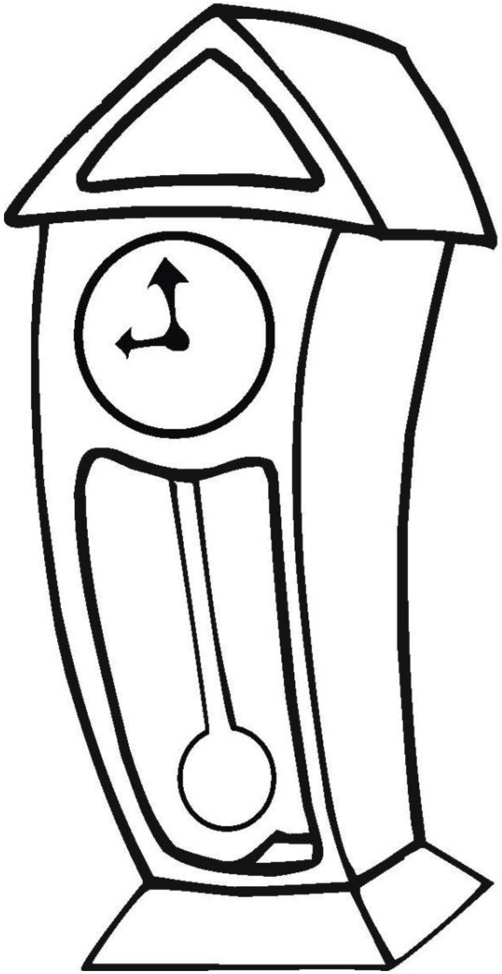


$$T_{pendulum} = 2\pi\sqrt{\frac{L}{g}}$$

Name: ______________________

		A	M	E
• Raw data	teacher initialed raw data sheet		☐	
• variables	identifies the independent variable and dependent variable	☐		
	gathers at least 5 values of length (L) and period (T)*, over a range of at least 0.7 m	☐		
	states control of key variable(s)		☐	
• accuracy improving	states techniques used to improve the accuracy of the measured values		☐	
• initial non-linear graph	plots points on a graph showing the relationship between the independent and the dependent variables, on axes labelled properly with quantities and units, and acceptable curve	☐		
	States the type of relationship that exists between L and T, with correct proportionality of variables	☐		
• raw data transformation	transforms values of L to $L^{1/2}$ or T to T^2, with appropriate significant figures and units*		☐	
• straight line graph	plots a linear graph showing the relationship between the independent and the dependent variables, on axes labelled properly with quantities and units, and acceptable line of best fit through data points		☐	
• gradient of transformed (linear) graph	calculates the gradient of the linear graph		☐	
	gives a conclusion that states the mathematical equation from graph, T = (gradient) $\mathbf{L}^{1/2}$ or T^2 = (gradient) **L**		☐	
	spring constant value calculated or theoretical gradient comparison made		☐	

Your report should include: ☑

- ☐ state your investigation Aim
- ☐ the dependent and independent variables used
- ☐ the techniques you used to improve measurement accuracy
- ☐ a suitably labelled data table which records *all* raw measurements with appropriate units and to an appropriate number of significant figures
- ☐ the non-linear graph you have drawn
- ☐ state clearly the type of mathematical relationship that the non-linear graph suggests exists between the variables **L** and **T**
- ☐ a suitably labelled table which records processed data with appropriate units and significant figures.
- ☐ the straight-line / linear graph you have drawn
- ☐ a conclusion statement that shows the mathematical relationship between **L** and **T**, based on your straight-line graph and calculations showing how you have determined a value for the for gravity, g
- ☐ teacher initialled page containing your raw data used in the lab report

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

Graphing and Data Collection

Consider the experiment to find the relationship between The period and length of a simple pendulum

Independent variable

~ the variable that **you have control over**. eg: The length of a pendulum measured from swing point to center of mass of 50g mass.

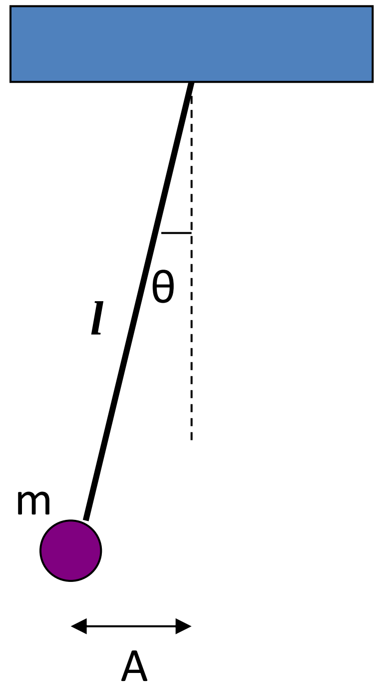
(You can adjust and measure l)

Dependent Variable

~ this is the quantity that is affected by the independent variable.

~ the variable that **you measure**

eg. The period of the pendulum.



