y axis. The label for the Y axis is **Frictional Force**. Click on the three dots next to Y. Select Column Options



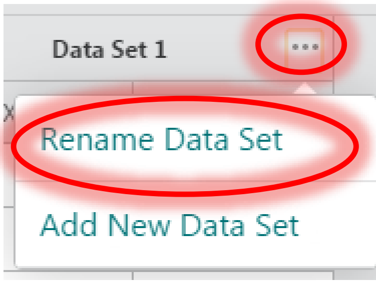


See step 5 for image. Type the name of the y axis (**Frictonal Force**) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

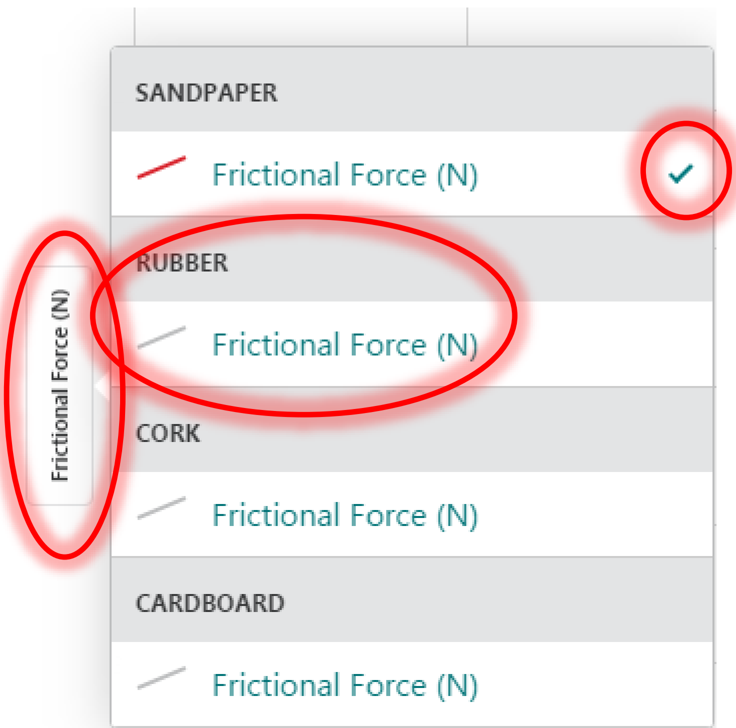
7. To enter the next 3 sets of data, click on the three dots next to Data Set 1 at the top of the screen, and then select ADD NEW DATA SET. Perform this step 2 more times. Use the scroll bar at the bottom of the data set to navigate between each one. Copy and paste the X values for Data Set 1 into the X values for the 3 new data sets if they are the same. Type in the Y values for the 3 new data sets.



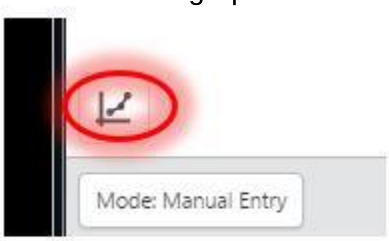
8. Each data set needs to be named to represent the four sets of data. Click on the three dots next to each of the four Data Sets and select Rename Data Set. Once you type the new name in the box click on the RENAME button. The names should be Cardboard, Sandpaper, Robber, and Cork.



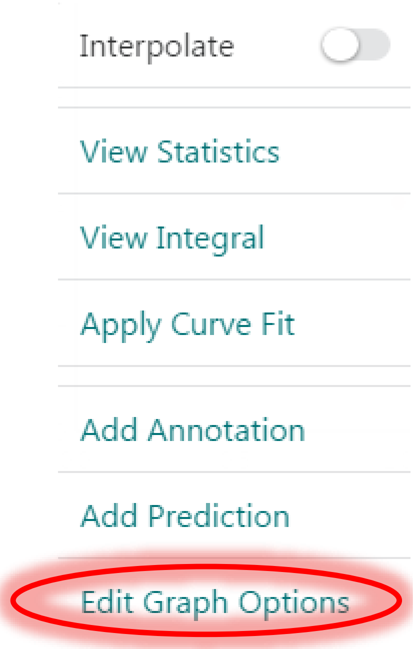
9. To display the four sets of data points on the same graph, click on the words Frictional Force on the Y-axis of the graph. Notice below there is already a check mark next to Sandpaper. This will display on the graph. Click on the words Frictional Force for each of the data sets that need to be displayed. A check mark will appear to indicate that it will display. Click anywhere on the graph and the box will close.



10. Click on the graph icon in the lower left of the screen.

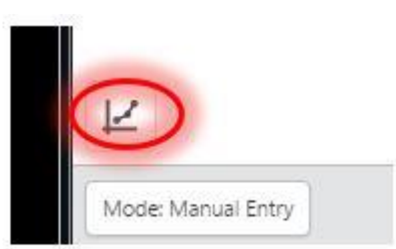


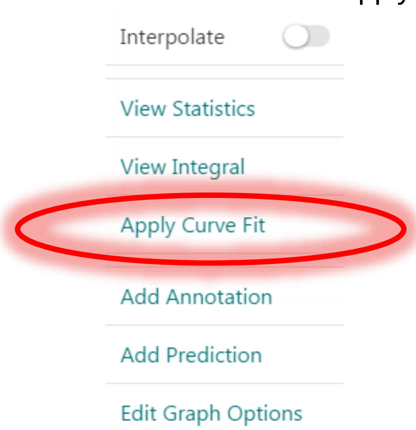
11. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to points. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.



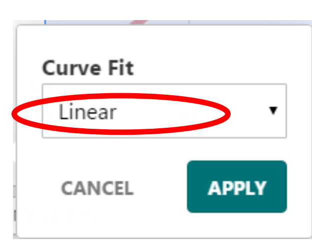
Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to insure that your graph starts with 0. 0 in the lower left corner.

12. Click on the graph icon in the lower left of the screen. Select Apply Curve Fit.

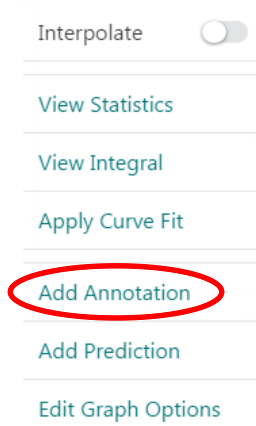




13. Select Linear Fit as shown below



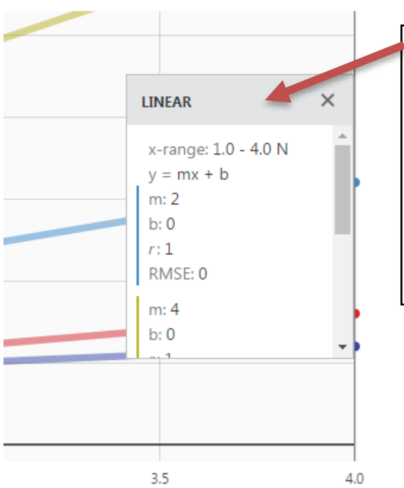
14. Title each best fit line. Click on the graph icon in the lower left of the screen. Select Add Annotation.



In the box that opens type in the name of the data set (Cardboard, Sandpaper, Rubber, and Cork) and slide the box to the corresponding best fit line. Do this for all 4 data sets, DO NOT COVER YOUR BEST FIT LINE with the name. You can only add one box at a time. Once you move it to the best fit line it will change to a normal looking simple textbox. Then you will be able to add the next data set name.

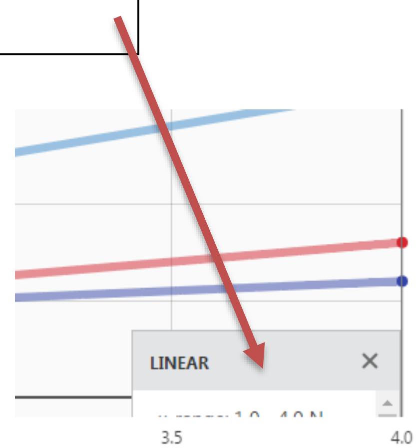
15. Uncover your best fit lines.

BEFORE



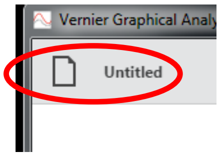
Notice the box that opens with your best fit lines. If it is covering your best fit lines move it down so that it is not covering any of the lines. You will not see the contents of the box, but that's okay. If you need the slopes you can write them down.

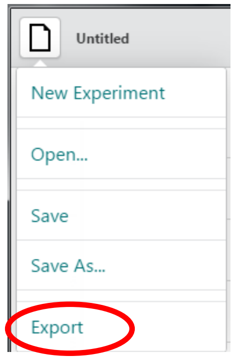
AFTER

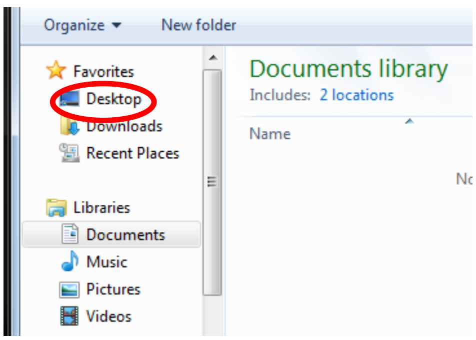


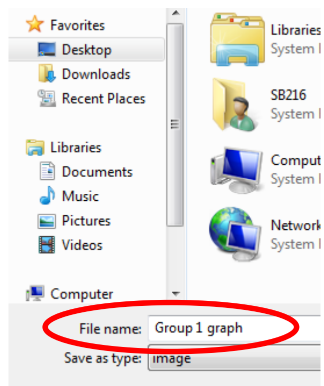
16. **Save** AND **Print** your graph(s).

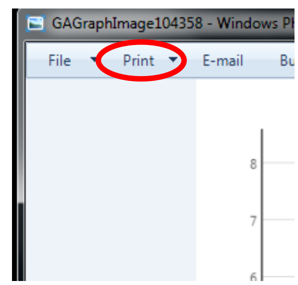
Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> Friction Graph. Print.











• 05 •
FORCES and SIMPLE MACHINES

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Name	Section #	Kit #	Topic #

Friction

A. **A. How much static friction force is there between wood and 4 other surfaces?**

Obtain the multi surface friction board and place it near the end of the table. You will need to place a heavy weight (found in the kit) on it to prevent sliding. Cut a piece of string approximately 60 cm long. Make a loop at each end of the string. Place one end of the loop on the hook of a wood block. Place the other end of the loop over the edge or pulley connected to the edge of the table. Place the block on one of the surfaces. Begin by hanging a 10 gram mass from the loop that is dangling. Does it cause the block to slide? Determine the maximum amount of weight that can be hung from the string without causing the block to slide. **This hanging weight is equal to the static force of friction between the block and surface it is on.** (Remember weight is a force.) (Look for DATA PATTERNS)

How to calculate weight: weight = hanging mass (in kg) x 9.8 m/s^2.

Example: What does a 33.32 gram mass weigh? First convert from grams to kg.

Mass = 33.32 grams = 0 .03332 kg. **weight = 0.0332 x 9.8 = 0.33 N.**

Perform the experiment again but this time place a mass (as indicated on the table below) on the wood block.

Mass of wood block ___________grams = _____________kg. Weight of wood block = ________N

(x-axis) Weight of wood block + weight of additional mass (N)		(y-axis) Cardboard /wood Hanging weight plus chain (N)	(y-axis) Sandpaper/wood Hanging weight plus chain (N)	(y-axis) Rubber/wood Hanging weight plus chain (N)	(y-axis) Cork/Wood Hanging weight plus chain (N)
	Frictional force (N) No additional mass on wood block.				
	Frictional force (N) +20 grams on wood block				
	Frictional force (N) +40 grams on wood block				
	Frictional force (N) +60 grams on wood block				
	Frictional force (N) +80 grams on wood block				
	Frictional force (N) + 100 grams on wood block				

Important Note: Be careful when hanging the masses to avoid jerking the block.

1. Make 4 plots of Frictional Force (y axis) vs (weight of block + additional weight) (x axis) on one graph. Answer the following questions based on your graph.

2. Which surface pair exhibited the greatest frictional force? Explain why. (How do you know from your graph?)

____

3. Does placing additional weight on the wood block change the amount of frictional force between the block and the surface it is on? Explain why or why not. (How do you know from your graph?)

____

B. Kinetic friction (Use wood blocks or flat masses for race.)

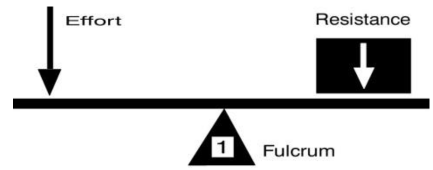
Place the board on the table with equal metal weights on the 4 different surfaces. The results are better if you use the flatter brass 10 g or 20 g masses or 4 like coins. Slowly lift the board from the starting position end. The weights will begin to slide as it is raised. Once they begin sliding you are observing kinetic friction (friction when one surface slides against another surface).

4. Which surface has the greatest amount of kinetic friction? How do you know based on what you observed? Make sure not to confuse static friction with kinetic friction!!!!!

5. Which surface has the least amount of kinetic friction? How do you know based on what you observed? Make sure not to confuse static friction with kinetic friction!!!!!

6. How does the force of static friction compare with the force of kinetic friction? (Compare the surface pair with the greatest static friction with the surface pair that has the greatest kinetic friction etc….) Discuss the results.

PRE-LAB PREP Complete all of the following tables and answer the questions.

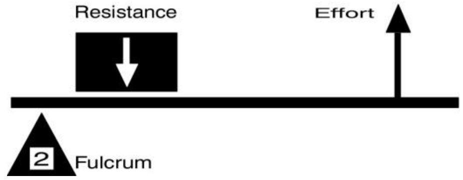


Part A - Lever

Section 1: 1st Class Levers

	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement	0.100	0.100	0.200
b. Resistance Distance D_R	.0051	.0111	.0100
c. Effort Placement	0.050	0.100	0.050
d. Effort Distance D_E	0.010	0.020	0.020
2. Force (Newton's) a. Resistance R	5.0	5.0	5.0
b. Effort E	2.4	2.5	2.5
3. Ideal Mechanical Advantage $IMA = D_E / D_R$			
4. Ideal Effort (Newton) $IE = R / IMA$			
5. Actual Mechanical Advantage $AMA = R / E$			
6. Error (between E and IE)			
7. %Error for E and IE where IE is the theoretical value			

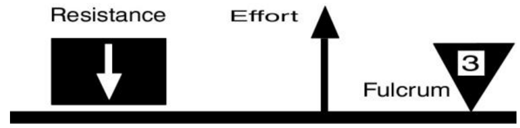
1. Explain any difference between the ideal Mechanical Advantage and the Actual Mechanical Advantage? Why should they be the same?



Section 2: 2nd Class Levers

	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement	0.050	0.050	0.100
b. Resistance Distance D_R	.0071	.0100	.0101
c. Effort Placement	0.100	0.150	0.150
d. Effort Distance D_E	0.020	0.030	0.030
2. Force (Newton's) a. Resistance R	5.0	5.0	5.0
b. Effort E	1.7	1.7	1.7
3. Ideal Mechanical Advantage $IMA = D_E / D_R$			
4. Ideal Effort (Newton) $IE = R / IMA$			
5. Actual Mechanical Advantage $AMA = R / E$			
6. Error (between E and IE)			
7. %Error for E and IE where IE is the theoretical value			

1. Explain any difference between the Ideal Mechanical Advantage and the Actual Mechanical Advantage? Why should they be the same?

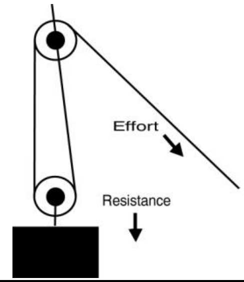


Section 3: 3rd Class Levers

	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement	0.200	0.200	0.300
b. Resistance Distance D_R	0.003	.0051	.0050
c. Effort Placement	0.050	0.100	0.100
d. Effort Distance D_E	0.010	0.020	0.020
2. Force (Newton's) a. Resistance R	5.0	5.0	5.0
b. Effort E	1.2	1.2	1.3
3. Ideal Mechanical Advantage $IMA = D_E / D_R$			
4. Ideal Effort (Newton) $IE = R / IMA$			
5. Actual Mechanical Advantage $AMA = R / E$			
6. Error (between E and IE)			
7. %Error for E and IE where IE is the theoretical value			

1. Explain any difference between the Ideal Mechanical Advantage and the Actual Mechanical Advantage? Why should they be the same?

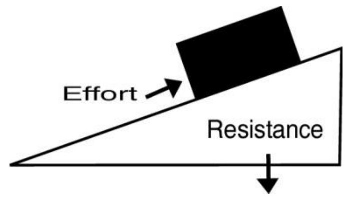
Part B - Pulley



	Section 1 One Pulley	Section 2 Two Pulleys	Section 3 Three Pulleys	Section 4 Four Pulleys
1. Distance (meters) a. Resistance Distance D_R	0.100	0.100	0.100	0.100
b. Effort Distance D_E	.1012	.1991	.3102	.3893
2. Force (Newton's) a. Resistance R	5.0	5.0	5.0	5.0
b. Effort E	5.1	2.5	1.7	1.3
3. Ideal Mechanical Advantage $IMA = D_E / D_R$				
4. Ideal Effort (Newton) $IE = R / IMA$				
5. Actual Mechanical Advantage $AMA = R / E$				
6. Error (between IMA & AMA)				
7. %Error for IMA and AMA where IMA is the theoretical value				

1. Explain any difference between the Ideal Mechanical Advantage and the Actual Mechanical Advantage. Should they be the same? Explain why or why not.

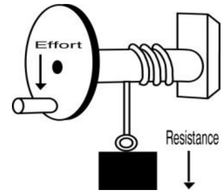
Part C - Inclined Plane



	Trial 1	Trial 2	Trial 3
Support Rod Placement	1	3	5
1. Distance (meters) a. Resistance Distance D_R	.2800	.4738	.6671
b. Effort Placement (notch on inclined plane)	2	2	2
b. Effort Distance D_E	1.087	1.087	1.087
2. Force (Newton's) a. Resistance R	5.0	5.0	5.0
b. Effort E	1.3	2.2	3.1
3. Ideal Mechanical Advantage $IMA = D_E / D_R$			
4. Ideal Effort (Newton) $IE = R / IMA$			
5. Actual Mechanical Advantage $AMA = R / E$			
6. Error (between IMA and AMA)			
7. %Error for IMA and AMA where IMA is the theoretical value			

1. Explain any difference between the Ideal Mechanical Advantage and the Actual Mechanical Advantage. Should they be the same? Explain why or why not.

Part D - Wheel and Axle



	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement (Axle)	0.045	0.045	0.045
b. Resistance Distance D_R	.1422	.2910	.4444
c. Effort Placement (Wheel)	0.045	0.090	0.135
d. Effort Distance(1 rotation $2\pi r$) D_E	0.283	0.565	0.848
2. Force (Newton's) a. Resistance R	5.0	5.0	5.0
b. Effort E	2.5	2.5	2.5
3. Ideal Mechanical Advantage $IMA = D_E / D_R$			
4. Ideal Effort (Newton) $IE = R / IMA$			
5. Actual Mechanical Advantage $AMA = R / E$			
6. Error			
7. %Error for IMA and AMA where IMA is the theoretical value			

1. Explain any difference between the Ideal Mechanical Advantage and the Actual Mechanical Advantage. Should they be the same? Explain why or why not.

FORCES and SIMPLE MACHINES

Self-Evaluation

Test 051

Directions: Select the best answer

1. 05.2 What force (in Newtons) is required to act on a rocket of 2.000 kg mass to make it travel in free space with a uniform rate of acceleration of 10.000 meter/s^2?
   - A. 20 million Newtons
   - B. 20 billion Newtons
   - C. 15 million Newtons
   - D. 15 billion Newtons

2. 05.4 Which of Newton's Laws Of Motion states "for every action there is an equal and opposite reaction"?
   - A. Newton's first Law
   - B. Newton's second Law
   - C. Newton's third Law
   - D. Newton's fourth Law
   - E. Does not apply to Newton's laws

3. 05.4 Which of Newton’s Laws Of Motion states "anybody moving uniformly in a straight line or at rest will remain in uniform motion or at rest. unless acted upon by some outside force"?
   - A. Newton's first Law
   - B. Newton's second Law
   - C. Newton's third Law
   - D. Newton's fourth Law
   - E. Does not apply to Newton's laws

4. 05.5 An inclined plane cut in a spiral around a shaft is the:
   - A. wheel and axle
   - B. wedge
   - C. screw
   - D. pulley
   - E. lever

5. 05.1 The force applied to a machine is:
   - A. resistance
   - B. effort
   - C. IMA
   - D. AMA
   - E. wedge

6. 05.5 Simple machines that are extensions of the inclined plane are two (2) of the following:
   - A. pulley
   - B. levers
   - C. wedge
   - D. wheel and axle
   - E. screw

7. 05.1 The simple machine that consists of a rigid body. typically a metal bar pivoted on a fixed fulcrum is a:
   - A. pulley
   - B. lever
   - C. wheel and axle
   - D. wedge
   - E. screw

8. 05.6 A third class lever can be defined in the following way:

A. the resistance lies between the force and the effort.
B. the fulcrum precedes both the resistance and the effort.
C. a third class lever does not have a fulcrum.
D. the effort is between the resistance and fulcrum

9. 05.6 A wheelbarrow is an example of which type of lever?

A. first class
B. second class
C. third class
D. fourth class
E. fifth class

10. 05.7 If a box was pushed up a ramp 0.80 meters, and the ramp was 0.27 meters off of the ground, what is the ideal mechanical advantage (IMA) of this simple machine?

A. 2.96
B. .216
C. 29.6
D. 2.70

11. 05.7 If the ideal mechanical advantage IMA is 2 and the effort distance is 0.10 meters, what would the resistance distance be?

A. 0.10m
B. 0.05m
C. 0.04
D. 0.15m
E. 1m

12. 05.8 If a machine has a Distance Effort of 1.00 meters and a Distance Resistance of 0.37 meters along with a Resistance of 5.20 Newton, what is the machine's ideal effort?

A. 1.93 Joules
B. 14.08 Newton
C. 1.93 Newton
D. 14.05 meters

13. 05.8 Determine the ideal effort of a simple machine if the resistance is 5.4 Newton and the ideal mechanical advantage is 3.08.

A. 1.75
B. 2.43
C. 3.23
D. 3.10
E. 1.43

14. 05.9 An object weighs 5.20 Newtons. When lifted by a pulley 16.00 Newton force is needed to move the resistance. Identify the actual effort?

A. 5.20 Newton
B. 16.00 Newton
C. 83.2 Newton
D. 3.08 Newton

15. 05.9 It takes 2.20 Newtons to move an object that weighs 5.20 Newtons. What is the Actual Effort involved?

A. 2.20 Newton
B. .220 Newton
C. 7.4 Newton
D. 11.44 Newton

16. 05.10 Given the resistance to be 5.70 Newtons and an effort of 2.14 Newtons, what is this machine's AMA?

A. 2.66
B. 0.122
C. 0.375
D. 12.20

17. 05.10 Determine the actual mechanical advantage of a simple machine if the resistance is 5.4 Newtons and the actual effort is 2.8 Newtons.

A. 1.9
B. 1.0
C. 1.5
D. 0.5
E. 2.7

18.05.2 Calculate the mass of an object accelerating with a speed of 1.3 m/s^2 and experiencing a force of 451 Newtons.

A. 58.6 kg
B. 2.8 kg
C. 0.002 kg
D. 154 kg
E. 347 kg

19.05.3 Calculate the weight of an object that has a mass of 55 kg.

A. 5.6 N
B. 54.2 N
C. 156 N
D. 539 N
E. 55 N

20.05.3 Calculate the mass of an object that has a weight of 1000 Newtons.

A. 9800 kg
B. 988 kg
C. 102 kg
D. 98.8 kg
E. 10.2 kg

E N E R G Y

Topic 06

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given definitions identify their correct terms.

   chemical, electrical, energy, energy conversion, force, heat, horsepower, joule, kinetic energy, light, mechanical, newton, nuclear, potential energy, power, sound, velocity, watt, work

2. Identify the seven forms and two types of mechanical energy.

3. Correctly state and apply the two laws of energy identified in this topic.

4. Identify, explain and provide examples of the conversion of one form of energy to another.

5. Given the formula for potential energy PE = m x 9.8 x h, and the formula for Kinetic Energy KE. = $^1/_2$ m x v^2, determine which formula to use and calculate the amount of energy.

6. Given the formula for work, W = F x d. calculate the amount of work given force and distance.

7. Given the formula where P = power, W = work, and t = time calculate the power using the formula P = W / t.

8, Given appropriate data (from Topic 5) determine Work Output (W_O) of a simple machine,

   W_O = Resistance x Distance the resistance moved = R x D_R

9. Given appropriate data (from Topic 5) determine Work Input (W_I) of a simple machine.

   W_I = Effort x Distance the effort moved = E x D_E

10. Given appropriate data (from Topic 5) determine the percent of efficiency (%E) of a simple machine.

    %E = (Work output / Work input) x 100

INTRODUCTION

All life depends upon energy which allows us to move and interact with our environment. Formally energy is defined as the ability or capacity to do work. Most of the energy on the Earth comes from the sun. The sun's rays are needed so that plants can make food. Animals and human beings use the energy found in food to operate their bodies and muscles. The sun's energy is also stored in coal, wood, and oil, which are burnt to do work.

People often confuse energy, force, work, and power. Force is a push or a pull on an object. **Work is energy.** Work and energy are measured in the same units. The amount of work is determined by the strength of the force used to move an object times the distance the object moves. Power measures the rate at which work is done.

All energy originates from four fundamental forces: strong nuclear forces, weak nuclear forces, gravitational forces, and electromagnetic forces. We find that these fundamental forces act to produce common forms of energy in our environment. These forms include: thermal, light, sound, mechanical, electrical, chemical, and nuclear.

Seven Forms of Energy

Thermal energy (heat), is associated with the motion of atoms or molecules in matter. Thermal energy is transmitted by conduction through solid and fluid media, by convection through fluid media, and by radiation through empty space (and in some cases through solids and liquids). Thermal energy conducted by radiation is an electromagnetic wave produced by the motion of atoms and molecules.

Light is a form of energy which exists as a wave propagating as a periodic disturbance of an electromagnetic field and having a frequency in the visible region of the electromagnetic spectrum. An electromagnetic field can be pictured as a force field (with both electric and magnetic components) that is produced when an electric charge (such as an electron) is accelerated.

Sound energy is associated with a vibratory disturbance in the pressure and density of a fluid or solid. The vibrations occur within the range 20 to 20.000 cycles per second and are capable of being detected by the organs of hearing.

Mechanical energy is associated with the motion and position in space of matter. There are two forms of mechanical energy: kinetic and potential energy. The Mechanical energy of an object is the sum of Kinetic Energy plus Potential Energy, Kinetic energy is the ability of a mass in motion to do work. Potential energy is the energy that is stored in some object due to its position (i.e.. a compressed spring or a massive object at some height, h, above the ground). Mechanical energy can be transmitted in wave form, in which kinetic energy is passed through impact from one particle of matter to the next. Examples of mechanical energy are ocean waves and Earthquakes.

Electrical energy arises from the existence and interactions of electric charge. The movement or flow of this charge is considered as electric current. This electric current is used as a source of energy.

Chemical energy is the energy stored in the chemical bonds that hold together the atoms or ions in chemical compounds.

Nuclear energy is associated with the nucleus of an atom. It is the energy released when atomic nuclei undergo fission or fusion. Nuclear fission is the process in which the nuclei of a heavy element splits into two or more lighter elements, with the release of other particles (such as neutrons and electrons) and substantial amounts of energy. Nuclear fusion is a process in which the nucleus of several light isotopes, such as hydrogen, are forced together at ultra-high temperatures to form the nucleus of a heavier element (such as helium) while releasing substantial amounts of energy.

Law of Conservation of Energy

In investigating energy, we find that when energy is transformed, certain conditions always occur. These conditions are referred to as the first and second laws of thermodynamics. The first law is known as the Law of Conservation of Energy. In any energy transformation, energy is neither created nor destroyed, but merely changed from one form to another. Let's consider what happens when a rock is dropped. The friction created when the rock drops through the air causes the air molecules to move faster so their average temperature rises. This means that some of the rock's original potential energy has been transferred to the air molecules as heat. When the rock hits the ground more of its energy is transferred to the soil (as a gain in the form of heat). The energy lost by the rock is exactly equal to the energy gained by the surroundings.

First Law- ***Energy input always equals energy output - energy is neither created nor destroyed.***

According to the second law, energy transfers are always degraded to a more dispersed and less useful form. When a car is driven, only about 10 percent of the high-quality chemical energy in the gasoline is converted to mechanical energy used to propel the vehicle. The remaining 90 percent is degraded to low-quality heat that is released into the environment. When electrical energy flows through the filament wires in a light bulb, it is converted into about 5 percent luminous energy, (light), and about 95 percent into low-quality heat. For one system to do work on another system there must be a difference in energy between the two systems.

The first law of energy tells us we will never run out of energy, but according to the second law, we can run out of high-quality, or useful energy. Not only can we not get something for nothing (the first law), we can't even break-even in terms of energy quality (the second law).

Second Law - When energy is converted from one form to another, the result is to move from higher level energy (gasoline) to lower level energy (heat).

Energy Conversions and Energy Chains

Energy can be transformed or converted from one form or type of energy to another. A match after being struck converts chemical energy to heat and light. A series of conversions leading to a final outcome is called an energy chain. The energy used while typing this sentence originated with the sun. A partial energy chain illustrating this would include:

nuclear →	electromagnetic radiation →	stored chemical →	used chemical →	mechanical
sun	waves	photosynthesis	food-digestion	typing

Developing A Quantitative Concept of Energy

To develop a concept of energy we will begin by reviewing the concepts of velocity, acceleration, force and work. Since work can only be accomplished through the use of energy, the amount of work done will be used as an indication of the amount of energy used.

Velocity

An automobile moving down the highway needs energy to overcome frictional forces and to maintain its motion. We can determine its average speed if we know how far it has traveled and the amount of time taken. The following will allow this determination:

average speed = distance / time or $v = d / t$

Where:

v = the velocity of the automobile (Measured in meters per second).
d = the distance that the automobile has traveled. (measured in meters).
t = the amount of time taken to travel that distance. (measured in seconds).

For Example: When d = 200 Km (or 200.000 m) and t = 4.0 hr. then

$v = d / t$
$v = 200.000$ m / 4.0 hr
$v = 50.000$ m/hr
or 833 m/min.
or 14 m/ sec

Acceleration

Looking at our automobile more closely we note that its velocity was not constant. It varied over the course of its trip. This indicates that the automobile had accelerated or decelerated (negative acceleration) at some point during the trip. The acceleration can be measured by:

acceleration = change in velocity / time taken for velocity to change

$$a = \Delta v / t$$

Where:

a = the acceleration of the object that moved and is an indication of a change in velocity over a period of time. Acceleration is measured in meters / second^2.

Δv = change in velocity between two points. This is measured in meters / second or m/s.

t = time taken for the change in velocity to occur measured in seconds.

For Example: When $\Delta v = 13.9$ m / sec and $t = 3$ s then

$a = \Delta v / t$
$a = 13.9$ m/s / 3 s
$a = 4.63$ m/s^2

Force

When acceleration takes place, something caused it to occur. Some force had to be exerted on the automobile to change its velocity. This force can be examined by taking into account the mass of the automobile and its acceleration. The following will allow its calculation:

Force = mass x acceleration or **F = m x a**

Where:

F = The force (a push or a pull) that tends to produce an acceleration of some mass in the direction of its application measured in kg - m / s^2 is a unit of measurement called a Newton.
(Note: 4.5 Newtons are approximately 1 pound).

m = the mass of the object moved (measured in kilograms).

a = the acceleration of the object that moved in a straight line and is an indication of a change in speed over a period of time. Acceleration (measured in meters / $second^2$).

For Example: When m = 800 kg and a = 4.63 m/s^2

F= m x a

F = 800 kg x 4.63 m/s^2

F = 3.704 kg-m/s^2 or 3.704 N

Two Types Of Mechanical Energy

Energy is formally defined as the ability or capacity to do work. The forms of mechanical energy are potential and kinetic energy. They are described by the amount of stored (potential) and/or dynamic (kinetic) energy an object possesses.

Potential energy *is* the energy stored by an object as a result of its position or the position of its parts. A rock on a table is an example of an object that has potential energy as a result of its position in space. The rock has potential energy because of its height that can be released and converted to kinetic energy and heat, if it is dropped. It can do work.

Potential Energy = mass x acceleration of gravity x height or **PE= m x g x h**

Note: this relationship is often written PE = mgh

Where:

PE = potential energy is equal to force (Force = mass x acceleration due to gravity = weight for freely falling objects) multiplied by distance. The result is a unit of measurement labeled Newton-meters. 1 Newton-meter is a unit called a joule.

m = the mass of the object being considered

g = The acceleration of gravity on planet Earth, 9.8 meters / $second^2$. (i.e. an object that is dropped will accelerate at a rate of 9.8 m/s^2)

h = height in meters that the object falls.

For Example: When m = 378 kg. g= 9.8 m/s^2 and h = 200 m

P.E. = m x g x h

P.E. = 378 kg x 9.8 m/s^2 x 200 m

Note: 1 kg- m / s^2 represents a unit of measurement called the Newton

P.E. = 740.880 N-m or 740.880 Joules

Kinetic energy is the dynamic energy that matter has because of its motion and mass. A moving car, a falling rock, a bullet shot from a gun or a flow of electrons are all examples.

$$\text{Kinetic Energy} = {}^1/_2 \text{ mass} \times \text{velocity}^2 \quad \text{or} \quad KE = {}^1/_2\, m \times v^2$$

Where:

KE = the energy that a body possesses as a result of its mass and velocity. The result is a unit of measurement labeled Newton-meters. 1 Newton-meter is a unit called a Joule.

m = the mass of the object moved and would be measured in Kilograms.

v = the velocity measured in meters per second.

For Example: When m = 1000 kg and v 38.5 m/s

$$K.E. = {}^1/_2 \times m \times v^2$$

$$K.E. = {}^1/_2 \times 1000 \text{ kg} \times (38.5\text{m/s} \times 38.5\text{m/s})$$

$$K.E. = 741.125 \text{ kg-m}^2/\text{s}^2$$

K.E. = 741.125 Newton-meter

K.E. = 741.125 Joules

Work

Work is defined as the expenditure of energy that occurs when a force is used to move an object through a given distance. A quantitative measure of work is determined by the product of the force acting and the distance moved in the direction the force acts:

Work = Force x distance or **W = F x d**

Where:

W = the work done and is equal to force (in Newtons) multiplied by distance moved. The result is a unit of measurement labeled Newton-meters. 1 Newton-meter is a unit called a Joule.

d = is an indication of how far the body moved (measured in meters).

F = the force (a push or a pull) that tends to produce an acceleration of some mass in the direction of its application (measured in $kg - m / s^2$).

1 $kg - m / s^2$ is a unit of measurement called a Newton.

For Example: When F = .78 N and d = .30 m then:

W = F x d
W = 0.78 N x .30 m
W = 0.23 N-m or 0.23 Joules

Power

Power is the rate of doing work. Power is commonly measured in watts and horsepower.

Power = work / time or **P = W / t**

Where:

P = the rate of doing work. Power is measured in watts or horsepower. A watt is a **unit of power** equal to 1 Joule / s and 746 watts are approximately equal to 1 horsepower.

W = the work done and is equal to force (in Newtons) multiplied by distance moved. The result is a unit of measurement labeled Newton-meters. 1 Newton-meter is a unit called a Joule.

t = time taken to do the work done to occur (measured in seconds).

For Example: When W = .23 Joules and t = 1.9 s then:

P = W / t
P = 0.23 Joules/ 1.9 sec
P = 0.121 Joules / s or 0.121 watts

Principles of Machines

A machine produces force and controls the direction and the motion of force. But it cannot create energy. A machine can never do more work than the energy put into it. In other words, a machine can change the relationship between force and distance (Work = F x d) but the total amount of work done is constant. It only transforms one form of energy such as electrical energy, to another form of energy. such as mechanical energy. The ability of a machine to do work is measured by two factors. These factors are known as efficiency and mechanical advantage.

The *efficiency* of a machine is the ratio between the energy (work) it supplies and the energy (work) put into it. Machines that transmit only mechanical energy may have an efficiency of nearly 100 percent. But some machines have efficiency as low as 5 percent. No machine can operate with 100 percent efficiency, because the friction of its parts always uses up some of the energy that is supplied to the machine. All machines produce some friction. For this reason, a perpetual-motion machine is impossible.

$$\%E = (\text{Work output} / \text{work input}) \times 100$$

The resistance is the force exerted by the object being moved. The effort is the force that is exerted to move the object. The effort distance is the distance the force (effort) moved. The resistance distance is the distance that the object (resistance) actually moves. As you work on simple machines try to identify these four variables. These four variables represent the relationship between work input, to the machine. and work output.

$$\text{Work}_{input} = \text{Work}_{output}$$

$$(F_{effort} \times D_{effort})_{input} = (F_{resistance} \times D_{resistance})_{output}$$

This relationship between input force and distance can vary as long as the equality is maintained by varying the output force and distance.

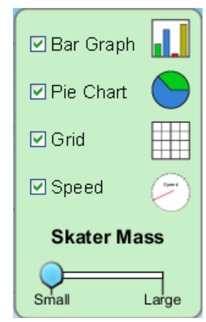
$$(F \times \mathbf{D})_{input} = (\mathbf{F} \times D)_{output} \quad \text{or} \quad (\mathbf{F} \times D)_{input} = (F \times \mathbf{D})_{output}$$

Virtual Laboratory

Topic 06 – Energy

Name	Section #	Date	Topic #
			06

Energy Skate Park: Basics



Introduction:
When Tony Hawk wants to launch himself as high as possible off the half-pipe, how does he achieve this? The skate park is an excellent example of the law of **conservation of energy**. The law of conservation of energy tells us that we can never create or destroy energy, but we can change its form, In this virtual lab. we will look at the conversion of energy between *gravitational-**potential*** energy, work, and ***kinetic*** (or moving) energy.
Use the internet, your textbook, or notes to define the following key terms:

1. Kinetic Energy ____

2. Potential Energy ____

3. Mechanical Energy____

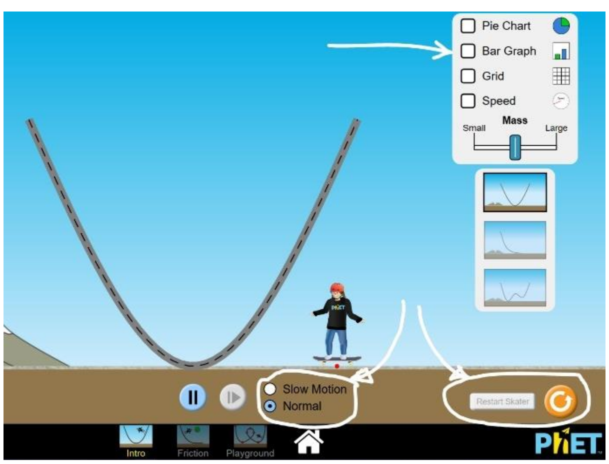
4. Joule ____

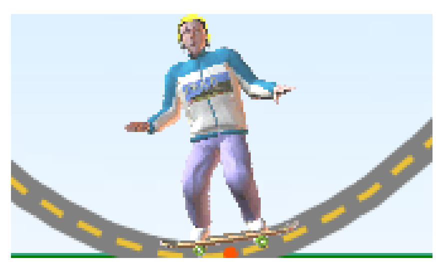
5. State, in **your own words**, the **Law of the Conversation of Energy**. ____

____

Procedure: *Google PHET Energy Skate Park: **Basics***

Click on INTRO. Take some time and play with the skater. Turn on the Bar Graph, Pie Chart, and Speed options. Become familiar with the orange '***Reset***' button on the right and how to change the speed of the simulation with the buttons on the bottom.





How does increasing skater's **mass** change the skater's….

6. Kinetic Energy? _______________ 7. Potential Energy? ______________ 8. Total Energy? __________________

The following words are used to answer the following questions: Increase, decrease, stays the same, maximum value, minimum value, or zero.

9. How does the skater's **kinetic energy** change as he moves **down** the ramp? ______________________________

10. How does the skater's **kinetic energy** change as he moves **up** the ramp? ________________________________

11. How does the skater's **potential energy** change as he moves **down** the ramp? ____________________________

12. How does the skater's **potential energy** change as he moves **up** the ramp? ______________________________

13. How does the skater's **total energy** change as he moves **down** the ramp? _______________________________

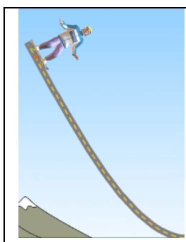
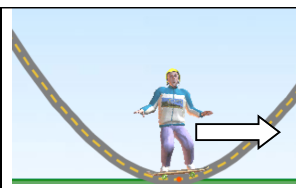
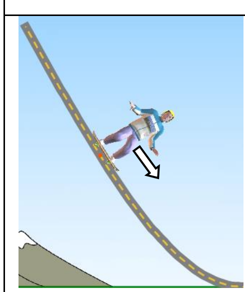
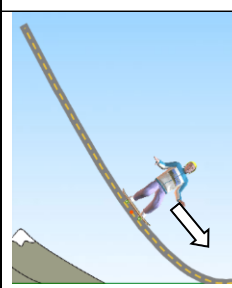
14. How does the skater's **total energy** change as he moves **up** the ramp? __________________________________

15. Describe the skater's **kinetic** energy at the bottom of the ramp. ____

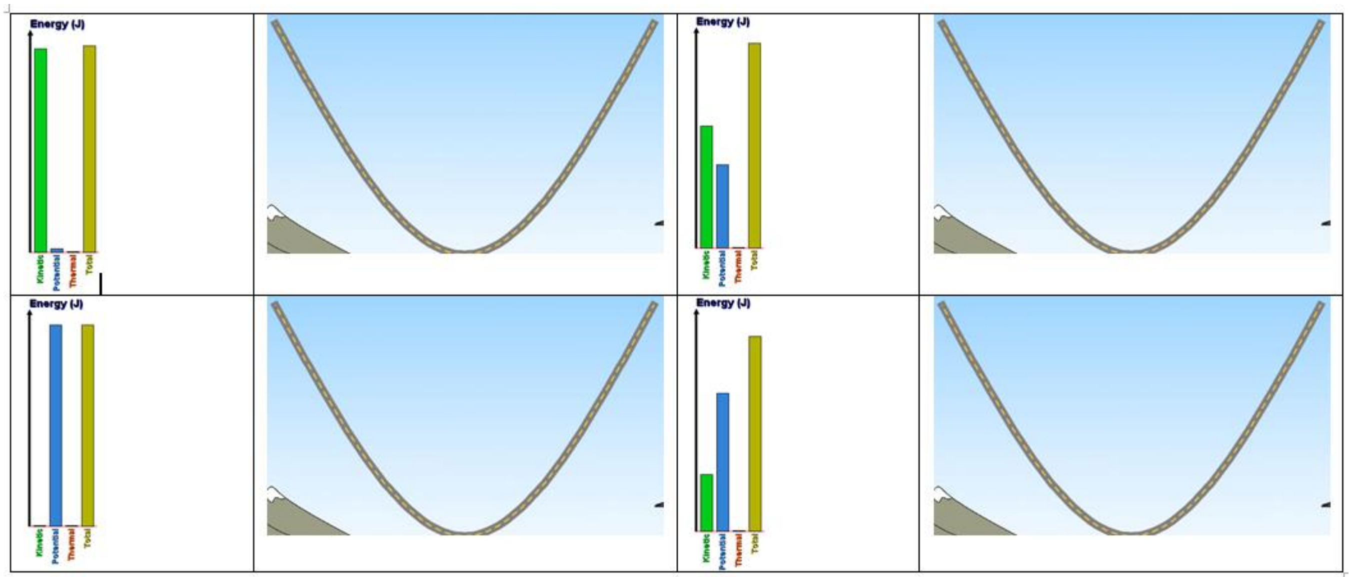
16. Describe the skater's **potential** energy at the bottom of the ramp.
____

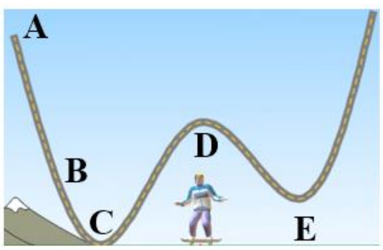
17. What happens when the skater is dropped onto the ramp from above the ramp? (Look at the bar graph.)
____
____

18. - 25. Observe the following situations. Draw the possible bar graphs for the situation shown. (**The following instruction is for hybrid section students only**: In Microsoft word click on INSERT at the top of your screen. Then click on SHAPES. Select the rectangle. Click the location on the page where you want it, and drag to the desired shape and location. If you have difficulty with this, just print this document, hand draw your answers on it, and bring your assignment to class.)

<table>
<tr>
<td> Top of the ramp. stopped for just an instance.</td>
<td>
</td>
<td> Bottom of the ramp. zooming past the middle.</td>
<td>
</td>
</tr>
<tr>
<td> Mid-way down the ramp. picking up speed.</td>
<td>
</td>
<td> 3/4 of the way down the ramp. moving pretty fast.</td>
<td>
</td>
</tr>
</table>

Draw where the skater might be based on the bar graphs shown. Just copy, paste, and drag the red dot into position. Or you can make your own mark. **3 of the pictures below will have 2 red dots**. 





← Consider this zany track. What point or points on this track would the skater have
Note: Points B and E are located at the same height above the ground.

19. The most kinetic energy? __________________

20. The most potential energy? __________________

21. The same kinetic energy (two points) __________ and __________

<u>Questions:</u> (**highlight** ***the correct answers***)

22. At the highest point kinetic energy is *zero / maximum* while the potential energy is *zero / maximum*.

23. At the lowest point kinetic energy is *zero / maximum* while potential energy is *zero / maximum*.

24. Mass *affects / does not affect* the amount of energy.

25. As an object falls in gravity, kinetic energy *increases / decreases / remains the same*.

26. As an object falls in gravity, potential energy *increases / decreases / remains the same*.

27. As an object falls in gravity, total energy *increases / decreases / remains the same*.

28. A freely falling object travelling faster and faster has a kinetic energy that *increases / decreases / remains the same*.

29. A freely falling object travelling faster and faster has a potential energy that *increases / decreases / remains the same*.

30. As a freely falling object speeds up, the total energy *increases / decreases / remains the same.*

31. As a freely falling object slows down, the total energy *increases / decreases / remains the same.*

32. How ***useful for your learning*** was this science activity, compared to other science class activities? (highlight your answer)

More useful About the same Less useful

How ***enjoyable*** was this science class activity. compared to other science class activities? (circle)

More enjoyable About the same Less enjoyable

Why did you or did you not find it useful or enjoyable?

Hands-on Laboratory

Topic 06 – Energy

MATERIALS

toy truck Newton scale	
2 - .060 Kg masses	photogates
toy car - battery powered	string for mass
device to change height of inclined plane	.0355 Kg mass
meter stick	balance
pre-massed objects	stopwatch
inclined plane - ramp	

PROCEDURE

The procedure section is not separate from the data sheets this week. Find the instructions below.

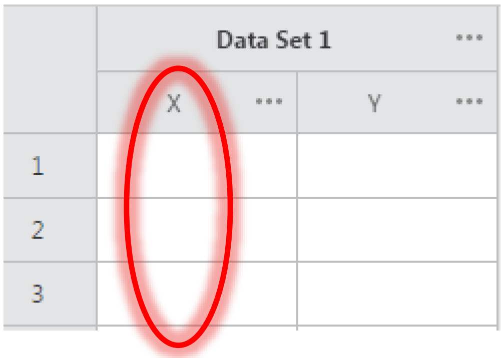
There is a pre-lab prep, Complete all of part A and complete all of Part C, Fill in the tables, complete the required calculations, and answer the questions.

Graphing Using Graphical Analysis Program

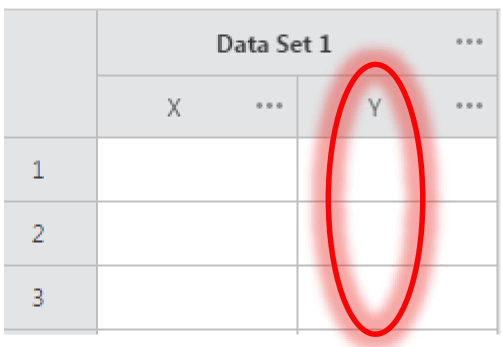
For Topic 6 you will make 3 separate graphs.

Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

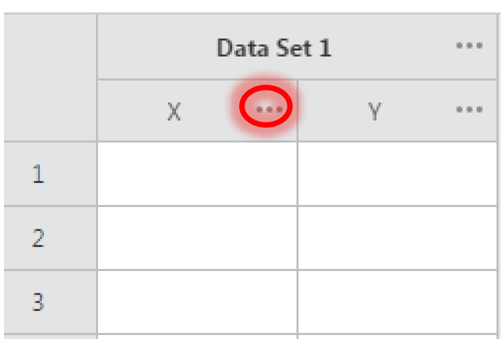
1. Enter the X data into the table; only the numbers, not the units.



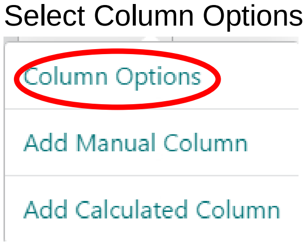
2. Enter the Y data into the table; only the numbers, not the units.



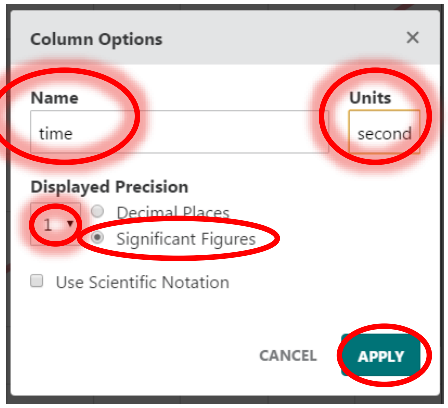
3. Click on the three dots next to X.



