FACTOR-LABEL METHOD FOR CONVERTING UNITS (Dimensional Analysis)

A very useful method of converting one unit to an equivalent unit is called the **factor-label method** of unit conversion. You may be given the speed of an object as 25 **km/h** and wish to express it in **m/s.** To make this conversion, you must change **km** to **m** and **h** to **s** by multiplying by a series of factors so that the units you do not want will cancel out and the units you want will remain. Conversion: 1000 m = 1 km and 3600 s = 1 *h*,

★cross out terms top/Bottom: SHOW WORK!

$$\left(\frac{25\ \cancel{km}}{\cancel{h}}\right)\left(\frac{1000\ m}{1\ \cancel{km}}\right)\left(\frac{1\ \cancel{h}}{3600\ s}\right) = \frac{125}{18} = 6.94\ m/s$$

A. What is the conversion factor to convert km/h to m/s?

$$\frac{1\ km}{1\ h} \cdot \frac{1\ h}{60\ m} \cdot \frac{1\ m}{60\ sec} \cdot \frac{1000\ m}{1\ km} = \frac{1000\ meters}{3600\ seconds} = .277\ m/s$$

B. What is the conversion factor to convert m/s to km/h?

$$\frac{1\ m}{1\ sec} \cdot \frac{3600\ sec}{1\ hr} \cdot \frac{1\ km}{1000\ m} = \frac{3600\ km}{1000\ hr} = 3.6\ km/hr$$

Carry out the following conversions using the factor-label method. **Show all your work!** ★

1. How many seconds are in a year?

$$\frac{365\ days}{1\ year} \cdot \frac{24\ hr}{1\ day} \cdot \frac{60\ min}{1\ hr} \cdot \frac{60\ sec}{1\ min} = 31{,}536{,}000\ seconds$$

2. Convert 28 km to cm.

$$\frac{28\ km}{} \cdot \frac{1000\ m}{1\ km} \cdot \frac{100\ cm}{1\ m} = 2{,}800{,}000\ cm$$

3. Convert 45 kg to mg.

$$\frac{45\,kg}{} \left|\frac{1000\,g}{1\,kg}\right| \frac{1000\,mg}{1\,g} = 45{,}000{,}000\,mg$$

4. Convert 85 cm/min to m/s.

$$\frac{85\,cm}{1\,min} \left|\frac{1\,min}{60\,sec}\right| \frac{1\,m}{100\,cm} = \frac{85\,m}{6{,}000\,sec} = 0.014\,m/s$$

5. Convert the speed of light, $3x10^8$ m/s, to km/day.

$$\frac{3 \cdot 10^8\,m}{1\,sec} \left|\frac{86400\,sec}{1\,day}\right| \frac{1\,Km}{1000\,m} = 2.592 \cdot 10^{13}$$

6. Convert 823 nm to m

$$\frac{823\,nm}{} \left|\frac{1\,cm}{10000000\,nm}\right| \frac{1\,m}{100\,cm} = 0.000000823\,nm$$

7. 8.5 cm^3 to m^3

$$\frac{8.5\,cm^3}{} \left|\frac{.0000010\,m^3}{1\,cm^3}\right| = 8.5 \cdot 10^{-6}\,m^3$$

Solving Equations:

Often problems on the AP exam are done with variables only. Solve for the variable indicated. Don't let the different letters confuse you. Manipulate them algebraically as though they were numbers. You must Show work! INCLUDE all STEPS!

1. $K = \frac{1}{2}kx^2$, $x =$ $\sqrt{\frac{2K}{k}}$

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

$2K = kx^2$

$\frac{2K}{k} = x^2$

$\sqrt{\frac{2K}{k}} = x$

2. $T_p = 2\pi\sqrt{\frac{\ell}{g}}$, $g =$ $\frac{\ell}{\left(\frac{T_p}{2\pi}\right)^2}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$\frac{T_p}{2\pi} = \sqrt{\frac{\ell}{g}}$

$\left(\frac{T_p}{2\pi}\right)^2 = \frac{\ell}{g}$

$g\left(\frac{T_p}{2\pi}\right)^2 = \ell$

$g = \frac{\ell}{\left(\frac{T_p}{2\pi}\right)^2}$

3. $F_g = G\frac{m_1 m_2}{r^2}$, $r =$ $\boxed{\sqrt{\frac{G m_1 m_2}{F_g}}}$

$r^2 F_g = G m_1 m_2$

$r^2 = \frac{G m_1 m_2}{F_g}$

$r = \sqrt{\frac{G m_1 m_2}{F_g}}$

4. $mgh = \frac{1}{2}mv^2$, $v =$ $\boxed{\sqrt{2gh}}$

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

$2mgh = mv^2$

$\frac{2mgh}{m} = v^2$

$\sqrt{2gh} = v$

5. $x = x_o + v_o t + \frac{1}{2}at^2$, $t =$ $\frac{x - x_0}{V_0} - \frac{1}{2}at^2$

