Factors that Affect the Frequency of a Pendulum

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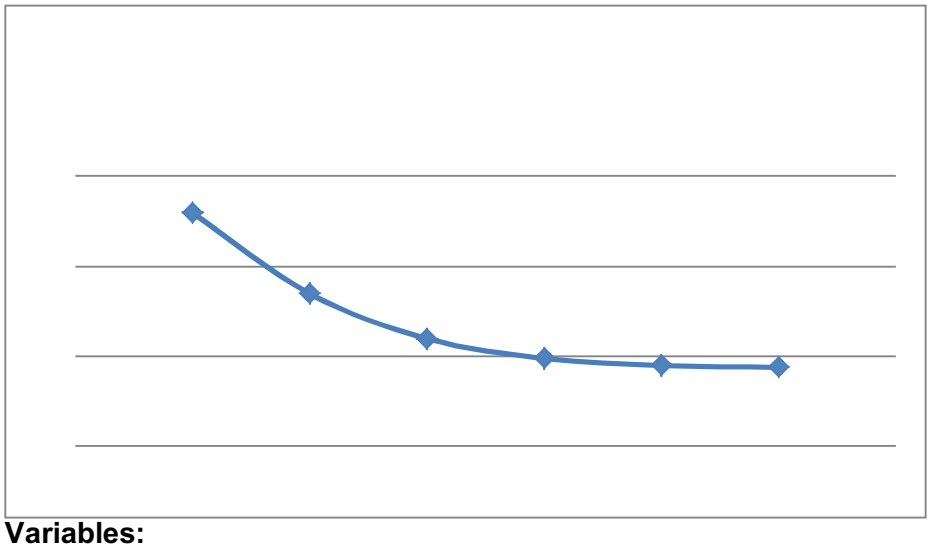
Question: Does the length of the string holding the pendulum in mid-air affect the frequency?

Hypothesis: If the length of the string is increased then the frequency of the pendulum will decrease.

Explanation: When the length of the string is increased, the frequency decreases as it takes more time for the pendulum to complete one cycle. The more time it takes the slower the movement meaning the lower the frequency. Since frequency equals number of cycles divided by total time, the larger the time amount the more the cycles are divided by, which would result in a smaller number. This is similar to water waves as the larger the wave the slower it moves and the lower its frequency.

Figure 1: Graph Sketch



Variables:

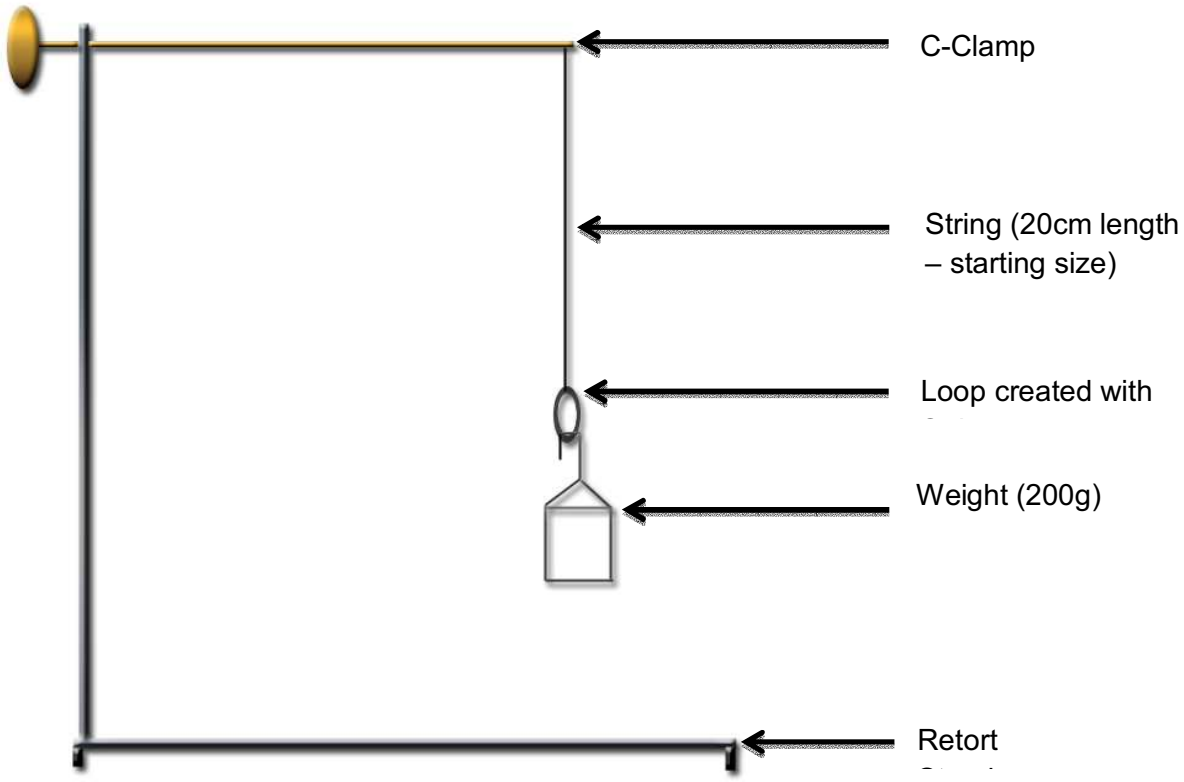
Independent Variable: Length of the String (cm)
Dependent Variable: Frequency of the Pendulum (in Hz)
Controlled Variables: Number of Cycles (15), Mass of the weight (g), Room Temperature (~ 23°C)

