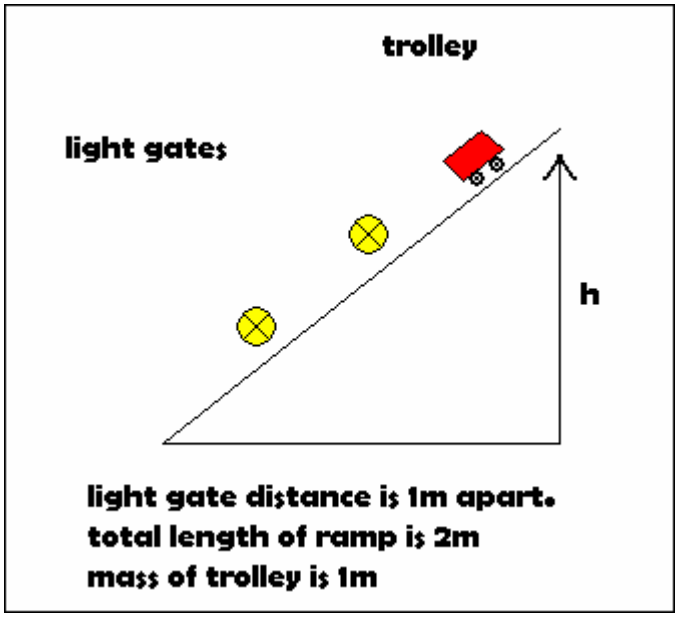
Making sense of data

Trolley project

Data Provided:



Height (m)	Time (s)	
	1	2
0.088	1.89	1.92
0.106	1.48	1.5
0.128	1.28	
0.145	1.14	1.14
0.163	1.02	1.03
0.182	0.953	0.957
0.198	0.883	0.887
0.215	0.833	0.836
0.236	0.793	0.795
0.252	0.753	0.754
0.271	0.721	0.72
0.291	0.695	0.696
0.311	0.666	0.66

The experiment I have chosen to analyze is a test to see how changing the height of a slope will affect the time it takes for a trolley to pass through a set of light gates. I hope to explore the data and consider what other conclusions can be drawn from it. To do this I must first ask the relevant questions, such as:

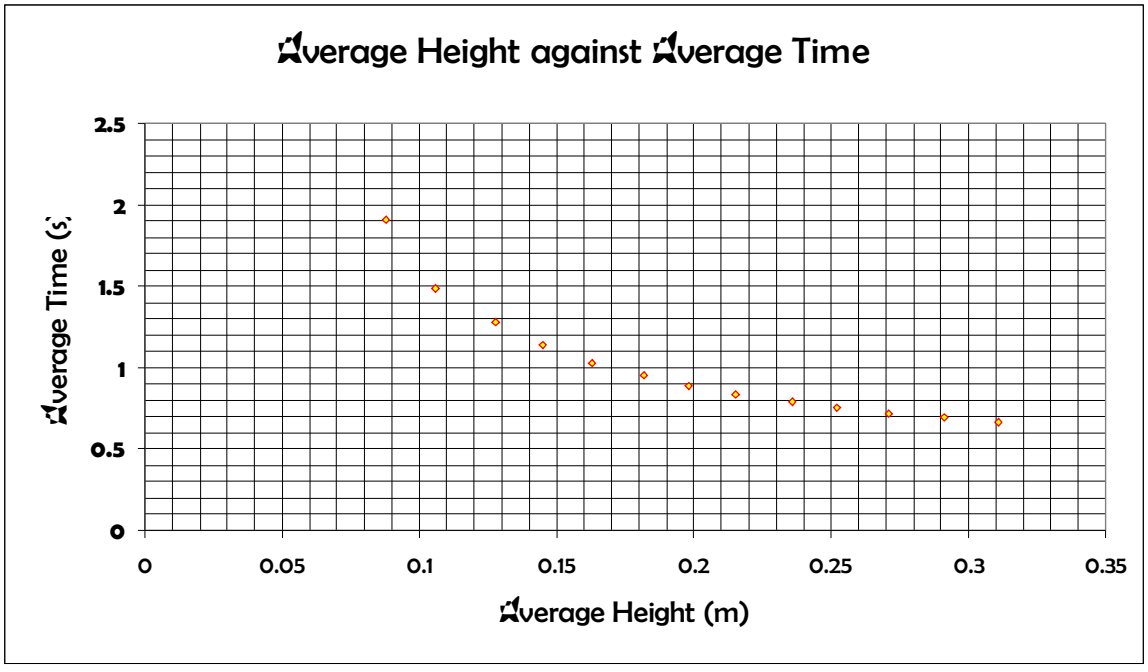
- What is the average time for each height?
- What is the average velocity through the light gates for each height?
- What is the final velocity for each height?
- What is the angle of the slope for each height?
- What is the speed at the first and second light gate?
- What is the acceleration?
- Is the ramp a smooth plane or will friction slow down the trolley, if so what is the coefficient of friction?
- How far up the slope are the light gates?