$x - x_0 = V_0 t + \frac{1}{2}at^2$

$\frac{x - x_0}{V_0} = t + \frac{1}{2}at^2$

$\frac{x - x_0}{V_0} - \frac{1}{2}at^2 = t$

$2\left(\frac{x - x_0}{V_0}\right) = t + at^2$

6. $B = \frac{\mu_o I}{2\pi r}$, $r =$ $\frac{\frac{\mu_0 I}{2\pi}}{B}$

$rB = \frac{\mu_0 I}{2\pi}$

$r = \frac{\frac{\mu_0 I}{2\pi}}{B}$

7. $x_m = \frac{m\lambda L}{d}$, $d =$ $\frac{m\lambda L}{x_m}$

$x_m = \frac{m\lambda L}{d}$

$d x_m = m\lambda L$

$d = \frac{m\lambda L}{x_m}$

8. $pV = nRT$, $T =$ $\frac{pV}{nR}$

$pV = nRT$

$\frac{pV}{nR} = T$

9. $\sin\theta_c = \frac{n_1}{n_2}$, $\theta_c =$ $\sin^{-1}\left(\frac{n_1}{n_2}\right)$

$(\sin\theta_c = \frac{n_1}{n_2}$

$\sin^{-1}(\sin\theta_c) = \sin^{-1}\left(\frac{n_1}{n_2}\right)$

10. $qV = \frac{1}{2}mv^2$, $v =$ $\sqrt{\frac{2qV}{m}}$

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

$2qV = mv^2$

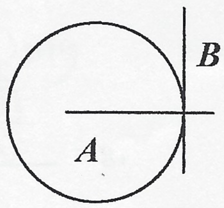
$\frac{2qV}{m} = v^2$

$\sqrt{\frac{2qV}{m}} = v$

Geometry

#11. Solve the following geometric problems.

a. Line ***B*** touches the circle at a single point. Line ***A*** extends through the center of the circle.



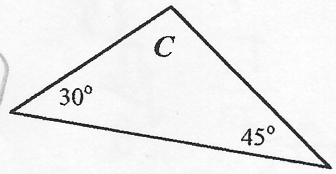
i. What is line ***B*** in reference to the circle?

Tangent

ii. How large is the angle between lines ***A*** and ***B***?

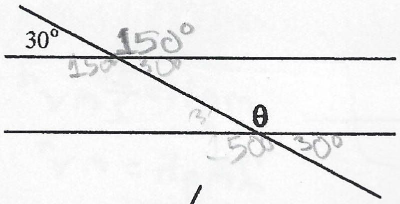
90°

b. What is angle ***C***?



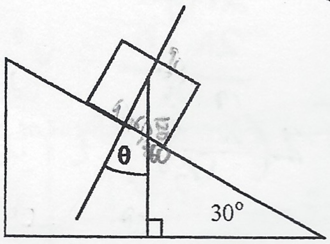
$180-(45+30)=105^\circ$

c. What is angle **θ** ?



150°

d. How large is ***θ***?



30°

#12. a. The radius of a circle is 5.5 *cm*,

i. What is the circumference in <u>meters</u>?

60.5π cm $.605\pi$ m

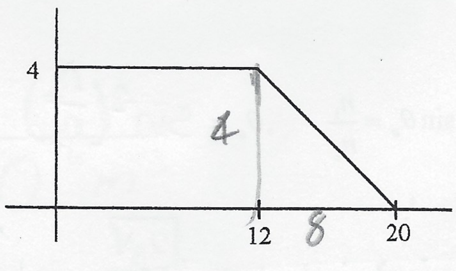
ii. What is its area in <u>square meters</u>?

$30.25\pi\ cm^2$ $.3025\pi$ m

b. What is the area under the curve at the right?

