Characterization of the motion of a bifilar pendulum

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Abstract

The period of a bifilar pendulum oscillating about a vertical axis through its COM was observed and compared with the theoretical values. This was done by measuring the number of full oscillations in one minute, with a setup of constant separation distance d and varying thread length L, as well as constant thread length and varying thread separation. It was shown that a linear relationship exists between L vs T^2, and T vs L/d. The deviations were calculated to be no more than 8.54%.

Keywords: equations of motion, bifilar suspension, pendulum, moment of inertia.

1 Introduction

In classical mechanics, we never forget to study pendulums. Many systems are described by the behavior of oscillations. This helps us understand many systems we can simulate and learn from. A metal rod is usually used to observe oscillation modes.

A cylindrical rod is a suitable material to oscillate to many points and axes. This property reveals many physical phenomena such as bifilar torsional oscillations to its chaotic behavior. There are many cases we can consider: vertical pendulum, horizontal pendulum, bifilar suspension, double pendulum, chaotic pendulum, torsional pendulum, and horizontal pendulum [1].

One famous system mentioned above is the bifilar suspension where the rod is suspended horizontally by two vertical strings. Bifilar suspension is a technique physicists use to find the moment of inertia of an object suspended [2]. The relationship between the periodic time of the oscillation and the length of the wires tell us details about the rod. By the setup of equal length strengths, several motions are possible. For this experiment, we investigate torsional oscillations about a vertical axis through the rod's center of mass. The period T of an oscillator under such motion is given by

$$T = 2\pi\sqrt{\frac{L-r}{g}}\frac{2R}{d\sqrt{12}} \tag{1}$$

where L is the thread length, R is the long axis length, r is the short axis length, d is the thread separation, and g is the acceleration due to gravity.

The experiment aims to investigate the motion of the suspended rod by the two threads, and is organized as follows: in Section 2 we describe and detail the methods used in performing the experiment. In Section 3, we analyze and discuss the results. We conclude and summarize the paper and give recommendations to improve similar experiments in Section 4.

2 Methodology

A bifilar suspension was set-up by suspending a rod, with $R = 50 \pm 0.5$ cm and $r = 0.5 \pm 0.05$ cm, horizontally using two parallel strings of length L and apart for some distance d. Figure 1 shows the setup used for this experiment.

Two sets of measurements of the time period for the oscillation were made. For the first set of measurements, the thread length L was varied while keeping the threads separation distance d constant. While for the second set the thread separation distance was varied while keeping the thread's length constant. For each set the rod is made to swing by releasing one side of the rod from a small angle, then the number of swings made in one minute is counted.

Using the measured values from the first set, period T against the thread length L over separation distance d. The measurements obtain from the second part of the experiment we were also able to plot L vs T^2.

3 Results and Discussion

Figure 2 shows the data obtained for five different L at a constant $d = 46 \pm 0.5$ cm along with the plot for the theoretical values calculated from (1), which shows a linear relationship between L and T^2. This is supported by Table 1, which shows the observed and calculated pendulum periods, all with deviations no more than 6.03%. This agrees with the observation that when the thread length is decreased, the frequency (i.e. the inverse of the period of oscillation) increases.

Figure 2 shows the data obtained for three different d at a constant $L = 23.4 \pm 0.05$ cm, similar to Figure 2, and a linear relationship can also be observed between T and L/d. This is supported by Table 2, which also shows the observed and calculated pendulum periods, all with deviations no more than 8.54%. This agrees with the observation that the frequency decreases when the separation distance of the threads is decreased.

Sources of error may stem from (a) the pendulum losing energy due to non-conservative forces, consequently decreasing the oscillation frequency, (b) reaction time causing a misreading either in the number of oscillations or operating the timer.

4 Conclusions

The period of a bifilar pendulum oscillating about a vertical axis passing through its center of mass was observed and compared to the theoretical using (1). The observed behavior was concluded to agree with the theoretical by proving the linear relationship of L vs T^2, and T vs L/d. Excellent precision was exhibited due to the calculated deviations being no more than 8.54%.

References

[1] Oscillations of Rod [PDF]. (n.d.). Physics Project Lab.

