AP Physics 1: Summer Work

Dr. Pollock

adapted from *AP Physics Summer Work* by John Castellaneta

2021-2022

1 Welcome to AP Physics!

1.1 Directions

Please print out this document and write your answers directly on the sheet. If you do not have room for a particular answer, you may attach additional pages.

The assignment is due **Friday, August 27, 2021** and is to be **submitted via email as a PDF attachment.** to DrP at rpollock@ves.org
Note: Singular photos of each page will not be accepted.

You should be good at this after virtual school but if not:
–The Notes App on iPhones has a "scan documents" function if you press the camera while in Notes
–Use another PDF scanning app-my favorite is Genius Scan
Note: Please submit as a grayscale or color NOT as a photo

1.2 Additional information

The AP Physics Lab Report format for Pendulum Lab can be found here

If you are having particular trouble understanding the Pendulum lab data analysis this is a good resource. You can also try googling "linearization of data physics" there are some great web pages and videos out there.

I won't spend any time reviewing scientific notation, SI unit conversions, dimensional analysis, or right angle trigonometry so, if you are super excited to get started, please start reviewing this information on your own. In addition, there are few video links below that might be useful for the first few weeks of school.

What is a vector?–Intro to vector components
Vector addition using components– Speed velocity acceleration

**if you do not have access to google docs and YouTube–all relevant information can be found here

Upon return to school in the fall, we will quickly review the material covered in the summer work packet, learn about vector addition, and then have a test within the first or second week of the marking period. As always, if you have any questions, please let me know, via email. I can't guarantee an immediate response, but I'll do my best.

Have a great summer! -DrP

2 Science

2.1 The Metric System

Everything in physics is measured in the metric system, also known as SI (Systemè International). Physicists use MKS system of measurement within the metric system where kilograms, meters, and seconds are the base units. Meaning, with every measurement that we do, we must first convert into these three units. Kilograms instead of grams is the one that most people forget.

Problems. Convert the following numbers within the metric system.

1. 525 g to ______________ kg
2. 45 m to ______________ km
3. 260 mL to ______________ L
4. 5.0 cm to ______________ m
5. 6.80 km to ______________ m
6. 72.3 mg to ______________ kg
7. 0.045 L to ______________ mL
8. 25 g to ______________ kg
9. 0.77 m to ______________ cm
10. 15 kg to ______________ g

2.2 Scientific Notation

Scientific notation is used to write very large or very small numbers. It is rare that you will need to do actual calculations with these numbers, but converting in and out of scientific notation will probably be helpful a few times during the course, especially when it comes to rotational inertia.

Often scientific notation is used in conjunction with significant figures. Please make sure that you know how to identify how many significant digits a number has. This is something that is often taught in high school chemistry.

Problems. Convert the following either into or out of scientific notation and determine the number of significant digits

1. 5,140 ______________ _____ sig figs
2. 0.000360 ______________ _____ sig figs
3. 7.1×10^6 ______________ _____ sig figs
4. 4.80×10^{-5} ______________ _____ sig figs

2.3 Unit Conversions

Not all unit conversions are as simple as converting centimeters to meters. Sometimes you are required to convert miles per hour into kilometers per second. The method to do this is called the **factor-label method**. Think stoichiometry from chemistry.

Example. Convert 55.0 miles per hour to meters per second

$$\left(\frac{55.0\text{ miles}}{1\text{ hour}}\right)\left(\frac{5280\text{ feet}}{1\text{ mile}}\right)\left(\frac{12\text{ inches}}{1\text{ foot}}\right)\left(\frac{2.54\text{ cm}}{1\text{ inch}}\right)\left(\frac{1\text{ meter}}{100\text{ cm}}\right)\left(\frac{1\text{ hour}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ sec}}\right)$$

your units should cancel out
multiply everything on the top, divide everything on the bottom. OR
you can multiply across the top and bottom then divide.

$$\left(\frac{8.85x10^6\text{ meters}}{360,000\text{ sec}}\right) = 24.6\frac{\text{meters}}{\text{sec}}$$

Problems. Make sure to show **all** work and units

1. How many seconds are in 7.5 weeks?

2. The moon is 2.50x10^5 miles away. How many centimeters is it from earth?

3. If a wheel rotates 15 times per minute, how many radians per second is this?
   note: there are 2π radians in one revolution

4. Chicago uses 1.2x10^9 gallons of water per day. How many liters per second must be pumped from the lake to supply the city?