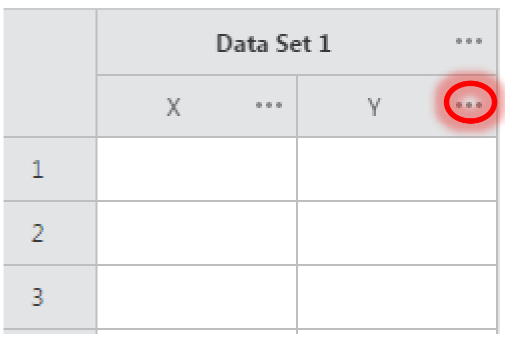
4. Select Column Options

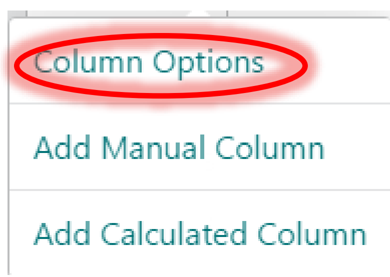


5. Type the name of the x axis (independent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



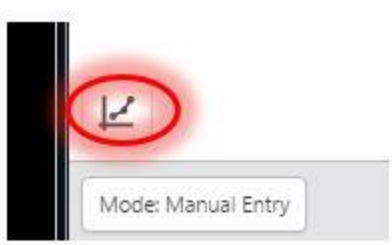
6. Repeat steps 3 – 5 for the Y axis. Click on the three dots next to Y. Select Column Options



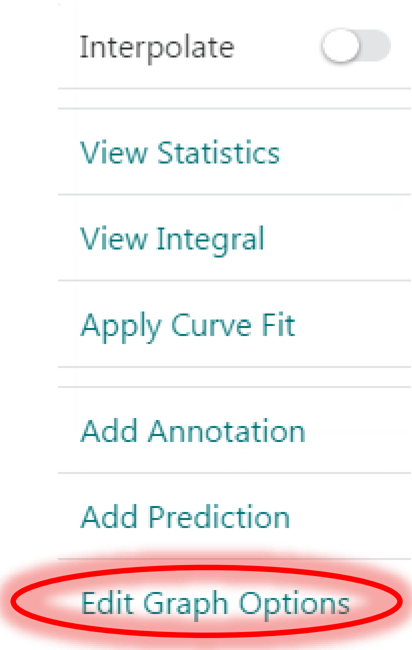


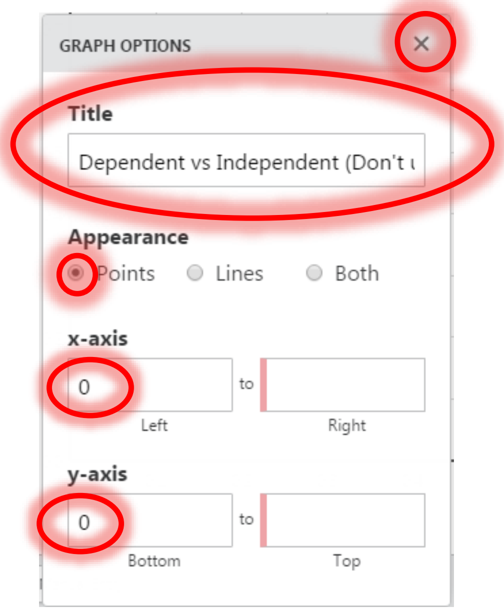
See step 5 for image. Type the name of the y axis (dependent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

7. Click on the graph icon in the lower left of the screen.



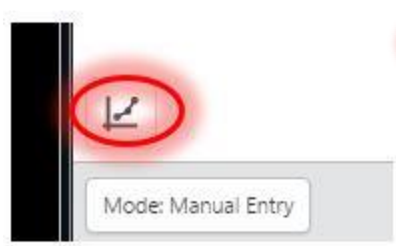
8. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to points. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.

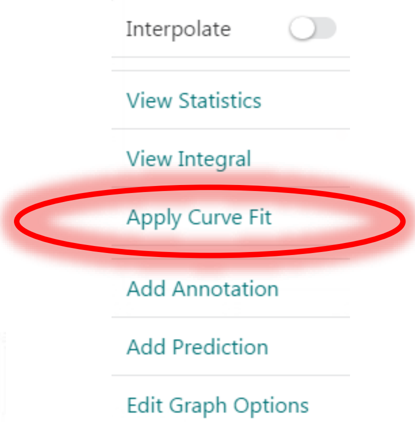




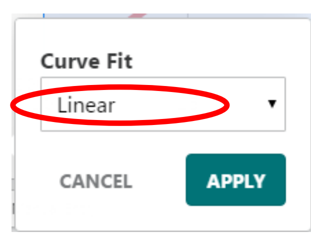
Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to insure that your graph starts with 0. 0 in the lower left corner.

9. Click on the graph icon in the lower left of the screen. Select Apply Curve Fit.



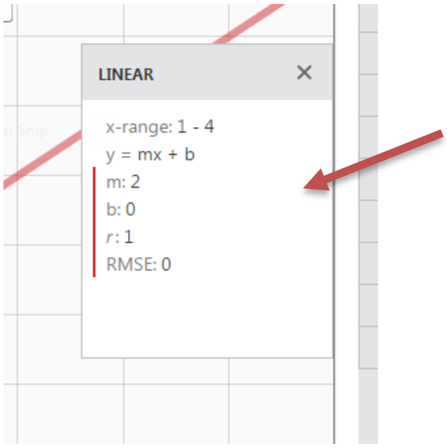


10. For the graphs select Linear Fit as shown below.



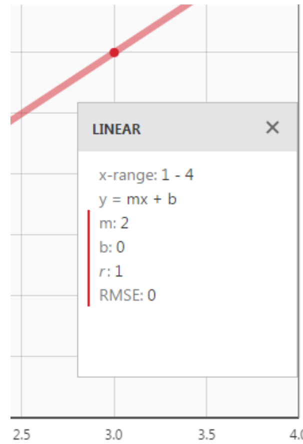
11. Uncover your best fit line or curve.

BEFORE



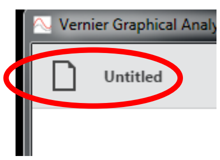
Notice the box that opens with your best fit line. If it is covering your best fit line move it so that it is not covering anything important.

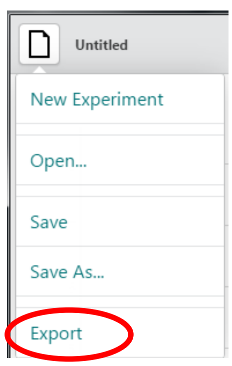
AFTER

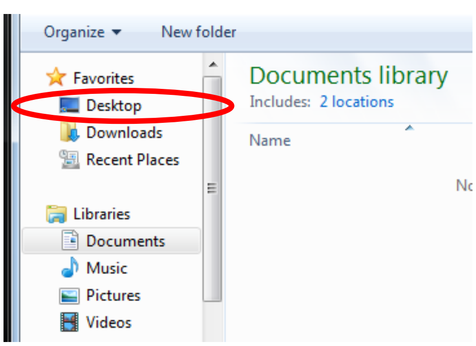


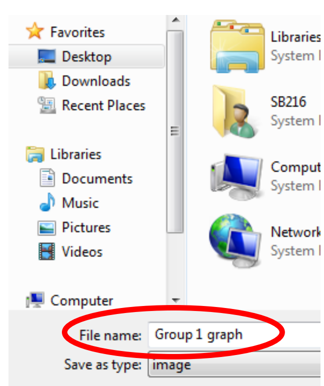
12. **Save** AND **Print** your graph(s).

Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> Graph A. B. or C. Print.









• 06 •
E N E R G Y

			Report Name (ie. 019912)
			06
			06
			06
Name	Section #	Kit #	Topic #

Part A - Energy Conversions

How can one form of energy be converted to another form of energy?

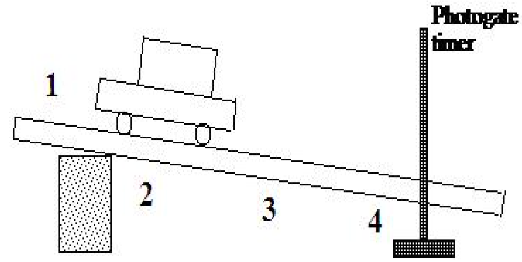
In the chart write the name of a device that converts the form of energy listed along the left of the chart to the form of energy listed along the top of the chart. For example: the conversion of light energy to mechanical occurs using a device called the Radiometer.

	Light	Mechanical	Heat	Sound	Electrical	Chemical
Light		Radiometer				
Mechanical						
Heat						
Sound			HIFU High Intensity Focused Ultrasound			
Electrical						
Chemical						

1. Describe all steps in an energy chain beginning with the sun and ending with a light bulb. _____

Part B - Energy Conversions Quantitatively

In this experiment you will compare the gravitational potential energy stored in the truck to the kinetic energy that the truck has at various heights.



Set up the inclined track as indicated. Measure the height of the truck above the table at positions 1, 2, 3, and 4. Be consistent by always measuring the vertical distance from the table to the same point on the truck for each position. Use a piece of tape to keep track of each position. (Do not place position 1 at very top of ramp!)

Truck Mass _________(kg) **PE = mass x 9.8 x height**

	Position 1	Position 2	Position 3	Position 4
Height (m)				
Potential Energy (J)				

Place the truck at the top of the ramp and release it from rest. The truck is released from this position for all 4 trials. Use the photogate timer (Gate Mode) to time the truck as it passes through the photogate at each position. Make sure it reads zero before each measurement. Repeat the time measurement 3 times for each position and then average these times to calculate the speed, v, of the truck at positions 2, 3, and 4. Calculate the kinetic energy for each position, and the total energy using the Potential energy from the table above and add it to the kinetic energy from the table below.

Remember: v = d / t, where **d = width of the flag** and t = avg. time. Total E = PE + KE d= _____________m
KE = ½ x mass x v^2 NOTE: Look for pattern in the times. If broken retake measurement.)

	Position 1	Position 2	Position 3	Position 4
Time 1 (seconds)				
Time 2 (seconds)				
Time 3 (seconds)				
Average time (s)				
Speed (m/s)				
Kinetic Energy (J)				
Total Energy (J)				

1. Make 3 separate graphs. (Note: the following are all Y vs X.)
   a. Graph Kinetic Energy vs. Potential Energy.
   b. Graph speed vs. Potential Energy.
   c. Graph Total Energy vs. Potential Energy.

Your answers to the following questions are based on your graphs.

2. When the potential energy is large, the kinetic energy is
   a. also large
   b. small
   c. about the same

3. The relationship between kinetic and potential energy is
   a. a straight line sloping down
   b. a curve that is concave up
   c. a curve that is concave down.
   d. a horizontal straight line
   e. a straight line sloping up

What does this mean? ____

4. When the potential energy is large. the speed is
   a. also large
   b. small
   c. about the same

5.The relationship between potential energy and speed is
   a. a straight line sloping down
   b. a curve that is concave up
   c. a curve that is concave down.
   d. a horizontal straight line
   e. a straight line sloping up

   What does this mean? ____

6. When the potential energy is large the total energy
   a.is also large   b.is small   c. stays about the same

7. The relationship between potential and total energy is
   a. a straight line sloping down
   b. a curve that is concave up
   c. a curve that is concave.
   d. a horizontal straight line
   e. a straight line sloping up

   What does this mean? ____

8. Is total mechanical energy conserved? (Does the total energy stay about the same for all 4 positions)? Explain your answer.

9. How much work was done between positions 1 and 4? (W = F x d) Hook the force meter onto the truck and hold it parallel to the inclined plane. Measure the distance, along the inclined plane between positions 1 and 4.

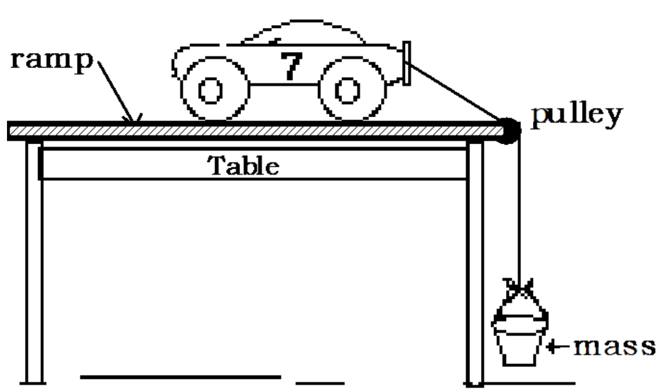
   W = __________N x __________m = _________ Joules

10. Calculate the Percent Error between the Work and ΔKE Energy. ____________

$$\%Error = \frac{|\Delta KE - W|}{AverageTotalEnergy} x100\%$$ where $\Delta KE = KE_4 - KE_1$.

Determine the horsepower of a small battery powered car

Determine the horsepower of a small battery powered car as it lifts a load (force = weight) through a timed distance. Use photogates in **Pulse Mode**. Set-up the equipment on the table top as indicated in the above figure. If the wheels spin you will need to wash them with soapy water and possibly even the tabletop to get the best traction.



To determine *work* done by the car measure the distance, in meters, that your car pulls the load and multiply it by the force of the load being lifted. W = F x d. Convert the Power in Watts to Horsepower.

Force (weight of load) F = m x g			Work W = F x d		Power Power = Work / time		Horsepower 1 Hp = 746 Watts
m. (kg)	g (m/s^2)	F (Newton)	d (meters)	W (Joules)	t (seconds)	P (watts)	Hp
	9.8						

Part C – Simple Machines revisited

Pre-lab Preparation: Copy your data from Forces & Simple Machines Lab into the tables below. Then complete the calculations for W_I, W_O, and % E. Answer all questions that follow the tables. This section should be completed at home prior to attending the Energy Lab.

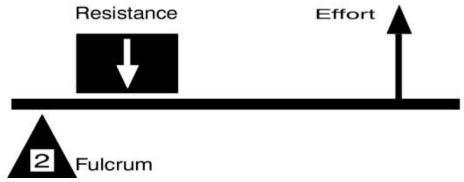
Lever

Section 1: 1st Class Levers

	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement	0.100	0.100	0.100
b. Resistance Distance D_R			
c. Effort Placement	0.050	0.100	0.050
d. Effort Distance D_E	0.010	0.020	0.020
2. Force (Newton's) a. Resistance R			
b. Effort E			
3. Work Input (Joules) $W_I = E \times D_E$			
4. Work Output (Joules) $W_o = R \times D_R$			
5. % EFFICIENCY $\%E = (W_O / W_I) \times 100$			

Average % Efficiency of First Class Levers = _____

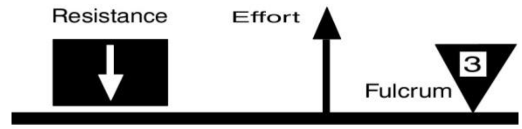
Is this answer realistic? Explain.



2^{nd} Class Levers

	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement	0.050	0.050	0.050
b. Resistance Distance D_R			
c. Effort Placement	0.100	0.150	0.150
d. Effort Distance D_E	0.020	0.030	0.030
2. Force (Newton's) a. Resistance R			
b. Effort E			
3. Work Input (Joules) $W_I = E \times D_E$			
4. Work Output (Joules) $W_O = R \times D_R$			
5. % EFFICIENCY $\%E = (W_O / W_I) \times 100$			

Average % Efficiency of Second Class Levers = _____
Is this answer realistic? Explain.



3rd Class Levers

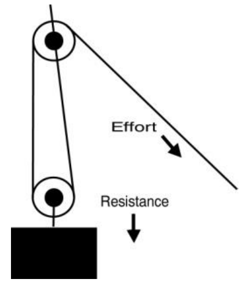
	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement	0.200	0.200	0.200
b. Resistance Distance D_R			
c. Effort Placement	0.050	0.100	0.100
d. Effort Distance D_E	0.010	0.020	0.020
2. Force (Newton's) a. Resistance R			
b. Effort E			
3. Work Input (Joules) $W_I = E \times D_E$			
4. Work Output (Joules) $W_O = R \times D_R$			
5. % EFFICIENCY $\%E = (W_O / W_I) \times 100$			

Average % Efficiency of Third Class Levers = _____

Average % Efficiency for All Levers = _____

Are these answers realistic? Explain.

1. Describe the relationship of force and distance for work input and work output. $E \times D_E = R \times D_R$ _____
2. Why are W_O and W_I are not the same for levers. _____
3. How could an efficiency of greater than 100% be obtained? In reality is it possible? _____
4. How does the mechanical advantage compare to the change in effort? _____
5. Could the placement distances of the effort and the resistance be used to estimate the work input and work output? _____



Pulley

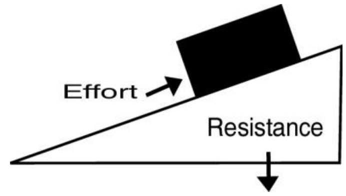
	Section 1 One Pulley	Section 2 Two Pulleys	Section 3 Three Pulleys	Section 4 Four Pulleys
1. Distance (meters) a. Resistance Distance D_R	0.100	0.100	0.100	0.100
b. Effort Distance D_E	0.1012	0.1991	0.3102	0.3893
2. Force (Newton's) a. Resistance R				
b. Effort E				
3. Work Input (Joules) $W_I = E \times D_E$				
4. Work Output (Joules) $W_O = R \times D_R$				
5. % EFFICIENCY $\%E = (W_O / W_I) \times 100$				

Average % Efficiency for All Pulleys = _____

Is this answer realistic? Explain.

1. Describe the relationship of force and distance for work input and work output. $E \times D_E = R \times D_R$ _____
2. Explain why W_O and W_I not the same for pulleys. _____
3. How could one obtain an efficiency of greater than 100%. _____
4. How does the mechanical advantage compare to the change in effort? _____

Inclined Plane



	Trial 1	Trial 2	Trial 3
Support Rod Placement	1	3	5
1. Distance (meters) a. Resistance Distance D_R			
b. Effort Placement (notch on inclined plane)	2	2	2
b. Effort Distance D_E			
2. Force (Newton's) a. Resistance R			
b. Effort E			
3. Work Input (Joules) $W_I = E \times D_E$			
4. Work Output (Joules) $W_O = R \times D_R$			
5. % EFFICIENCY $\%E = (W_O / W_I) \times 100$			

Average % Efficiency for Inclined Planes = _____

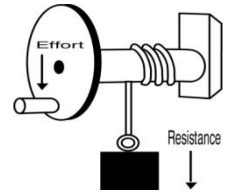
1. Describe the relationship of force and distance for work input and work output. $E \times D_E = R \times D_R$ _____

2. Explain why W_O and W_I are not the same for inclined planes. _____

3. How could one obtain an efficiency of greater than 100%? Is it possible? ______

4. How does the mechanical advantage compare to the change in effort? _____

Wheel and Axle



	Trial 1	Trial 2	Trial 3
1. Distance (meters) a. Resistance Placement (Axle)	0.045	0.045	0.045
b. Resistance Distance D_R			
c. Effort Placement (Wheel)	0.045	0.090	0.135
d. Effort Distance(1 rotation $2\pi r$) D_E	0.283	0.565	0.848
2. Force (Newton's) a. Resistance R			
b. Effort E			
3. Work Input (Joules) $W_I = E \times D_E$			
4. Work Output (Joules) $W_O = R \times D_R$			
5. % EFFICIENCY $\%E = (W_O / W_I) \times 100$			

Average % Efficiency for Wheel and Axle = _____

1. Describe the relationship of force and distance for work input and work output. $E \times D_E = R \times D_R$ _____

2. Explain why W_O and W_I are not the same for wheel and axles. _____

3. How could one obtain an efficiency greater than 100%? Is it possible? _____

4. How does the mechanical advantage compare to the change in effort? _____

5. Compare the efficiencies of all the machines studied. _____

6. Which simple machine would you use to move your refrigerator? __________________
   Describe how you would move your refrigerator onto your truck. _____

E N E R G Y

Self Evaluation

Test 061

Directions: Select the best answer.

1. 06.1 What quantity described the amount of matter contained in an object?
   A. gravitational force
   B. mass
   C. weight
   D. friction
   E. power

2. 06.1 A unit of energy representing 1 Newton-meter is?
   A. potential
   B. kinetic
   C. lumen
   D. watt
   E. joule

3. 06.2 A burning match would produce which of the following form(s) of energy (you may select more than one.
   A. Heat
   B. nuclear
   C. electrical
   D. mechanical
   E. light

4. 06.2 The gasoline in the tank of your car contains energy (used to move the car, in which of the following form(s).
   A. chemical
   B. nuclear
   C. electrical
   D. mechanical
   E. light

5. 06.3 "Energy is neither created nor destroyed" is the:
   A. First Law of Energy
   B. Second Law of Energy
   C. First and Second Law of Energy
   D. Neither law applies

6. 06.3 A piece of coal has 1000 Joules of chemical energy but when burned only 200 Joules could be converted to mechanical energy. The remaining 800 Joules were converted to heat. Identify which law applies.
   A. First Law of Energy
   B. Second Law of Energy
   C. First and Second Law of Energy
   D. Neither law applies

7. 06.4 Which of the following would allow heat to be converted to Kinetic Energy?
   A. solar calculator
   B. toaster
   C. hair dryer
   D. photosynthesis
   E. automobile

8. 06.4 Which of the following would allow light to be converted to electricity?
A. radio
B. toaster
C. hair dryer
D. solar calculator
E. automobile

9. 06.5 Which of the following has the most energy?
A. A 1 pound weight suspended at a height of 975 meters
B. A 975 pound weight suspended at a height of 1 meters
C. An object experiencing a force of 425 N is suspended at a height of 10 meters
D. An object experiencing a force of 22500 N suspended at a height of .2 meters
E. All of the above have the same amount of energy

10. 06.5 What is the amount of kinetic energy in a 22 Kg object moving at a velocity of 20 m/s?
A. 42 Joules
B. 440 Joules
C. 1.1 Joules
D. 2.200 Joules
E. 4.400 Joules

11. 06.6 How much work have you done to move a object with a force of 75 N through a distance of 250 cm?
A. 0.3 Joules
B. 187.5 Joules
C. 3.3 Joules
D. 325 Joules
E. 18.750 Joules

12. 06.6 How much work will be done walking up a flight of stairs 2.7 meters high assuming you weigh 145 pounds?
A. 172 Joules
B. 391.5 Joules
C. 1.761.75 Joules
D. 12.1 Joules
E. 0.04 Joules

13. 06.7 What is the horsepower of a car that is experiencing a force of 1.600 pounds and is moving 100 meters in 7 seconds?
A. 137.9 Hp
B. 1.120.000 Hp
C. 1.707 Hp
D. 22.9 Hp
E. 2.4 Hp

14. 06.7 Calculate the amount of power used by a person who is experiencing a force of 145 pounds and is moving 60 meters in 10 seconds.
A. 222 watts
B. 3.915 watts
C. 215 watts
D. 87.000 watts
E. 121 watts

15. 06.7 Determine the work output of a simple machine. The resistance is 5.4 Newton and the resistance distance is 0.05 meters.

A. 0.27 Joules
B. 0.54 Joules
C. 0.81 Joules
D. 1.08 Joules
E. 0.50 Joules

16. 06.7 What is the work output (Wo) of a simple machine if the resistance is 5.4 Newton and the resistance distance is 0.20 meters?

A. 6.9 Joules
B. 3.4 Joules
C. 2.5 Joules
D. 10.8 Joules
E. 1.08 Joules

17. 06.8 Determine the work input of a simple machine. The effort distance is 0.045 meters and the actual effort is 5.4 Newtons.

A. 0.24 Joules
B. 0.29 Joules
C. 0.32 Joules
D. 0.36 Joules
E. 0.43 Joules

18. 06.8 If the work input is 1.10 Joules and the effort distance is .20 meters. determine the actual effort.

A. 2.9 Newtons
B. 2.8 Newtons
C. 11.0 Newtons
D. 5.5 Newtons
E. 5.2 Newtons

19. 06.10 If the work output is 0.54 Joules and the work input is 0.55 Joules. what is the percent of efficiency of a simple machine?

A. 105%
B. 108%
C. 104%
D. 103.8%
E. 98.2%

20. 06.10 Determine the percent of efficiency of a simple machine whose work input is 1.08 Joules and the work output is also1.08 Joules.

A. 96.4%
B. 93.1%
C. 104%
D. 100%
E. 98.2%

H E A T

Topic 07

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct term.

   calorie, calorimeter, Celsius, conduction, Conservation of Energy, convection, equilibrium, Fahrenheit, heat, Kelvin, mass, radiation, specific heat capacity, temperature, thermal expansion, thermal heat transfer

2. Calculate the amount of Heat energy given the formula, $\Delta H = m \times \Delta T \times c$, where m = mass. the ΔT = temperature change, and c = specific heat capacity of a substance.

3. Calculate the Specific Heat Capacity given the formula $c = H / (m \times \Delta T)$.

4. Given the formula for Thermal Expansion: $\Delta L = \partial \times L \times \Delta T$, calculate the thermal expansion of a substance.

5. Given the formula for Thermal Heat Transfer: $H = (k \times \Delta T \times A \times \Delta t) / d$, calculate the thermal heart transfer, and be able to explain it.

INTRODUCTION

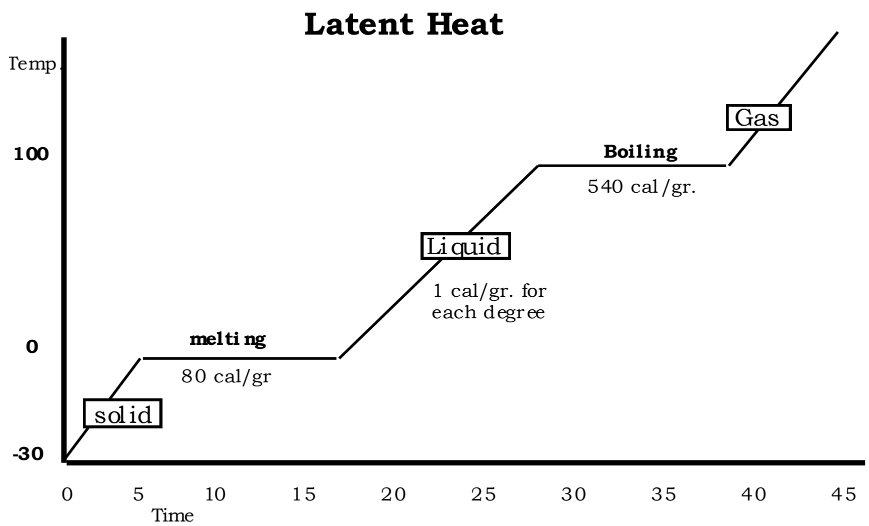
Characteristics of Heat

Every body of matter, whether solid, liquid or gas, consists of atoms or molecules which are in constant motion. Their motion gives every object internal kinetic energy. The level of internal kinetic energy in an object depends on how rapidly its atoms or molecules move. Heat is a form of energy, which, when added to a body of matter, increases its internal kinetic energy content, and causes its temperature to rise. Temperature is an indication of an object's internal kinetic energy level.

It is important to recognize that temperature and heat are not the same thing. Temperature is simply an indication of the level of internal kinetic energy found in objects. Heat is the transfer of energy from one object to another, as a result of temperature differences. As heat raises the internal kinetic energy of an object, its atoms or molecules move faster. As more heat is added to an object, the motion of its atoms becomes even more disorderly. The addition of heat to an object will always increase its internal kinetic energy. Usually, the heat added also raises the temperature of the object. Heat radiating out of an object will always decrease the internal kinetic energy of that object. The heat loss also usually lowers the temperature of the object.

Latent Heat

When heat is continuously added to a solid, it grows hotter and hotter, and finally begins to melt. While it is melting, the material remains at the same temperature, and the absorbed heat goes into changing the state of the substance from a solid to a liquid. After all of the solid has melted, the temperature of the resulting liquid then increases as more heat is supplied, until it begins to boil. Now the material again stays at a constant temperature until all of it has become a gas, after which the temperature of the gas rises. This is explained by realizing that under certain circumstances, the addition of heat causes no increase in temperature. Instead, the disorder of the atoms in the object increases, causing the material to change states. The heat needed to change a material from a solid to a liquid to a gas is called latent heat. For water, the heat required to change one gram of ice into water is 80 cal/g, and 540 cal/g additional heat is needed to change water into water vapor.



Calories per gram needed for change in State

The standard unit for measuring heat transfer is the calorie. For our purposes, we can generalize this definition by simply saying that a calorie is the amount of energy required to raise the temperature of one gram of water one degree Celsius. You may be familiar with the calories used to indicate the energy content of food. One food calorie is equal to 1 kilocalorie and is designated with a capital C.

The Law of Conservation of Energy:

When two systems or objects of different temperatures come into contact, energy (in the form of heat) is transferred from the warmer system into the cooler one. This transfer of heat raises the temperature of the cooler system, and lowers the temperature of the warmer system (provided that no changes of states of matter occur in either system). Eventually, the two systems reach a common, intermediate temperature, and the heat transfer stops. This transfer of heat from the warmer (warm front) to the cooler (cold front) can be related to the weather. Warm and cold air masses are always trying to bring one another into equilibrium, and this struggle causes wind. At present, there are three commonly used scales available to measure temperature: Kelvin (or absolute), Centigrade (or Celsius), and Fahrenheit. We will use the Celsius scale for our measurements of temperature.

Heat Measurement:

Heat is different than temperature. Temperature measures the random motion of the molecules of the material being measured by the thermometer. Heat describes the relationship among mass, temperature change, and the specific heat of the substance. Heat is measured in calories and is determined by multiplying the mass by the change in temperature by the specific heat of the material. **The Unit of heat energy is the calorie**.

Heat Energy Problem:

Let us determine the amount of heat energy transferred to or from a sample. Let us assume the mass (m), is 60 grams, the temperature of the sample changes from 20^{o} C to 220^{o} C. (that is: ΔT = 200^{o} C), and the specific heat capacity is 0.01 cal/g ^{o}C. To determine the number of calories of heat energy:

$\Delta H = m \times \Delta T \times c$

Where

ΔH = heat energy

m = mass of the sample.

ΔT = change in temperature of the specimen.

c = the specific heat capacity of the material.

In this problem

m = 60 g

ΔT = 200^{o} C

c = 0.01 cal/g ^{o}C.

Then

$\Delta H = m \times \Delta T \times c$

ΔH = 60g x 200 ^{o}C x .01 cal/g ^{o}C

ΔH = 120 calories.

In the laboratory, you will combine hot and cold water of known temperatures and masses. You will determine the amount of energy transferred from the hot water to the cold water once they are mixed. As indicated in the Law of Conservation of Energy whether heat energy was conserved will be determined by analyzing the results of the experiment.

Specific Heat Capacity

So far, we have looked at two closely related ideas, heat and temperature. Let's look at things *thermally* for a while longer, and take a trip around the world. We will take our time, and explore the planet's surface, interior, seas, rivers, and oceans. Let us say that the objective of the trip is to collect as many different samples of objects (solids, liquids and gases) as possible, so that we can bring them home to analyze them from a *thermal* point of view. At home, a simple thermal analysis would consist of taking the sample, heating it by giving it so many calories of heat (which we will call H), and observing its change in temperature. This change we will call ΔT (remember Δ means change in), one way to determine how the various samples are thermally different is by obtaining the ratio of heat to temperature change, H/ΔT. This ratio will be different for the different samples, thus distinguishing the samples from one another.

This ratio does not take into account the mass of the sample (a real goof-up). To correct this, we simply divide the ratio H /ΔT by the mass, (m), or H/ (m x ΔT). Such a ratio is a measure of the specific thermal characteristics of a sample, and it is assigned the symbol (c). and given the name Specific Heat Capacity,

$c = \Delta H / (m \times \Delta T)$

The unit for specific heat capacity is (calories/gram ^{o}C).

Specific Heat Capacity Problem:

Let us take one of the various samples and run a test: assume the mass, is 60 grams, and that by heating it in the oven with 120 calories of heat, the temperature of the sample changes from 20^{o} C to 220^{o} C. (that is: ΔT = = $T_f - T_i$ = 200^{o} C). To determine the specific heat capacity which is the amount of heat energy stored per gram for each 1^{o}C change in the formula:

$c = H / (m \times \Delta T)$

Where H = heat energy.

m = mass of the sample.

ΔT = change in temperature of the specimen.

In this problem

H = 120 cal

m = 60 g

ΔT = 200^{o} C.

Then

$c = H / (m \times \Delta T)$

c = 120 cal / (60g x 200^{o} C)

c = 0.01 cal/g ^{o}C.

You will be asked to measure the specific heat capacity of several samples using the expression c = H / (m x ΔT), which can also be expressed as H = m x c x ΔT. This can also be interpreted as the heat (H), injected into an object of mass (m), Specific heat (c) can be determined by multiplying the mass (m), by the specific heat (c), and then by the change in temperature (ΔT), which resulted from putting that much heat (H) into the object.

Thermal Expansion:

All gases (and most liquids and solids), expand when heated. But they do not expand equally. If a gas, liquid, and solid receive enough heat to raise their temperatures the same amount, the gas will expand the most, the liquid much less, and the solid the least.

Thermometers, thermostats. and many other devices work on this principle of expansion and contraction. Many thermometers contain a liquid (such as alcohol or mercury), which expands and contracts evenly as the temperature changes.

The expansion and contraction of the materials in bridges, buildings, and other structures can cause serious problems unless builders allow for this. For example, the steel beams in a building will bend or break if they do not have enough room to expand. For this reason, structures have expansion joints. Expansion joints provide space for the expansion and contraction of building materials as the temperature changes. without damaging the structure itself. Engineers can determine how much the length of any material will be increased by a rise in temperature. if they know the coefficient of linear expansion of the material. The coefficient of linear expansion indicates how much longer each meter of a material will become if its temperature is increased by one degree.

Thermal Expansion Problem:

Workers place steel railroad rails exactly end-to-end for a distance of 10 kilometers on a day when the temperature is 5^{o} C. How much will the railroad track expand on a day when the temperature reaches 35^{o} C?

$\mathbf{\Delta L = \partial \times L \times \Delta T}$

Where
- ΔL = change in length as a result of temperature change
- ∂ = coefficient of linear expansion of the given material
- L = length of the given material
- ΔT = temperature change of the given material in this problem.

In this problem
- ∂ = 0.000011 cm/cm ^{o}C
- L = 10 km x 1000 m/1 km x 100 cm/ 1 m = 1.000.000 cm
- ΔT = 35^{o} C - 5^{o} C = 30^{o} C.

Then

$\Delta L = \partial \times L \times \Delta T$

ΔL = 0.000011 cm/cm^{o}C x 1.000.000 cm x 30^{o} C = 330 cm.

If you observed the rails you would note that the workers leave a small gap between the rails to allow for expansion or contraction of the steel due to temperature changes.

Thermal Conductivity:

Heat is transferred by three methods: (1) conduction, (2) convection, and (3) radiation.

Conduction is the movement of heat through a material. When heat travels by conduction, it moves through a material without carrying any of the material with it. For example, the end of a copper rod placed in a fire quickly becomes hot; the atoms in the hot end begin to vibrate faster, causing adjoining atoms to vibrate faster. In this way. the heat travels from atom to atom until it reaches the other end of the rod.

Convection is the transfer of heat by the movement of the heated material. For example, when a hot stove heats the air around it by conduction, this heated air expands, and thus becomes lighter than the colder air surrounding it. The heated air rises, and cooler air replaces it. This movement of heated air away from a hot object, and the flow of cooler air toward that object, is called convection current.

Infrared radiation is the transfer of heat energy through empty space. In any object, the moving atoms or molecules create waves of radiant energy. These waves are also called infrared rays. Hot objects give off more infrared rays than colder objects. When radiant energy strikes an object, it speeds up the atoms or molecules in that object. Most of the energy from the sun travels through space to the Earth by this means.

Insulation is a way to control the movement of heat by keeping it in or out of a place. People commonly use three methods of insulation because heat can travel in the three different ways discussed. Certain materials, such as plastic and wood, make good insulators against the movement of heat by conduction. The movement of heat through the air by convection can be controlled by blocking the space between hot and cold areas. Surfaces that reflect infrared rays can insulate against heat traveling by radiation.

Thermal Conductivity Problem:

A thermostat in a house keeps the inside temperature of a room at 23^{o} C. The temperature outside the house is 0^{o} C. How much energy is lost (by conduction) through a glass window in 60 seconds if the glass window is 0.5 cm. thick. and measures 100 cm. high by 200 cm. wide?

$$\Delta H = (k \times \Delta T \times A \times \Delta t) / d$$

Where

ΔH= total heat loss by conduction through the given object

k= thermal conductivity of the material

ΔT= temperature difference between the hot and cold sides of the material

A= area of the material through which heat conduction occurs

Δt= time for which heat conduction is considered

d= thickness of material through which heat conduction occurs.

In this problem

k= 0.0020 cal/sec cm ^{o}C

ΔT= 23^{o}C - 0^{o} C = 23^{o} C

A= 100 cm x 200 cm = 20.000 cm^2

Δt= 60 s

d= 0.5 cm.

Then

ΔH= (k x ΔT x A x Δt) / d

ΔH= (0.0020 cal/s cm ^{o}C x 23^{o} C x 20.000 cm^2 x 60 s) / (0.5 cm)

ΔH= 110.400 calories.

By comparison, it takes about 18.217 calories to heat an 8 oz cup of water from room temperature to boiling. In other words, our example window is losing enough energy to heat approximately six 8 oz cups of water to the boiling point every minute.

Table 1. Thermal Properties of Selected Materials:

Substance	Specific Heat Capacity c		Thermal Expansion δ	Thermal conductivity k
	cal/g ^oC	J/g K	cm/cm ^oC	cal/sec cm ^oC
Aluminum	0.220	0.921	0.000026	0.4900
Brass	0.087	0.364	0.000019	0.2600
Copper	0.091	0.381	0.000017	0.9200
Glass	0.160	0.669	0.000009	0.0020
Iron	0.110	0.461	0.000011	0.2000
Steel			0.000011	
Lead	0.030	0.126	0.000029	0.0830
Water	1.000	4.187	0.001430	0.0014
Ice	0.500	2.094	0.001326	0.0040
Wood	0.420	1.759	0.000400	0.0002
Sand	0.200	0.837		

Virtual Laboratory

Topic 07 – Heat

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Show your work. (Show how you arrived at your answer.)

1. Determine the heat energy needed to raise 175 grams of **water** from a temperature of 22^{O}C to the boiling point.

2. Determine the heat energy needed to raise a 105 grams of **aluminum** from a temperature of 15^{O}C to 38^{O}C.

3. Calculate the specific heat of an unknown substance, and identify that substance using the chart provided in your textbook. The mass of the substance is 500 g. It undergoes a 100^{o}C change in temperature when 11.000 calories of heat are added.

4. Calculate the specific heat of an unknown substance. The mass of the substance is 310 g. Its temperature changes from 20^{o}C to 80^{o}C, when 2976 calories of heat are added.

5. Calculate the thermal expansion of a 425 m **glass** rod when its temperature changes from 5^{O}C to 50^{O}C.

6. Calculate the thermal expansion of a 100 m **brass** rod when its temperature changes from 5^{O}C to 90^{O}C.

7. Calculate the amount of heat transfer for a 6.00 cm thick **wood** wall when its temperature changes from 25 ^{O}C to 50 ^{O}C in 60 seconds. The area of the wall is 5000 cm^2.

8. Calculate the amount of heat transfer for a 6.00 cm thick **copper** wall when its temperature changes from 50 ^{O}C to 25 ^{O}C in 60 seconds. The length of the wall is 90 cm and its width is 40 cm.

Hands-on Laboratory

Topic 07 – Heat

MATERIALS

Celsius thermometer	aluminum sample
sample holder	lead sample
Calorimeters (Styrofoam cup)	copper sample
2 Styrofoam cups	thread
800 ml beaker (refill hot water supply)	
Metric scale (grams)	hot plate or stove
Ring stand or double boiler	hot and cold water
800 ml beaker (for source of hot water)	

PROCEDURE

Remember to apply the Measurement Rule!

Part A - Conservation of Energy

There are three trials listed in the data table at the end of these instructions. Each trial uses different amounts of hot and cold water. Your instructor will tell you which trial(s) your class will conduct. Identify the trial your instructor has assigned by circling one or more of the following:

Trial 1. Trial 2. or Trial 3.

Pre-Lab Prep: State the Law of Conservation of Energy:

____

Pre-Lab Prep: Identify the research question. (Make sure to identify the mass of the water that is gaining the heat and the mass of the water that is losing the heat.)

____

Pre-Lab Prep: Write your hypothesis (don't forget to include the prediction about what will gain heat and what will lose heat).

____

1. Obtain two Styrofoam cups. One Styrofoam cup will be the Hot water supply cup. and the other cup will be the Cold water supply cup.
2. Obtain hot water with a temperature greater than 85^{o} C.
3. Obtain cold water with a temperature less than 10^{o} C
4. Place a Styrofoam cup on the gram scale and obtain its mass. Add cold water until the scale reads approximately 150-grams and record its actual mass (cup and water). Subtract the mass of the cup from the mass of the cup + water in the data table, to obtain the mass of the water alone.

   Remove the cup of water from the scale and place a thermometer in the water. Make sure there is NO ice in the cup.

5. Place another Styrofoam cup on the gram scale and obtain the mass of the cup. Add hot water until the scale reads approximately 150-grams and record the actual mass (cup and water). Subtract the mass of the cup from the mass of the cup + water in the data table, to obtain the mass of the water alone. Remove the cup of water from the scale and place a thermometer in the water.

6. Next we must to do two things as quickly as possible.
    - First read and record the temperatures of the hot and cold water. Record the temperature of the cold water as $\mathbf{T}_{cold}$ and the temperature of the hot water as $\mathbf{T}_{hot}$.
    - Now mix the hot and cold water together in one cup.
7. Stir the mixed hot and cold water with the thermometer until the temperature stabilizes. Measure the final temperature of the mixture and record it as $\mathbf{T}_{final}$.
8. From your data determine the temperature change of the cold water and the temperature change of the hot water and record. (Note: The symbol Δ means change in. This means Δ T is change in temperature. You will determine the change in temperature of the water that was initially cold after it is mixed with the hot water. Then you will calculate the change in temperature of the water that was originally hot after the cold water is mixed with it.)

$$\Delta\mathbf{T}_{cold} = \mathbf{T}_{final} - \mathbf{T}_{cold}$$

$$\Delta\mathbf{T}_{hot} = \mathbf{T}_{hot} - \mathbf{T}_{final}$$

9. Calculate the heat gained by the cold water and the heat lost by the hot water and record your results.
   Calculate heat, as measured in calories, using this formula:

   $\Delta H = M \times \Delta\mathbf{T} \times c$ (Note: c is the specific heat of water, which is 1.00cal/g ^{o}C)

   In our experiment we would use the following:

   Heat Gain of the cold water: $\Delta H = (\mathbf{M}_{cold\ water}) \times (\Delta\mathbf{T}_{cold}) \times c$

   Heat Loss of the hot water: $\Delta H = (\mathbf{M}_{hot\ water}) \times (\Delta\mathbf{T}_{hot}) \times c$

   (Note: we are using the mass, (M), of the water before mixing)

10. To provide an indication of the quality of our work we can calculate the percent of error:
    a. Obtain the theoretical value by calculating the average between heat loss and heat gain. This assumes that the true value of theoretical lies somewhere between heat loss and heat gain.
    b. Select either heat loss or heat gained as your experimental value.
    c. Calculate the error and percent error for this trial and determine if heat gain is equal to the heat loss. A percent error equal to ten percent or less should be viewed as an acceptable result that falls within experimental uncertainties in measurements. This means that although your heat loss or heat gained numbers are not identical to the average value; they can be treated as identical as long as they are within 10% of the average value.

Part B - Specific Heat Capacity (Your instructor may conduct this portion of the lab as a demonstration. may provide the data to the class to complete the lab, or may require you to conduct this experiment with your group. Ask your instructor what the plan is.)

There are three trials listed in the data table at the end of these instructions. Your instructor will identify which sample you are to use for this portion of the lab if you are performing the experiment. Circle one of the following as assigned by your instructor: Aluminum, lead and/or copper.

CAUTION: This experiment involves the use of boiling water, and HOT metal!

The specific heat of a substance, usually indicated by the symbol c, is the amount of heat required to raise the temperature of one gram of that substance by one Celsius degree.

1. Place approximately 1-liter of water in a container and heat it to boiling. If you are using a ring stand and hot plate. suspend the samples so that they do not touch the bottom of the container. If you are using a stove use a double boiler. (Do NOT place the wooden "Ring Stand" on the stove) Your instructor may set up this step for you.

2. Obtain a Styrofoam cup (it should be empty and dry) for use as a **calorimeter**. Measure the mass of your calorimeter and record as: M_{cup}.

3. Measure or obtain the mass of one of the following as assigned by your instructor; lead, copper, or aluminum samples, Record the mass in the table as M_{sample}.

4. Attach a thread to the metal sample and suspend the sample in boiling water. Allow a few minutes, approximately 3-4 min, for the sample to heat completely. (Multiple samples can be accomplished simultaneously.)

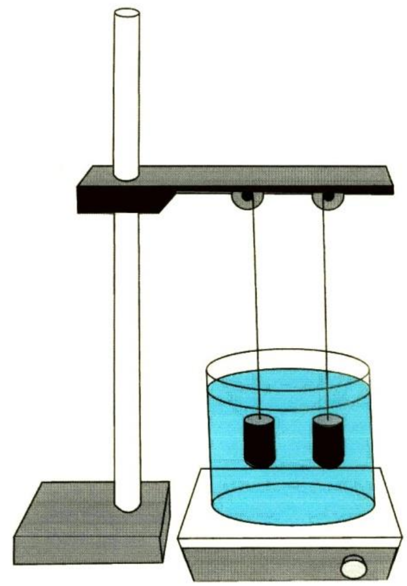
5. Fill the calorimeter with as close to 200.0-g, of cold water (less than 15ºC) as possible and record the actual mass of the water + cup. To obtain the mass of the water subtract the mass of the cup from the mass of the cup + water.

6. Measure the temperature of the hot water, T_{hot}. and record your measurement. Since the water is boiling the temperature will remain constant.

7. Measure the temperature of the cold water, T_{cold}, and record your measurement.

8. Immediately following your temperature measurement, remove the metal sample from the boiling water. and place it in the cold-water cup (calorimeter).

9. Use the thread to gently raise and lower the sample, keeping it off the bottom of the calorimeter, **but not raising it out of the water**. At the same time, stir the water with your thermometer. When the temperature remains constant for several readings record that temperature as $\mathbf{T}_{final}$.



10. For each metal sample determine:
    a. The temperature change of the water due to each metal sample (ΔT_{water})

    $$\Delta \mathbf{T}_{water} = \mathbf{T}_{final} - \mathbf{T}_{cold\ water}$$

    b. The temperature change of the metal sample due to the water (ΔT_{sample})

    $$\Delta \mathbf{T}_{sample} = \mathbf{T}_{hot\ water} - \mathbf{T}_{final}$$

11. The calculation of specific heat is based on the law of energy conservation. The law of energy conservation indicates that the heat loss of the metal sample equals the heat gain of the water;

    HEAT LOST OF THE SAMPLE = HEAT GAIN OF THE WATER (in the cup)

    $$(M_{sample}) \times (\Delta \mathbf{T}_{sample}) \times (\mathbf{c}_{sample}) = (\mathbf{M}_{water}) \times (\Delta \mathbf{T}_{water}) \times (\mathbf{c}_{water})$$

    Note: (c_{water} is the specific heat of water)

    Solving this relationship for $\mathbf{c}_{sample}$

    $$\mathbf{C}_{sample} = \mathbf{[}\ (\mathbf{M}_{water}) \times (\Delta \mathbf{T}_{water}) \times (\mathbf{c}_{water})\ \mathbf{]\ /\ (}\ (\mathbf{M}_{sample}) \times (\Delta \mathbf{T}_{sample})\ \mathbf{]}$$

12. Determine the specific heat of your sample and record it in the data table.

13. Obtain the theoretical specific heat from Table 1 and record.

14. Calculate the error and percent error.

• 07 •
H E A T

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PART A - Conservation of Energy

Lab Prep: State the Law of Conservation of Energy: ____

Lab Prep: Identify the research question, (Make sure to identify the mass of the water that is gaining the heat and the mass of the water that is losing the heat.**)** ____

Lab Prep: Write your hypothesis (don't forget to include the prediction about what will gain heat and what will lose heat**).** ____

	Trial 1 150-g. hot + 150-g. cold	Trial 2 200-g. hot + 100-g. cold	Trial 3 75-g. hot +225-g. cold
$M_{\text{cold water Cup}}$ (grams)			
$M_{\text{cold water + Cup}}$ (grams)			
$M_{\text{cold water}}$ (grams)			
$M_{\text{hot water Cup}}$ (grams)			
$M_{\text{hot water + Cup}}$ (grams)			
$M_{\text{hot water}}$ (grams)			
$T_{\text{hot water}}$ (^{o}C) (before mixing)			
$T_{\text{cold water}}$ (^{o}C) (before mixing)			
T_{Final} (^{o}C) (after mixing)			
$\Delta T_{\text{hot water}}$ (^{o}C) = $T_{\text{hot}} - T_{\text{final}}$			
$\Delta T_{\text{cold water}}$ (^{o}C) = $T_{\text{final}} - T_{\text{cold}}$			
Heat gain: (calories) $\Delta H_{\text{cold}} = M_{\text{cold water}} \times \Delta T_{\text{cold}} \times c$			
Heat loss: (calories) $\Delta H_{\text{hot}} = M_{\text{hot water}} \times \Delta T_{\text{hot}} \times c$			
Theoretical Value The theoretical value is the average of the heat gain and heat loss.			
Error			
Percent Error			
Does Heat Loss equal Heat Gain within experimental uncertainty?			

Do your results support your hypothesis? Explain your answer. ______________________________________

____

PART B - Specific Heat Capacity

	Trial 1 Aluminum	Trial 2 Lead	Trial 3 Copper
M_{cup} (grams)			
$M_{water+Cup}$ (grams)			
M_{water} (grams)			
M_{sample} (grams)			
$T_{hot\ water}$ (^{o}C) (this is also the temperature of the sample)			
$T_{cold\ water}$ (^{o}C)			
T_{final} (^{o}C) (temperature of water with sample in it)			
ΔT_{water} (^{o}C) = $T_{final} - T_{cold\ water}$			
ΔT_{sample} (^{o}C) = $T_{hot\ water} - T_{final}$			
Specific heat capacity (cal/g ^{o}C) (keep 3 decimal places) $C_{sample} = (M_{water} \times \Delta T_{water} \times c_{water}) / (M_{sample} \times \Delta T_{sample})$			
Theoretical Specific heat (from table provided in chapter)			
Error			
Percent Error			

Suppose you have three equal mass samples placed in equal amounts of water at the same temperature. Then suppose you light similar candles and place a candle under each of the masses (lead, copper and aluminum), letting the candles burn for **equal times**. Would one of the materials **change temperature more** than the other? (This is not asking about the fastest temperature change.)

If so, which one and why? (Use Table 1 in your textbook for assistance.)

____

Part C – Graphical analysis

A research question is: How does the specific heat capacity change for the chemical elements as the atomic number increases?

What does *atomic number* mean? ____

Your hypothesis is: ____

Create your hypothesis before going to the website.

Go the following website http://periodictable.com/Properties/A/SpecificHeat.html **and review the graph of Specific Heat vs. Atomic Number.** Notice that if you place your cursor on the graph a purple line will appear. You can obtain information for each atomic number by placing the purple line on the atomic number of interest. Look above the graph, to the left, for the information.

From the graph identify the following:

1. The dependent variable (include the units): _________________________________
2. The independent variable: _________________________________
3. What is the value of each tick mark on the horizontal scale: _________________________________
4. What is the value of each tick mark on the vertical scale: _____________________________________

Observe patterns in the behavior of specific heats for the chemical elements:

5. Describe what you observe for the atomic numbers 0 – 10. ____________________________________
6. Describe what you observe for atomic numbers 10-20. _______________________________________
7. Describe what you observe for atomic numbers 20-60. _______________________________________
8. Describe what you observe for atomic numbers 60-92. _______________________________________
9. What is the value of specific heat for atomic number 35 _______?
10. Name this chemical element. ________________ 11. What is the chemical symbol? ___________

12 . What is the value of specific heat for the atomic number 53 _______?

13. Name this chemical element. ________________ 14. What is the chemical symbol? ___________

15. Develop a *general* statement concerning the specific heat values for the chemical elements. Does it agree with your hypothesis?

H E A T

Self-Evaluation

Test 071

Directions: Select the best answer.

