Processing and Presenting Data for IB Labs

The main aim of the Data Collection and Processing skill set of the IB IA criteria is to find a linear relationship between two quantities so that a linear graph can be plotted that is of the equation form:

$$y = mx + b$$

where m is the slope (gradient) and b is the y-intercept.

You can then use the uncertainty of your plotted data to determine a min and max gradient for your line, which then gives you the uncertainty for your gradient.

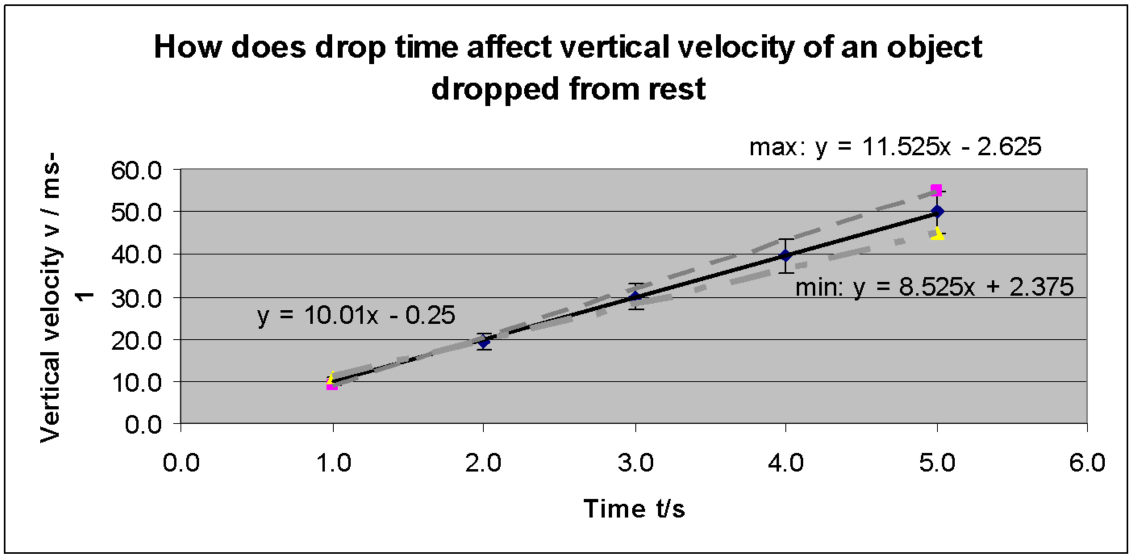
In simpler experiments, you may find when plotting the dependent variable (y) vs. the independent variable (x), a linear relationship already exists between the two.

Example: Let's say that in an experiment, a student wanted to determine how the vertical velocity of a ball dropped from rest varied as time passed. Vertical velocity would be his dependent variable, and time would be his independent variable.

The student conducted five trials each for the following times: 1.0s, 2.0s, 3.0s, 4.0s, and 5.0s, calculated the average velocity for each time, and determined the uncertainty for each time. His data results are shown in the table below.

Drop time t / s +/- 0.1s	**Vertical velocity v / ms^{-1}**
1.0	9.9 +/- 1.0
2.0	19.5 +/- 2.0
3.0	30.0 +/- 3.0
4.0	39.6 +/- 4.0
5.0	49.9 +/- 5.0

Plotting these data points, you get the following graph:



Since the student was able to draw a straight line that passed through the uncertainty bars for each of his data points, the student was able to conclude that a linear relationship exists between vertical velocity and time. The student was then able to draw a line of best fit, calculate the gradient, and use the uncertainty of the first and last data points to calculate the max and min gradient lines for the relationship between vertical velocity and time.

