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Determining the relationship between number of cords and the K constant

Abstract

The purpose of this experiment was to determine whether or not the relationship between the K constant of a system and the number of cords that comprised the system was linear. Hooke's law states that the spring constant of a system comprised of two springs will be equal to the sum of the individual K constants. To test this we first found the k constant of one cord by hanging varying masses from the cord and measuring the displacement from equilibrium. We then entered this data into excel and determined the k constant from the slope of the resulting graph. This process was then repeated with other systems of equal equilibriums but varying numbers of cords. The result of the above experimentation was a graph that related the k constant to the number of cords and exhibited a modified Hooke's law behavior. The behavior is said to be modified because the bungee cords, while similar to springs, do not act exactly the same. Due to this small variation in behavior, the results of this experiment can be used to give a general estimate of the k constant of of a system comprised of several cords.

Introduction

The purpose of this experiment was to determine if there was a linear relationship between the number of cords in a system and the systems k constant. As Hookes law states, springs in parallel should have a total k constant equal to the sum of the two springs k constants. The main equation that was utilized in this experiment was:

$$F=k\,x$$

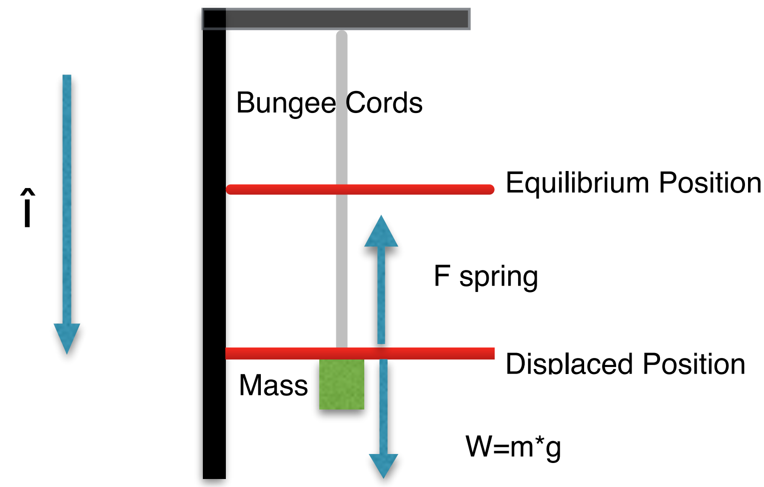
with F being the force applied to the system (mass times gravity of the object hung from the bungee cord), K being the spring constant of the system, and x being the distance from equilibrium.

Hypothesis: It was expected that the spring constants of the varying systems would display a linear relationship. That is, the k constant of a 2 bungee cord system should be twice the k constant of 1 cord.

Methods

To determine wether or not the bungee cords exhibit Hooks law behavior we tested several systems, each comprised of a different number of bungee cords. With each system several masses were hung and the displacements from the equilibrium position were measured. The data was then entered into excel and graphs which plotted force (mass times gravitational constant) against displacement were produced. through analysis of the slopes of these graphs the spring constants of the systems could be deduced.

Diagram



Setup and Procedure

We used a system consisting of a tall stand, bungee cords, and a hook like mechanism which attached to the cords and was used to hold masses. We began by attaching a single cord to the tall stand and measuring the cords equilibrium position. We then hung various masses to the cord and measured the distance the cord stretched from the equilibrium position. Once we varied the mass 5 times we added an additional cord to the system, keeping the same equilibrium position, and once again began to hang masses from the system. We continued this process until we had collected data for the system made up of 4 cords. All the data was then entered into excel and graphs where produced which plotted the force applied to the system (mass times gravitational constant) to the displacement. From these graphs we were able to determine the individual K constants of each system, found to be the coefficient of the x term. We then took this calculated data and made a graph of K constants vs Number of cords to determine if the relationship between the two was linear as predicted by Hookes law.

<u>Results</u>

Data was collected by measuring the displacement from equilibrium of several systems when the masses attached to the systems were varied. This data was then entered into excel and graphs where produced. From these graphs the K constants of each system were determined. These K constants were then also graphed to determine wether or not the relationship between k constant and number of cords exhibits linear behavior.

Table 1: 1 Cord

Mass (g)	Force (N)	Displacement (m)
50	0.4905	0.102
70	0.6867	0.162
100	0.981	0.253
120	1.1772	0.35
150	1.4715	0.493

The above table shows the displacements from equilibrium when varying masses were hung from a single bungee cord. The equilibrium position was .49 m.

