Clearview Regional High School District
2015 Summer Assignment Coversheet

Course:	Honors Physics
Teacher(s):	Tim Vitale
Due Date:	Monday, September 14, 2015
Purpose of Assignment:	To measure and maintain algebraic skills, basic vocabulary, and early physics concepts. Students will also be exposed to the level of work they can expect in the course throughout the school year.
Description of Assignment:	**Daily / 4.00 (Equivalent of 4 Daily Grades)** There are 5 reference sheets and 4 assessments (Calculator Review does not have an assessment). Students will receive a point total for each assessment which will be converted to a percentage. ➢ For example, Algebra Review has 48 possible points. If a student gets 40/48, he or she will receive an 83% for one daily grade. This will continue for a total of 5 different daily grades. **NOTE: Students who turn the summer assignment in one day late receive an immediate 50% deduction. If there are questions please e-mail me (see contact info below).**
Common Core and/or NJ Core Curriculum Content Standards covered:	**NJCCCS** • Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. • Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. • Use data representations and new models to revise predictions and explanations. **Common Core** • Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics. • Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Grading/Use of Assignment: Category/Weight for Q1:	**Complete 4 assignments with 5 reference sheets:** 1. Algebra Review [16 problems / 48 pts.] 2. Calculator Review [No Assessment] 3. Metric Review [14 problems / 31 pts.] 4. Experimental Design [19 problems / 54 pts.] 5. Graphing Scientifically [16 problems / 50 pts.]
Specific Expectations:	Students should work on the packet ***throughout*** the summer. Those who decide to wait until much later in the summer to begin the work may experience stress, anxiety, and frustration. Students are expected to work on it individually.
Where to Locate Assignment:	On the guidance website, on my MyBigCampus website, extra printed packets available at the High School main office.
Teacher Contact Information:	Students and parents may contact me via e-mail at vitaleti@clearviewregional.edu. My e-mail syncs to my phone so this is the fastest method of communication. Science Supervisor: Ron Antinori antinoriro@clearviewregional.edu Phone: 856-223-2747
Additional Help/ Resource(s):	Resources are available and will be available on MyBigCampus.

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U1R1: Algebra Review

R

When studying the subject of physics, we use math as a language to describe relationships between physical quantities and ideas. More specifically, physics can be understood fundamentally by using the concepts covered in your Algebra I class. One of the most frequently utilized algebraic skills in physics is being able to isolate variables in order to solve for them.

But first, it is important that we know the order of operations. Many times, it is taught using the mnemonic device, PEMDAS, or, “Please Excuse My Dear Aunt Sally.” This explains that when solving algebra problems, you start solving with numbers in Parentheses or Exponents. Then, you Multiply or Divide, and then you Add or Subtract.

For example, the following problem can be solved below using PEMDAS:

$$6 + (3\ x\ 2^2 + 1) =$$

If you do not use PEMDAS, or the correct order of operations, you will get the wrong answer. The first step is to look for exponents or parentheses. The 2^2 must be resolved first, which is 4.

$$6 + (3\ x\ 4 + \ 1) =$$

Then, see that there are three numbers in the parentheses—these must be looked at first. Inside, there is multiplication and addition. According to PEMDAS, multiplication comes first, so we must multiply 3 and 4 first, and THEN add 1.

$$6 + (12 + 1) =$$
$$6 + (13) =$$

Finally, there is nothing left to do but to add the 6 and the 13.

$$6 + 13 = 19$$

Great! The answer is 19! Now you’re a master of PEMDAS. In order to isolate variables, however, we need to use the order of operations BACKWARDS. Confused? It’s easy, just take a look at the next page!

For example, below is an equation that needs to be solved. We are solving for the variable, x.

$$6x + 6 = 42$$

In order to isolate the x variable, we need to use PEMDAS, backwards. So first, we look for Addition or Subtraction to do first. The + 6 needs to be taken care of. So in ordered to eliminate (+6) on the left side to isolate the x, we need to subtract 6 on both sides.

$$6x + 6 - 6 = 42 - 6$$
$$6x = 36$$

Now, in order to get x by itself, we need to divide both sides by 6.

$$\frac{6x}{6} = \frac{36}{6}$$

$$x = 6$$

It's easy when you use numbers, but what if we only use variables?

$$p + q^2 = c$$

Now there are no numbers, but we still need to isolate q to be by itself on one side of the equation. Remember your PEMDAS rules! Here's the solution:

Start by subtracting p on both sides to get q^2 by itself.

$$q^2 = c - p$$

Then, you have to square root everything in order to eliminate the squared on the q.

$$q = \sqrt{c - p}$$

This would be your final answer. You may find that solving for variables without numbers is a little more difficult, but it often proves useful when solving problems in physics class. If you can master this skill, isolating the variable in terms of other variables will create less careless mistakes and may even help you understand the relationships of the quantities better.

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U1W1: Algebra Review

48 pts.

Part 1: Solve for x. All fractions may be left in fraction form.
[3 pts. ea.]

1. $6 = 3x$
2. $144 = x^2$
3. $6x = 22$
4. $88x^2 = 44$
5. $4x^2 + 2x^2 = 12$
6. $\sqrt{x} = 6$

Part 2: Solve for x in terms of the other variables. **[3 pts. ea.]**

7. $y = mx + b$
8. $ax^2 = b$
9. $nx = n + k$
10. $PV = xRT$
11. $\frac{t}{x} = ax$
12. $E = mx^2$

Part 3: Use the following equation to solve the following problems:
[3 pts. ea.]

$$\boxed{a = bg^2 - c}$$

13. Solve for a, when b = 5, g = 2, and c = 1.

14. Solve for c, when a = 10, b = 2, and g = 3.

15. Solve for g, when a = 10, b = 3, and c = 1.

16. Solve for b, when a = 3, g = 2, and c = -1.

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U1R2: Calculator Review

R

Who's Smarter: You or Your Calculator?

I'll give you the first answer, it's you! Why? The calculator needs your help to enter numbers and operations using the correct syntax[1].

Using Parentheses

Tip: The calculator doesn't always understand you, so be explicit! Make using parentheses a habit!

Example: When you see an equation that looks like this: $\frac{7}{2\pi}$ You may be tempted to enter it into your calculator like this:

7 / 2π
10.99557

The calculator interprets this as $\frac{7}{2}\pi$. That's definitely not the same as $\frac{7}{2\pi}$.

This is the correct way of entering this equation into your calculator:

7 / (2π)
1.114084

Practice: Practice typing this into your calculator: $\frac{8+4}{6}$ Write how it might look in your calculator by following the example above.

