Spring Mastery Lab

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1 Synopsis

Springs are great, simple harmonic oscillators. They can either be compressed or stretched, which allows them to "spring" out or pull back in. This creates the back-and-forth movement through a point of equilibrium known as "oscillation," which is the process of restoring the spring back to equilibrium. The focus of this lab is to analyze the spring force and the *spring constant* of a spring under tension of a block of different masses. We took the measurements of the spring in two instances, which were the spring in a *dead hang* and *simple harmonic motion* with different masses attached. Below is a breakdown of the materials needed, procedure, and calculated analysis of the lab.

2 Bill of Materials

- **Stable laboratory table**
- **Computer** – laptop or desktop with analysis software
- **I/O interface box (DAQ)** – analog input channels to connect multiple sensory peripherals
- **Meter stick** – 1 m length, with centimeter notches
- **Support rods & mounting clamps** – steel lab rods with base plates and adjustable right-angle clamps
- **Spring** – helical steel spring, we'll be finding the spring constant of this
- **Force sensor** – bidirectional
- **Mass hanger** – 50 g (or similar) for stacking slotted masses
- **Set of blocks with different masses** – assorted regular blocks

3 Procedure

3.1 Overview

The experiment aims to determine any distinguishable difference in the spring constant coefficient 'k' between a spring in a dead hang, acting as a tension string, and being displaced a vertical distance, and a spring oscillating in simple harmonic motion, also in the vertical direction as well as displaying from our data points that the spring constant is a linear relation according to Hooke's law.

3.2 Environment Set Up

We set up our environment by clamping the rods to the table, connecting the I/O interface box to the computer, and making sure that the force sensor was properly connected to the I/O box.

(Here's how the force sensor should be hanging from the rods clamped to the table.)

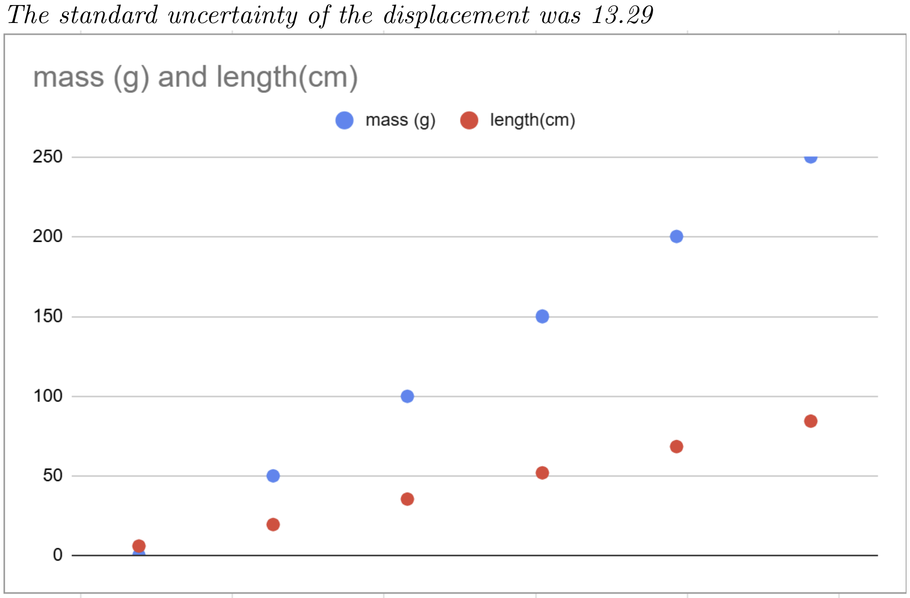
After the setup is complete, we place our spring in position and find the point of equilibrium without any additional mass by measuring the length of the spring alone. This will help us find the total displacement of the spring later on. The measurement of our spring was 5.9 centimeters.

3.3 Spring Force and Displacement (dead hang)

We recorded the spring force via displacement by adding a series of different valued masses (in grams) to the spring and allowing the spring to hang in equilibrium without motion, and recording the force. The force was recorded with the force sensor via Capstone, and the displacement was recorded using a meter stick. With the displacement, we took the total length of the spring with the mass and subtracted the unstretched length of the spring to get the pure measurement of the displacement.