Table 2: 2 Cords

Mass (g)	Force (N)	Displacement (m)
100	0.981	0.124
150	1.4715	0.198
200	1.962	0.29
250	2.4525	0.405
300	2.943	0.535

The above table shows the displacements from equilibrium when varying masses were hung from two bungee cords. The equilibrium position was .49 m.

Table 3:3 Cords

Mass(g)	Force (N)	Displacement (m)
150	1.4715	0.08
250	2.4525	0.175
300	2.943	0.242
350	3.4335	0.302
400	3.924	0.377

The above table shows the displacements from equilibrium when varying masses were hung from three bungee cords. The equilibrium position was .49 m.

Table 4:4 Cords

Mass (g)	Force (N)	Displacement (m)
250	2.4525	0.107
350	3.4335	0.184
450	4.4145	0.287
550	5.3955	0.389
650	6.3765	0.525

The above table shows the displacements from equilibrium when varying masses were hung from four bungee cords. The equilibrium position was .49 m.

Table 5: K constants

Number of Cords	K Constant
1	2.487
2	4.7087
3	7.3665
4	9.3341

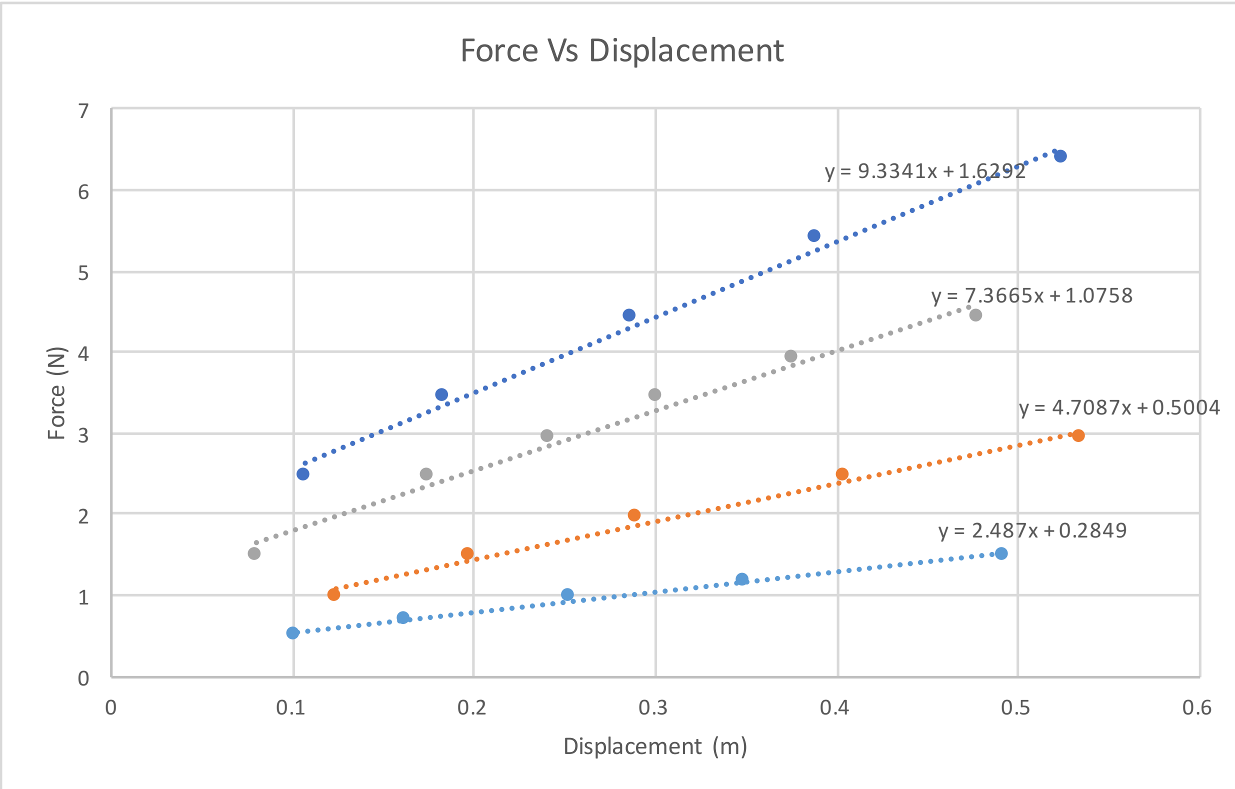
The above table shows how the K constants vary depending on the number of cords. The constants in the table were found to be the coefficients on the x values of the graphs of force vs displacement.