3 Math

3.1 Algebraic Solutions

In AP physics it is always helpful and often required to solve algebraic equations in the terms of variables, rather than with given values or numbers. This involves basic addition, subtraction, multiplication, and division of coefficients and variables as seen in the example below. Please solve each equation or expression for the desired coefficient. Doing this quickly and efficiently is a critical skill required for this class. It is very helpful to think of this process as "rearranging" an equation to make it more useful for a specific purpose. Do not worry if you have no idea what any of these equations mean, this is only a mathematical exercise.

Example. Solve the following for v

$$a = \frac{v^2}{r}$$

Solution.

$$ra = v^2 \qquad \text{(multiply both sides by r)}$$

$$v = \sqrt{ra} \qquad \text{(square root both sides)}$$

note:

Problems. It is not necessary to show your mathematical work or explain your process in words, but you do need to show the individual steps of how you arrived at your final answer.

1. Solve for v:

$$\frac{1}{2}mv^2 = mgh$$

2. Solve for a:

$$v_f^2 = v_o^2 + 2a\Delta x$$

3. Solve for x:

$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$$

4. Solve for θ_2:

$$n_1\sin(\theta_1) = n_2\sin(\theta_2)$$

5. Solve for v:

$$\frac{GMm}{r^2} = \frac{Mv^2}{r}$$

6. Solve for g:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

7. solve for T_2

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

8. solve for v_f

$$m_1v_1 + m_2v_2 = m_1v_f + m_2v_f$$

9. solve for x

$$m_1(x) = m_2(3 - x)$$

10. solve for r

$$\frac{m_1v^2}{r} = m_2gh$$

11. solve for a in terms of m_1 , m_2, and g. You cannot have F_T in your expression.

$$m_1g - F_T = m_1a$$

$$F_T = m_2a$$

3.2 Proportionality

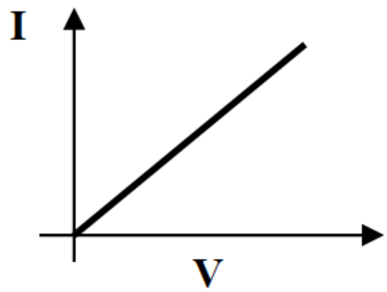
Understanding proportionality can be extremely helpful in AP Physics. When two values are proportional, that means that as one increases, so does the other. Two values are directly proportional to each other when the line that describes their relationship travels through the origin. When two values are inversely proportional, that means as one increases, the other decreases.

$I = \frac{V}{R}$ is Ohm's Law where I is current, V is voltage and R is resistance (we will learn more about this law later). Ohm's Law shows both of these proportionalites clearly. I is *proportional* to V. As voltage increases so does current. I is *inversely proportional* to R. As resistance increases, current decreases. A *constant of proportionality* is any number included in an equation that is NOT a variable. There is no C.o.P in this equation.

Graphs of Proportionalities

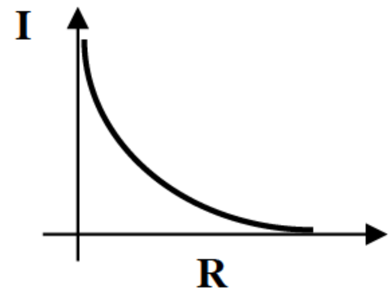
If you were to plot a proportional relationship, such as I vs. V, you would see a trend like the one below on the left (notice how the line passes through the origin, if there is 0 voltage there must also be 0 current). When the line goes through the origin when say the two variables are *directly proportion*, as compared to a situation where there would be a y-intercept. If you were to plot an inversely proportional relationship, such as I vs. R, you would see a trend like the one on the right (notice how it approaches infinity and zero as R becomes very small or large respectively).