Control variables:

apart from length, **ANY other variables that may affect the period (or length) and need to be identified and or tested, and kept constant.**

eg: the mass of the pendulum bob, the amplitude or the size of the semi-vertical angle θ, type of string...

☐ the dependent and independent variables used

Control variables

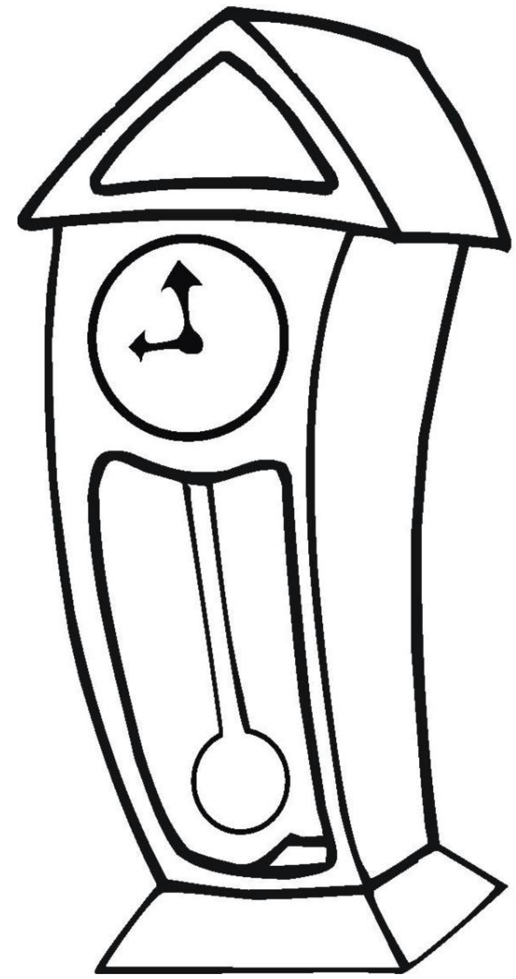
What are control variables?

Things that are not supposed to change when collecting the data to be graphed

eg   50g Mass

eg Angle of swing   (hint look at grandfather clock picture…)

You could **carry out separate trials** to see if the Period times were different for a larger mass or small vs big swings...



☐ the techniques you used to improve measurement accuracy

Make a quick note of any techniques or ideas that would improve data accuracy:

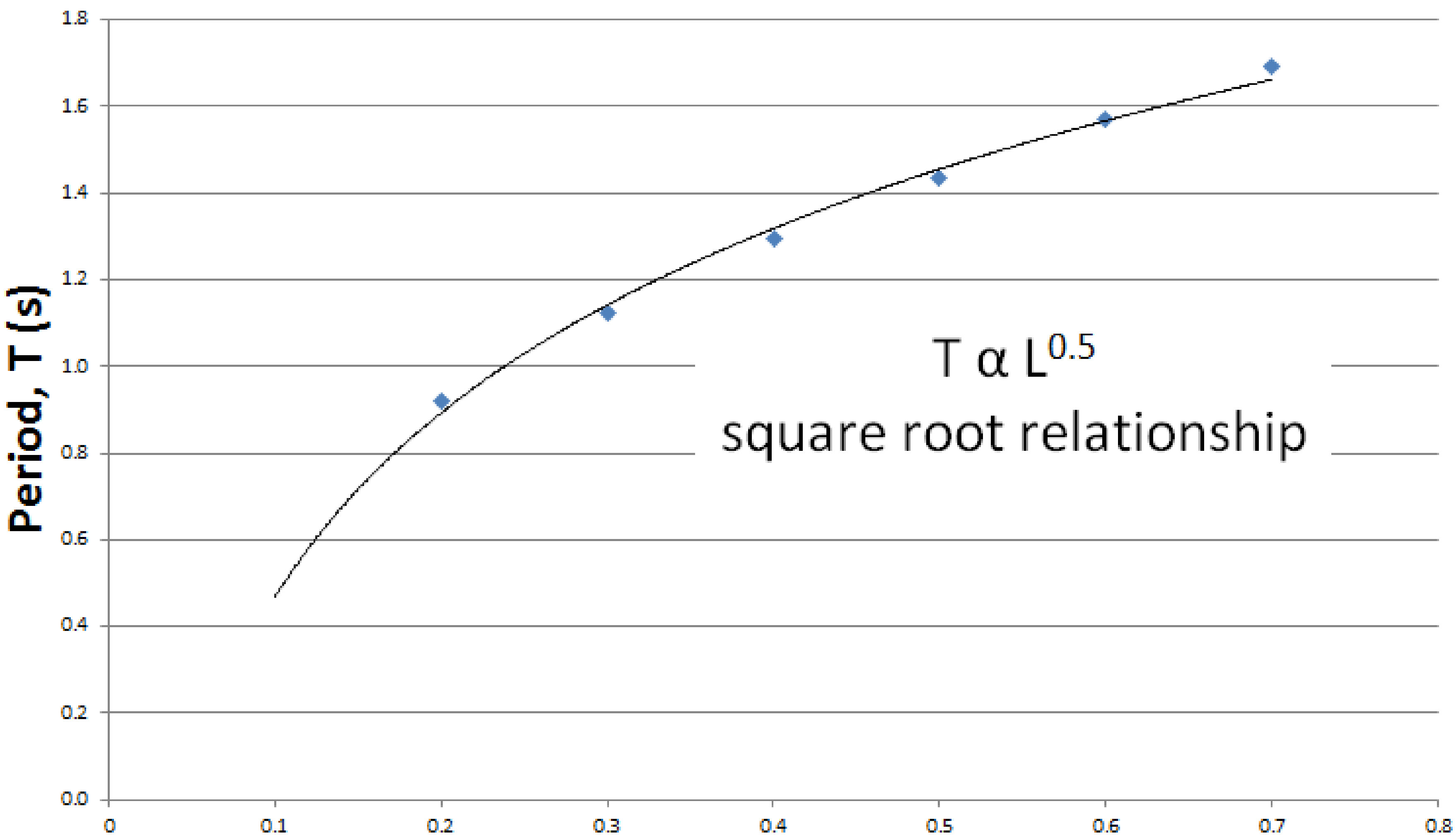
- measure 10 oscillations
- repeat 3 times
- Reduce parallax error by…
- Measure Length of pendulum from center of mass…

