Note Booklet #1:

Physics Skills

Scientific method

A hypothesis is a possible explanation for some phenomenon. The difference between a hypothesis and a guess is that a hypothesis must make a ____. There must be some ________________________ we could perform to test our hypothesis.

Example: A ball is rolled away from someone, but it then rolls back to the experimenter.

Hypothesis #1:

Predication:

Hypothesis #2:

Predication:

Hypothesis #3:

Predication:

Positive and Negative Powers of 10

Exponential Form	As a multiplication	Standard Form
10^5		
10^4		
10^3		
10^2		
10^1		
10^0		
10^{-1}		
10^{-2}		
10^{-3}		
10^{-4}		
10^{-5}		

Scientific Notation

We use scientific notation to simplify the writing of very large or very small numbers. **As a rule of thumb in this class you should use scientific notation for all numbers greater than 1000 and less than 0.01.**

Scientific notation consists of a number between _____ and ______ that is multiplied by a power of 10.

Which of the following are written in scientific notation?

5×6	54×10^3	5×10^3
5.3×10^{-3}	0.26×10^{19}	1.996235×10^3

Write "0.00045 grams" in scientific notation

Write "$2\ 562\ 000$ seconds" in scientific notation

Write "260.9 mL" in scientific notation

Write "4.355×10^6 mL" in standard notation

Write "9.46×10^{-5} seconds" in standard notation

Write "4.1×10^{-4} litres" in standard notation

Operations with scientific notation

The easiest method to work with numbers in scientific notation is to use your calculator. Most calculators have a button such as "Exp" which means $\times 10$ to the power of.

For example, on my calculator $9\ [Exp]\ 3 = 9000$.

Use your calculator to determine the solution to the following and express it in scientific notation:

$(5.34 \times 10^4)(2.63 \times 10^9) =$

$(5.1 \times 10^{-5})(2.9 \times 10^9) =$

$\frac{5.36\times10^{-3}}{19} =$

$3.5 \times 10^4 + 9.52 \times 10^3 =$

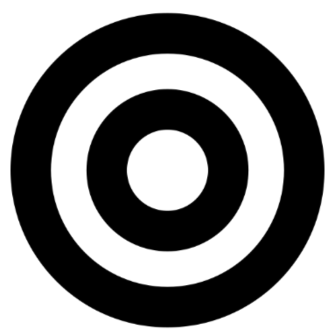
$7.5 \times 10^9 - 1.532 \times 10^{10} =$

<u>Precision and Accuracy</u>

There is a major difference between counting and measuring. In counting unless you make a mistake you will be ______________________________. If you are measuring, there will _______________ be a difference between the measured value and the true value.

___________________ is a measure of how close measured values are to each other.

___________________ is a measure of how close measured values are to the true value.



Example: You measure an object that has mass of 5.61 grams on 4 different scales, 4 times each. Determine the average of the measurements and explain the precision and accuracy of each scale.

	Scale A	**Scale B**	**Scale C**	**Scale D**
Measurement 1	5.60 g	6.21 g	4.25 g	4.62 g
Measurement 2	5.62 g	6.23 g	8.23 g	6.05 g
Measurement 3	5.61 g	6.24 g	1.45 g	5.92 g
Measurement 4	5.63 g	6.24 g	2.45 g	5.23 g
AVERAGE				

If measurements are accurate:

Practice:

1. An object has density of $1.65\ g/mL$. Its density is measured three times with the results of $1.36\ g/mL$, $1.25\ g/mL$ and $1.32\ g/mL$.
    a. Discuss the accuracy of the measurements.

    b. Discuss the precision of the measurements.

2. An object has density of $9.25\ g/mL$. Its density is measured three times with the results of $9.26\ g/mL$, $9.24\ g/mL$ and $9.24\ g/mL$.
    a. Discuss the accuracy of the measurements.

    b. Discuss the precision of the measurements.