$16\ u^2$

$\frac{8 \cdot 4}{2}$



Graphing

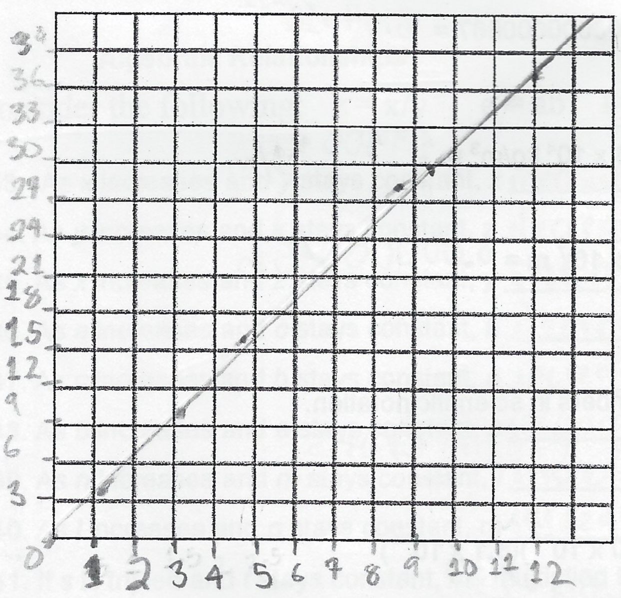
You have been asked by your teacher to measure the diameter, radius and circumference of some round objects, such as tin cans, lids, CD's, coins, etc. You have collected the measurements and recorded them in the table below:

x Radius (cm)	y Circumference (cm)
1.1	3.5
3.2	10.0
4.8	15.1
8.8	27.5
9.6	29.9
12	37.6

13. You are to graph the data in the graph below. The radius is the independent variable here and the circumference is the dependent variable. What does this mean for how you graph the data?

The radius is the independent variable so it should be on the x-axis and the y-axis should have the circumference

14. Label the axis and with the name of the quantity, appropriate scaling of numbers and units. Then plot the points and draw the best straight line through as many points as possible, known as best-fit-curve (DO NOT JUST CONNECT THE DOTS!)



15. Find the slope of the graph. Does it have a name or a physical meaning?

$y = 3.12x + 0.05$

$m = 3.12x$

The slope is rather close to π.

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16. Is the slope constant? How do you know this?

Yes because it is linear and a straight line

17. Does your graph have a y-intercept, if it does, what is it and does it have any significance?

Yes $y = \cancel{3.12(0)} + 0.05$ It is where the line crosses the y-axis
(0, 0.05) y = 0.05

18. Using the fact that the equation for a straight line is $y = mx + b$ write the specific equation for this graph using the appropriate symbols for radius and circumference in place of the and symbols.

$C = 3.12r + 0.05$

Scientific Notation:

Examples: 200,000 = 2×10^5 0.00000123 = 1.23×10^{-6}

Express the following numbers in scientific notation:

13. 86,400 s = $8.64 \cdot 10^4$ s

15. 300,000,000 m/s = $3.0 \cdot 10^8$ m/s

14. 0.000564 m = $5.64 \cdot 10^{-4}$ m

16. 0.0000000000667 = $6.67 \cdot 10^{-11}$

Convert from scientific notation to normal notation:

17. 9×10^9 = 9000000000

19. 1.93×10^4 kg/m³ = 19300 kg/m

18. 1×10^{-3} m = 0.001 m

20. 4.5×10^{-7} m = 0.00000045 m

Multiplying Numbers in Scientific Notation

21. In your own words, explain how you multiply numbers in scientific notation.

Multiply the coefficient, add the exponents

22. $(2.5 \times 10^8) \times (1.2 \times 10^1)$
$3.0 \cdot 10^9$

24. $(6.0 \times 10^{-2})(6.1 \times 10^{-2})$
$3.66 \cdot 10^{-3}$

23. $(1.8 \times 10^3)(7.3 \times 10^{-8})$
$1.314 \cdot 10^{-4}$

25. $(5.5 \times 10^9) \times (4.0 \times 10^{11})$
$2.2 \cdot 10^{22}$

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Adding Numbers in Scientific Notation

26. In your own words, explain how you add numbers in scientific notation.

I make the scientific notation have equal exponents and then add the coefficient.

27. $(2.5 \times 10^{8}) + (1.2 \times 10^{8})$

$3.7 \cdot 10^{8}$

29. $(6.0 \times 10^{-2}) + (6.1 \times 10^{-2})$

$1.21 \cdot 10^{-1}$

28. $(1.8 \times 10^{3}) + (7.3 \times 10^{2})$

$18 + 7.3 = 25$

$2.53 \cdot 10^{3}$

30. $(5.5 \times 10^{9}) + (4.0 \times 10^{11})$

$.04$

$5.54 \cdot 10^{9}$

31. Why do scientists use scientific notation?

Scientific notation provides a way to represent large and small numbers that are easier to comprehend compared to writing numbers long hand.