WHY you used these techniques – give a more 'detailed' mention in discussion…

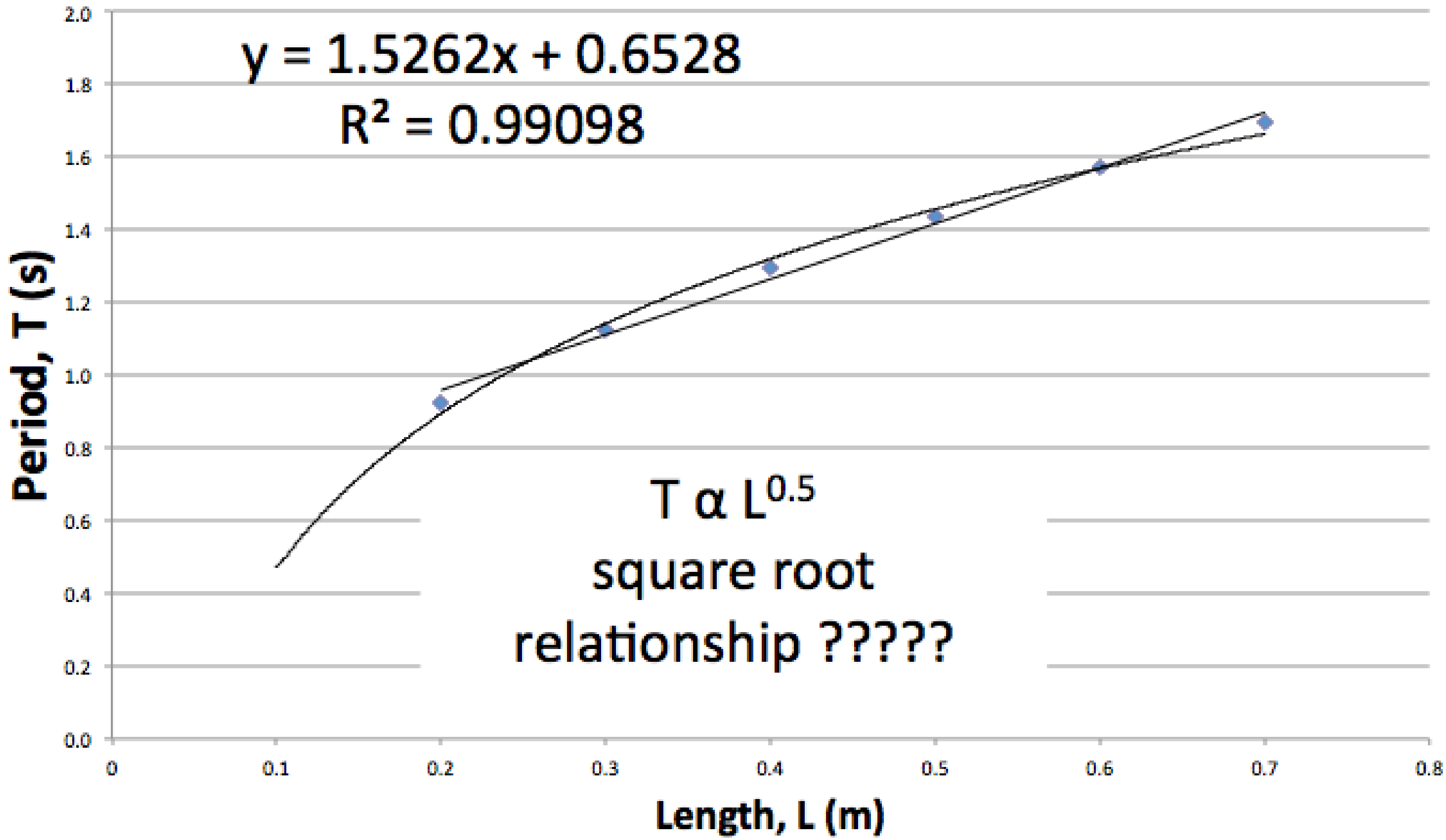
‘Neat’ Raw data

	10T(s)				
L(m)	#1	#2	#3	10T(s)	T(s)
0.7	17.03	16.84	16.94	16.9	1.7
0.6	15.62	15.66	15.78	15.7	1.6
0.5	14.34	14.34	14.43	14.4	1.4
0.4	12.91	12.91	12.97	12.9	1.3
0.3	11.25	11.25	11.25	11.3	1.1
0.2	9.28	9.12	9.21	9.2	0.92

☐ a suitably labelled data table which records *all* raw measurements with appropriate units and to an appropriate number of significant figures