First of all, from the data I have been given, I know that on the first test the height of the ramp is given as 0.088 metres, and the time the trolley took to travel between the light gates was 1.89 seconds on the first run and 1.92 seconds on the second run.

From this I can then work out the mean time the trolley takes to travel between each light gate,

Height (m)	Time (s)		
	1	2	Average
0.088	1.89	1.92	1.905
0.106	1.48	1.5	1.49
0.128	1.28		1.28
0.145	1.14	1.14	1.14
0.163	1.02	1.03	1.025
0.182	0.953	0.957	0.955
0.198	0.883	0.887	0.885
0.215	0.833	0.836	0.8345
0.236	0.793	0.795	0.794
0.252	0.753	0.754	0.7535
0.271	0.721	0.72	0.7205
0.291	0.695	0.696	0.6955
0.311	0.666	0.66	0.663

I have drawn a graph to show the relationship between height and time



From this graph I can see that as height and time are proportional as when height increases time decreases. However as it is not a straight line graph, it does not tell me much. I will find the logs of height and time and draw and see if this will get me a straight line graph.

From this I can get the equation $t = dh^n$

Using logs I know that: (Where (t)=time, (h)= height and (n) and (a) are unknowns)

$$\log t = \log(dh^n)$$

$$\log t = \ln(h^n) + \log(a)$$

$$\log t = n \log h + \log a$$

I know that the formula of a straight line is $y = mx + c$, so if I substitute the logs we get,

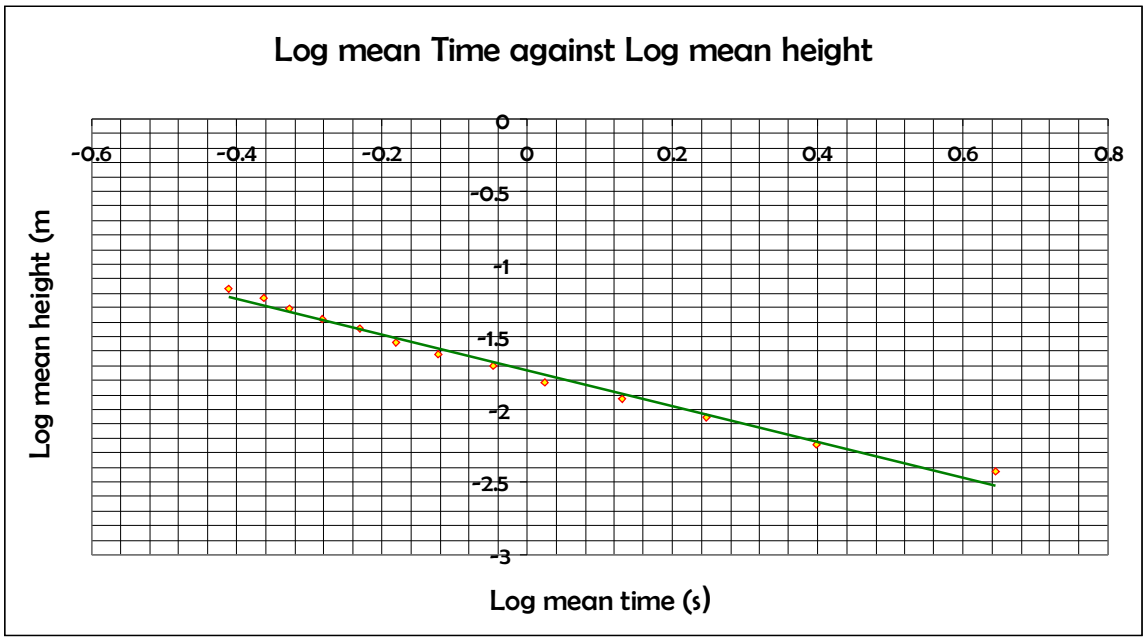
$$\log t = n \log h + \log a$$
$$y = mx + c$$

Where (t)= y axis (n) = gradient, (h) = x axis and (a) + the y intercept.

