Hang on Tight: A Deeper Look

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into Conservation of Energy in

Springs with Falling Masses

Introduction

- **Purpose:** Conduct an experiment that illustrates conservation of energy principles in a spring.
- **Researchable Question:** How does the stretched length of a spring change the lowest point a constant mass dropped at a constant height will reach?
- **Hypothesis:** Increasing the stretched length of a spring will decrease the lowest point a constant mass dropped at a constant height will reach in a linear way.

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Methodology

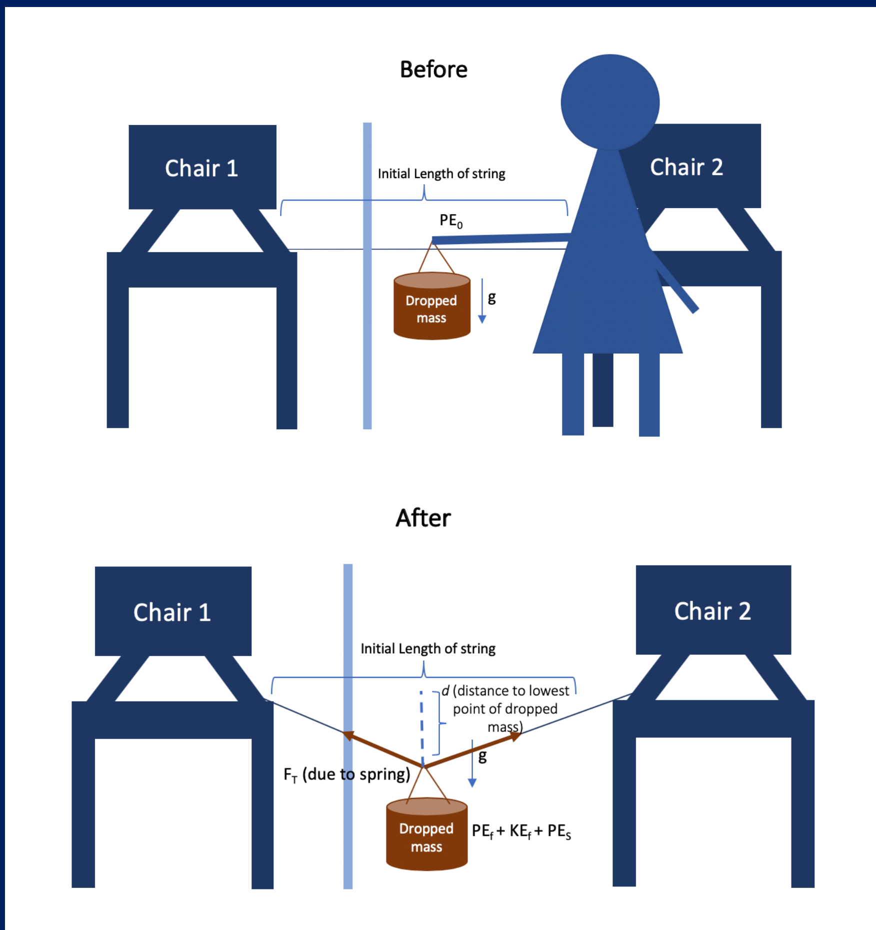
1) The team gathered the materials: a paper clip, bucket, [MASS OF ROCK] g rock, 45 cm black stretchable string, two chairs with seats at 40 cm high, ruler, meter stick, and a camera capable of slow-motion.
2) The team assembled the apparatus as follows:
   a) The first end of the black string was attached to the right metal bar holding up the back seat of the first chair with a knot, and the other end of the string was attached to the left metal bar holding up the back seat of the second chair with a knot such that the distance between the two endpoints was at a slack length of 35.63 cm. The chairs were arranged such that the distance between the two endpoints was minimized.
   b) The rock was put inside the bucket, which was attached with a paperclip to the apparatus at the midpoint of the string.
   c) The meter stick was held perpendicular to the ground by Garima behind the string near the midpoint of the string. The meter stick did not touch the string.
3) Garima recorded the distance between the two endpoints in the excel file.
4) Darshan held the paperclip to the black string such that the mass hung from his hand (without exerting a force on the spring) 40 cm above the ground.
5) Darshan dropped the mass at this height. Ishita recorded the drop on the slow-motion camera.
6) Ishita recorded the height of the lowest point of the drop as indicated in the slow-motion video in the excel file.
7) The team repeated steps 4-6 10 times.
8) Garima then moved the endpoints of the strings to vary the distance between them, and the team repeated steps 3-8 for the other four settings of string length.

