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Determining an Approximation of Spring Constant *k* of a Sample Cord By Measuring Force Versus Displacement On a Sample Cord and Hanging Mass System

Abstract

The ultimate goal of the bungee challenge is to design a bungee jump using a latex cord. This will allow an egg to come as close to the ground as possible without damage. In part 1 of the bungee challenge, the spring constant *k* of the bungee cord was determined to be used in this final test. By hanging masses of various weights from a sample bungee cord, we measured the force on the system versus the displacement of the bungee cord. Using many different masses, we graphed force versus displacement and found the slope of the graph was an approximation of the spring constant *k*. This value ended up being 3.09 and can be used in our final test of designing a quality bungee experience. If we know an approximation of *k* for our bungee cord used in the final test, we can use this value to keep the egg safe.

Introduction

The purpose of the lab was to determine the *k* of the bungee cord. The ultimate goal of the bungee challenge is to design a quality bungee jump. In part 1 of the bungee challenge, we focused on Hooke's law by modeling the spring-like behavior of our bungee cord sample. Hooke's law is a principal of physics that states that the force needed to extend or compress a spring by some distance is proportional to that distance (F of spring = -kx). Elastic materials, such as the sample, exhibit Hooke's law behavior and have specific relationships between the amount of the stretch and the force causing the stretch. We used a model of a linear spring to characterize the cord's relationship between force and displacement to determine how the length of the cord affects its force-displacement relationship. The equation $mg = k(x_o - x_l)$ is an approximation of the true form of Hooke's law, where

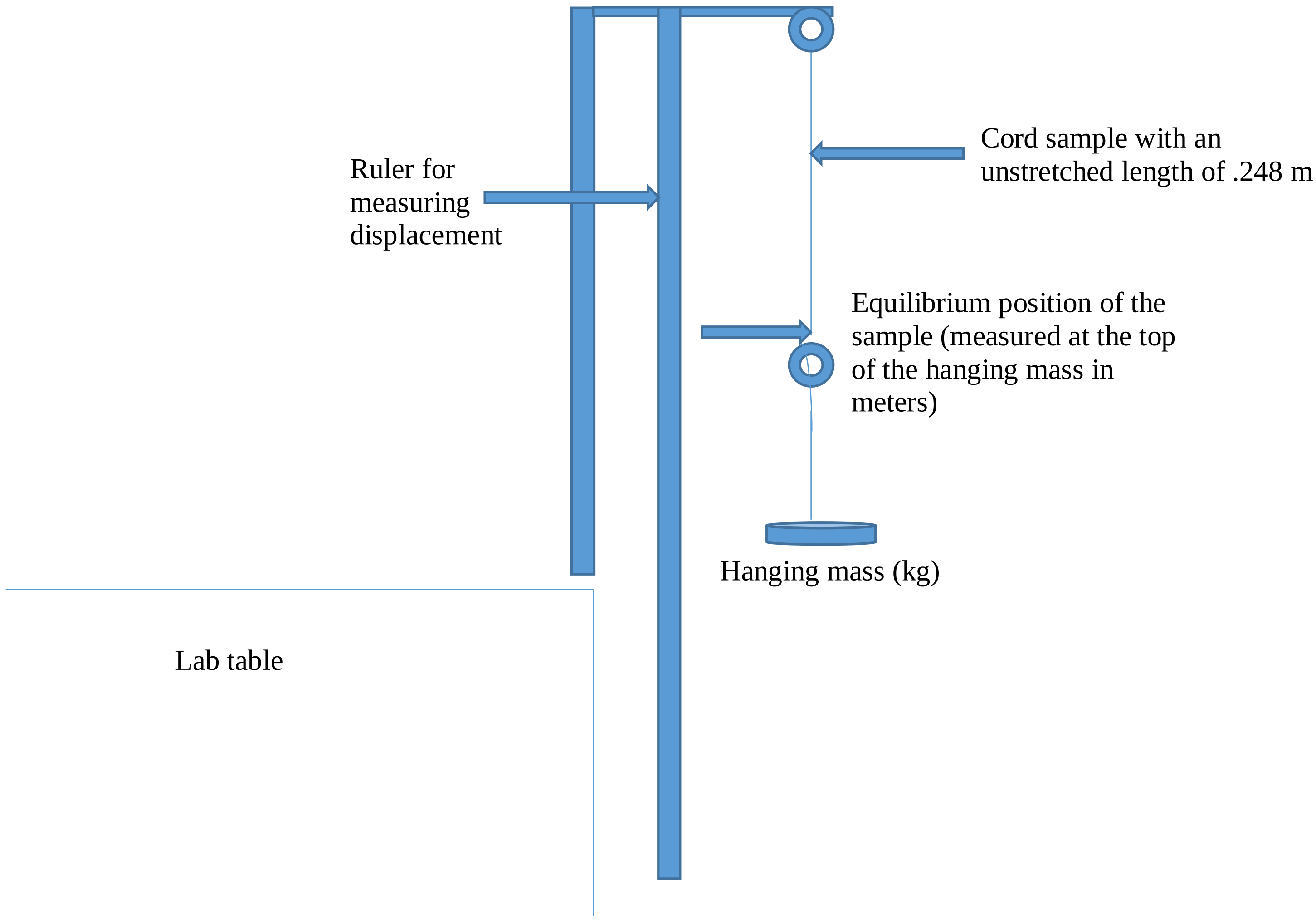
m = hanging mass in kg
g = acceleration of gravity hanging mass = 9.81 m/s^2
k = spring constant of bungee cord
x_o = equilibrium position of hanging mass on cord
x_l = unstretched length of cord