Explanation: The calculator knows PEMDAS[2] to a certain extent. It will calculate exponents before subtraction, and parentheses before addition. Calculators, however, read from left to right. Because of this fact, calculators are limited by how they read the characters that you type. That is why it is important that you group numbers and operators[3] appropriately.

1. **syntax:** The way particular terms are put together in the calculator. 2. **PEMDAS:** (aka Please Excuse My Dear Aunt Sally) The order of operations (parentheses, exponents, multiplication, division, addition, subtraction). 3. **operators:** in this case, +, -, ÷, x and more.

Using Scientific Notation

Tip: Scientific notation can be scary to look at—imagine trying to type it in the calculator. There's actually an easy way. Just use your calculator's **EE** or **EXP** button!

Example 1: When you see a number written like this: 6.67×10^{-11} you may be tempted to enter it into the calculator like this:

```
6.67 * 10^-11
                0.00000000000667
```

In this case, you'd be correct! However, when you start adding, subtracting, multiplying, and dividing these numbers together, this way of writing scientific notation can get hairy. This is the correct way of entering this equation into your calculator:

```
6.67E-11
                0.00000000000667
```

Example 2: You may have to multiply or divide these numbers at some point. Take for example,

$$\frac{1.5\ x\ 10^6}{8.6\ x\ 10^8}$$

You may enter it in like this:

```
1.5 * 10^6 / 8.6 * 10^8
                  17441860470000
```

But this is wrong! Here is the correct way to enter this into your calculator:

```
1.5E6 / 8.6E8
                     0.001744186
```

Practice: Practice typing this into your calculator: $(6.022 \times 10^{23})/(1.60 \times 10^{-19})$ Write how it might look in your calculator by following the example above.

Explanation: By using the **EE** or **EXP** button on your calculator, you are basically eliminating an extra operation that can sometimes be the cause of a calculator error. Notice how by using those buttons, the ***10^** portion of the statement turns to just **E**.

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U1R3: Metric Review

R

In many other countries besides the United States, the SI unit system is used to make measurements. The SI system (abbreviated SI from French: Le Système international d'unités), uses prefixes for units that all are based on multiples of 10. In the U.S. we use this system for science because it is much easier to convert, read, and use these units. For example, instead of using feet to measure length, scientists prefer to use meters. Here is a table of imperial units (used in U.S.) and their partner metric units:

Measurement	Imperial (U.S)	Metric / SI
length	feet, inches	meters
time	seconds	seconds
volume	gallons, in^3	liters
mass	pounds, ounces	kilogram
temperature	Fahrenheit	Celsius, Kelvin

Many times, we abbreviate units to either one or two letters. Here are conventional abbreviations for the metric units that will most likely be used in this class:

Unit	Abbreviation
kilogram	kg
second	s
meter	m
liter	L
Celsius	°C
Kelvin	K

As stated before, the metric system uses a prefix and a base unit. There are many prefixes, however the most common prefixes used in physics class are in a table below:

Prefix	Abbreviation	Multiplier	Sci. Not.
nano	n	x 0.00000001	x 10^{-9}
micro	μ	x 0.000001	x 10^{-6}
milli	m	x 0.001	x 10^{-3}
centi	c	x 0.01	x 10^{-2}
deci	d	x 0.1	x 10^{-1}
kilo	k	x 1,000	x 10^{3}
mega	M	x 1,000,000	x 10^{6}
giga	G	x 1,000,000,000	x 10^{9}

So, let's use meters as an example. If you measured something to be 120 millimeters, how many meters is that equal to?

1. Look for the prefix before the base unit, meters. The prefix in this case is milli.
2. Look on the chart for milli (you will probably begin to remember these as you practice the problems). The multiplier for milli is "x 0.001", or "x 10^{-3}." What this means is that a millimeter is one thousandth of a meter. Or, another way to say it is that there are 1,000 millimeters in one meter.
3. Replace "milli" with the multiplier. 120 **milli**meters…120 "x 0.001" meters.
4. Now, simply carry out the calculation. 120 x 0.001 = 0.120.

We find that 120 millimeters is 0.120 meters. This makes sense because we know that millimeters are much smaller than meters, and that 120 thousandths of a meter is 0.120 meters!

For the most part, a base unit is a unit that has no prefix, as is the case with meters, seconds, and liters. However, we usually consider the kilogram (kg) to be the base unit, but kilogram already has a prefix!

Let's talk about 1,000,000 micrograms (10 µg). First, we need to eliminate the prefix by substituting it with the multiplier like we did before.

1. 1,000,000 **µ**g
2. 1,000,000 x 0.000001 grams
3. 1 gram

Now we are left with 1 gram (1 g) but now we need to convert that into base units, which are in this case, kilograms. Since we are going to be adding a prefix to the unit, we need to perform the opposite action—instead of multiplying we will divide.

1. 1 gram
2. 1 ÷ 1,000 **kilo**grams
3. 0.001 kilograms
4. 1 gram = 0.001 kilograms

As with just about anything else, with practice comes perfection! In addition to completing the worksheet that goes along with this review sheet, you can also make up your own conversions and check them on Google! Just type in, for example, "0.5 ms to s," and Google will do the rest!

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U1W3: Metric Review

31 pts.

Part 1: Write out the unit with its prefix on the spaces provided. The first one has been done for you as an example. **[2 pts. ea.]**

1. mg milligram	2. kL ________________
3. kg ________________	4. Mm ________________
5. µm ________________	6. ns ________________
7. dL ________________	8. cm ________________

Part 2: Convert the following measurements into base units. The first one has been completed for you as an example. <u>You must include units for full credit!</u> **[3 pts. ea.]**

9. 5,000 µm 0.005 meters

10. 600 cm ____

11. 540 g (*) ____

12. 4 kL ____

(*) Remember what the base units for grams are? Go back and check!

Part 3: Solve the following questions by checking the **larger** quantity, or checking "EQUAL" if they are the same. **[2 pts. ea.]**

13.	50 mL	☐	0.05 L	☐	EQUAL	☐
14.	\$100M	☐	\$1,000,000,000	☐	EQUAL	☐
15.	60 cm	☐	0.06 m	☐	EQUAL	☐
16.	23 µs	☐	0.000023 s	☐	EQUAL	☐

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U1R4: Experimental Design

R

Variables and Constants

In an experiment, someone is usually trying to discover a relationship between two different variables. A recent example could be how carbon emissions are affecting global climate change. There are two things that are changing (variables) – the amount of carbon emissions and the rate of climate change.