Constants And Equations

Total Hanging Mass = _____ h_0= 40 cm g = -9.80 m/s^2 Slack Length of String = 45 cm	$TE_i = mgh_0$ $TE_f = \frac{1}{2}mv_f^2 + mgh_f + \frac{1}{2}k\Delta x^2$ $d = \frac{2mg}{k}$

Constants: Streched Length of String Versus Obtained K-value	
Streched String Length (cm)	**K-value**
39.12	0.10
45.56	0.06
54.53	0.30
62.23	
86.63	

Diagram



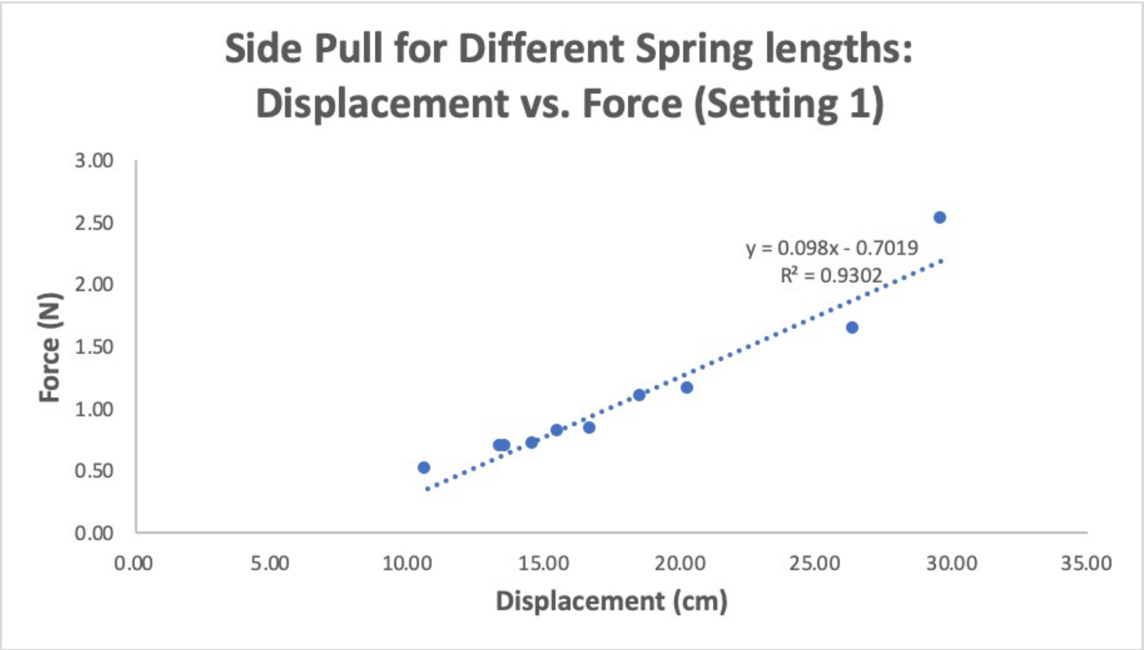
Before
Chair 1
Initial Length of string
Chair 2
PE0
Dropped mass
g
After
Chair 1
Chair 2
Initial Length of string
d (distance to lowest point of dropped mass)
g
FT (due to spring)
Dropped mass
PEf + KEf + PES

Results and Analysis: Data Summary

Strech of String vs. Lowest Height of Hanging Mass (cm)								
Length of string (cm)	Average	STDEV	%RSD	DV_{theo}	%ERR	TE_i	TE_f	$\%\Delta TE$
39.12	17.74	0.83	4.67					
45.56	16.32	1.01	6.19					
54.53	18.45	0.39	2.13					
62.23	27.61	0.47	1.71					
86.63	37.40	0.19	0.52					
Hanging Mass (g):								
Start Height (cm):		40.00						