1. 07.1 A law that describes the relationship between heat gained and the heat lost in a thermal reaction:
   A. the law of definite thermal proportions
   B. the thermal heat law
   C. The law of conservation of energy
   D. the law of specific heat
   E. the first heat law

2. 07.1 When heat moves through a material by passing the energy from atom to atom it is called?
   A. conduction
   B. insulation
   C. radiation
   D. convection
   E. temperature

3. 07.2 Determine the number of calories needed to raise 10 grams of water from a temperature of 10^{o}C to boiling: Note: You may need to reference Table 1.
   A. 1500 calories
   B. 3500 calories
   C. 1000 calories
   D. 20 calories
   E. 900 calories

4. 07.2 Determine the heat energy needed to raise 100 grams of lead from a temperature of 30^{o}C to 100^{o}C. Note: You may need to reference Table 1.
   A. 1200 calories
   B. 6.9 calories
   C. 230 calories
   D. 210 calories
   E. 77 calories

5. 07.3 Calculate the specific heat capacity of a 625 gram unknown substance if it undergoes a 105^{o}C change in temperature when 13.125 calories of energy are added. Identify that substance. using the chart provided:
   A. Iron
   B. Brass
   C. sand
   D. Wood
   E. Glass

6. 07.3 Calculate the specific heat capacity of an unknown substance, and identify that substance using the chart provided

where: Mass = 100 g.
Change in temperature = 60^{o}C.
Heat = 6000 calories.

A. water
B. Brass
C. Aluminum
D. Wood
E. Iron

7. 07.4 Calculate the thermal expansion of aluminum.

The temperature changes from 25 ^{o}C to 65 ^{o}C and L = 3000 m.

A. 19500 cm.
B. 3.3 cm.
C. .05 cm.
D. 312 cm.
E. 12000 cm.

8. 07.5 Calculate the amount of heat loss for a copper wall.

The temperature changes from 0 ^{o}C to 45 ^{o}C.
A = 50 cm x 50 cm.
Δt = 60 s
d = 2.54 cm.

A. 93750.5 calories
B. 252.7 calories
C. 2.444.881.89 calories
D. 4.59 calories
E. 9.090.000.65 calories

WAVES and S O U N D
Topic 08

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct term.

   amplitude, decibel, Doppler effect, frequency, intensity, interference, longitudinal waves, loudness, medium, period, resonance, sound, speed of sound, vibration, wavelength

2. Develop a model showing the following: a) how sound travels, b) the movement of sound through various media, c) demonstrated loudness, and d) demonstrated frequency.

3. Given various Celsius temperatures (T), calculate the speed of sound, using the relationship:
   $V_T = 331 \text{ m/s} + (0.6 \text{ m/s}\,^0\text{C} \times T)$.

4. Given any two of the three variables, and the formula $v = f \times \lambda$, calculate the third variable, whether speed of sound, frequency, or wavelength.

5. Measure the length of a resonating column, and calculate the wavelength of the sound wave, using the following formula: wavelength = 4 x length of air column.

6. Determine the distance between yourself and an object reflecting an echo using:
   $D = (v_T \times t) / 2$ where D = distance from observer to a reflecting surface, V_T is velocity of sound at a given temperature, and t is time interval needed to hear the echo.

INTRODUCTION

An age-old question asks: If a tree falls in a forest where there is no one to hear it, does it make a sound? To answer this question, the phenomena of sound must be defined. In the physiological sense, there are three requirements for sound:

1. a source of energy.
2. a transmitting medium for the energy.
3. a receiver to receive and decode the energy.

In the physical sense, sound is a series of energy disturbances in a material medium, not necessarily requiring a receiver or observer. Therefore, the answer to the above question depends on the definition used. In this topic, "sound" will be interpreted in its physical sense.

Sound may be specifically defined as a mechanical vibration in a material medium (solid, liquid, gas) within a frequency range approximately between 20 waves/s and 20.000 waves/s. One wave/s is 1 Hertz (Hz). These frequencies are capable of affecting the human ear (providing that its intensity is between 0 db and 120 db). Waves of frequencies lower than 20 Hz are called infrasonic, and those of frequencies higher than 20.000 Hz are known as ultrasonic.

Model of Sound

Suppose you take a very thin strip of wood or a piece of steel like a hacksaw blade and clamp one end in a vise. If you strike this clamped material sharply, the free end would vibrate back and forth. If you cause the wood or steel to vibrate rapidly, it would produce a humming sound that could be heard. You could do other experiments, such as the plucking of a guitar string, or the striking of a fork, which show that sounds are produced by vibrating matter.

As the vibrating strip moves forward it moves the gas molecules compressing them thus transferring mechanical energy to the molecules in the direction in which the compression occurs. At the same time, the gas molecules on the other side of the strip expand into the space left behind the strip, and they become more separated or rarefied. The combined effect of the simultaneous compression and rarefaction transfers energy to the molecules in the direction of the vibration of the strip. The type of wave produced as this mechanical process continues is called a longitudinal wave.

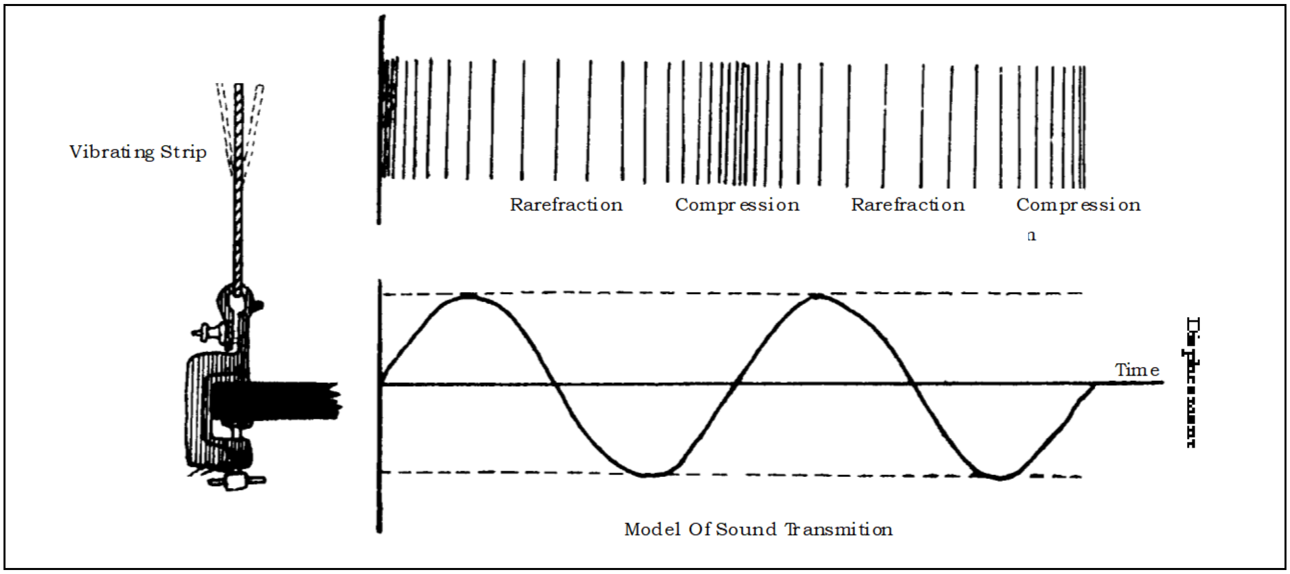


Figure 1

Waves possess five basic characteristics.

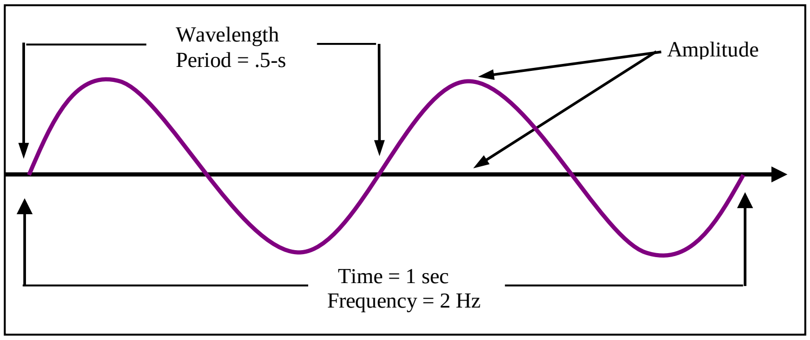


Figure 2. Model of Sound

1. Wavelength (λ), is the distance from a point on a wave to the next point
2. Amplitude (A), is the maximum displacement (distance) of any wave. Amplitude indicates the loudness of a sound.
3. Period (t), is the time (usually expressed in seconds) that it takes for a wave to travel one full wavelength.
4. Frequency (f), is the number of vibrations (waves) occurring in one second of time. This indicates the pitch of a sound.

5.Wave speed (v), is the rate the wave is traveling; the units of measurement are meters/s

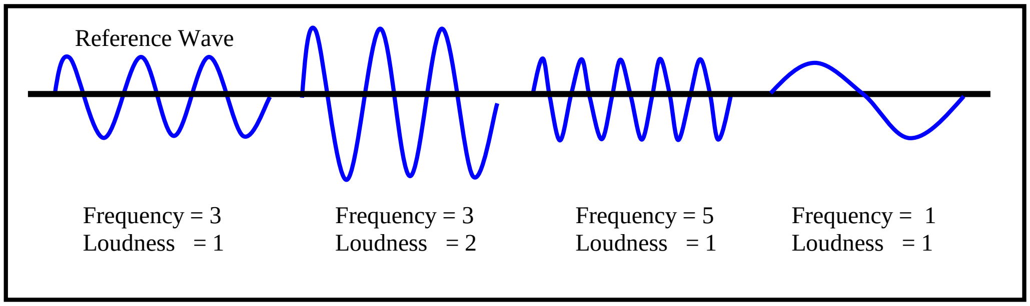


Figure 3 Examples of Frequency and Loudness

The model of sound contains two fundamental characteristics, loudness and frequency. Loudness is indicated by the height or amplitude of the wave. The frequency or pitch is indicated by the number of waves drawn in a given distance.

Loudness

The loudness of a sound depends on the affect (as indicated in our model by amplitude) of the sound waves on the ears. In general, sound waves of higher amplitude or intensity are louder. The ear is not equally sensitive to sound of all frequencies. Consequently, a high frequency sound may not seem as loud as one of lower frequency having the same intensity. An increase in the intensity of a sound of fixed frequency, while the observer remains at a fixed distance from its source, causes the sound to seem louder. However, the relation between intensity and loudness is not a one-to-one relationship. For example: sound must be ten times more intense before it becomes twice as loud; and 100 times as intense before it becomes three times as loud. Intensity is measured with acoustical apparatus, and does not depend on the sense of hearing of an observer. (see figure 6 for examples)

Frequency

Frequency is what we perceive as a note played by a instrument. We would consider the note to be of a high pitch or a low pitch. Frequency is the number of waves per second measured in Hertz. As the frequency, or number of waves per second, increases the wavelength decreases. As the frequency of a sound decreases the wavelength increases.

Characteristics of Sound

Interference

The concept of waves is not unique to sound. For instance, if you drop a rock into a pond, waves will be produced. These waves can overlap, and in overlapping, some of the effects of the waves may be increased, decreased, or neutralized. As the crest of one wave overtakes the crest of another, the affects combine. The result is a wave of increased amplitude. This is called constructive interference, or reinforcement. By the same token, when the crest of one wave overlaps the trough of another, their individual affects are reduced. The high part of one wave simply fills in the low part of another. This is called destructive interference, or cancellation. These concepts transfer neatly from the rock in the water example described above to the fundamental concepts of sound.

Doppler Effect

When a sound is moving with respect to the observer the sound's pitch appears to change. Because of the motion of the source, illustrated here as a racing car, the sound waves appear to be bunched up in front and spread out in back. This results in shorter wavelengths, or an increased frequency, in the front of the source and longer wavelengths, or a lower frequency behind the source.

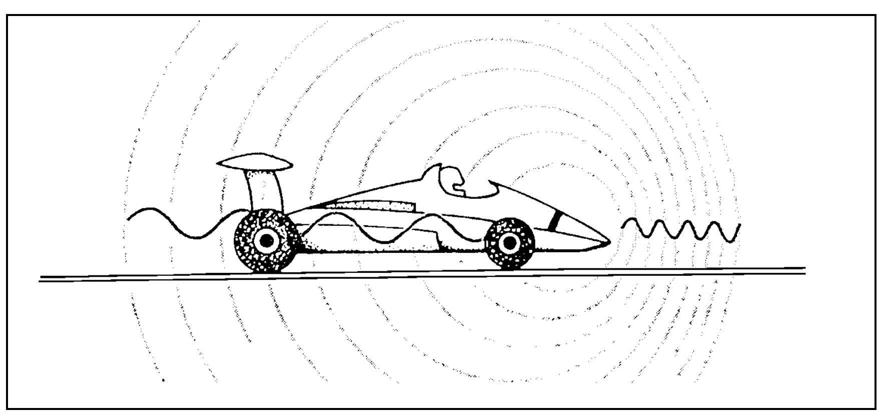


Figure 4

Speed of Sound

The speed of sound in the air is about 330 meter/second at 0^o C. As the temperature of the air rises, the speed of sound increases, at a rate of about 0.6 meter/second for each C^o. The formula or relationship can be stated as:

$$\mathbf{V_T = 331\ m/s + (.6\ m/s\ {}^0C\ \ x\ \ T)}$$

It must be noted this formula works only for sound traveling in air. The temperature must be in units of ^oC. **The unit for the speed of sound is m/s.**

If the temperature was 19^o C then the speed of sound would be:

$$331\ m/s\ + (.6\ m/s\ {}^0C\ x\ 19^o)\quad or\quad 342\ m/s$$

In a liquid such as water the speed of sound at 19^o C is 1461 meters/second approximately four to five times faster than air. In some solids, the speed of sound is even greater, for example: in iron, sound may travel 5.000 meter/second, about 15 times faster than air. The speed of sound in various substances can be seen in the following chart.

Velocity of Sound in Various Substances			
Substance	Temp C^o	m/s	ft/s
Solids (bulk)			
Aluminum	-	6.420	21.063
Copper	-	5.010	16.437
Platinum	-	3.260	10.696
Iron (Armco)	-	5.960	19.554
Nickel	-	6.040	19.816
Liquids			
Alcohol	20.5	1.213	3.980
Benzene	0	1.166	3.825
NaC1 10% solution	15	1.470	4.823
NaC1 20% solution	15	1.650	5.413
Water	13	1.435	4.708
Gases			
Air	0	330	1.083
Carbon Dioxide	0	258	846
Hydrogen	0	1.268	4.160
Oxygen	0	317	1.041

Table 1

Sound waves are given off in all directions from a vibrating body. If they travel through a uniform medium, they spread out in a spherical pattern. Thus, the area of the expanding wave front is increasing in proportion to the square of the distance from the source. Since the total energy of the wave is constant, the intensity of the wave diminishes as it moves away from the source. The sound waves produced by a whistle are only one-fourth as intense at a distance of two kilometers as they are at a distance of one kilometer from the source. The loudness of a sound at any point can be measured using a relationship referred to as the **Inverse Square Law**. The interesting thing about this law is that it describes the energy of various forms of energy. We will investigate this law more closely in later topics.

Resonance

You may have noticed that a person singing or a sound from the radio or television can cause some object in the room to vibrate. This is referred to as resonance. (Is it live, or is it Memorex?) Resonance occurs when the natural rates of vibration of two objects are the same. If you hold a vibrating tuning fork over a plastic cylinder as shown in the Figure, you can observe resonance. You will need to adjust the length of the tube by moving it up and down, until the sound produced seems the loudest. The following paragraph and Figure will explain how the sound becomes louder.

When a vibrating tuning fork is in the 'down' position (b), the sound wave travels down the tube, reflects off the water, and returns to the tuning fork, just as it reaches the 'up' position (a). The reflected sound reinforces the sound made by the tuning fork, making it seem louder. The sound has gone down the length of the tube (L) and back; or 2L, in half of a wavelength. (distance a to b). The length of the tube is half a wavelength divided by 2, or 1/4 wavelength. The length of the tube is one-quarter of the wavelength of the sound being produced. To determine the wavelength of the sound produced multiply the length of the tube by four.

This relationship can be expressed as: $\lambda = 4 \times L$.

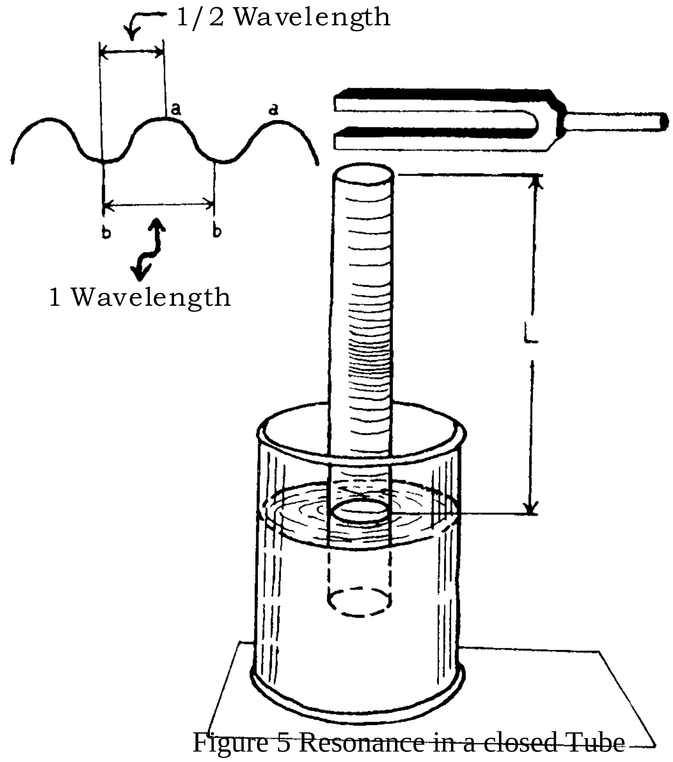


Figure 5 Resonance in a closed Tube

By investigating the relationship between frequency (vib/s) and wavelength (m/vib) one would observe that if they are multiplied together and we cancel appropriate units the results would be units of (m/s).

$$\text{Frequency} \times \text{Wavelength} = \text{Velocity}$$

$$\left(\frac{\text{vibration}}{\text{second}}\right) \times \left(\frac{\text{meters}}{\text{vibration}}\right) = \frac{\text{meters}}{\text{second}}$$

Since the tuning forks are stamped with their frequency (f) and the wavelength (λ) can be obtained through resonance we can calculate the velocity of sound in the classroom.

Decibel Levels

A decibel meter (db meter) is an instrument designed to measure the intensity of the waves from a source of sound. such as a vibrating string. an explosion. etc. Although the units for measuring sound intensity are known as watt/m^2. a more practical unit has been developed. the decibel. The relationship between these two units can be evaluated by looking at the decibel levels of a number of familiar noises. The threshold of hearing is defined as the lowest level of sound that the ear can perceive. The threshold of pain is defined as a sound so loud that it can be felt (pain) by the ear in terms of pressure applied to the ear drum.

DECIBEL SCALE

Decibels	Watts/m^2	
10	10^{-11}	
		Threshold of hearing-average
20	10^{-10}	Rustle of leaves
		Whisper at five feet
30	10^{-9}	Broadcast studio
		Average dwelling
40	10^{-8}	Quiet office
		New York City at midnight; household refrigerator
50	10^{-7}	Average office
		Quiet automobile
60	10^{-6}	Conversation; average restaurant
		Quiet typewriter
70	10^{-5}	Automobile passing
		Average factory
80	10^{-4}	Noisy restaurant; printing press
		Truck passing
90	10^{-3}	Inside train; noisy factory
		Heavy city traffic
100	10^{-2}	Train
		Riveter
110	10^{-1}	Boiler factory
		Punch press
120	10^{0}	**Threshold of Pain**
		Airplane motor at 20 feet
130	10^{1}	Pneumatic rock drill

Figure 6 Loudness Scale

Virtual Laboratory

Topic 08 – Waves and Sound

			08
Name	Section #	Date	Topic #

Google **PHET Waves on a String**. (These instructions are for the html5 version.)

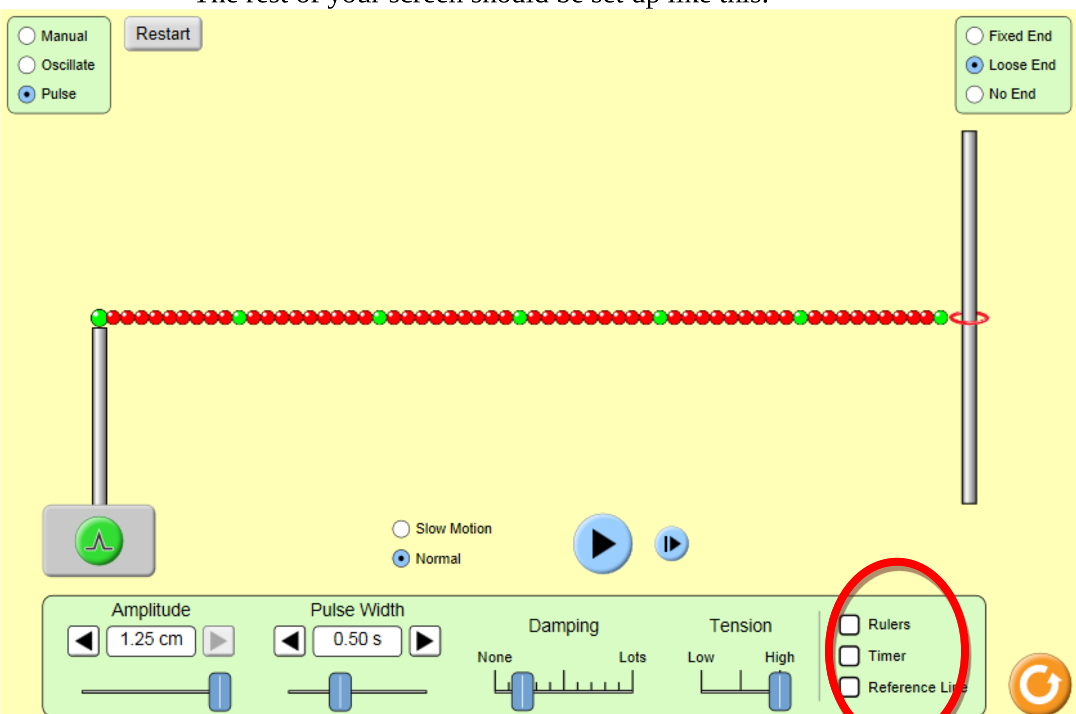
Learning Goals:

- Be able to describe the fundamental properties of waves.
- Be able to explain how amplitude. frequency and wavelength are related.

Play with the simulation to gain familiarity with the controls.

- Set your controls to 

- The rest of your screen should be set up like this:



(You can change the position of the rulers by dragging them with the cursor.)

Change the amplitude slider settings and observe the resulting waves. (Click on the  button to make the wave move along the string.)

1. What amplitude setting makes the tallest waves? ___________________________
2. What amplitude setting makes the shortest waves? _______________________
3. Explain what amplitude means in your own words. _________________________

- Set your controls to 

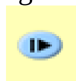
 and  Loose End

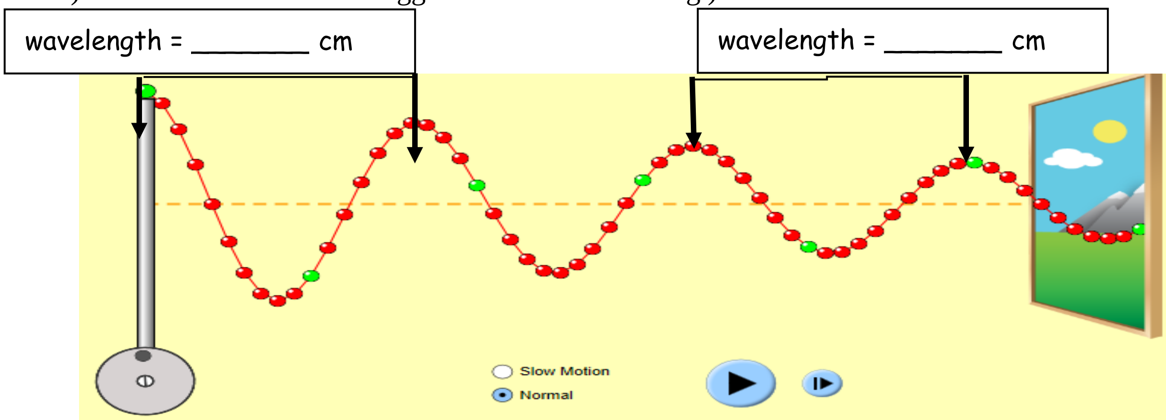
Notice the pause play buttons. Change the amplitude slider setting to 50 and change the frequency setting. Observe the resulting waves. (Click on the PLAY button to make the wave move along the string.)

4. What do you observe at the lowest frequency setting (that works)? _____________________
5. What do you observe at the highest frequency setting (that works)? ____________________
6. Explain what frequency means in your own words. _________________________

Change your settings to observe wavelength and frequency:

- Set your controls to Oscillate and Fixed End
- Set amplitude at 1.25 cm and frequency at 3 HZ.
- Use the pause button to stop the wave for easier measurement.

7. Use the ruler to measure the wavelength at the two points on the diagram below and record your results in the space provided. (Hint: Use the  button after you hit pause to line up the large green ball (on the left side moving up and down on the stick) to its maximum height so that your wave looks like the one below.) Note: The ruler can be dragged for easier measuring.)



What did you discover about the 2 wavelengths?

Does this match your expectations?

Why or why not?

8. Make a prediction about what you think will happen to the wavelength if you increase the frequency setting.

Change the frequency settings several times and observe the effect this has on the wavelength. Do you see a pattern? Describe your observations:

9. a. Now record some data as you change the frequency settings, (Remember to keep all the other settings constant! Frequency is found in the box above the frequency setting, and you use the ruler to measure the wavelength. Press pause to take your measurements.)

FREQUENCY	WAVELENGTH

9.b. Based on your data, write a statement about the relationship between frequency and wavelength.

Sound Waves

Learning Objectives:

- Explore and draw conclusions about the nature, properties and behaviors of sound waves.
- Use the simulation to develop your own definition of frequency and amplitude.
- Describe how frequency and amplitude affect the sounds we hear.
- Given a description of a sound like "high pitched and loud", describe the amplitude and frequency.
- Calculate the speed of sound, and sound waves.

Go to the website http://phet.colorado.edu/en/simulation/sound . and click on the play button.

10. Discuss examples of things that make the different types of sounds listed in the table below. **Write your examples in the table below.**

Use the **Listen to a Single Source** tab. Turn on the **Audio Enabled** so you can hear the sound. Adjust the Frequency and Amplitude using the control panel provided.

Create the sounds in the table below.

Sound	**Example of something that makes this sound**	**Explain how you used the simulation to make the right noise**
Case A: Loud. High-pitched		
Case B: Soft. High-pitched		
Case C: Loud. Low-pitched		
Case D: Soft. Low-pitched		

11. Which cases above:
    a. Have a high frequency? ____________________
    b. Have a large amplitude?_____________________
    Explain what controls pitch. and what controls loudness.

12. In the **Listen to a Single Source** tab click on listener and make sure audio enabled is still checked.
    a. Explain what happens to the sound when you move the person towards and away from the speaker.

b. Increase and decrease the frequency and record what happens to the waves and the sound. Record your results.

c. Increase and decrease the amplitude and record what happens to the waves and the sound. Record your results.

d. What can you conclude about amplitude and frequency of sound waves?

13. Now go to the **Measure** tab. Notice the timer in the yellow box. Press start and then stop to measure the time of one of the waves exiting the speaker. Make sure the timer is starting from 0.0000 sec.
    a. Measure how long it takes the sound waves to reach 5 meters. ________seconds. Calculate the speed of sound in m/s. __________
    b. Increase and decrease the frequency and amplitude of the waves and see if they make a difference in the speed of the waves. Record your results. Do frequency and wavelength affect the speed of sound? _______. Explain how you arrived at this conclusion. _________________

14. Go to **Two Source Interference** tab. Make sure audio enabled is checked.
    a. Click on a speaker and drag further and closer to the other speaker. Describe what happens to the sound. Why does this happen?

    b. What happens when you adjust the frequency and amplitude of the two sources?

15. Go to **Interference by Reflection** tab. Notice the waves reflecting off of the wall.
    a. Change the wall's angle by sliding the bar in the control panel. What happens to the reflections when the slider is in the most up position as compared to when it is in the most down position?

    b. Change the wall's position by changing the sliding bar in the control panel. What happens to the reflections as the wall gets further away from the source of sound?

    c. When is the interference greatest; when the wall is closer or further away from the sound source?

16. Go to http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/ClassMechanics/Beats/Beats.html
    And review the six slides/pages provided about Beats. Skip the math page. Follow the instructions on each page. Listen carefully on the last page when you click the 1+2 button.

    Describe what you heard when you clicked on the 1+2 button. Using your own words describe why you heard this phenomenon.

    ____
    ____.

Hands-on Laboratory

Topic 08 – Waves and Sound

MATERIALS

1 hollow tube. 2 cm. in diameter	1 striking pad
1 hollow tube. 4 cm. in diameter	beaker or container to hold water
2 unknown sources of sound	tuning fork - 512 hertz
tuning fork - 480 hertz	scissors
Computer Sound Analysis Program - Audacity	
ring stand	
straws	thermometer

PROCEDURE

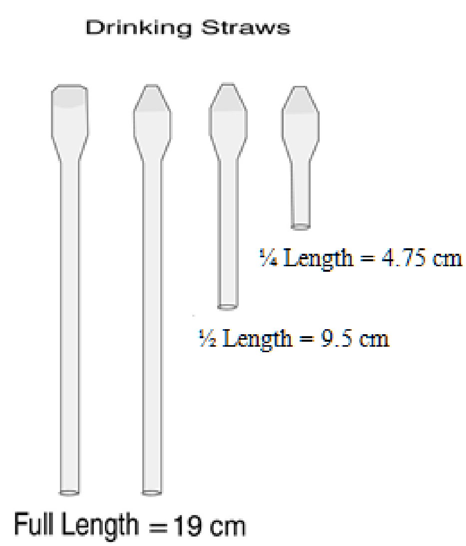
Part A - Problem: How do you use the model of Sound? **Prelab prep:** Complete part A section 1 prior to the lab meeting.

Section 1 – Applying the Model of sound

1. The drawings in part A section 1 illustrate a model of a particular sound.
2. The frequency of each sound is the number of vibrations occurring each second (f = vib/sec). To determine the frequency of a sound we must obtain the number of waves and the time needed for those waves to occur.
3. For each figure of sound count the number of waves and record.
4. Determine the time for the number of waves. Notice the number line that is scaled from 0 to 0.2 s
5. Calculate the frequency of each sound using f = number of wavelengths/second

Section 2 – Applying the Model to a Musical Instrument

1. Obtain a soda straw, and flatten one end for a distance of about one to two centimeter. Cut off corners for about .5 cm as indicated in the drawing. The cuts should produce reed-like mouth-piece.
2. Place this trimmed end in your mouth, far enough in your mouth so that the flaps are free to vibrate, and blow. If the straw doesn't produce a sound, chew the trimmed end to further soften the mouth-piece.
3. The sound is something like that of a saxophone. This sound is produced because the reeds vibrated in unison with the pitch of the air column, that is, the reed conforms to the specific vibrating tendency of the air column.
4. Use a pair of scissors cut the straw in half. Blow into the straw. Next cut the remaining straw in half once again. This will produce successively higher-pitched notes.
5. If figure B, on the data sheet, represents the model of sound made by the full straw length which figures would represent the one-half and one-quarter straw lengths?



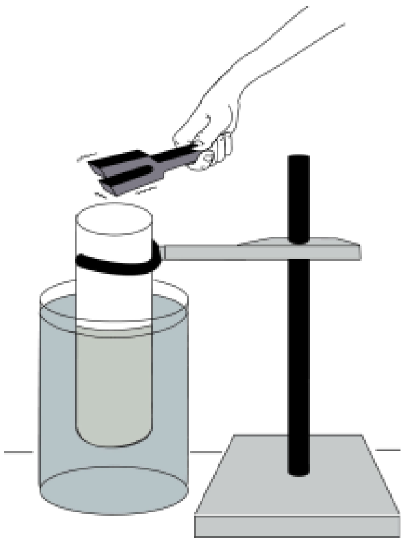
Part B - Problem: Measuring the velocity of sound using Resonance

Make sure to employ the measurement rule for this portion of the lab!

Pre-lab prep: What is the research question for this portion of the lab?

____

Pre-lab prep: Develop your hypothesis (don't forget the prediction - see step 2 below):



1. Measure the air temperature in the area of the experiment.
2. Predict the velocity of sound using the temperature method. This velocity of sound is the **theoretical value**.
   V_T = 331.3 m/s+ (.6 m/sec ^{0}C x T)
3. Measure the length of the tube where resonance will occur and use that length to determine the velocity of sound.
   a. Clamp the 5.00-cm diameter plastic tube in a vertical position on a ring stand.
   b. Place a container filled with water to within approximately 2-cm of the top of the container.
   c. Strike the tuning fork on the rubber mat provided causing it to vibrate. The number stamped on the tuning fork (480 Hz. 512 Hz), is the frequency (f) of the sound.
   d. Hold the vibrating tuning fork over the tube as close to the tube as possible. Adjust the position of the tube in the water by raising it or lowering it until the sound from the vibrating tuning fork is intensified. This is the point at which resonance occurs. Clamp the tube so an accurate measurement can be made.
   e. Measure the length of the air column in the tube (in meters) from the surface of the water to the top of the tube, (L), The wavelength (λ) of the sound is equal to four times the length of the air column.

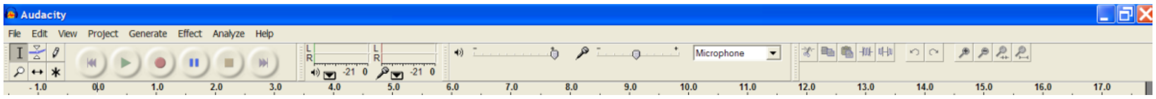
   Remember: When a vibrating tuning fork is in 'down' position, the sound wave travels down the tube, reflect off the water, and returns to the tuning fork, just as it reaches the 'up' position. The reflected sound reinforces the sound made by the tuning fork, making it seem louder, The sound has gone down the length of the tube and back; or 2L. in half of a wavelength. The length of the tube is therefore one-fourth the wavelength. To determine the wavelength of the sound produced multiply the length of the tube by four. This relationship can be expressed as:

   $\lambda = 4 \times L$ (Record this value in meters.)

4. The velocity of sound is equal to the product of the wavelength and frequency, $V_E = f \times \lambda$. This velocity of sound will be considered the experimental value.
5. Compute error/percentage of error using the above values of V_E and V_T, and record them. If your value for the percent error is more than **10%**, look closely for errors, and repeat the experiment.
6. If time permits repeat steps 1- 5. using a tuning fork with a different frequency

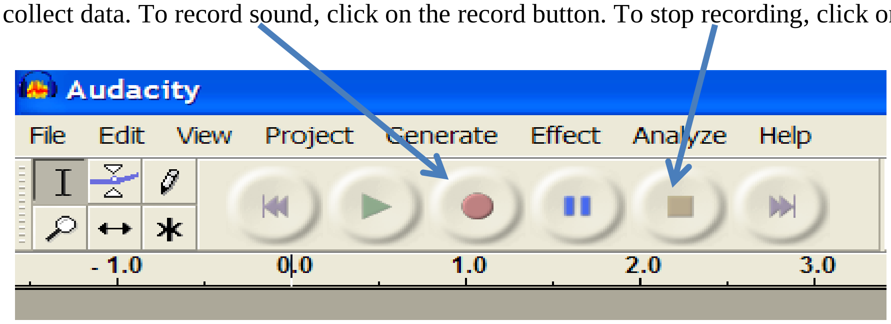
Part C - Problem: Measuring Frequency

1. The following steps provide the procedure for determining the frequency of a sound using the computer. (You may want to try this on your computer. Audacity is a free download.)
   a. Click on the Audacity icon under ALL Programs:
      1) The control bar for Audacity looks like the following

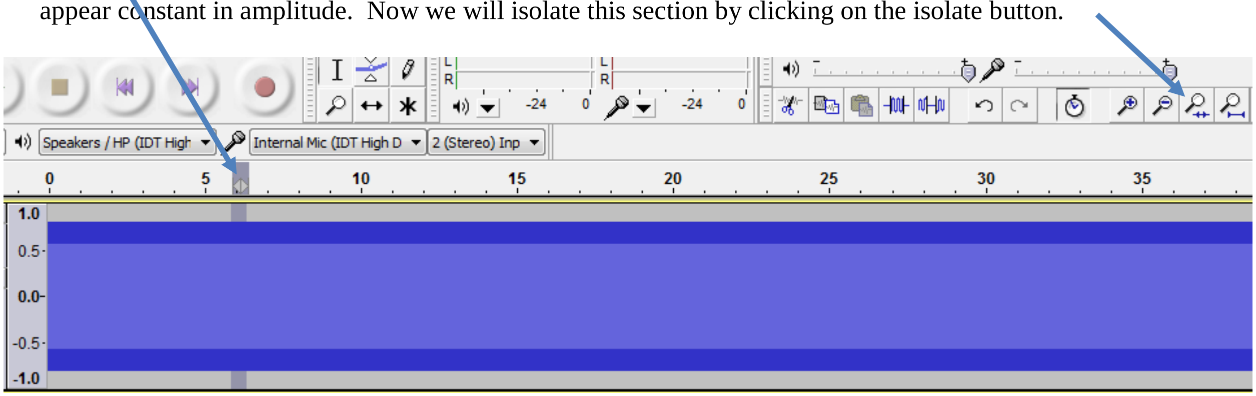


2. Use built in mic on laptop, (Left hole above screen.) When recording a sound place the object near the microphone.

3. You are ready to collect data. To record sound, click on the record button. To stop recording, click on the stop button.

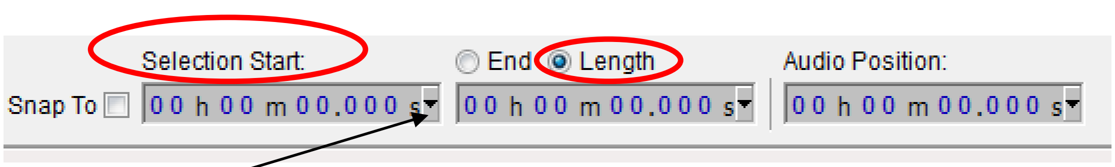


4. After recording your sound you will observe the sound wave pattern underneath the control bar. But, we won't be able to see the individual wavelengths. To do this we need to isolate a small section of the wave pattern **by highlighting**, with the cursor, a very small selection of the wave pattern (1 – 2 mm in width). Choose a section where the peaks appear constant in amplitude. Now we will isolate this section by clicking on the isolate button.



5. To determine the time for one wavelength, we will begin by **highlighting and isolating 10 complete wavelengths** using the cursor (see the image above). One wavelength is one complete crest and trough. To obtain the cursor click on the button that looks like a capital I. <u>Make sure that there is not a check mark in the Snap To box at the bottom of the screen next to the time boxes, See image for step 7.</u>

6. In the above image (step 6) you can see the times just above the wave pattern. Notice the numbers 1.740, 1.750, 1.760, etc…. These are the number of seconds. It is not easy to precisely determine the time for our selection using the time bar. We are interested in determining the precise time for 10 waves. We can do this by looking down at the lower left corner of the page. You will see the following:



Click on the arrow button next to the Selection Start box. Check hh:mm:ss + milliseconds from the menu that opens. Make sure the Length button is selected. The box directly underneath the Length button will give you the time for the 10 waves you have highlighted.

7. To find the time for one wave divide by ten, (This example is 0.020 ÷ 10 = 0.0020 s)

8. To find the **experimental frequency** of your sound, take one second and divide by the time for one wave (that you found in step 7).

$$\text{frequency} = 1 \text{ sec} \div 0.0020 \text{ sec} = 500 \text{ waves per second or } 500 \text{ Hertz.}$$

9. Read the number on the tuning fork using this number as the **theoretical value,** and calculate your percent error. For this **example**, the theoretical frequency is 512 Hertz.

   %Error = [(experimental value - theoretical value) ÷ theoretical] x 100
   %Error = [(500 hertz - 512 hertz) ÷ 512 hertz] x 100
   %Error = 2.3%

10. Use the procedure outlined above to determine the frequency of an object selected by your instructor. Record your data and calculate the percent error (if applicable – check with your instructor). Identify what your instructor wants you to measure the frequency of: ___________________________________

Note: If you make several recordings just make sure to use the Stop button after completion of the previous recording. Each new recording starts on a new line.

Part D Measuring Loudness

Set the decibel meter to MAX HOLD. When the loudest sound level is reached the number will be held until something louder comes along. Fill in the number of decibels for the following situations:

Source	dB from decibel meter	Similar dB to which object from list on page 156?
Whisper at 5 feet		
Quiet Classroom		
Noisy classroom		
Toilet Flushing		
Quiet Bathroom		

• 08 •
WAVES and S O U N D

			08
			08
			08
Name	Section #	Kit #	Topic #

Part A – How to use the Model of Sound:

Section 1 – Applying the Model of Sound

1. The following drawings indicate a model of a sound. The frequency of each sound is the number of wavelengths occurring each second or f = # of wavelengths/s For each sound count the number of waves, determine the time for those waves and calculate the frequency of each sound.

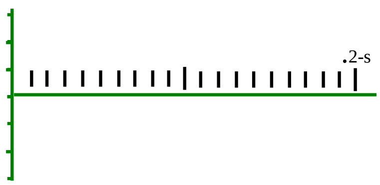


Figure A

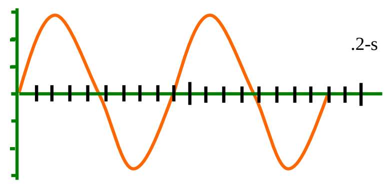


Figure B

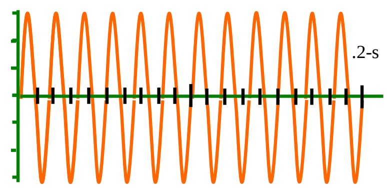


Figure C

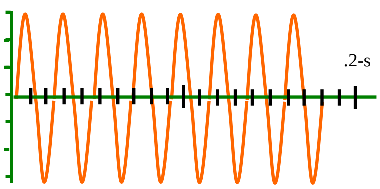


Figure D

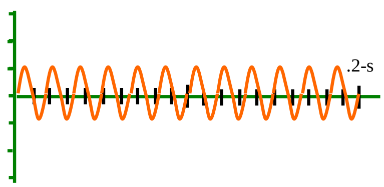


Figure E

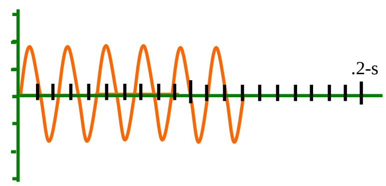


Figure F

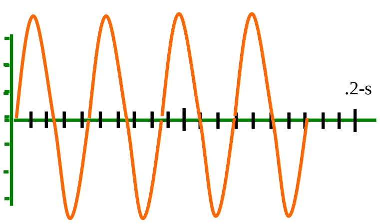


Figure G

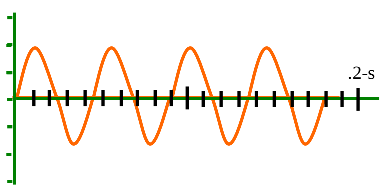


Figure H

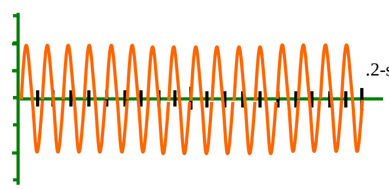


Figure I

	Sound Model								
	A	B	C	D	E	F	G	H	I
Number of Waves	0								
Time	-								
Frequency (# of waves / time)	-								

2. According to the model which sound is the loudest? _____

3. Which sound is the softest ? _____

4. Which sounds have the same frequency but different loudness? _____ and _____

5. Which sound is the highest frequency? _____

6. Which sound is the lowest frequency? _____

Section 2 – Applying the Model to a Musical Instrument (the straw)

1. If figure B represents the model of sound made by the full straw length which figures could represent the one-half straw lengths ______ and one-quarter straw lengths ______?

Part B – Resonance and the Velocity of sound

Pre-lab prep: What is the research question for this portion of the lab?

____

Pre-lab prep: Develop your hypothesis (don't forget the prediction):

____

5 cm Resonance Tube	480 Hertz Tuning Fork	512 Hertz Tuning Fork
Air Temperature (^{0}C)	^{0}C	^{0}C

Velocity of sound in the air (Theoretical) **V_T = 331.3 m/s+ (0.6 m/s ^{0}C x T)**	m/s	m/s

Measured Length of air column for Resonance (L)	meters	meters
Wavelength λ= **4 x L**	meters	meters
Experimental Velocity of sound **V_E = f x λ** (the frequency is indicated on the tuning fork)	m/s	m/s

Error = $\|V_E - V_T\|$ (notice absolute value bars)	m/s	m/s
% Error = 100 x Error / V_T	%	%

1. Which tuning fork has a higher pitch? _____
2. Do your best to strike each tuning fork with an equal force so that they vibrate with equal amplitudes. Is one louder than the other one? **Explain your results**. Are these the results you expect? **Explain.**
3. What effect did changing the tuning forks (frequency) have on the length of the air column? _____

Part C – Measuring the frequency of sound

Determine the frequency of ___________________________ (as indicated by your instructor)

Label On the Sound Source (if there is one) _____

Time for ten waves	________________	seconds
Time for one wave	________________	seconds
Experimental Frequency	________________	Hertz (waves/sec)
Theoretical Frequency	________________	Hertz (waves/sec)
Error ($f_{exp} - f_{theo}$)	_____________	Hertz (vib/sec)
% Error = (Error ÷ f_{theo}) x 100	________________	%

1. Explain why your results might be different from the theoretical frequency. Provide an explanation that includes your numerical results and compares them to the theoretical results. In other words, if your results are greater than expected, what could cause this to occur? If your results are less than expected, what could cause this? Provide explanations.

   ____

2. The wave pattern you see on the computer is a graphical representation of the sound.

   What is plotted on the vertical axis? __________________

   What is plotted on the horizontal axis? __________________

   Typically, we say the vertical axis is the dependent variable and the horizontal axis is the independent variable. Is this true in this case? Explain your answer. ___________________________________

Part D Measuring Loudness

Set the decibel meter to MAX HOLD. When the loudest sound level is reached the number will be held until something louder comes along. To re-set the meter for the next item turn the MAX HOLD off and then back on. **Decibal Meter Settings**: Auto. A weighting. Slow Response. Fill in the number of decibels for the following situations:

Source	dB from decibel meter	Similar dB to which object from list on page 164
Whisper at 5 feet		
Quiet Classroom		
Noisy classroom		
Toilet Flushing		
Outside		

WAVES and S O U N D

Self-Evaluation

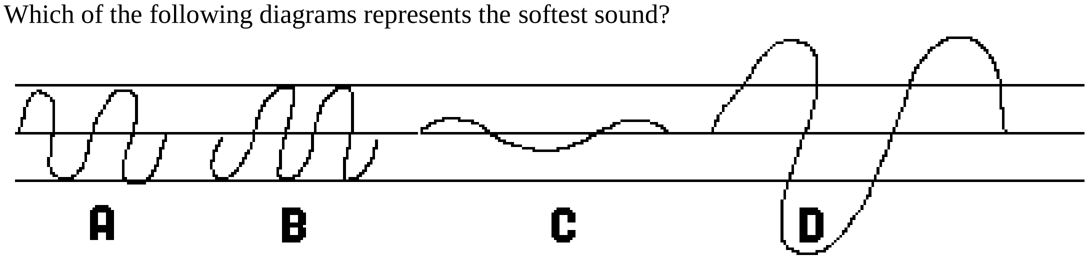
TEST 081

Directions: Select the best answer.

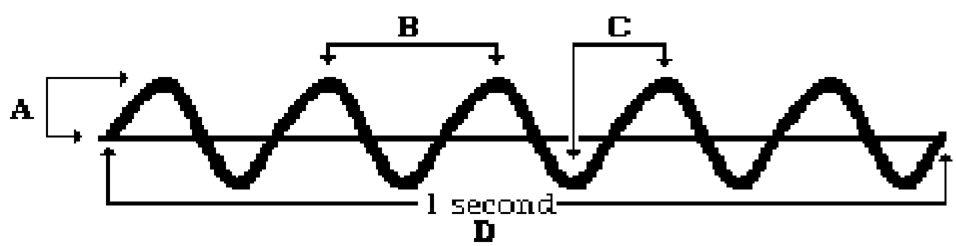
1. 08. 1 The power of sound (as judged by the ear. is represented by:
   - A. wavelength
   - B. frequency
   - C. amplitude
   - D. tone

2. 08. 1 Matter that is vibrating produces:
   - A. electricity
   - B. sound
   - C. magnetism
   - D. light

3. 08. 2 Which of the following diagrams represents the softest sound?



4. 08. 2 A and B. respectively. are:
   - A. wavelength and tone
   - B. frequency and tone
   - C. wavelength and frequency
   - D. amplitude and wavelength
   - E. none of the above



5. 08. 3 Given the air temperature 21^{o} C. calculate the speed of sound:
   - A. 343 m/s
   - B. 0.15 m/s
   - C. 275 m/s
   - D. 1250 m/s

6. 08. 3 What is the speed of sound at 45^{o} C?

A. 1347 m/s
B. 3.57 m/s
C. 1180 ft/s
D. 357 m/s
E. 1860 m/s

7. 08. 4 What is the velocity of a sound whose wavelength is 3.0 cm and whose frequency is 1235 Hz?

A. 37 m/s
B. 411 m/s
C. 3650 cm/s
D. 458 m/s
E. 275 m/s

8. 08. 4 What is the velocity if the wavelength is 4 meters, and the frequency is 282.5 Hz?

A. 1090 m/s
B. 1120 m/s
C. 1130 m/s
D. 1140 m/s

9. 08. 5 What is the wavelength of a sound resonating in a closed tube 10 cm long?

A. 30 cm
B. 45 cm
C. 40 cm
D. 15 cm
E. 74 cm

10. 08. 5 What is the wavelength of a sound resonating in a closed tube 105 cm long?

A. 105 cm
B. 210 cm
C. 315 cm
D. 420 cm
E. 530 cm

11. 08. 6 A person shoots a gun near a reflecting surface. The same person hears the echo 7 seconds after the shot. If the temperature is 40^{o}C. how far is the person from the reflecting surface?

A. 2478 m
B. 2841 m
C. 1239 m
D. 3870 m

12. 08. 6 A person is standing near a reflecting surface. He shouts. and hears an echo 10 seconds later. If the temperature is 25^{o} C how far is he from the surface?

A. 172.5 m
B. 8625 m
C. 1725 m
D. 33m

ELECTRICITY

Topic 09

Objectives

1. Given the following list of terms, you will identify each term's correct definition. Conversely, given the definition. identify the correct term.

   alternating current, ampere, conductors, current electricity, dielectric, direct current, fuse, insulators, nonconductors, ohm, static electricity, volt, resistance, voltage

2. Compare and contrast static electricity and current electricity, and be able to state which static electrical charges are repelled, and which are attracted when brought together.

3. Explain household wiring, and identify the difference between series and parallel circuits.

4. Describe how to measure volts, amperes, and ohms.

5. Given Ohm's Law: I (amperes) = € (volts) / R (ohms), solve for current, voltage, or resistance.

6. Identify and explain the effects of length, diameter, and composition of a conductor on the resistance in a circuit.

7. Given appropriate data and the formula: P(watts) = € (volts) x I (amperes), determine the amount of electric power a given device uses. In addition, be able to calculate power, current, or voltage, and be able to determine how many electrical appliances can be plugged into the same circuit without tripping the circuit break.

NOTE: Common abbreviations: Amperes (A), Volts (V), Watts (W), Ohm (Ω)

INTRODUCTION

Overview of Electricity

Electricity is a form of energy that occurs everywhere in nature, in space, in the atmosphere, in living creatures, in chemical bonds that hold atoms together, in molecules, and in the atoms themselves. Lightning bolts are an example of a large-scale display of an electric affect. On a much smaller scale, weak electrical impulses are transmitted from one nerve cell to the next in animals, providing signals for the brain and other parts of the organism.

