Basic Physics Skills Name____

Skill 1: Plug and Chug

Look at the attached equation sheet to solve these physics problems. Do not worry about units for now!

Step 1: **List** the variables that are given in the problem, including the unknown variable.
Step 2: **Identify** the equation that includes all of those variables.
Step 3: **Plug** each known variable in its proper place in the equation.
Step 4: Solve for the unknown variable using algebra. (**"Chug"**)
(Step 5: If there is more than one unknown variable, check for another equation that might help you find one of them.)

1. A car with a mass of 1000 "somethings" is traveling at a speed of 20 "somethings". What is its momentum? Do not worry about units for now, just solve for a number.

2. What is the car's kinetic energy?

3. What is the current in a wire which allows 2 "somethings" of charge to pass during every half-second?

4. A hanging spring has a mass of .200 "somethings" hanging from its end. If we set it into motion, and it oscillates with a period of 0.5 "somethings", what is the spring constant of the spring?

5. What is the centripetal acceleration of an object traveling at a speed of 5 "somethings" around a circle with a radius of 3 "somethings"?

Skill 2: Find the units of a quantity using dimensional analysis.

Rules for units:

- Rule 1: Only units that are *the same* can be added or subtracted.
  - Example: You may add 1 meter + 1 meter = 2 meters. However, if you add 1 meter + 1 second, it doesn't make any sense, and the two terms do not combine. This is because the two numbers are in different *dimensions*.
- Rule 2: You may multiply or divide units, but it changes the unit.
  - Example: 3 men are working for 5 hours each.
    You have to pay them for a total of (3 men)(5 hours) = 15 man-hours
  - Example: You travel 6 meters for every 1 second that ticks by.
    Your speed is (6 meters)/(1 second) = 6 meters/second
- Rule 3: Multiplying or dividing by a *unitless constant* does not change the unit.
- Rule 4: Any time units are *multiplied* together, you hyphenate the units (man-hours or light-years)
- Rule 5: Any time units are *divided,* you use the word "*per*". (meters per second, kilograms per cubic meter)
- Rule 6: Any time an *exponent* is used, that same exponent applies to the unit (meters^2 is square-meters. Seconds^{-1} is inverse-seconds, or units per second)

Find the units of the unknown variable by plugging in units instead of numbers.

6. A car with a mass of 1000 kilograms is traveling at a speed of 20 meters per second. Solve for the unit for momentum.

7. Solve for the unit for kinetic energy.

8. A wire allows 2 coulombs of charge to pass during every half-second. What is the unit for current?

9. A hanging spring has a mass of .200 kilograms hanging from its end. If we set it into motion, and it oscillates with a period of 0.5 seconds, what is the unit for the spring constant of the spring?

10. An object travels at a speed of 5 meters per second around a circle with a radius of 3 meters. What are the units for centripetal acceleration?

Skill 3: Converting to SI units

Write down the SI unit for each quantity.

Distance:
Time:
Speed:
Frequency:
Area:
Volume:
Mass:

First, **estimate** what units are being used in these problems. None of them are SI units. Then, **convert** them to SI units using these conversion factors:

Physics Conversion Factors and Constants

METRIC CONVERSION FACTORS

Prefix	Abbreviation	Conversion Factor		For Example...	For Example...
Mega-	M	1000000	10^6	1 Megabyte = 1 x 10^6 bytes	1 byte = 10^{-6} Megabytes
kilo-	k	1000	10^3	1 kilometer = 1000 meters	1 meter = 0.001 kilometers
deci-	d	0.1	10^{-1}	1 deciliter = 0.1 liters	1 liter = 10 deciliters
centi-	c	0.01	10^{-2}	1 centimeter = 0.01 meters	1 meter = 100 centimeters
milli-	m	0.001	10^{-3}	1 milliliter = 0.001 liters	1 liter = 1000 milliliters
micro-	µ	0.000001	10^{-6}	1 microgram = 10^{-6} grams	1 gram = 10^6 micrograms
nano	n	0.000000001	10^{-9}	1 nanometer = 10^{-9} meters	1 meter = 10^9 nanometers
pico	p	0.000000000001	10^{-12}	1 picometer = 10^{-9} meters	1 meter = 10^{12} picometers

OTHER CONVERSION FACTORS AND CONSTANTS

by ER.FAIZY
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Weight/Mass	Volume	Length/Distance
16 ounces = 1 pound	1 liter = 1.0567 quarts	1 inch = 2.54 centimeters
1 kilogram = 2.2 pounds	1 mL = 1 cm^3	1 mile = 5280 feet = 1.609 kilometers
454 grams = 1 pound	1 gallon = 3.78 liters	1 yard = 3 feet = 36 inches = 0.9144 meters
1 ton = 2000 pounds	1 gallon = 4 quarts = 128 fluid ounces	1 meter = 39.37 inches = 3.281 feet = 1.094 yards
	1 quart = 2 pints = 32 fluid ounces	1 kilometer = 1094 yards = 0.6215 miles
	1 pint = 2 cups = 16 fluid ounces	

Notes/Examples:

11. Distance: The U.S. is about 3000 __________ wide. Take your best guess as to which unit goes into the blank, then convert to SI.

