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IB Physics SL
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PHYSICS LABORATORY: The Simple Pendulum

The purpose of this lab was to experimentally determine a value for g, the acceleration due to Earth's gravitational field, by using the given 'pendulum equation', experimental data for the period of a pendulum, and the length of a pendulum string.

HYPOTHESIS: I expect our value of 'g' to be close to 10.0 ms^{-2}, which around the accepted value near the surface of the Earth. Any deviation from this 'normal' and accepted value will likely be obscured by errors and uncertainties in the laboratory procedures.

DATA COLLECTION AND PROCESSING (DCP)

Data collected on 12 November 2013 with Scarlett Gemmer. The mass on the pendulum was 200 g. Standard instrument uncertainty was assumed for the stopwatch timing and the length. The length of the string was measured from the metal rod to the top of the hook on the mass.

Table 1: RAW DATA

String Length (± 0.001 m)	10T TRIAL 1 (±0.60 s)	10T TRIAL 2 (±0.60 s)	10T TRIAL 3 (±0.60 s)
0.600	15.54	15.56	15.28
0.486	14.09	14.10	14.03
0.435	13.31	13.22	13.34
0.371	12.25	12.66	12.62
0.273	10.66	10.81	10.75
0.198	9.09	9.03	9.25
0.106	6.69	6.47	6.63

Table 2: PROCESSED DATA

10T Ave (s)	Unc in 10T (s)	T Ave (s)	Unc in T (s)	T^2 (s^2)	Unc in T^2 (s^2)
15.46	0.14	1.55	0.02	2.39	0.07
14.07	0.04	1.41	0.01	1.98	0.02
13.29	0.06	1.33	0.01	1.77	0.02
12.51	0.21	1.25	0.03	1.57	0.05
10.74	0.08	1.07	0.01	1.15	0.02
9.12	0.11	0.91	0.02	0.83	0.05
6.60	0.11	0.66	0.02	0.44	0.07

We decided to measure the time taken for 10 full swings of the pendulum for each length.

SAMPLE CALCULATIONS (using first data point):

Average 10T: $\frac{15.54\ s + 15.56\ s + 15.28\ s}{3} = 15.46\ s$

Uncertainty in 10T: $\frac{MAX\ VALUE - MIN\ VALUE}{2} = \frac{15.56\ s - 15.28\ s}{2} = 0.14\ s$

To get the average period and uncertainty, I divided each average and uncertainty for 10T by 10.

Uncertainty in T^2:

$$percent\ uncertainty\ in\ T = \frac{0.02}{1.55} = 0.0129$$

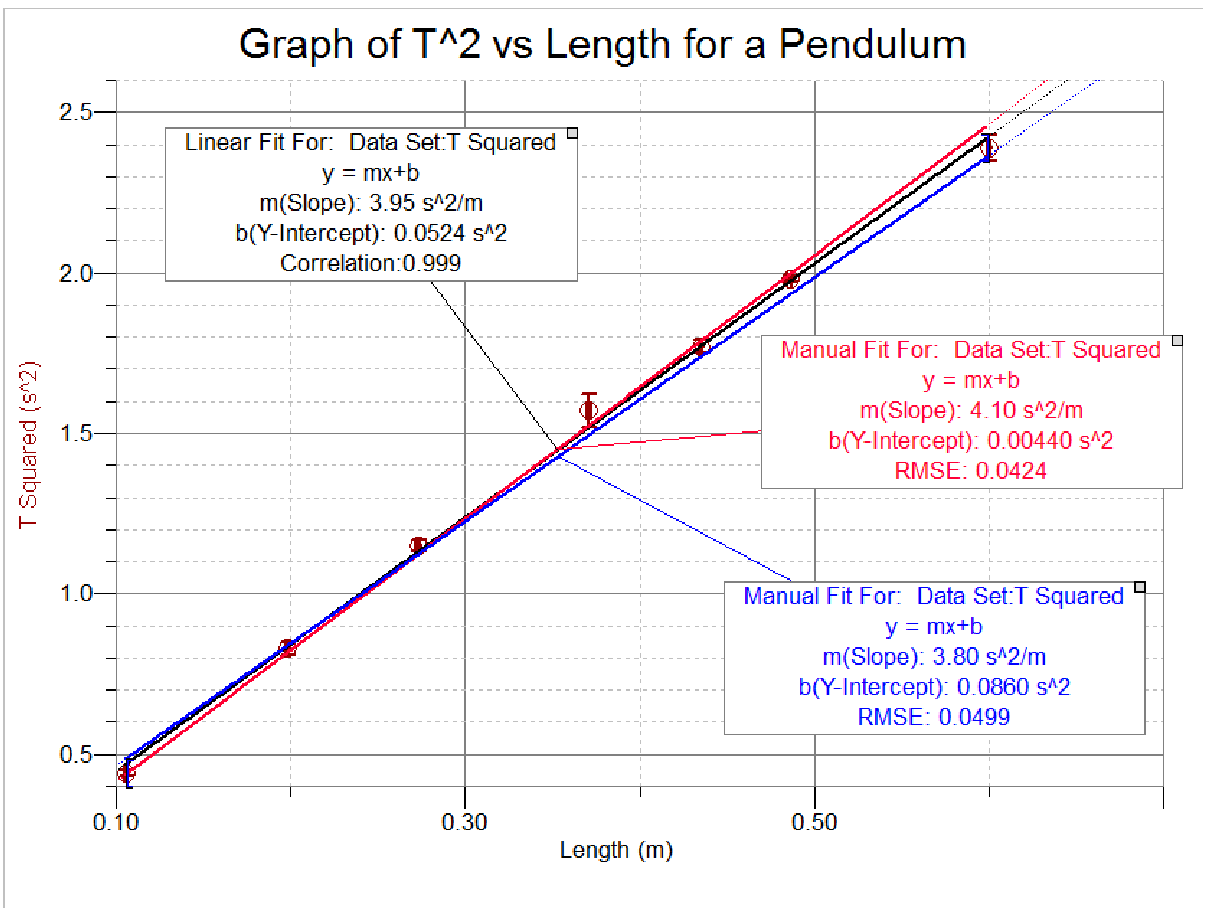
$$percent\ uncertainty\ in\ T^2 = 2 \times 0.0129 = 0.0258$$