32. Which of the following is written in proper scientific notation?

(A) 0.25×10^{3} (B) 2.5×10^{2} (C) 25×10^{1} (D) 250

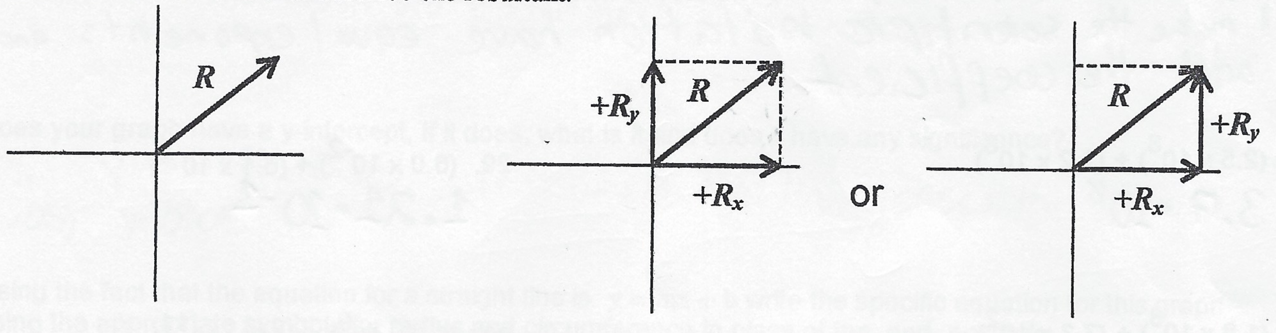
Algebraic Relationships

Consider the following: $z = x/y$ $c = ab$ $1 = m\sqrt{n}$ $r = s^2/t^2$

33. As *x* increases and *y* stays constant, *z* increases.
34. As *y* increases and *x* stays constant, *z* decreases.
35. As *x* increases and *z* stays constant, *y* increases.
36. As *a* increases and *c* stays constant, *b* decreases.
37. As *c* increases and *b* stays constant, *a* increases.
38. As *b* increases and *a* stays constant, *c* increases.
39. As *n* increases and *m* stays constant, *l* increases.
40. As *l* increases and *n* stays constant, *m* increases.
41. If *s* is tripled and *t* stays constant, *r* is multiplied by nine.
42. If *t* is doubled and *s* stays constant, *r* is multiplied by four.

Component Vectors

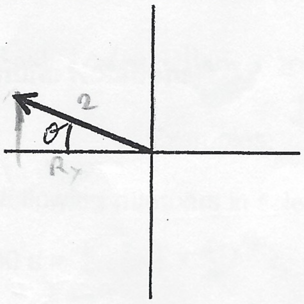
A resultant vector is a vector resulting from the sum of two or more other vectors. Mathematically the resultant has the same magnitude and direction as the total of the vectors that compose the resultant. Could a vector be described by two or more other vectors? Would they have the same total result? This is the reverse of finding the resultant. You are given the resultant and must find the component vectors on the coordinate axis that describe the resultant.



Any vector can be described by an x axis vector and a y axis vector which summed together mean the exact same thing. The advantage is you can then use plus and minus signs for direction instead of the angle.

Break down the vectors into their components as shown above. CALULATE THE MISSING SIDES!

a.



Θ = 25° 2sin(25)=Ry

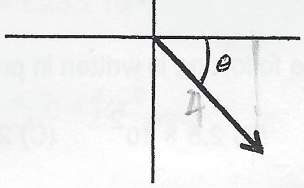
R= 2m/s

2cos25=Rx

R_x = -1.812 m/s

R_y = 0.845 m/s

c.



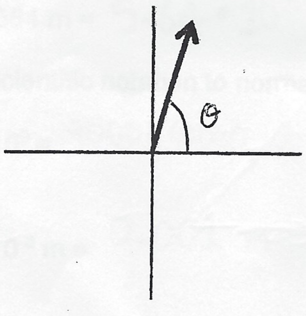
Θ = 50° 4sin(50)=Ry

R= 4m

R_x = 2.571 m/s

R_y = -3.064 m/s

b.