In the past 100 years or so, many techniques for harnessing electricity and putting it to use have been developed. All industrial societies have been dramatically transformed by the ability to generate electric power, and to transmit it over long distances. Electric power runs electric motors in factories, provides building and street lighting in cities, and runs appliances and lights in homes. In addition, electrical phenomena are the heart of telephone, radio, television, and radar systems.

Electricity also plays an important role in many industrial processes, such as the electroplating and electric arc welding of metals, and the use of electrostatic precipitators to remove waste particles from furnace exhausts in many kinds of industrial plants.

All the electrical phenomena we are familiar with depend on the forces existing between the electrical charges carried by electrons and protons, two of the principal constituents of all atoms. Protons contain the positive charges of atomic nuclei, and electrons are the source of all negative charges. The attractive force between positive and negative charges holds atomic nuclei and electrons together to form atoms. Under many circumstances, one or more electrons can disassociate from atoms, and flow through metals or other matter to produce electric currents. Certain actions of electrons and electric charges give us electric current and electric power. To make current, a Force is needed to drive electrons away from some part of matter. The force must keep pressing the electrons so that they cannot flow directly back. This leaves a positive charge at the place from which the electrons were torn loose.

All matter consists of atoms, which are essentially electrical, Each atom has one or more electrons, and one or more protons. An electron is a negative particle, and a proton is a positive particle of electricity. These tiny particles always have equal-but-opposite charges of electricity. Protons are heavier than electrons, however, and are bound tightly to the centers of atoms. Because of this strong attraction, only electrons can move freely.

Static Electricity

Ordinarily, an atom is neutral. This means that it has an equal number of electrons and protons. If an atom gains some electrons, it becomes negatively charged. If an atom loses some electrons, it becomes positively charged. Atoms that either gain or lose electrons become electrically charged, and are called ions. Charged atoms always attract uncharged atoms. Atoms with like charges repel each other, while atoms with unlike charges attract each other.

There are two kinds of electricity: (1) static electricity, and (2) current electricity. Essentially, however, both are really the same. Static electricity consists of electrons or ions that are not moving. Current electricity consists of ions in motion, which produces important magnetic affects. To understand electricity, you must also know something about the relationship of electricity to magnetism.

Static electricity makes your hair crackle when combed, or it may give you a shock if you touch a person or a metal doorknob after walking across a carpet on a cold day. Static electricity has fewer uses than current electricity. You can produce static electricity by rubbing a comb with a piece of wool. The atoms in the wool lose some of their electrons, and the atoms in the comb gain them, so the comb becomes negatively-charged. and the wool becomes positively-charged.

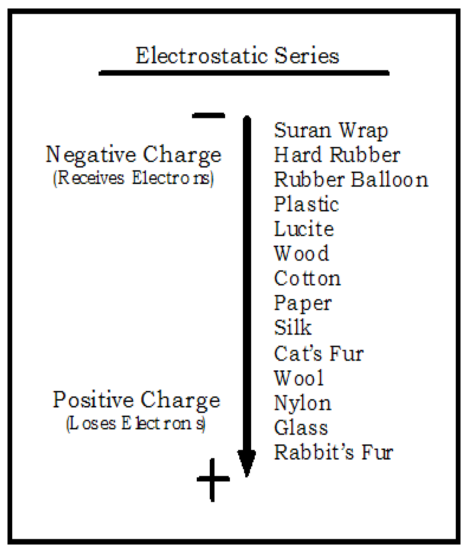
Static electricity occurs when there is an excess of free electrons or atoms that are missing electrons. In a poor conductor, the free electrons are unable to move away from its atom. nor to an atom without electrons, so the charges remain in the material. That is, electrons can be grouped in one place and the atoms without electrons in another place. The charge produced must be equal and opposite. Static electricity is produced in three ways:

a. *friction* • Objects can be charged by rubbing them together. As the two objects touch, one gives up loosely held outermost electrons to the other. Thus, the material that receives electrons becomes negatively charged and the material that loses electrons becomes positively charged. When you walk across a room on a rug on a cool dry day, you may gain a static electric charge by friction. The rubber soled shoes rub against the wool carpet and gain electrons from the carpet. When you reach for the metal door knob, these excess electrons are discharged to the knob, causing a shock.

b. *contact* • A material can be charged if electrons are transferred from one material to another by contact This generally happens when one material is charged and it touches either a neutral or oppositely charged material. If you have ever seen a person put his/her hand on a Van de Graff generator, you have observed charging by contact.

c. *induction* • A material may be charged by induction when it is brought near a charged body. If the material is a conductor, it has electrons that are relatively free to move.

A substance will not always have the same charge when it is rubbed. For example, if you rub a piece of glass with silk. the silk becomes negatively charged, and the glass positively- charged. But if you rub a piece of rubber with silk, the silk becomes positively charged, and the rubber becomes negatively-charged, The electrostatic series indicates whether a substance will become positively or negatively charged when rubbed with another substance.



Current Electricity

There are two main kinds of electric currents: direct and alternating. Direct current flows in only one direction. Alternating current rapidly reverses its direction of flow many times a second.

Electrons travel through any conductor from a negative source to a positive source of electricity. Benjamin Franklin wrongly surmised that electricity travels from positive to negative. This belief was accepted for many years, and electricians and electrical engineers still say that electricity flows from positive to negative. Scientific tests now prove that electrons flow the other way. from negative to positive in electric circuits.

In order to conduct electricity, the atoms of a substance must have electrons that are free to move from atom to atom. In a conductor, the electrons in the outer shell of the atoms are able to move freely. The number of electrons in the outermost energy level determines how easy these electrons are moved. The greater the number of electrons the harder it is to move them, In fact, materials can be classified according to the number of electrons. These are classed as insulators, semiconductors, and conductors. Insulators have from 5 to 8 electrons. Materials with 8 electrons are very good insulators or dielectrics. In some materials such as rubber and glass, the electrons are bound so tightly to their atoms that few can move. These materials conduct little electricity. Semiconductors have 4 electrons. Materials such as germanium and silicon have 4 electrons. Conductors have 1 to 3 electrons in their outermost energy level. Materials such as gold, copper, etc., are in this group.

Electricity and magnetism are closely related. The area around a magnet where its force can be felt is called a magnetic field. Electricity flowing through a wire sets up a magnetic field about the wire. In addition, a magnetic field can produce electricity in a wire. If you move a wire so that it cuts across a magnetic field, electricity will be generated in the wire. All electric generators work on this principle.

An electric circuit requires a minimum of three components. 1. A pathway or conductor, such as copper wire which electrons can flow. 2. A source of electrons, such as a battery or a generator. 3. An object for the electrons to act on. such as a toaster or a television set. The circuit leads electrons in a continuous path from a driving force to a positive charge. The flow will continue as long as the driving force acts.

Electric current can flow in solutions containing ions. Ions provide the electrons in liquids and gases which conduct electricity. Positive ions flow in one direction while negative ions flow in the opposite direction. This explains how electrical signals move through the human body.

Electrons are among the smallest known particles. For example, in a 60-watt light bulb about 3.000.000.000.000.000.000 or 3 x 10^{18} (three billion billion) electrons flow through the wires, to the bulb, each second. These electrons travel from atom to atom in the wires at a speed of approximately .01 cm per second every second. But electrical energy, or the ability of electricity to do work, travels through a wire almost as fast as the speed of light, which is 3 x 10^{8} meters per second. When you speak into a telephone, the person to whom you are talking hears your voice almost instantly. Electric current in a wire works much like a 100-foot long hose filled with water. If you connect the hose to a water source and turn it on, you will have sent a signal 100 feet, although any drop of water in the hose will have moved only a few inches. The flow of electric current and water both depend on three factors: (1) volts,, the pressure which causes the current to flow (2) amperes, the rate of the current flow, and (3) ohms, the resistance of the conductor (wire or hose) to the flow. The flow also produces power (work done per unit of time measured as watts.)

The Use of Meters

Meters are expensive and easily damaged. It is wise to know something about their construction and the proper methods of use before employing them in experimental work. All D. C. meters must be connected with the proper polarity. The negative markings of the power source are connected with the negative marking of the meter, and the positive source to the positive terminal of the meter. By convention, sources of D. C. current use the color red to designate the positive terminal and black to designate the negative terminal. If the precautions indicated are observed, the laboratory equipment will provide you with accurate data, and no damage will result to the instruments.

Most common meters are of the **galvanometer** type. In this type of meter, a small current is allowed to flow through an armature composed of fine wire wrapped around an iron core. With the current flowing, the armature becomes an electromagnet, which orients itself in an external magnetic field. This orientation results in the movement of the indicator. The armature of such an instrument is wound with very fine wire, and the heating effect of any excessive current will damage them. If a galvanometer is called for, and a multipost galvanometer is available, first connect the instrument to the "high range" posts, and successively introduce the most sensitive ranges, until the one of optimum value is found. The galvanometer is to be connected in series in the circuit.

The meter that you will use is called a digital multimeter. This is because it contains several meters in one case and the display is digital. To use the multimeter you must turn on the meter using the on or power switch. Select the voltage, current, or resistance to be measured by the indicated switch. As you are taking a reading, using the multimeter, it is normal to observe that the last one or two digits are changing. Do not expect the digits to stop changing. You should make a reading to represent the average of each digits change.

An **ammeter** is always connected in series in a circuit. This must be done so that the instrument carries all the current. Most of the current is shunted around the armature, but if the ammeter is overloaded, the armature will carry more than it is designed to carry, resulting in damage to it. Before a two-post meter is connected in a current- bearing circuit, be sure the magnitude of the current is not beyond the range of the instrument.

A **voltmeter** is always connected in parallel. Resistors in the instrument prevent the armature from being overloaded when used properly. However, damage to the instrument may result if it is forced to carry too much current. If a single-range meter is used, be sure the voltage to be measured is not beyond the range of the instrument.

Virtual Laboratory

Topic 09 – Electricity

			09
Name	Section #	Date	Topic #

PHET Electrostatics

Part I

1. Google PHET Balloons and Static Electricity Link. Or use this link http://phet.colorado.edu/en/simulation/balloons
2. Click the Playbutton or Run Now.
3. Check **Show all Charges**. Nothing else should be checked.
4. Rub the balloon on the shirt by clicking on the balloon. and dragging it.
5. What overall charge does the balloon now have? ________________________________
6. What overall charge does the shirt now have? ___________________________________
7. What happens when you drag the balloon away from the shirt and let it go? ___________
8. Why? ____
9. Click the **Reset** button on the lower left.
10. Check the **Wall** box. (The Show all Charges should remain checked.)
11. Rub the balloon on the shirt again.
12. What happens to the negative charges in the wall when you move the balloon near it?

    ____
13. What happens to the positive charges in the wall when you move the balloon near it?

    ____
14. Why don't all the positive charges move toward the balloon? ______________________
15. Hold the balloon in between the wall and shirt and release it
16. Why doesn't the balloon just stay in the middle? ________________________________

    ____

    Close the program.

Part II

17. Google PHET John Travoltage or use this link http://phet.colorado.edu/en/simulation/travoltage
18. Click the Play button or Run Now.
19. Experiment with rubbing Travolta's foot against the carpet and touching his finger to the door handle. (Click on the foot or finger and drag.)
20. Place his finger on the door and rub his foot vigorously on the carpet.
21. What happens? ____
22. Move his finger away from the door knob and build up another charge.
23. What happens? ____
24. Which of the following two statements is true? A or B? _________

    A. Most electrons will go into the knob and down to the earth.

    B. Some electrons will go from the earth through the knob and into the man.
25. Why are shocks worse when you touch conductors rather than insulators? ____________

    ____

26. If you take your hat off on a dry winter day, sometimes your hair will stand up. Explain this phenomenon.

____

____

Part III

27 Google PHET Electric Hockey or use this link http://phet.colorado.edu/en/simulation/electric-hockey

28 Click on the Play button or Run Now.

29 The goal of this game is to get the black positive puck to go in the goal.

30 How can you set up just one negative charge to score a goal? Test your idea. (Remember to click **Start**.) Describe what you did to score the goal.

____

31 Click **Clear** each time you try a new set up. **Reset** if you want to retry your current set up.

32 How can you set up just one positive charge to score a goal? (The puck must remain positively charged.)

____

33 **Reset**. Check the **Field** box.

34 Place the puck near a + charge. Replace the + charge with a – charge. Notice how the field lines are different for the two situations. Use what you observed to explain why like charges repel and unlike charges attract.

35 Now play the game. You can practice a little bit if you want.

36 Set difficulty to 1. then 2. then 3. Remember to press PLAY to observe what happens. When you beat each level (when you score a goal), draw your set up just using + and - signs. Hint: Leaving the field box checked might help you.

37 Level 1 set up:

38 Level 2 set up:

39 Level 3 set up (only for those who like a challenge!):

Ohm's Law Pre-Lab Prep **($\varepsilon = IR$)**

You must show all your work to receive credit. You must indicate the formula, and then rewrite the formula with the numbers. Show all mathematical steps!

1) If the voltage is 12 V and the resistance in the wire is 3 Ω, what is the current in the circuit?
   A. 6 Amps
   B. 2 Amps
   C. 12 Amps
   D. 4 Amps
   E. 36 Amps

2) If the resistance in the circuit is 10 Ω and the current is 3 Amps, what is the voltage of the battery?
   A. 3 V
   B. 10 A
   C. 30 V
   D. 3.33 V
   E. 0.3 V

3) If you connect a 7 V battery to a wire and measure the current to be 2 mA, what is the resistance of that wire?
   A. 35 V
   B. 14 A
   C. 14 Ω
   D. 3500 Ω
   E. 2000 Ω

4) If you connect a wire with 18 Ω of resistance to a battery, and measure the current to be 10 A, what is the voltage of the battery?
   A. 18 Ω
   B. 1.8 V
   C. 240 V
   D. 190 A
   E. 180 V

5) If the voltage of the battery is 5 V and the resistance in the circuit is 2.5 Ω, What is the current?
   A. 2 A
   B. 12.5 A
   C. 2.5 A
   D. 50 V
   E. 0 V

6) What is the resistance in the circuit that is connected to a 63 V battery, and is measured to have a current of 9 A.
   A. 10 A
   B. 7 Ω
   C. 657 Ω
   D. 63 Ω
   E. 7 V

7) If the current equals to 14 A and the resistance is 3 Ω, what is the voltage of the battery?
   A. 4.66 V
   B. 10 A
   C. 42 V
   D. 3 V
   E. 26 Ω

8) What would happen to the current in the circuit. if the voltage increases?

9) What will happen to the current. if the resistance increases?

Power (P = VI) (You must show all your work to receive credit!)

Calculate the Power for Problems 1 – 7 on the previous page. Remember to include units!

10)______________________

11)______________________

12)______________________

13)______________________

14)______________________

15)______________________

16)______________________

Hands-on Laboratory
Topic 09 – Electricity

MATERIALS

metal plate	small neon light bulb
piece of wool cloth	insulated connecting wire
Styrofoam	resistance coil set
power supply holder	4 - pieces of insulated wire
3 - 6 volt light bulbs	2 - black banana plug wires
3 - bulb holders	2 - red banana plug wires
multi range multimeter	packing "peanut"
6 volt power source	
Masking tape	1 balloon and clips

PROCEDURE

The pre-lab prep is found on the previous 2 pages.

Part A - Static Electricity

Rubbing - The Mystery Balloon

1. Inflate a balloon, and then use marker to make three lines, evenly spaced around the balloon. Number the lines 1, 2, and 3.
2. Allow small pieces of paper or Styrofoam to fall on the three lines placed on the balloon to determine if there is a charge at these positions on the balloon.
3. Give the marked balloon and the wool cloth to another person. That person should, without you seeing, rub the balloon along only one of the three lines being careful to handle the balloon by the knot and return the balloon to you.
4. Test each of the three lines placed on the balloon by allowing small pieces of paper or Styrofoam to fall on each line to determine the location of the charge placed on the balloon.
5. Describe the production of static charge through rubbing and the movement of static charge on a non-conductor such as the rubber balloon.

Contact - The Repulsive Peanut

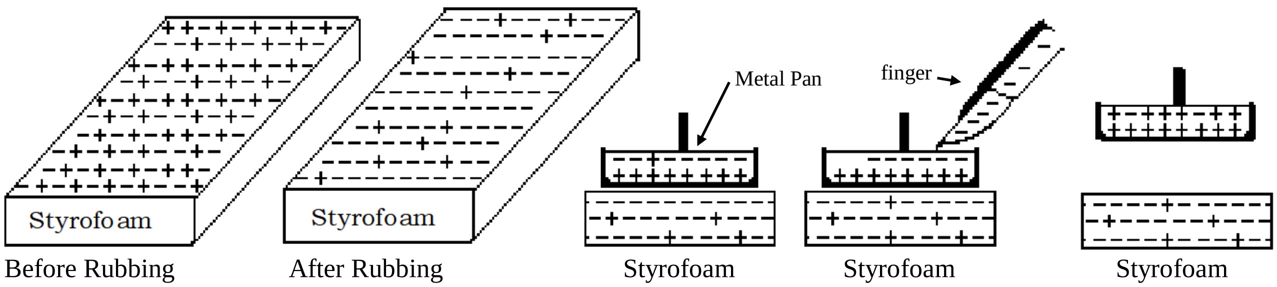
1. Attach a piece of string to packing "peanut" and suspend. Then inflate a balloon.
2. Bring an uncharged balloon near the suspended packing "peanut" and observe the packing "peanut".
3. Charge a balloon by rubbing with a piece of wool.
4. Bring a charged balloon near the suspended packing "peanut" and observe the reaction.
5. Describe the transfer of static charge produced through contact.

Induction - The Attractive Yard Stick

1. Obtain a yardstick and balance a yardstick on a ping pong ball which has been placed on a film canister.
2. Bring an uncharged balloon near the end of the yardstick.
3. Describe the motion of the yardstick.
4. Rub a balloon with a wool cloth to place a charge on the balloon.
5. Bring the charged balloon near the end of the yardstick.
6. Describe any motion of the yardstick.
7. Describe the induction of charge in the yardstick by the charged balloon.
8. Run water over your hands. Remove the excess water and touch the rubbed side of the balloon with your damp hand. Next place the rubbed side of the balloon near the end of the yardstick. Describe and explain your observations using the electrical charges of the balloons.
9. Describe what the effect of damp weather would be on static electricity.

Part B - Bringing the Three Ways of Producing Static Charges Together

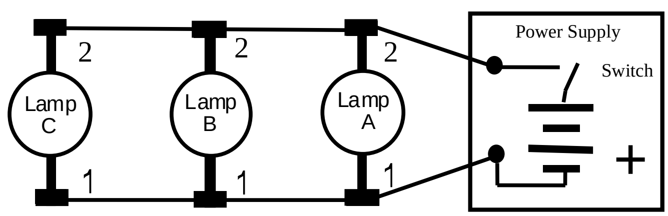
1. Vigorously rub a piece of Styrofoam with the wool cloth. (See diagram.) This will transfer electrons to the Styrofoam. (*Rubbing*)
2. Obtain a metal pie pan with a handle in the center. Using your right hand place the metal pan near but not touching the Styrofoam. (*Induction*)
3. With the pan near, but not touching, the Styrofoam touch the *upper surface* of the pan with your left hand. Observe a small spark as you finger touches the pan. (*Contact*)



4. Lift the pan away from the Styrofoam while still holding the pan with your right hand.
5. Slowly approach the *bottom surface* of the pan with a fingertip of the left hand. Observe and record what happens. Steps 2-5 may be repeated several times.
6. Repeat steps 1-4 once again but this time hold one of the two wires of a small neon light bulb between your thumb and index finger. Touch the other wire to the pan and then record your observation. This can also be repeated several times while rubbing the Styrofoam only once.
7. Explain why this happens, in terms of the electrical charge of the pan.
8. Rub a balloon suspended from a string with the wool. Bring the pan near the balloon and describe what happens. Explain. using the electrical charges of the balloon and the pan.

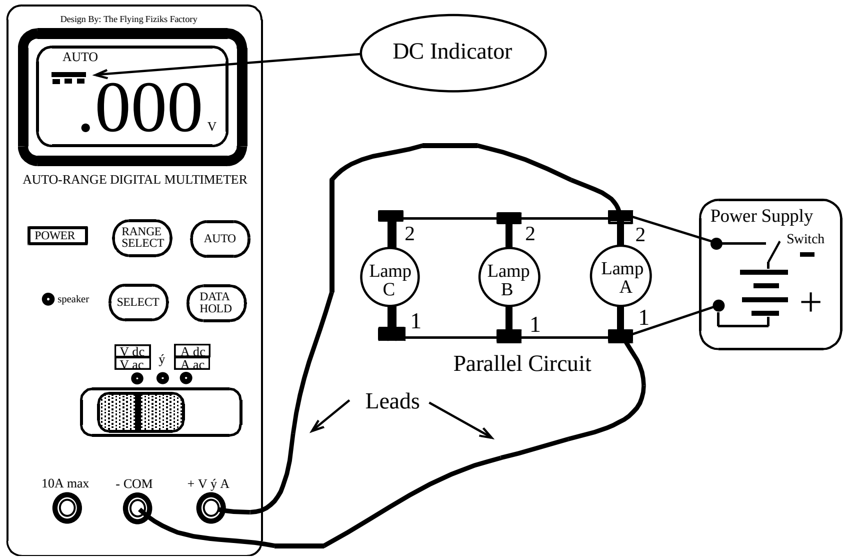
Part C - Electric Circuits

Section 1 - Identifying the Characteristics of Parallel Circuits



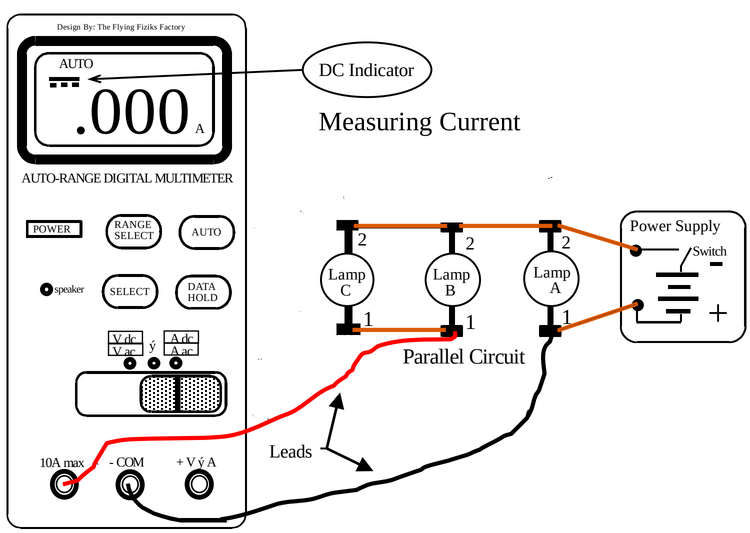
Note: a parallel circuit arranges the electrical devices so that the like poles or connectors are connected to a single conductor.

1. Note that each bulb has a connector. Attach wires between the connectors as indicated in the circuit above using the 6-volt power supply or battery pack.
2. Close the switch (push the button on the power supply) and record your observations of the brightness of the bulbs.
3. Unscrew lamp A enough to break the circuit - so that the lamp will no longer light. Describe how the other two lamps are affected. Replace the lamp when finished.
4. Next, unscrew lamp B. Is lamp C affected?
5. Set up the equipment as indicated to measure voltage.
   - turn on multimeter
   - select Voltage
   - push/slide the button labeled “SELECT” to DC
   - plug one lead into -COM and the other lead into +VΩA
   - make sure AUTO is indicated



Measuring Voltage

6. Screw in the bulbs and using a voltmeter, and the drawing, measure the voltage across each lamp. Attach the leads of a voltmeter at: A_1A_2 then B_1B_2, then C_1C_2, and then across the power supply.
   a. How does the voltage across the lamps compare?
   b. How does the voltage of each lamp compare with the voltage of the power supply?
7. With the voltmeter attached at C_1C_2 measure the voltage with three, two, one and zero bulbs screwed in or connected. (Replace all bulbs when done)
8. To measure the current in the circuit set up the equipment as indicated.
   - turn on multimeter
   - select ammeter
   - push the button labeled “SELECT” to select DC
   - plug one lead into -COM and the other lead into 10A
   - make sure AUTO is indicated



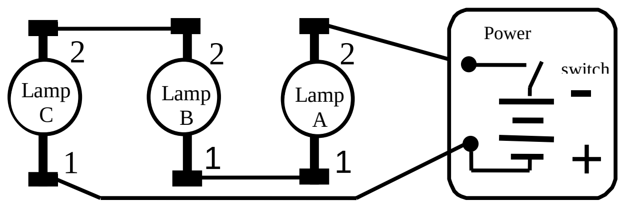
9. Using a multimeter measure the current in the circuit with the multimeter connected between points: A_1B_1 then B_1C_1 and finally connected between A_1 and the power supply.

*To obtain the current reading the ammeter must be placed **in** the circuit forcing the current to flow through the meter. To do this, remove the wire between the indicated points, i.e. A_1B_1, and connect the ammeter between points A_1B_1 as indicated in the drawing. Obtain your reading and replace the wire, A_1B_1.*

To obtain the current through lamp A, take the current of the Power Supply and subtract the current that you measured for lamps B & C. To obtain the current through lamp B take the current through Lamps B & C and subtract the current going through lamp C. The current thorough lamp C is ust the current you measured through lamp C.

10. Describe the current throughout the circuit.
11 With the ammeter between A_1 and the power supply measure the current with three. two and one bulbs lit. How does the current change?

Section 2 - Identifying the Characteristics Series Circuits

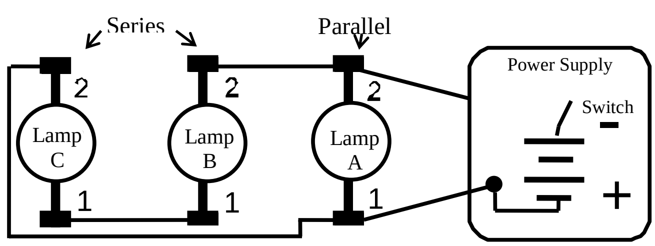


Note: in a series circuit the electrical devices are arranged so that the current flows through every component in a sequential manner

1. Wire the circuit as indicated above using the 6-volt power supply.
2. Close the switch (push the button on the power supply) and record your observations.
3. Unscrew lamp A enough to break the circuit - so that the lamp will no longer light. Describe how the other two lamps are affected then tighten lamp A. Next, unscrew lamp B. Is lamp C affected? When done screw in the bulbs.
4. Using a multimeter, measure the voltage across each lamp by placing the leads (wires) of a voltmeter successively at points A_1A_2, then B_1B_2, then C_1C_2, and then power supply.
   a. How does the voltage across the lamps compare?
   b. How does the voltage of each lamp compare with the voltage of the power supply?
5. With the voltmeter between points A_2C_1 measure the voltage with three, two, one and zero bulbs screwed in or connected. How does the voltage change? (Replace all bulbs when done)
6. Using a multimeter, measure the current in the circuit between points A_1B_1, B_2C_2, and A_2 and the power supply.

   *To obtain the current reading the ammeter must be placed **in** the circuit forcing the current to flow through the meter. To do this, remove the wire between the indicated points, i.e. A_1B_1, and connect the ammeter between A_1B_1. Obtain your reading and replace the wire.*
7. Describe the current throughout the circuit.
8. With the ammeter between A_2 and the power supply measure the current with three, two and one bulbs lit. How does the current change?

Section 3 - Applying the Characteristics of Parallel and Series Circuits



Note: This parallel and series circuit combines the characteristics of both the series and parallel circuits.

1. Wire the circuit as indicated above using the 6-volt power supply.
2. Close the switch (push the button on the power supply) and record your observations.
3. Unscrew lamp A enough to break the circuit - so that the lamp will no longer light. Describe how the other two lamps are affected. Replace the lamps when finished.
4. Unscrew lamp B. Is the other lamp affected? When finished screw in the lamps.

5. Using a multimeter setup to measure voltage, measure the voltage drop across each lamp by placing the leads of a voltmeter successively at points A_1A_2. then B_1B_2, then C_1C_2, and then across the power supply (A_1A_2).
   a. How do the voltage drops across the lamps compare?
   b. How do the voltage drops of each lamp compare with the voltage of the power supply?
6. Using a multimeter, measure the current in circuit with the multimeter connected between points: A_2B_2 then B_1C_1 and then connected between A_1 and the power supply.

   *To obtain the current reading the ammeter must be placed **in** the circuit forcing the current to flow through the meter. To do this, remove the wire between the indicated points, i.e. A_2B_2, and connect the ammeter between A_2B_2. Obtain your reading and replace the wire.*
7. Using your previous observations concerning series and parallel current calculate the current for each bulb in this circuit (C, B, and A).
8. Describe what happens with voltage and current in this circuit.

Part D - Comparing Series and Parallel Circuits

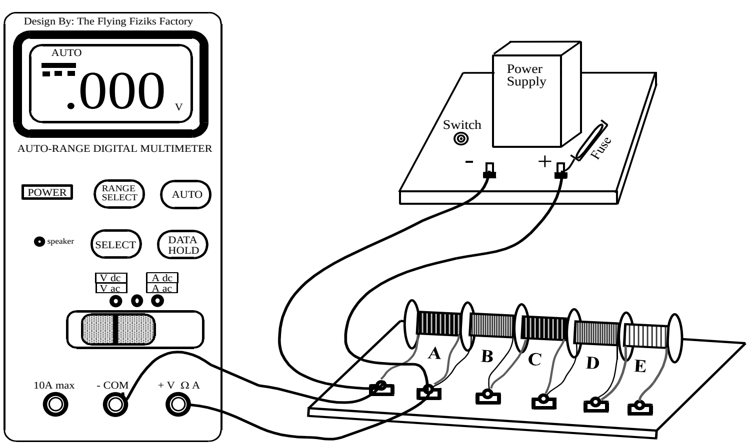
1. Which circuit, (series or parallel) is the brightest?
2. Which circuit, (series or parallel) is the dimmest?
3. From which circuit, (series or parallel) did removing one bulb cause the others to go out?
4. From which circuit did removing one bulb not cause the others to go out?
5. List the general requirements needed for any circuit to function.
6. Describe and compare voltage in parallel and series circuits.
7. Describe and compare current in parallel and series circuits.

Part E - Ohm's Law

Section 1 - Problem: How can we measure volts, current, and resistance?

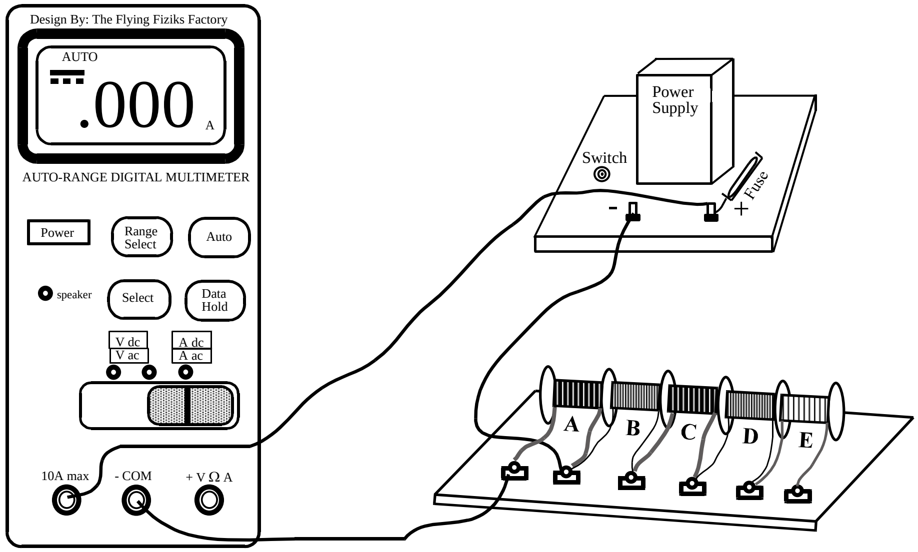
1. Set up the equipment as indicated to measure voltage for each coil in the circuit.
   • turn on multimeter
   • select Voltage
   • push the button labeled “SELECT” to select DC
   • plug one lead into -COM and the other lead into +VΩA
   • make sure AUTO is indicated

2. Obtain voltage readings for each resistance coil (A, B, C, D, E) by connecting a multimeter, set for voltage, in parallel. using the following circuit.



Measuring Voltage

3. Obtain ammeter readings for each resistance coil. To measure the current in the circuit set up the equipment as indicated.
   • turn on multimeter and select Ammeter
   • push the button labeled “SELECT” to select DC
   • plug one lead into -COM and the other lead into 10A max.
   • make sure AUTO is indicated



Measuring Current

4. Calculate the resistance for each resistance coil, using the following formula:
   Resistance (ohms) = Voltage (volts) / Current (amperes)

Section 2 - Problem: Does resistance depend on length?

1. Compare the resistance for coils A and C. (They differ only in length)
2. Make a statement on the effect of length on resistance.
3. Compare the resistance for coils B and D to verify the above statement.

Section 3 - Problem: Does resistance depend on diameter?

1. Compare the resistance for coils A and B. (They differ only in diameter)
2. Make a statement explaining the effect of diameter on resistance.
3. Compare the resistance for coils C and D to verify the above statement.

Section 4 - Problem: Does resistance depend on substance?

1. Compare coils A and E. (They differ only in the substance from which they are made)
2. Make a statement explaining the effect of substance on resistance.

Part F - Problem: How many watts is each coil using?

1. Power is defined as the electrical power. The mathematical relationship is: Voltage multiplied by current being used.
   P (Watts) = ϵ (Volts) x I (Amperes)
2. Calculate the power for each coil.
3. Using your data from part C, calculate the power for the three light bulbs.

• 09 •
ELECTRICITY

			09
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Name	Section #	Kit #	Topic #

Part A - Static Electricity (Charge a balloon.)

Rubbing

1.(5) Describe the production of static charge through rubbing. _____

2.(5) Describe the movement of static charge on a non-conductor._____

Contact

3.(5) Describe the motion of the "peanut" and the transfer of static charge produced through contact. _____

Induction

4.(3) Motion of the yardstick with uncharged balloon. _____

5.(6) Motion of the yardstick with charged balloon. _____

6.(7) Describe the induction of charge in the yardstick by the charged balloon. _____

7.(6) What happens when a charged balloon is rubbed with a damp hand? _____

8.(6) What is the effect of damp weather? _____

Part B - Bringing the Three Ways of Producing Static Charges Together

1.(5) What happens when finger touches pan? _____

2.(6) What happens when bulb touches pan? _____

3.(7) Why does this happen? _____

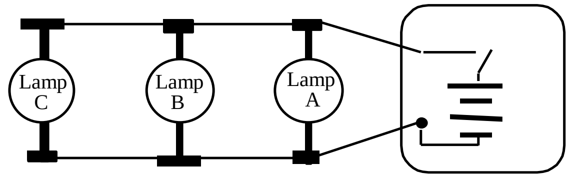
Part C - Electric Circuits

Section 1 - Identifying The Characteristics Of Parallel Circuits

1.(2) Describe the bulbs with circuit closed. _____

2.(3) Describe the bulbs with bulb A unscrewed _____

3.(4) Describe the bulb with bulb B unscrewed _____



Parallel Circuit

4.(6)

Location	Voltage
A_1A_2 -- Lamp A	
B_1B_2 -- Lamp B	
C_1C_2 -- Lamp C	
Across Power Supply (Entire Circuit)	

5.(6a) How does the voltage across the lamps compare? _____

6.(6b) How does the voltage of each lamp compare with the voltage of the power supply? _____

7.(9)

Location	Current	bulb	Current
A_1B_1 -- Lamps B & C		A	
B_1C_1 -- Lamp C		B	
A_1 Power Supply -- Lamps A & B & C (Entire Circuit)		C	

8.(10) Describe the current throughout the circuit _____

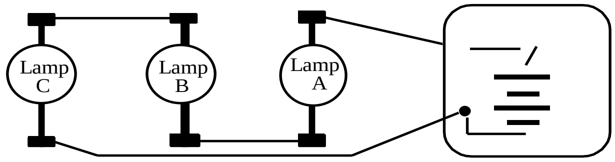
How does the current change? _____

Section 2 - Identifying the Characteristics of a Series Circuits

1.(2) Describe the bulbs with circuit closed _____

2.(3) Describe the bulbs with bulb A unscrewed _____

3.(3) Describe the bulb with bulb B unscrewed _____



Series Circuit

4.(4)

Location	Voltage
A_1A_2 -- Lamp A	
B_1B_2 -- Lamp B	
C_1C_2 -- Lamp C	
Across Power Supply -- (Entire Circuit)	

5.(4a) How does the voltage across the lamps compare? _____

6.(4b) How does the voltage of each lamp compare with the voltage of the power supply? _____

Describe how the voltage changes? _____

7.(6)

Location	Current
A_2B_2 -- Lamps B	
B_1C_1 -- Lamp C	
A_1 Power Supply -- Lamps A & B & C (Entire Circuit)	

8.(7) Describe the current throughout the circuit. _____

How does the current change ? _____

Part D - Comparing Series and Parallel Circuits

1.(1) Which circuit (series or parallel) is the brightest? _____

2.(2) Which circuit (series or parallel) is the dimmest? _____

3.(3) From which circuit did removing one bulb cause the others to go out? _____

4.(4) From which circuit did removing one bulb not cause the others to go out? _____

5.(5) List the general requirements needed for any circuit to function. _____

6.(6) Describe and compare voltage in parallel and series circuits _____

7.(7) Describe and compare current in parallel and series circuits. _____

Part E - Using Ohm's Law ε = IR

Section 1 - How can we measure voltage. current. and resistance?

	Resistance Coils				
Description	**A** or **1**	**B** or **2**	**C** or **3**	**D** or **4**	**E** or **5**
Length	10m	10m	20m	20m	10m
Wire Diameter (Gauge)	22	28	22	28	22
Substance	Copper	Copper	Copper	Copper	German Silver
Voltage (Volts)					
Current (Amperes)					
Resistance (Ohms)					

Note: Number 22-gauge wire has twice the diameter of number 28 gauge wire.

Section 2 - Does resistance depend on length? __________

1. (1) Compare the resistance for coils A and C. _____

2. (2) What is the effect of length on resistance? _____

3. (3) Compare the resistance for coils B and D. _________

Section 3 - Does resistance depend on diameter? ___________

1. (1) Compare the resistance for coils A and B. _____

2. (2) What is the effect of diameter on resistance? _____

3. (3) Compare the resistance for coils C and D._________

Section 4 - Does resistance depend on the kind of material? __________

1. (1) Compare coils A and E. _______

2. (2) What is the effect of material on resistance? _____

Part F - How much Power? $P = \varepsilon \times I$

Resistance Coils

Coil	Voltage (Volts)	Current (Amperes)	Power (Watts)
A			
B			
C			
D			
E			

Parallel Circuit

6.(3) Parallel Circuit

Bulb	Voltage (Volts)	Current (Amperes)	Power (Watts)
A			
B			
C			

Series Circuit

7.(3) Series Circuit

Bulb	Voltage (Volts)	Current (Amperes)	Power (Watts)
A			
B			
C			

ELECTRICITY
Self-Evaluation
Test 091

1. 09.1 A device that protects a circuit from being overloaded is called:
A. generator
B. electroscope
C. electrolyte
D. ohmmeter
E. fuse

2. 09.1 The current which flows in one direction and then the other is called:
A. ampere
B. direct
C. alternating
D. static

3. 09.2 Like static charges ______ each other. and unlike charges _______ each other.
A. attract. attract
B. repel. repel
C. attract. repel
D. repel. attract

4. 09.2 Which of the following explains why a balloon rubbed with wool will stick to a wall?
A. like charges attract
B. rubber is always attracted to walls
C. unlike charges attract
D. the air in the balloon is attracted to the wall
E. some strands of the wool adhere to the balloon and stick to the wall

5. 09.3 Which of the following explains what happens if a light in a series circuit is removed (and nothing else is changed)?
A. the rest of the lights become dimmer
B. the rest of the lights become brighter
C. the rest of the lights are not changed
D. the rest of the lights go out
E. the fuse will blow out

6. 09.3 Which of the following explains what happens if a light in a parallel circuit is removed (and nothing else is changed)?
A. the rest of the lights become dimmer
B. the rest of the lights become brighter
C. the rest of the lights are not changed
D. the rest of the lights go out
E. the fuse will blow out

7. 09.4 How is a voltmeter connected in a circuit?
A. connected in series
B. connected in parallel
C. magnetic induction
D. only to the high scale
E. none of the above

8. 09.4 How is an ammeter connected in a circuit?
A. connected in series
B. connected in parallel
C. magnetic induction
D. only to the high scale
E. none of the above

9. 09.5 Given a voltage of 120 V. and a resistance of 8.9 ohms, what is the current?
A. 120 amps
B. 1.52 amps
C. 22.4 amps
D. 4.6 amps
E. none of the above

10. 09.5 Given a resistance of 0.5 ohms, and a current of 7.0 amperes, what is the voltage?
A. 7.5 volts
B. 3.5 volts
C. 10.5 volts
D. 14 volts
E. 12.0 volts

11. 09.6 If the diameter of a resistor wire were increased, one would expect the resistance to:
A. increase
B. decrease
C. stay the same
D. double
E. none of the above

12. 09.6 If the length of a resistor wire were increased, one would expect the resistance to:
A. increase
B. stay the same
C. decrease
D. double
E. none of the above

13. 09.7 If you have a 15 ampere fuse, (which will burn out at exactly 15 amps), on a 120 volt line, what is the maximum number of 100 watt light bulbs can you light before the fuse blows?
A. 1
B. 6
C. 12
D. 17
E. all you want

14. 09.7 How much power is being used if the voltage is 12.1V and the current is 7.3 A?
A. 19.4 watts
B. 88.3 watts
C. 6.66 watts
D. 53.3 watts
E. 146.4 watts

MAGNETISM

Topic 10

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct term.

   armature, commutator, diamagnetic materials, domains, electromagnet, ferromagnetic materials, frequency, generator, hertz, insulators, inverse square law, magnet, magnetic declination, magnetic field, magnetism, north pole, south pole, paramagnetic materials,

2. Given a set of materials identify the magnetic and nonmagnetic materials.
3. State or identify the Law of Magnetism and apply it to the Earth's magnetic field.
4. Identify the geometry, or shape, of the magnetic field surrounding a magnet or a combination of magnets.
5. Describe the structure of a magnet at the atomic and domain level.
6. Identify or explain the relationship between flowing electrons and the production of a magnetic field.
7. Identify or explain the relationship between a moving magnetic field and the production of electricity.
8. Identify or explain why the phrase *intensity falls off with the square of the distance* can be used to describe the strength of the force surrounding a magnet, in the same way it can be used to describe light, gravitational, or electric fields. Apply and use the Inverse Square Law, to determine strength, as presented in this topic.

   Strength of Force at point B = Strength of Force at point A x (distance to A)^2 / (distance to B)^2

9. Identify or explain how a direct-current electric motor works applying the magnetic principles in this unit.

INTRODUCTION

Building a Model of Magnetism

The Magnetic Nature of Matter

More than 2000 years ago, an iron ore called magnetite was discovered to be able to attract small bits of iron. The term magnetism came to be applied to the force of attraction or repulsion between certain substances. If you were to investigate all the known materials, you would find that most materials fall in the following classifications

diamagnetic materials – these are materials that are not attracted to a magnet and are sometimes referred to as nonmagnetic materials.

paramagnetic materials – these materials are weakly attracted to a magnet; however, the attraction may be so weak it is not even noticeable. These are commonly referred to as nonmagnetic materials also.

ferromagnetic materials – these are materials such as magnetite, those do-dads and souvenirs we prominently display on our refrigerator doors, and any other materials that can be used to produce a "permanent magnet". These are also the kinds of materials that are most strongly attracted to a permanent magnet.

Permanent magnets are pictured as being surrounded by a magnetic field. When one permanent magnet is brought into the vicinity of another permanent magnet, the magnetic fields of the two interact with each other. It is this interaction of the magnetic fields that causes the attraction and repulsion that we observe between the magnets. When any "magnetic material" is brought into the vicinity of a magnet, the magnet induces a "temporary magnetic field" in the material causing an attraction of the material to the magnet. This is possible because of "things" that are happening at the atomic level (which we will look at later). When a "nonmagnetic material" is brought into the vicinity of a magnet, the same "things" do NOT happen (at least not to the same degree) and there is no resulting attraction between the material and the magnet. Our first goal is to determine which materials are magnetic and which are not.

The Law of Magnetism

When one investigates various materials to determine which are magnetic materials and which are not you may notice that all of the magnetic materials are "attracted" to the magnets, none were repelled. However, we all know that sometimes magnets attract each other and sometimes they repel each other. This attraction or repulsion (and why it is sometimes one and sometimes the other) is known as the Law of Magnetism.

Magnetic Fields

We can determine the magnetic field surrounding a magnet by using another magnet, such as a directional compass, to physically plot the field. The simplest form of the compass is a magnetic needle mounted on a pivot in such a way that the needle can move freely. The compass needle, when placed in an external magnetic field, will align itself in the direction of the external magnetic field.

As we move the compass around a magnet, the needle will stay in line with the direction of the magnetic field. We picture the field as a group of imaginary lines pointing in the direction shown by the compass. These imaginary lines curve from the north pole of the magnet to the south pole of the magnet. (These field lines are actually closed loops, with part of the loop inside the magnet and another part forming the magnetic field outside the magnet.)

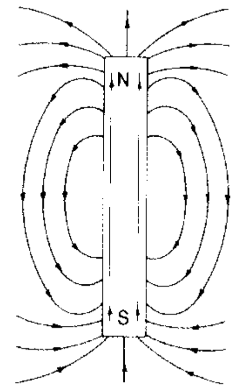
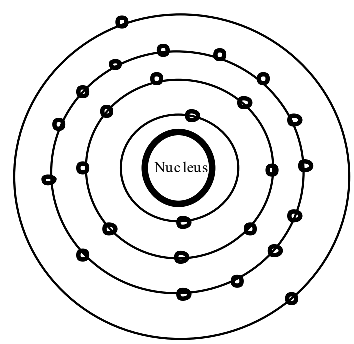


Figure 1

The Structure of Magnets

To understand magnetic materials, one first has to consider the structure of the atom. Our model of the atom includes the dense core (or the nucleus) containing the positively charged protons and the electrically neutral neutrons. Surrounding the nucleus and orbiting around it like the planets orbiting the sun, are the negatively charged electrons. As these electrons orbit the nucleus we picture them spinning, or rotating, in much the same way the Earth spins on its axis, thus, the electrons are said to have "spin" (sometimes referred to as atomic spin. or magnetic spin). These motions of the electrons produce a magnetic field (in fact, it is one of the great scientific discoveries of all time that a moving electric charge produces a magnetic field).



Iron
Figure 2

Thus, each moving electron generates its own magnetic field. In atoms with two or more electrons, each electron is "paired together" with another electron (except for the occasional lone electron that has no one to pair up with). These two electrons have almost the same energy and are said to occupy the same energy level, or orbit (in fact, this is why they are said to be paired). The electrons in each pair usually have opposite spins, and their magnetic fields cancel each other out. However, in atoms of magnetic elements (such as iron, nickel, and cobalt), the fields do not cancel each other but instead reinforce each other (the spins are in the same direction) and, in effect, create a "tiny magnet". These materials are the "ferromagnetic materials" we spoke of earlier, (The Latin word for iron is fermium. from which we get ferromagnetic). In these materials there is also a strong interaction, or coupling, between neighboring atoms. This strong interaction results in large groups of atoms with their electron spins pointing in the same direction. These large groups of atoms are called magnetic domains.

Magnet Domains

The strength of a magnet is dependent upon the number of magnetic domains that are aligned. When the magnetic domains (represented by arrows in Figure 3) are randomly arranged the material does not act as a magnet. However, when the magnetic domains in the material are lined up in the same general direction, the material does act like a magnet. The greater the alignment of the domains, the stronger the magnet.

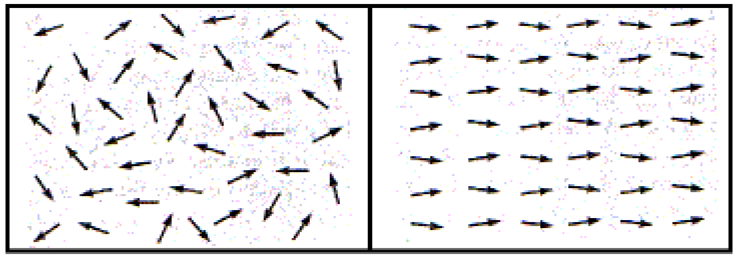


Figure 3

Models used to represent varying degrees of magnetic strength would look like those shown in Figure 4. The orderly arrangement of the tiny rectangles in the bottom picture of Figure 4 represents the arrangement of the domains necessary to produce a substance with north and south magnetic poles.

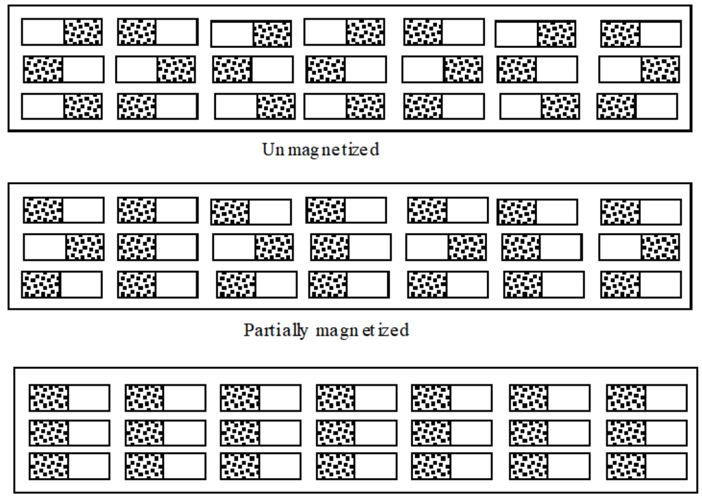


Figure 4

Stroking a magnetic material with a permanent magnet causes the magnetic domains in the material to align themselves like those at the bottom of Figure 4. The material, at least temporarily, becomes a magnet. In the activity we are about to do we will use iron filings to represent the magnetic domains. At first. these iron filings. like the magnetic domains they represent, are pointed in random directions. When stroked with the magnet, however, the iron filings line up in the same direction.

One can test our model by applying it to a piece of un-magnetized coat hanger wire (which is made up of ferromagnetic materials). If you obtained a length of coat hanger wire about 18 cm (7-in.) long and moved a compass along the wire you would note that the compass was attracted to the metal of the coat hanger. You could then magnetize the wire by stroking the wire in one direction with one pole of a bar magnet approximately twenty-five times. If you then moved a compass along the wire you would observe the direction the needle, of the compass, points as you move the compass along the length of the coat hanger.

Ordinarily the magnetic domains in the wire point in different directions, canceling each other out, and the wire is not a magnet. However, if a strong external magnetic field (from a strong magnet for instance) is placed near the wire. the magnetic domains are influenced by this field and align themselves in the same general direction as the external field itself (i.e. the magnetic field of the wire points in the same direction as the external field). Thus, we induced a weak magnetic field in the wire that wasn't there originally. This induced magnetic field is such that the wire is attracted to the magnet. However, once the influence of the strong magnet is removed the domains in the wire revert to a random orientation.

Stroking the wire with the pole of the magnet caused the domains to align themselves also, but this time the domains remained aligned (for a while at least) even after the magnet was removed. Thus, by stroking the magnet, we made the wire itself into a "temporary" magnet. The stroking action strengthened the magnetic field in the wire by forcing more of the domains to align themselves. This, in turn, helped freeze them in place also, the more domains that are aligned, the longer the material will retain its magnetic field.