Table 6: Variance in the Y intercepts

Number of Cords	Y Intercept
1	0.2849
2	0.5004
3	1.0758
4	1.6292

The above table shows who the y intercept varies with the number of cords. Because the cords do not act exactly as springs they therefore do not strictly obey Hookes laws. Because of this, whenever trend lines were applied to the graphs of force vs displacement they were quite inaccurate because they attempted to go through the origin. however whenever the y intercept was not set to (0,0) they fit the points much better.

Graph 1: Force vs Displacement



The above graph shows that the relationship between force applied and displacement from equilibrium is linear, as expected by Hookes law F=kx. The lowest line, the light blue one, represents 1 cord, the orange line represents 2 cords, the grey represents 3 cords, and the dark blue represents 4 cords.

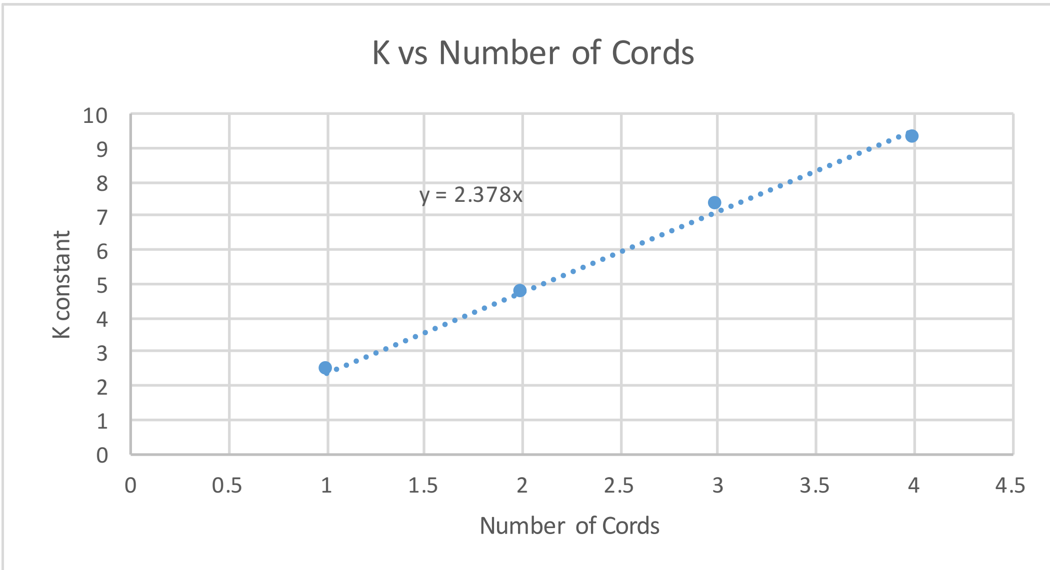
K 1 cord= 2.487 standard error .1371 percent error