The variable that we manipulate in an experiment is called the **independent variable**. The variable that we measure is called the **dependent variable**. You can remember this because we are expecting that the dependent variable is <u>dependent upon</u> the independent variable. To use the previous example, we are expecting that the rate of climate change [dependent] is dependent upon the amount of carbon emissions [independent].

Another example would be measuring the amount of water flow versus the amount of water pressure. We can manipulate the water pressure by turning a knob. From there, we measure the amount of water that flows from the faucet by collecting it in a bucket. In this example, water pressure is the independent variable and water flow is the dependent variable.

When you are performing this experiment, there may be a few things that you want to keep **constant**. Some of these may seem so obvious, but are actually important to note because they could change the entire experiment. For example, one thing that is held constant in the water flow example is the fact that the substance coming from the faucet is water and not sand or molasses.

Finding the Slope of a Line

Finding the **slope** of a line is something that is taught in math classes, but is used very frequently in physics class. As you will see in the next reference sheet, finding the slope of the line will help us determine relationships between variables. For now let's just focus on the math and how to calculate a slope.

1. We can only calculate slopes for lines. Curves have changing slopes and therefore cannot be calculated using algebra. Be sure that you have a line before you start to find the slope.
2. Choose two points on the line [x_1,y_1], [x_2,y_2]. If the line goes through the origin (0,0), then choose that as one of your points—it will make your life easier!
3. Plug those points into this equation. You may know it as "rise over run."

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

4. Be sure to include the units in your final answer. For example, my points were (0,0) and (2,6):

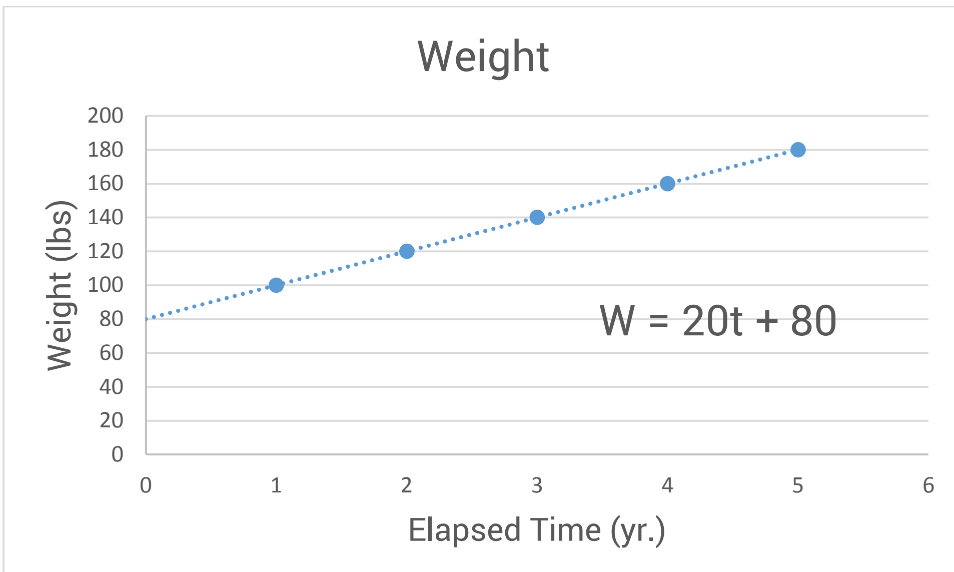
$m = \frac{y_2 - y_1}{x_2 - x_1}$ $\quad m = \frac{6kg - 0kg}{2L - 0L}$ $\quad m = 3\ \frac{kg}{L}$ *The slope represents density!*

The Y-Intercept and the "5% Rule"

Hopefully you will also remember the equation of a straight line from your Algebra class as well. To refresh your memory, here it is:

$$y = mx + b$$

Where y is for the variable on the y axis, x is for the variable on the x axis, m stands for the slope of the line, and b is the **y-intercept** (or where the line crosses the y axis). Physically, the y-intercept could mean something in an experiment. Usually we say "when the x-variable goes to 0, the y-variable is…" You would fill in the rest. Take a look at the example below:



Note that the y-intercept is 80 lbs. This means something **physically**. In this example, a student is measured over the course of 5 years. 80 pounds is this student's starting weight. That is what the y-intercept means, physically.

Sometimes, it would make more sense for our graph to have a y-intercept of 0. Maybe for the pendulum lab, it would make sense to have a period of 0 seconds when the length is 0 meters. Yet when you graph it, it looks like the y-intercept is NOT zero. There is a rule that we use to check to see whether or not that y-intercept is actually significant.

The **"5% Rule"** goes like this:

1. Identify your max y value on your data table or on the graph. [y_{max}]
2. Locate/identify the y-intercept of the line. [b]
3. Divide b by y_{max}.
    a. If the number you get is >= 0.05 (5%) then you must keep this y-intercept in your equation, and it most likely is NOT zero for a reason.
    b. If the number you get is < 0.05 (5%) then you may eliminate it from your equation, and assume that b = 0.

Error (Experimental, Human, and Percent)

When making measurements in a lab, especially as high school students, with high school equipment, there tends to be some error in our data. **The important part in the lab is not that you get the correct data, but that you understand what the data that you collected means.** Sometimes, this means understanding error and where seemingly incorrect data comes from.

Experimental error is an error in the design of your experimental process or apparatus. An **apparatus** is the setup of your lab, with the objects you are measuring and the measuring devices included. Some examples of experimental error in the pendulum lab are letting the excess string rub against the swinging pendulum, not ensuring the pendulum is level with the ground, not accounting for friction or air resistance, and more.

Human error is an error in the execution of the lab. Usually, we take multiple trials when collecting data to account for this error. Human error should almost always be anticipated and accounted for before the experiment is carried out. In short—human error is not an excuse for poor data, and usually should not be included in your lab report as a source of error. An example of this is human reaction time, or not calculating something correctly.

Percent error is a way to calculate the difference between two values, an experimental value (the one you derived from your data), and a theoretical value (one that has existed, or what your data should match). The equation to calculate percent error is below:

$$Percent\ Error = \frac{Experimental - Theoretical}{Theoretical}\ x\ 100$$

Imagine that I found the density of Aluminum to be 2.5 kg/L. In actuality, the density of Aluminum is 2.7 kg/L. See below how to solve for percent error in this scenario:

$$Percent\ Error = \frac{2.5\frac{kg}{L} - 2.7\frac{kg}{L}}{2.7\frac{kg}{L}}\ x\ 100 = -7.4\%$$

Percent error can be positive or negative (it either means you overshot or undershot the number). The closer the percent error is to 0, the closer your experimental value is to the accepted or theoretical value.