3. A scale always adds exactly 0.32 grams to its measurements. When the real measurement is 1.00 grams the scale reads 1.32 grams. When the real measurement is 2.00 grams the scale reads 2.32 grams. Does the scale have a **precision problem** OR **an accuracy problem**?

4. A clock has stopped, its hands no longer move. Compare the accuracy and precision of this clock to a functioning clock.

Error

There are 3 broad categories of error in measurement.

Systemic Errors cause measurements to be always either too high or too low. Systemic errors affect the accuracy of your measurements. If systemic errors have occurred all measurements must be repeated or corrected.

Random Error cause the measurements to be too high sometimes and too low sometimes. Random errors affect the precision of your measurements are unavoidable and can be controlled by averaging several measurements.

Blunders are major errors that are caused mistakes in measurement. Any measurement with a blunder should be removed from calculation.

Example: An experimenter is measuring the length of a ramp. They measure three times with a tape measure and record 5.62 metres, 5.61 metres, and 2.34 metres. What type of error is there and what should they do to fix it?

Example: An experimenter measures the temperature of a solution in a test tube. They hold the test tube in their hand as they measure three times and get the following results. $12.23°C$, $12.24°C$ and $12.21°C$. What type of error is there and what should they do to fix it?

Example: An experimenter measures the time it takes for a ball to fall and records the times as 5.62 seconds, 5.65 seconds, and 5.61 seconds. What type of error is there and what should they do to fix it?

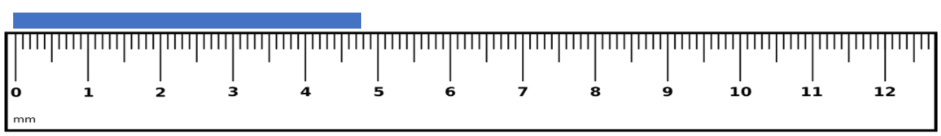
Significant Figures

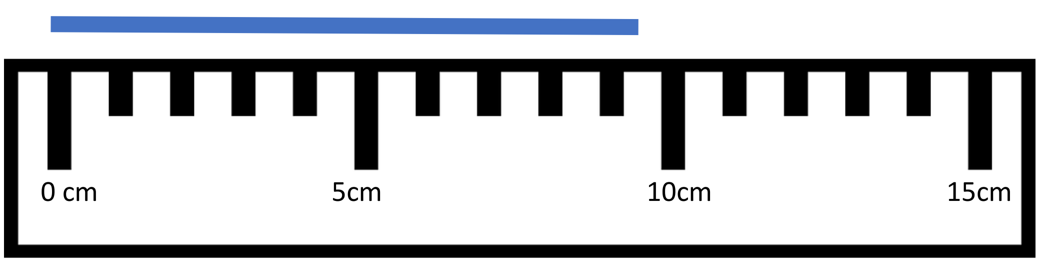
A number in science is not just a number, it also shows the ____________________ of the measurement.

The number of significant figures is equal to all the certain digits plus the first uncertain digit.

Example: The measurement of the volume of liquid in this beaker was recorded as "37 mL" Which of those digits is certain, which is uncertain?

Example: Determine the length of the following lines:





Example: A digital scale reads "5.4 grams", another reads "5.40" grams, what is the difference?

<u>Rules of Sig Figs:</u>

Leading zeros and not significant

Example: How many significant digits are there in the following measurements?

25 g

0.025 kg

0.000304 cm

3005 mL

Trailing zeros are significant only if the number is written with a decimal

Example: How many significant digits are there in the following measurements?

250 g

250.0 g

0.006 mL

0.0060 mL

0.00603 mL

0.00560 g

2.340×10^3

KEY IDEA: If you need the zero to write the number mathematically that zero is ___________________

To show a measurement that IS exactly a "round" number use scientific notation

Example: Radhanath Sikdar measures the height of a mountain to be exactly 29 000 feet tall how should he record this measurement to show it is not rounded.