K 2 cords= 4.7087 standard error .38 percent error 8%

K 3 cords=7.3665 standard error .657 percent error 7%

K 4 cords= 9.3341 standard error .53 percent error 6%

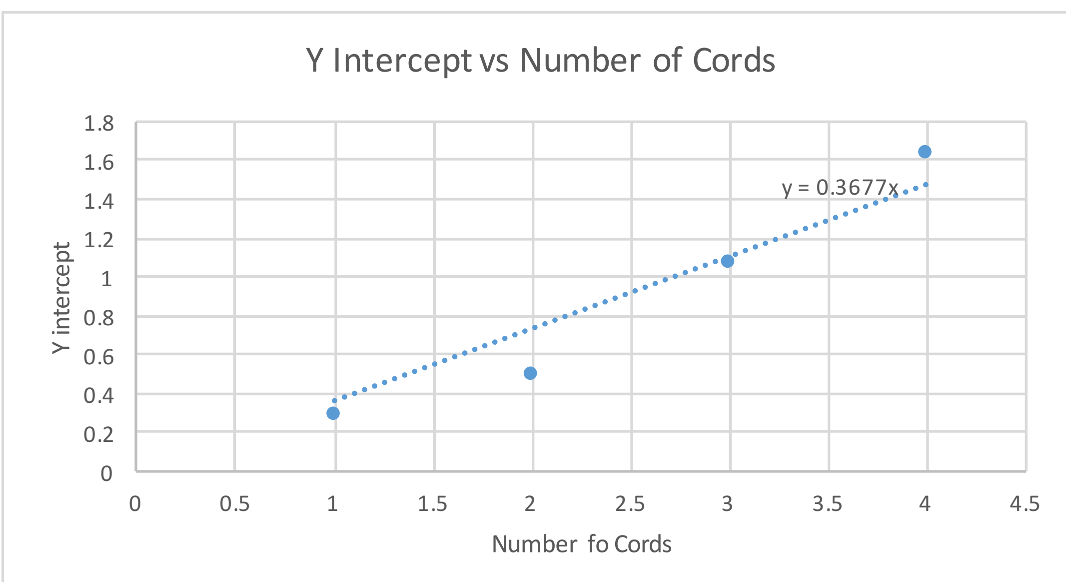
Graph 2: K vs Number of Cords



The above graph shows the relationship between K constant and the number of cords in the system. It can be seen above that the relationship is quite linear. The value of interest in the above graph is the coefficient on the x term.

experimental value 2.37 standard error .089 percent error 4%

Graph 3: Y intercept vs Number of Cords



The above graph attempts to determine a relationship between the y intercepts of each curve and the number of cords. It can be seen that the relationship is not quite linear, however there is an upward sloping trend. The experimental value of interest is also the coefficient of the x term.

experimental value .3677 standard error .059 percent error 16%

From the above tables and graphs it can be seen that while the bungee cords do not adhere strictly to hooks law for springs in parallel, they do exhibit a modified version. The "modification" made to the law is found in the variance in the y intercepts of the different systems. As the k constant increased the value of the y intercept also increased.

Discussion

From this experiment it can be seen that the experimental values of interest, the k constants of each system, behave according to a modified version of Hookes law for springs in parallel. This can be seen in the graph that plots the number of cords against the k constant. It is stated in Hookes Law that the spring constant of a system consisting of 2 identical springs should be equal to 2 times K. This being said, in the ideal case of a graph of number of strands vs k constant, the coefficient of the x term should be 2, however we found it to be 2.378. While this value does vary a large amount from 2, the graph still exhibited a linear relationship.

Error Analysis

experimental K value of 2 cords= 4.71 Accepted value of 2 cords= 4.974 % error= 6%

experimental K value of 3 cords= 7.37 Accepted value of 2 cords=7.461 % error= 1%

experimental K value of 4 cords= 9.33 Accepted value of 4 cords= 9.948 % error= 7%

For each of the values above, the percent uncertainty was greater than or equal to the percent error. This means that the results for k constants found from this experimentation can be deemed accurate within the experimental uncertainty.

experimental relationship between k constant and number of cords = 2.387
Theoretical relationship = 2 %error = 19%

The above values show that the constant found to represent the relationship between number of bungee cords and the k constant of a system vary greatly from the theoretical value. Because the %error is larger than the %uncertainty, the relationship found would not be accepted to model springs in parallel.

Graph 3: This graph only serves the purpose of illustrating the general upward trend of the y intercepts when the number of cords increases. While the graph has a linear fit trend line, it is clear that the line is not linear and rather exhibits the behavior of something more similar to a power function.

Sources of Uncertainty

Uncertainty can be attributed to several sources. To begin with, as the experiment progressed the bungee cords were subjected to more and more force, stretching the cords farther and farther. Over time this repeated stretching could change the equilibrium position of the cord, therefore changing the displacements measured for each mass and subsequently the k constants that were calculated. Furthermore, the knots that were used to attach the cords to the stand structure and the hooks to the cords do not have the same k constant as the rest of the system. This variance causes the masses to hang from slightly different displacements than they would if the k constant of the entire system were equal.

It was hypothesized that the k constant of a system comprised of 2 springs should be twice that of a stem comprised of 1 spring. The data found has indeed supported said hypothesis, with the k constant of a system exhibiting a linear relationship with the number of cords in the system.

<u>Conclusion</u>

Through experimentation with the number of cords that comprise a system and the displacement of the system when masses are hung from it, it was found that the k constants of the different systems vary according to a linear relationship with the number of cords that it is made up of. This conclusion is in agreement with Hooke's Law for springs in parallel, however since bungee cords do not behave exactly as springs do, a modification had to be made in which the y intercepts of the graphs of Displacement vs Force were not through the origin. Furthermore, whenever the varying k constants for each system were graphed, they exhibited a linear relationship as expected by Hooke's Law. This data can be used to calculate the number of cords that should be used in a system for tests such as the egg drop in which the egg should come as close to the ground without making contact.