Θ = 80° 5sin(80)=Ry

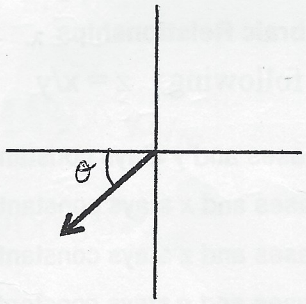
5cos(80)=Rx

R= 5m/s

R_x = 0.868 m/s

R_y = 4.924 m/s

d.



Θ = 45° 10sin(45)=Ry

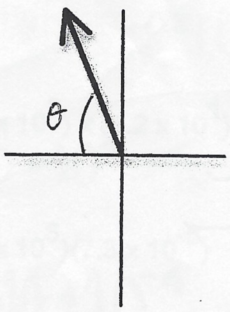
10cos(45)=Rx

R= 10cm

R_x = $-5\sqrt{2}$ cm

R_y = $-5\sqrt{2}$ cm

e.



Θ = 75° 1.5sin(75)=Ry

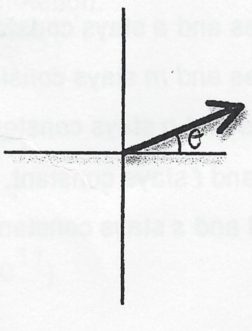
1.5cos(75)=Rx

R= 1.5inches

R_x = -0.388 in

R_y = 1.448 in

f.



0.5sin15=Ry

0.5cos15=Rx

Θ = 15°

R= 0.5km

R_x = 0.482 Km

R_y = 0.129 Km

Obviously, the quadrant that a vector is in determines the sign of the x and y component vectors.

8.

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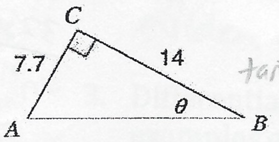
Right Triangles

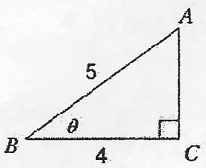
Directions: Find the measure of the angle or side indicated. Please show all of your work.

1) Find θ



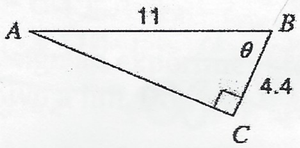
$\tan^{-1}\frac{7.7}{14} = \boxed{28.810^\circ}$

2) Find θ



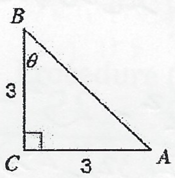
$\cos^{-1}\frac{4}{5} = \boxed{36.869^\circ}$

3) Find θ



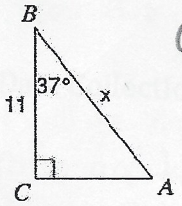
$\cos^{-1}\frac{4.4}{11} = \boxed{66.421^\circ}$

4) Find θ



$\tan^{-1}\frac{3}{3} = \boxed{45^\circ}$

5) Find x

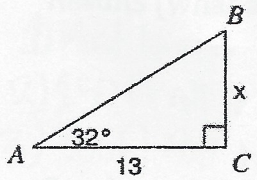


$\cos 37 = \frac{11}{x}$

$x \cos 37 = 11$

$x = \frac{11}{\cos 37} = \boxed{13.773}$

6) Find x



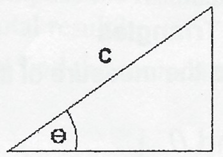
$\tan 32 = \frac{x}{13}$

$13 \tan 32 = x = \boxed{8.123}$

9.

Trigonometry

Using the generic triangle to the right, Right Triangle Trigonometry and Pythagorean Theorem solve the following. ***<u>Your calculator must be in degree mode.</u>***



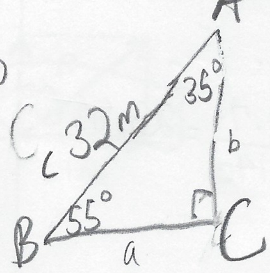
$32\sin 35 = a\sin 90$ $\quad \frac{\sin 90}{32} = \frac{\sin 35}{a}$

$\frac{32\sin 35}{\sin 90} = 18.354 = a$

law of sines AAS

$32\sin 55 = b\sin 90$

$\frac{32\sin 55}{\sin 90} = 26.212$



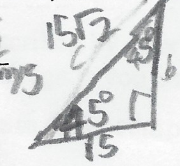
$\frac{\sin 90}{32} = \frac{\sin 55}{b}$

g. **θ** = 55° and ***c*** = 32 *m*, solve for ***a*** and ***b***.