$$absolute\ \ uncertainty\ in\ T^2 = 0.0258 \times (1.55^2) = 0.0619\ s = 0.07\ s$$

The simple pendulum equation was given to us as $T = 2\pi\sqrt{\frac{l}{g}}$

which means if we graph T against l, we should get a square root function. In order to determine a value for g, however, we had to graph T^2 against l, then consider the gradient of the linear function.

These calculations were done in an Excel spreadsheet, which rounded the values to 2 decimal places. When it performed the calculations, therefore, more decimal places were used.



This graph is of the form $y = (gradient)(x) + b$

which, from the pendulum equation, is equivalent to: $T^2 = \left(\frac{4\pi^2}{g}\right) l$

Hence, the gradient of this graph should be $gradient = \left(\frac{4\pi^2}{g}\right)$. Rearranging gives: $g = \left(\frac{4\pi^2}{gradient}\right)$

From the graph, with uncertainty given by (max slope – min slope)/2 :

$$\text{gradeient} = 3.95 \pm 0.15 \;\; s^2m^{-1} = 3.95 \pm 3.80\% \;\; s^2m^{-1}$$

The final experimental value for g therefore is: $\mathbf{g = 9.99 \pm 0.40 \;\; m\, s^{-2}}$

CONCLUSION AND EVALUATION (CE)

This goal of this experiment was to determine an experimental value for g using the simple pendulum equation and measuring the period against varying lengths of string. The mass at the end of the string was held constant at 200 g.

From the graph of T^2 against l, the final experimental value of g was found to be **9.99 ± 0.40 ms^{-2}** . This agrees well with the given (theoretical) value of at the Earth's surface of 9.81 ms^{-2}.

In fact, the percent error is $\left|\frac{theoretical\ value - experimental\ value}{theoretical\ value}\right| \times 100 = \left|\frac{9.81 - 9.99}{9.99}\right| \times 100 =$ 1.8%.

The graph of T^2 against l is linear, which suggests that that period is proportional the square root of the length ($T \propto (l)^{.5}$). This verifies the pendulum equation.

There were no notable irregularities in the data and I believe the method was both reliable and valid. However, there were limitations in the method. The following are the main limitations and possible ways to address these limitations if I were to repeat the experiment:

Limitation	How to address it
The pendulum did not have a consistent initial displacement (angle from the vertical from which is was let go was not constant).	Use a draftsman's triangle to precisely maintain a 20 or 30° angle each time, or set up some set object against which to measure this initial position for each trial.
During the 10 periods I measured, the pendulum likely lost amplitude due to friction between mass-air and the string-rod above.	Measure the time for 5 swings instead, and/or put lubricant between the string above and the metal rod; or use a thin but strong string like fishing line.
It was very difficult (especially with short string lengths) to measure even 10 swings accurately, because it was hard to tell when the mass reached the 'edge' of its swing.	Use Vernier Photogates, which would allow us to measure one swing very accurately.

It may be that these limitations did not affect the period of the pendulum anyway; nevertheless, they are important to mention here.

Other related and interesting experiments:

1. Repeat this one with the pendulum mass under water, and investigate whether the variables of length and period are related as they are here. Variables: length and period.

2. Keep the string length constant but change the mass and see how the period would be affected. Variables: mass and period.