[2] Gibbs, K. (n.d.). Bifilar Suspension. Retrieved March 1, 2019, from http://www.schoolphysics.co.uk/age16-19/Mechanics/Simple_harmonic_motion/text/Bifilar_suspension/index.html.

Appendix

Figures and Diagrams

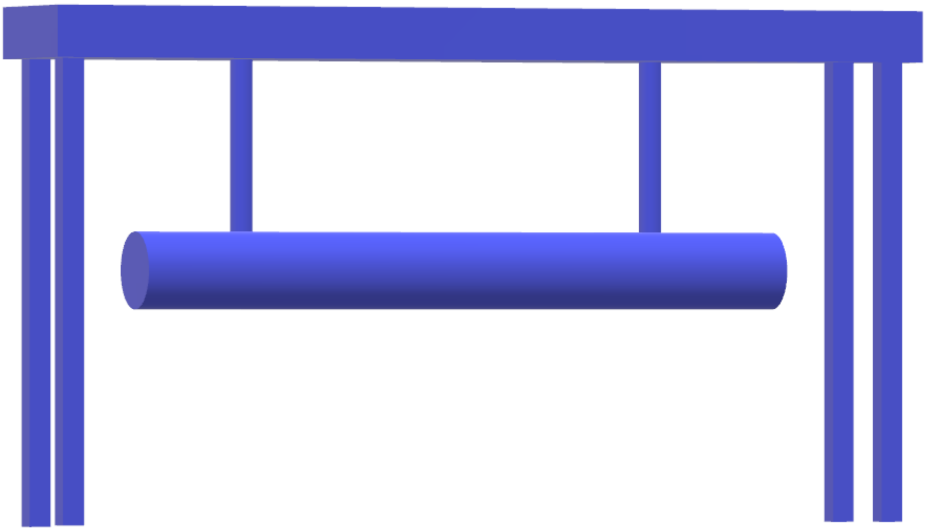

Figure 1: Bifilar suspension setup

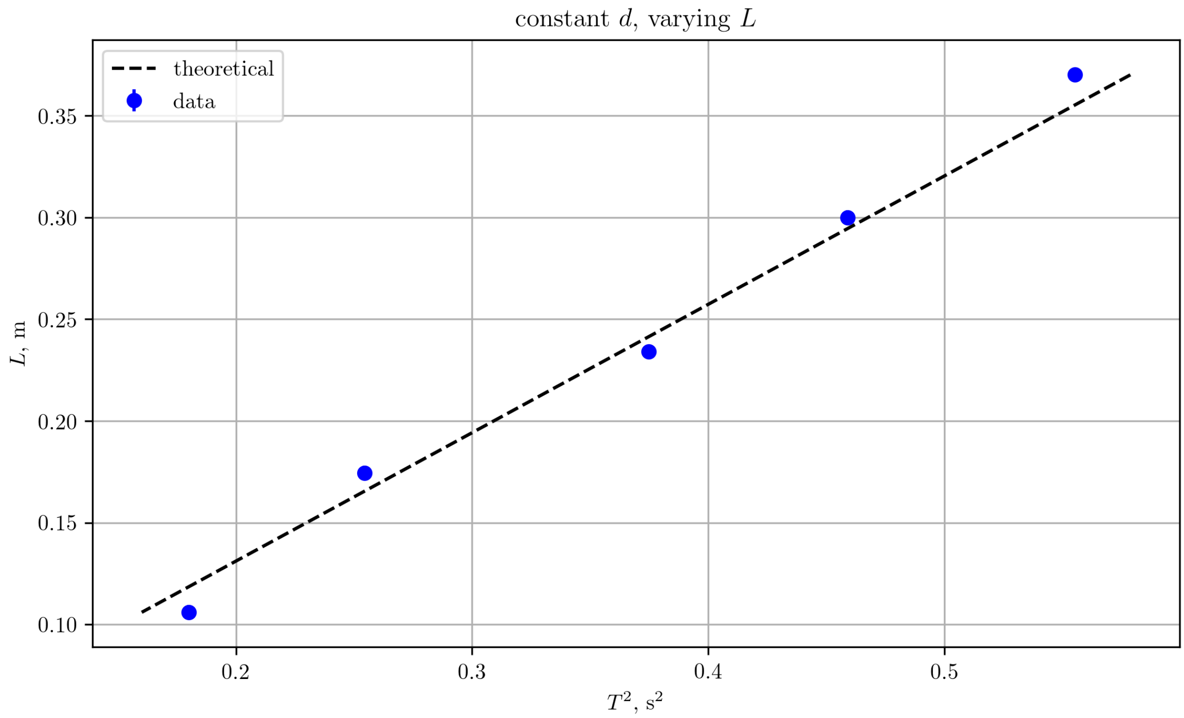

Figure 2: L vs T^2 for constant d and varying L

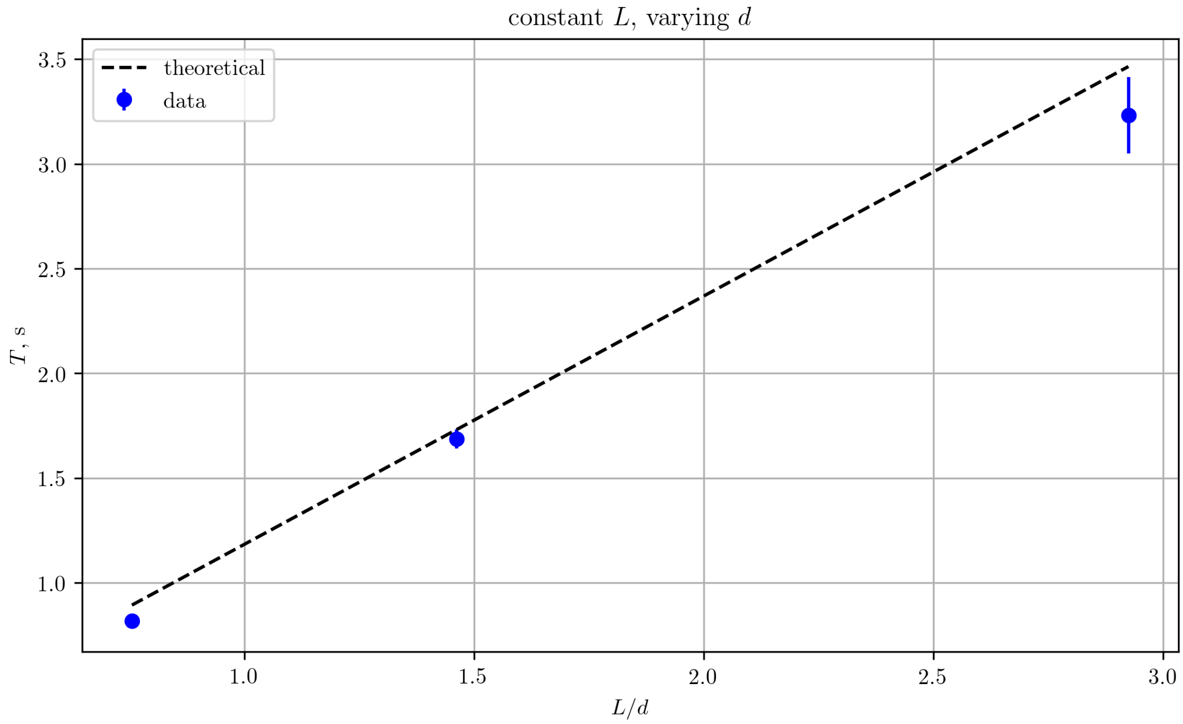

Figure 3: T vs Ld^{-1} for constant L and varying d

Table 1: Pendulum periods for constant $d = 46 \pm 0.5$ cm and varying L.

Observed T [s]	Theoretical T [s]	% Error
0.755	0.761	2.04
0.688	0.684	0.93
0.612	0.603	1.61
0.504	0.528	2.70
0.424	0.400	6.03

Table 2: Pendulum periods for constant $L = 23.4 \pm 0.05$ cm and varying d.

Observed T [s]	Theoretical T [s]	% Error
0.818	0.894	8.54
1.687	1.732	2.62
3.233	3.465	6.70