Round the following to 2 significant figures:

16.23

19.523

0.003523

1006

0.000102

Significant figures are only used for measured quantities, for counted quantities we assume the measurement is perfect.

Example: Which of the following was likely obtained by measurement, which was likely obtained by counting?

23 graduated cylinders each with 23 mL of solution in them.

Operations with sig figs

What is wrong with saying a desk is 110 cm long, so if we add 5.75 cm to it then it will be 115.75 cm long?

SIG FIG RULE FOR CALCULATIONS IN THIS CLASS:

$5.6 + 7.23 =$

$\frac{0.025}{29.3} =$

$600 + 30 =$

$(5.6)^3 =$

$6.2 \times 10^5 + 2.7 \times 10^6 =$

If a number is a counted value or is part of a formula, we do not apply the rules of significant figures to it.

1. The formula for the circumference of a circle is $C = 2\pi r$. What is the circumference of a circle with diameter of 5.623 cm?

2. The formula for the volume of a cone is $V = \frac{\pi r^2 h}{3}$ where r is the radius and h is the height. What is the volume of a cone with height of 620 cm and radius of 44.25 cm?

3. The formula for the surface area of a cylinder is $SA = 2\pi rh + 2\pi r^2$ where r is the radius and h is the height. What is the surface area of a cylinder with radius of 2.34 cm and height of 52 cm?

4. There are 30 beakers each of which has mass of 46.0 grams. What is the total mass?

<u>Dimensional analysis</u>

Unit analysis is a method for converting one measurement into an equivalent measurement with different units.

A conversion factor is a way of writing "1": $\frac{\text{1 hour}}{\text{60 minutes}}\ or\ \frac{\text{60 minutes}}{\text{1 hour}}$

If you multiply by a conversion factor so the same unit is on top and bottom, you can _______________ that unit.

Example 1: A reaction is known to take 5600.0 seconds, how many minutes will this be?

Example 2
Convert 2.58 yards into feet (1 yard = 3 ft):

Example 3
Chickpeas cost $1.60 per hundred grams; how much chickpeas can you get for $5?

Example 4 * sometimes you need to do several steps
How many feet is 1.00 meter? (there are exactly 12 inches in a foot, and approximately 39.37 inches in a meter)

We can multiply units together. Consider the unit "worker-hours" which is the amount of work one person working for one hour can achieve.

Example 5: If 12 people work together for 8 hours, how many "worker-hours" of work were done?

We can also divide units. When we do, we have a rate. For example $95\frac{km}{hr}$ means 95 kilometers ______ hour. That is, in one hour a person with this speed travels _______ km.

Example 6
What is 5.52 metres per second in km per hour?

Example 7
What is 25 grams per minute in kg per hour?

Example 8
What is 5900 square inches in square feet?

Example 9
What is 4.6 cubic metres in mL? ** Note that 1mL = 1 cubic cm

Dealing with uncertainty in experimental data

Recall that if measurements are accurate, the average of the measurements will get closer to the actual value.

Example: We measure the time it takes water to boil 5 times

Trial #1	86.34 seconds
Trial #2	89.34 seconds
Trial #3	82.56 seconds
Trial #4	90.23 seconds
Trial #5	85.26 seconds

What is the average time it took to boil the water?

In reporting our uncertainty, we need to balance two things

- A large range of values for measurements makes us ____________________ about the average.
- A large number of measurements makes us ____________________________ about the average.

A formula for uncertainty in the average is

$$\frac{\text{max value} - \text{min value}}{2\sqrt{\#\text{ of measurements}}}$$

Note that more measurements means ____________ uncertainty and more range between max and min values means _____________ uncertainty.

We round uncertainty to _________ sig fig, and round the average to the _________________________ of the uncertainty

Example: We measure the distance a ball rolls in 6.000 seconds, 10 times.