Before I plot my graph I need to find the logs of the mean heights and times, these are shown in the table below.

log avg time	log Height (m)
0.644482	-2.430418465
0.3987761	-2.244316185
0.2468601	-2.055725015
0.1310283	-1.931021537
0.0246926	-1.814005078
-0.0460439	-1.703748592
-0.1221676	-1.619488248
-0.1809225	-1.537117251
-0.2306718	-1.443923474
-0.2830263	-1.378326191
-0.3278099	-1.305636458
-0.3631243	-1.234432012
-0.4109803	-1.167962367

From these values I can then draw the graph.



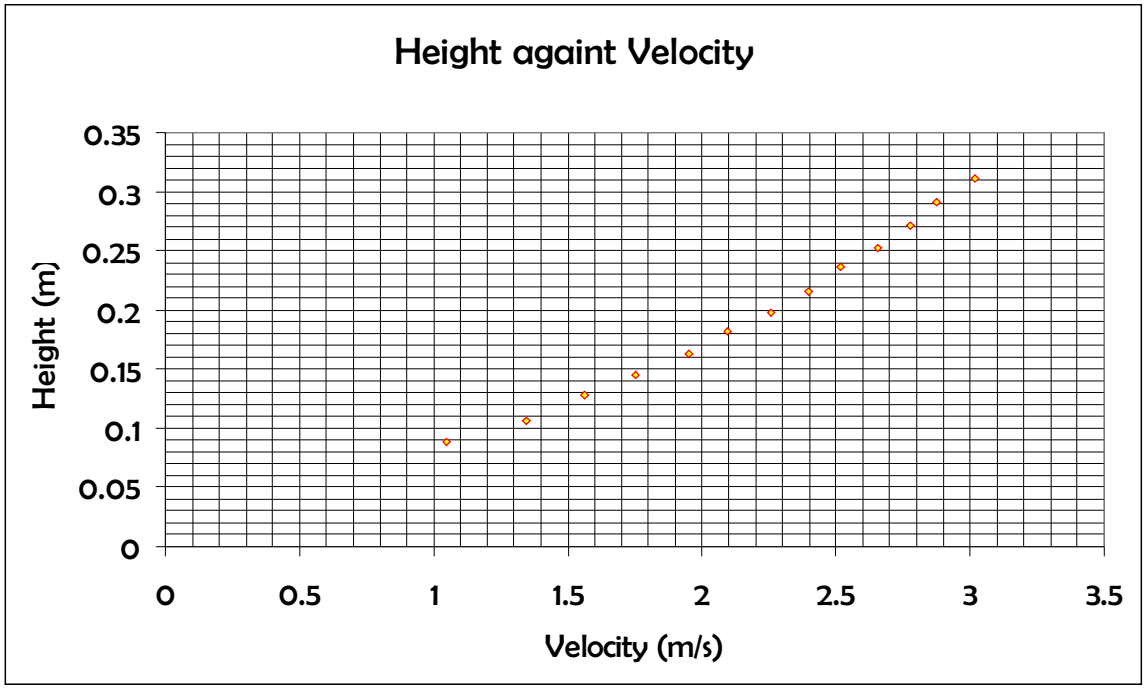
From the formula $\lg\ t = n \lg\ h + \lg\ a$, I can get an average gradient of -1.2304 and a y intercept of -1.7311.

As I have an average for the time it took for the trolley to travel between light gates, it is possible to find the average velocity between the light gates for each height.

I can do this using $s = \frac{d}{t}$ $velocity = \frac{1m}{time}$

Height (m)	Time (s)			Velocity
	1	2	Average	
0.088	1.89	1.92	1.905	1.04987
0.106	1.48	1.5	1.49	1.34228
0.128	1.28		1.28	1.5625
0.145	1.14	1.14	1.14	1.75439
0.163	1.02	1.03	1.025	1.95122
0.182	0.953	0.957	0.955	2.09424
0.198	0.883	0.887	0.885	2.25989
0.215	0.833	0.836	0.8345	2.39664
0.236	0.793	0.795	0.794	2.51889
0.252	0.753	0.754	0.7535	2.65428
0.271	0.721	0.72	0.7205	2.77585
0.291	0.695	0.696	0.6955	2.87563
0.311	0.666	0.66	0.663	3.01659