Materials with many domains (ferromagnetic materials) will quickly respond to an external magnetic field and be attracted to a magnet. Ferromagnetic materials can be easily magnetized also, as we have just done. Paramagnetic materials (like aluminum and tin) and diamagnetic materials (like copper) behave a little differently. An external magnetic field will induce a magnetic field in both the paramagnetic material and the diamagnetic material; however, the induced magnetic fields are much, much weaker than the induced fields associated with ferromagnetic materials. In the paramagnetic material, the induced field is in the same direction as the external field, but in the diamagnetic material the induced field is in the opposite direction (i.e. the diamagnetic material is actually repelled by the magnet a little). Also, neither paramagnetic materials nor diamagnetic materials will retain the induced magnetic fields once the external field has been removed. Thus, these materials cannot be used to make permanent magnets.

Measuring Magnet Force - The Inverse Square Law

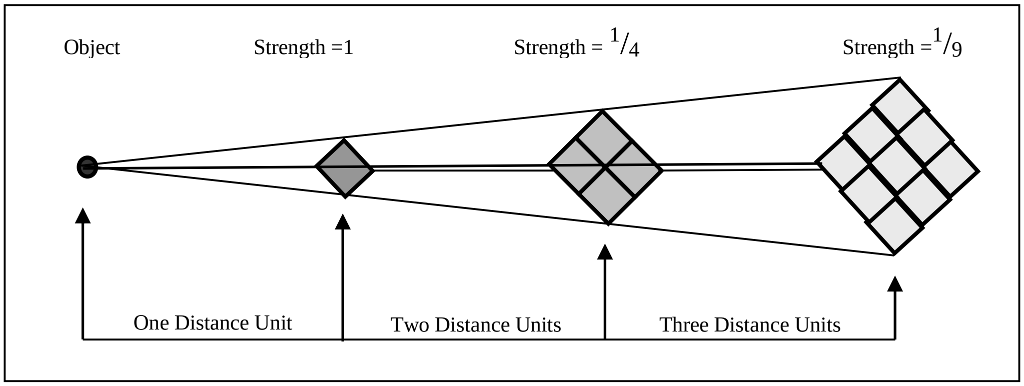


Figure 5

The intensity. force, or strength of most types of energy (such as light, sound, gravity, electricity, and magnetism) diminishes as we move away from the source. We have all seen the pattern created when a flashlight's beam spreads out as it is moved further from a wall in a darkened room. The changing intensity of this pattern is described by the Inverse Square Law. The Inverse Square Law also describes the force of attraction or repulsion that a magnet exerts on any given material under very special conditions. This law would describe a magnetic field by stating that the strength (or the intensity) of a magnetic field varies inversely with the square of the distance from the magnet. This means that if the distance (d) increases, the force strength (S) decreases by the square of the distance from the source (i.e. S is proportional to $1/d^2$). The following diagram shows this relationship.

If we are interested in determining the strength of a field at a point given the strength at another point we can use the following relationship based on the Inverse Square Law.

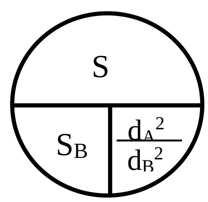
$$\frac{\text{Strength}B}{\text{Strength}A} = \frac{(\text{distance}A)^2}{(\text{distance}B)^2} \quad \text{or} \quad \frac{S_B}{S_A} = \frac{d_{A^2}}{d_{B^2}} \quad \text{or} \quad S_B = S_A \times \frac{d_A{}^2}{d_B{}^2}$$

Example 1

Determine the force strength of a field at 3 meters given a force strength of 1 Newton at 1 meter.

$$\frac{S_B}{S_A} = \frac{d_A{}^2}{d_B{}^2} \quad \text{or} \quad \frac{S_B}{1} = \frac{1^2\,\text{meter}}{3^2\,\text{meter}} \quad \text{or} \quad S_B = \frac{1}{9}$$

This relationship could be represented by the following diagram:



Example 2

Determine the force of a field at 3 meters given a force of 36 Newtons at 2 meter.

$$\frac{S_B}{S_A} = \frac{d_A{}^2}{d_B{}^2} \quad \text{or} \quad \frac{S_B}{36} = \frac{2^2\,\text{meter}}{3^2\,\text{meter}} \quad \text{or} \quad S_B = 36 \times \frac{2^2\,\text{meter}}{3^2\,\text{meter}} \quad \text{or} \quad S_B = 36\,x\,\frac{4}{9} \quad \text{or} \quad S_B = 16$$

Applying Magnetic Principles

Determining Direction and the Earth's Magnetic Field

The Earth spins on an imaginary axis that connects the North Geographic Pole and the South Geographic Pole, Near each of these poles, the Earth also has a magnetic pole. However, the situation is a little more confusing than one might expect because the magnetic properties of these poles differ from their geographic location. The north magnetic pole is actually located in the southern hemisphere of the planet while the south magnetic pole is located in the northern hemisphere. These magnetic poles act just like the ends of a magnet. The south magnetic pole is located near Bathurst Island in northern Canada, about 1.600 kilometers from the North Geographic Pole. The north magnetic pole is located in Wilkes Land, Antarctica. about 2.570 kilometers from the South Geographic Pole.

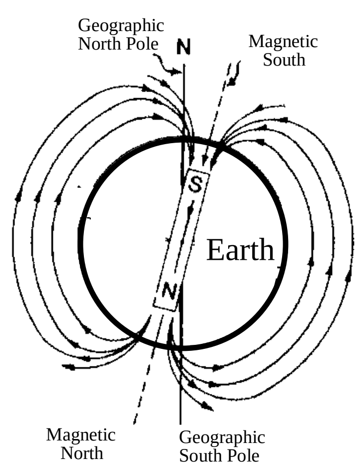


Figure 6

Because the north magnetic pole on a compass actually points northwards toward the south magnetic pole, it seldom points directly toward the geographic North Pole. The difference between the direction of the magnetic pole and the geographic pole is called the magnetic declination. The declination is different at different places on the Earth, and actually changes slightly from year to year. In order to use a magnetic compass to its fullest potential, a person must also have a declination chart. This is a chart that shows exactly what correction must be made in order to read the compass accurately. For our area, true north is approximately 6^{o} declination west of the direction given by a compass.

Magnets, Electricity, electromagnets and Oersted's Discovery

In the early 1700's, reports of lightning changing the direction of compass needles and making magnets out of objects such as knives and forks led scientists to suspect a relationship between electricity and magnetism. Danish schoolteacher Hans Christian Oersted discovered the first concrete evidence of this relationship in 1820. His discovery was quite accidental. Oersted laid the current-carrying wire of an electric circuit beside a directional compass. As he did so, he happened to notice the compass needle turning. He immediately recognized that a magnetic field must have been emanating from the wire causing the compass needle to be deflected. He also realized that the magnetic field had to be produced by the current flowing in the wire because, when the current was turned off, the needle ceased to be deflected, Oersted's discovery of the relationship between electricity and magnetism led to a very important principle: when current flows in a wire (or any other conductor), it generates a magnetic field which surrounds the wire. Wrapping the wire around a piece of soft iron can strengthen the magnetic field created by the electric current. In fact, if we wrap the wire around the soft iron core several times, we can strengthen the magnetic field tremendously. This arrangement is called an electromagnet. The iron core offers an easy path for the field inside the coil, and thus provides a minimum of magnetic resistance. In essence, the core concentrates the field and, by doing so, strengthens it. Electromagnets allow magnetism to be turned on or off at will, and are currently used in many areas of modern society.

Generator

The voltage that a generator produces can be increased in three different ways. The first way is to increase the strength of the magnet. This, of course, increases the strength of the magnetic field, and a stronger magnetic field will generate a greater current in the wire. The second way is to increase the speed at which the coil rotates. If the coil rotates faster, the magnetic field changes faster. A faster changing magnetic field will also produce more current. The final way is to increase the number of loops in the coil of wire which, as we saw earlier, also increases the amount of current in the wire.

One complete revolution of the coil is called a cycle. The number of cycles (or revolutions) that occur each second is called the frequency. The frequency is just a measure of how many times the voltage or current changes direction each second. Frequency is measured in units called hertz. One hertz equals one cycle (or revolution) per second. The electric current in most American homes has a frequency of 60 hertz.

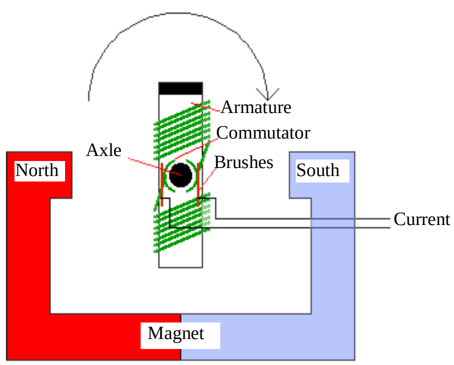


Figure 7

Motors

A generator converts mechanical motion into electric current. A motor converts electric current into mechanical motion. However, the three parts of a motor are the same as those in a generator: (1) a stationary magnet; (2) a coil, called an armature, that is free to rotate between the poles of the magnet; and, (3) a device called a commutator, which changes the direction of the current in the armature.

First, a current is passed through the armature, making it an electromagnet. The armature turns until its poles are next to the opposite poles of the magnet. The armature would stop turning (due to the magnetic attraction between the opposing poles) if the direction of the current in the armature were not reversed. The timing is such that the current reverses itself just as the N pole of the armature is next to the S pole of the magnet. The N pole of the armature now becomes an S pole (due to the change in direction of the current), and is repelled by the S pole of the magnet. Due to the repulsion, the armature makes another half-turn until its two poles are again next to the opposite poles on the magnet, The process then repeats itself until the current is turned off.

Virtual Laboratory

Topic 10 – Magnetism

		10
Section #	Date	Topic #

____

Name

Magnetism Questionnaire

Answer the following questions based upon your reading.

1. What creates a magnetic field? ____

2. How are magnetic poles labeled?

   Magnetic Poles are labeled _________ and __________ .

3. What is the magnetic polarity of the geographic North Pole of the Earth?

   The geographic north end of the Earth is the ________________ pole of a magnetic field.

   A compass needle is a magnet—it's ____________ end is marked NORTH.

4. Magnetic field is defined as going from the __________ end of a magnet to the ________ end.

5. What are the two factors that determine the strength of the magnetic field surrounding a magnet?
   ____
   ____
   ____

PHET Electromagnets:
a. Go to: http://phet.colorado.edu/simulations/sims.php?sim=Faradays_Electromagnetic_Lab.

Google **PHET Farday's Lab**. Click the Play button and then RUN NOW. **At the top of the PHET page there are 5 tabs. Click on BAR MAGNET. Please answer all questions below using complete sentences. Utilize punctuation. capitalization. and proper grammar.**

6. Here you will find a compass and a bar magnet. What do the two have in common (and the question is not asking about color)?
   ____
   ____
   ____

7. Slowly move the compass around the bar magnet. What are your observations? Explain what you are witnessing.
   ____
   ____
   ____

8. Increase and decrease the strength of the bar magnet (use slider) and continue to slowly move the compass around the bar magnet. What effect does changing the magnet's field strength appear to have on the compass?
   ____
   ____
   ____

9. Place the compass next to the South Pole of the bar magnet and press the **Flip Polarity button**. What happens to the magnet and the compass? Explain.

____
____
____

10. Click **See Inside Magnet box**. What do you see? Explain what it means.

____
____
____

11. Click **Show Field Meter** and move the meter around. In what position outside of the magnet is the magnetic field greatest? Where is it weakest? (B represents the field strength. G is the abbreviation for the Gauss unit.)

____
____
____

Click the tab for **Electromagnet. (Remember to answer questions using complete sentences.)**

12. Notice that the electrons moving through the wire loops create a magnetic field. Slide the voltage bar inside the battery to the opposite end of the battery to switch the magnetic field. A) What happens to the magnetic field if the direction of current in the wire loop is reversed? B) What happens to the strength of the magnetic field as more electrons move (as current increases)? (Use the slider bar to increase voltage.)

A. ____

B. ____

13. Slide the voltage bar in the battery. When there is no voltage the electrons are still moving randomly though you can't see the random movement in this simulation. (Since the number of electrons moving in one direction is balanced by electrons moving the opposite direction, there is no net magnetic field.) There is no magnetic field because there is no net flow of electrons. **Predict** what you think will happen if a bar magnet approaches the coil of wire. Will the movement of electrons (in the coil) cause the magnetic field to increase, decrease, or stay the same? Will the movement of electrons producing the opposite magnetic field be encouraged or discouraged? Explain your reasoning. (You will refer to this answer later.) Just do the best you can. Don't do web searches looking for the right answer.)

____
____
____
____
____
____

Click the tab for **Pickup Coil.**

14. Slowly move the north end of the magnet towards the coil. What happens to the electrons in the wire as the field in the coil of wire from the north pole of the magnet increases in strength? What happens to the light bulb?

____
____
____

15. Slowly move the north end of the magnet away from the coil. What happens to the electrons in the wire as the field from the north pole of the magnet decreases in strength?

____
____
____

16. Slowly move the south end of the magnet towards the coil. What happens to the electrons in the wire as the field from the south pole of the magnet increases in strength? (Move the magnet to the other side of the coil of wire.)

____

____

____

17. Slowly move the south end of the magnet away from the coil. What happens to the electrons in the wire as the field from the south pole of the magnet decreases in strength?

____

____

____

18. Consider your prediction from question number 13. Example: A general rule for how a pickup coil will respond to a magnetic field might be:

Electrons in a pickup coil will move to minimize the disturbance in a changing magnetic field. They will tend to move so that the polarity of the coil is opposite the change in the field.

Explain. in your own words. what you think is happening to cause the electrons to move.

____

____

____

____

At the top of the page click the **Generator** tab.

19. Turn the faucet on by sliding the bar located on the faucet.

a. How does a generator use the effect you noticed in the pickup coil to generate electrical energy?

Increase the number of loops in the box on the right.

b. What effect does changing the number of coils (loops) have on the current?

c. What energy transformations are taking place?

d. Why does this generator make an alternating current?

LABORATORY

Topic 10 – Magnetism

MATERIALS

Aluminum core	galvanometer
insulated connecting wire	small rectangular magnet
soft iron core	2 bar magnets
Wood core	Staples or small paper clips
5-meters #24 coated wire	2 large paper clips
35.0-cm #20 coated wire	30-cm number 26 enameled wire
plastic tube	small magnet
Styrofoam cup	Iron filings
small compass	Plastic lid or small bowl
Magnetic materials kit	

6 volt. 10 ampere Power source or 1.5 D cell battery Pack
1 D cell - battery

Note: If you wish to keep the motor you make. you must purchase your own rectangular magnet. 2 cm x 2.54 cm. They can be obtained from your local electronic or craft store.

PROCEDURE

Part A - Problem: Which Materials Are Magnetic?

1. If you were to test all the known materials only certain ones would be attracted by a magnet. Obtain the set of Magnetic Materials.
2. Test each one of the materials with a magnet. Identify and indicate, in the data sheet, all that you find that are magnetic. All known magnetic materials are included in the set of materials.

Note: All of the materials that were attracted to the magnet are classified as ferromagnetic materials. All the others are classified as diamagnetic or, in the case of the aluminum and tin, paramagnetic.

Part B – Problem: What is the Law of Magnetism? Pre-lab prep is to answer questions in part B.

1. Obtain the reference magnet and two unmarked magnets.
2. Set the reference magnet on the table with the Red-S side up. Adjust one of the unmarked magnets so that it is attracted to the reference magnet. Place a mark on the unmarked magnet indicating the polarity of the attracted end.
3. Adjust the second unmarked magnet so that it is also attracted to the reference magnet; place a mark on the second unmarked magnet indicating the polarity of the attracted end.
4. You have now identified (and marked) the ends of each ‘unmarked’ magnet. The sides that are now marked both behave the same with respect to the reference magnet. This means that the marked sides are similar or like poles (i.e. they are alike in nature). Bring these two recently marked ends together. Describe what happens when two like poles are brought together.
5. Bring one marked end and one unmarked (unlike) end together. Describe what happens when two unlike poles are brought together.

Note: If things worked well we should have successfully developed the Law of Magnetism: Like Poles Repel. Unlike Poles Attract. Therefore, when magnetic materials are attracted to a magnet the magnetic material must have a pole “unlike” the pole in the magnet itself. Since we have said that the magnet “induces” a temporary magnetic field in the magnetic material, this means that we can associate a magnetic pole with this induced magnetic field. Also, it seems that this induced pole is always an “unlike pole” since the materials were always attracted.

Part C - Problem: Plotting magnetic fields: (Select only one Method – Section 1 or Section 2)

Section 1 - Identifying the Magnetic Fields Using a Compass

Making a Drawing of the Magnetic Field of a Single Magnetic

1. Placing a magnet on the diagram of the single magnet in C1 of the data sheet.
2. Determine which end of your compass is the North Pole. Hint: It is the end that points to geographic north.
3. Place your compass near the starting point shown in Figure 8 below. One end of the compass needle will point toward the magnet; the other end should point directly away from the magnet. Move the compass around until the North Pole of the needle points directly away from the magnet at one of the starting points.
4. With a sharp pencil. make a dot just beyond the north pole of the compass needle as in Figure 8.
5. Move the compass again until the north pole of the compass needle points directly away from this dot.
6. With a sharp pencil. make another dot just beyond the north pole of the compass needle.
7. Continue in this manner, until the series of dots run off the paper, or returns to the bar magnet.

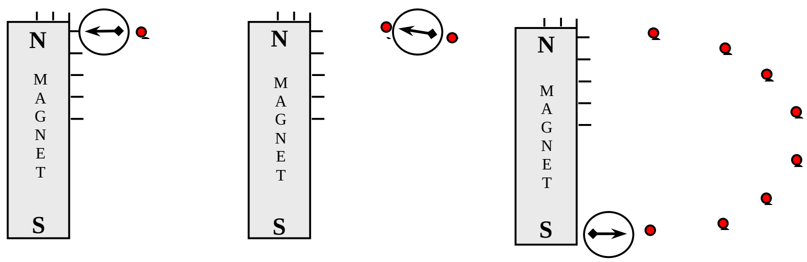


Figure 8

8. Connect the dots by a smooth line. This line is called a magnetic line of force. In the middle of the line, place an arrowhead that points in the same direction as the North Pole of the compass needle (the north pole of the compass needle will point to the south pole of your test magnet as we just learned with the Law of Magnetism). This arrowhead indicates the direction of the line of force or the magnetic field line. External to a bar magnet, the field lines exit the North end and enter the South end.
9. Repeat steps 3 - 8 for each of the other positions indicated by a dash next to the magnet on the drawing above. Steps 3 – 8 can also be done for the same positions on the other side of the magnet in figure 8. This will show the symmetry of the magnetic field surrounding the magnet and should look very similar to the magnetic field diagram shown in Figure 1. which shows the magnetic field surrounding a simple bar magnet.

Making A Drawing of The Magnetic Field Of Two Unlike Magnets

Make a drawing of the magnetic fields of two magnets with unlike poles facing one another as in C1 of the data sheet using the above procedure.

Making A Drawing of The Magnetic Field Of Two Like Magnets

Make a drawing of the magnetic fields of two magnets with like poles facing one another as in C1 of the data sheet using the above procedure.

Compare and Select:

Compare each of your drawing to the standard set of drawings provided on the data sheet, in C2, and select the drawing that matches each of your drawings.

Section 2 - Identifying the Magnetic Fields Using Iron Filings Pre-Lab Prep is to identify pictures on page 203.

1. Place a magnet(s), as indicated, on the data sheet drawing C1.
2. Place a clear plastic lid on top of the magnet(s).
3. Sprinkle iron filings on the plastic and tap the plastic with your finger. Compare the pattern produced by the iron filings to the standard set of drawings provided on the data sheet, in C2, and select the drawing that matches the pattern.

   Please remove any iron filings that might have stuck to the magnet(s) and return ***all*** the iron filings to their original container.

Part D - Problem: What is the effect of electricity upon magnetic fields?

Section 1 – What is The Effect of Electricity on the Production of Magnetism?

1. Attach the ends of the 35.0-cm #20 coated wire to the contacts of a 1.5-D cell power source. (Make sure there is a battery in the power source.)
2. Test for the presence of magnetism by aligning the wire with the needle of a compass. Close the switch and describe any movement of the needle. Please note: It is important that the wire and compass needle are parallel to one another.

3. Place the wire on a piece of scrap paper and sprinkle a small amount of iron filings onto the wire without turning on the electricity and then lift up the wire and describe what happens.
4. Return the wire to the paper and cover the wire with iron filings. Close the switch (push the button) allowing the current to flow in the wire and then, carefully, lift the wire and describes what happens.

Figure 11

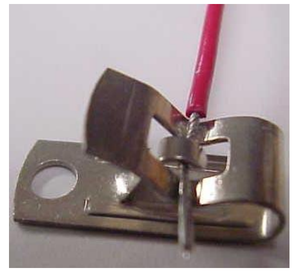


Figure 12

5. What does your comparison suggest concerning a magnetic field near a Current Caring Wire?

Section 2 - Observing the magnetic field above and below a current carrying wire

1. Remove the data sheet from the book; place the Electricity and Magnetism Device on the data sheet. Align the positive end of the wire with the positive end (look at the battery) of the wire in the drawing, E2, on your data sheet.
2. Place the compass on the top shelf next to the wire.
3. Push the power button and mark the end of the needle, in the drawing, that indicates the direction of the movement of the north end of the compass needle.
4. Move the compass around the wire. Each time record the direction of the movement of the compass needle on the drawing provided when current passes through the wire.
5. Make a statement regarding the effect of electricity on the production of magnetic fields.

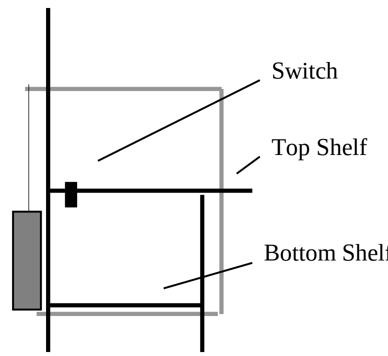


Figure 13

Part E - Problem: The Earth's Magnetic Field

1. Using a directional compass and figure 14, orient a sheet of paper to point directly north. Then remove the compass.
2. Locate the clear plastic container and place it next to figure 14 on the table. Partially fill the plastic container with water.
3. Float a magnet. Place a small magnet on the boat/Styrofoam and float them on the water as shown in figure 15.
4. The magnet and boat/Styrofoam will turn and come to rest with the magnet pointing in a specific direction. Carefully twist the boat/ Styrofoam disk, causing the magnet to point in some other direction. Now release the boat/Styrofoam and observe what happens. Record your observations.
5. Remove the plastic container, boat/Styrofoam, and magnet from the drawing and replace them with a compass.

   <u>Make sure that the magnet is not near the compass</u>.

   a. What direction did the north pole of the magnet point?

   b. In which direction does the needle of the compass point?

   c. Does the needle point in the same direction when the compass is turned?

   d. Why are the poles of a magnet named North and South?

   e. How could the North pole. and South pole be identified if the markings were removed?

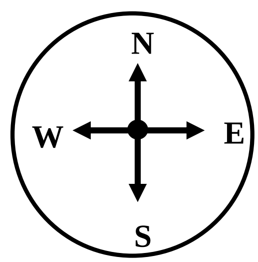


Figure 14

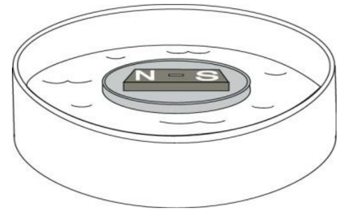


Figure 15

Part F - Problem: What is the effect of magnetism upon electricity?

1. A galvanometer is a very sensitive instrument used only to detect a very small current or voltage such as those resulting from a bar magnet passing through a coil of wire. Connect a piece of coated wire (approximately 5.0-m.) to the terminals of a galvanometer.
2. Wrap the wire five times around the plastic tube.
3. Slide a bar magnet in and out of the tube, read and record the galvanometer.
4. Take the wire and make wrappings of 10, 20. and 40 turns, being careful to read the galvanometer each time, and record your findings. Remember to leave approximately 25 cm at the ends of the wire to attach to the galvanometer.
5. Make a statement regarding the effect of magnetism upon the production of electricity.

Your results should indicate that an electric current can be generated only when there is relative motion between the wire and the magnet. No motion, no current. However, as long as the magnet or the coil was in motion relative to the other, we detected a flow of current in the wire (however slight that may have been).

If you were watching carefully as you performed step 3, you would have noticed that the needle on the compass deflected in a different direction depending on whether the magnet was moving into the coil or out of the coil. This tells us that the direction of motion of the magnet (or coil) determines the direction of flow of current in the wire. By moving the magnet in and out rapidly, we can set up an alternating current in the wire.

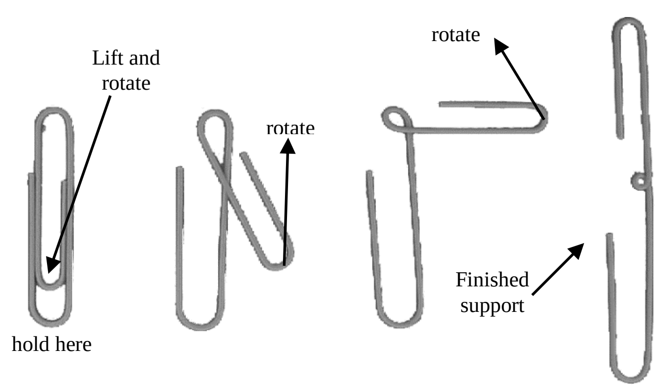
As we have just seen, moving a conductor in a magnetic field will generate an electric current in the conductor. **In fact, any device used to produce an electric current is called an electric generator.** A simple electric generator would consist of a U-shaped magnet and a coil of wire that could be rotated in the magnetic field as shown in figure 7. If you rotate the coil of wire between the poles of the magnet. an electric current is induced (generated) in the coil.

Part G - Problem: How can we determine the strength of an electromagnet?

1. Obtain approximately 5.0 meters of coated wire.
2. Place the soft iron core approximately 50 cm. from the end of the length of wire, hold the wire in place with a piece of tape, and wrap the rest of the wire tightly around the soft iron core a total of 25 turns. Note: The iron core is the core that is attracted to a magnet.
3. Connect the ends of the wire to the power source.
4. Close (turn on) the switch and bring the compass near the end of the soft iron core. Does the compass indicate the presence of a magnetic field? Notice: Close the switch only long enough to make an observation as the wire begins to heat. If the wire does heat-up stop, and allow the wire and power source to cool.
5. Pick up as many ***staples*** as you can with one end of the electromagnet, and record the number of staples that were picked up. Note: make sure to close the switch.
7. Disconnect from the power source, and carefully remove the soft iron core from the coil.
8. Insert aluminum and wood cores respectively repeating the above.
9. Repeat the above for 50, 75, and 100 turns for each.
10. Which core was the strongest?
11. How does the number of turns of wire affect the strength of an electromagnet?
12. Which combination of core and number of turns was the strongest?

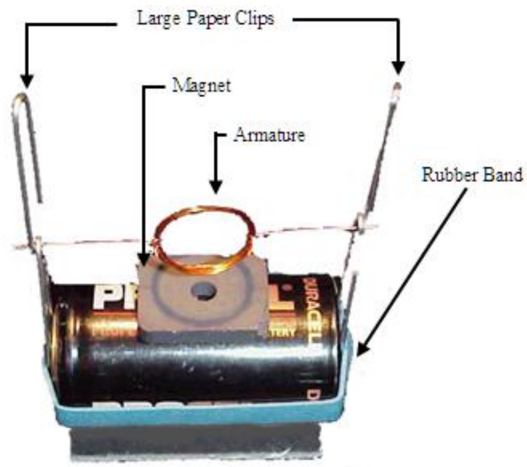
Part H - Problem: How can we make an electric motor?

1. The armature supports are made out of two ***large paper clips***. Unbend the paper clips by lifting and rotating one end to form a small loop in the center of the paper clip.
2. Use the rubber band to hold the paper clips on the ends of the battery. Adjust the loops so they are approximately 2 cm. above the battery.
3. To prevent the battery from moving, a piece (2.5-cm by 5.0-cm) of self-stick tile can be attached to the bottom of the battery.



4. The Armature is made by wrapping 30 cm. of number 26 insulated enameled copper wire 8 - 10 turns around your index finger. Wrap the ends of the wire around the coil tightly twice, leaving the ends sticking out like handles.

Make sure that the coil is balanced and will rotate smoothly.



5. The wire you used to make the armature has a coating on it. This coating must be carefully scraped off to allow the electricity to flow. Scrape off *all* the coating, at one end, and the *top surface only* at the other end. Scrape off enough of the wire so that the scraped area can make contact with the armature supports placed on the battery, ***Remember: make sure that the coil is balanced and rotates smoothly.***

6. Place the armature in the paper clip supports. Make sure that the scraped area of the armature touches the paper clips. If not readjust or re-scrape the wire.

7. Place the small magnet under the wire loop and hold it in place with a piece of tape.

8. Rotate and/or adjust the loop until it begins to work.

9. Explain how the motor works. in terms of the concepts of magnetism and electricity.

10. Give the armature to your instructor. The armature will be a good indication of the quality of your motor.

I. Graphing the Earth's Magnetic Field Intensity (Pre-lab Prep)

The Research Question: How has Earth's magnetic field changed during the last 800 thousand years?

Your hypothesis: ____

Test your hypothesis: Go to the following website to obtain the data to plot on a graph of Intensity vs. Time (Before Present Day). You will need to add the following data point that is not included on the table: The age of the Earth is 0.0 representing *today*. The Earth's magnetic field strength intensity today is 11.5 units.
http://image.gsfc.nasa.gov/poetry/venus/Revstudent.html

Scientists don't know for sure what the intensity level is that occurs with the Earth's magnetic poles reverse, but they are currently thinking it is around 2 intensity units or less. For the purpose of addressing the questions below we will assume that the field reverses for values of 2.0 units.

1. Identify the dependent variable.
2. Identify the independent variable.
3. Analyze the graph by answering the following questions.
   a. How many times has the field changed directions in the last 800 thousand years?
   b. How long ago was the magnetic field intensity least? What was the intensity?
   c. How long ago was the magnetic field intensity greatest? What was the intensity?
4. How do your results compare to your hypothesis? Explain.
5. Using your graph. predict when the next reversal will occur. Explain your reasoning.

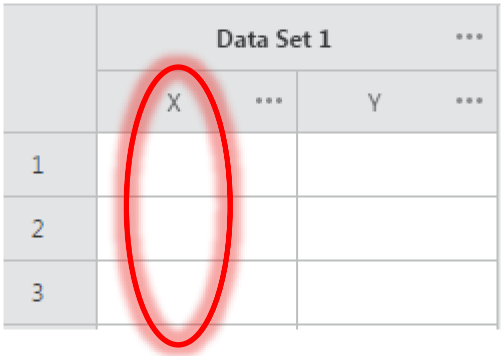
Graphing Using Graphical Analysis Program

For Topic 10 you will make 1 graph.

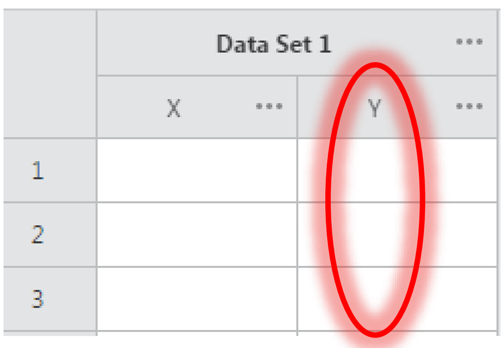
Important Note: These instructions are very different from the norm.

Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

1. Enter the X data into the table; only the numbers, not the units.

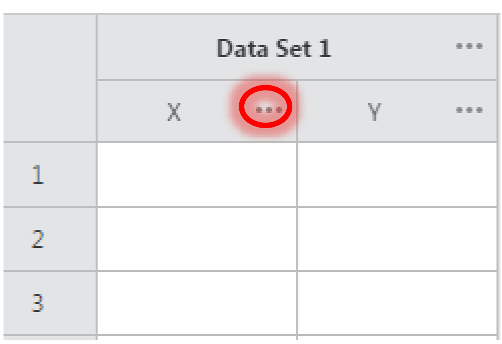


2. Enter the Y data into the table; only the numbers, not the units.

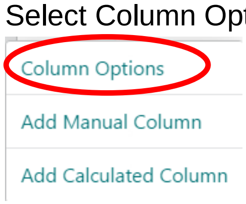


Did you remember to include that the field strength is 11.5 units at time t = 0 in your data entry?

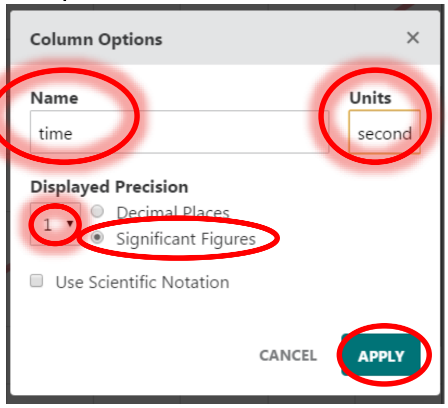
3. Click on the three dots next to X.



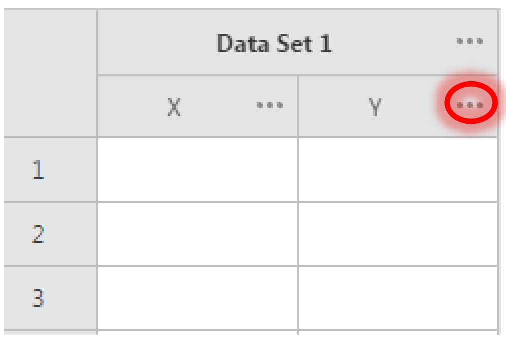
4. Select Column Options

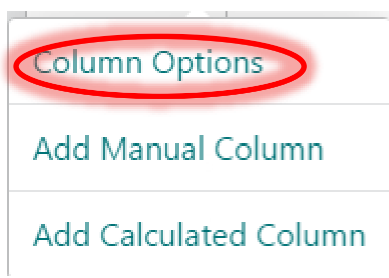


13. Type the name of the x axis (independent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



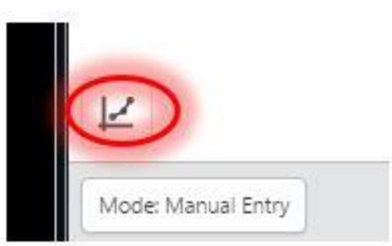
14. Repeat steps 3 – 5 for the Y axis. Click on the three dots next to Y. Select Column Options



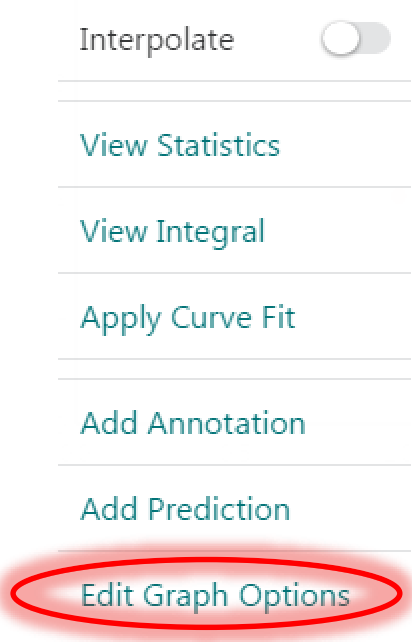


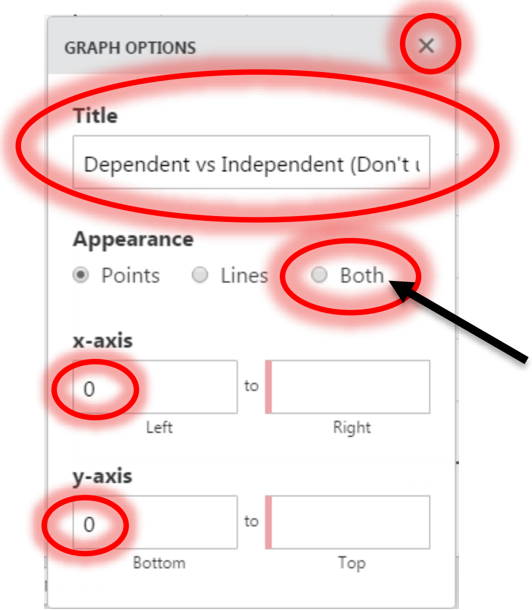
See step 5 for image. Type the name of the y axis (dependent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

15. Click on the graph icon in the lower left of the screen.



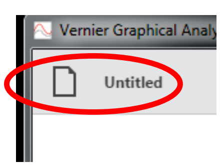
16. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to the word BOTH. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.

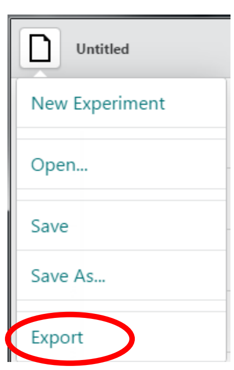


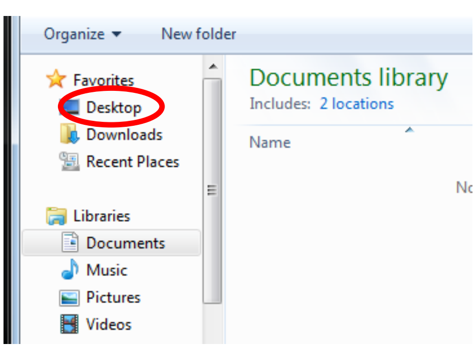


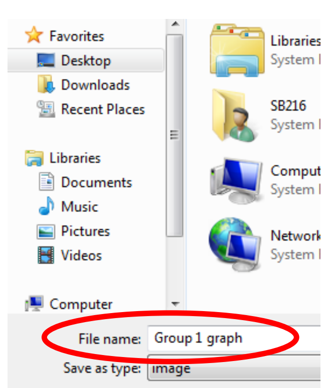
Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to insure that your graph starts with 0. 0 in the lower left corner.

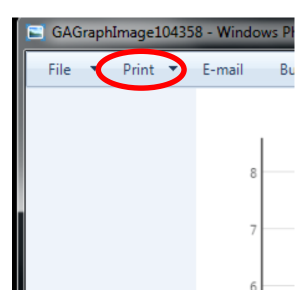
17. **Save** AND **Print** your graph(s).
Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> Magnetism Graph. Print.











• 10 •
MAGNETISM

			10
			10
			10
Name	Section #	Kit #	Topic #

Part A - Which Materials are Magnetic?

1.(2) Indicate by placing an Y or N for any magnetic materials found. Test with both ends of magnet.

Material	Magnetic (Y/N)	Material	Magnetic (Y/N)
Lead		Wood	
Steel		Rubber	
Plastic Shot		Candy Topping	
Colored Glass		Zinc	
Aluminum		Gravel	
Cobalt		Silver	
Copper		Magnesium	
Nickel		Tin	
Brass			

2. Using the above table list any magnetic materials found _____

Note: All of the materials that were attracted to the magnet are classified as ferromagnetic materials. All the others are classified as diamagnetic or paramagnetic.

Part B – What is the Law of Magnetism? Pre-lab Prep

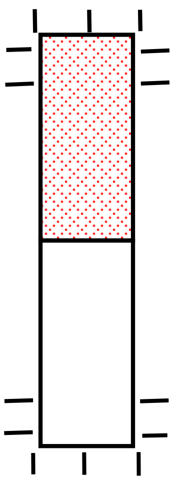
1. (4) Describe what happens when two like poles are brought together. _____
2. (5) Describe what happens when two unlike poles are brought together. _____
3. State the Law Of Magnetism. _____

Part C - Magnetic Fields:

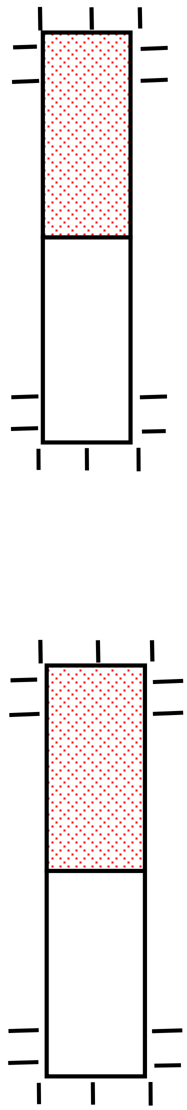
C 1 – Sketching Magnetic Fields

Note: Your lines of magnetic force will overlap between the sections. **Use a different color for each section**.

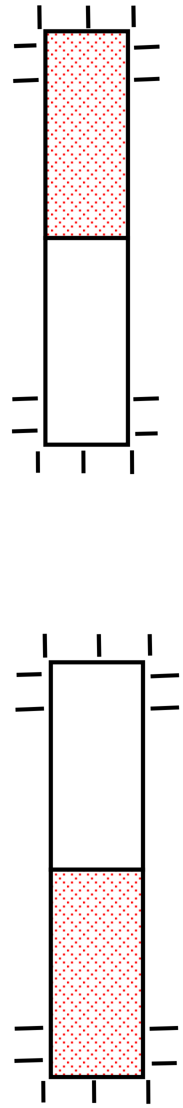
Single Magnet



Unlike Poles



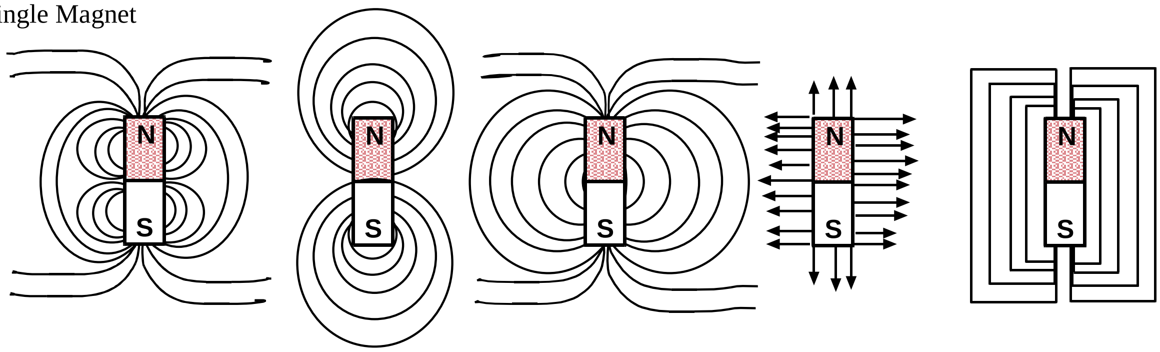
Like Poles



Summarize your findings concerning magnetic fields: ____

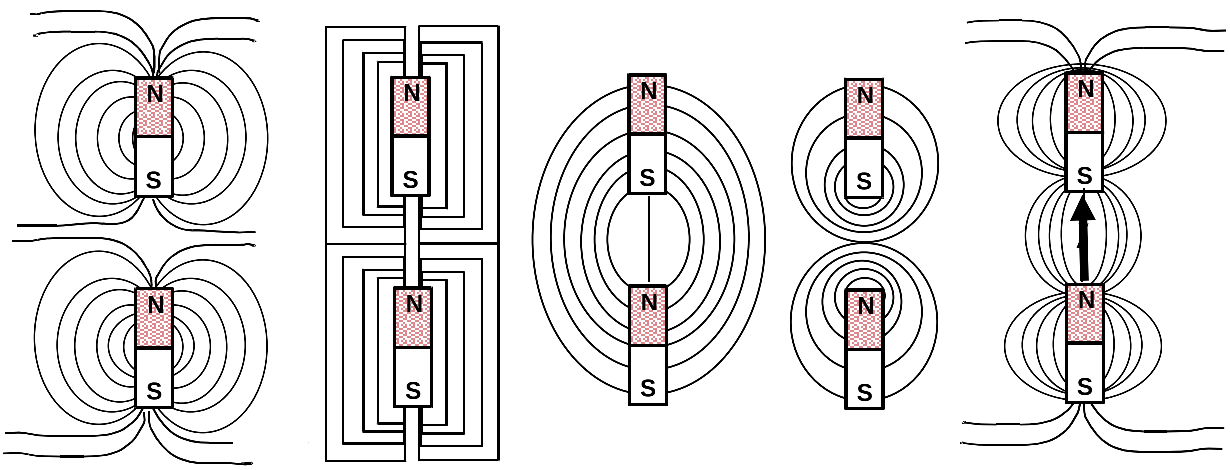
C2 – Selecting Magnetic Fields (Pre-Lab Prep)

Single Magnet



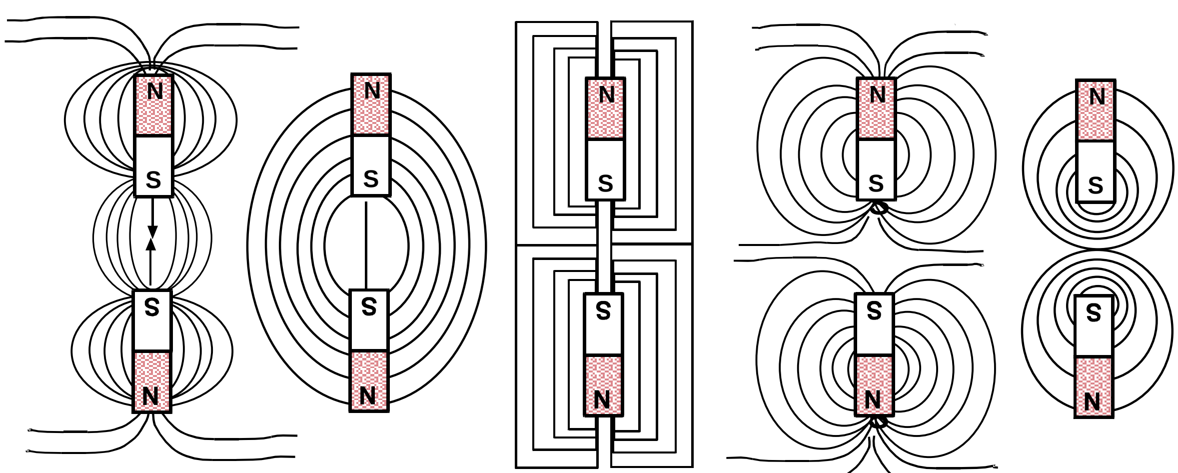
A B C D E

Unlike Poles



A B C D E

Like Poles



A B C D E

Which is the correct drawing for: Single _____ Unlike Poles _____ Like Poles _____

Summarize your findings concerning magnetic fields.

Part D - What is the Effect of Electricity upon Magnetic Fields? <u>**Be careful of magnetic fields from power outlets. extra magnets. and laptops. These can affect your results.**</u>

Section 1 - What is The Effect of Electricity on the Production of Magnetism?

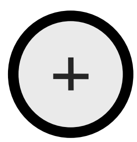
1. (2) Describe any movement of the compass needle _____

2. (3) Describe what happens when you place the wire on a piece of scrap paper and sprinkle a small amount of iron filings onto the wire with the electricity turned *off* while lifting up the wire.
_____

3. (4) Describe what happens when you place the wire on a piece of scrap paper and sprinkle a small amount of iron filings onto the wire with the electricity turned *on* while lifting up the wire.
_____

4. (5) What does your comparison suggest concerning a magnetic field near a Current Carrying Wire?
_____

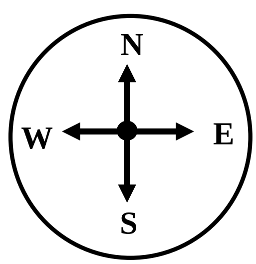
Section 2 – Observing the magnetic field around a current carrying wire. Draw the new positions of the compass needles on the drawing.



End View of Wire

Describe the magnetic field around the wire carrying an electric current _____

Part E - The Earth's magnetic field:



1.(4) What direction is the north pole of the magnet pointing? _____

2.(5) In which direction does the needle of the compass point? _____

3.(5) Does the needle point in the same direction when the compass is turned? _____

4.(6) Why are the poles of a magnet named North and South? _____

5.(7) If a bar magnet had the N and S markings rubbed off how could the North pole. and the South pole of the magnet be identified? ________

Part F - The effect of magnetism upon the production of electricity:

	Number of Wire Wraps			
	5	10	20	40
Galvanometer Reading				

How does magnetism affect the production of electricity: _____

Part G - Determining the strength of an electromagnet:

Trial	Turns	Observation	Iron	Aluminum	Wood
1	25	Compass (Yes or No)			
		Number of Staples			
2	50	Compass (Yes or No)			
		Number of Staples			
3	75	Compass (Yes or No)			
		Number of Staples			
4	100	Compass (Yes or No)			
		Number of Staples			

1.(10) Which core was the strongest? _____

2.(11) How does the number of turns of wire affect the strength of an electromagnet? _____

3.(12) Which combination of core and number of turns was the strongest? _____

Part H - The Electric Motor

1.(9) Explain how the motor works using the concepts in this topic. _____

2. Motor Certification (if appropriate have obtain your instructors initials) _____

Part I - Graphing the Earth's Magnetic Field Intensity Pre-lab prep

The Research Question: How has Earth's magnetic field intensity changed during the last 800 thousand years?

Your hypothesis: ____

Test your hypothesis: Go to the following website to obtain the data to plot on a graph of Intensity vs. Age (Before Present Day). **You will need to add the following data point that is not included on the table**: The age of the Earth is 0.0 representing *today*. The Earth's magnetic field strength intensity today is 11.5 units.
http://image.gsfc.nasa.gov/poetry/venus/Revstudent.html

Scientists don't know for sure what the intensity level is that occurs when the Earth's magnetic poles reverse, but they are currently thinking it is around 2 intensity units or less. For the purpose of addressing the questions below we will assume that the field reverses when the intensity is around 1.9 units or less. Use your graph to answer the following questions.

1. Identify the dependent variable. ________________________________

2. Identify the independent variable. ________________________________

3. Analyze the graph by answering the following questions.

   a. How many times has the field changed directions in the last 800 thousand years? _______

   b. How long ago was the magnetic field intensity least? _______ What was the intensity ? ______

   c. How long ago was the magnetic field intensity greatest? _______ What was the intensity ? ______

4. How do your results compare to your hypothesis? Explain

____

5. Use your graph to predict when the next reversal will occur. **Explain your reasoning**.

____

MAGNETISM

Self-Evaluation

Test 101

1. 10.1 Materials that can be magnetized are called:
   A. ferromagnetic
   B. domains
   C. conductors
   D. insulators
   E. hertz

2. 10.1 Which of the following indicates the measurement of frequency for voltage or current?
   A. ferromagnetic
   B. domain
   C. conductor
   D. insulator
   E. hertz

3. 10.2 Which one of the following sets of materials contain the most nonmagnetic materials?
   A. silver, gold, copper, brass
   B. iron, nickel, zinc, aluminum
   C. carbon, zinc, cobalt, lead
   D. copper, zinc, aluminum, iron
   E. brass, iron, nickel, cobalt

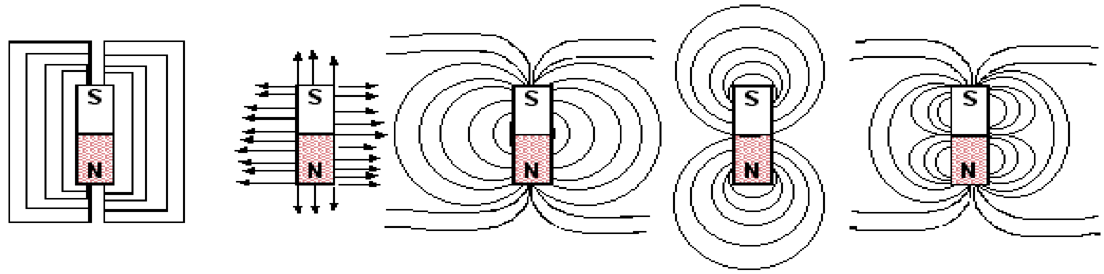
4. 10.2 Which of the following sets of materials contain the most magnetic materials?
   A. silver, gold, copper, brass
   B. steel, iron, nickel, cobalt
   C. carbon, zinc, cobalt, lead
   D. copper, zinc, aluminum, iron
   E. iron, nickel, zinc, aluminum

5. 10.3 Which of the following best indicates the Law of Magnetism?
   A. Like charges attract and unlike charges repel
   B. Like poles attract and unlike poles repel
   C. Unlike charges attract and like charges repel
   D. Unlike poles attract and like poles repel
   E. Unlike poles attract and like charges repel

6. 10.3 Which of the following statements is correct about the Earth's magnetic field?
   A. The north pole, of a magnet/compass, points to the north magnetic pole of the Earth.
   B. The Earth's north geographic and north magnetic poles are near one another.
   C. The north pole, of a magnet/compass, points to the south magnetic pole of the Earth.
   D. The north of a compass needle points north because the compass needle's end, pointing north, is actually the south end of a magnet.
   E. The Earth's magnetic field is caused by mineral deposits in the crust of the Earth.