12. Time: This class lasts 1.5 ___________. Convert to SI.

13. Speed: The highway speed in New Jersey is 65 __________________. Convert to SI.

14. Frequency: The smallest hand of a clock goes around the circle at a rate of 1 _________ per 60 __________. Convert this to SI.

15. Area: A basketball has a surface area of about 150 ____________. Convert to SI.

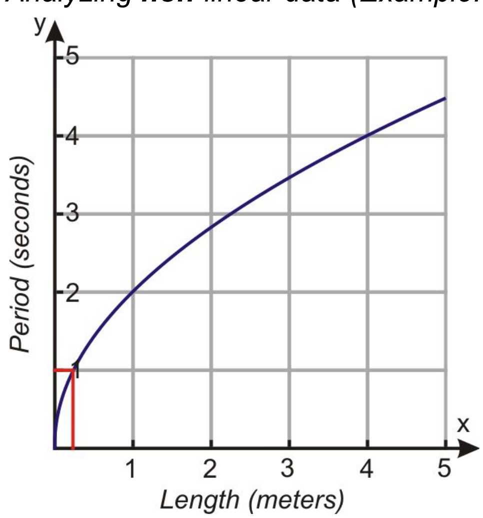
16. Volume: The basketball takes up about 4000 ______________ of space. Convert to SI.

17. Mass: A highschooler typically has a mass between 100 and 300 _____________. Convert both to SI.

Skill 4: Graphical analysis with units

Analyzing Linear Data
Take any notes for our activity here.

*Analyzing **non**-linear data (Example: period vs. length of a pendulum)*



<u>Linear data</u>

Linear data looks like a line on a graph when plotted. In all linear data, when the x variable increases by a uniform (unchanging) increment, the y variable will also change by a uniform increment. Linear data comes in one general format. You may know this format from your algebra classes:

y = mx + b

In Physics, we generalize this formula to fit whatever experiment we are performing.

“y” is our *dependent variable.*
“x” is our *independent variable.*
“b” is the *y intercept*, however usually b is not included, and it often can be assumed to equal 0.
“m” is the quantity we are looking to find from our experiment, which is always obtained through a *slope* calculation. This is the best way to combine multiple data points into one result.

So, we can write out our formula in a generalized way:

(dependent variable) = (slope quantity or result quantity)(independent variable) + (y-int)

All experiments include a dependent variable and an independent variable. For example, let’s say we want to find the speed of a toy car going at a relatively constant speed. We use a video camera to record the car, and take a position measurement every half-second on the video. Our goal is to figure out “v” for the car, or its speed. Rather than simply taking one time measurement with one distance measurement, science requires that we take *multiple* data points and factor each data point in our answer. To do that, you must use a special method that you may have never used before, but this method is one of the *core* learning goals for our AP Physics class. Our data for the experiment may look like this:

t (seconds)	x (meters)
0.5	0.75
1.0	1.50
1.5	2.23
2.0	3.71

And the physics formula for this relationship happens to be x = vt. This is linear data, which is already arranged in our preferred format:
(dependent variable) = (slope quantity or result quantity)(independent variable)
(x) =(v)(t)

Note that this means that if we want to find “v”, then we can rearrange this to be (v) = (x)/(t).

If you're solving for "v", you might be tempted to simply plug in each data point to the equation and solve for four "v" values, and average them out. **However, that method is not statistically sound,** which means that you may get a slightly different final value for "v" than you should.

To get around this, and in order to utilize all the data points you have *at once*, you must use technology to find the slope of the best fit line, which takes *all* data points into account.

So instead of calculating v=x/t four times, use technology (Google Sheets is a good one) to calculate v = [all x data] \ [all t data], which is the slope of the best fit line for the data (slope is rise-over-run). If you need help with the technology, watch the video posted on our Google Classroom under the "Class Resources" topic.

Use technology to solve:
v = ___________ m/s

Linearizing non-linear data

What about when data is not linear? Take this data, for example:

t (s)	x (m)
1.0	4.9
2.0	19.6
3.0	44.1
4.0	78.4

In this example, the car is *accelerating*, meaning its speed is increasing at a constant rate. Our new objective is to find the amount of acceleration. But this is no longer linear! We cannot find the slope of this graph, because the slope changes continuously throughout. Furthermore, physics tells us that the mathematical relationship between position and acceleration is this:

$x = ½ at^2$

Which does not follow our format:

(dependent variable) = (slope quantity or result quantity)(independent variable)

But we can **make** it follow our format with a little creativity. Here's how. What if, instead of the independent variable being "t", instead let's make the independent variable "$½ t^2$" To do that, all we have to do is take each datum we have for t, and square it and halve it:

t (s)	x (m)	$1/2t^2$
1.0	4.9	$½(1.0)^2$ =0.5
2.0	19.6	2.0
3.0	44.1	4.5
4.0	78.4	8.0

Now, it will follow our format:

(dependent variable) = (slope quantity or result quantity)(independent variable)
(x) = (a)($½ t^2$)

Only after you do this step to linearize nonlinear data, then you may find **a** using Google Sheets, using the same method as before, but instead of using the "t" column, use the "$1/2\ t^2$" column:

a = ________________m/s^2

Practice

Dataset 1:

- We stretch a spring to see how its restoring force (F) increases with displacement (x).
- Physics equation: F = -kx

x (m)	F (N)		
0.10	-19		
0.20	-37		
0.30	-57		
0.40	-77		

1. Is this data linear or nonlinear? How can you tell?

2. (Only if it is nonlinear) Use algebra to linearize it. If you need to transform either column, put the new numbers in the blank column(s), and label it.