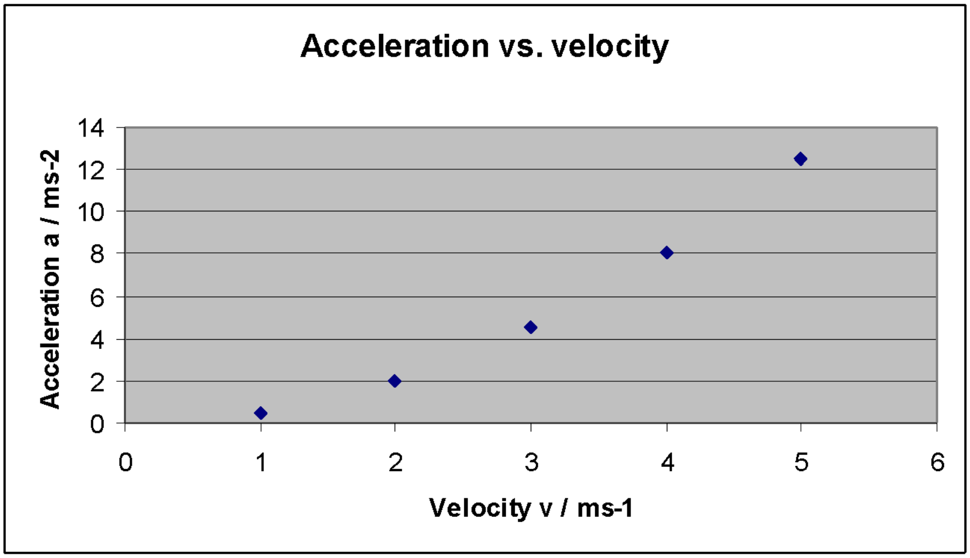
In many experiments, when you plot the data to show the relationship between your independent and dependent variable, the resulting data does not indicate a linear relationship.

In these cases, you need to look at the plotted data and try to determine what type of relationship exists between the variables (what type of graph it is). Once you've identified the relationship (ex: squared, inverse, inverse squared, exponential), you can use this knowledge to create a linear plot.

Once you've plotted your data, being able to recognize different types of graphs will help you to determine what to graph next.

Take a look at the graph below. What type of relationship exists between the acceleration and velocity of the object?

Velocity v / ms-1	Acceleration a / ms-2
1	0.5
2	2
3	4.5
4	8
5	12.5

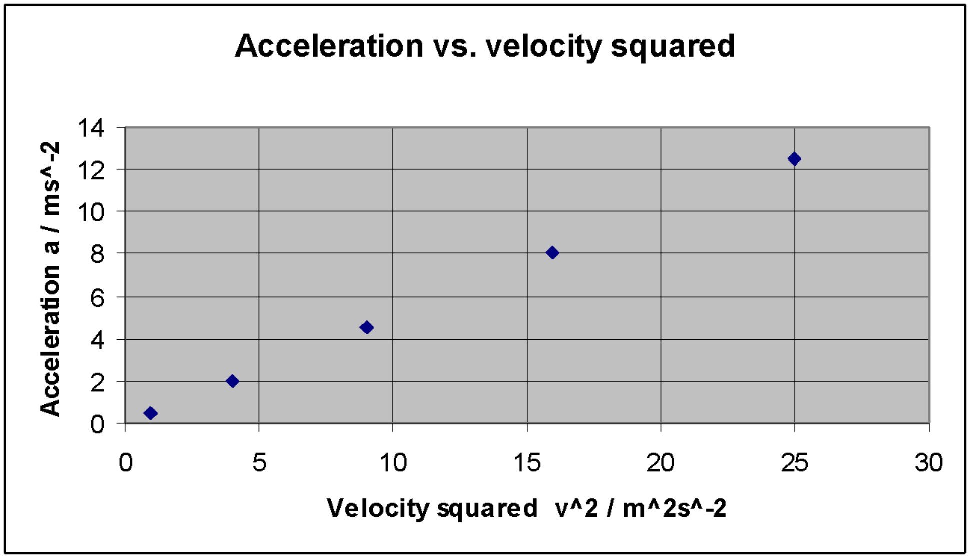


From the shape of the graph, you might hypothesize that there is a squared relationship between a and v, such that the equation for this graph is of the form:

$$a = Cv^2, \text{ where C is some constant}$$

Again, the aim is to find some kind of linear relationship between a and v. We can see that the relationship between a and v themselves is not linear, but in looking at the equation, $a = Cv^2$, you can see that a linear relationship would exist between a and v^2. Let's calculate v^2 in the table below and then plot the resulting data points in the graph below.