- ☐ the non-linear graph you have drawn
- ☐ state clearly the type of mathematical relationship that the non-linear graph suggests exists between the variables **L** and **T**



y = 1.5262x + 0.6528
R² = 0.99098
T α L^0.5
square root
relationship ?????
Period, T (s)
Length, L (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

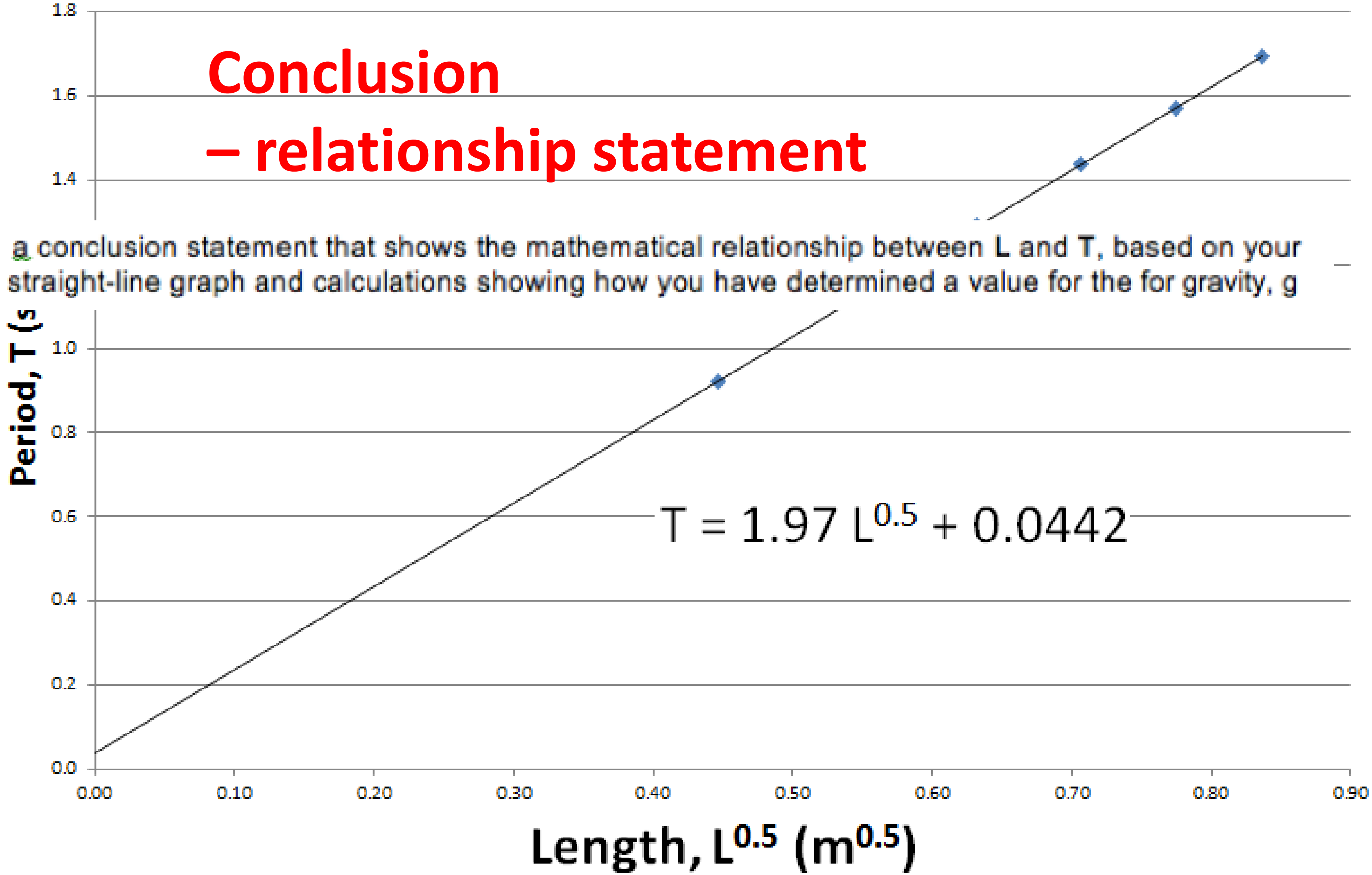
- [ ] a suitably labelled table which records processed data with appropriate units and significant figures.