Trial #1	63.1 cm
Trial #2	63.2 cm
Trial #3	63.2 cm
Trial #4	62.9 cm
Trial #5	63.2 cm
Trial #6	63.4 cm
Trial #7	63.1 cm
Trial #8	62.9 cm
Trial #9	62.8 cm
Trial #10	63.4 cm

What is the average distance the ball rolled with uncertainty reported?

Practice

1. An experiment is performed to determine the force of an explosion by measuring the depth of the crater left after the explosion. The experiment is performed 3 times with the following results. Record the average with uncertainty.

	Depth
#1	2.34 m
#2	3.52 m
#3	1.95 m

2. An experiment is performed to determine if salt water boils faster than unsalted water. 6 samples of each types of water are boiled and the time to boil recorded. Determine the average with uncertainty for the time it takes to boil each and what can be concluded from the data.

Salted	Time (sec)
#1	65.23 sec
#2	67.26 sec
#3	62.96 sec
#4	70.11 sec
#5	65.24 sec
#6	67.23 sec

Unsalted	Time (sec)
#1	64.52 sec
#2	64.95 sec
#3	64.64 sec
#4	65.12 sec
#5	64.74 sec
#6	67.84 sec

Formula Manipulation

The ________________ of a formula is the variable by itself.

What is the subject of the following:

$y = mx + b$

$v_f = v_0 + at$

To change the subject of an equation the golden rule is to

You can add or subtract the same quantity to or from each side

$v_f = v_0 + at$, make the subject v_0

$y = mx + b$, make the subject b

You can multiply or divide both sides by the same quantity

$E_p = mgh$, make the subject g

$\frac{t}{5.3} = mb$, make the subject t

Often a combination of these approaches is required, in these cases it is usually easier to add or subtract first and then multiply and divide.

$v = v_0 + at$, make the subject t

Remove fractions by multiplying all terms by the denominator

$\frac{a}{b} = m + h$, make the subject a

$\frac{h}{m} = 2y + z$, make the subject h

$h = \frac{m}{x}$, make the subject x

$h = \frac{m}{x} + k$, make the subject x

You can square root both sides to remove a square, in this case you need to consider the positive and negative roots.

$E_k = \frac{1}{2}mv^2$, make the subject v

You can square both sides to remove a square root.

$m = \sqrt{k} + v$, make the subject k

Linear relations

Recall the equation for a straight line is

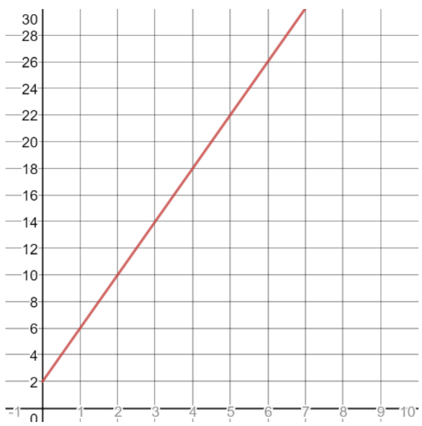
Where x is the ______________________________ variable

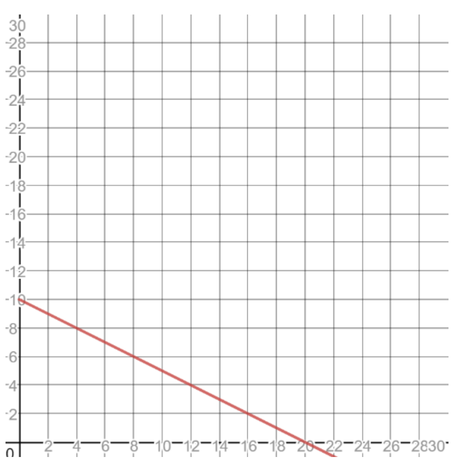
y is the _______________________ variable