We will be able to determine an approximation of *k* of a bungee sample cord by measuring the force versus displacement of a mass hanging from a bungee sample cord.

Methods

We measured the unstretched length of the sample cord in meters. We then hung different masses from the cord to find the equilibrium positions. The displacement was measured by subtracting the unstretched length of the cord from the equilibrium position. We were able to determine the spring constant by measuring the relationship between the weight of the hanging masses (which was the only force acting on the system) and the displacement.

Figure 1: Diagram of the Setup



- 10 different masses were used
- Sample cord used had an unstretched length of .248 m
- Sample cord was hung using a special knot demonstrated to us by the professor
- The masses were hung from the bottom end of the cord, using the same knot
- The equilibrium position was measured from the top of the hanging mass in meters
- Displacement was measured by subtracting the unstretched length of the bungee sample from the equilibrium position
- The weight of the hanging masses was taken because it was the only force acting on the system
- Weight was graphed versus displacement, and the slope of this graph measured *k* of the cord

Results

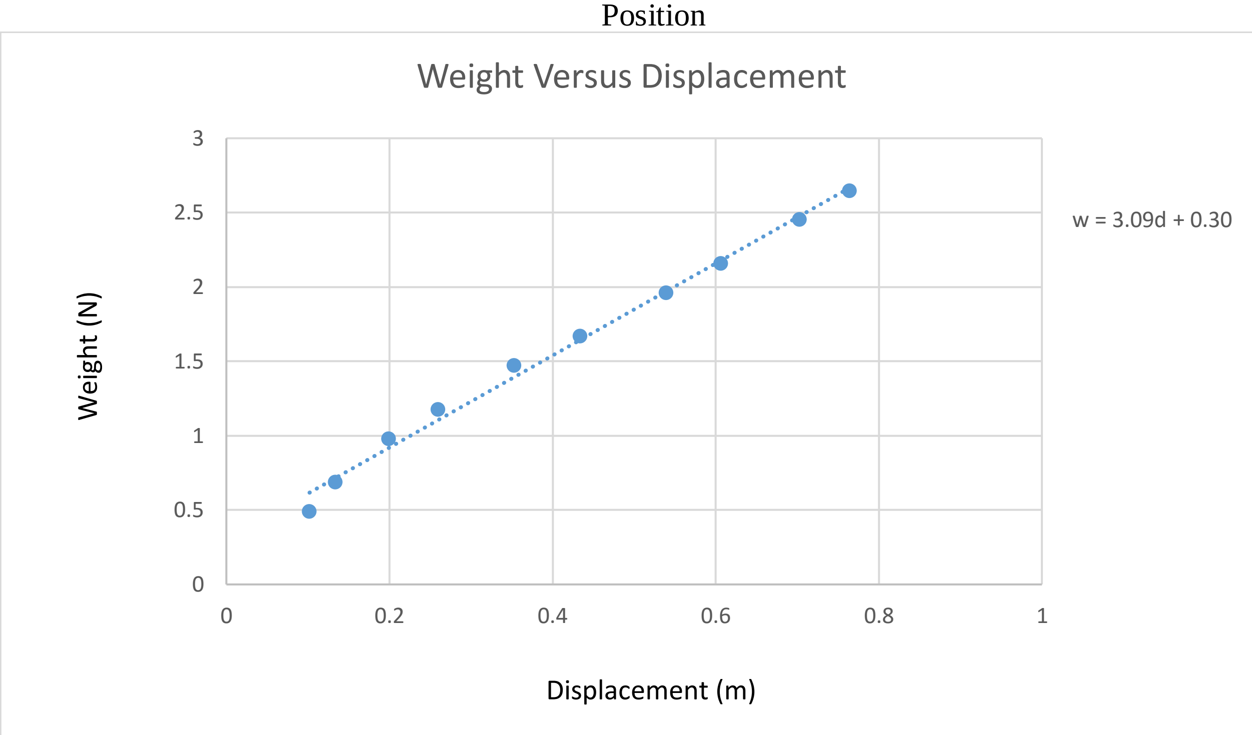
We determined *k* of the cord by measuring the relationship between the force acting on the system (the weight of the hanging masses) and the displacement (the equilibrium position of the cord for each hanging mass – the unstretched position of the cord). This bungee sample uses an approximation of Hooke's law, $mg = k(x_o - x_l)$.