			10T(s)				
	L(m)	$L^{0.5}$ ($m^{0.5}$)	#1	#2	#3	10T(s)	T(s)
	0.7	0.84	17.03	16.84	16.94	16.9	1.7
	0.6	0.77	15.62	15.66	15.78	15.7	1.6
Option A	0.5	0.71	14.34	14.34	14.43	14.4	1.4
	0.4	0.63	12.91	12.91	12.97	12.9	1.3
	0.3	0.55	11.25	11.25	11.25	11.3	1.1
	0.2	0.45	9.28	9.12	9.21	9.2	0.92
		2sf					2sf

		10T(s)					
	L(m)	#1	#2	#3	10T(s)	T(s)	T^2 (s^2)
	0.7	17.03	16.84	16.94	16.9	1.7	2.9
	0.6	15.62	15.66	15.78	15.7	1.6	2.5
Option B	0.5	14.34	14.34	14.43	14.4	1.4	2.1
	0.4	12.91	12.91	12.97	12.9	1.3	1.7
	0.3	11.25	11.25	11.25	11.3	1.1	1.3
	0.2	9.28	9.12	9.21	9.2	0.92	0.85
							2sf

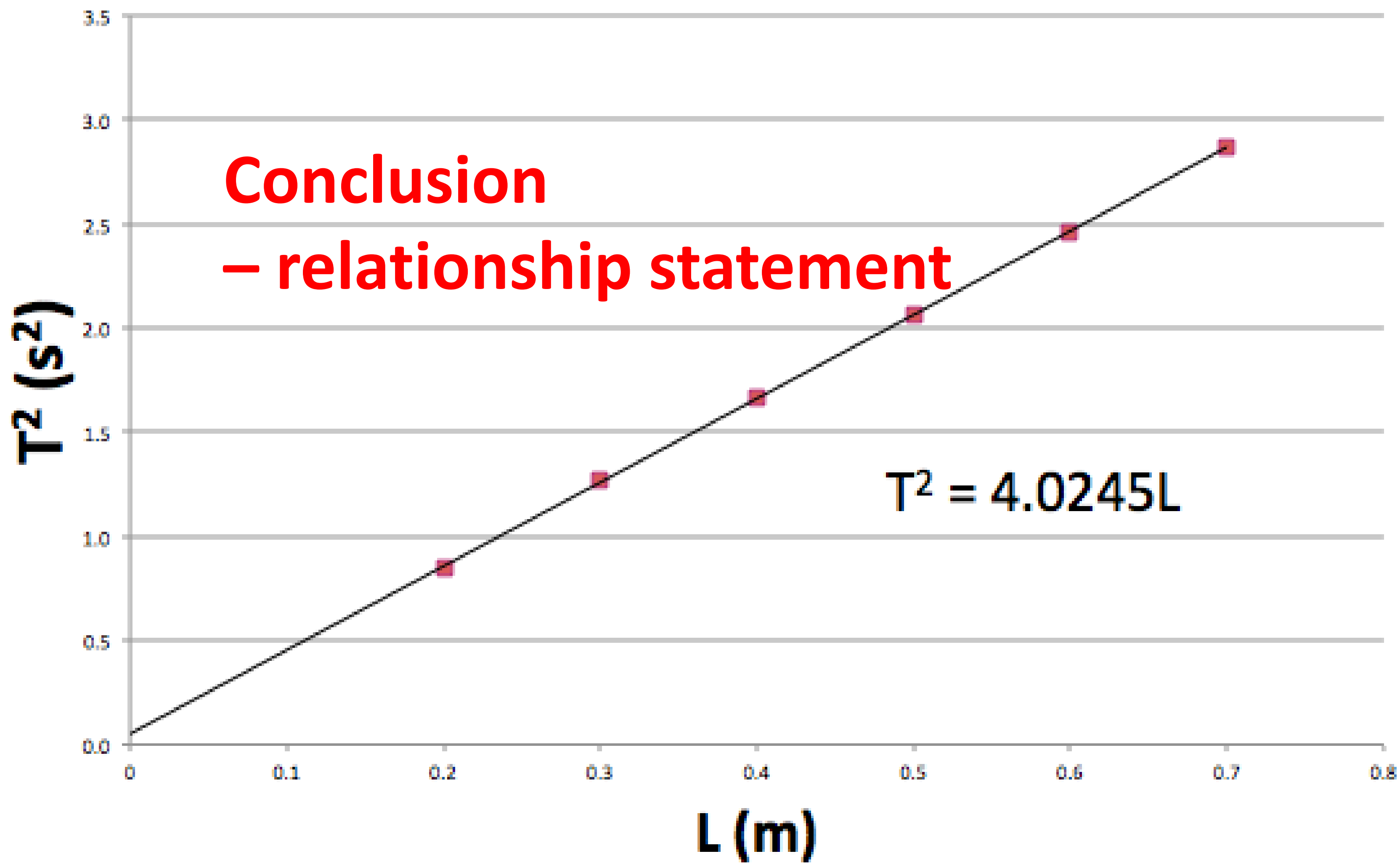
Conclusion – relationship statement

