

How Length Can Affect Time Regarding Pendulums—Physics IA

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Introduction

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While looking for some of the oldest human inventions for a history assignment, I was surprised to see something quite familiar and not at all what I was expecting. I saw a common day grandfather clock. This caught my curiosity so I decided to do more research on grandfather clocks and I was surprised to find out that these clocks have to be calibrated only around once a week for their pendulums within to stay visible swinging. An idea that I almost didn't believe at first due to other pendulum-like objects such as Newton cradles and even school playground swings. While it's most likely that grandfather clocks get away with their prolonged swinging because of the somewhat frictionless gears, I was still rather perplexed by this phenomenon; more specifically the relationship between the length of the string and the period it takes for it to oscillate. The key variables under investigation include the independent variable, which is the length of the string. The string starts at 50 inches, and is shortened by an inch after every test. The dependent is the period it takes the pendulum to oscillate 5 times. The mass of the

ball along with the angle of pull back are controlled variables. I believe that as the spring length shortens, the speed of the pendulum will also decrease at the same rate.

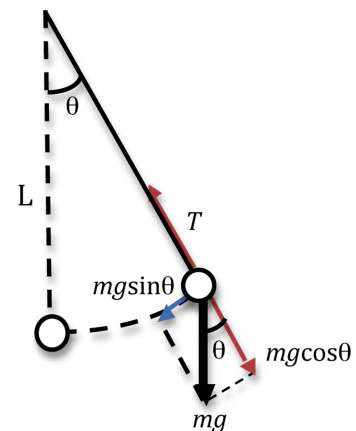
The mass of the ball, along with the distance the string is pulled back, are the dependent variables and remain constant throughout the experiment.

After this question first caught my attention, I started noticing more and more pendulums in my everyday life, such as diving boards, metronomes, and even the natural mechanics of swinging your legs. With all the constant thinking and thinking, I realized this would be a great physics IA topic. And after thinking more about this, I realized I couldn't even come up with the relationship between the length of the string period regarding a pendulum to oscillate.

Background Information

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This investigation looks at the original pendulum, which can be simplified down to a mass hanging from a massless yet taut string, with a length of L . And there's only two forces acting on the structure, which are gravity and the tension from the string; these can be represented as mg and T , according to Newton's second law.



Mg has the more prominent role where gravity acts towards the center of earth,

Figure 1: forces on a pendulum

This means that if displaced from equilibrium, a component of gravitational force will act on the mass which will cause it to accelerate towards equilibrium in the opposite direction of its original displacement. This acceleration is given by $a = -\omega^2 x$, where x is the pendulum's displacement from equilibrium and ω is the angular frequency $\frac{2\pi}{T} = \frac{2\pi}{2\pi\sqrt{\frac{L}{g}}} =$

$$\sqrt{\frac{g}{L}}.$$

You can see this payout in figure 1. Where θ is the angle between the string and the vertical, g the acceleration due to gravity, and $mg \sin \theta$ The accelerating force, tension and the remaining component of gravity are equal and opposite, so there's no effect on the system due to that. The angle θ which was formerly known as the angular displacement of a pendulum, is defined as its angular amplitude when at maximum.