m is the _______________________ of the line

This equation tells you how y changes as _________ changes

$m = \text{slope} =$

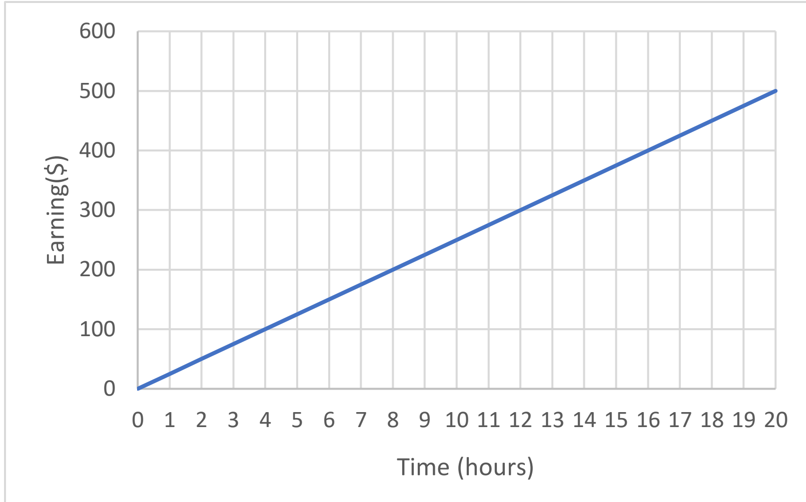




<u>Units</u>

When writing the equation of a graph which describes a real world situation we usually use variable names that help us understand what the variables mean, not always x and y.

We also must use units with the slope and y-intercept.

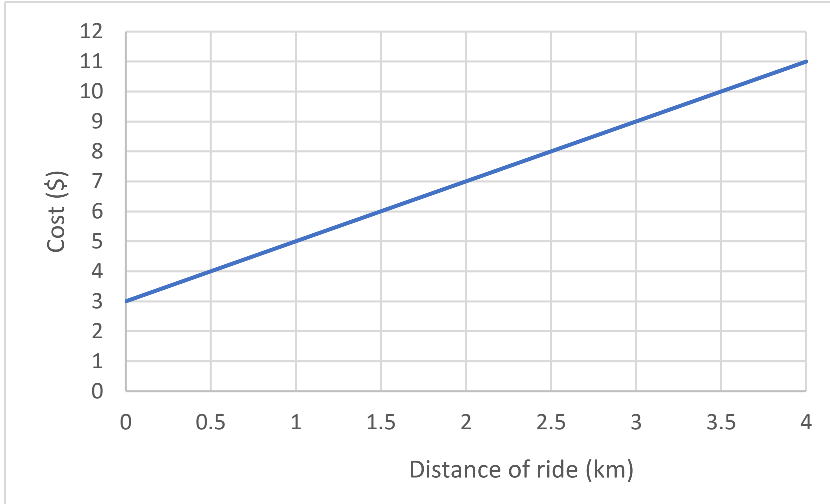


Consider the graph shown. The independent variable is ____________________ and the dependant variable is _______________________.

Determine an equation for this relation:

Use the equation to determine how much someone would earn if they worked 3.2 hours.

EXAMPLE: Determine an equation with units for the cost of a taxi ride given by the graph shown.



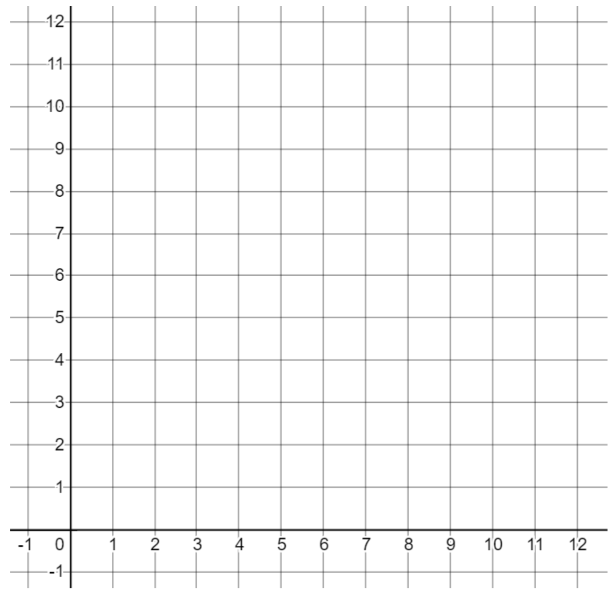
Use your equation to determine the cost of a 9.2 km ride.