Materials:

- Retort Stand
- String (in the following lengths: 20cm, 30cm, 40cm, 50cm)
- Weight (200g)
- C-Clamp
- Timer (±0.5s)

- Ruler (±0.05cm)

Figure 2: Setup of Lab



Procedure:

1. Setup the materials as shown in figure 2.
2. Note: Make sure to tie one end of the string with the Pendulum Clamp and create a loop on the other end of the string for the pendulum to hang off of.
3. Using a Ruler (cm side) measure 20cm from the Pendulum Clamp downwards and move the bottom of the string loop, up or down till it meets 20cm from the Pendulum clamp.
4. Using a Ruler (cm side) measure 15cm away from the rest position and pull and hold the pendulum (hanging in the loop of the string) at that distance.
5. Release the Pendulum
6. Start The Timer (Start at the same time as the pendulum is released)
7. Count till 15 cycles are complete
8. Stop the timer (as soon as the pendulum completes 15 cycles)
9. Record observations (time in seconds) in table
10. Repeat steps 3-9 for 30, 40 and 50cm string length (from C-Clamp to bottom of string loop), 4 times each, and 3 more times for 20cm length to get 4 trials for each length.

Observations: Table 1: Comparing String Length with Time

Trial	String Length (cm) ±0.01	Time (seconds) ±0.5
1	20	16.1
2		15.9
3		15.8
4		15.8
5	30	18.6
6		18.2
7		18.6
8		18.4
9	40	20.5
10		20.6
11		20.6
12		20.6
13	50	22.2
14		22.2
15		22.4
16		22.3

*Retort Stand wobbled throughout the experiment

Analysis:

Sample Calculation:

To determine standard error in time:

Standard error $= \frac{X_{max} - X_{min}}{2\sqrt{N}}$ Where: N = number of

$$= \frac{16.09\ Hz - 15.77\ Hz}{2\sqrt{4}}$$

Standard error = ±0.08Hz

To determine Frequency of the Pendulum:

$$\text{Frequency (Hz)} = \frac{\text{number of cycles}}{\text{total time}}$$

$$= \frac{15}{16.09\ s}$$

Frequency (Hz) = 0.93Hz

To determine the average frequency:

