

The simple pendulum lab

[Science](#), [Physics](#)



Objective

The objective of this experiment is to examine the simple harmonic motion and to determine the value of the acceleration due to gravity from the analysis of the period of the simple pendulum. [1]

Background

There are three equations that will be used to calculate the period of motion of the simple pendulum. They are the slope of the line of the graph of $T\pi$ against L , and the gravity of the pendulum motion.

The period of the motion is the time needed for one complete cycle that a pendulum bob swings from the initial position to the other end, and then back to the initial position.

[1] The equation to calculate the period is, $T = 2\pi \sqrt{L/g}$

Where, T = Period of the motion, measured in s.

L = Length of the pendulum, measured in cm.

g = Acceleration due to gravity, measured in m/s^2 . The slope of the line in the graph of T^2 against L can be used to determine the gravity of the pendulum motion. It is because,

$$y = mx$$

$$m = T^2 / L = 4\pi^2 / g = \text{Slope of the line in the graph } T^2 / L.$$

Therefore, to find the gravity of the pendulum motion, we can use the slope of the graph.

The slope of the graph is given by the formula, $g = 4\pi^2 m$ $g =$ Acceleration due to gravity, measured in m/s^2 .

Procedure and Observations

Materials:

- String
- Metre Stick
- Stopwatch
- Stand
- Pendulum bob

Procedure:

1. The materials listed above were taken for the experiment.
2. The pendulum bob was tied tightly with the string.
3. The string with the pendulum bob was hung on the stand.
4. A meter stick was used to measure the distance between the center of mass of the bob and the top of the string.
5. The distance was recorded in the observation table.
6. The pendulum ball was held at a distance from the center and it was released.
7. A stopwatch was used to time the time needed to complete ten cycles.
8. The time was recorded in the observation table.
9. Steps 4-7 were repeated four more times with different lengths.

Observations:

L (m)	10T (s)
0.185	9.01
0.39	14.13
0.595	15.04
0.79	17.58
1	19.67

Diagram of the Pendulum

Figure [1] Calculations and Results Method 1 – Graph of T² vs. L Data collected

L(m)	T ² (s ²)
0.18	0.81
0.39	1.99
0.59	2.37
0.79	3.09

1	3.86
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Hand drawn graph

Δx

Δy

Figure [2]

The slope can be determined by $m = \frac{\Delta x}{\Delta y}$.

So, by taking a value for x

$$x = 0.4 \text{ cm}$$

y must then be

$$y = 1.4 \text{ cm}$$

$$m = \frac{1.4 \text{ cm}}{0.4 \text{ cm}}$$

$$m = 3.5$$

The error would be given by

$$\Delta m = \Delta x_1 \times \frac{1}{x^2} + \Delta x_2 \times \frac{2}{x^3}$$

$$\Delta m = m \left(\frac{0.05}{1.4} + \frac{0.05}{0.4} \right)$$

$$\Delta m = 3.5 \left(\frac{0.05}{1.4} + \frac{0.05}{0.4} \right)$$

$$\Delta m = 0.45$$

The acceleration due to gravity is given by

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

$$g = \frac{4\pi^2 (0.5)}{(2.3)^2}$$

$$g = \frac{4\pi^2 (0.5)}{(2.3)^2}$$

$$g = 11.3 \text{ m/s}^2$$

Calculating the error for g would yield

$$\Delta g = \frac{\Delta m}{m^2}$$

$$\Delta g = \frac{0.453}{(2.3)^2}$$

$$\Delta g = \frac{0.453}{5.29}$$

$$\Delta g = 0.0856 \text{ m/s}^2$$

$$g = 11.3 \text{ m/s}^2 \pm 0.0856 \text{ m/s}^2$$

Solving for the percentage deviation would give

$$\% \text{ deviation} = \frac{\text{Actual value} - \text{Expected value}}{\text{Expected value}} \times 100\%$$

$$\text{Expected value} = 9.8 \text{ m/s}^2$$

$$\% \text{ deviation} = \frac{11.3 \text{ m/s}^2 - 9.8 \text{ m/s}^2}{9.8 \text{ m/s}^2} \times 100\%$$