a=18.354 m b=26.212 m

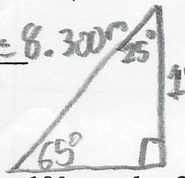
h. **θ** = 45° and ***a*** = 15 *m/s*, solve for ***b*** and ***c***.

b=15 m/s c=15√2 m/s



i. ***b*** = 17.8 *m* and **θ** = 65°, solve for ***a*** and ***c***.

c=19.640m a=8.300m



$\frac{\sin 65}{17.8} = \frac{\sin 90}{c}$

$17.8\sin 90 = c\sin 65$

$\frac{17.8\sin 90}{\sin 65} = c$

$\frac{\sin 65}{17.8} = \frac{\sin 25}{a}$

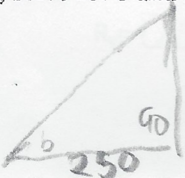
$17.8\sin 25 = a\sin 65$

$\frac{17.8\sin 25}{\sin 65} = a$

j. ***a*** = 250 *m* and ***b*** = 180 *m*, solve for **θ** and ***c***.

c=308.058 m

B=35.753°



$250^2 + 180^2 \sqrt{94900}$

law of cosine: $\frac{308.058^2 + 250^2 - 180^2}{2(308.058)(250)}$

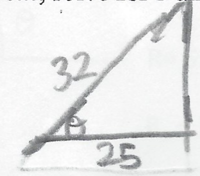
B=35.753

A=54.246

k. ***a*** =25 *cm* and ***c*** = 32 *cm*, solve for ***b*** and **θ**.

b=47.686 cm

θ=38.624°



$25^2 + b^2 = 32^2$

$b^2 = 2274$

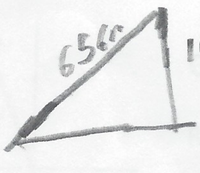
$b = 47.686$

$\cos^{-1}\left(\frac{25}{32}\right) = 38.624$

$\frac{32^2 + 25^2 - 47.686^2}{2(32)(25)}$

l. ***b*** =104 *cm* and ***c*** = 65 *cm*, solve for ***a*** and **θ**.

no solution ∅



$a^2 + 104^2 = 65^2$

$a^2 + 10816 = 4225$

Experimental Design:

1. What is the difference between an experiment and a case study?
An experiment is designed to reach a conclusion by controlling variables and using the scientific method. A case study is an observation of ~~the~~ a field.

2. What is a hypothesis?
Hypothesis is an educated idea based on postulation and limited evidence.

3. Differentiate "independent variable" from "dependent variable," give examples of each:
Independent variable is a variable that does not depend on a variable e.g. time.
Dependent variable is a variable that depends on the variable e.g. solar panel power output
Independent variable is what causes change, dependent variable is the result

4. What are extraneous variables? Give examples:
Extraneous variables are variables that are not part of controlled, independent or dependent variables but may influence the outcome e.g. a person, instrument discrepancies.

5. What is the difference between "correlation" and "causation?"
Correlation is when two events/variables seem related e.g. US spending on science, space, and technology correlates (r=0.994) with suicides by hanging, strangulation and suffocation but that does not mean one causes another. Causation is when one variable directly causes change in another variable e.g. more income made means more income tax.

Design an experiment testing how height would affect the speed of a bowling ball rolling down a hill. Don't do the experiment, just design it and follow this sequence:

Introduction (Hypothesis):
If the same bowling ball is dropped from two different heights, then the higher height will yeild a faster velocity due to more time spent reaching its terminal velocity.

Procedure (# the steps):
1) Gather tools: 10 pound bowling ball, hill, speedometer
2) Mark two different places in a hill, one is 150ft tall, another 300ft tall (at different heights)
3) Let the bowling ball roll from the marked places, do it three times for each place
4) Meausure the speed throughout the roll, average the top speed for every roll from two different marked place

Data Collection & Analysis (how you will collect and interpret data):
I will use the speedometer and meausure the speed throughout the three rolls and take the top speed for each roll and average; this is for 150ft place then repeat for 300ft place. I will interpret the average speed from the two different places and calculate the change in speed.

Results (what are the possible results?):
1) Most likely: 300ft roll reaches a higher top speed than the 150ft roll
2) 150ft roll reaches a higher top speed than 300ft roll.
3) 300ft roll have the same top speed as the 150ft roll.

Conclusion (overview the experiment):
I will try to correct for my errors and minimize the variables and repeat the experiment.