Often we gather data and have to plot it on a graph to analyze it.

Using the table below:

- label both axis (time is independent)
- plot the data points
- determine the equation for the relation

Height of candle (cm)	Time burning (min)
12	0
11	6.0
10	12



Use your equation to determine the height of the candle after 15 minutes.

Rearrange your equation so that time is the subject, then use that equation to determine how long it will take until the candle has burnt out.

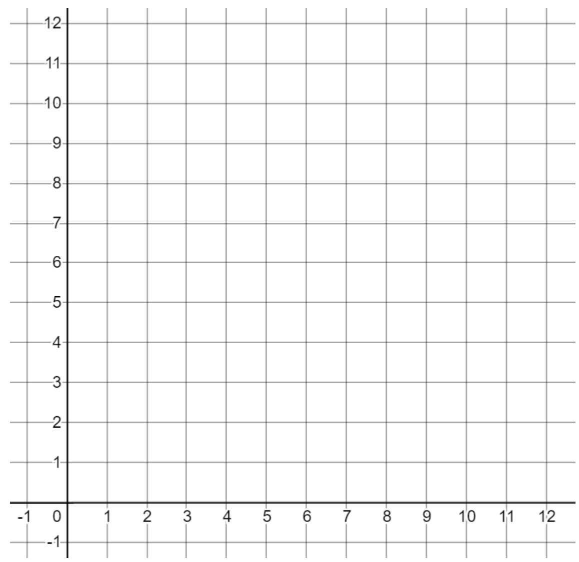
Scatter Plots and Lines of Best Fit

Due to random errors, the data we gather rarely lies perfectly on a line, so we make a scatter plot where we place all the data points and then we can draw a line of best fit which will give an estimation at the equation behind the relations.

When we do this by hand we try and draw a line with the same number of data points ______________________________ and ______________________________the line.

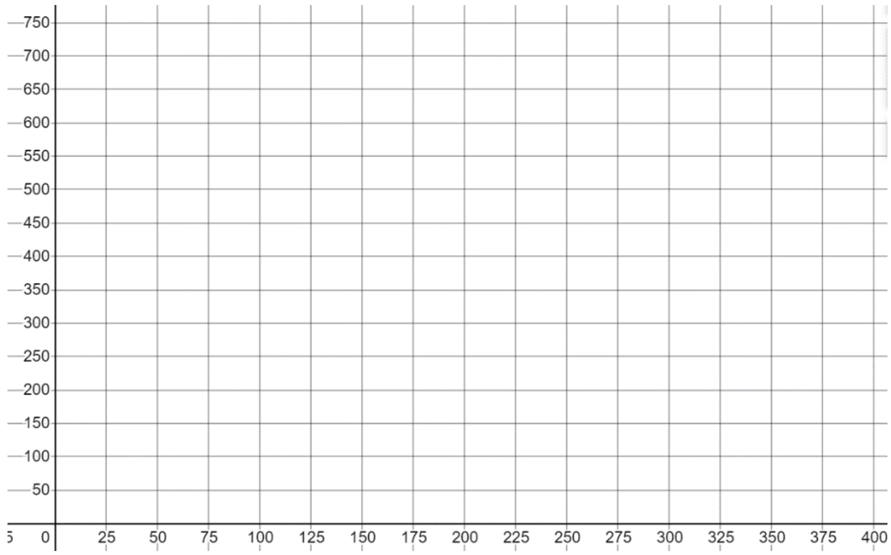
Draw a scatter plot and a line of best fit then use **two points on the line of best fit** to determine the equation of the line.