Other Experimental Jargon

Here are a few vocabulary words that are specific to our setting. Below are definitions that are specific to your physics class:

Quantitative – using numbers (quantities) to describe a solution or solve a problem. This method usually involves calculations or exact measurements.

Qualitative – using just about anything besides exact numbers to describe a solution or solve a problem. This method could include drawings (sketches), open ended answers, rough estimates, and more.

Accurate – How close measurements are to actual (theoretical) values. Throwing darts at the bull's-eye is an example of accuracy.

Precise – How close measurements are to each other. Throwing darts in the same location each time (even if it is not the bull's-eye) is being precise.

Experimental – Pertaining to your current experiment, or something that has not been verified yet. An experimental value is a value that you have come up with from the data.

Theoretical – Pertaining to the current accepted theory. A theoretical value is an accepted value based on years of observation and research.

Ambiguous – Vague, unclear. We try to stay away from ambiguous definitions and explanations.

Value – A number used to represent a quantity. Ex. 30, 20 (as in 30 monkeys, or 20 lbs/L)

Unit – Something used to measure a quantity. Ex. Kilograms, seconds, liters

Apparatus – The set-up of all of the measurement tools and objects in your experiment. The pendulum, with the stand, string, and all, was the apparatus for the pendulum lab.

Hypothesis – A prediction based on previous knowledge or education, which is tested in an experiment.

Theory – Based on years of research and observation; the best explanation for a physical phenomenon.

Phenomenon – A situation that is observed, usually something we'd like to understand and know more about. An example is dropping a ball and seeing it fall to the ground.

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U1W4: Experimental Design

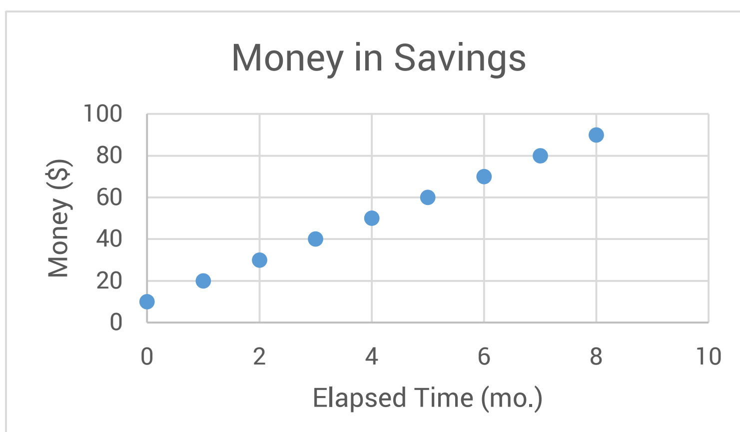
54 pts.

Part 1: Identify the independent and dependent variables, and the constant in each experimental scenario. [2 pts. ea.]

1. A freshman thinks that the older a person gets, the taller they become. So he sets up an experiment where he measures the height of students that are different ages. He is only choosing students from his high school.
   a. Independent variable: ____
   b. Dependent variable: ____
   c. Constant(s): ____

2. Mr. Vitale thinks that his coffee stays hotter longer when it is heated to a certain temperature. He takes 5 different 100 mL cups of the same brand of coffee and heats each of them to different temperatures. He lets them sit out in the same room for 5 minutes and he measures their new temperature.
   a. Independent variable: ____
   b. Dependent variable: ____
   c. Constant(s): ____

Part 2: Use the graph to answer the following questions. [3 pts. ea.]

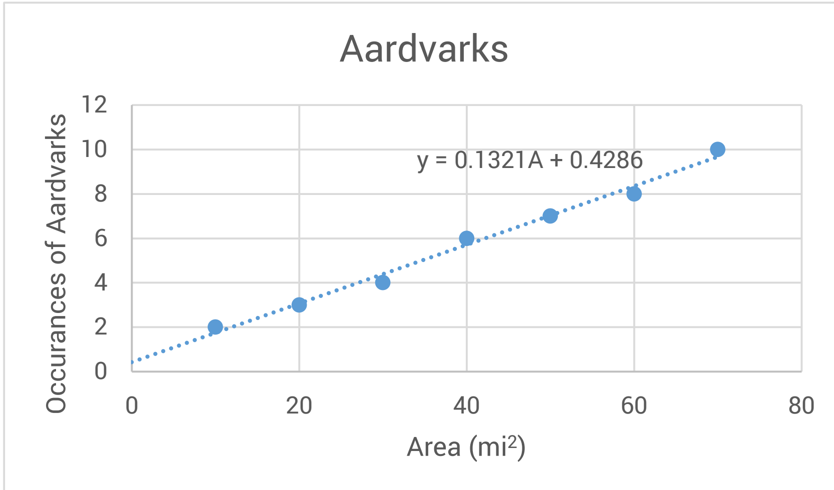


3. What is the y-intercept (with units)?

4. What is the slope (with units)?

5. Describe a scenario for this graph. Use both the y-intercept and the slope to explain what might have happened with “Money in Savings”.

Part 3: Use the graph below to answer the following questions. [3 pts. ea.]



6. Locate the equation on the graph above. What is the y-intercept?

7. Using the 5% rule, verify whether or not the y-intercept is significant.

8. The slope represents the population density of Aardvarks. If the theoretical value for the population density is 0.1731 Aardvarks/mi^2, what is the percent error? (Hint: your slope is the experimental value.)

Part 4: Identify the type of error for each scenario by writing experimental or human error below the question. [2 pts. ea.]

9. When setting up the lab, Joanna didn't check to make sure the apparatus was level.

10. While his group was working, Colin kept bumping into the lab set-up, causing it to shake.

11. "I measured it wrong," says Lexi, after she saw her data made no sense.

12. When measuring the speed of a package dropping, Sarah realized she did not account for air resistance.

Part 5: Vocabulary Practice: Fill in the following blanks with the appropriate words from the list on U1R4: Experimental Design (or the word bank from below). [1 pt. per blank]

13. A __________________________ answer is one that includes numbers, where as a __________________________ answer could include sketches or any non-number answer.
14. The students were very excited when their ____________________________ value, or value obtained in their experiment, matched the current accepted ______________________________ value.
15. Ben knew that the ___________________________ was a world-wide accepted explanation for a phenomenon, not just an untested ______________________________, or a prediction.
16. Vince repeated his experiment and got 10 meters every single time, so he knew his measurements were _________________________. When he compared his measurements to the actual theoretical values (50 meters), he knew that they were not ________________________.
17. When writing an equation, Mason was sure to write the __________________________, or number, and also the ________________________, which happened to be kilometers.
18. When Joey was writing his lab report, he included a drawing of his experimental set-up, or _____________________________. The drawing was sloppy and unlabeled though, so it was ______________________________, or unclear.
19. "What an interesting _______________________________!" Gabby thought, as she began to wonder about what had just happened.

