The period and length of a pendulum

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Aim:

This experiment aims to determine the acceleration due to gravity by investigating the relationship between the period squared and length of a pendulum.

Apparatus:

- Stand
- Ruler
- Thread
- Stopwatch
- Bob

Introduction and Theory:

In this experiment, the dependence of a simple pendulum's period, T, on its length, L, is conformed and exploited to indirectly determine the acceleration due to gravity, g. The simple pendulum consists of a light string fixed at one end with a massive bob attached to the other end. Note that the period depends on the length of pendulum but not on the bob's mass.

Giovanni Battista Riccioli is credited with performing the first accurate experiment on the acceleration due to gravity in 1651. His interest was to investigate the claims of Galileo and not to determine the acceleration due to gravity, however. He used meticulously calibrated pendulums to time the free fall of bodies from deferent heights.

As this experiment shows, g can be determined without using free falling bodies but just using the pendulum itself. The experiment calls for the measurement of 20 cycles of the pendulum with a certain length, L. By measuring the time for 20 cycles, one reduces the uncertainty. If the length is changed and the procedure repeated, the data can be used to plot the period squared, T^2

versus length, L.

$$T^2 = \frac{4\pi^2}{g} L \qquad (1)$$

This is the equation of the straight line with the term in brackets as a slope. Therefore, from the slope of the graph of $T^2\ vs\ L$ one can determine the value of g.

Method:

We suspended the pendulum bob from the stand using a thread. We adjust the length of the pendulum to equal 1.0 m.

We displaced the bob through an angle and released it to oscillate 20 times. We determined the time for 20 oscillations, this was done three times to get three different time values.

We repeated this for the length of a string of 0.90m, 0.80m, 0.70m, 0.60m, 0.50m, and 0.40m.

We calculated the average time for each length of pendulum and divide it by 20 to get the period.

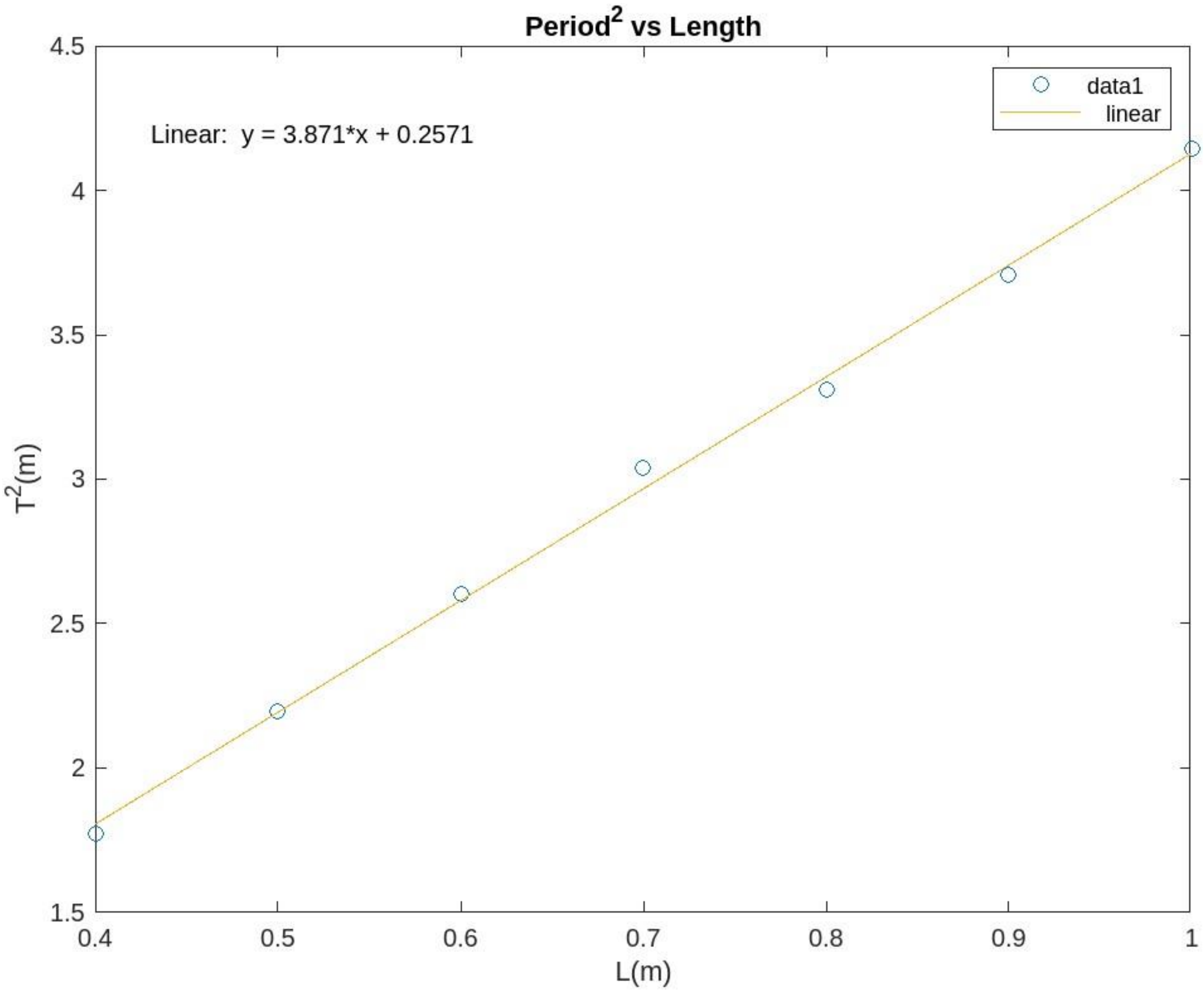
We squared the period and recorded the values in a table.