x	y
0.0	0.0
1.0	1.2
2.0	2.5
3.0	3.6
4.0	4.2
6.0	7.3
8.0	9.6
10.0	12.4



The time it takes to boil a certain amount of water is measured. The independent variable is the volume of water, the dependant is the time to boil. Plot the data, draw a line of best fit and determine the equation for the relation.

Volume of water (mL)	Time (sec)
50.0	86.5
100.0	179
150.0	245
200.0	346
225.0	409
250.0	433
400.0	702



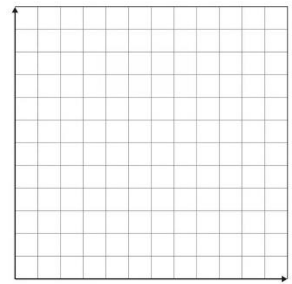
Use your equation to determine the time it would take to boil 500.0 mL of water.

Rearrange your equation to so that volume is the subject. Use your equation to determine how much water you could boil in one hour.

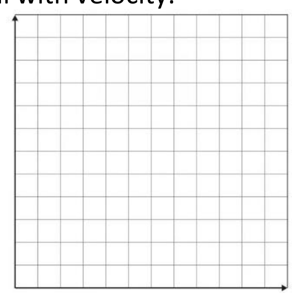
Types of Relations

There are infinite ways that two quantities can be related, however in this course we will be primarily interest in 5 different relations.

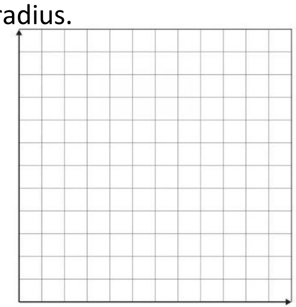
1) A quantity may be **directly proportional** (linear) with another.
    - Example: Distance travelled is proportional to the time travelled if you move at a constant velocity.



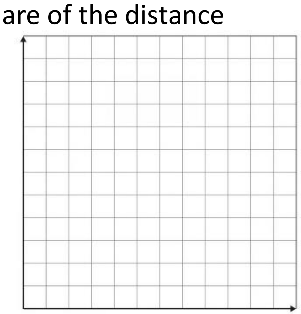
2) A quantity may be **inversely proportional** with another
    - Example: Time to travel a certain distance is inversely proportional with velocity.



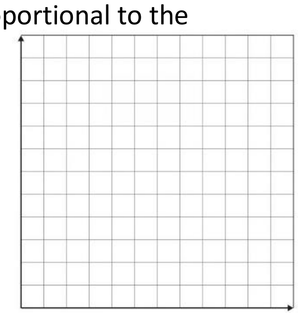
3) A quantity may be **proportional with the square** of another
    - Example: The area of a circle is proportional to the square of the radius.



4) A quantity may be **inversely proportional with the square** of another.
    - Example: The intensity of light is inversely proportional to the square of the distance from the source.



5) A quantity may be **proportional with the square root** of another.
    - Example: The time it takes a pendulum to go back and forth is proportional to the square root of length of the pendulum.

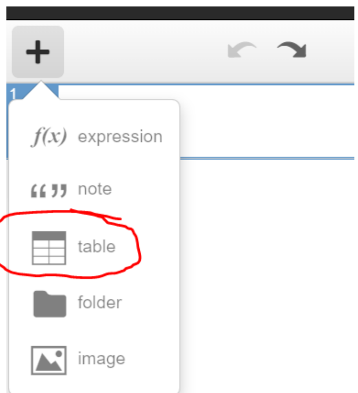


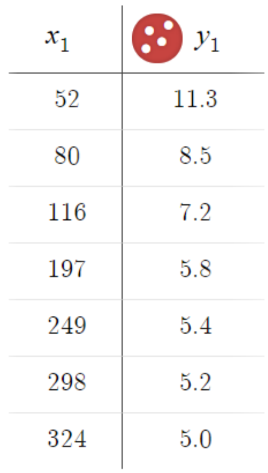
We can use technology to determine the best equation for data.