Methodology

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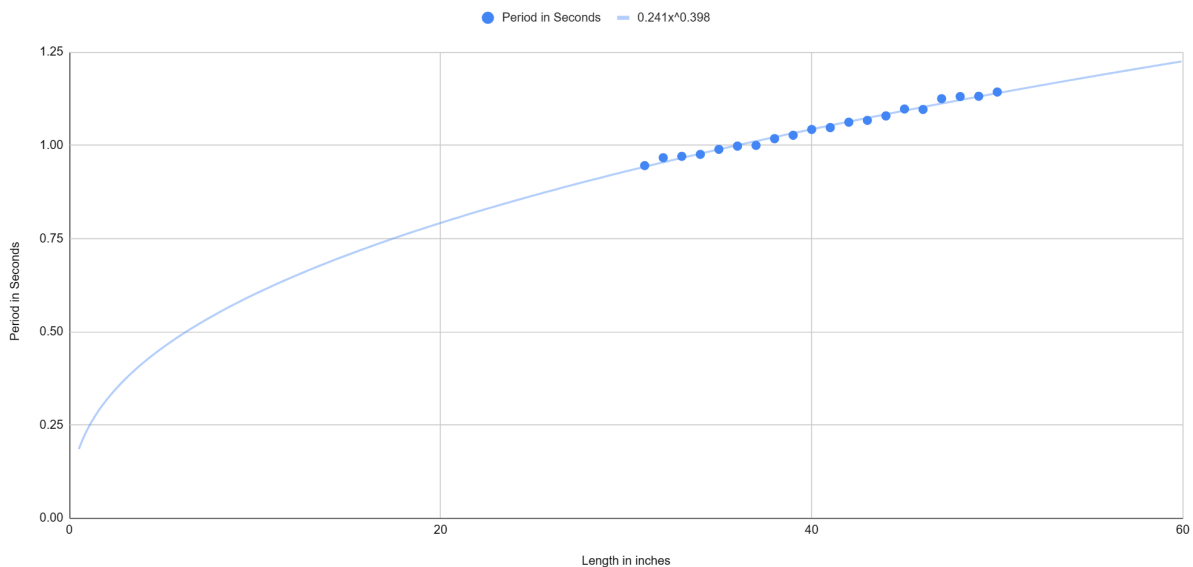
I set up my own pendulum similar to the one in figure 1, taking care to ensure that the combined string weight is virtually weightless. In addition I had a wooden board set 76.2 centimeters behind the ball to make sure the pull back was constant. For my first test I made sure the string was 50 inches long, and pulled the pendulum back so it touched the wood board and started the stopwatch. After the pendulum oscillated 5 times I hit stop, recorded the time, and did the same thing two more times. After I got three periods using the same length of string, I shortened the string by one inch. I did three tests per string length to ensure the times are averaged.

Analysis [\(Data File\)](#)

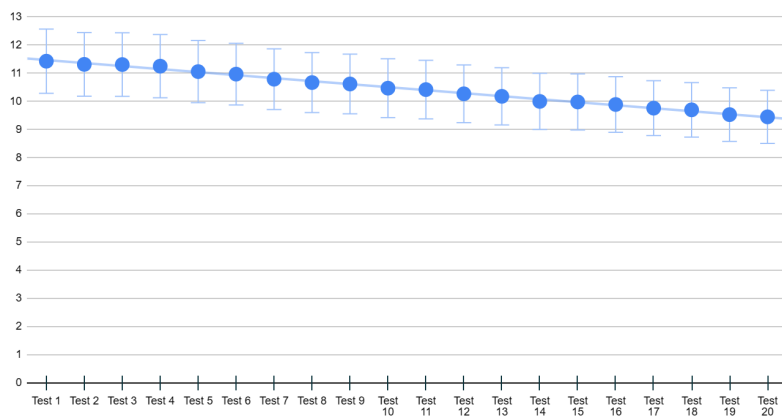
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In the graph below is my raw data:

Period in Seconds vs. Length in inches



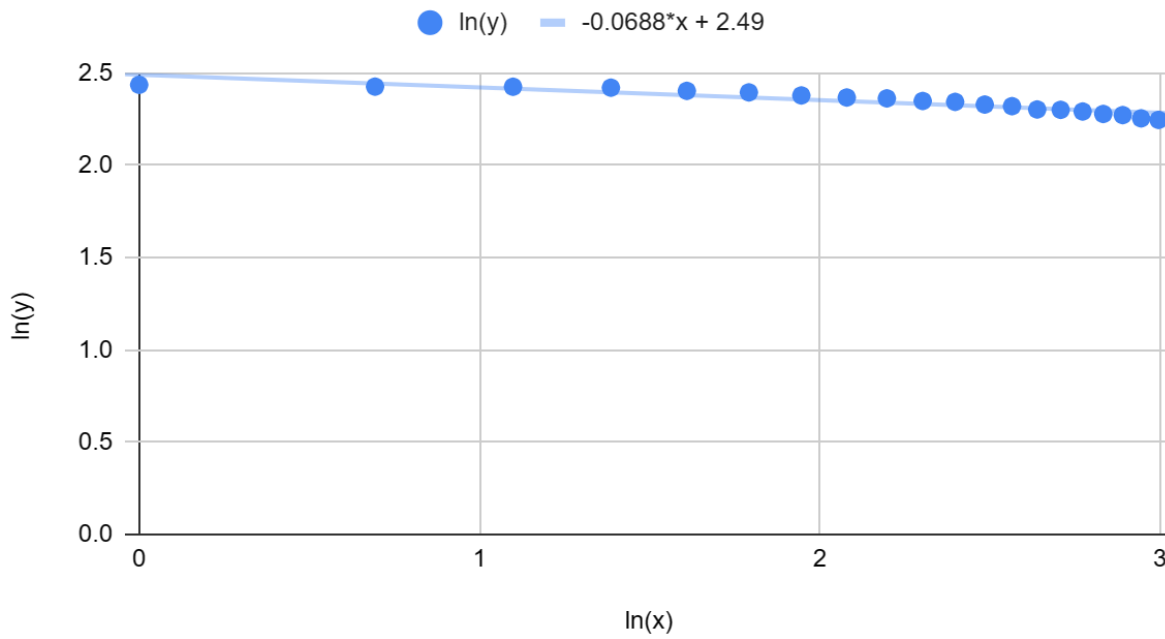
You can see the three trials for each string length and how the periods collectively lower as the string length decreases.