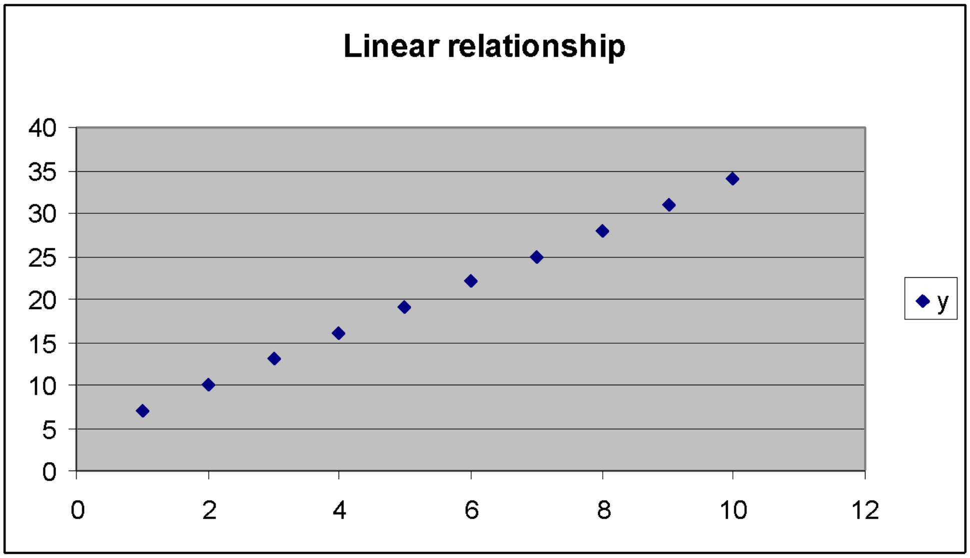
Velocity v / ms-1	**Velocity^2 v^2 / m^2s^{-2}**	**Acceleration a / ms^{-2}**
1		0.5
2		2.0
3		4.5
4		8.0
5		12.5



From the plotted data, it's easy to see that a vs. v^2 appears to yield a linear relationship, such that they could be written in the form y = mx + b
In this case, y is acceleration, x is v^2, the slope of the resulting line of best fit would yield m, the gradient, and the place where the line of best fit would cross the y-axis would be b, the y-intercept.

Thus, you could plot a vs. v^2 to yield a linear relationship, then determine the max and min gradients of this plot to determine the uncertainty in the relationship. The equation of the resulting line yields the relationship that exists between a and v.

The key to completing this is being able to recognize a variety of types of plotted data. Below is a sampling of plotted data graphs, and the type of relationship they likely signify.