Qualitative **Quantitative** **Precise** **Accurate** **Experimental**

Theoretical **Ambiguous** **Theory** **Hypothesis** **Value** **Unit**

Apparatus **Phenomenon**

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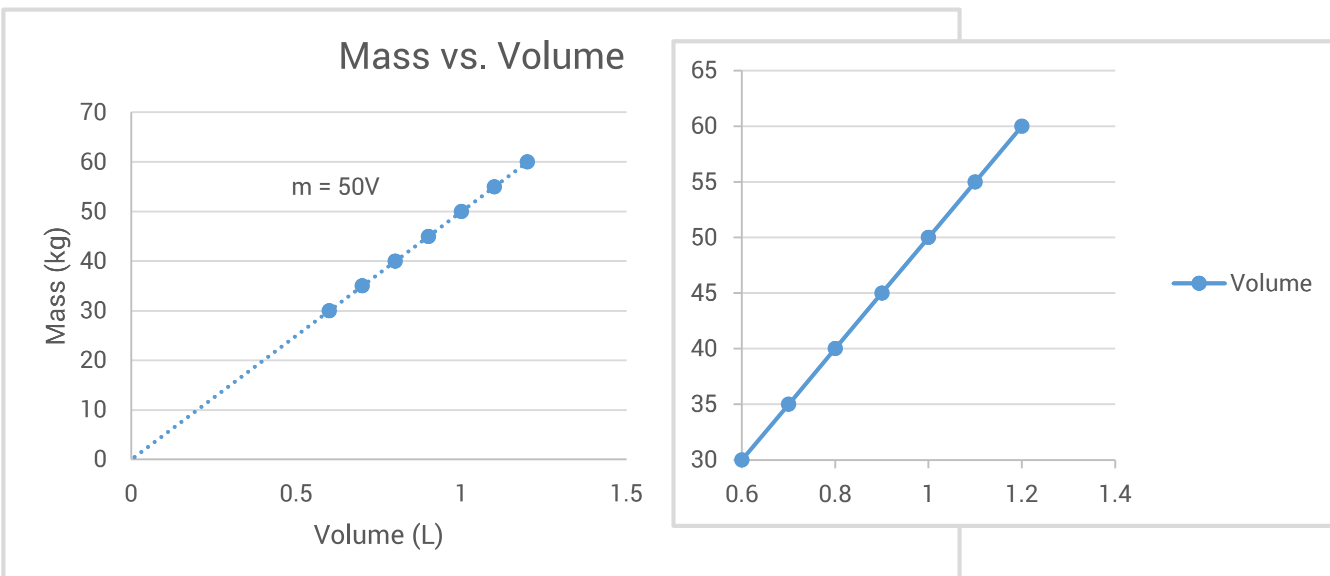
U1R5: Graphing Scientifically

In science, but even in many other fields too, graphs are used to display data to achieve different goals. Politicians and folks in the media may use graphs to persuade or inform an audience. Those in business and industry may use graphs to measure growth, sales, and more. Scientists use graphs in many ways, but in this class, we will be using graphs to discover and validate relationships between concepts. Therefore, it is important for us to be sure we are graphing data appropriately.

Take a look at the following two examples and decide for yourself which is the better graph:



Which did you choose? The graph on the left has things labeled, yet the data points are disconnected, and far from the origin. The graph to the right has the points starting from the origin and are connected with a nice solid line.

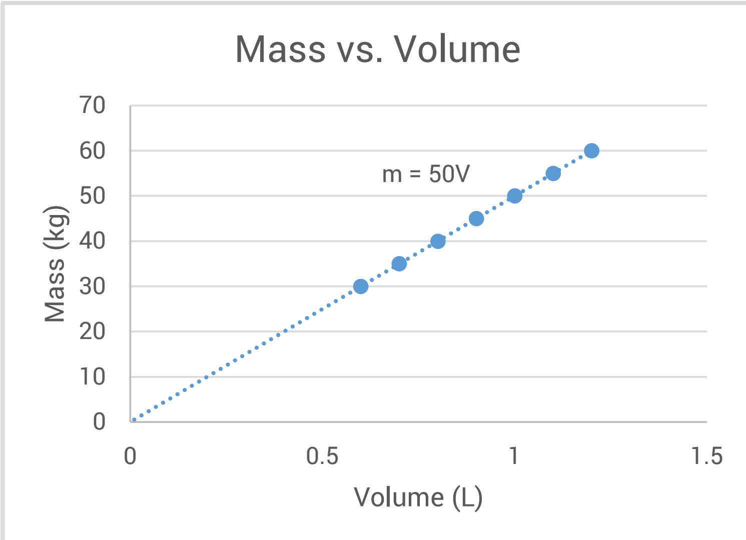
The first graph has everything we want in a scientific graph:

- Graph title
- Axes, labeled with units
- Origin of (0,0)
- A trend line (linear fit) with a equation

The second graph is missing all of these things. It may look better because it appears to start from the bottom left corner of the graph, but this can be misleading!

Parts of a Graph

First, just in case you aren't familiar, let's look at all of the parts of a graph.



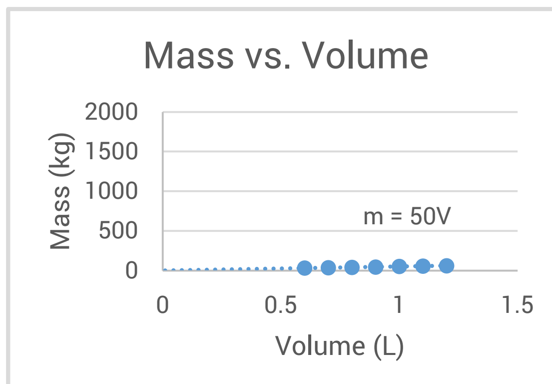
Graph Title – Every graph needs a title because the title explains what the data is about. For example, "Mass vs. Volume" informs me that this graph is about the relationship between the two of these things.