Consider the relationship between height and cargo shown below

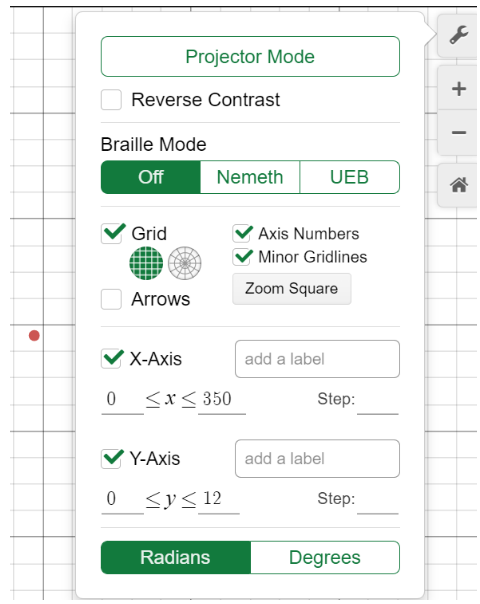
Height (m)	11.3	8.5	7.2	5.8	5.4	5.2	5.0
Cargo (tonnes)	52	80	116	197	249	298	324

We can plot this data in Desmos by adding a table, filling in the data, and changing the graphing setting to show the data.





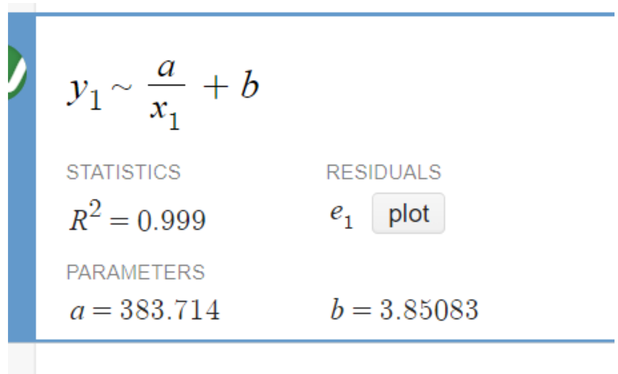
x_1	y_1
52	11.3
80	8.5
116	7.2
197	5.8
249	5.4
298	5.2
324	5.0



Once we have the data, we can determine type of relation by looking at the shape of the graph. In this example it appears height is inversely proportional to cargo.

In the equation field we enter $y_1 \sim \frac{a}{x_1} + b$

We can then determine the equation, in this case it is



In addition we can see the R^2 value, the closer this is to __________ the better the line describes the data.

Practice: Use Desmos to make a scatter plot, determine the shape of the graph, and then determine the curve of best fit and R^2 value.

The Distance Fallen by a Stone vs Time: From the top of a tall building a stone is dropped. The distance it has fallen is determined by taking photographs every second.

Dependant Variable	Distance(m)	0.0	5.0	19	43	77	120	173	235	307
Independent Variable	Time(s)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0

Electric Force vs Distance: Two electric sources are placed different distances apart and the force of attraction is measured.

Dependant Variable	Force (N)	10.0	5.6	3.6	2.5	1.8	1.4	1.1
Independent Variable	Distance(cm)	3.0	4.0	5.0	6.0	7.0	8.0	9.0

Voltage and Current: The change in voltage as current is increased in measured.

Dependant Variable	Voltage (V)	7.5	12	20	26	35	44	52	56	66
Independent Variable	Current (A)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0