Lab Report Outline—the Bones of the Story

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TITLE:

Determining the Value of *k* for a Bungee Cord

ABSTRACT:

In this experiment, a bungee cord was treated as a spring which could be modeled by Hooke's law, $F_{spring} = -kx$, and the total value of *k* was determined for various lengths of the cord. This was done by hanging metal weights from a hook tied to the end of a given length of cord, measuring the displacement of the cord for each amount of added mass, and graphing the displacement versus the total force on the cord to yield the value of *k*. The values of *k* determined were graphed versus the initial length of cord used and versus one over the initial length of cord used. Finally, a similar test was performed using two strands of bungee cord in order to determine how that affected the value of *k*. This experiment showed that the value of *k* decreases as the length of bungee cord used increases and increases as the number of strands used increases. It also yielded an equation that can be used to predict the value of *k* for a given length of bungee cord. The fact that the value of *k* changes with the initial length of bungee cord used can potentially be explained by considering the cord to be composed of multiple polymers each acting as a separate spring.

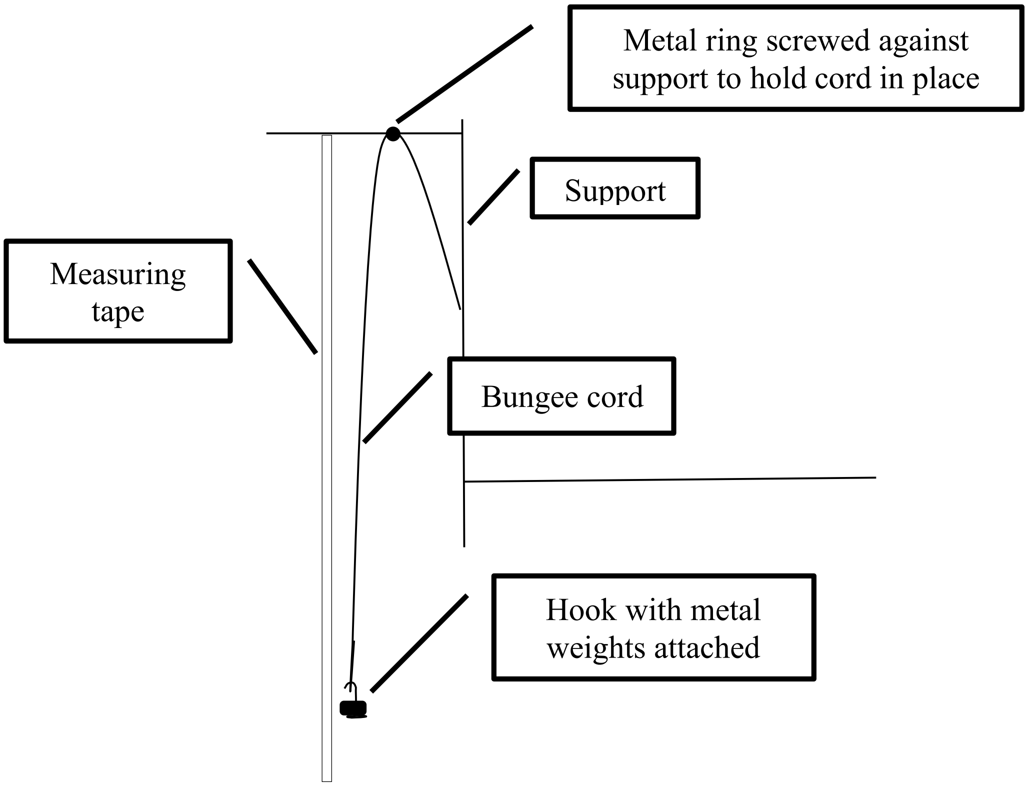
INTRODUCTION:

- The major experiment in Physics 113 is designing a bungee jump for a raw egg, using a bungee cord provided by the instructors. One of the goals of this experiment is to get the egg as close to the floor as possible without letting the egg actually hit the floor. In order to determine how long a piece of the bungee cord to use, it is useful to know how the spring constant of the cord can be changed, and how to determine the value of the spring constant for different lengths of the cord.
- Hooke's law states that $F_{spring} = -kx$. F_{spring} is the x-component of the force exerted by the spring on an attached mass, *k* is the spring constant, which depends only on the spring used, and *x* is the x coordinate of the mass attached to the spring.
- The value of *k* will change as the length of bungee cord used changes.

METHODS:

Metal weights were hung from a length of bungee cord, exerting a force on the cord that caused it to stretch. The displacement of the cord could be graphed with the total force on the cord to yield the spring constant of that length of cord.

Figure 1. Diagram of Setup



- A metal support was attached to a table.
- A metal ring was screwed onto the support so that it held a piece of bungee cord in place with one end hanging freely and the other end secured out of the way.
- A metal hook with a mass of 0.005 kg was tied to the hanging end of the cord.
- A measuring tape was hung from the support so that it hung next to the cord.