Axes – There are two axes on a graph, the x and the y axes. In this case, the x axis is Volume (L) and the y is Mass (kg). These should <u>always</u> be labeled, with names, tick marks, and units. The independent variable usually goes on the x axis, and the dependent variable goes on y.

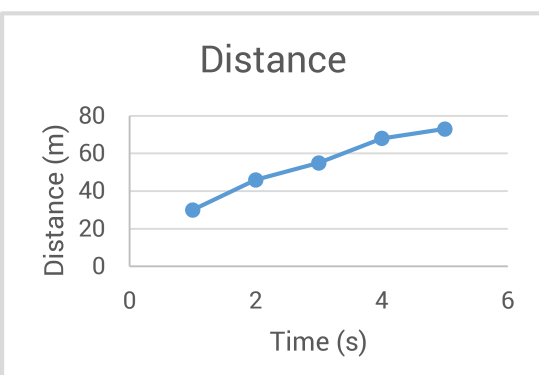
Data – Obviously, what is a graph without data?! In almost all cases in this class, we will plot our data as a scatterplot, because scatterplots best help us determine any trends or relationships in data.

Origin – The origin is the coordinate point (0,0). In this class, it is useful and required that all graphs include the origin as (0,0), even if the data starts well beyond that point (such as this graph).

Scaling – Your goal is to scale the graph so that the trend (if there is a trend) is visible. Take a look at an example to the right of the <u>same</u> data from above, but shown with a different (wrong) scale. The y axis maximum is 2000 kg, which is well beyond the max mass that was recorded (60 kg).



Trend Line / Linear Fit / Curve Fit – The important part of graphing is to look at trends in data. This graph in particular tells us how mass and volume are related to each other for a certain type of material. In this case, the trend is linear, which means that it follows a straight line. In other scenarios, it may follow a curved path. In all cases, however, a linear or curve fit should be included in the graph.



*Take note that in your scatterplot, you <u>never</u> have the data points connected by individual lines like in the example to the left. These lines only serve to connect the dots, which does not tell us anything about the data and how they are related.

Analyzing Graphs

The entire purpose for creating a graph in physics is to analyze it to discern its meaning. Some common questions that you should ask yourself (and that will be asked of you) are:

- What is the relationship between [x] and [y]? (Replace [x] with the x variable, for example: "what is the relationship between volume and mass?")
- What does the slope of the graph mean, physically?
- What does the y-intercept of the graph mean, physically?
- Is the y-intercept significant?

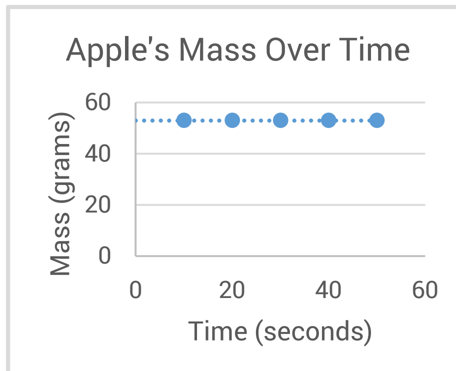
In the following sections we will address how to answer these questions. It would be helpful to you to save this reference material to use for the rest of the school year.

Types of Relationships

1. No Relationship – Sometimes, two variables just do not affect each other at all. Imagine measuring the mass of an apple over time. The mass would probably not change over a small amount of time. In this case, we would see a horizontal line, and so we would conclude that the mass of an apple does not change over time. Let "m" stand for mass.

   General Equation: y = b

   Specific Equation: m = 53 grams



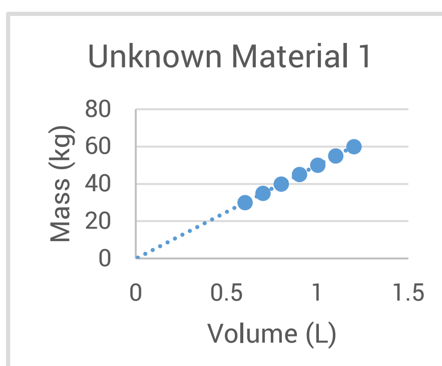
General Equation: This is the mathematical equation that describes the line or curve. It includes variables like x and y, b for the y-intercept, and m for the slope. These are equations you might see in math class.

Specific Equation: In this, we replace the variables from the general equation with things we know. For example, we replace x and y with the respective variables that are graphed on those axes. In this first example, y is replaced with m (for mass) because mass is the y variable. The y-intercept, b, is replaced with the actual y-intercept, 53 grams. These are the equations we focus on in physics class.

2. Linear Relationship – A linear relationship is just that—any data that shows a trend in the form of a line. The line can have a positive or negative slope. When the line goes directly through the origin (0,0), it is called a directly proportional relationship. Let "m" stand for mass and "V" stand for volume.

   General Equation: y = mx + b

   Specific Equation: m = 50 kg/L • V + 0 kg



*Note that the y intercept is 0 kg, so it can be omitted from the equation. Rewritten, it would look like: m = 50 kg/L • V

Linear Equations: Hopefully you have seen y = mx + b before in your Algebra class. This is the generic form of the equation for a line, where m stands for the slope, and b stands for the y-intercept. The slope of a line indicates how much the y variable changes as the x variable changes. Both the slope and the y-intercept of a line stay constant. When we write constants in our equation, we always include the units so that it makes sense to us, physically.

General Equation: y = mx + b

m (slope) = 50 kg/L   b (y-intercept) = 0 kg

Specific Equation: m = 50 kg/L • V + 0 kg

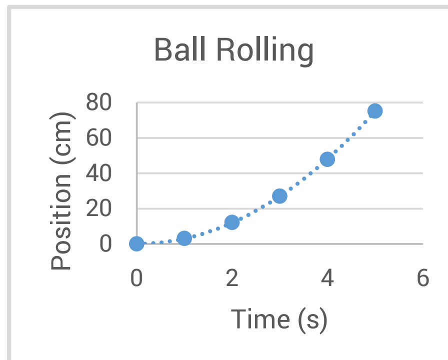
Take note that m and V stay as variables in the specific equation. This is because they may change; by plugging in one value for V, you yield a different value for m. Do NOT include the units for the variables when writing the equation.

An example of what you **should NOT do:** m kg = 50 kg/L • VL + 0 kg   OR   kg = 50 kg/L • L + 0 kg

3. Square Relationship – This type of relationship is also known as a top-opening parabola. As x^2 increases, y increases proportionally. From these types of graphs, it is not possible to use the same method for finding slope as we use for a line. Note that along the curve, the slope is constantly changing. Let "x" stand for position and "t" stand for time, and "k" stand for some constant.