☐ a conclusion statement that shows the mathematical relationship between **L** and **T**, based on your straight-line graph and calculations showing how you have determined a value for the for gravity, g



☐ the straight-line / linear graph you have drawn

Conclusion – relationship statement

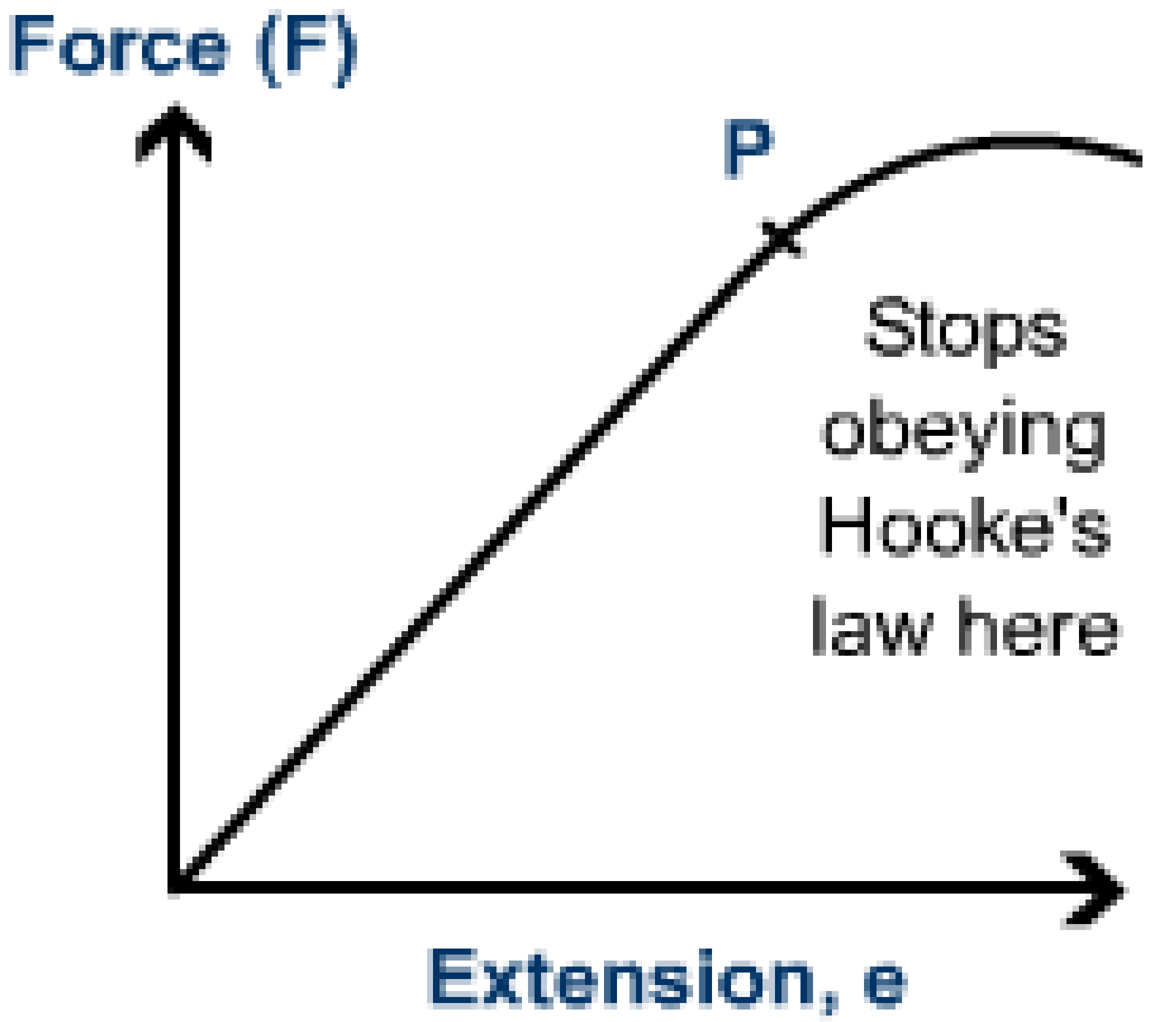


☐ the straight-line / linear graph you have drawn

You must obtain your gravity value from your graph

NOT from averaging values or using a individual point…

Otherwise it raises the question of why bother to graph your data in the first place! The reason – so you can see the trend / relationship over the range of independent data collected.