Direct Proportion



$$\boxed{I = \frac{V}{R}}$$

Inverse Proportion



Problems. Write an equation based on the sated proportionality of the given law.
It is okay if you have no idea what these values or laws are.

1. The period (T) of an oscillator is inversely proportional the frequency (f) of the oscillator. Write the equation for the period of an oscillator in terms of frequency.

2. The capacitance (C) of a parallel plate capacitor is directly proportional to the charge (Q) stored on the plates and is inversely proportional to the voltage (V) across the plates. Write an equation for capacitance (C) in terms of voltage (V) and charge (Q)

3. The force (F) needed to stretch a spring is directly proportional to both the stiffness of the spring (k) and the distance (x) that it is stretched. Write an equation for the force (F) needed to stretch a spring.

4. The power (P) dissipated in a circuit element is proportional to the square of the voltage (V) across the element and inversely proportional to the resistance (R) of the element. Write an equation for the power (P) dissipated in a circuit element in terms of voltage and resistance.

5. Newton's Law of universal gravitation states: The gravitational force (F_G) between any two masses (m_1 and m_2) is directly proportional to the mass of both objects, and is inversely proportional to the square of the distance between the masses (r). The constant of proportionality is the universal gravitational constant, G.

3.3 Mathematical relationships

There are four primary types of relationships between variables that you will experience in physics.

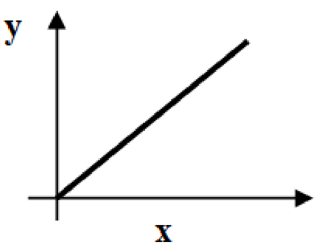
a **direct proportion** is a function whose graph is a non-horizontal like that passes through the origin. $y = kx$; where the constant of proportionality, k, is also the slope of the graph.

a **linear** function has a graph that his a non-horizontal line. $y = mx + b$; where m is the slope of the line and b is the y-intercept. A direct proportion is a special case of a linear function, where b=0

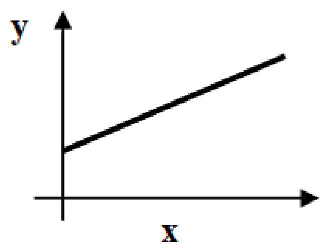
a **quadratic** function has a graph that is a parabola. when y is proportional to x^2, the graph goes through the origin and has a slope that increases as x increases. $y = ax^2 + c$

a **inverse** relationship has a graph that is a hyperbola (in the first quadrant). When y is proportional to $1/x$, the graph is asymptotic to the x and y axes. $y = k/x$

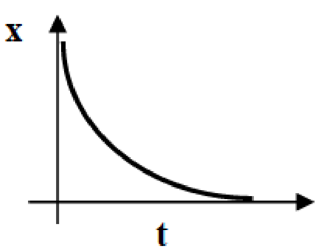
Direct Proportion



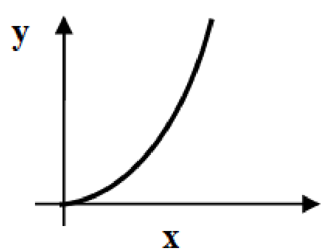
Linear



Inverse



Quadratic



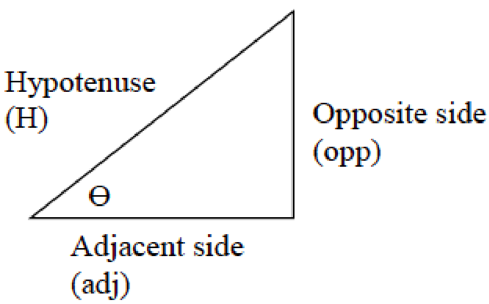
Problems. If a graph is non-linear it can be linearized by plotting the y variable vs the relationship of the x-variable. for example, if it is an inverse function, $y = c/x$ a graph of y vs $1/x$ will linearize function and the remainder of the equation will become the slope, in this case, c. A quadratic graph, such as $y = \frac{1}{2}cx^2$can be linearized by plotting y vs. x^2 and the slope of the linearized graph will be $\frac{1}{2}c$.