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$$\% \text{ deviation} = 15.3\%$$

Method 2 – Linear Regression

Excel graph

Figure [3]

The equation of the line is given by $T^2 = 3.53L + 0.33$

Where

$$m = 3.53$$

The acceleration due to gravity is given by

$$g = 4\pi^2m$$

$$g = 4\pi^2(3.53)$$

$$g = 4\pi^2(3.53)$$

$$g = 11.1 \text{ m/s}^2$$

Solving for the percentage deviation would give

$$\% \text{ deviation} = \frac{\text{Actual value} - \text{Expected value}}{\text{Expected value}} * 100\%$$

$$\text{Expected value} = 9.8 \text{ m/s}^2$$

$$\% \text{ deviation} = \frac{11.1 \text{ m/s}^2 - 9.8 \text{ m/s}^2}{9.8 \text{ m/s}^2} * 100\%$$

$$\% \text{ deviation} = \frac{11.1 \text{ m/s}^2 - 9.8 \text{ m/s}^2}{9.8 \text{ m/s}^2} * 100\%$$

$$\% \text{ deviation} = 13.2\%$$

Conclusion

By comparing these two methods of calculating the acceleration due to gravity it is clearly noticeable that there is a difference between the two, when it comes to the accuracy. When calculating g using the hand drawn graph method it yielded $= 11. \text{ m/s}^2 \pm 1. 45 \text{ m/s}^2$. However, when using the linear regression method on excel, it yielded $g= 11. 1 \text{ m/s}^2$. This is clearly closer to the expected value of $9. 8 \text{ m/s}^2$. There are several reasons contributing to the conclusion that linear regression is more accurate, than measuring calculating the slope off of a hand drawn graph. First of all, computers are much more accurate than humans. There is no denying the fact that humans are not perfect and no hand drawn graph will be as precise as a computer drawn graph.

A ruler was being used, which may lead to believe that the line is perfectly straight, whereas it is actually not. This is clearly noticeable when one zooms in on a hand-drawn graph. Another problem with the ruler is that no matter how hard one tries to measure the distance between two different points, one will never be able to get the exact distance. Computers, however, Excel, in this case, draw perfectly straight lines. Also the location of the line of best fit line, in the hand-drawn part of the experiment, was estimated, which obviously leads to an inaccurate result.

Excel, however, uses the calculation of linear regression to draw the line of best fit and this is extremely accurate since the exact slope is being calculated by Excel. It is clear that the method of linear regression is more accurate by looking at the percentage deviations for each method. The %

deviation for the hand-drawn graph yielded 15.3%, whereas the percentage deviation for the linear regression method only was 13.2%. Even though the linear regression method was more accurate than the hand-drawn method, there was still a pretty significant difference, between that value, namely $g = 11. \text{ m/s}^2$, and the expected value of 9.8 m/s^2 . This is due to a few sources of error when this experiment was conducted. One of the errors that contributed to this difference was that the length of the string was not exactly measured. Thus, the relation between the length and the period was wrong, leading to false results. Another reason that contributed to the inaccuracy was the fact that when the bob was not swinging the way it was supposed to. It was only supposed to have a linear motion, but it had a slightly circular motion, which of course led to a longer period.

This again resulted in a wrong relationship between the period and the length, leading to the wrong result. There was another major aspect of the experiment that led to this result. Namely the fact one could not tell where the bob actually started its swinging motion exactly; therefore the exact period could not be measured with the stopwatch. It is evident, however, that if these errors could have been avoided, the acceleration due to gravity could have been calculated very accurately using the method of linear regression.

References

1. PCS 125 Laboratory Manual, 2008