- All measurements of bungee cord length were made from the point at which the cord was attached to the support to the bottom of the hook.
- The same person performed all measurements of cord length.
- The initial length of the part of the cord used was measured.
- Metal weights were added to the hook.
- The length of the cord was measured when the weights were attached, and the initial length was subtracted from this length, to measure the displacement of the cord.
- The displacement of the cord was measured for each of six added masses.
- The masses added were 0.050, 0.100, 0.125, 0.150, 0.175, and 0.200 kg. These masses were chosen because they were around the expected weight of the egg and harness, (0.100 – 0.170 kg), that will be used for the bungee jump. For each trial, the total hanging mass was calculated by summing the added mass and the mass of the hook.
- The total force on the cord was calculated by multiplying the total hanging mass by the acceleration due to gravity (9.81 m/s²).
- The displacement of the cord was graphed versus the total force on the cord so that the slope of the trendline would equal the value of *k*.
- This experiment was repeated three more times with different initial lengths in order to determine the value of *k* for a variety of initial lengths.

- The same setup was used to determine the value of *k* for two strands of bungee cord. A loop was made in the cord so that both strands were helping to support the hanging mass.

RESULTS:

The displacement produced by each amount of added mass on each initial length of bungee cord was recorded and graphed with the force produced by that mass to determine the value of *k*.

Figure 2. Initial Length, Force, and Displacement. The force was calculated by multiplying the total mass (added mass plus mass of hook) by the acceleration due to gravity (9.81 m/s^2).

Initial Length (m) ± 0.002 m	Force (N)	Displacement (m) ± 0.003 m
0.203	0.540	0.023
	1.030	0.064
	1.275	0.091
	1.521	0.122
	1.766	0.151
	2.011	0.182
0.407	0.540	0.068
	1.030	0.186
	1.275	0.264
	1.521	0.351
	1.766	0.440
	2.011	0.522
0.672	0.540	0.118
	1.030	0.311
	1.275	0.446
	1.521	0.615
	1.766	0.781
	2.011	0.964
0.922	0.540	0.177
	1.030	0.479
	1.275	0.684
	1.521	0.906
	1.766	1.123
	2.011	1.337

Figure 3. Force vs. Displacement. Unrounded values were used for Force. A linear trendline was added to each series. The slope is the value of *k* for that initial length of bungee cord.