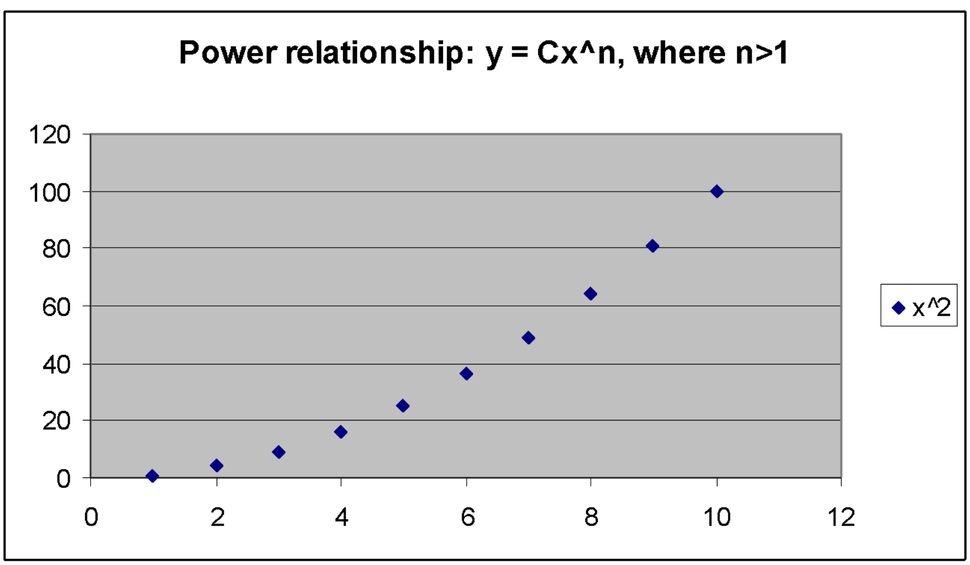


Linear relationship

Equation style: y = mx + b

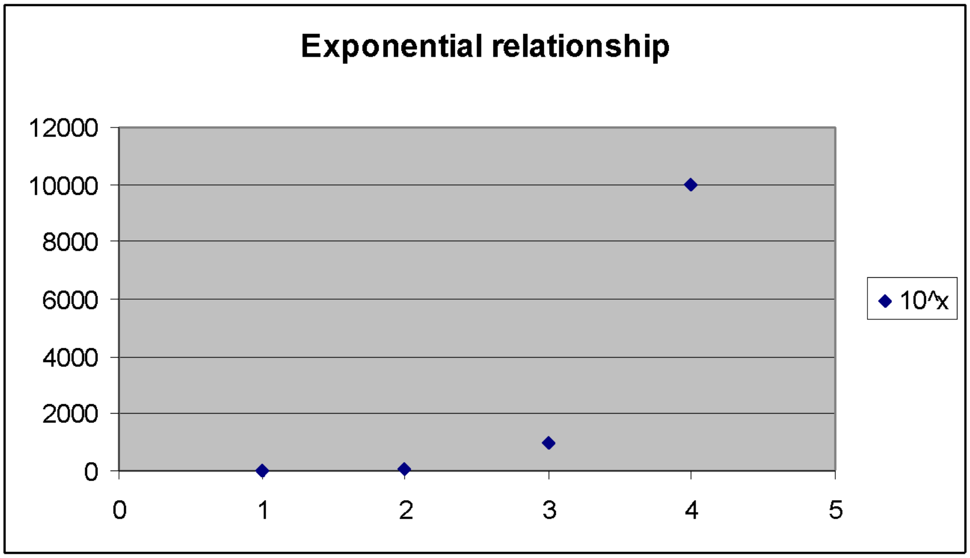
Plotted data of this style is already in the linear form

You can simply draw the line of best fit, calculate the gradient, and calculate and draw in the max/min gradient lines.