3. Use technology to find k, the spring constant. k = _______________ N/m

Dataset 2:

- We shoot a ball of mass (m) out of a cannon at several different speeds (v), and measure the amount of work it does to an object by pushing it, which is the same as the kinetic energy (K) that it had while moving. We want to find "m".
- Physics equation: $K = \frac{1}{2}mv^2$

v (m/s)	K (J)		
5.0	50		
10.0	199		
15.0	453		
20.0	805		

4. Is this data linear or nonlinear? How can you tell?

5. (Only if it is nonlinear) Use algebra to linearize it. If you need to transform either column, put the new numbers in the blank column(s), and label it.

6. Use technology to find = _______________ kg

Dataset 3:

- We increase the drag force (F) on coffee filters as they fall down to the floor by increasing the number of coffee filters in the stack each time, and measure their terminal velocity (v). We are trying to find “n”, the drag coefficient (this has to do with the shape of the falling object).
- Physics equation: $F = v^n$

F (N)	v (m/s)		
1.74	2.0		
2.08	2.5		
2.41	3.0		
2.72	3.5		

7. Is this data linear or nonlinear? How can you tell?

8. (Only if it is nonlinear) Use algebra to linearize it.If you need to transform either column, put the new numbers in the blank column(s), and label it.

9. Use technology to find n, the drag coefficient. n = _______________

Vectors
*FOR HELP, watch https://www.youtube.com/watch?v=xp6ibuI8UuQ

A *vector* is a quantity that has magnitude and direction. It is usually represented by drawing an arrow or ray. Examples: Wind blowing 5 m/s due north, or a river flowing 2 m/s at 30° north of east.

A *scalar* is a quantity that has a magnitude, but no direction. Examples: your age, the number of leaves on a tree, the wattage of a lightbulb.

You can perform math operations with vectors, just like you can with scalars. It's just a little more complex.

Multiplying a vector by a scalar

1. Draw a vector that is 3 boxes long, going due east. **It doesn't matter where you start your vector from!** That vector is called **A**.
2. Now, draw a new vector that you think represents 3**A**.
3. Now, draw a new vector that you think represents -2**A**.

Multiplying a vector by a scalar multiplies only the vector's *magnitude*.

Adding vectors together

Vectors always add together by moving them *Tail to Tip.* They can also overlap each other. The resultant (sum) vector goes from the first tail to the last tip. *Subtracting* a vector makes it reverse direction.

A is 5 boxes due east. **B** is 3 boxes due east.

4. Draw **A** + **B.**
5. Draw **A** - **B.**
6. Draw **A** - 2**B.**
7. Draw **A** + **A - B.**

Adding 2-D vectors

Sometimes, you have to add together vectors that don't occupy the same dimension. The left and right dimension has one unit, **i**, and the up-down dimension has another unit, **j**. For example, if you walk 4 boxes east and 3 boxes north (which would translate to 4**i** + 3**j**), how far from your starting point are you?

Draw these vectors tail to tip, and draw the *resultant* vector.
Find the magnitude of the resultant vector. Hint: the answer isn't 7!
Find the direction of the resultant vector. There are two correct ways to express the answer!

8. **A** is 4 blocks south. **B** is 6 blocks east. What is the magnitude and direction of **A** + **B?**
9. **A** is 5**j**. **B** is -5**i**. What is the magnitude and direction of **A** + **B?**
10. **A** is -4**j**. **B** is -3**i**. What is the magnitude and direction of **A** + **B?**

Decomposing "slanty" vectors

All slanty vectors are made from vertical and horizontal components, A.K.A. a certain number of **i**'s and **j**'s. Trigonometry is required to find the number of **i**'s and **j**'s in a slanty vector. If the vector is labeled with a letter such as **A**, then the component vectors are labeled as $\mathbf{A_x}$ and $\mathbf{A_y}$.

Find $\mathbf{A_x}$ and $\mathbf{A_y}$ of each of these vectors:

11. **A** has magnitude 6 and direction 30° N of E
12. **A** has magnitude 4 and direction 30° N of W
13. **A** has magnitude 7 and direction 18° W of S

Final Challenge: **Adding slanty vectors**

To add slanty vectors, you must first break them down into components, and then add the components.

14. **A** is 45° N of E with magnitude 5. **B** is 5 blocks due east. What is the magnitude and direction of **A** + **B**?

15. **A** is 57° W of N with magnitude 5. **B** is 5 blocks due east. What is the magnitude and direction of **A** + **B**?