Force (F)
P
Stops obeying Hooke's law here
Extension, e

Conclusion – relationship statement

- **the type of mathematical relationship that the non-linear graph suggests exists between the variables L and T**

The graph showed a square root relationship

- **a conclusion that states the correct mathematical relationship between L and T based on your straight-line graph**

The relationship between pendulum length L and period T is: $T = 1.97L^{1/2}$ or $T^2 = 4.02L$

• discussion	**E1.** gives a justification for why a variable needs to be controlled	makes **good** statements relating to **Four** discussion points ☐
	E2. gives a description of any difficulties encountered when making measurements and how these difficulties were overcome	
	E3. gives a reason why there is a limit to either end of the value chosen for the independent variable	
	E4. gives a description of any unexpected results and a suggestion of how they could have been caused and/or the effect they had on the validity of the conclusion.	makes **reasonable** statements relating to **Five** discussion points ☐
	E5. states the relationship between the findings and physics theory	
	E6. links back the theoretical relationship to the original context	

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

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- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

E1

Control variables:

- Testing that Mass is independent of Periods

$$T_{pendulum} = 2\pi\sqrt{\frac{L}{g}}$$

- Angle of swing is semi independent ideally if θ <20° then slight error
- Larger angle does not mean longer period!

  Larger angle just means more acceleration / faster speeds – Y13 Mechanics

  Note Grandfather clock picture – restricted small angle ✓✓

- Ideally to a 'side' test, document it and then discuss it ✓✓

- What about Friction? – pendulum eventually will come to a stop due to energy loss due to friction ~ as for angle no effect on Period

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

E2

the period is relatively short (more so L < 0.3m) that the reaction time when starting and stopping the stopwatch is significantly large in comparison. So measuring 10 oscillations ensures this reaction time error is spread and reduced.

Repeat measurements ~ at least three, allow review of data spread to suggest if 10 oscillations have been correctly counted or not.

Human reaction times can be slower than 1/10th of a second and therefore repeat and average time measurements to reduce random errors

The clamp stand may have wobbled and needed to be clamped to the bench – would this have made the pendulum motion consistent or meant it swayed had to move further – suggesting a larger Period

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

E3

justify their choice of shortest length (as a shorter one makes the time too short to be measured accurately by a stopwatch)

justify their choice of the longest length (for example, because of a limit to the string provided or the height of the clamp stand)

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

E4

- A non zero y axis intercept – theoretically should be zero
  - Can you give a reason why?

- Selected data points not fitting the graphs LBFs
  - Can you give a reason why ?
    - Say it wobbled more with L< 0.2 m resulting in …

- If your experiment value is too low eg g = 6.5 ms^{-2} (therefore unexpected!)
  - Can you give a reason why eg
    - If g is low then m, gradient is too large, due to T values for large L values being to high or systematic errors in measured L values

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

E5

- Relates their experimental g value to $9.8ms^{-2}$
- Relates experimental gradient to theoretical gradient of 4.02

$$T_{pendulum} = \frac{2p}{\sqrt{g}}\sqrt{L}$$

Could use % difference

Eg $g_{exp} = 10.6$

% = (10.6 – 9.81) / 9.81 x 100

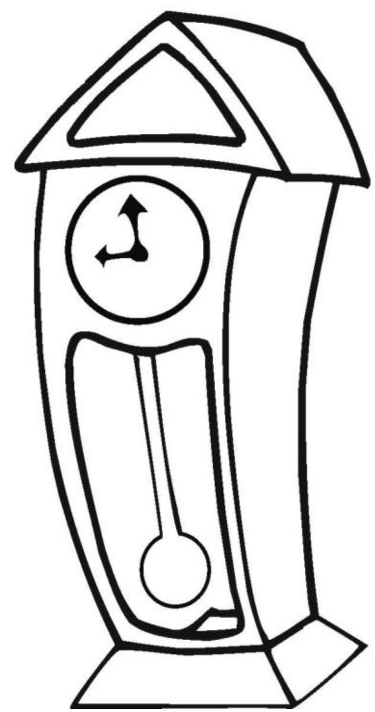
= 8% difference

A discussion that validates your conclusion, you should address such critical issues as:

- ☐ variables that required controlling (explain why they needed controlling and how you controlled them)
- ☐ difficulties encountered when making measurements (explain how you overcame these difficulties)
- ☐ why there was a limit to the range of values you chose for the independent variable
- ☐ any unexpected results (suggest what might have caused these and what effect if any they may have had on the validity of the conclusion)
- ☐ compare your investigation findings with physics theory
- ☐ compares the theoretical relationship to the original context

E6

- Relate your findings back to the Grandfather Clock
  - Ie suggest why it is long and narrow… Length should be 1 m long for T=2s
  - Could mention how energy is added to the motion so that it is continuous…