equation	graph:	Relationship:	linearize/slope:
1. $x = vt$	x vs. t	direct proportion	v represents the slope
2. $I = V/R$	I vs. R	inverse	graph I vs. $1/R$ to linearize
3. $D = m/v$	D vs. v	inverse	graph D vs. $1/v$; slope is m
4. $F_g = G\frac{m_1 m_2}{r^2}$	F_g vs. r	inverse square	graph F_g vs $1/r^2$; slope is Gm_1m_2

5. $F = -kx$	F vs. x	__________	k represents the ____________
6. $U = mgh$	U vs. h	__________	the slope of the graph is __________
7. $a = F/m$	a vs. m	__________	graph a vs $1/m$; slope is ____________
8. $E_k = \frac{1}{2}mv^2$	E_k vs. v	__________	graph____________to linearize
9. $x = \frac{1}{2}at^2$	x vs. t	__________	graph x vs t^2; slope is ____________

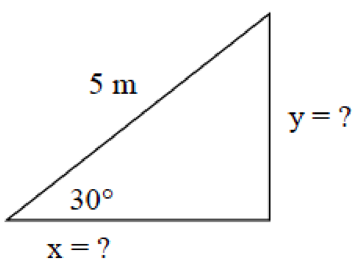
3.4 Right Angle Trigonometry

Many topics in this course deal with two dimensions, therefore it is crucial that you can break vectors (arrows) into their horizontal (left-right) and vertical (up-down) components with ease. This means using basic trigonometry (SOH CAH TOA).



Opp = H·sin(Θ)

Adj = H·cos(Θ)

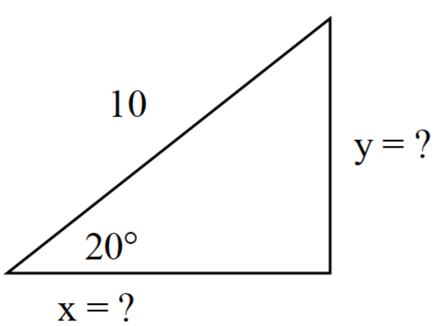


y = 5sin(30) = 2.5 m

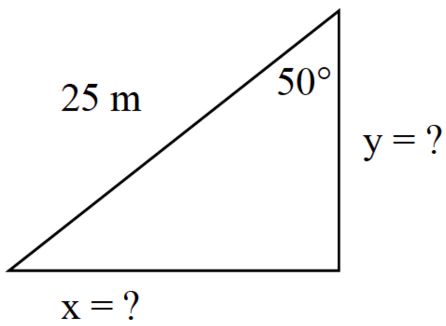
x = 5cos(30) = 4.33 m

Problems. solve for the missing sides or angles

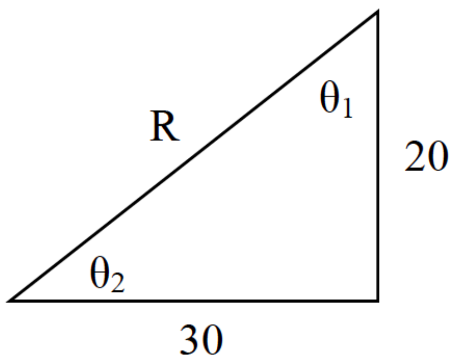
1. Solve for x and y



2. solve for x and y



3. solve for R, Θ_1 and Θ_2



4 Experiments

4.1 guidelines

Data Collection

In all experiments in AP Physics we will try our best to follow the "8 by 10" rule. This means you should have at least eight data points and they should vary by at least a factor of ten. For example, in an experiment if the smallest length that you use is 0.25 m then the largest length will need to be at leas 2.5 m. if the smallest mass you use is 50 g (0.050 kg) then the largest mass needs to be at least 500 g (0.500 kg). *Note: you do not need to evenly space your data points.*

Graphs

You should create a graph of your data whenever possible. The independent variable (what you change) should be graphed on the x-axis and the dependent variable (what you measure) is graphed on the y-axis. That said, time does not depend on anything, and therefore should be always be graphed on the x-axis.