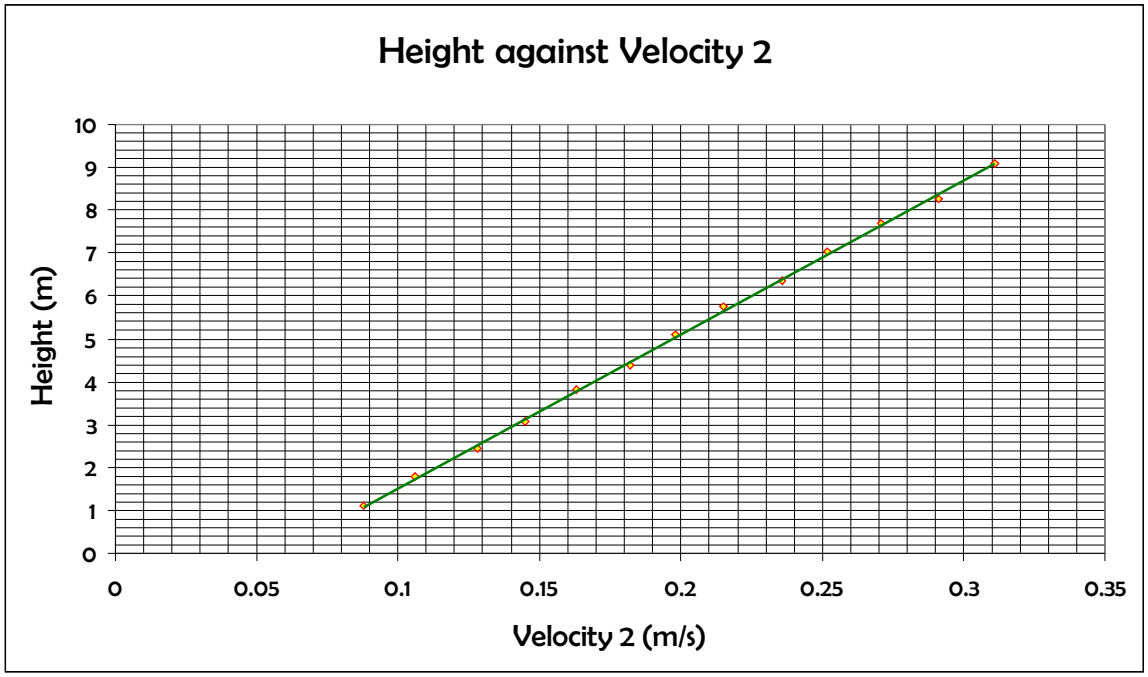
I believe that the differing factor making the speed increase is height. To see if this is correct I have drawn a graph showing the relationship between height and velocity



From the graph I can see that as the height increases, so does the velocity. However I think I will learn more if the graph where a straight line. To do this I will use velocity squared, as shown below:

Velocity	Velocity ^{2}
1.04987	1.102224
1.34228	1.801721
1.5625	2.441406
1.75439	3.07787
1.95122	3.807258
2.09424	4.385845
2.25989	5.107089
2.39664	5.743906
2.51889	6.344815
2.65428	7.045202
2.77585	7.705344
2.87563	8.269242
3.01659	9.099823

I can now draw the graph



From this graph I can see that it now forms a straight line graph. The gradient is 35.88 and the y intercept is 2.0657. This means that the friction involved is negligible and the ramp acts essentially as a smooth plane.

As well as height another factor influencing the velocity between the light gates is the angle of the slope. I can calculate this using trigonometry.