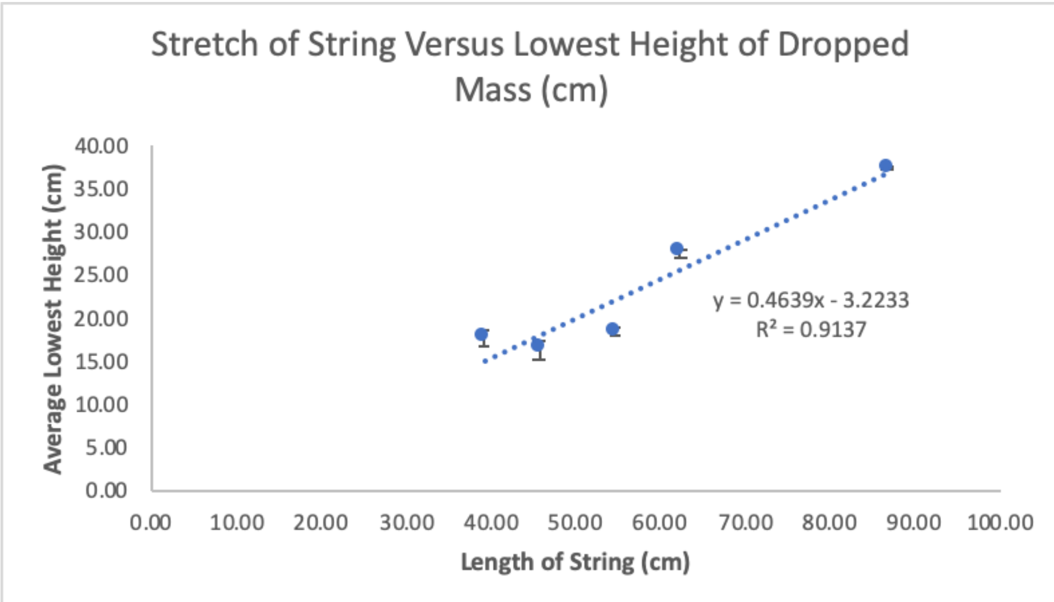
- The above table indicates the summary data indicating the varying the lowest height of hanging mass depending on the length of the string. See Appendix for full data.
- The standard deviation indicates that each setting varies up to only approximately 0.58 cm per trial.
- The %RSD indicates [FIX FORMULA].
- The mean percent error was _____, which indicates ____.
- The mean percent change in energy was ____, which indicates ____.

Results and Analysis: Obtained K-Constants



- Data was taken after experimentation, for each of the five length settings.
- K constants were found by finding the slope of the best fit linear line for each setting. See *Constants* for a tabular format of each spring length versus its k-constant.

Stretch of String vs. Lowest Height of Dropped Mass



- The model has an R^2 of 0.9137, indicating a moderate fit.
- This shows that the length of a stretchable string is moderately linearly correlated with the mass's

Sources of Error

- Inaccurate positioning of the mass.
  - In our experiment and DV_{theo} calculations, we assumed that the mass was dropped from the midpoint of the string, so that the tension was distributed evenly across the string.
  - The positioning of the mass in the experiment was done by estimating the midpoint visually.
  - This may lead to additional variability in our height measurements and increased percent error.
- The height readings in the slow-motion videos may be inaccurate.
  - In our slow-motion videos, the resolution and quality of the camera was oftentimes not enough to pinpoint the exact lowest height and time at which it occurred.
  - This may increase variability in the height measurements.

Conclusions

- In conclusion, our experiment supported our original hypothesis.
  - There is a moderate linear correlation between string length and lowest height for a constant mass dropped at a constant height at the midpoint of the string.
- ANALYZE STATS
- In the future, this experiment will make more stringent attempts to ensure the positioning of the mass and more accurate height readings.
- Moreover, the data and k-constants can be fit with higher-order functions instead of linear lines to account for varying k-constants and attempt to make the analyses more accurate.

Appendix

Part A: Full Data Table (Obtaining K-constants)

Part B: Full Data Table (String Length versus Lowest Height)

Part C: DV_{theo} derivation

Picture of Apparatus

Figure 1: A picture of the apparatus used to conduct the experiment.