   General Equation: $y = k \cdot x^2$

   Specific Equation: $x = 3\text{cm/s}^2 \cdot t^2$

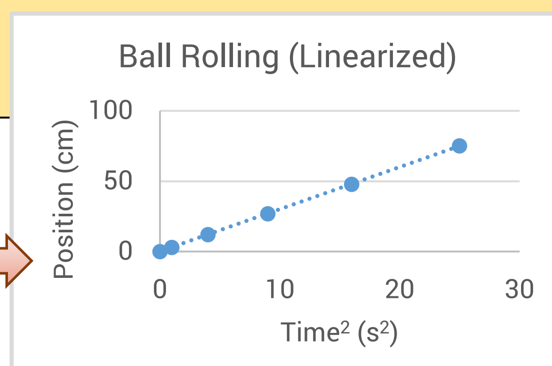


How do we find "slope" from parabolic relationships? - Linearization

Note that the graph above does not have a set slope, so using our previous method for finding slope will not work when analyzing this graph. In order to make some sense from this graph, we will need to linearize it.

Linearization is a process where you first create a "test plot" by taking the data and plotting it differently. A test plot will be successful if after the data is replotted, it appears to be linear. For top opening parabolas or square relationships, a successful test plot will be y vs. x^2. To create this test plot, simply take the data from the original graph, square the x values (not the y values), and replot the graph—this time y vs. x^2 (as opposed to y vs. x). Check out the visual process below:

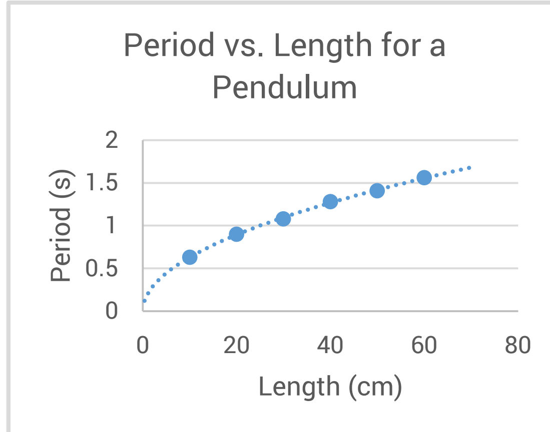
Time (s)	*Position (cm)*	*Time² (s²)*	*Position (cm)*
0	0	0	0
1	3.1	1	3.1
2	12.2	4	12.2
3	27	9	27
4	47.9	16	47.9
5	75.2	25	75.2



4. <u>Square Root Relationship</u> – This type of relationship is also known as a side opening parabola. As x increases, y^2 increases proportionally. This particular graph is slightly larger than the others because it is difficult to see the trend clearly. At first glance, this may look linear, but it is, in fact, square root related. Let "T" stand for the period, and "l" stand for length.

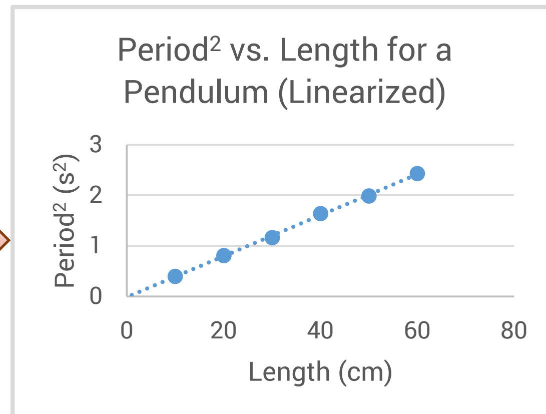
   General Equation: $y^2 = kx$

   Specific Equation: $T^2 = 0.2\ \mathrm{s^2/cm} \cdot l$



Linearization:

Length (cm)	*Period (s)*	*Length (cm)*	*Period² (s²)*
10	0.63	10	0.40
20	0.90	20	0.81
30	1.08	30	1.17
40	1.41	40	1.64
50	1.56	50	1.99

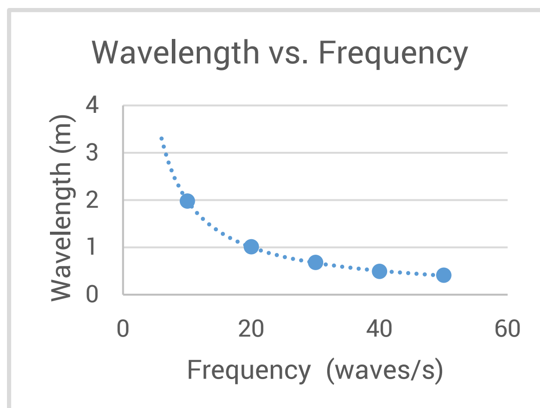


To linearize, just plot y^2 vs. x. In this case, you are squaring the y variable (which is T, or period), and plotting it versus the x variable, which is length (l).

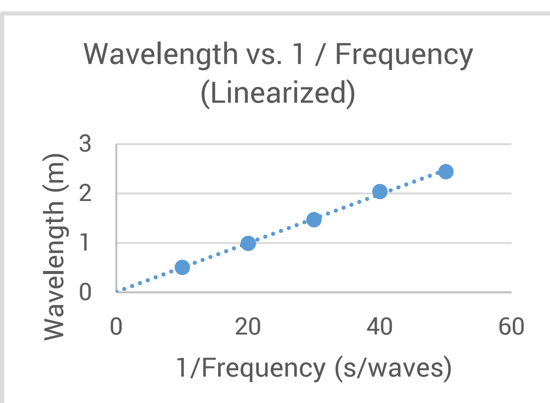
5. <u>Inverse Relationship</u> – This type of graph looks just like a 1/x function. As x increases, y decreases. Check out the graph to the right. As the frequency of the wave increases, the wavelength decreases. Let "λ" stand for wavelength and let "f" stand for frequency.