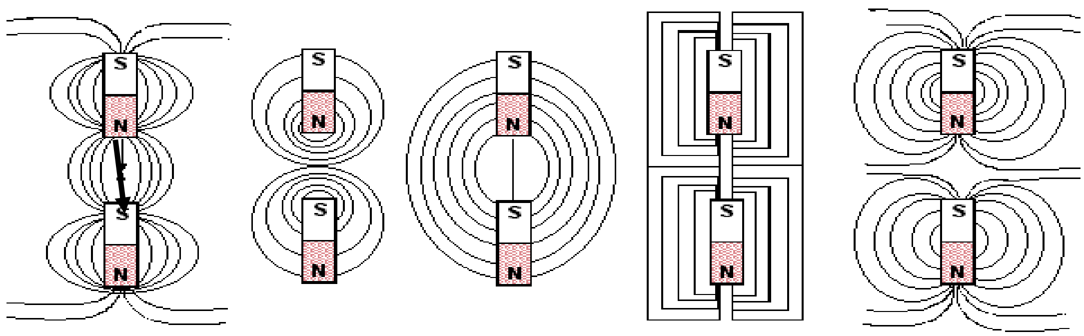
7. 10.4 Identify the correct geometry, or shape, of the magnetic field surrounding a single magnet.

A. B. C. D. E.

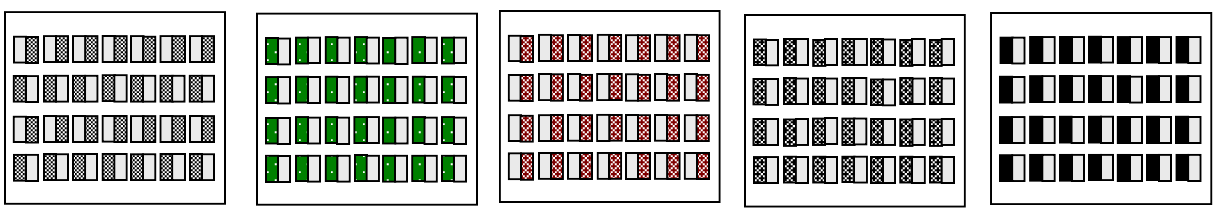


8. 10.4 Identify the geometry, or shape, of the magnetic field surrounding two unlike magnets.

A. B. C. D. E.

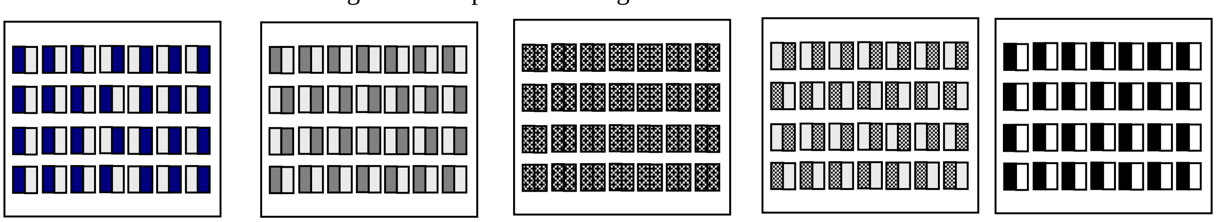


9. 10.5 Which one of the following models represents a non-magnetic material?



A. B. C. D. E.

10. 08.5 Which one of the following models represents a magnetic material?



A. B. C. D. E.

11. 10.6 The magnetic lines of force near a current carrying wire are:

A. straight lines parallel to the wire
B. straight lines perpendicular to the wire
C. circular in a plane. perpendicular to the wire
D. circular in a plane parallel to the wire

12. 10.6 Magnetic fields are produced by:

A. motion of an electric charge
B. static electric charge
C. free electrons moving in magnetic fields
D. photon motion

13. 10.7 A generator produces electrical current by:

A. heating water and burning it into steam which is used to make electricity
B. moving a coil of copper wire through a magnetic field
C. using fuel oil or some other source of energy
D. using Ohm's law
E. none of the above

14. 10.7 Moving a copper wire through a magnetic field produces:

A. positive charge
B. ions
C. flow of electrons
D. an electrolyte

15. 08.8 Which of the following explains why the force of a magnet decreases with distance?

A. ferromagnetism decreases with distance
B. dipoles decrease with distance
C. lower frequency at greater distance
D. inverse square law
E. flow of electrons decreases with distance

16. 10.8 If a magnet has a strength of 32 Newtons at 1 meter what is the force at 4 meters?

A. 1 Newton
B. 2 Newtons
C. 3 Newtons
D. 4 Newtons
E. 5 Newtons

17. 10.9 Which of the following is/are needed for an electric motor to work?

A. armature
B. commutator
C. magnet
D. conductor
E. all of the above

18. 10.9 Which of the following occurs in an electric motor works?

A. reverse square law
B. switching the flow of electric current in a magnetic field
C. flow of electrons in ferromagnetic conductors
D. dipole insulators in magnetic poles with free electron movement
E. all of the above

ELECTROMAGNETISM and L I G H T

Topic 11

Objectives

1. Given the following list of terms, identify each term's correct definition. Conversely, given the definition, identify the correct term.

   concave lens, convex lens, diffusion, electromagnetic radiation, electromagnetic waves, focal length, gamma rays, index of refraction, light, normal, opaque, optical medium, principal focus, radiant energy, reflection, refraction, translucent, transparent
2. Identify the electromagnetic spectrum in order, including: gamma rays, x-rays, ultra-violet, optical (violet, indigo, blue, green, yellow, orange, red), infrared, radio waves, electric waves.
3. Given various features of the surface of the Earth, identify and rank their *absorption* of radiant energy.
4. Given a situation concerning reflection, (like diffusion or curved mirrors), describe the situation, applying the *Law of Reflection*.
5. Sketch and describe in terms of the three *Laws of Refraction* any situation involving refraction, i.e.. eyeglasses, convex or concave lenses, microscopes, telescopes.

INTRODUCTION

Light and The Electromagnetic Spectrum

Light is a form of energy known as radiant energy. Light tells us many things about our environment. An object that light can pass through unchanged is referred to as transparent. An object that light can pass through but the image is unclear is referred to as translucent; and one that light cannot pass through is referred to as opaque.

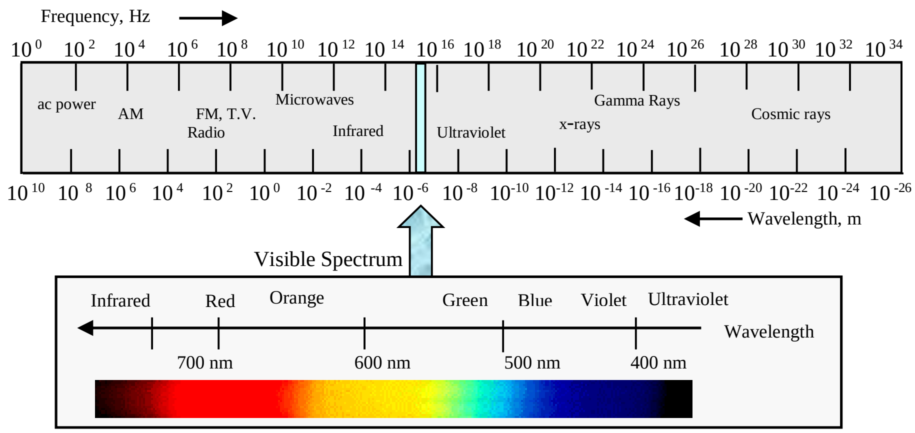
Light travels outward in straight lines in all directions from a source. Since light waves radiate both electrical and magnetic fields around themselves, they are called electromagnetic waves. From our study of atomic structure, we know that electrons whirl around the positively-charged nucleus in various orbits or energy levels. The greater the energy of the electron, the farther it can move from the attracting force of the positively-charged nucleus. When light energy is added to an atom, for example, the atom becomes "excited", and some of its electrons absorb enough energy to jump to a higher level, moving them farther away from the nucleus. If no further energy is added, these electrons return to their former energy levels, and their potential energy is converted to radiant energy in the form of electromagnetic radiation.

There are four properties of electromagnetic radiation which we will deal with:

1. Speed of 3×10^8 meters per second or 186.000 miles per second through a vacuum.
2. Electromagnetic radiation generates both electric and magnetic fields.
3. Electromagnetic radiation can transfer energy through a vacuum.
4. Electromagnetic radiation energy can be converted to other forms of energy through absorption by matter.

The electromagnetic spectrum would look like this:

The Electromagnetic Spectrum



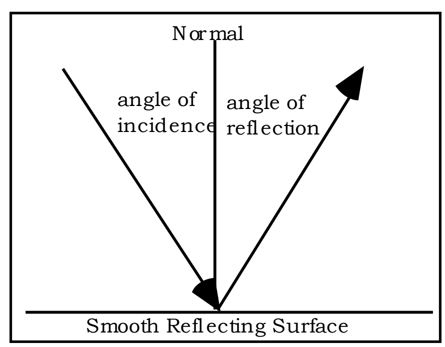
Absorption

Space is cold because there is very little matter to absorb the radiant energy of sunlight. Our Earth and the matter on it are heated as the radiant energy of the sun strikes it and causes the speed of the matter's molecules to increase. Three-fourths of the Earth is covered by oceans, and the water surfaces they present to the sun's rays are highly uniform. The surfaces of the continents and islands, on the other hand, are far from uniform. The surface may be barren, as on a mountain top or in a sand desert. Or it may be covered by grasses, jungles, or forests. How does the nature of the Earth's surface affect the absorption of radiation and the conservation of this energy to heat energy?

You will conduct an investigation to compare different surface colors to determine their absorption and radiation of heat energy. An incandescent light bulb will be used as a "sun". This “sun” will shine on the surfaces of three cans - one a white, one gray, and the other a dull black. The air temperature inside each can will be observed at regular intervals while the cans are in the artificial "sun", and as the cans cool off, without the "sun".

Reflection

When a light beam hits a highly polished surface such as a mirror, it will bounce off, or be reflected from the surface. Two angles are created by this light beam, with each angle measured from the normal. The first angle is made by the incoming beam and the normal, and is called the angle of incidence. $<_i$. The second angle is formed when the beam bounces off the smooth surface, and is made by the outgoing beam and the normal. This second angle is called the angle of reflection. $<_r$.



Law of Reflection

The angle of incidence equals the angle of reflection ($<_i = <_r$). This has been determined to hold true, regardless of the medium which the light travels, or the nature of the light used (red, green, etc.).

Application

To determine how a ray of light is reflected as it strikes a smooth reflecting surface follow these steps.

1. Draw a normal at the point the light ray touches the smooth surface.
2. Measure the angle of incidence- the angle between the normal and the light ray.
3. The angle of reflection will occur at an angle equal to the angle of incidence. Measure off an angle from the normal equal to the angle of incidence. This will be the reflected ray.

Refraction

The speed of light in a vacuum is approximately 3 x 10^8 meters per second. The speed of light varies, however, if we vary the material (medium) through which it travels. If the speed of light is less in one substance than in another, the first substance is said to be an optically denser medium. A light ray will bend when it enters a medium, with a different optical density, at an angle. This bending of light is known as refraction, which results from the difference in the speed of the light. The degree to which the light bends is dependent upon the index of refraction of the medium through which the light passes.

The index of refraction of a pure, transparent substance is a constant quantity, and is a definite physical property of that substance. Consequently, the identity of a substance can be determined by measuring its index of refraction. A refractometer is an instrument used to measure the index of refraction of substances quickly and accurately. For example, butterfat and margarine have different indexes of refraction. One of the tests done to determine whether butter has been adulterated with margarine is the measurement of its index of refraction. The extremely high index of refraction provides us with one of the most positive tests for the identification of a diamond. The facts about refraction of light may be summarized in three "Laws of Refraction"

Laws of Refraction

First Law:

The incoming ray, the refracted ray, and the normal will all be in the same plane. (A normal is an imaginary line which runs perpendicular to the surface at the point at which the incoming and refracted rays come together.)

Second Law:

The index of refraction is constant for any medium.

Third Law:

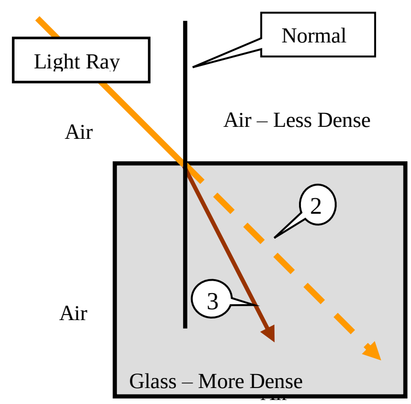
- A ray of light passing from one optical medium to another on the normal will not be bent.
- A ray of light passes from a medium of lesser optical density (light travels fast) to one of greater optical density (light travels slow, will be bent toward the normal. (FST)
- A ray of light passes from a medium of greater optical density (light travels slow) to a medium of lesser optical density (light travels fast), will be bent away from the normal. (SFA)

Application:

To determine how a ray of light is refracted as it passes from one optical medium to a different optical medium follow these three steps.

1. Determine the position of the normal. (See first law.)
2. Determine where the ray of light would have gone if the medium through which the light passed had not changed.
3. Determine whether the ray is bent away from, or towards the normal. (See third law.)

NOTE: In the example air has less optical density than glass. The light ray is passing from a medium of lesser optical density to one of greater optical density. Therefore, the light ray will bend towards the normal.



A lens is a piece of glass (or any other transparent material) with two curved surfaces, or with one curved and one flat surface. A convex lens is a lens which is thicker in the middle than at its edges. Refraction through such a lens causes parallel light rays to converge (meet) at a point called the principal focus. A concave lens is thinner in the middle than at its edges, and causes light rays to diverge, or spread apart. A magnifying glass is a double convex lens. It can concentrate light rays to such a degree that they can burn a hole in paper, or cause a fire.

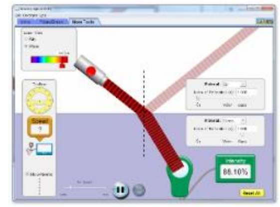
The lens of your eye is a double convex lens which focuses an image on the retina of the eye. If a person is farsighted, the eyeball is too short from front to back, and the point of focus will fall behind the retina. Such people can see only distant objects clearly. Glasses with convex lenses are used to correct farsightedness. If a person's eyeball is too long from front to back, the point of focus will be in front of the retina, and the person will be nearsighted, meaning that only close objects can be seen clearly. Concave lenses are used to correct nearsightedness.

Optical instruments depend upon lenses of specific focal lengths and adequate light sources for their operation. The focal length is the distance from the lens to the principal focus, the point where rays converge. The ordinary light microscope is used to investigate tiny structures, such as cells and bacteria, which would be otherwise invisible to the unaided eye. This instrument uses a combination of convex lenses. The telescope also uses convex lenses to bring distant objects into view. There are two types of astronomical telescopes used to investigate the heavens: 1) the refracting telescope, which uses two convex lenses and 2) the reflecting telescope, which uses mirrors to collect and direct light rays to a single lens. In the following activity, you will collect and direct light rays to a single lens, and you will make devices that will allow you to understand the affects various optical materials have on light.

Virtual Laboratory

Topic 11 – Electromagnetism and Light

			11
Name	Section #	Date	Topic #



REFRACTION

Purpose: To investigate the behaviors and characteristics of light when it bends due to refraction. These properties and characteristics will be true for all other EM (electromagnetic) waves - and sound as well.

Questions:

1. What happens to the speed of light as it goes from air to water?

   ____

2. What happens to the frequency of light as it goes from air to water?

   ____

3. What happens to the wavelength of light as it goes from air to water?
   Enter your hypothesis here.

   ____

Procedure:

Go to the PhET website http://phet.colorado.edu/en/simulation/bending-light. or use the link provided in Canvass. Click on Run Now. Experiment with the controls and tools provided on the Intro tab. Perform the following tasks:

- Learn how to turn the beam on and off.
- Learn how to change the beam to a wave.
- Learn how to change the angle of the beam.
- Note that the symbol c = the speed of light on the light meter.

You will be systematically learning about changing angles in **refraction.**

4. Which beam is best suited for measuring angles. the ray or wave? ___________________________________

5. Which tool should you select for measuring angles. the protractor or intensity meter? ___________________

Using this setup and tool. you will investigate and discover: (Indicate towards or away from normal or no bending.)

6. How the **angle of refraction** compares to the **angle of incidence**. measured from the **normal**. when going from air to water.

   ____

7. How increasing and decreasing the **index of refraction** of the bottom material changes the angle of refraction.

   ____

8. What conditions produce no refraction? What conditions produce maximum refraction?

   ____

Investigate the materials further: set the *top* material to be water. and the *bottom* one to be air. Systematically investigate and discover:

9. How does the angle of refraction compare to the angle of incidence, measured from the normal, when going from water to air?

   ____

10. At what angle of incidence does something different happen that did not occur in the first investigations?
____

11. Describe what happens to the refracted beam at this **critical angle**.
____

12. How does increasing or decreasing the index of refraction of the bottom material change the angle of refraction?
____

13. How does increasing or decreasing the index of refraction of the bottom material affect when the critical angle appears?
____

14. What conditions produce no refraction? What conditions produce maximum refraction?
____

You are now ready to investigate the beam itself. Click on the <u>More Tools</u> tab, and change your beam to a wave. **Note: The distance between dark bands, or the red bands, is the wavelength.**

15. Using the speed tool what is the connection between the **index of refraction** of the bottom material and the **speeds of the beams** in air and in the bottom material?
____

16. Using the time tool, what is the connection between the **index of refraction** of the bottom material and the **frequency of the beam** in that material compared to the beam in air? What is the **wavelength of the beam** in the material compared to its wavelength in air? (You can slow down or pause the simulation for this. The wavelength is the distance between the black bands.)
____

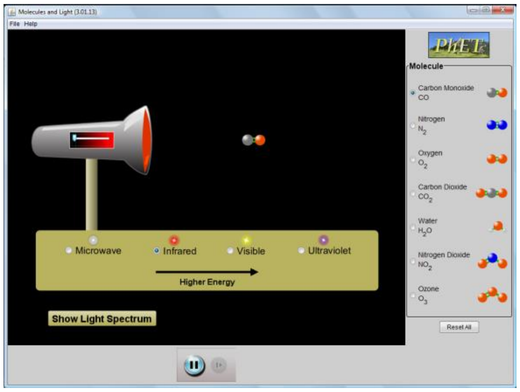
17. What is the effect **changing the color** (wavelength) of the beam on any of the refraction behaviors you already recorded?
____

Conclusion:

18. What were your hypotheses, and were they validated by the results of your investigations? If not, what did you learn?
____

Molecules and Light

Purpose: Explore how light interacts with molecules in our atmosphere.



19. What do the 4 types of radiation above have in common?

____

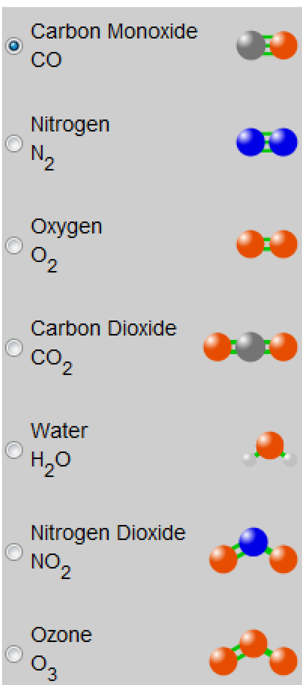
____

20. How are the 4 types of radiation above different from each other?

____

____

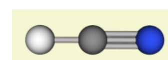
Explore what happens for each molecule for each type of light.



21. What patterns did you find? Be descriptive.

____

____

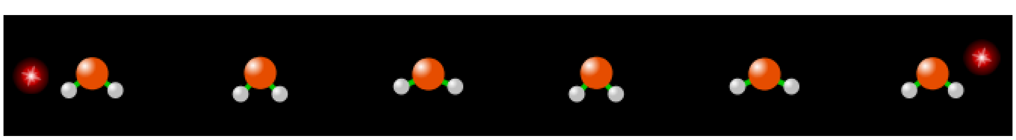


22. Based on your observations. how would you predict HCN to interact with microwaves?

____

____

IV. Look closer at how Infrared light affects water in the sim or in the movie below.



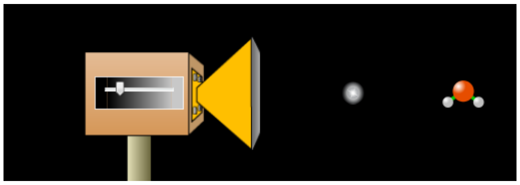
23. What do you think is happening?

____

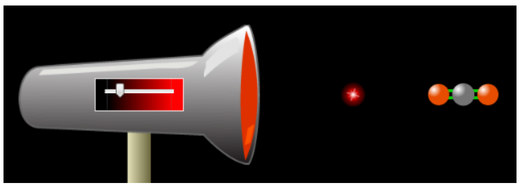
____

24. Pick <u>**one**</u> of the topics below to study in more depth. *Run the simulation and then do some research.*

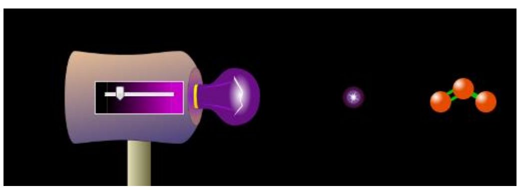
A. **Microwaves -** How do microwave ovens cook food?



B. **Greenhouse effect -** What is a greenhouse gas and why is it necessary on Earth?



C. **Ozone layer -** What does the Earth's ozone layer do?



Hands-on Laboratory

Topic 11 – Electromagnetism and Light

MATERIALS

Ray box	Absorption cans	Meter Stick
lens clips	Water block	Lamp with incandescent bulb (150 watt)
plane Mirror	3 Celsius thermometers	Plastic Block

Lens Kit:

- metal concave /convex mirror
- plastic prism
- plastic concave lens
- plastic convex
- plastic Plano-convex lens (parallel lens)
- Glass Double Convex lens - 15 cm.
- Glass Double Concave - 45 cm.
- Glass Double Convex lens - 45 cm.

PROCEDURE

Part A – Research Question: How does surface color affect absorption of radiation (light energy) and emission of energy?

PRE-LAB PREP: The following experiment was conducted, data collected and recorded in the data sheet provided,

1. Obtain three cans. and insert thermometers about halfway into each can.
2. Make certain that the thermometers are placed at the same level.
3. Place the 150-watt lamp so that it is at a distance of about 25 centimeters from the center can.
4. Record temperature of the thermometer.
5. Turn on the 150-watt lamp. (Make sure the lamp is 150 watts).
6. Record the temperature of the thermometer every three minutes for eighteen minutes.
7. At the end of eighteen minutes. turn the lamp off.
8. Continue to take temperature readings every three minutes for an additional eighteen minutes.
9. Record all readings.
10. Develop a hypothesis that addresses the research question *before* looking at the data table. After, plot the data from the data table provided on graph paper, or use a program as instructed by your instructor, for the three different surfaces. Answer the questions following the graph based on the information from the graph.

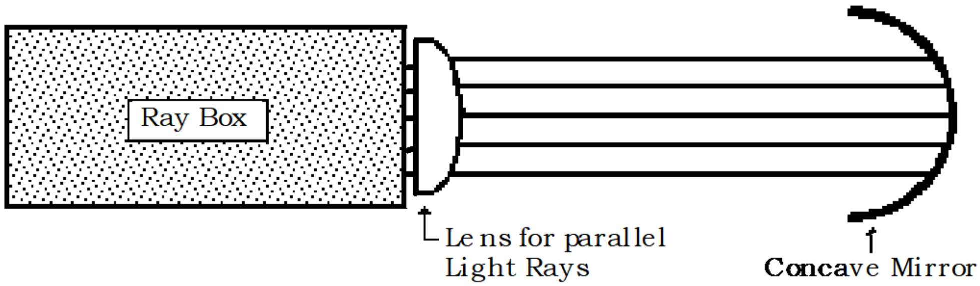
Part B - Reflection

Section 1 - Problem: How is light reflected from a smooth surface?

1. Connect the Ray Box to a 115-volt AC. outlet. Five light rays should be clearly visible when the switch is moved to "ON". NOTE: The ray box becomes hot after a while, so handle it from the cord end.
2. You will need only one ray for this section so place masking tape over the four other slits in the Ray Box. leaving one slit open.
3. Tear your data sheet out from your book. Using the drawing provided on the data sheet. place the Ray Box in the indicated position on the sheet. approximately 10-15 cm. from the protractor.
4. Place the flat mirror in the position indicated in the drawing. The mirror is mounted on a block of wood and is slanted forward to reflect the light onto the paper.
5. Adjust the Ray Box so that the single ray will shine over one of the angles listed in the table and the midpoint of the protractor. The angle created between the normal and the incoming ray is the angle of incidence. Measure the angle of incidence and record.
6. Locate the reflected ray of light. The angle created between the normal and the reflected ray of light is the angle of reflection. Measure the angle of reflection and record.
7. Move the Ray Box so that the incoming ray passes over each of the other angles listed in the table. Collect the data so that you can obtain the angles of incidence and the angles of reflection. Record the data.
8. Make a written statement summarizing reflection. This statement could be called the "Law of Reflection".

Section 2 - Problem: How is light reflected from a curved surface?

1. Obtain the metal concave /convex mirror.
2. Set up the Ray Box. on your data sheet. so that the five rays are visible. In order to make the light rays parallel place the plastic lens that is flat on one side and curved on the other. in front of the ray box. Place the flat side of the parallel lens against the Ray box as indicated.

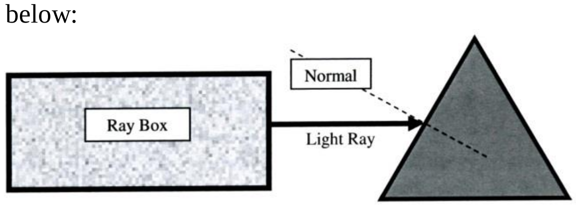


3. Place the concave mirror in the path of the rays so that the center ray. from the ray box. lines up with the ray on the drawing.
4. To draw the incoming rays (to the mirror) place a dot where each ray exits the lens and a dot where each ray touches the mirror then connect each set of dots with a straight line. Repeat this process for each of the incoming rays (there should be five).
5. Draw the reflected rays by placing a dot where the ray touches the mirror and another dot at approximately 5-10-cm. along the reflected ray and then connecting these two dots with a straight line.
6. Draw the normal for each of the incoming rays of light. To draw a normal for a curved surface find the center of the curve (indicated in the drawing with a dot and labeled circle center) and draw a line from the circle center (dot) to the point the incoming light ray touches the mirror.
7. After you have drawn the incoming, reflected rays and the normal for each incoming ray compare the angle of incidence to the angle of reflection for each incoming light ray. Does the angle of incidence equal the angle of reflection for each incoming ray? Do curved surfaces obey the "Law of Reflection?"
8. Repeat steps 1-7 for the convex mirror.

Part C - Refraction

Section 1 - Problem: What is refraction?

1. Cover the two outside slits on each side of the Ray Box, leaving the middle slit open.
2. Obtain the plastic block provided in the kit.
3. Set up the equipment as shown below:



4. Using the drawing on the data sheet draw the bending of the ray of light as it *enters* the plastic triangle. Make sure to include and label: (1) the normal, (2) where the ray would have gone if it was not bent and, (3) where the light went due to refraction.
5. Using the drawing on the data sheet draw the bending of the ray of light as it *exits* the plastic triangle. Make sure to include and label: (1) the normal, (2) where the ray would have gone if it was not bent and, (3) where the light went due to refraction.
6. Describe the bending of the light ray upon entering and exiting the triangle of plastic.

Section 2 - Problem: How does a double convex lens affect light?

Note: a double convex lens is one that is thicker in the center then on the edges.

1. Set up a Ray Box so that all five slots can be used.
2. Place the plastic lens (used to make the rays parallel) directly in front of the Ray Box. (See Part B. Section 2).
3. Place the plastic double convex lens approximately 5 cm. from the Ray Box.
4. Describe how the rays are affected.
5. Measure and record the distance from the lens to the principal focus. (The principal focus is the point where the rays will come together.)
6. Draw the light rays from the ray box through the lens showing the effect of the lens in the space provided on the data sheet.

Section 3 - Problem: How does a double concave lens affect light?

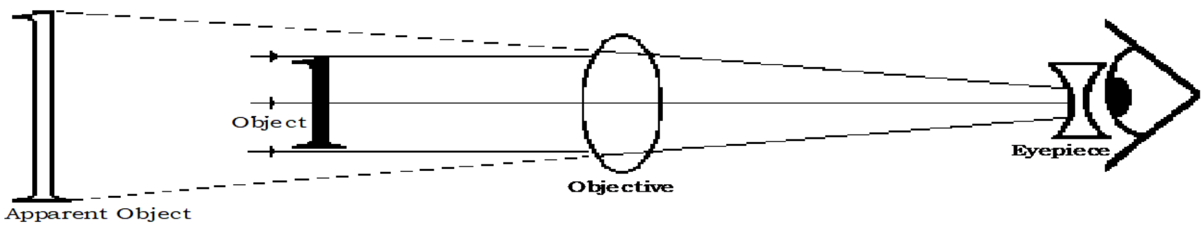
Note: a double concave lens is one that is thinner in the center then on the edges.

1. Using the same set up for the Ray Box in Section B, place a plastic concave lens approximately 5 cm. in front of the box.
2. Describe how the rays are affected.
3. Measure the distance from the lens to the principal focus. To determine the focal length, you will need to determine where the rays would come together. (HINT: Follow the outgoing rays backwards, and identify the point where they would come together).
4. Draw the light rays from the ray box through the lens showing the effect of the lens in the space provided on the data sheet.

Section 4 - Problem: How does a telescope work?

1. For the eyepiece obtain a double concave glass lens with a focal length of -15 cm. Using the lens clip provided, mount near the end of a meter stick.
2. For the objective lens obtain a double convex glass lens with a 40 to 50 cm. focal length. To select the correct lens measure the focal length of all the glass double convex lenses, in your kit, using the same procedure indicated previously in section C-2.
3. Using the lens clip provided, mount it on the meter stick a short distance inside the principal focus of the objective lens, using the lens clip.
4. Adjust the objective lens to bring it into focus.
5. Describe the results. Be sure to include all measurements on the drawing provided on your data sheet.

Telescope

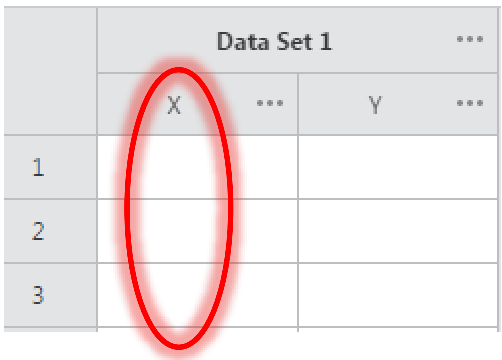


Graphing using Graphical Analysis Program

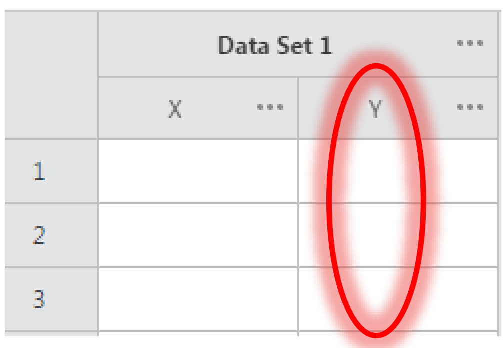
Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

<u>You will place 3 sets of data on one graph.</u>

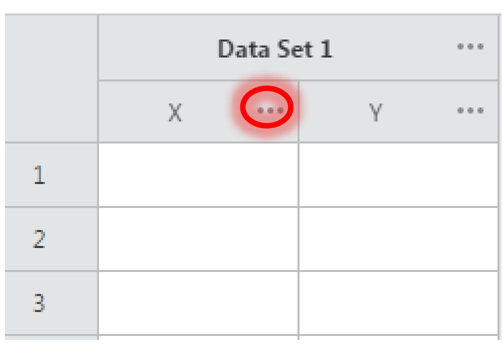
1. Enter the X data into the table; only the numbers, not the units.



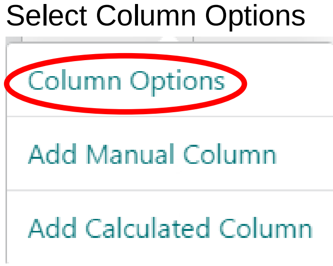
2. Enter the Y data into the table; only the numbers, not the units.



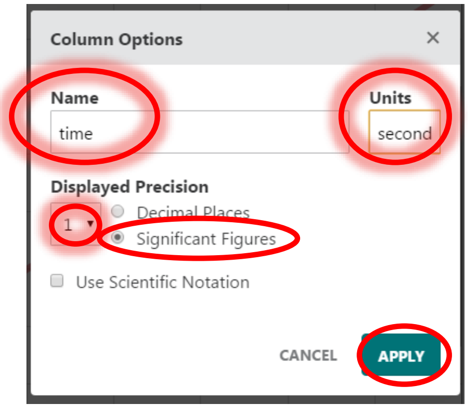
3. Click on the three dots next to X.



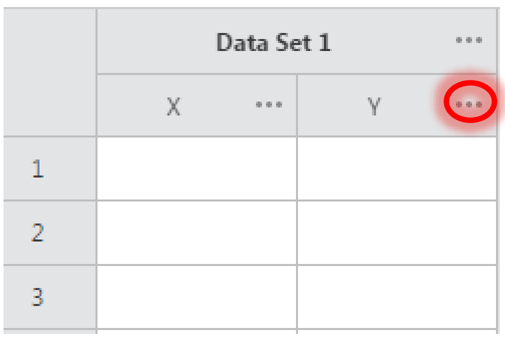
4. Select Column Options

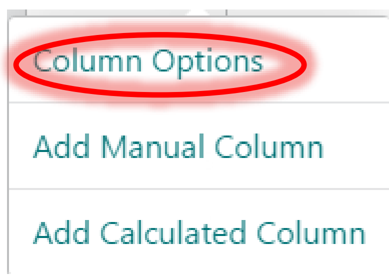


5. Type the name of the x axis in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



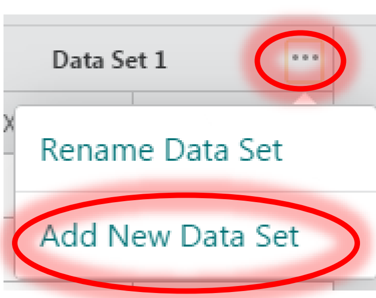
6. Repeat steps 3 – 5 for the Y axis. The label for the Y axis is **Temperature**. Click on the three dots next to Y. Select Column Options



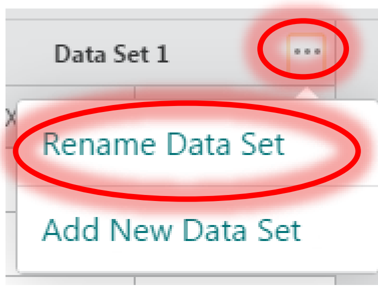


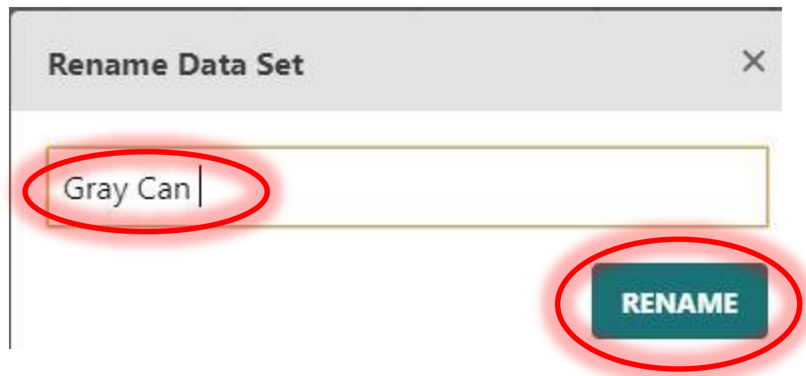
See step 5 for image. Type the name of the y axis (**Temperature**) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

7. To enter the next 2 sets of data, click on the three dots next to Data Set 1 at the top of the screen, and then select ADD NEW DATA SET. Perform this step 1 more time. Use the scroll bar at the bottom of the data set to navigate between each one. Copy and paste the X values for Data Set 1 into the X values for the 2 new data sets since they are the same. Type in the Y values for the 2 new data sets.

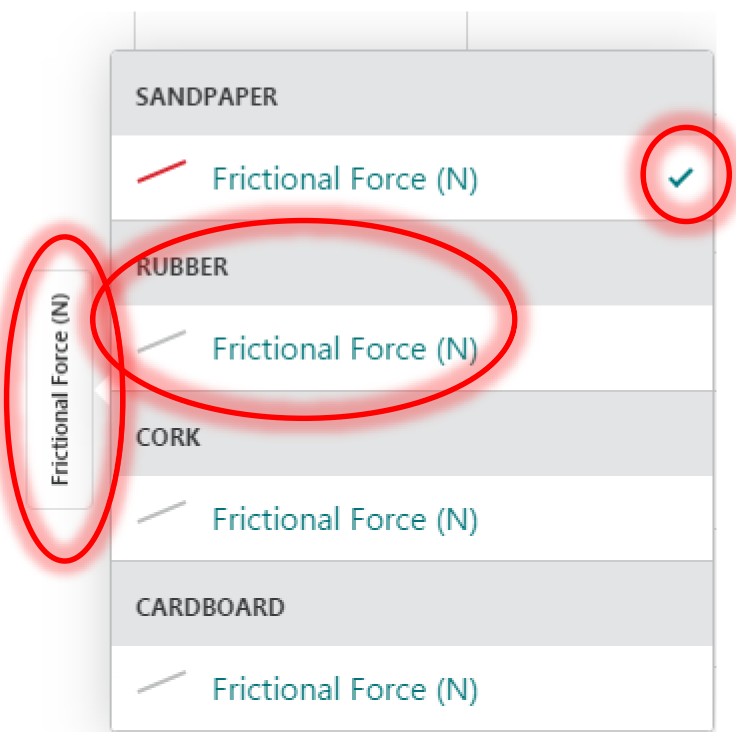


8. Each data set needs to be named to represent the three sets of data. Click on the three dots next to each of the four Data Sets and select Rename Data Set. Once you type the new name in the box click on the RENAME button. The names should be White Can. Gray Can. Black Can.



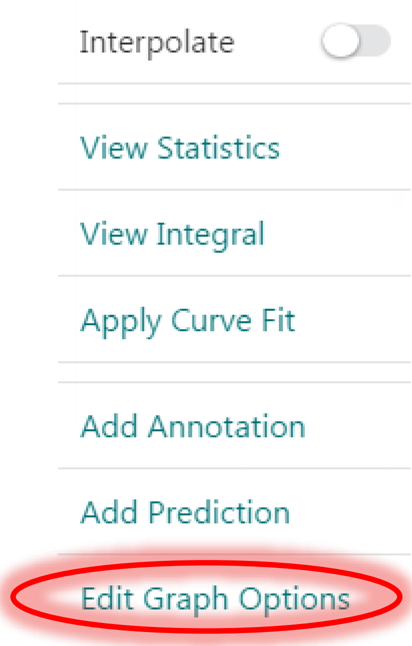


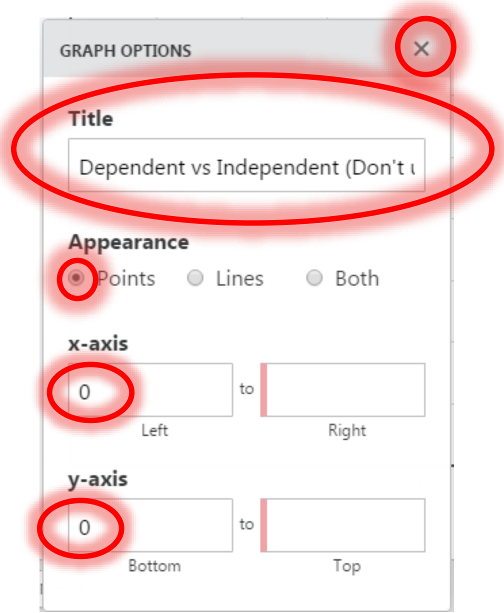
9. To display the three sets of data points on the same graph. click on the words Temperature on the Y-axis of the graph. Click on the words Temperature for each of the data sets that need to be displayed. A check mark will appear to indicate that it will display. Click anywhere on the graph and the box will close. The image below does NOT display the words you will see.



10. Click on the graph icon in the lower left of the screen.

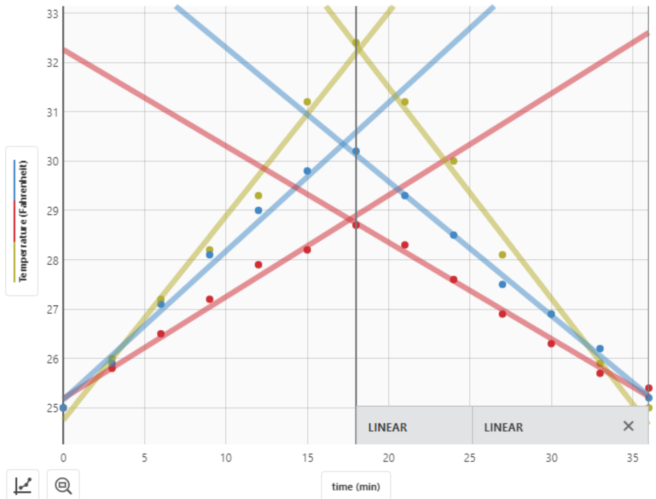
11. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to points. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.





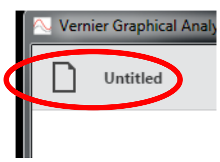
Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to insure that your graph starts with 0. 0 in the lower left corner.

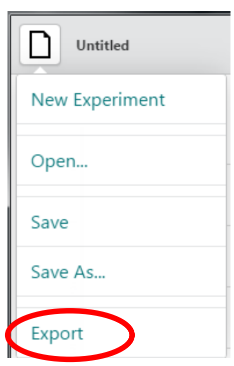
***For these graphs you will manually make best fits lines using a ruler after you make your print out. DO NOT PLAY CONNECT THE DOTS! You will draw 6 best fit lines; 2 best fit lines for each colored can. Use a different colored pencil for each can. Each can will have a best fit line for increasing temperature and one for decreasing temperature. The result will look like 3 upside down V's. Make sure to identify each set of colored best fit lines. See an example of what the best fit lines will look like on the next page.

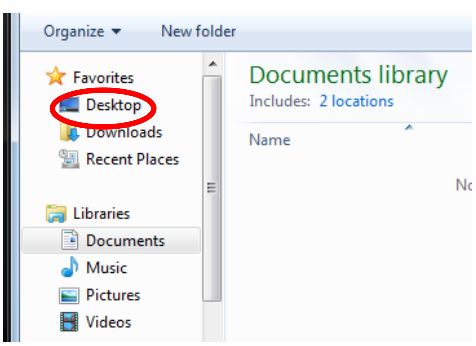


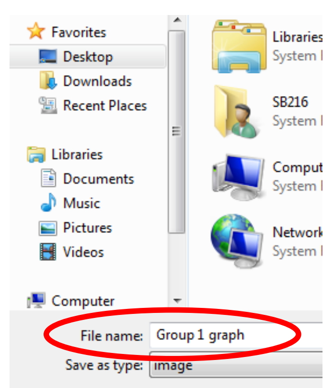
12. **Save** AND **Print** your graph(s).

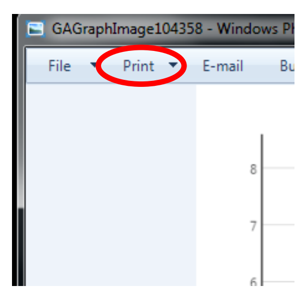
Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> Friction Graph. Print.











•11•
ELECTROMAGNETISM and L I G H T

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		11

Name Section # Kit # Topic #

PRE-LAB Prep: Develop your hypothesis. Plot the graph using 3 colored pencils and answer all questions 1- 16.

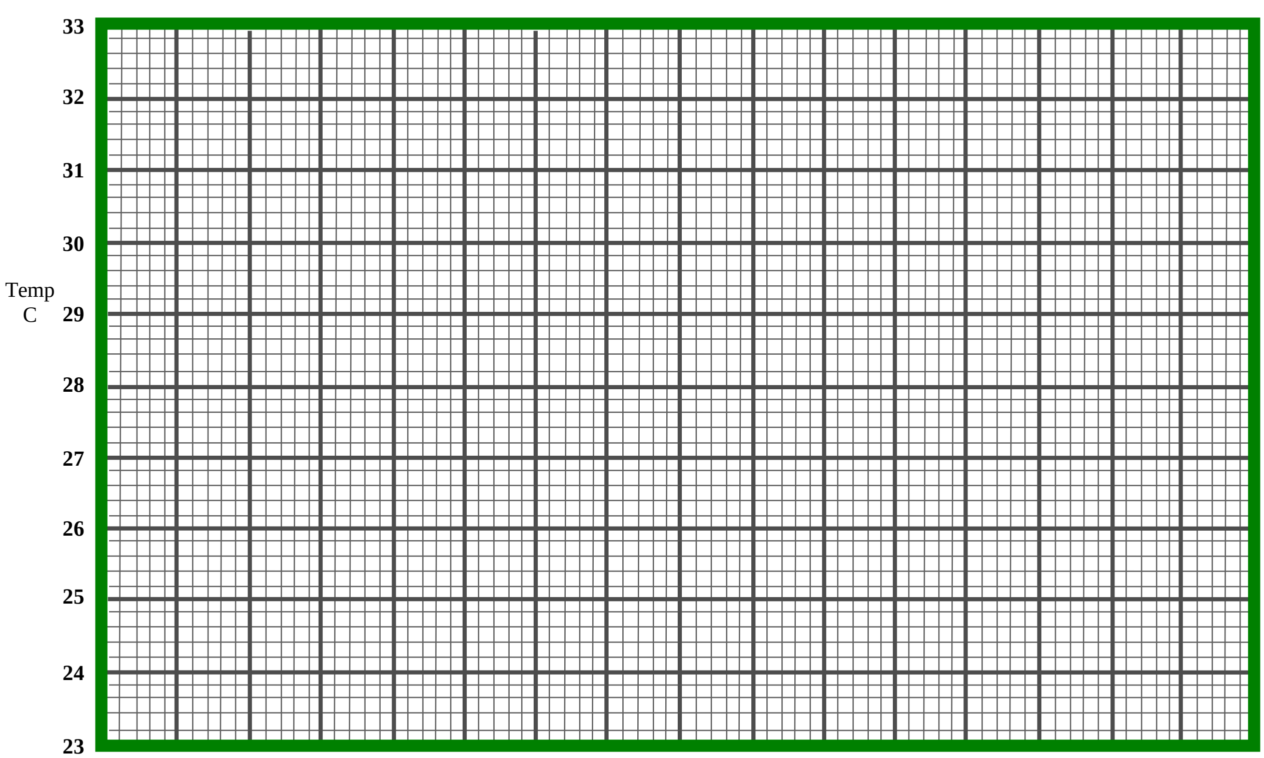
Part A – Research Question: How does surface color affect absorption of radiation (light energy) <u>and</u> emission of energy? Your Hypothesis (include prediction): ____

____

	Light on (min.)							Light off (min.)					
	0	3	6	9	12	15	18	21	24	27	30	33	36
White °C	25.0	25.8	26.5	27.2	27.9	28.2	28.7	28.3	27.6	26.9	26.3	25.7	25.4
Gray °C	25.0	25.9	27.1	28.1	29.0	29.8	30.2	29.3	28.5	27.5	26.9	26.2	25.2
Black °C	25.0	26.0	27.2	28.2	29.3	31.2	32.4	31.2	30.0	28.1	26.9	25.9	25.0

If using a graphing program, delete the following graph, and copy and paste the plot from the program into the space below.

Title: _____



Time (minutes) _____

1. Identify the dependent variable from the graph(s). ____

2. Identify the independent variable (s). ____

3. Identify the constant(s). ____

4. Are all three cans made of the same material? (circle or highlight one of the following) YES or NO. Does this make the type of material used in the experiment a constant? (circle or highlight one of the following) YES or NO

5. What is the benefit of plotting the data for all three cans on one graph? _________________________________

6. What is the benefit of plotting the data for when the light is shining on the can on the same graph as the data for when the light is not shining on the can?

____

You may find the following helpful when answering the following questions to use terminology that is often used when analyzing a graph.

Directly Proportional relationship: Graph is a straight line that passes through the origin.
Linear relationship: Graph is a straight line that does not pass through the origin.
Non-linear relationship: The graph is not a straight line, but curves.
The graph increases, decreases, gradual increase or decrease, drastic increase or decrease, remains constant, increases exponentially. Can you think of more?

7. **White can**: How does the dependent variable change with respect to the independent variable while the light is shining on the can? ____

8. **White can**: How does the dependent variable change with respect to the independent variable when the light is not shining on the can? ____

9. **White can:** Compare and contrast the behavior of the dependent variable with respect to the independent variable when the light is shining on the can. and when it is not shining on the can.

____

10. **Gray can**: How does the dependent variable change with respect to the independent variable while the light is shining on the can? ____

11. **Gray can**: How does the dependent variable change with respect to the independent variable when the light is not shining on the can? ____

12. **Gray can:** Compare and contrast the behavior of the dependent variable with respect to the independent variable when the light is shining on the can. and when it is not shining on the can.

____

13. **Black can**: How does the dependent variable change with respect to the independent variable while the light is shining on the can? ____

14. **Black can**: How does the dependent variable change with respect to the independent variable when the light is not shining on the can? ____

15. **Black can:** Compare and contrast the behavior of the dependent variable with respect to the independent variable when the light is shining on the can. and when it is not shining on the can.

____

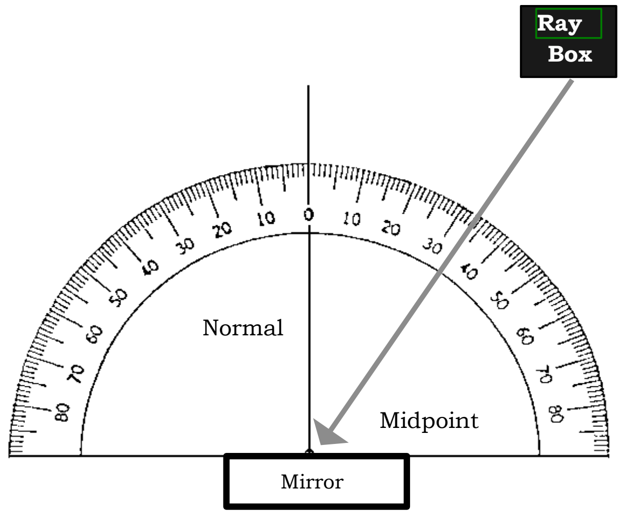
16. Does your data support your hypothesis? Explain your results.