Results:

$L(m)$	$t_1(s)$	$t_2(s)$	$t_3(s)$	$t_{avg}(s)$	$T = \frac{t_{avg}}{20}(s)$	$T^2(s)$
1,0	40,580	40,650	40,920	40,720	2,036	4,145
0,9	38,340	38,580	38,550	38,490	1,925	3,706
0,8	36,480	36,260	36,400	36,380	1.819	3,309
0,7	34,820	34,860	34,880	34,850	1,743	3,038
0,6	32,210	32,260	32,310	32,260	1,613	2,602
0,5	29,800	29,690	29,440	29,640	1,482	2,196
0,4	26,690	26,620	26,590	26,630	1,332	1,774

Analysis:

Below is the graph of period square versus length, using MATLAB.



From the graph we get a slope value of: 3.871

We can use the value of the slope to calculate the value of g, using equation (1):

$$T^2 = \frac{4\pi^2}{g} L$$

From this equation the slope is equal to $\frac{4\pi^2}{g}$ therefor we can calculate g using the slope of the graph (3.871):

$$3.871 = \frac{4\pi^2}{g}$$

$$g = \frac{4\pi^2}{3.871}$$

$$g = 10.20\ m.s^{-2}$$

Comparing the theoretical g value of 9.81 $m.s^{-2}$ with the actual g value of the experiment, we can calculate the %error of the experiment in the following:

$$\%error = \frac{(actual)g - (theoretical)g}{(actual)g} * 100$$

$$\%error = \frac{10.20 - 9.81}{9.81} * 100$$

$$\%error = 3.98\%$$

Conclusion:

Judging from the graph and the low percentage error we can conclude that the data is nicely or accurately described by the equation; $T^2 = \frac{4\pi^2}{g} L$. However, there are some discrepancies which are the result of human error during the experiment these include not having measured the accurate length of the pendulum and not having accurately followed the procedure.

The value of the gravitational acceleration using the graph is:

10.20 $m.s^{-2}$

Whilst the value of the theoretical spring constant is:9.81 $m.s^{-2}$

Reference:

- courses.lumenlearning.com. (n.d.). *The Simple Pendulum | Physics*. [online] Available at: https://courses.lumenlearning.com/suny-physics/chapter/16-4-the-simple-pendulum/#:~:text=Section%20Summary.
- Russell, D. (2018). *Oscillation of a Simple Pendulum*. [online] Psu.edu. Available at: https://www.acs.psu.edu/drussell/Demos/Pendulum/Pendulum.html.
- Omnicalculator (2019). *Simple Pendulum Calculator - Omni*. [online] Omnicalculator.com. Available at: https://www.omnicalculator.com/physics/simple-pendulum.

MATLAB program:

```
l = [0.400 0.500 0.600 0.700 0.800 0.900 1.000 ]; % height (m)
t = [1.774 2.196 2.602 3.038 3.309 3.706 4.145]; % Time (s)

n = length(l);
suml =0.0;
sumt =0.0;
sumlt =0.0;
sumll =0.0;

for i = 1:n
    suml = suml + l(i);
    sumt = sumt + t(i);
    sumlt = sumlt + l(i)*t(i);
    sumll = sumll + l(i)*l(i);
end

slope = (n*sumlt - suml*sumt)/(n*sumll - suml*suml);
y_intercept = (sumll*sumt - suml*sumlt)/(n*sumll - suml*suml);
z =slope*l + y_intercept;
plot(l,t,'o');
xlabel('L(m)');
ylabel('T^2(m)');
title('Time^2 vs Length');
% Errors
di = t -(slope*t + y_intercept);
Error_in_slope =sqrt(sum(di.*di)/(n-2))/(sqrt(n*sumll - suml*suml));
Error_in_y_intercept = sqrt(sum(di.*di)*sumll/(n*sumll - suml*suml))/(sqrt(n*sumll
- suml*suml));
```