   General Equation: $y = k/x$

   Specific Equation: $\lambda = 19.4\ \mathrm{m/s} \cdot f$



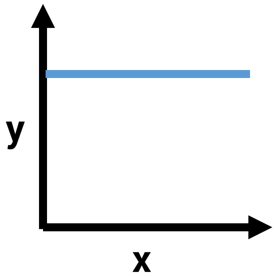
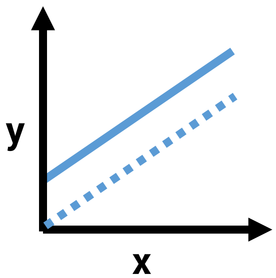
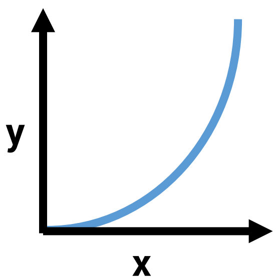
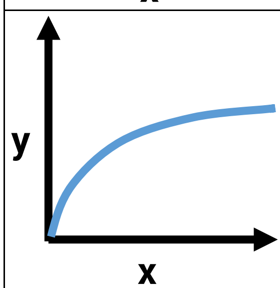
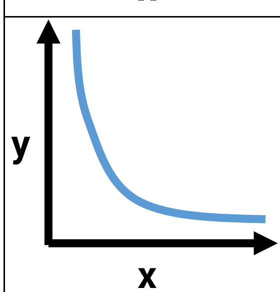
Linearization:



Frequency (waves/s)	*Wavelength (m)*	*1/Frequency (s/waves)*	*Wavelength (m)*
1.98	10	0.51	10
1.01	20	0.99	20
0.68	30	1.47	30
0.49	40	2.04	40
0.41	50	2.44	50

To linearize just plot y vs. 1/x. In this case, we take the reciprocal of the frequency values and plot them versus wavelength.

Graph Types Reference Sheet

Graph Shape	Written Relationship	Modification Required to Linearize Graph	General Equation
	**No Relationship** As x increases, y remains the same. There is no relationship between the variables.	No modification required.	y = b
	**Linear Relationship** As x increases, y increases. y varies directly and linearly as x. **Direct Relationship** (when b = 0)	No modification required.	y = mx + b y = mx
	**Square Relationship** As x^2 increases, y increases proportionally. y is directly proportional to x^2.	Graph y vs. x^2	$y = mx^2$
	**Square Root Relationship** As x increases, y^2 increases proportionally. y^2 is directly proportional to x.	Graph y^2 vs. x	$y^2 = mx$
	**Inverse Relationship** As x increases, y decreases. y is inversely proportional to x.	Graph y vs. 1/x	y = m(1/x) or y = k/x

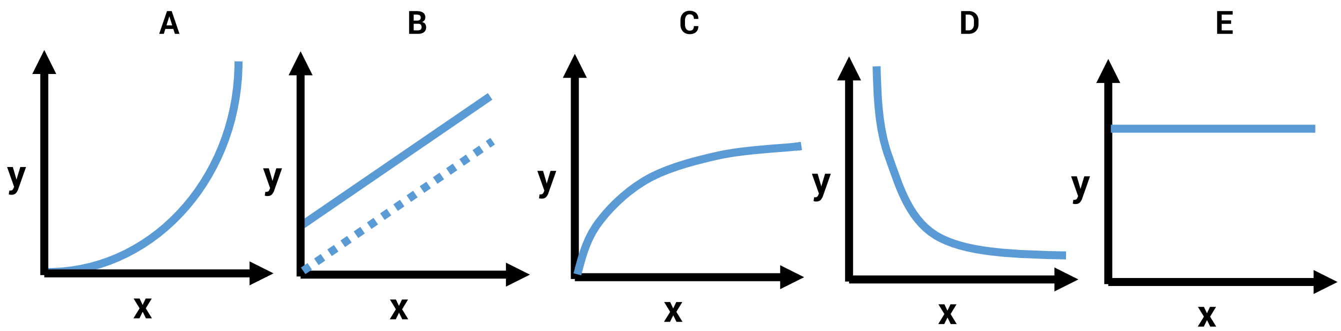
Reference Sheet and Some Content from *Experimental Design and Graphical Analysis of Data*, Rex P. Rice – 2000

Name: ____ Date: ____________________ Pd: _______

U1W5: Graphing Scientifically

50 pts.

Part 1: Match the following graphs with their respective relationships. You may use the same letter twice. **[2 pts. ea.]**

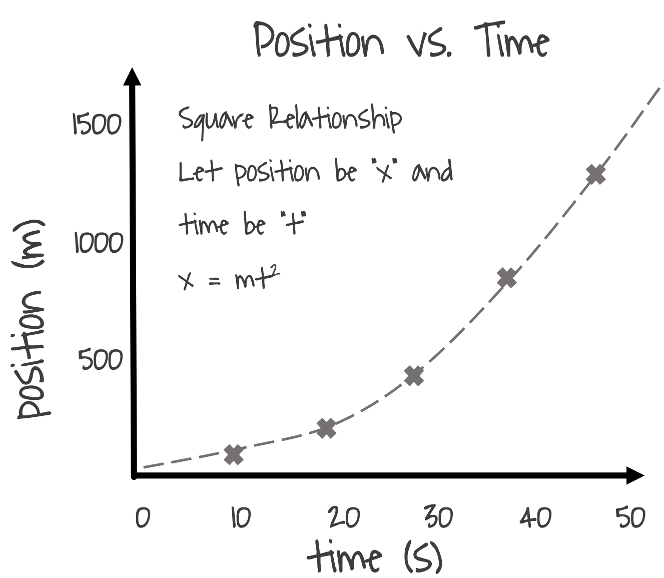


1. No Relationship __________ 6. $y = mx + b$ __________
2. Linear Relationship __________ 7. $y = k/x$ __________
3. Square Relationship __________ 8. $y = mx^2$ __________
4. Square Root Relationship __________ 9. $y^2 = mx$ __________
5. Inverse Relationship __________ 10. $y = b$ __________

Part 2: Take a look at the data provided below. For each set of data, sketch a graph and include the following: an origin (0,0), a scale along your axes, labels for both axes including units, graph title, and a curve or linear fit. Then, identify which relationship is present in the data and write the specific equation. The first one has been done for you as an example. **[5 pts. ea.]**

Ex.

Time (s)	Position (m)
10	50
20	200
30	450
40	800
50	1250



11.

Length (cm)	Width (cm)
5	10
10	20
15	30
20	40
25	50

12.

Time (s)	Mass (kg)
1	51.1
2	51.2
3	51.4
4	51.3
5	51.2

13.

Length (m)	Period (s)
25.2	5.1
35.8	6.3
49.3	7.0
64.0	8.2
81.4	8.9

14.

Pressure (Pa)	Volume (L)
20	0.10
35	0.057
45	0.044
50	0.04
60	0.033

15.

Time (s)	Position (m)
1	5
2	20
3	45
4	80
5	125

Part 3: Take one of the data tables from the previous problems and linearize it (**note that you can only use data that shows non-linear trends**). After you linearize the data, plot it again to verify that you have correctly done so. **[5 pts.]**