____

Part B - Reflection of Light:

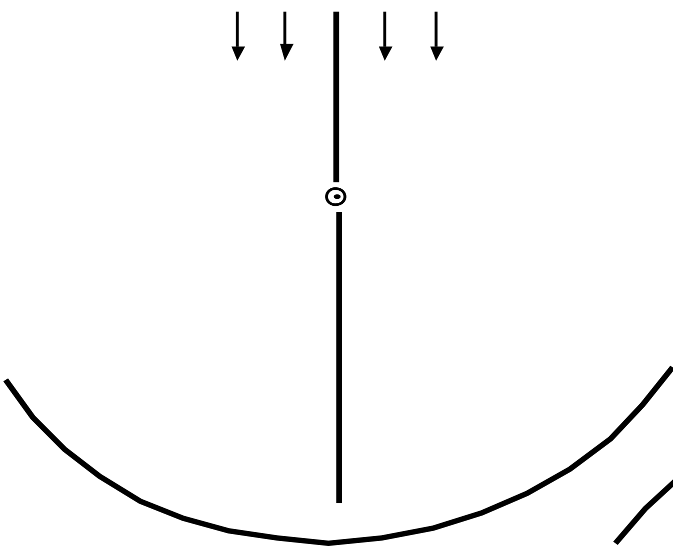
Section 1 - Plane surfaces:

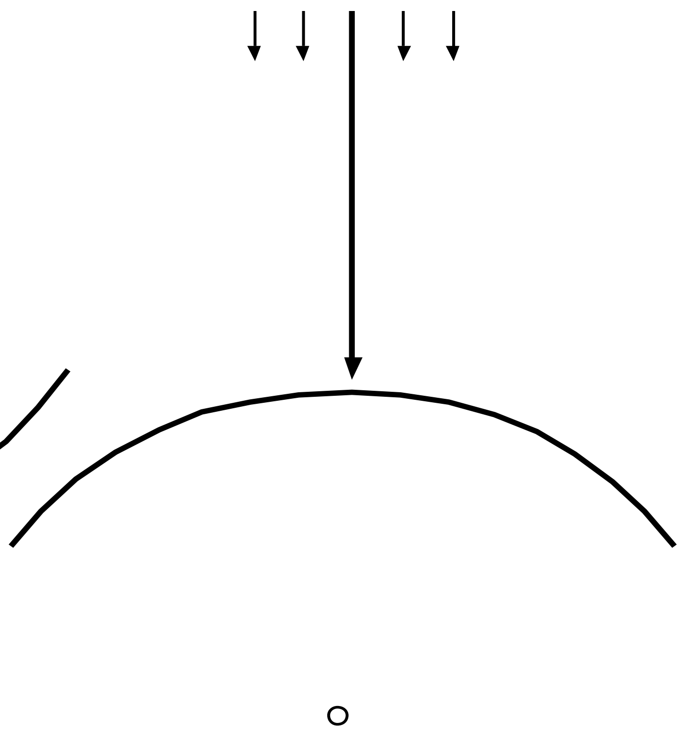
Reflection of A Light Ray	
Incoming Angle of Incidence	Outgoing Angle of Reflection
30	
50	
60	
70	
0	



Make a statement which summarizes your data and describes the Law of Reflection. _____

Section 2- Curved surfaces: Does the law of reflection explain curved surfaces? Draw the ***incoming***, ***normal***, and ***reflected*** rays, using different colors for each type of ray, and compare the incoming and reflected angles.





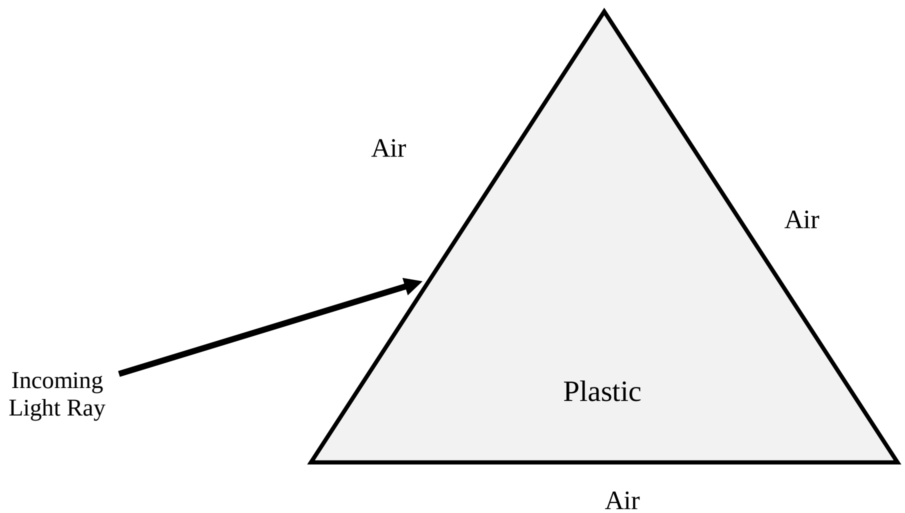
Does the Law of Reflection apply to curved surfaces? Explain. _____

Part C – Refraction

Section 1- How does light refract in a plastic triangle?

1. Place the plastic triangle as indicated on the drawing. And Draw the normal line at all points where the light ray enters or exits the triangle.
2. Draw a ray of light as it enters the plastic triangle. Make sure to include and label:
   a. the normal
   b. where the ray would have gone if it was not bent and
   c. where the light went due to refraction inside the triangle.

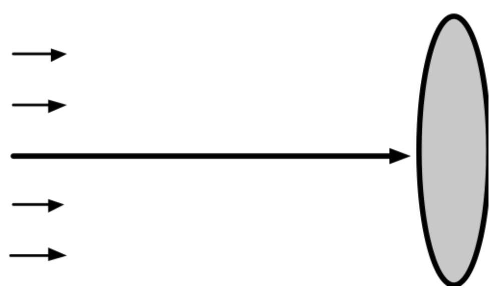
3. Repeat this process to describe the light *exiting* the plastic triangle.



8. How is the light bent (with respect to the normal) upon entering and exiting the block of plastic?

____

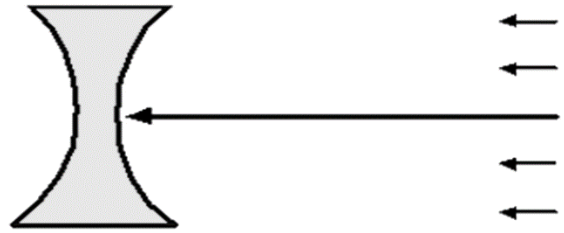
Section 2 - Convex Lenses (plastic):



Measure the focal length ___________

Describe how the rays behave after passing through the lens. ________________________________

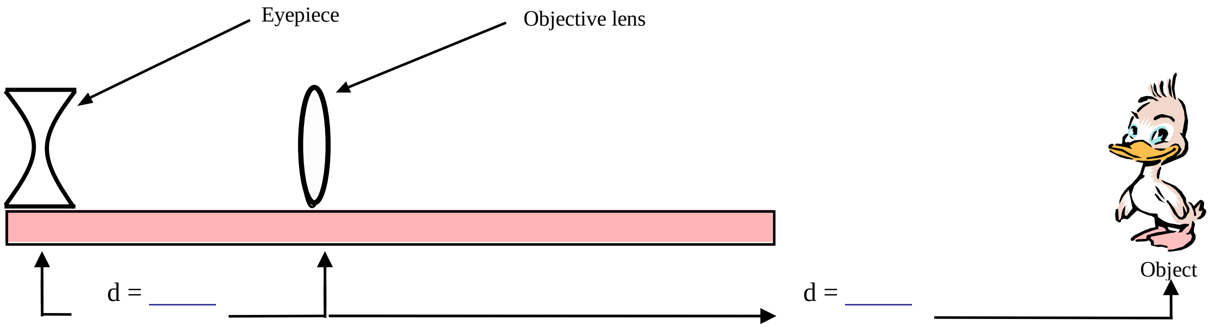
Section 3 - Concave Lenses (plastic):



Measure the focal length ______

(2) Describe how the rays behave after passing through the lens. ________________________________

Section 4 - Telescope: (record the distance between the glass lenses and the objective lens and the object)



ELECTROMAGNETISM and L I G H T

Self-Evaluation

TEST 111

Directions: Select the best answer.

1. 11.1 Wave energy which affects changes in the structures of atoms and molecules is called:
   A. radiation
   B. kinetic energy
   C. radiant energy
   D. electrolytic energy

2. 11.1 A lens that is thicker in the center than on the edges is called:
   A. refraction
   B. concave
   C. convex
   D. plano

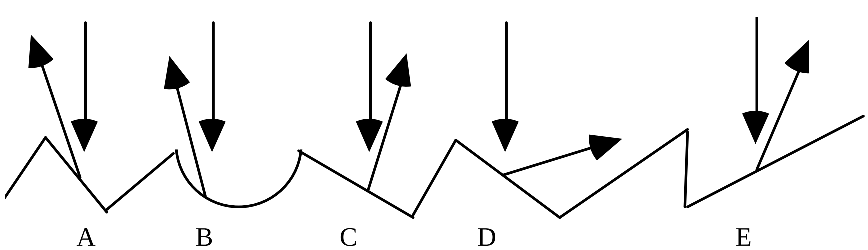
3. 11.2 Which of these groups of wavelengths is in proper order from shortest to longest?
   A. red light. gamma ray. ultraviolet. radio waves
   B. gamma ray. radio waves. red light. ultraviolet
   C. gamma ray. ultraviolet. red light. radio waves
   D. none of the above

4. 11.2 Wave energy which moves at a rate of 186.000 miles per second. and which has wavelengths between .0000385 mm and .0000765 mm. is called:
   A. sound
   B. light
   C. magnetism
   D. electricity

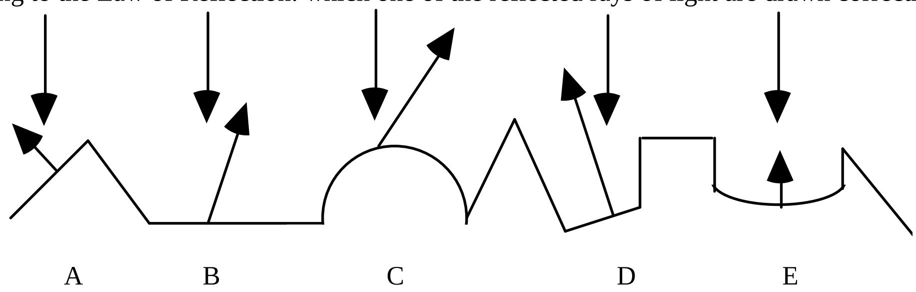
5. 11.3 Which of the following surfaces will absorb light energy least easily?
   A. water
   B. grass lands
   C. snow
   D. a plowed field

6. 11.3 Which of the following surfaces will absorb light energy most easily?
   A. water
   B. grass lands
   C. snow
   D. a plowed field

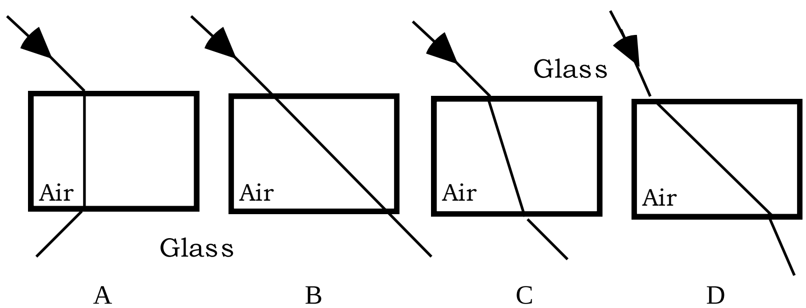
7. 11.4 According to the Law of Reflection. which one of the reflected rays of light are drawn correctly?



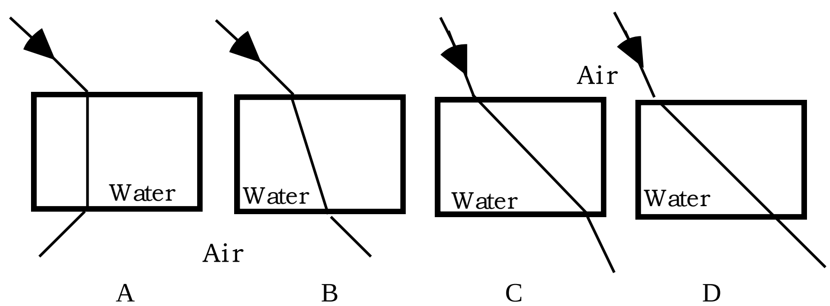
8. 11.4 According to the Law of Reflection. which one of the reflected rays of light are drawn correctly?



9. 11.5 Which one of the following drawings demonstrates the "Laws of Refraction" for the indicated situation?



10. 11.5 Which one of the following drawings demonstrates the "Laws of Refraction" for the indicated situation?



COLOR
Topic 12

Objectives

1. Given the following list of terms, you will identify each term's correct definition. Conversely, given the definition, you will identify the correct term.

   blue, color addition, color subtraction, complementary colors, constructive interference, cyan, diffraction grating, green, light, magenta, primary colors of light, prism, red, secondary colors of light, spectroscope, spectrum, yellow

2. Identify two ways to produce a spectrum, the colors of the spectrum in order of wavelength, and the primary colors.
3. Identify the colors produced by mixing colored lights using color addition.
4. Identify the colors produced by movement of color using color addition.
5. Identify the colors produced by color spacing using color addition.
6. Identify the colors produced by overlapping secondary and or primary filters using color subtraction.
7. Given the color of a colored light, identify the color of an object produced by absorption of light using color subtraction.
8. Given any two secondary and/or primary colored pigments identify the color resulting from their mixture using color subtraction.
9. Identify or explain how we perceive color produced by a Benham Disk.

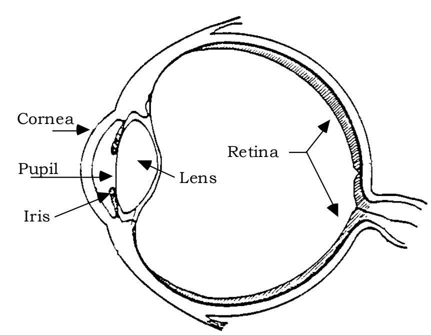
INTRODUCTION

From childhood onward we enjoy the richness of color in the world around us. We are fascinated by the questions: "How do we see color? Why do colors sometimes mix to give quite different colors? What does it mean to say that a tomato is red? Is color part of the tomato in the same way as shape?" Color can be explained by understanding that color is dependent upon the physical properties of the light energy reaching our eyes and how our brain processes that information.

How We See Color

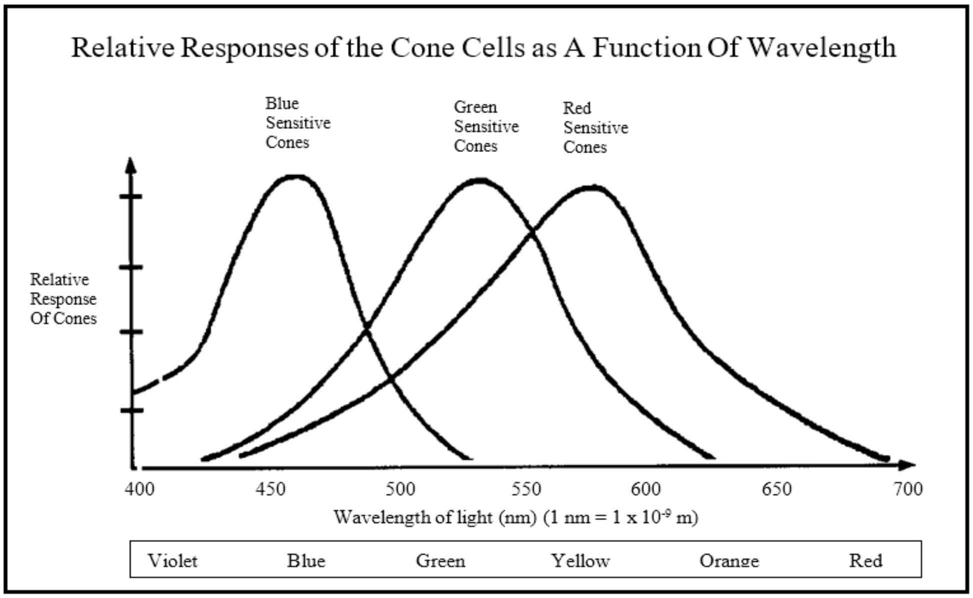
The function of our eyes is to bring information from the outside world into our brain. If you look around a room you see things: furniture, pictures, tables, objects, and shadows. Sometimes it is hard to realize that the things you see are really pictures inside your head; parts of images formed by the brain and eye.

To form these pictures, your eyes receive light that reflects from the objects around you. Your brain and eye work together to process the information carried by this light to create an internal image of what is outside. This internal image of the outside world is not complete and your brain fills in this incomplete internal picture. We are hardly ever aware of the idiosyncrasies of our own vision.



Your eye lets in only a very small amount of light into its interior. The light enters through the clear cornea, enters through the pupil, and then passes through the lens to finally focus on the retina. There are light-sensitive cells in the retina which send nerve impulses to the brain, which in turn interpret these impulses to create our internal image of the world.

The retina is a thin layer of light-sensitive cells at the back of the eyes. These cells, called cones and rods are responsive to incoming light. Rods function in dim light and are stimulated by motion and differences in lightness and darkness. You can see an object out of the corner of your eye before you can distinguish its color. Cones function in bright light and are responsive to color. Some cones are sensitive to green, others to red and some to blue.



The Spectrum

From earliest times the rainbow had delighted and puzzled observers. People invented myths to explain the beautiful arc of multicolored light that appeared after the rain. But a scientific answer to the puzzle of the rainbow did not come until the 17th century, Isaac Newton directed a small beam of sunlight into a darkened room through a prism. The beam produced a band of colors just like the rainbow, ranging from red, orange, yellow, green, blue and violet. He then passed each of these colors through other prisms and found that certain colors could not be further subdivided. But when he passed the whole band of colored light through a prism in reverse position, the colored band became sunlight again. From this he reasoned that white light is really a mixture of colored lights, and that each color is bent by a different amount when it passes through the prism. This difference in bending enables each color to stand out separately and be visible. The band of colored lights thus formed is called a spectrum. The rainbow is actually a spectrum, formed by sunlight passing through raindrops.

Separating light into its colors is accomplished by refraction (bending) of light in the prism. Each of the colors has a specific wavelength. The wavelength determines how much each color will bend. Red bends the least and violet the most, Scientists use the prism in a device called a spectroscope. The spectroscope reveals that the spectral pattern of light is different for various types of light sources. Light from the sun, from certain lamp filaments, and from molten metals produce a spectrum that has all colors in an unbroken array. Such a pattern is called a continuous spectrum. Incandescent gases give off only certain colors. in fine lines. Their spectra are called bright-line spectra. Scientists have obtained spectra corresponding to the different elements and have measured and charted every line. When they wish to learn the composition of a star, they photograph its spectrum and then check the lines against these charts for the elements.

In the late 19th century the theory that light travels in the form of electromagnetic waves won acceptance. Waves are described by speed, wavelength, and frequency. In a given medium, such as air or a vacuum, all light waves travel at the same speed, but they differ in wavelength and frequency. Wavelength and frequency are inversely proportional to each other due to the observation that the longer the wavelength the lower the frequency. For the visible light spectrum, scientists commonly specify only the wavelength.

Each color is associated with a range of wavelengths. The name green or red does not apply to just one color. A wide segment of the spectrum contains colors that are called green. These include blue-green, apple green, and chartreuse, as well as many intermediate greens. Another wide segment contains colors that are called red. Colors of nearly the same wavelength look exactly alike to the human eye.

The colors of the spectrum range, in order, from violet, through blue, green, yellow, and orange, to red. The wavelengths of violet are the shortest, ranging from 380 to about 450 nanometers. (A nanometer is one billionth of a meter long.) Wavelengths of red are the longest, ranging from about 630 to 760 nanometers. Wavelengths shorter than those of violet are called ultraviolet radiation; wavelengths longer than those of red are infrared radiation, "Black" is the absence of color.

Colors can be observed in nature as specifics wavelengths of light or can be produced by three fundamental processes that can allow us to see most of the colors of the spectrum. These three processes are Color Addition, Color Subtraction and Color Perception.

Color Addition

There are three ways to produce color through color addition: 1) Addition or mixing of different colors of light (2) Movement of two or more different colors rapidly and 3) Color Spacing using small dots of different colors placed near one another.

Mixing of Colored Lights

Newton discovered that by mixing two differently colored rays of light he could produce other colors. When he projected light beams from different prisms onto a white background, he found that sometimes the new color looked like one of the other colors of the spectrum. Red and yellow, for example, could be mixed to look like the orange of the spectrum. He found that almost all colors can be made by three beams of differently colored light. The greatest number of different colors can be produced when a combination of one of the reds, a green, and a blue are used. For this reason, red, green, and deep blue are called the primaries for additive color mixing. You will develop the Color Addition facts that will allow you to predict the color produced when the primary colors are mixed.

Complementary Colors

When only two of the additive primaries are mixed in a certain amount, the resulting color is called the complementary color, or complement, of the third additive primary. When red and green light beams are mixed, the resulting color is yellow, the complementary color of blue. A mixture of red and blue makes a purplish color called magenta, the complement of green. And green and blue mixed together form cyan. the complement of red.

Rapid Movement of Colors

An object can be produced with exhibits two or more colors. If this object is moved rapidly the colors will appear to blend and appear to the viewer as though there is only one color on the object. This color that one observes can be predicted using the rules of Color Addition.

Color Spacing

One can use small dots of color to construct a picture or to cover some surface. From a distance these dots seem to blend together and appear as one color to our eyes. Postimpressionist painters used a method of painting called pointillism. They painted tiny dots of pure spectrum colors next to one another so that light reflected by one dot would combine with light reflected by a second dot in an additive mixture. One of the most famous paintings of this school is Georges Seurat's `Sunday Afternoon on the Island of the Grande Jatte'. This technique is also used to produce a picture on our television. The color that is observed can be predicted using the rules of Color Addition.

Color Subtraction

Absorption

When light strikes an object, it may be transmitted, absorbed, or reflected. A windowpane, for example, transmits almost all the light that strikes it. Since it does not change the light, the pane looks colorless, or clear. A black colored object, on the other hand, absorbs almost all the light that strikes it and therefore--since blackness is the absence of light-- looks dull and black. A plaster wall both reflects and absorbs light. If the wall is white, it reflects almost all the light that falls on it. The yellowish color of light from an electric lamp changes most colors, but our eyes tend to see the colors unchanged. By looking at colored objects under pure colors of light or through colored filters we see a pronounced change. In very dim light colored objects appear gray. Under red light, red appears red but green and blue appear black. Under blue light, blue objects appear blue while red and green objects appear black. Under green light, green appears normal, but red and blue appear black. The color that is observed can be predicted using the rules of Color Subtraction, which will be developed in the laboratory.

Filters

Sometimes a substance absorbs some but not all the colors that reach it. For example, a red tomato absorbs all wavelengths but those of red, which, after bouncing from molecule to molecule within the top layers of the tomato, are redirected outward. When blue light (which does not contain red wavelengths) shines on a tomato, the blue wavelengths are absorbed and the tomato looks black because no red light is reflected.

Transparent red objects such as red cellophane, red plastic, or red glass absorb all wavelengths but red ones, which they partly transmit and partly reflect. Such transparent objects are called color filters because when white light strikes them they filter out all colors except their own. which can pass through them easily.

Color filters are the basis of subtractive color mixing, just as colored beams of light are the basis of additive mixing. Subtractive color mixing is a complicated procedure because the different dye molecules in two different filters may produce the same color sensation yet absorb different wavelengths of light. The description of subtractive color mixing that follows assumes that ideal filters are used.

When a beam of white light strikes a yellow filter, the wavelengths that make up yellow can pass through the filter while all other wavelengths are absorbed. Since yellow is a mixture of green and red light, the wavelengths of those colors pass through, but the wavelengths of blue--the complement of yellow--are absorbed. A yellow filter is sometimes called minus-blue, since it can filter out blue light. Similarly, a magenta filter allows wavelengths of red and blue to pass but absorbs wavelengths of its complement, green. For this reason, magenta is sometimes called minus-green.

If a yellow filter (minus-blue) is placed on top of a magenta filter (minus-green) and a beam of white light is passed through them, the yellow filter absorbs blue, the magenta filter absorbs green, and only red light emerges.

A cyan filter (minus-red) absorbs its complement, red, If a yellow, a cyan, and a magenta filter are aligned in front of a beam of white light, all three of the additive primaries are absorbed and no light emerges. This is called subtractive color mixing because the filters absorb, or subtract, color from a beam of light. The color that is observed using one or more filters can be predicted using the rules of Color Subtraction.

Pigments

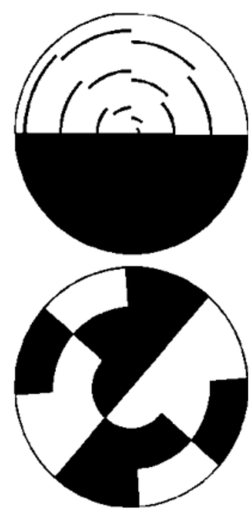
Pigments are chemicals that have the ability absorb certain colors and reflect others. Because of their widespread use to color our homes, cars, clothes, and in general our world we will investigate them as a specific form of Color Subtraction. Mixtures of Paint usually exhibit the complex behavior of subtractive mixing. A mixture of yellow and cyan watercolors produces green.

Colors produced by the subtraction of wavelengths, or filtering, often occur in nature. The reds and oranges of a sunset are caused by the filtering action of the sky. The sky scatters light of short wavelengths, such as blue. At midday, when the sun is overhead, the scattered blue light does not have to travel through very much air to reach a viewer. The sky looks blue because a great deal of blue light is reflected from it. But, at sunset the light must travel through much more air on its way to Earth. The blue is soon scattered, and only the colors of longer wavelengths--combined to appear orange and red--can be seen.

Perception of Colors

The perceived color of an object depends both on the color of the light that shines on it, the colors absorbed by the dyes in the paper and certain other factors. When light reflected from an object enters a human eye, it passes through the cornea, the pupil, and the lens and lands on the retina. The interpretation of this information allows us to perceive our environment. When this information can be interpreted in more than one way it may be perceived incorrectly and visual illusions may arise. As we collect and process information it is extremely important to understand how we perceive images as well as how color will influence our perception of our environment.

Benham Disks



The Benham disk is a black and white pattern that when spun rapidly seems to produce color. Benham's disk was invented by a nineteenth-century toy maker who noticed colors in a black and white pattern he had mounted on a top. What is perceived is a result of the eye-brain system intercepting intermittent patterns of black and white light entering the eye. The best explanation involves the properties of the three types of cone cells found in the eye. Each cone type responds mainly to light from a different region of the spectrum. When white light shines in the eye, all three cone types respond equally. After white light stops entering the eye. all cones turn "off" but not immediately and not at exactly the same time. One type turns off a little sooner, and another turns off a little later. Thus, when you look at the spinning Benham disk, white light intermittently enters your eye. This makes the cones "turn off" and "turn on" at different times causing your eye-brain system to receive different responses from the three types of cones. This stimulation of the cones is perceived by the brain as color.

Afterimages

Perhaps the best known visual affect that shows how our eyes perceive color is the afterimage. When people watch a motion picture, they are actually observing a series of rapidly projected still pictures. During the very short interval between pictures, a person retains an image of the preceding picture. This image blends into that of the following picture, giving an impression of continuous motion. The retained image is called a positive afterimage.

Persistence of vision in the absence of a physical stimulus occurs if people look at a patch of one color for about 30 seconds and then look at a blank sheet of white or gray paper. They will probably see a patch of color that is the complement of the original color. This is called a negative afterimage.

Virtual Laboratory

Topic 12 – Color

			12
Name	Section #	Date	Topic #

Use the link provided in Canvas, or you can use this http://phet.colorado.edu/en/simulation/color-vision . Click on Run Now. The only color choices you can use as answers for this assignment are Red, Blue, Green, Magenta, Yellow, Cyan, White, and Black. Answering using colors of orange, purple, pink, etc… will result in a lower grade.

Part I – Use the RGB Bulbs Tab

1) Each light has a color gradient. For the best results, slide the bar to the very top of each color. **Each color should be observed individually** for this first part. To stop the color, return the bar to the black location.
   a) What color is seen when the red light is on? ______________________________

   b) What color is seen when the green light is on? ______________________________

   c) What color is seen when the blue light is on? ______________________________

2) For the next part we will investigate the effects of mixing two colors. Before you begin each part **be sure to make a hypothesis.**
   a) What color *do you think* the man will see when **red and green** are mixed together?
   ____

   b) Turn on the red and green, both to the very top of the color scale. What does the man *actually see*?
   ____

   c) Experiment with the degree of color. While doing this, make sure that both colors are in equal locations on the scale. What colors are observed? Do they still fit into the same color family as the color observed in 'b'?
   ____

3) Keep the red light on (to the top red location), and turn off the green. We will be looking at red and blue next.

   a) What color *do you think* the man will see when **red and blue** are mixed together?
   ____

   b) Turn on the red and blue, both to the very top of the color scale. What does the man *actually see*?
   ____

   c) While experimenting with the degree of color make sure that both colors are in equal locations on the scale. What colors are observed? Do they still fit into the same color family as the color observed in 'b'?

4) Keep the blue light on (to the top blue location), and turn off the red. We will be looking at green and blue next.
   a) What color *do you think* the man will see when **green and blue** are mixed together?
   ____

   b) Turn on the green and blue. both to the very top of the color scale. What does the man *actually see*?
   ____

   c) Experiment with the degree of color. While doing this, make sure that both colors are in equal locations on the scale. What colors are observed? Do they still fit into the same color family as the color observed in 'b'?

5) Now we will be looking at mixing all three colors.

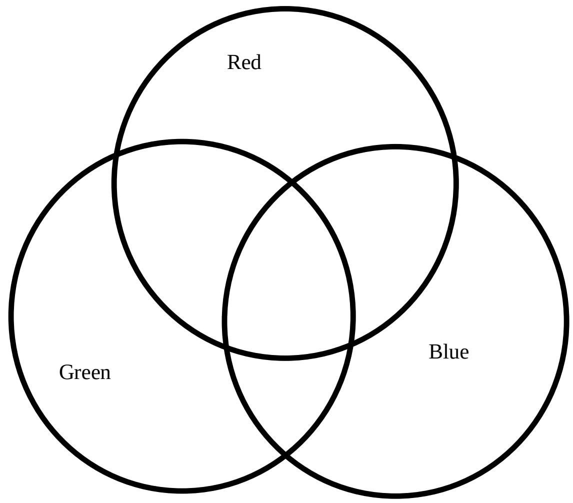
a) What color *do you think the man* will see when **red, green and blue** are all mixed together?

____

b) Turn on all three colors, all to the very top of the color scale. What does the man *actually see*?

____

6) Fill in the color **addition** diagram below.



II – Use the Single Bulb Tab

7) Set the simulation to the following: **bulb type** – 'white', **beam** – 'photons', and **filter color** – 'off'.

a) What is coming out of the bulb?

____

b) What color light does the man see?

____

Set the simulation to the following: **bulb type** – 'white', **beam** – 'solid', and **filter color** – 'off'.

a) What is coming out of the bulb?

____

b) What color light does the man see? ____

8) Set the simulation to the following: **bulb type** – 'white', **beam** – 'photons', and **filter color** – 'on'.

a) Choose any filter color. Record the color

b) What is coming out of the bulb before the filter (in the area just in front of the filter)?

____

c) What is coming out after the filter? ____

d) What color light does the man see? ____

e) Choose another filter color. Record the color. ____

f) What is coming out of the bulb before the filter (in the area just in front of the filter)?

____

g) What is coming out after the filter? ____

h) What color light does the man see? ____

i) What is the filter doing? ____

9) Set the simulation to the following: **bulb type** – 'white', **beam** – 'solid, and **filter color** – 'on'.

a) Choose any filter color. Record the color

b) What is coming out of the bulb before the filter (in the area just in front of the filter)?

____

c) What is coming out after the filter? ____

d) What color light does the man see? ___________ ____

e) Choose another filter color. Record the color. ____

f) What is coming out of the bulb before the filter (in the area just in front of the filter)?

____

g) What is coming out after the filter? ____

h) What color light does the man see? ____

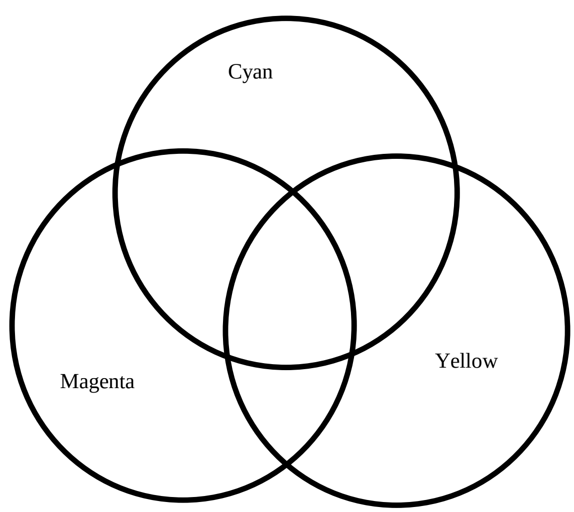
i) What are the differences between question 7 (photon setting) and question 9 (solid setting)?

____

j) What are the similarities between question 7 (photon setting) and question 9 (solid setting)?

____

10) Fill in the color **subtraction** diagram below.



Hands-on Laboratory

Topic 12 – Color

MATERIALS

diffraction grating
color device
comic strip picture
7X magnifier
spinning disks - Benham
chromatography kit
- water soluble black pen
- water soluble green pen
- chromatography paper
- dropper bottle of water

Fluorescent light
Neon light
Krypton light
Test pattern videotape

spectroscope
set of primary filters
set of secondary filters
black and white picture
spinning disks - colored
color reflection card
afterimage picture - heart
afterimage picture - flag
Screen pointer

Incandescent light
Sodium light
Mercury light
Hydrogen

PROCEDURE

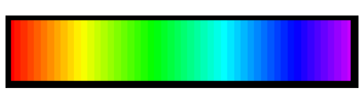
Note: 1. When describing colors, refer to them as red, blue, green, yellow, magenta, or cyan. Since all other colors are mixtures, hues, or intensities do not use other color names. (Black, the absence of all color, and white, the presence of all colors, may also be used when describing colors).

2. Many parts of the following laboratory require a prediction. These should be done before you come to class to do the actual hands-on portion of the laboratory.

Part A - Problem: Spectrum (*Note: best in a dark area.)*

1. Using a reference of your choice, define or describe a diffraction grating.

2. Obtain the device labeled "Color Projection Device". Place the "projection screen" in front of the lights. Place a diffraction grating in front of the center projector and turn on the projector to produce a spectrum on the screen. You will note that there are two spectrums, one on each side of the light beam produced. Choose one spectrum for your consideration which should look something like the following representation



Incandescent Light

3. Explain the various colors of the spectrum using the model of electromagnetic spectrum. Name the colors, in order. of the spectrum.

4. Obtain a spectroscope. It has an eyepiece consisting of a round hole and a piece of diffraction grating at one end and a slit at the opposite end to allow the light to enter. When looking through the eyepiece, round hole, of the spectroscope the spectrum will be seen to the right or left near the eyepiece.

5. Observe and name the picture of the spectrum shown in your data sheet. In order to name each spectrum use other reference such as textbooks or internet, which show the name the spectrum of the light sources included for you laboratory. You could then match the reference spectrum to yours and then name.

Atomic#	**Light Sources**	
	Fluorescent	- long round tubes that look white found in home or businesses
	Incandescent	- pear shaped bulb commonly found in homes
11	Sodium	- parking lots or street lights, golden orange color
10	Neon	- found in store signs
36	Krypton	- new brighter flashlight bulbs - check packaging
80	Mercury	- street lighting, blue color
1	Hydrogen	- use web reference

Hint: while looking at the colored spectrum pictures provided on the internet as part of your electronic data sheet use "View" and zoom to 200%. This view will allow you to see your spectrum in great detail.

6. Note that three colors of light seem to stand out in the fluorescent and incandescent light, which are most like sunlight. If you were to do additional experiments, these three colors are not able to be broken down into other colors. Because these three colors are fundamental they are referred to as the primary colors. Identify these three colors.

7. Indicate how the spectral patterns could be used to identify different light sources such as stars, lights, or burning chemicals?

Part B - Problem: Color Addition

Section 1 - Problem: Color Addition of Light *(Note: best in a dark area.)*

1. Obtain the "Color Projection Device" and the set of "Colored Filters". Select the colored filters of the three primary colors.

2. Using the center projector, practice projecting each of the colored filters on the screen.

3. Using the two side projectors place a red colored filter in front of one projector and the green filter in front of the other projector. Adjust the projectors so that one colored circle of light overlaps the other by approximately half. Notice that a new color will be formed in the overlapping area. Remember to use one of the six indicated colors when identifying this new color. This process develops our first color addition fact.

   Red light + green light = ______________________________

4. Using the two side projectors place a blue colored filter in front of one projector and the green filter in front of the other projector. Adjust the projectors so that one the colored circles of light overlaps the other by approximately half. Notice that a new color will be formed in the overlapping area. This process develops our second color addition fact.

   Blue light + green light = ______________________________

5. Using the two side projectors place a red colored filter in front of one projector and the blue filter in front of the other projector. Adjust the projectors so that one the colored circles of light overlaps the other by approximately half. Notice that a new color will be formed in the overlapping area. This process develops our third and final color addition fact.

   Red light + blue light = ______________________________

   Note: The three colors, cyan, magenta, yellow, are called secondary colors.

6. Describe the formation of the secondary colors using the interaction of the wavelength of the various colors.

White light and Colored Shadows

7. Using the color projector device place a red colored filter in front of one projector, the blue filter in front of the center projector and the green filter in front of the third projector. Adjust the projectors so the colored circles of light overlap one another. Notice the color that is formed in the overlapping area of all three colors.

   Red light + blue light + green light = ______________________________

   Using the color projector, project each of the colors, (red, blue, green, cyan, magenta, yellow) and white light on the screen using only the primary filters (red, blue, green). Place the pointer into the light, approximately 1.0-cm. in front of the screen. This will produce a shadow. Record the color of each of the shadow(s) produced for each color listed in the data table.

Components of Primary and Secondary Colors

8. The primary and secondary colors have now been identified. Determine or verify the color(s) contained in the primary and secondary colors. Place the red colored filter in front of the center projector. Place the diffraction grating in front of the colored slide and observe the color(s) produced on the screen. Repeat this process for each of the filters (blue, green, cyan, magenta, yellow). Do the results support the color addition facts?

Complementary colors

9. A complementary color is the color that when added to another color produces white light. Using the color addition facts *predict* the complement of each of the colors listed in the data chart.
10. Verify the complement of each of the colors. listed in the data sheet, through experimentation. Using the two side projectors place a colored filter in front of one projector and experiment. by placing various filters in front of the other projector, to determine the colors complement.

Section 2 - Problem: Color Spacing

Color Television *(Note: best in a dark area.)*

1. The color television screen is composed of sets of red, blue and green phosphor dots (or dashes). There are beams of electrons that move around and strike the various dots. The location of the beam is controlled by the television and the signals received. When struck by the electrons, some of the dots glow red, some glow green, and some glow blue depending on the frequency of the electron beam. When examining a particular area of the television screen, the colors of the dots appear to glow with varying degrees of brightness depending on the intensity of the electron beam.

2. For our laboratory work we will consider these small red, blue, green, dots or rectangles can be turned "ON", "OFF" or "DIM" to make the color produced on the TV screen.
   a. Using the colors in the data sheet predict, using color addition, which color rectangles would have to be "ON" and which would have to be "OFF" to produce the colors seen on the television.
   b. Obtain the videotape entitled "Color" or the computer file "Color Wheel. Run the program so that you can view a color wheel on your television or computer monitor. Either will present a picture consisting of a color wheel on the TV/monitor screen.
   c. Obtain a 7x magnifier to look at each of the colors on the color wheel.
   d. Start with the black, which has all the red, blue, and green turned "OFF" and white, which has all the red, blue, and green turned "ON", you will be able to identify "ON and "OFF".
   e. Look at colors on the color wheel (Red, Blue, Green, Magenta, Yellow, Cyan, Black, and White) using a 7x magnifier. Record the brightness of each of the three colors, (red, blue, green) used to produce the color on the color wheel, as OFF, ON, or DIM.

Newsprint (*Note: best in a brightly lit area.)*

3. Obtain the black and white newsprint picture. Using the magnifier look at it closely and describe how the blacks, dark grays and light grays, are produced to make the picture.

4. Pictures from the Sunday comics provide an excellent way to investigate properties of colored printing. Printers use four different colored inks to print their colored pictures. The four inks are magenta, cyan, yellow, and black. Printers use four different techniques to produce a colored print.
   a. *Blending* several pigments or inks to produce the color they want and use that for printing. This will produce a very uniform appearance to the color printing.
   b. *Small dots* of different colors are placed next to each other. From a distance these two or more colors appear to blend together and look like one color.
   c. *Small overlapping dots* of different colors are placed so that they overlap. Since these inks are semitransparent some of the bottom color can affect the overall color. Overlapping various combinations of these four inks on white paper will produce only the following eight colors: white, black, yellow, cyan, magenta, red, blue, and green. The saturation and the lightness of these colors would produce other colors.
   d. *Dot Density* is used where a part of a picture is to appear lighter. The dots are printed smaller, and thus more of the white background shows through. Where part of the picture is to appear more saturated, the dots are printed larger. To make the area appear darker, black dots are usually added.
5. Obtain the color newsprint picture. Using the magnifier determine how colors are produced in the picture. Given each of the above techniques, locate a part of the comic that used that technique and describe that part of the comic.

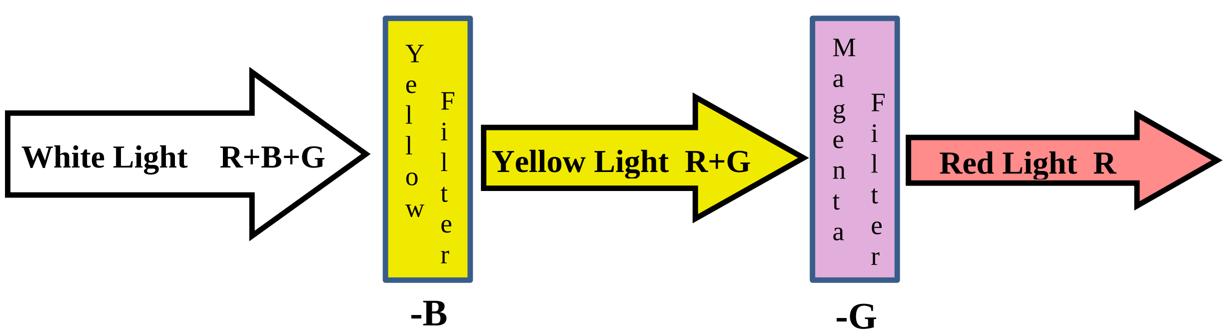
Section 3 - Problem: Color Movement (*Note: best in a brightly lit area.)*

1. Obtain the "Spinning Disks". Using the color addition facts predict the color that will be produced when each of the disks are rapidly spun? Record your predictions in the data table.
3. Select one of the colored disks, indicated in the data table in the laboratory, and place it on the spinner.
4. Spin the disk briskly. (You have been provided with a yellow "spinner handle extension". Attach it to the existing spinner handle in order to make the spinning of the color disks easier.) Observe whether the original colors are still clearly visible or have they been blended or merged into a new color.
5. Record the color observed? *Please realize that the quality of color observed is dependent on the pigments of the dyes or colors of the original material.*
6. Repeat for each of the disks indicated in the laboratory data sheet.

Part C - Problem: Color Subtraction

Section 1 - Problem: What Is The Effect of Colored Filters On Viewing? *(Note: best in a brightly lit area.)*

1. Looking through several filters at the same time can produce quite amazing results. Please note that the order of the filters does not affect the color of light that gets through. In this activity you will be asked to overlap several filters while looking at a piece of white paper which has been illuminated with a white light source.
2. The following diagram illustrates Color Subtraction for a yellow filter and an overlapping magenta filter. This same procedure can be used to explain color subtraction for all other cases. Make predictions for each of the overlapped sets of filters indicated in the data chart.



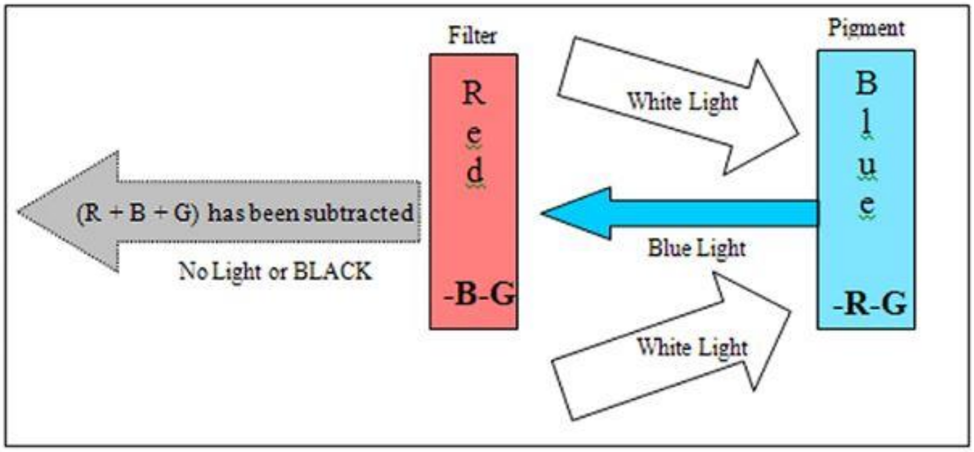
Minus (B) and (G) = Red

3. Select the color filters indicated in the data table. Overlap the filters while looking at a piece of white paper that has been illuminated with a white light source. Record the actual color observed.

Section 2 - How do various colors look through colored filters? *(Note: best in a light area.)*

Note: One can select the frequency of the observed light (color) reflecting off of an object by placing a filter in front of a light source or by looking, at the object, directly through a filter. In this activity you will look at the Color Wheel while looking through colored filters. Each filter, "selects" a specific light frequency reflected from the material, that the light is shining on and produces a color that we see.

1. Looking at the "Color Wheel Card" and using color subtraction predict the color that would be observed when looking through the filter indicated in the data table.



OR Blue Light (B) minus (B) and (G) = Black

2. Place the "Color Wheel Card" in front of the screen. Select the colored filter indicated in the data table. While looking through the filter(s) observe each of the colors on the card. Record the color observed.

3. What is the difference between the primary and secondary colors of light and the colors that they can illuminate?

Section 3 - Color Chromatography (*Note: best in a brightly lit area.)*

1. Obtain the kit labeled "Color Chromatography". On the strip of the chromatography paper draw a line across the paper with the black marker approximately 1.0-cm from one end of the paper.

2. Predict what colors make up the black marker and record in the data sheet.

   Example: White Light - (____________ + ____________ + ____________) = Black

3. Place four to six drops of water near the end of the paper with the marker and allow it to 'develop' for a few minutes. If the material being tested is soluble in the solvent, the material can be carried by the water as the water moves through the chromatography paper. If the material is made up of different materials, each material can move at different rates, based upon the molecular size, thus separating the original material.

4. Predict what colors would make up the green marker.

   Example: White Light - (________________ + ________________) = Green

5. Repeat the procedure for the green marker. Record the actual colors observed in the data sheet. Retain the chromatography strips for your records.

• 12 •
COLOR

Name	Section #	Kit #	Topic #
			12
			12
			12

Part A - Problem: Spectrum

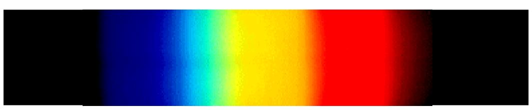
Pre-Lab Prep (1-3 and 5-6.)

1.(1) Diffraction Grating is: _____

2.(3) Colors are based upon the differences of: _____

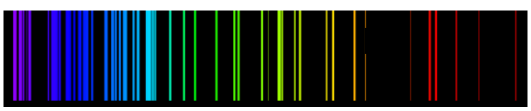
3.(3) "Roy G. Biv" stands for: _____

4.(5) Name each the following light sources as seen with a spectroscope:

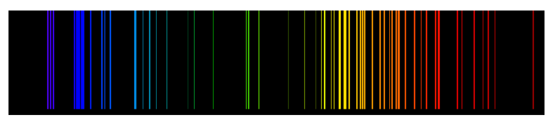


Spectrum A

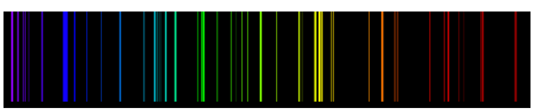
Spectrum B



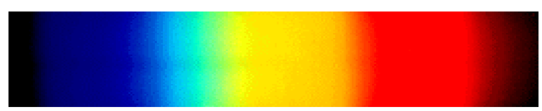
Spectrum C



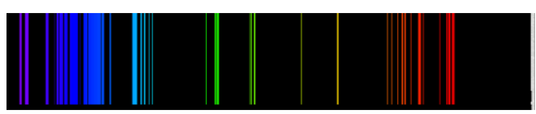
Spectrum D



Spectrum E



Spectrum F



Spectrum G

Name of Spectrum A _____

Name of Spectrum B _____

Name of Spectrum C _____

Name of Spectrum D _____

Name of Spectrum E _____

Name of Spectrum F _____

Name of Spectrum G _____

5.(6) The Three primary colors of light are: _____ . _____ . _____

6. (7) How are spectral patterns used to identify specific light sources? _____

Part B - Problem: Color Addition

Section 1 - Problem: Color Addition of Light (PreLab Prep 7 – 11)

7.(3) Red light + green light = _____

8.(4) Blue light + green light = _____

9.(5) Red light + blue light = _____

10.(6) How are the secondary colors of light formed? _____

White light and Colored Shadows

11.(7) Red light + blue light + green light = _____

Light Color on Screen	Number Of Projectors	Slides Used	Color(S) Of Shadow's Produced by Insertion of Object Between Screen and Projectors
Red Light	1	red	
Blue light	1	blue	
Green Light	1	green	
Cyan Light	2	blue + green	
Magenta Light	2	red + Blue	
Yellow Light	2	red + Green	
White Light	3	red + Blue + Green	

12.(8) Components of Primary and Secondary Colors

Light	Observed Color(s) Produced By Diffraction Grating
Red Light	
Blue light	
Green Light	
Cyan Light	
Magenta Light	
Yellow Light	

13.(8) Do the results of this experiment support the color addition facts?

14.(9) Complementary Colors (pre-lab prep - predicted column)

Light	Complement Predicted	Actual Complement
Red Light		
Blue light		
Green Light		
Cyan Light		
Magenta Light		
Yellow Light		

Section 2 - Problem: Color Spacing

Color Television Record the brightness of the color dots that make up the main colors.