$$\text{Average } f = \frac{\sum \text{frequency}}{\#\text{ frequency}}$$

$$\text{Average } f = \frac{0.93\ Hz + 0.95\ Hz + 0.95\ Hz + 0.95\ Hz}{4}$$

$$\text{Average } f = 0.94\ Hz$$

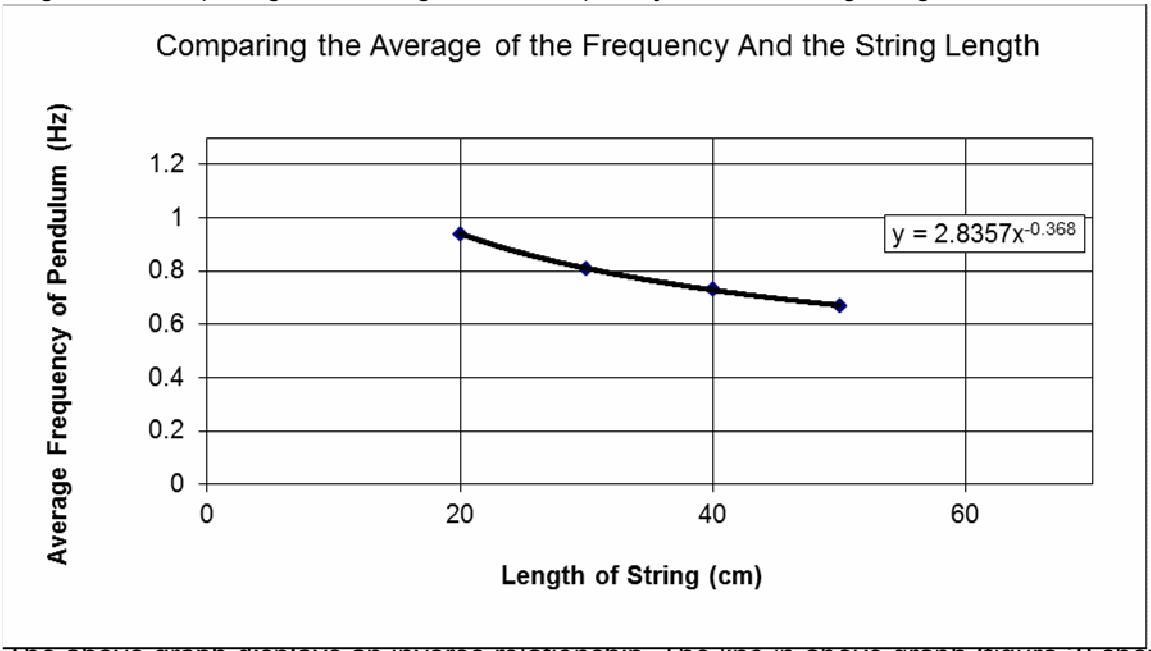
Table 2: The Frequencies of the Pendulum for Each String Length

Length of String (cm)	Frequency (Hz)
20	0.93
	0.95
	0.95
	0.95
30	0.81
	0.82
	0.81
	0.81
40	0.73
	0.73
	0.73
	0.73
50	0.67
	0.68
	0.67
	0.67

Table 3: Length of String vs. Average Frequency of the Pendulum

Length of String (cm)	Average Frequency (Hz)	Standard Error for String Length Frequency (s)
20	0.94	±0.089
30	0.81	±0.12
40	0.73	±0.034
50	0.67	±0.040

Figure 3: Comparing the Average of the frequency and the String Length



The above graph displays an inverse relationship. The line in above graph (figure 3) shows that as the length of the string increases the Frequency decreases.

According to the observations and analysis graph, the hypothesis was correct. The observations (table 1) shows that increasing the length of the string increased the time for the entire 15 cycles to complete, which effects the frequency that was calculated from the equation in the analysis. In table 2 & 3 the frequency of the smaller string length is greater than the frequency of the larger string length. (Ex. 20cm string length frequency avg. is 0.94 which is higher than avg. frequency of the 50cm string length which is 0.67). Also in Figure 3, the inverse line shows that as the length of the string increases the frequency decreases.

One source of error is the instability of the retort stand. While the pendulum swings, the retort stand tends to wobble around which increases the amplitude from the one that is set (15cm). Since the amplitude is increased, the pendulum takes longer to complete the 15 cycles, which results in inaccurate time. This factor could be fixed by having a c-clamp hold down the retort stand to the table, so that the retort stand does not wobble.

Second Source of Error is the pendulum clamp interference with string while it moves. Since the String is looped around the pendulum clamp holder, and swings perpendicular to the clamp, the clamp interferes with the movement of the string. As the string swings it hits the clamp near the rest position which causes the string to slow down in its movement. When the string slows down the time increases which causes inaccurate frequency measurement and inaccurate timing. This factor could be fixed by having a clamp where the string hangs below it and swings below it, so that there is no interference in the movement of the string.