$$\sin\ \theta = \frac{o}{h}$$

$$\sin\ \theta = \frac{0.088}{2}$$

$$\sin\ \theta = 0.044$$

$$\theta = \sin^{-1}(0.044)$$

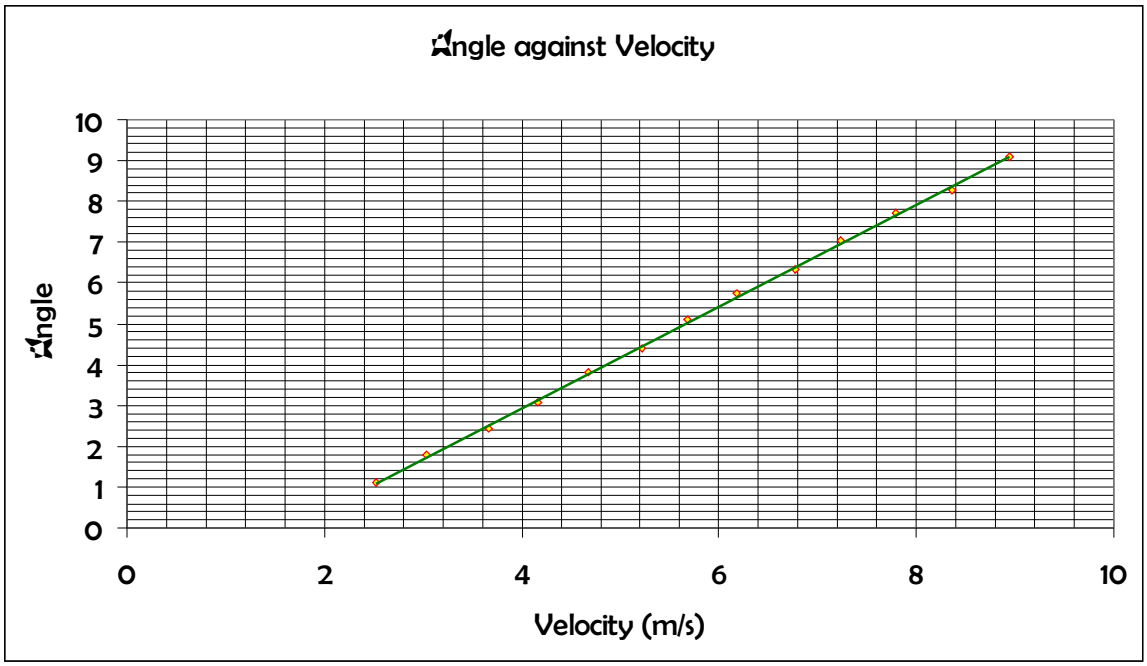
$$\theta = 2.52$$

For all of the other heights,

Height (m)	Angle
0.088	2.521828
0.106	3.0381
0.128	3.669438
0.145	4.157592
0.163	4.674791
0.182	5.221139
0.198	5.681589
0.215	6.171221
0.236	6.776691
0.252	7.238508
0.271	7.787533
0.291	8.366234
0.311	8.945796

Using Excel formula (=ASIN(K3/2)*180/PI())

I can then plot the graph



From the graph I can see that the velocity and the angle are directly proportional. This means that as the angle is greater then the velocity is too.

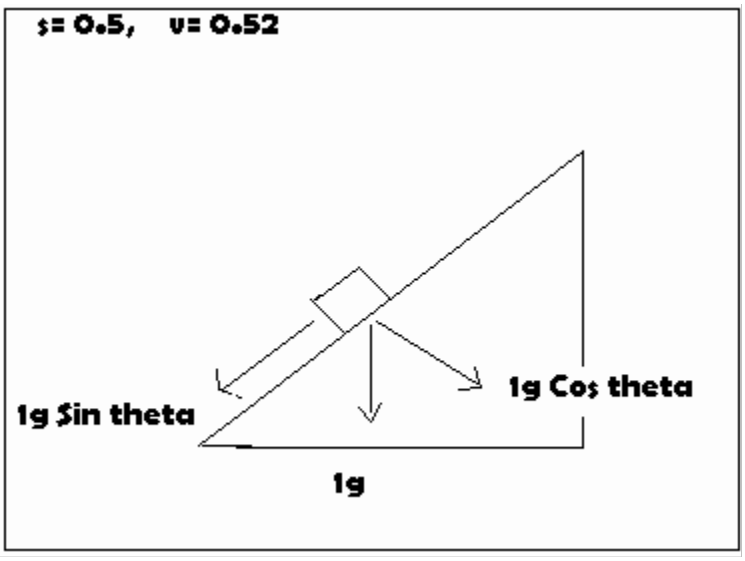
If I resolve the forces involved I can find the acceleration between the light gates as well.

Using height 0.088m

I know the speed is 0.52m/s

I know g(gravity) = 9.8

I know theta = 2.52



$$1g \sin\theta = a$$
$$9.8 \sin(2.52) = 0.43$$

This means that acceleration is 0.43. This is only the theoretical acceleration as it will change but I will take this as a constant throughout the slope.