	Distance (inches)
	Time
Test 1	11.43
Test 2	11.32
Test 3	11.31
Test 4	11.25
Test 5	11.06
Test 6	10.97
Test 7	10.79
Test 8	10.67
Test 9	10.62
Test 10	10.47
Test 11	10.42
Test 12	10.27
Test 13	10.18
Test 14	10.00
Test 15	9.98
Test 16	9.89
Test 17	9.76
Test 18	9.70
Test 19	9.53
Test 20	9.45

Above you can see the average data with error bars and the same data in a chart. And below is the Log Log graph that

ln(y) vs. ln(x)



Conclusion

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In summary, my findings indicate that my hypothesis—which states that the oscillations' speed will decrease as the string's length is shortened—was true. We know this because the pendulum falls farther the longer the string is. Consequently, the longer the period, the slower the pendulum would swing at the same length and angle and the lower its frequency.

Errors

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Error	Possible impact	Possible solution
Oscillations were not fully confined to the x dimension.	When releasing the swing, a combination of a wrong hand movement and the flow of the air could have caused the mass to sway	I could use a more rigid and tight pathway to release the mass to make sure it stays in the right axis.

	to the direction which was not accounted for.	
The string length could have loosened as during the trials.	This would have affected mostly the trial 2 and 3 for each test and could have affected the garages noticeably.	As I do each trial I check again the length of the string, for every trial.

Limitations, Accuracy, and future work.

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One major limitation during this experiment was the range of independent variables; only 20 different string lengths were used, all within an inch apart, as a result of limited work space. This made it difficult to draw definitive conclusions about the relationship between length and period, since the effect of much larger lengths could have provided data that my trendline couldn't have predicted. Repeating this experiment for a greater range in length is a productive avenue for potential future research.

However, the majority of the mentioned problems and restrictions were not large enough to negatively affect the results of the findings, as shown by the relatively similar data throughput during testing. This strengthens my conclusion that length affects pendulum periods; yet, in the future, I would measure a variety of lengths in the future to learn more about the science underlying pendulum oscillations.

bibliography

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Hansen, S.H. (february 16, 2021), *Why does length of string affect pendulums period.* Retrieved from [Why does length of string affect pendulum period? – Wise-Answer](#)

Alley, R.A. (March 4, 2023) *What affects the swing rate of a pendulum.* [What Affects the Swing Rate of a Pendulum? | Sciencing](#)

Related Links

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[Why Does a Pendulum Swing? | Sciencing](#)- really good regarding the basic science of pendulums.

[Pendulum | Definition, Formula, & Types | Britannica](#)- lots of insightful history of pendulums

[The Use of Pendulums in the Real World | Sciencing](#) cool connections from pendulums to the real world and usefulness.

[Pendulums – The Physics Hypertextbook](#)- detailed math and science on how pendulums work

[newtonian mechanics - Why is there no effect in the mass of the bob on the period of the simple pendulum? - Physics Stack Exchange](#) specific details regarding my topic