(Pre-lab prep - predicted columns)

	Brightness of individual dots. on TV. magnified 7X					
TV Color Wheel	Red Pixels		Blue Pixels		Green Pixels	
	Predicted	Actual	Predicted	Actual	Predicted	Actual
Red (circle)	*ON*		*OFF*		*OFF*	
Blue (circle)						
Green (circle)					*ON*	
Magenta(circle)						
Yellow(circle)						
Cyan (circle)					*ON*	
Black (circle)						
White (Area)						

Black and White Newsprint

14.(3) Describe how the blacks. dark grays. and light grays. are produced to make the picture.

Black ______

Light Gray ______

Dark Gray ______

Section 3 - Problem: Color Movement

Using the "Spinning Disks" predict and observe their colors.

(Pre-lab prep prediction column)

Original Colors	Prediction	Actual Color
half blue + half red	*magenta*	
half green + half blue		
half green + half red		

Colored Newsprint (See text for descriptions.)

15.(5) Locate printing techniques and describe a part of the comic that uses that technique.

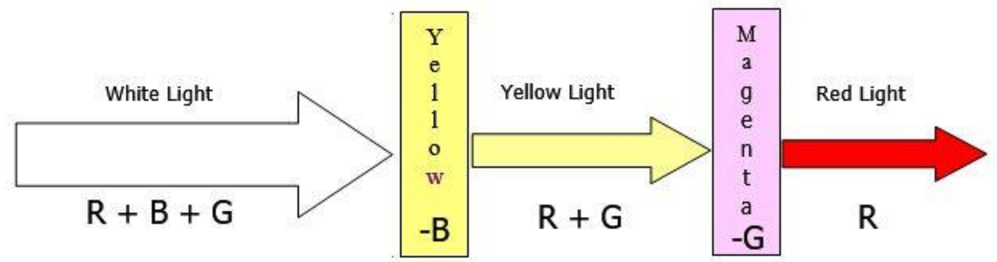
Technique	Description
Blending	
Small Dots	
Small Overlapping Dots	
Dot Density	

Part C - Problem: Color Subtraction

Section 1 - Problem: What Is the Effect of Colored Filters On Viewing?

Look through the indicated filters, at the same time, and determine the subtracted color(s), predict the color and observe the actual color seen when looking at white paper.

Remember to solve the color subtraction problems using the following process.



OR

White Light (R + B + G) — (B) (G) = Red

(Pre-lab prep subtracted and predicted columns)

		Color		
Light Color	Filter Color	Subtracted (pre-lab prep) (use one set of parenthesis for each color)	Predicted	Observed
R + B + G	Red + Blue	( ) (R. G)	Black	
R + B + G	Magenta + Blue	( ) ( )		
R + B + G	Magenta + Red	( ) ( )		
R + B + G	Magenta + Green	( ) ( )		
R + B + G	Magenta + Yellow	(G) (B)	R	
R + B + G	Magenta + Cyan	( ) ( )		
R + B + G	Yellow + Green	( ) ( )		
R + B + G	Yellow + Cyan	(B) ( )		
R + B + G	Cyan + Red	( ) ( )		
R + B + G	Cyan + Blue	(R) (R.G)		
R + B + G	Cyan + Green	( ) ( )		
R + B + G	Cyan + Yellow + Magenta	( ) ( ) ( )		

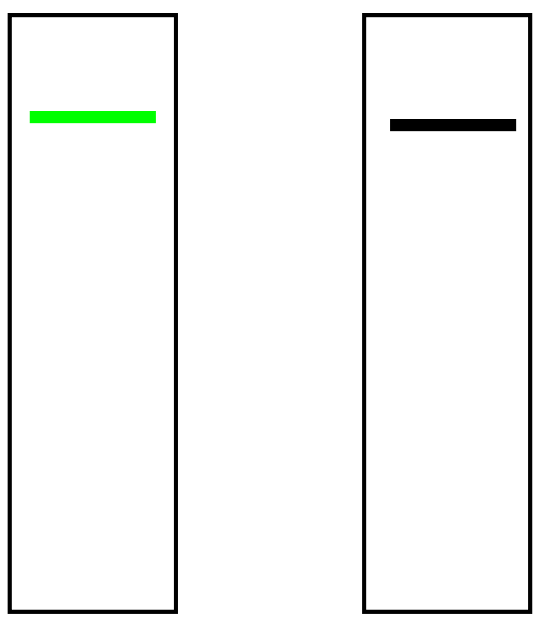
Section 2 - How do various colors look through colored filters? (Pre-lab prep prediction columns)

	Color Wheel Card As Seen With Colored Light											
Filter	Red		Blue		Green		Magenta		Yellow		Cyan	
	Prediction	Actual	Prediction	Actual	Prediction	Actual	Prediction	Actual	Prediction	Actual	Prediction	Actual
Red												
Blue												
Green												
Magenta	Red		Blue		Black		Magenta		Red		Blue	
Yellow												
Cyan												

16. (5) What is the difference between the primary and secondary colors of light and the colors that they illuminate?

Section 3 - Color Chromatography (pre-lab prep predicted column)

Marker Color	Predicted Color(s)	Actual Color(s)
Black		
Green		



COLOR

Self-Evaluation

Test 121

Directions: Select the best answer.

1. 12.1 The process of combining two different colors of light to produce a third is called?
   A. Primary colors of light
   B. Secondary colors of light
   C. Constructive interference
   D. Color Addition

2. 12.1 The color red, green and blue are called?
   A. Colors of the spectrum
   B. Primary colors of light
   C. Complementary colors
   D. Secondary colors of light

3. 12.2 The colors produced by a diffraction grating in order of increasing wavelength. is:
   A. Green, Yellow, Orange, Violet, Blue, Indigo, Red
   B. Indigo, Blue, Green, Red, Yellow, Orange, Violet
   C. Black
   D. Violet, Indigo, Blue, Green, Yellow, Orange. Red
   E. White

4. 12.2 The wavelength of light determines?
   A. How long it takes the eye to focus on a color
   B. The color the eye perceives
   C. Color subtraction ability
   D. The likelihood of color movement

5. 12.3 The colors yellow. magenta and cyan are called?
   A. Primary colors of light
   B. Secondary colors of light
   C. Complementary colors
   D. Colors of the spectrum

6. 12.3 The process of mixing together two primary colors and creating a secondary color is called?
   A. Color addition of light
   B. Color addition through movement
   C. Color addition through spacing
   D. Constructive Interference

7. 12.4 If the color blue is placed next to the color green on a wheel, what color will you see when it is moving fast.
   A. Red
   B. Blue
   C. Green
   D. Yellow
   E. Cyan
   E+A Magenta
   E+B White
   E+C Black

8. 12.4 If the color green is placed next to the color red on a wheel, what color will you see when it is moving fast?

A. Red
B. Blue
C. Green
D. Yellow
E. Cyan
E+A Magenta
E+B White
E+C Black

9. 12.5 If a small dot of the color green is placed next to a small dot of the color blue, in the Sunday comics what color will you see?

A. Red
B. Blue
C. Green
D. Cyan
E. Yellow
E+A Magenta
E+B White
E+C Black

10. 12.5 If a small dot of the color blue is placed next to a small dot of the color red. in the Sunday comics what color will you see?

A. Red
B. Blue
C. Green
D. Yellow
E. Cyan
E+A Magenta
E+B White
E+C Black

11. 12.6 What are the color(s) that are subtracted when using a green colored filter on white light?

A. Red
B. Blue
C. Green
D. Red and Blue
E. Red and Green
E+A. Green and Blue
E+B. Yellow
E+C. Cyan

12. 12.6 What color(s) will be observed when magenta and green colored filters are overlapped in white light?

A. Red
B. Blue
C. Green
D. Cyan
E. Magenta
E+A. Yellow
E+B. Black
E+C. White

13. 12.7 Using a cyan light shone on blue will be observed as which of the following colors?
A. Red
B. Blue
C. Green
D. Cyan
E. Magenta
E+A. Yellow
E+B. Black
E+C. White

14. 12.7 Using a cyan light shone on red will be observed as which of the following colors?
A. Red
B. Blue
C. Green
D. Cyan
E. Magenta
E+A. Yellow
E+B. Black
E+C. White

15. 12.8 Using two colors, yellow and red <u>pigments</u> what is the resulting color?
A. Red
B. Blue
C. Green
D. Cyan
E. Magenta
E+A. Yellow
E+B. Black
E+C. White

16. 12.8 Using two colors. magenta and blue <u>pigments</u> what is the resulting color?
A. Red
B. Blue
C. Green
D. Cyan
E. Magenta
E+A. Yellow
E+B. Black

17. 12.9 When no light (black) shines in the eye, how do cell cones respond?
A. Only one cell cone is stimulated
B. All cones are stimulated
C. Two of the three cone types are stimulated
D. None of the cones are stimulated

18. 12.9 Benham disk produces?
A. A 3-D affect using red and blue filters
B. A laser light show
C. Tiny little lines
D. Colors from black and white
E. Violet lines

SELF TEST ANSWERS

Topic 01 - Measurement

1. B	2. B	3. B
4. D	5. E	6. C
7. E	8. A	9. E
10. C	11. E	12. D
13. A	14. C	15. B
16. C	17. A	18. B

Topic 02 - Experimental Models

1. A	2. A	3. A
4. A	5. B	6. B
7. A	8. B	9. E
10. E		

Topic 03 - Structure of Matter

1. B	2. C	3. C
4. C	5. A	6. A
7. C	8. C	9. C
10. B	11. B	12. C
13. B	14. D	15. A
16. B	17. A	18. D
19. C	20. D	

Topic 04 - Motion

1. B	2. D	3.prelab prep
4. D	5. B	6.prelab prep
7.prelab pr	8. B	9.prelab prep
10.prelab prep		

Topic 05 – Forces & Simple Machines

1. A	2. C	3. A
4.. C	5. B	6. C+E
7. B	8. D	9. B
10. A	11. B	12. C
13. A	14. B	15. A
16. A	17. A	18. E
19. D	20. C	

Topic 06 - Energy

1. B	2. E	3. E+A
4. A	5. A	6. C
7. C	8. D	9. D
10. E	11. B	12. C
13. A	14. B	15. A
16. E	17. A	18. D
19.E	20. D	

Topic 07 Heat

1. C	2. A	3. E
4. D	5. C	6. A
7. D	8. C	

Topic 08 –Waves & Sound

1. C	2. B	3. C
4. D	5. A	6. D
7. A	8. C	9. C
10. D	11. C	12. C

Topic 09 - Electricity

1. E	2. C	3. D
4. C	5. D	6. C
7. B	8. A	9. E
10. B	11. B	12. A
13. D	14. B	

Topic 10 - Magnetism

1. A	2. E	3. A
4. B	5. D	6. C
7. C	8. A	9. A
10. E	11. C	12. A
13. B	14. C	15. D
16. B	17. E	18. B

Topic 11 - Light

1. C	2. C	3. C
4. B	5. C	6. D
7. D	8. E	9. D
10. B		

Topic 12 - Color

1. D	2. B	3. D
4. B	5. B	6. A
7. E	8. D	9. D
10. E+A	11. D	12. E+B
13. B	14. E+B	15. A
16. B	17. D	18. D

Optional Practice Laboratory

IMPORTANT NOTE TO THE STUDENT: The following graphs are for practice. Almost every lab this semester will require the student to develop a graph or analyze a graph. Some instructors will ask their students to plot graphs manually using pencil and a graph paper, and other instructors will have their students use graphing programs. **Check with your instructor what method they require**.

The practice data below is accompanied by small grids to be used to plot the data. At the end of the practice data sets there are instructions on how to use the Graphical Analysis program which is found on the classroom laptops.

Also included are instructions on how to copy the graphs using Snipping Tool and pasting them into your Word document. Some instructors will have their students submit their work to Canvas, and other instructors will want a print out. If your instructor wants you to print the assignment then ignore the instructions about submitting your assignment to Canvass
.

Graph Requirements

All graphs require a title. Use Dependent Vs Independent Variable (typically Y vs X).
Label the x axes and identify the units.
Label the y axes and identify the units.
Scale the graph. Scale it to be as large as possible.
Plot the data.
Draw a best fit line.
Analyze the graph. (What information does it give you?)

Graphs will be discussed in more detail in Topic 2.

Physical Science Name____________________________
Independent Practice
Graphing Section____________________

1.

X distance (cm)	**Y force (Newtons)**
2	6
6	10
1	5
4	8
3	7
9	13
5	9

Label (dependent or independent value)
Units (measuring device scale)

2.

X time (seconds)	**Y distance (meters)**
1.5	3
4	5.5
2.5	4
4.5	6
1	2.5
3.5	5

3.

X **time** **(seconds)**	**Y** **distance** **(meters)**
4	2
8	6
5	3
3	1
7	5
11	9
9	7

4.

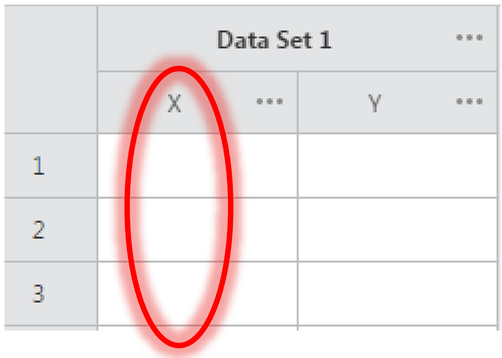
X **time** **(seconds)**	**Y** **distance** **(meters)**
1	1
3	9
5	25
2	4
4	16

Graphing Using Graphical Analysis Program

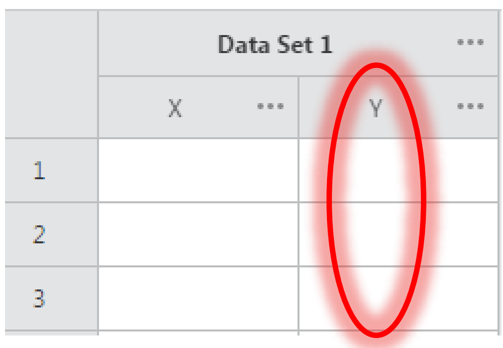
Optional Practice. **URGENT WARNING: Closing the laptop will lid delete all files you have saved.**

Click on WINDOWS BUTTON -> All Programs -> Vernier Graphical Analysis -> Manual Entry

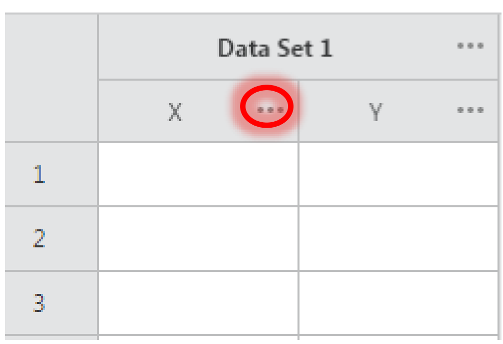
1. Enter the X data into the table; only the numbers, not the units.



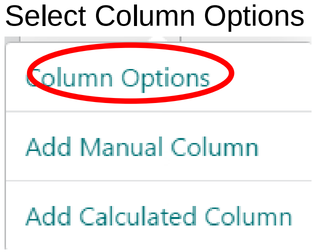
2. Enter the Y data into the table; only the numbers, not the units.



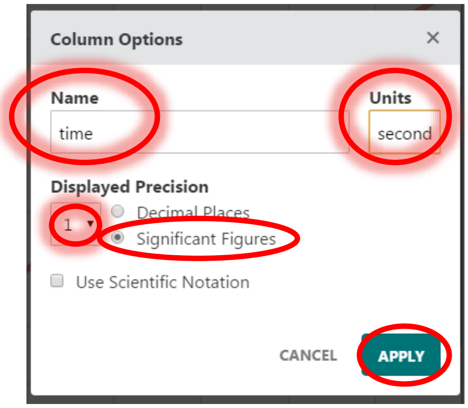
3. Click on the three dots next to X.



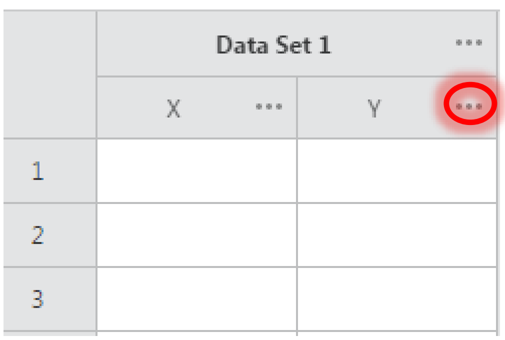
4. Select Column Options

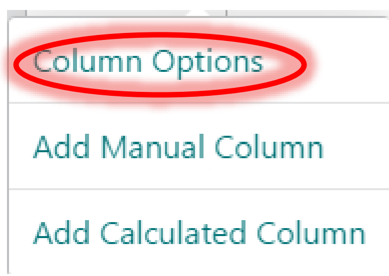


5. Type the name of the x axis (independent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the independent variable in the box.



6. Repeat steps 3 – 5 for the Y axis. Click on the three dots next to Y. Select Column Options

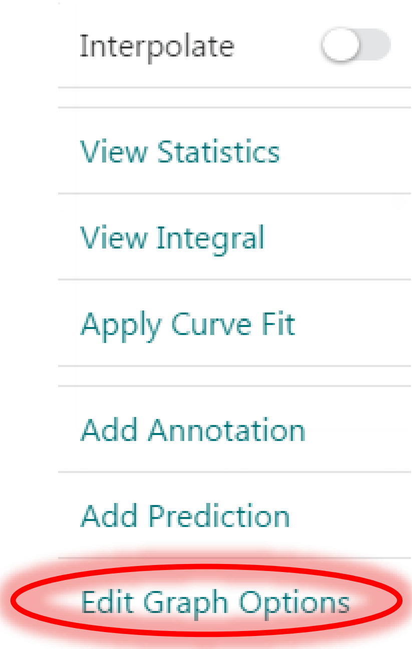


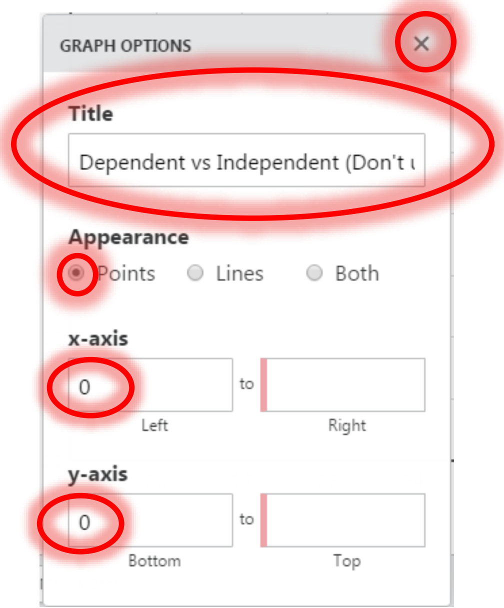


See step 5 for image. Type the name of the y axis (dependent variable) in the first box. Enter the unit in the second box. Click on the button next to Significant Figures. Enter the number of significant figures for the dependent variable in the box.

7. Click on the graph icon in the lower left of the screen.

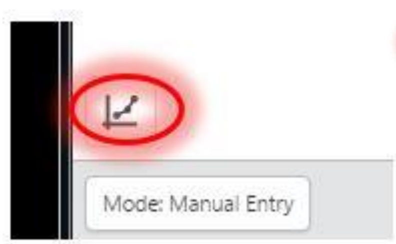
8. Click on Edit Graph Options. Enter the title of the graph. Remember it will be Y vs X. (Do not type the letters Y vs X!!!). Select the button next to points. Type a 0 in the left box of the x-axis. Type a 0 in the left (bottom) box of the y-axis. Close the box by clicking on the x in the upper right.

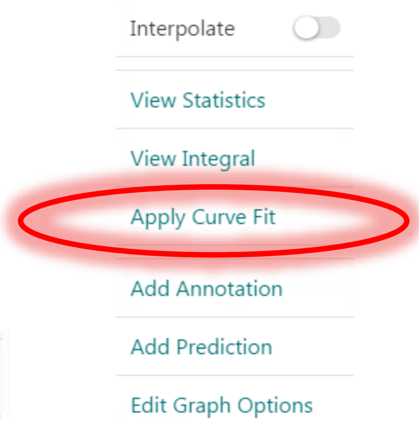




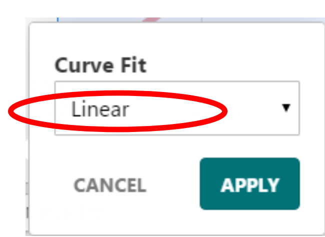
Note: If the graph is edited at all the 0's will revert to a number. You may need to re-enter the zeros again. Double check to insure that your graph starts with 0. 0 in the lower left corner.

9. Click on the graph icon in the lower left of the screen. Select Apply Curve Fit.



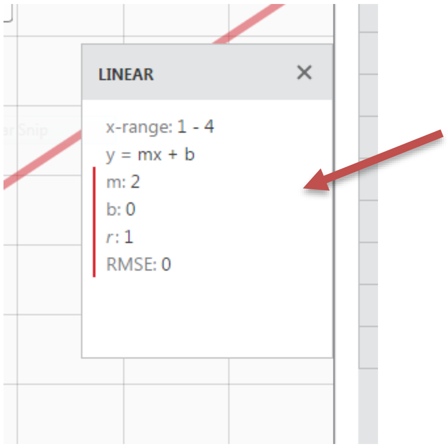


10. For the first three graphs select Linear Fit as shown below. For the fourth graph select POWER Fit. APPLY.



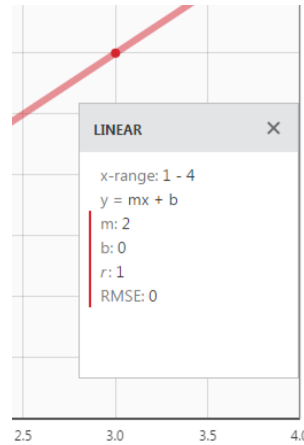
11. Uncover your best fit line or curve.

BEFORE



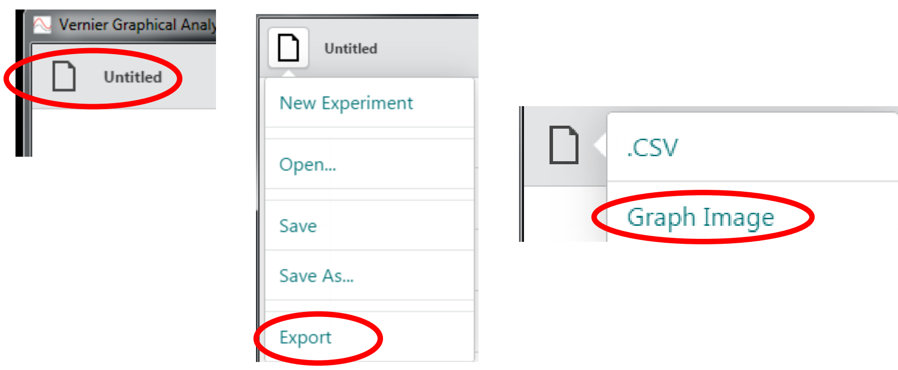
Notice the box that opens with your best fit line. If it is covering your best fit line move it so that it is not covering anything important.

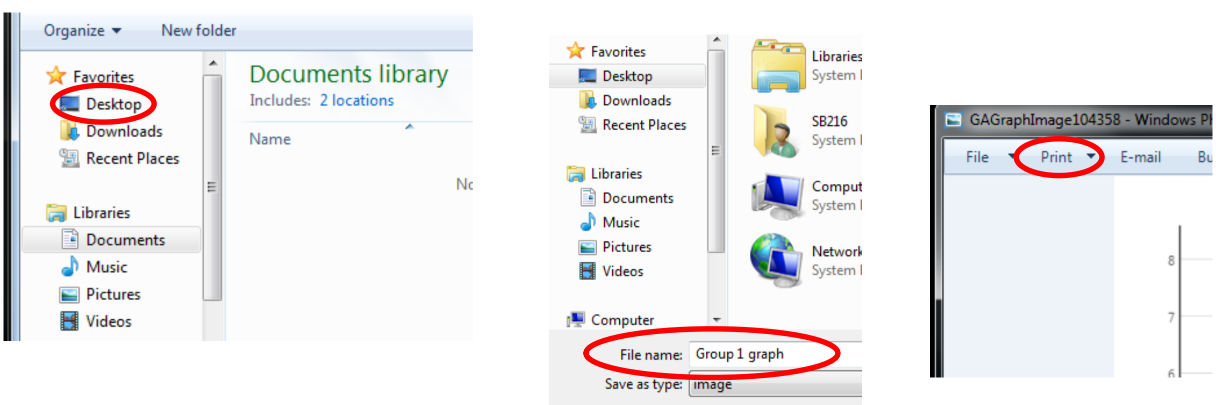
AFTER



12. **Save** AND **Print** your graph(s).

Click on paper icon in the upper left. EXPORT -> Graph Image -> Desktop File Name -> Practice Graph 1. 2. 3. or 4. Print.





Glossary

Absorber - A body which takes another substance into itself by means of the process of absorption.

Absorption - The process of taking a substance into itself. as water is taken up by a sponge. or as food is taken up and used by the body.

Acceleration - The change in the speed of an object. divided by the time it takes to affect such a change.

Acceleration of Gravity - The acceleration of a body as it falls freely at the surface of the Earth (about 9.8 m/s^2 or 32 ft/s^2).

Acids - A compound which contains hydrogen. In a water solution, forms no positive ions except H^+ions. Have a sour taste.

Activation Energy - The energy barrier that must be overcome in order to allow a chemical reaction to proceed.

Activity Series - A listing of elements based on their chemical reactivity with other elements. The elements are listed in sequence from high reactivity to low reactivity.

Actual Effort - The force which is actually applied to a simple machine to produce work.

Actual Mechanical Advantage - The ratio of the force that performs useful work (output of the simple machine) to the force applied to the machine (input by you).

Alpha Particle (Alpha Ray) - A helium nucleus, a heavy, positively-charged particle emitted during a type of radioactive decay known as alpha decay.

Alternating Current (A.C.)- An electric current that reverses its direction regularly and continuously.

Ampere - A unit of electric current which corresponds to the passage of one coulomb of electric charge per second.

Amplitude - Applied to waves or an object undergoing oscillatory motion, the distance between the middle and outer positions. In the case of a pendulum, it is the angular distance measured between the vertical. and the point of release of the pendulum.

Anode - The positive plate in an electrolyte system; the plate where oxidation takes place, and where electrons are lost.

Armature - The rotating coils of wire in a motor or a generator.

Atom - The smallest division of an element. An atom of an element has the properties special to that element. and is able to take part in chemical reactions.

Atomic Number - A number assigned to each element indicating the number of protons in the nucleus of the atom of that element. Elements are placed in the order of the increasing number of charges in their nuclei, starting with H as 1.

Atomic Weight - The mass of an atom of an element. measured in relation to that of an atom of Carbon, C. which is fixed at 12.

Average - A number which typifies a set of numbers. Average = $(x_1 + x_2 +. . . +x_n) / n$

Average Speed - The ratio which expresses the total distance traveled, and the total time taken to travel such distance.

Axis - 1. A real or imaginary line on which an object rotates, 2. A line used in constructing a graph. The units for the variables are plotted along the axis.

Blue - One of the three primary colors of light.

Background Count - The amount of natural radioactivity present at a given location. If an experiment is being done to measure the radioactivity of some object (i.e. the number of "decays" per minute), the background count must be subtracted from the measurement in order to arrive at a true value.

Base - A compound containing the hydroxyl group, which, when dissolved in water, forms no negative ions except OH^- ions. Has a bitter taste. and leaves the hands with a slippery feeling.

Beam - A group of rays radiating out in the same direction.

Beta Particle (Beta Ray)- A particle emitted from a nucleus during the type of radioactive decay known as beta decay; now known to be an electron or a positron.

Black - The absence of color.

Boiling Point - The temperature at which the vapor pressure of a liquid is equal to the atmospheric pressure, causing the liquid to boil.

Calorie - A unit of heat energy, originally defined as the amount of heat needed to raise the temperature of 1 gram of water 1 degree centigrade; one calorie equals 4.18 Joules.

Calorimeter - An apparatus for measuring amounts of heat in physical or chemical experiments.

Catalyst - A substance that changes the speed of a reaction without being itself permanently changed.

Cathode - The negative plate in an electrolytic system; the plate at which electrons are taken up and where reduction takes place.

Celsius- A temperature scale on which the boiling point of water, under standard atmospheric pressure, is 100^oC and the freezing point is 0^oC.

Centi - A prefix denoting one hundredth of a unit in the metric system. (1 cm = 0.01 m)

Chain Reaction - A series of chemical reactions in which the products of each reaction activates additional molecules of the reactants, thus causing new reactions.

Chemical - Any substance as used in chemistry or produced by a process of chemistry.

Chemical Change - The formation of new kinds of molecules from the atoms of other molecules.

Chemical Precipitate - A solid that separates from a solution in a chemical reaction.

Cloud Chamber - A vessel containing saturated water vapor whose sudden expansion reveals the passage of an ionizing particle by a trail of visible droplets.

Color - Any hue or tint as distinguished from white.

Commutator - A part of a motor that changes the direction of the current in an armature.

Complementary Colors - Any color of light that when added to another produces white light

Compound - A pure, homogenous substance consisting of atoms of two or more different elements in definite proportions, and usually having properties unlike those of its constituent elements.

Concave Lens - A lens with its two opposite faces concave, so that it is thinner in the middle than at the edges. It has a negative focal length and causes incident parallel rays to diverge after passing through it.

Condensation - To make denser or compact; reduce the volume of. To join with other atoms in the same or different molecules so as to form a new compound.

Conduction - The transfer of heat from one molecule to another as they collide.

Conductivity - Quality or power of conducting something (take from one place to another).

Conductor - A substance through which an electric charge can easily travel. Metals usually make the best conductors.

Constant Acceleration - Acceleration which is unchanging and is therefore uniform. You should note, that under these conditions speed would be increasing if the acceleration is positive and decreasing if it is negative.

Conservation of Energy - The principle that energy cannot be created or destroyed, but can be changed from one form of energy to another.

Constant Speed - Speed which is unchanging.

Constructive Interference - The addition of two waves in such a way as to alter the original amplitude of the waves and produce a wave with greater amplitude. In the case of light, to produce a brighter color, with sound. to produce louder sound.

Convex Lens - A lens with two opposite faces curved out so that it is thicker in the middle than at the sides. It has a positive focal length and causes incident parallel rays to converge after passing through it.

Covalent Bond - A chemical bond formed by shared electrons.

Convection - The transfer of heat from one region to another by molecular currents.

Covalence - A type of bonding resulting from the sharing of pairs of electrons between atoms.

Current Electricity - The flow of electric charge through a conductor.

Cyan - A secondary color of light made up of the two primary colors of light, green and blue.

Data - All the measurements recorded during an experiment.

Deci - Prefix denoting one-tenth in the metric system.

Decibel - One-tenth of a bel. A unit which compares levels of power. Often used to express sound intensities.

Density - The mass per unit volume of a substance.

Dependent Variable - A variable whose values are determined by one or more other independent variables.

Destructive Interference - The addition of two sound or light waves in such a way to alter the original frequency and wavelength. In the case of light, to produce a different color, with sound, to produce less sound.

Dielectric - A substance (such as mica and most plastics) that is a poor conductor of electric current.

Diffraction Grating - A flat glass or plastic plate covered with a great number of parallel lines very close together. By sending a narrow band of light through it, diffraction spectra are produced.

Diffusion - Occurs when light bounces off an irregular surface.

Dipoles - Magnetic poles. of equal magnitude. but of opposite polarity.

Direct Current (D.C.) - An electric current flowing in one direction.

Disintegration - A process in which the nucleus of an atom emits one or more particles or photons. either due to spontaneous radioactivity or as the result of collision.

Dissociation - The separation of the ions of an electrovalent compound by the actions of a solvent.

Dissolves - Go. put or take into solution.

Distance - The length between two points located on the same plane.

Domains - Any of numerous contiguous regions in ferromagnetic material in which the direction of spontaneous magnetization is uniform and different from that of neighboring regions.

Doppler Effect - The variation in frequency or pitch of sound waves created by the relative motion of the listener and the source. The principle also applies to electromagnetic waves emitted from a source moving relative to an observer.

Ductility - Ability of metals and alloys to retain strength and freedom from cracks when shape is altered.

Effort - An applied force.

Electricity - Pertaining to the movement or buildup of electrons.

Electrical Conductivity - Ratio of current density to applied electrical current.

Electric Field - The space occupied by electric lines of force. The space around a charged particle in which an electric force is exerted.

Electrolyte - A compound whose water solution conducts electric current.

Electromagnetic - Science of the properties of and relations between magnetism and electricity.

Electromagnetic Radiation - Any radiation made up of electromagnetic waves. A general name for Hertzian Waves, Gamma Rays, X-Rays, light, Ultra Violet, Infra-Red and radio waves.

Electromagnetic Waves - A wave made up of an electric field, at right angles to a magnetic field. The two fields move at the same rate in a direction at right angles to their plane.

Electromotive Series of Metals - The metals ranked in the order of the amount of electrical energy between the metal and a normal solution of any of its salts in which it is placed.

Electrons - The negatively charged particles that orbit the nucleus of an atom.

Electrovalent - The state in which the outer rings of an atom are complete (have the necessary electrons).

Elements - Any of those substances which are not able to be broken up chemically into simpler substances and of which all other substances are made.

Endothermic - A chemical reaction which absorbs heat leaving the surround material with less energy.

Energy - Is the property something has that enables it to do work. Energy has the same units of work. Some forms of energy are kinetic energy, potential energy, heat energy, chemical energy, electrical energy, radiation energy, light energy and magnetic energy.

Energy Conversion - Converting or transforming from one energy form to another energy form, i.e. sunlight to heat or electricity.

Error - The difference between the theoretical and the experimental value.

Equilibrium - A condition of balance. The condition in a reversible reaction or process when the two opposite processes are going on at the same rate so that there is no further change in the amounts of the two substances or phases.

Evaporation - Process by which a liquid or solid changes to a vapor, with or without boiling.

Exothermic - A chemical reaction which produces heat and increases the energy content of the surrounding material.

Fahrenheit - A temperature scale on which the boiling point of water, under standard atmospheric pressure. is 212^{o}F and the freezing point is 32^{o}F.

Farsightedness - Not being able to see objects within a close distance of the eyes. Objects far away are distinguishable.

Ferromagnetic - Any material which exhibits the ability to become magnetized. Magnetic materials are Nickel, Cobalt, Iron and various alloys.

Focal Length - The distance from the focus to the surface of a mirror or from the focus to the middle of a lens.

Focus - The point where light rays come together to form an image.

Force - A push or pull. Equal in magnitude to the product of the mass of the moving object and the acceleration resulting from the push or pull.

Frequency - The number of revolutions. rotations or vibrations per second.

Friction - The resistance to motion.

Fuel - Any material which may be used to obtain energy. usually by the evolution of heat.

Fulcrum - The point or support on which a lever turns.

Fuse - A device used for protecting electrical apparatus against excess current. It consists of a piece of metal (which is connected in the circuit to be protected) which melts and interrupts the circuit when an excess of current flows through it.

Gamma Ray - A high-frequency. very penetrating electromagnetic wave emitted during radioactive discharge.

Gas - A substance whose physical state is such that it always occupies the whole space in which it is contained.

Generator - A device. which produces electrical power. by passing a coil of wire through a magnetic field.

Gram - A unit used to measure the mass of an object.

Gravity - One of the four fundamental forces in nature**.** The force of attraction between an object and the Earth which causes the object to fall toward the center of the Earth.

Green - One of the three primary colors of light.

Group - Each large vertical column in the Periodic Table.

Half-Life - The time it takes for half the number of atoms in a radioactive sample to disintegrate.

Heat - A form of energy. The heat that a body possesses depends upon its temperature. its mass and the kind of material from which it is composed.

Heat of Formation - The quantity of heat absorbed when one molecule of a compound is formed from its elements in their normal state.

Hertz - A unit of frequency equivalent to cycles per second and abbreviated as Hz.

Heterogeneous - A substance whose constituent particles exhibit different properties.

Homogeneous - A substance whose constituent particles are alike.

Horsepower - The rate at which work is being done or energy is being expended (1hp = 746 watts).

Hypothesis - An educated guess that answers a scientific question.

Ideal Effort - The breakeven point at which the same amount of work is being input as is being output.

Ideal Mechanical Advantage - The ratio of force that performs useful work to the force applied to the machine.

Illumination - Intensity of light per unit of area.

Impact - The sudden sensation of movement by an object against another object.

Impulse - Occurs when there is a change in momentum. Momentum = mass x velocity.

Inclined Plane - A flat surface raised between 1 degree and 89 degrees that is classified as one of the simple machines.

Independent Variable - A variable whose values can be determined without using other dependent variables. The value(s) in an experimental situation that are not allowed to vary.

Indicators - A substance used to show by means of a color change whether an acid or base is present.

Inert - Possessing little tendency to undergo chemical change.

Inertia - The tendency of matter to resist a change in motion. If at rest, to remain at rest, or if moving, to keep moving in the same direction.

Inorganic - Refers to the chemistry of all elements of mineral origin which do not contain carbon compounds.

Insoluble - Not capable of forming a solution. It is a relative term since most substances have been shown to dissolve in water to some extent.

Insulator - A substance in which it is difficult (but not impossible) to establish an electric current.

Intensity - In electricity the force on a unit charge at a given point in an electric field; in light the brightness of a light and in sound the amount of energy in each wave.

Interference - The use of two or more waves of different frequencies added to or subtracted from each other to cancel or amplify the wave. Can be used with sound or color. to explain sound harmonics or secondary colors.

Inverse Square Law - The law governing the relationship between light intensity and source distance.

Ion - An atom or group of atoms which carries an electric charge.

Ionic Bond - The electrostatic force of attraction that holds two or more ions together.

Isotope - One of two or more elements having the same atomic number and the same chemical behavior but is/are different in atomic weight and in properties. such as radioactivity. dependent on the weight of. or the number of. neutrons in the nucleus.

Joule - The unit used to measure work or energy in the metric system. The force of 1 Newton acting through a distance of 1 meter.

Kelvin - Temperature equal to 1/273.16 of the absolute temperature of the triple point of water.

Kilo - Prefix denoting 1000 in the metric system.

Kepler - German Astronomer and mathematician.

Kilocalorie - The amount of heat needed to raise the temperature of one kilogram of water one degree centigrade.

Kinetic Energy - The energy which a moving body has because of its motion. The kinetic energy depends on the mass of the body and the rate at which it is moving.

Law - A scientific generalization whose correctness has been clearly demonstrated.

Lever - A rigid object that transmits or modifies force or motion; one of the simple machines.

Light - The form of radiant energy whose affect on the eye is the cause of seeing. Light moves at a rate of 186.326 miles per second or 3×10^8 meters per second. and has wavelengths that are between .0000385 mm and .0000765 mm.

Linear Motion - Motion occurring in a straight line.

Liquid - A substance which. unlike a solid. flows readily. but which. unlike gas. doesn't tend to expand indefinitely.

Liter - A unit of capacity in the metric system equal to the volume of a kilogram of distilled water at 4 degrees centigrade; it is equal to approximately 1.06 quarts.

Litmus - An indicator which turns from blue to red in an acid. or from red to blue in a base.

Longitudinal Wave - A wave in which the motions of the relevant particles are in the same direction as the direction of translation of energy.

Loudness - Power of a sound as judged by the ear. measured in decibels.

Luminous - Emitted radiant energy. Glowing or capable of being seen.

Magenta - One of the secondary colors of light made up of the two primary colors of light. red and blue.

Magnet - An object that demonstrates magnetic properties.

Magnetic Declination - The difference between the north magnetic pole and the geographic North Pole of the Earth.

Magnetic Field - The space occupied by magnetic lines of force. The space around a magnet in which a magnetic force is exerted.

Magnetism - The property of having the power of attraction for iron, cobalt and nickel and attraction of its opposite for substances like itself.

Mass - A fundamental characteristic of matter which causes an object to occupy space and attract other bodies that have mass. A measure of the total amount of material in a body.

Matter - The substance of which a physical object is composed.

Measurement - A figure, extent or amount obtained by measuring.

Mechanical - Of or pertaining to machines or tools. Pertaining to, produced by, or dominated by physical forces.

Medium - A substance with which another is mixed to give it the physical properties desired for some purpose.

Melting Point - The temperature at which a solid is transformed into a liquid.

Meniscus - The curved upper surface of a liquid column that is concave when the containing walls are wetted by the liquid and convex when not.

Meter - The basic unit of length in the metric system; it is approximately equal to 39.38 inches.

Metric System - A system of measurement based on powers of ten. using the meter. kilogram and second as basic units.

Milli - One thousandth of a unit in the metric system.

Mixture - Two or more substances having their parts completely mixed but not chemically united into a new substance.

Molecule - The smallest subdivision of a chemical element or compound which has the same physical and chemical properties as the element or compound; a structure of two or more atoms.

Momentum - A property an object possesses due to its motion**.** The momentum of an object produces an impact when a moving object strikes an object at rest. The momentum is equal to the object's mass multiplied by its velocity.

Nearsightedness - The inability to clearly distinguish objects that are far away.

Neutralization - The union of hydrogen ions of an acid with hydroxide ions of a base to form water and a salt.

Neutron - A nuclear particle having a slightly greater mass than a proton. but having no electric charge.

Newton - A unit used to measure force or weight in the metric system. ($1 N = 1 kg - m/s^2$).

Newton. Sir Isaac - English mathematician and philosopher who formulated the Laws of Gravity and Motion.

Nodes - Points of no vibration. Points where two interacting waves cancel one another.

Nonconductor - A substance that conducts heat. electricity or sound only in a very small degree.

Non-Pure Substance - A compound or mixture. which has not been broken down to its most elemental structure.

Normal - A hypothetical line drawn perpendicular to a surface. Used to determine the angle of reflection or refraction.

North Pole - A magnetic force produced by a magnet. so as to form an attraction to the opposite end of another magnet, said to be the South Pole.

North Celestial Pole - The northern point about which the celestial sphere appears to rotate.

Nuclear - 1. Anything associated with the nucleus of an atom. 2. The type of energy released when atomic nuclei undergo fission or fusion.

Nucleus - The central part of the atom. The fundamental particles of which are the protons and neutrons and constitutes almost all of the mass of an atom.

Observation - 1. An act of recognizing and noting a fact or occurrence. An observation often involves measurement with instruments. 2. A judgment of inference from what one has observed.

Ohm - A unit of electrical resistance.

Opaque - Any material which does not transmit light through it.

Optical - pertaining to or using light.

Optical Medium - The substance through which light travels.

Organic - 1**.** To do with living substance or living things. 2. Those materials containing carbon.

Oscillation - A single back and forth swing of a pendulum.

Parallel - Being an equal distance apart at every point.

Pendulum - A device consisting of weight or a "bob" swinging on the end of a string or wire.

Percent Efficiency - The ratio of work against the amount effort.

Percent of Error - Allows one experimenter to compare their results to another experimenters results on a common basis. %error = (error x 100) / theoretical value.

Period - 1. Chemistry: On the periodic table. a period is a horizontal series of elements (Group I through Group VIII) related by physical structure. 2. The amount of time for one oscillation of a pendulum.

Phenolphthalein - An indicator which is colorless in acid solution. but is red in basic solutions.

Phydrion - Measures the amount of acid or base. On the phydrion scale, one indicates an acid, fourteen indicates a base, with seven being neutral.

Physical Change - Any change in a body or structure which does not involve an alteration in its chemical composition.

Pitch - That property of a tone which is dependent on the second pressure but chiefly on the number of vibrations per second of the sound waves, the greater this number. the higher the pitch.

Polarization - The act of canceling out one or more planes of vibration of a transverse wave.

Poles - The part of the magnet, towards which the lines of magnetic flux apparently converge or from which they diverge, the former being called a South Pole, the latter a North Pole.

Potential Energy - The stored energy that an object possesses because of its position relative to other bodies or due to the arrangements of its parts.

Power - The rate of doing work. Power is commonly measured in watts and horsepower.

Prediction - Through the use of observation. being able to work out the eventual outcome.

Primary Colors of Light - The fundamental colors in the electromagnetic spectrum. of RED. BLUE and GREEN.

Principal Focus - For a lens or spherical mirror. the point at which rays of light parallel to the principal axis are made to come together.

Prism - A body having parallel and equal three-sided ends and 3 plane sides. 2 of them making equal angles with the third; used for the refraction or reflection of light rays.

Protons - The positively charged particles found in the nucleus of an atom.

Pulley - A wheel or set of wheels which are used, in combination with ropes, to decrease the amount of work or to move a mass a given distance.

Pure Substance - A material which has been broken down to its most elemental form.

Quantitative - Able to be measured or numbered.

Radiation - The transfer of energy through space by means of waves.

Radioactive Materials - Any material which has been affected by intense radiation and emits rays or particles capable of penetrating matter.

Radiant Energy - Energy transported or given out in the form of electromagnetic waves.

Radical - Two or more atoms joined together, but acting as a single atom.

Radioactivity - The emission of energetic particles and radiant energy by an unstable atomic nucleus.

Ray - A single line representing the direction in which light or radiant energy is traveling.

Real Images - An image that can be projected and viewed on a screen.

Red - One of the three primary colors of light.

Reflection - Occurs when a wave bounces off a surface; light is reflected by a mirror. sound by a wall.

Refraction - The bending of light caused by a change in the speed of light as it leaves one medium and enters another.

Resistance - The opposition to movement offered by a substance or object. Such as electricity through a conductor or an object to be moved by a simple machine.

Resonance - The effect caused when sound waves from one object (such as a bell) cause a second object to be set into vibration also. The second body must have the same natural frequency of vibration as the first body for this to occur.

Retina - The back wall of the eyeball in back-boned animals, which is acted on by light and on which pictures of things seen are formed.

Salt - A compound whose water solution contains a positive ion other than hydrogen ions, and a negative ion other than hydroxide ion.

Scientific Method - A step by step process used for solving problems.

Screw - An inclined plane wrapped around a cone. One of the six simple machines.

Secondary Colors of Light - Comprised of the three secondary colors cyan. magenta. and yellow.

Shells or Orbits - Any of the paths traveled by an electron as it circles the nucleus of an atom. The shells are pictured as spheres, one inside the other and named, starting with the one nearest the nucleus, K-shell, L-shell, M-shell, etc. Every shell has a maximum number of electrons and a fixed amount of energy.

Solid - Material that has a definite volume and shape no matter where it is placed; that is, it resists deformation.

Solute - That substance in a solution whose physical condition is changed into that of another or which is present in smaller amounts, so that it is looked on as being taken in by the other, e.g. in a solution of salt and H_2O. water is the solvent and salt the solute.

Solution - A mixed substance in which the molecules or ions of one substance have undergone regular distribution among those of the other so that there is no longer any physical sign that two separate substances are present.

Solvent - The substance in a solution which is present in greater amounts than the other.

Sound - The sense experience of which the ear or some like structure is the instrument.

South Pole - A magnetic force produced by a magnet, so as to form an attraction to the opposite end of another magnet, said to be the North Pole.

Specific Gravity - The relation of the weight of a given measure of a substance to the weight of the same measure of water at 4° C.

Specific Heat - The quantity of heat. per gram. required to raise the temperature of a substance by one degree celcius.

Spectroscope - An instrument for viewing sources of light and forming separate individual colors or spectra.

Spectrum - The full range of colors in a rainbow. Each "color" is comprised of many lines or bands of light. each with a particular wavelength.

Speed - The rate of movement or motion.

Stable Element - An element not readily decomposed.

Static Electricity - Electricity at rest.

Structural Formula - A chemical formula which in addition to showing the atoms present in a molecule. also gives an indication of its structure.

Temperature - 1. The degree of hotness or coldness of anything. usually measured on a thermometer. 2. A measure of the internal energy of a substance.

Theory - A theory is a logical structure built on several fundamental generalizations that explain a wide variety of phenomena.

Thermal Expansion - Expansion in solids. liquids. and gases due to the addition of heat.

Thermal Transfer - The transfer of heat energy from one material to another through the processes of conduction. convection. and radiation.

Time - The period between two events. or during which something exists. happens or acts. The shortest period of time being a moment

Tone - A sound produced by one regular vibration of the air at a fixed rate.

Translucent - Any material which allows passage of light. but not a clear image.

Transmit Light - To give out or give forth light.

Transmutation - A change of one thing into another.

Transparent - Clear. see-through. able to see an identifiable image.

Vacuum - A region of space containing no matter whatsoever.

Valence - The tendency of elements to form compounds; a number indicating a charge on an ion or the number of pairs of electrons shared by one element with another; the bonding in a compound.

Velocity - The distance traveled divided by the time of travel.

Virtual Image - An image that cannot be projected onto a screen to be viewed.

Vibration - A shaking motion, one complete back and forth movement.

Volatile - Changing readily to a vapor.

Volt - A unit used to measure the difference in potential between two points on a conducting wire or in an electric field. It is associated with the change in potential energy of a charged particle as it moves from one point to another.

Voltage - An electromotive force or difference in electrical potential expressed in volts.

Volume - The amount of space occupied by a body.

Watt - The unit of power used in the metric system. (energy / time)

Wave Form - A graphable line which forms a peak and valley.

Wavelength - The distance between two successive crests or valleys of a wave.

Wedge- One of the six simple machines based upon the inclined plane. Examples include a device used for splitting logs. a needle or a knife blade.

Weight - The force exerted on an object by the gravitational pull of the Earth.

Wheel and Axle - One of the six simple machines consisting of a wheel fused to an axle so they move as a single unit.

Work - Is accomplished when an object is moved as a result of the application of a force.
work = force x distance.

X-ray - High frequency electromagnetic waves produced whenever fast electrons are brought to rest quickly.

Yellow - One of the three secondary colors of light produced by red and green.

Formula

Measurement

$$\text{average} = \frac{x_1 + x_2 + x_3 + \text{-----------} x_n}{n}$$

Density = mass/volume

Error = |Experimental value – Theoretical value |

$T_{°F} = (9/5 \times T_{°C}) + 32$

$$\% \text{ Error} = \frac{100 \times \text{Error}}{\text{Theoretical value}}$$

$T_{°C} = (T_{°F} - 32) \times 5/9$

Motion

speed: $v = d / t$

acceleration: $a = (v_{final} - v_{initial}) / \text{time}$

momentum: $p = m \times v$

Kinetic Energy: $KE = ½ m \times v^2$

Forces/Simple Machines

Force: $F = m \times a$

Weight: $w = m \times 9.8$

Ideal Mechanical Advantage: $IMA = D_E / D_R$

Ideal Effort: $IE = R / IMA$

Actual Mechanical Advantage: $AMA = R / E$

Energy

Potential energy: $PE = m \times 9.8 \times h$

Kinetic Energy: $KE = {}^1/_2 m \times v^2$

Work: $W = F \times d$

Power: $P = W / t$

Simple Machines: Work Output : $W_O = R \times D_R$

Simple Machines: Work Input: $W_I = E \times D_E$

Simple Machines: Percent efficiency: %E = (Work output / work input) x 100

Heat

$T_{°F} = (9/5 \times T_{°C}) + 32$

$T_{°C} = (T_{°F} - 32) \times 5/9$

Heat Energy: $H = m \times \Delta T \times c$

Specific Heat Capacity: $c = H / (m \times \Delta T)$

Thermal Expansion: $\Delta L = \partial \times L \times \Delta T$

Thermal Energy Transfer: $H = (k \times \Delta T \times A \times \Delta t) / d$

Sound

Speed of Sound: $v_T = 330 + (0.6 \times T)$

Speed of Sound: $v = f \times \lambda$

Wavelength: $\lambda = 4 \times \text{length}$

Distance from reflecting surface (echo): $X = (v_T \times t) / 2$

Electricity

Ohm's Law: $\varepsilon = I \times R$

Power: $P = \varepsilon \times I$

Magnetism

Magnetic Force Strength: Force Strength (at point B) = force strength A x (distance to A)^2 / (distance to B)^2