Characteristics of a good graph:

1. has a descriptive title
   this can be as simple as, "the affect of *x-variable* on *y-variable*" or, "how the *y-variable* changes with x-variable"

2. includes labels for both the x- and y- axes.
   Include both the variable and the unit, in parentheses.
   example: velocity (m/s)

3. starts at the origin
   this goes without saying, but the origin is the point (0,0)

4. evenly spaced scale for axes.
   this is particularly important for hand-drawn graphs

5. the graph fills the space allotted
   this is particularly important for hand-drawn graphs

6. data points should be plotted with **no** line connecting them from point to point

7. a line of best fit
   if your data is not already linear, linearize it by creating a new graph.

4.2 Sample Experiment: Marbles in a cylinder

You received a graduated cylinder with three identical marbles and an unknown amount of water already in it. You placed extra identical marbles in the cylinder and obtained the data below.

Make a scatter plot on the graph provided on the next page.
Note: your graph should follows the *Characteristics of a Good Graph* outlined in this document

Create a best-fit line showing the relationship between the water level and the number of marbles. The y-intercept should be visible on the graph. Find the slope of the line. Remember that you need to use the best fit line (not the data points) to find the slope. Label your axes and include units.

Marbles	Water Level (mL)
3	18
4	21
5	23
6	25
7	28
11	39
15	45
19	57

From the graph

1. Write a mathematical formula for the water level for any number of marbles.

2. Give an explanation of your formula in words. Make sure to give an explanation of the slope and y-intercept of your formula.

4.3 Pendulums

Create an experiment that answers the question, "What affects the period of a pendulum?"

There are few variables that you can test to see if they affect the period *(the time that it takes to swing back and forth)*, those are: mass of the bob *(the thing at the end of the string)*, the length of the string, and the release height *(the angle)*.

You will need a piece of string or yarn, something small but massive tied to the end of it (a battery would work), a meterstick or ruler, and a timer.

If you do not have a meter stick available, you can call your longest length of string 1 unit and then shorten the string by fractions by folding it over itself. For example 1/3 (0.33 units), 3/4 (0.75 units)

As you change one variable, remember it is important to keep the other variables constant.

Suggestions: use a release angle that is no bigger than 45 degrees. Timing more than one period will help reduce error, but don't time too many because the bob will loose energy–if you do this make sure to divide by the number of swings to get the actual period. Conducting multiple trials at each length will also help reduce error in your experiment.

Record your data in the table below. *–feel free to cross out the headings if you want to change them*

Length (m)	Period (s) Trial 1	Period (s) Trial 2	Period (s) Trial 3	Period (s) avg

Write the lab up according to the AP Physics Lab Report Format guidelines given here. –dont worry about **Data Analysis** letters E-H (they don't pertain to this experiment)

Use the rubric at the end of the lab report document to gain a little more insight into how this lab will be graded.

Additional instructions/questions

the following information and questions will help inform your data analysis and provide context for your conclusion.

don't answer these as a 1-6, but rather include them in your lab report in paragraph form

1. Make a scatter plot of the data with length on the x-axis and and period on the y axis
   Is the above graph linear?
   see section 2.3 Mathematical Relationships if you are confused.

2. Create a new scatter plot of the data with length on the x-axis and and period squared on the y axis
   Is the above graph linear? Make sure each graph follows the *Characteristics of a Good Graph* outlined in this document

3. Create a line of best fit for your graph.

4. Give the equation for the line of best fit of your graph. (Should be in $y = mx + b$ form)
   What variable is graphed on the y-axis? Use this (T^2) instead of y in your equation.
   What variable is graphed on the x-axis? Use this instead of x in your equation.

5. What is the slope of your line?
   what are the units for slope?

6. What is your y-intercept, and units?
   Does this value make sense?

Note: if you have troubles, please see the Graphing Methods-Pendulums.pdf .