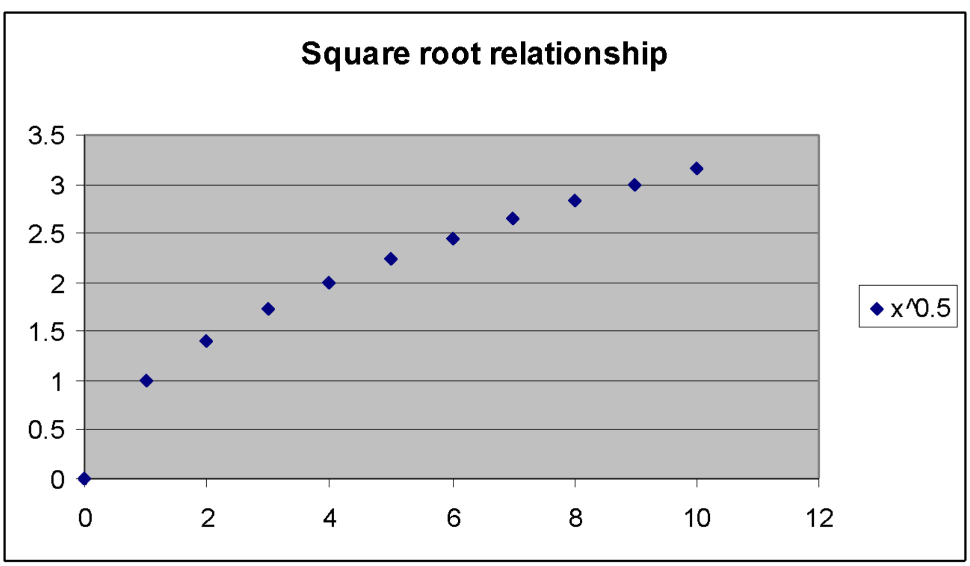
Power relationship

Equation style: $y = Cx^n$, where $n > 0$
Description: When graphs look like this, it usually means that there is what's called a **power** relationship between the variables, meaning that one variable is equal to another variable raised to a power > 1. These include squared, cubed, etc. relationships.



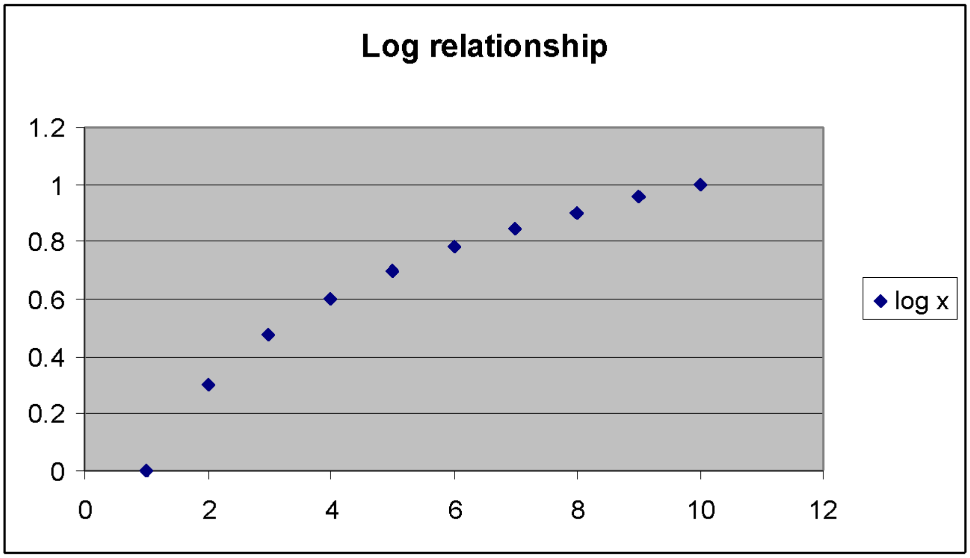
<u>Exponential relationship</u>

Equation style: $y = 10^x$
Description: Exponential relationships have the same general shape of power relationships, but increase at a much greater rate.