Mass(g)	Displacement(cm)	Force(N)
50	19.4	-.47
100	35.4	-.96
150	51.9	-1.44
200	68.4	-1.92
250	84.4	-2.4

The standard deviation of the displacement measurements was 29.73 cm.
The standard uncertainty of the displacement was 13.29

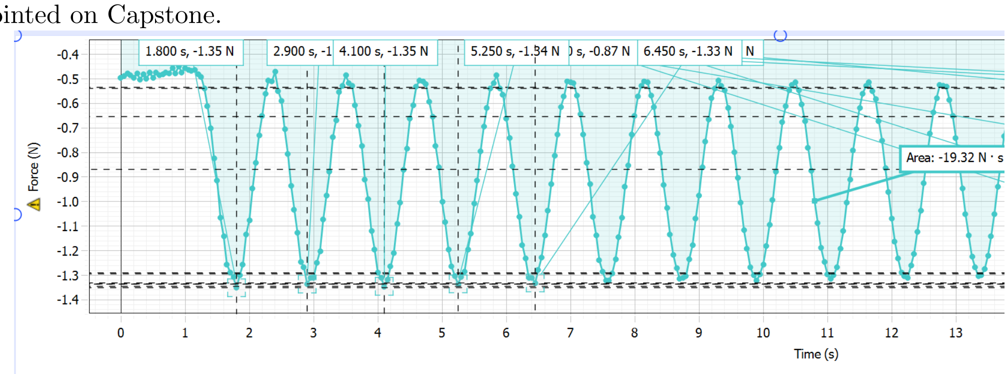


3.4 Determining The Spring Constant From Harmonic Motion

When finding the spring constant, certain components of the system have higher uncertainty than others. The two things we focused on were the mass and the period. Which allowed us to easily derive the constant using the equation:

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

Choosing these two things made it easy to control in our procedure. We used a variety of masses (in grams), and the period could be easily viewed and pinpointed on Capstone.

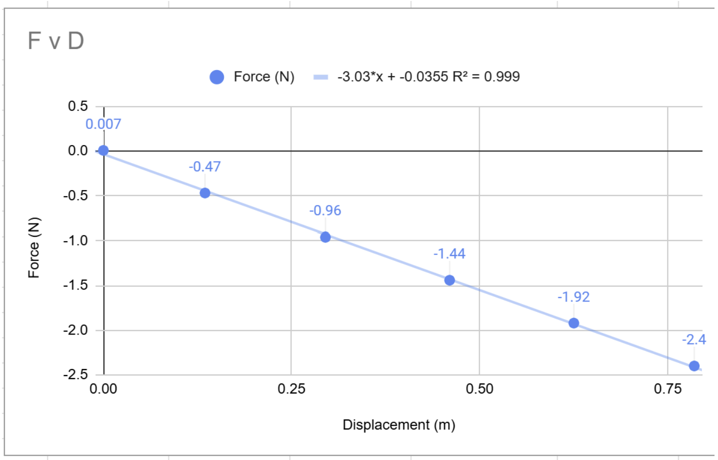


4 Analysis

4.1 Proving Our Spring Obeys Hooke's Law

To demonstrate that Hooke's Law is a linear relation, we graphed our data points of different masses and displacements and presented an equation that confirms its linearity.

From the visual alone, we can see that our scatter plot is extremely close to a line. But the main determining factor in our analysis is the equation the computer gave us based on our data points.



$$-3.03x - 0.0355R^2 = 0.999$$

Within this equation, our spring constant is -3.03 in front of x. The result of this equation is extremely close to 1 (0.999), which satisfies the relation of linearity. The standard deviation of our lengths in regard to our Force was 29.73 cm. A side note to the reader: Our "displacement" and "length" measurements represent different values, with the difference being that the length is the total measurement of the spring with the mass hanging from it, whereas the natural length of the spring is measured without any hanging mass. The displacement, however, is just the measurement of the amount the spring stretches from its natural length of 5.9 cm. Here's a table that compares both.

Length(cm)	Displacement(cm)
19.4	13.5
35.4	29.5
51.9	46
68.4	62.5
84.4	78.5

The difference between these two values is 5.9 cm.

4.2 Spring Constant Measurement From Simple Harmonic Motion

As mentioned in section 3.4 in our procedural overview, we were able to find our spring constant only using the period and mass values. We were also able to find the spring constant from the hanging equilibrium measurements using the Force and displacement values. These were the equations we used to find our two different measurements of the spring constant.

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

$$k = \frac{F_{spring}}{\Delta l}$$

Spring Constant from Simple Harmonic Motion

$$k = 3.19 \pm 0.11 \, N/m$$

Based on our 2 different values of the spring constant, we calculated the t' to be 0.37. Which is less than 1, making our measurements indistinguishable.

$$t' = \frac{k_{shm} - k_{static}}{\sqrt{(\delta k_{shm})^2 + (\delta k_{static})^2}}$$