Table 1

Mass ± .02 (kg)	**Displacement or equilibrium position - unstretched position ± .02 (m)**	**Weight ± .02 (N)**
.05	.10	.49
.07	.13	.69
.10	.20	.98
.12	.26	1.18
.15	.353	1.47
.17	.434	1.67
.20	.54	1.96
.22	.61	2.16
.25	.70	2.45
.27	.77	2.65

This table displays the different hanging masses, their displacement, and their weight.

Graph 1: Weight of the Hanging Mass Versus Displacement of the Equilibrium Position to the Unstretched Position



This graph displays the weight of the hanging masses versus the displacement of the bungee cord sample. The slope of the graph is an approximation of *k* for the cord.

Linear Equation: w = 3.09d + .30
Uncertainty for slope: .09
Percent uncertainty: 2.91%

Uncertainty for y-intercept: .04
Percent uncertainty: 13.33%

The uncertainties and percent uncertainties for slope and the y-intercept were found from the regression analysis performed on Graph 1.

The experimental value of interest from the graph and its equation was the slope that measured the relationship between weight and displacement. The slope is an approximation of *k* of the cord. The slope from the graph and its equation was 3.09. Its uncertainty was .09, and its percent uncertainty was 2.91%.

The purpose of this lab was to determine *k* of the cord. By measuring the force on the system versus the displacement, we were able to determine a *k* from an approximation of Hooke's law $mg = k(x_o - x_l)$. The *k* of the cord found from the slope of the graph measuring force versus displacement was 3.09.

<u>Discussion</u>

We don't know the accepted value, which is the true spring constant of the cord. This is due to the fact that the ultimate goal of the bungee challenge is to design a bungee experience that will allow a raw egg to come as close to the ground as possible without damage. Therefore, a good reflection of the accuracy our experimental results will be creating a quality bungee cord experience using the experimental results from part 1 of the bungee challenge. Our egg is more likely to avoid damage if the *k* determined now is close to the spring constant of the bungee cord that will be used in the final test.

The uncertainty *k* = 3.09 was .09, and the percent uncertainty was 2.91%. The uncertainty for the y-intercept was .04 and the percent uncertainty was 13.33%. The uncertainty and percent uncertainty for the slope, which is an approximation of *k* for the cord, were relatively small, and thus reasonably acceptable. A way to test this value for error would be to predict the displacement of masses not used in the experiment. If *k* is accurate, the actual displacement of the mass will be the same as the predicted displacement.

Some sources of uncertainty in the results are the possibilities of overstretching the bungee cords, leaving the mass hanging on the cords for too long, and fatiguing the cords more than necessary. Overstretching the cords, or exceeding four times their original length, can lead to the cords taking longer to recover their original length, or stretch permanently. This is also true of leaving the mass hanging on the cords for too long and fatiguing the cords more than necessary. All of these things could have contributed to a smaller *k* than the accepted value. If we overstretched or overfatigued the cords in any way before or during the experiment, the cord could have taken longer to recover its original length or been stretched permanently.

We did find an approximate value for *k* of our cord. It was equal to the slope of a graph measuring weight versus displacement. Our results were in agreement with the theory of Hooke's law that states that the spring constant determines the elasticity of a spring. Because of the low uncertainty and percent uncertainty for our experimental value of interest, we deemed our results acceptable.

<u>Conclusion</u>

This experiment revealed that it's possible to find an approximate spring constant from a bungee cord by measuring the weight versus displacement of a system consisting of a hanging mass and a bungee cord. We found our spring constant to be the slope of the graph measuring weight versus displacement. It had a value equal to 3.09. This value can be used in our final test with the raw egg when we design a quality bungee experience. If we know an approximation of the spring constant for our bungee cord used in the final test, we can use this value (along with the height from which the egg will be dropped, the mass of the egg and its container, and the length of the bungee cord) to allow the egg to come as close to the ground as possible without actually impacting it or decelerating too rapidly.

On my honor, I have neither given nor received any unacknowledged aid on this assignment.

Pledged: Juliana Kerper