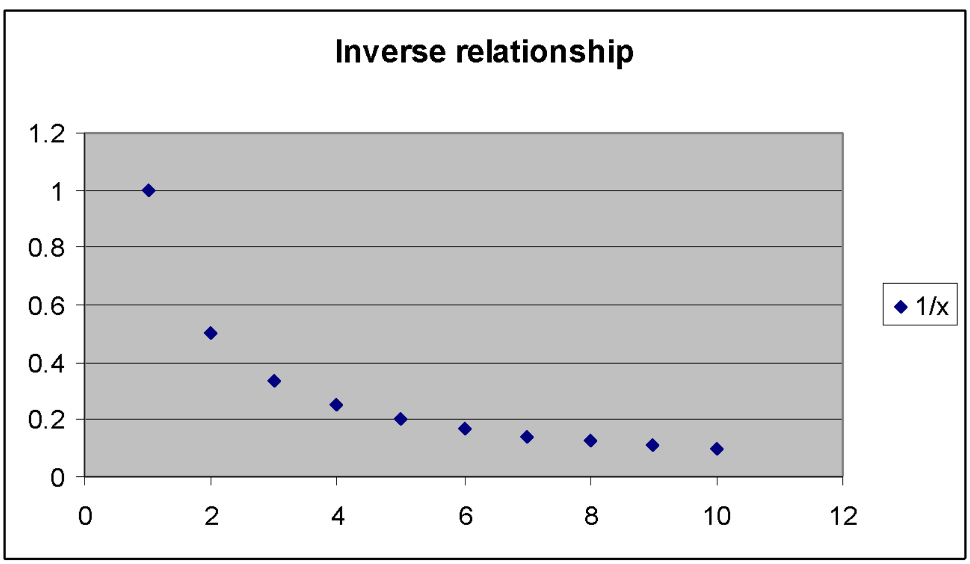


<u>Root (Square root) relationship</u>

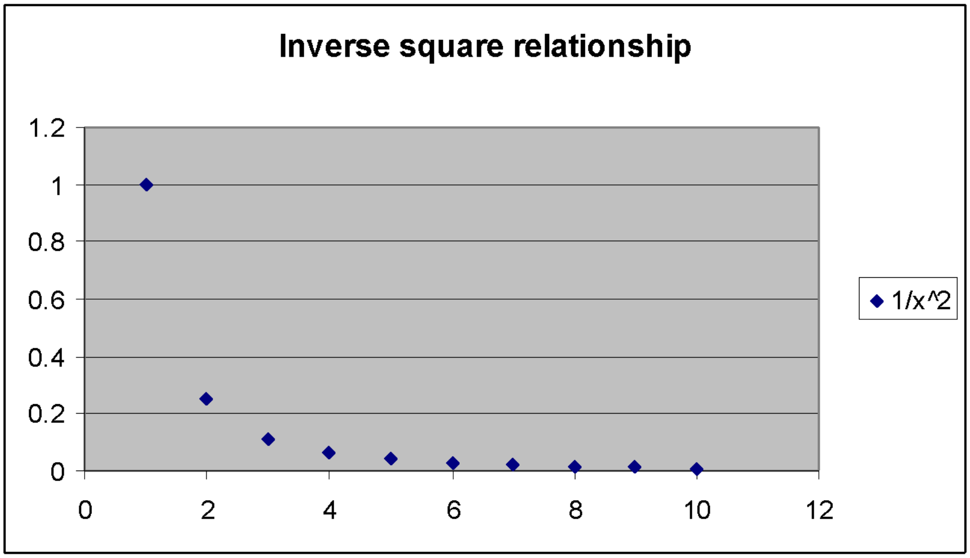
Equation style: $y = Cx^n$, $0 < n < 1$
Description: Graphs that start out steeply and then gradually diminish could be square root graphs. These are similar to power relationships, but for values between 0 and 1



Log relationship
Equation style: $y = \log x$
Description: Looks similar to a square root graph, where slope begins steeply and then becomes gradually less steep



Inverse relationship
Equation style: $y = C/x$
Description: These graphs begin with a steep negative slope, then slope decreases as it approaches x axis.



Inverse squared relationship

Equation style: $y = C/x^2$

Description: Similar in shape to inverse relationship graph, but steeper/more dramatic

Many graphs map back to some form of the equation: $\mathbf{y = Cx^n}$, where

- **C** is a constant value
- **n** is a number
    - If **n > 1**, graph will "turn upwards" (will have increasing positive slope)
        - Ex: $y = 2x^2$
    - If **n = 1**, graph is linear (will have constant positive slope) (e.g. $y = x$)
        - Ex: $y = 2x$
    - If **0 < n < 1**, graph will "turn downwards" (will have decreasing positive slope)
        - Ex: $y = 2x^{1/2}$ ("root" graph)
    - If **n < 0**, graph will be "inverse" (will have sharp negative slope that becomes gentler)
        - Ex: $y = 2x^{-2} = 2/x^2$

Procedure for obtaining linear graph:

- Plot data
- Use the above examples to try to figure out what type of relationship exists between variables.
- Using selected relationship, determine the data for determined relationship (e.g. If it's a squared relationship ($y = x^2$), calculate x^2 values
- Plot the resulting data; (e.g. y vs. x^2); if the resulting plot is linear, you've correctly determined the relationship
- Draw line of best fit; Determine the gradient
- Draw and determine the max and min gradient lines