KHS 2015 Grandfather Clock lab:

- Period not time being measured
- Do you get what is required by the conclusion statement? Ie $T = 1.85\ L^{0.5}$
- Look for clues on the front page picture
- Please print out your own report and handed in Signed Info sheet & initialed raw data sheet

Good points

- How the string was attached (knot loose) to the support structure was important to keep controlled as … could alter the friction acting as the string rotated
- Limit on how long… pendulum would collide with the floor… made a limit of 300mm to reduce the chance of human reaction error…
- …and this showed in my lowest data point which was far off the normal pattern of the LBF…
- … this to be because of the difficulties with measuring the period when the pendulum length is a very short length

KHS 2011 Pendulum lab: Good points

- … the way I drew my graph… my transformation was to square root the independent length variable… this caused my variable axis to be compacted together… implying my LBF was determined from a small range of values… it was not possible to record a smaller value less then 15 cm…
- My $L^{-0.5}$ values were between 0.4 & 0.8… any values below 0.4 is only a prediction
- I also noticed … the bob swayed as it was doing its cycle… this would have affected the period by slowing it…
- Repeated trials three times… I analysed my raw data and if the spread (range) was more then 0.5 s…
- My experimental value of… was slightly lower than then the theoretical value of gravity… this meant the gradient of the graph was slightly too high… for this to occur… the timings for each length must have been to long…

KHS 2015 Grandfather Clock lab: WHAT???   :O)

Discussion

Control variables

Certain variables throughout the investigation required controlling in order to remain constant and “controlled” and to aid in the process of gaining accurate data. One variable that required controlling was the voltage used in the power source which affected the frequency of the ticker timer. As a group, we ensure the voltage remained constantly at six volts (6V) during the time period of all tests taken.

A second variable was the length of data taken, all strips were measured and cut to 1meter long to ensure it had enough room to acquire a valid amount of data before hitting the floor and causing smudged dots that would in turn affect the overall outcome of this investigation.

However these problems must have not affected my experiment in any big way due to the almost perfect value for gravity in terms of physics theory, which is very interesting considering such experiments do not usually yield such accurate results, especially from high school students.

Not good points

All this … would give me better results …

If I would to do this experiment again I would be more precise with my measurements …

I would try to minimise variables which would affect the …

An unforeseen variable affected the results

The limitation in my experiment was the length of string being only one meter.

In my experiment I encountered problems while doing it.

There was no way I could…

I used weird measurements like 0.67m …

The error made my calculations difficult.

I would make sure measuring and releasing angle were more accurate to ensure I get a better result.

Discussion:-

Physics theory states that gravitational acceleration is $9.8\ ms^{-2}$, the findings of my investigation was that gravitational acceleration is $6.8\ ms^{-2}$. This means that ~~my~~ my investigation was not very accurate. I think that my data would have not been accurate because it was hard to

A mathematical comparison is given between the theoretical and experimental results. The student also gives explanations for the difference in the 'g' values. The explanation is weak as there is no reason to expect the time period would be more than it should be. The student has not explained why time periods that were too long would result in a 'g' value that is too small. The student makes a reasonable attempt to explain why taking a multiple measurement increases accuracy.

If I hadn't done this the data would have been even more inaccurate because the time for the period would be larger than it actually is because ~~of~~ the human reaction in timing the period would not have been reduced. Another reason why my findings ~~are~~ were inaccurate is because the clamp stand was

Accuracy improving techniques of repeating and averaging and multiples has been used.

Repeating and averaging improved the accuracy of my investigation by reducing the ~~error~~ error in outliers in the results.

controlled variables:

- By having the same person timing each of the swings, it ensured that the human reaction time was kept constant through each of the tests. This meant that the average period was more accurate because if a different person timed the swings each time, some of the times would have been a lot longer or shorter than others, this is because of their different reaction times, this therefore would have affected the average period and also then the g calculation of gravitational acceleration.

The student has collected data relevant to the aim and has provided a detailed description of why the control of the person timing the pendulum swing is important and how this was controlled. The difference in the reaction times of different timer would be catered for by the use of repeating and averaging.

A difficulty encountered while making measurements was that the wire that connected the weight to the string added about 2 cm to the length of string. This would have affected the results because it meant that the lengths of string ~~w~~ used to calculate the ~~gravitational acceleration~~ period was all shorter than they should have been, thus making the average period larger than it actually is, this then made the gradient larger than it should be. This then made the gravitational acceleration smaller than it should be. I could have improved my results by adding 2cm to each of the lengths of string. ~~and then~~

The student has described the difficulty of measuring the length of the string. They have correctly explained how this problem would have affected the gradient and hence the value for 'g.'

To achieve the standard more securely at Excellence the student could include the following:

- a reason why there is a limit to either end of the value chosen for the independent variable
- a correct justification for why a variable needs to be controlled.