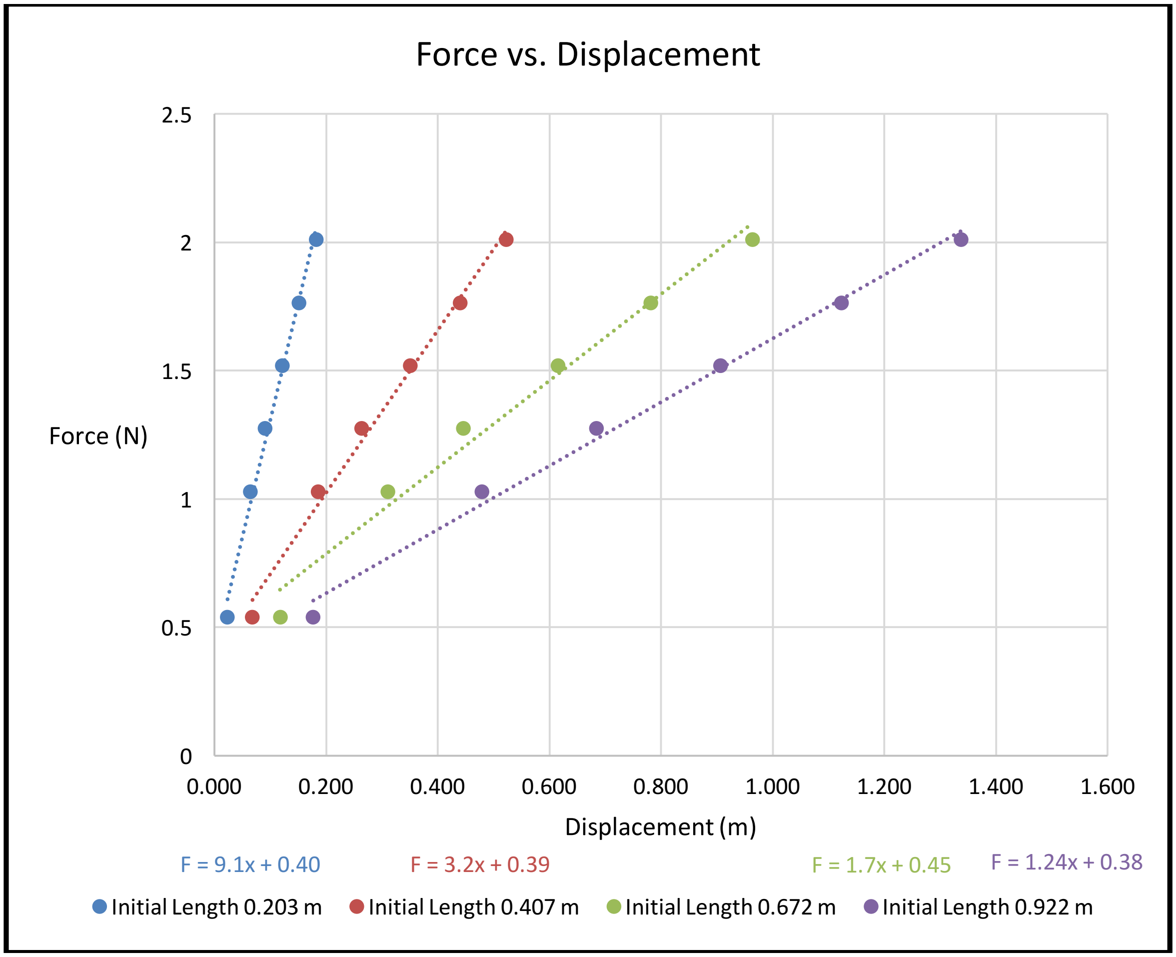


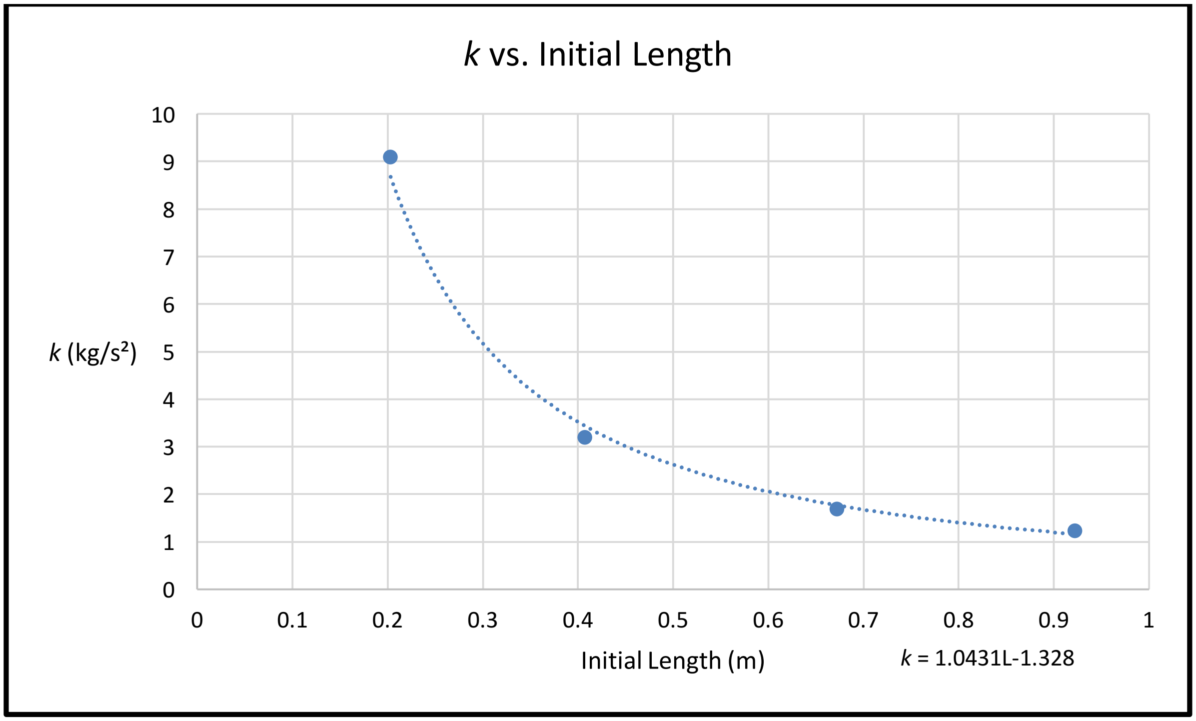
Figure 4. Uncertainties for Figure 3. These uncertainties were obtained using Excel's data analysis tool.

Initial Length (m)	Equation	Uncertainty of Slope (m)	Percent Uncertainty of Slope (%)	Uncertainty of y-intercept (N)	Percent Uncertainty of y-intercept (%)
0.203	F = 9.1x + 0.40	0.4	5	0.05	10
0.407	F = 3.2x + 0.39	0.1	4	0.05	10
0.672	F = 1.7x + 0.45	0.1	7	0.07	20
0.922	F = 1.24x + 0.38	0.05	4	0.05	10

Figure 5. Value of *k* for Each Initial Length

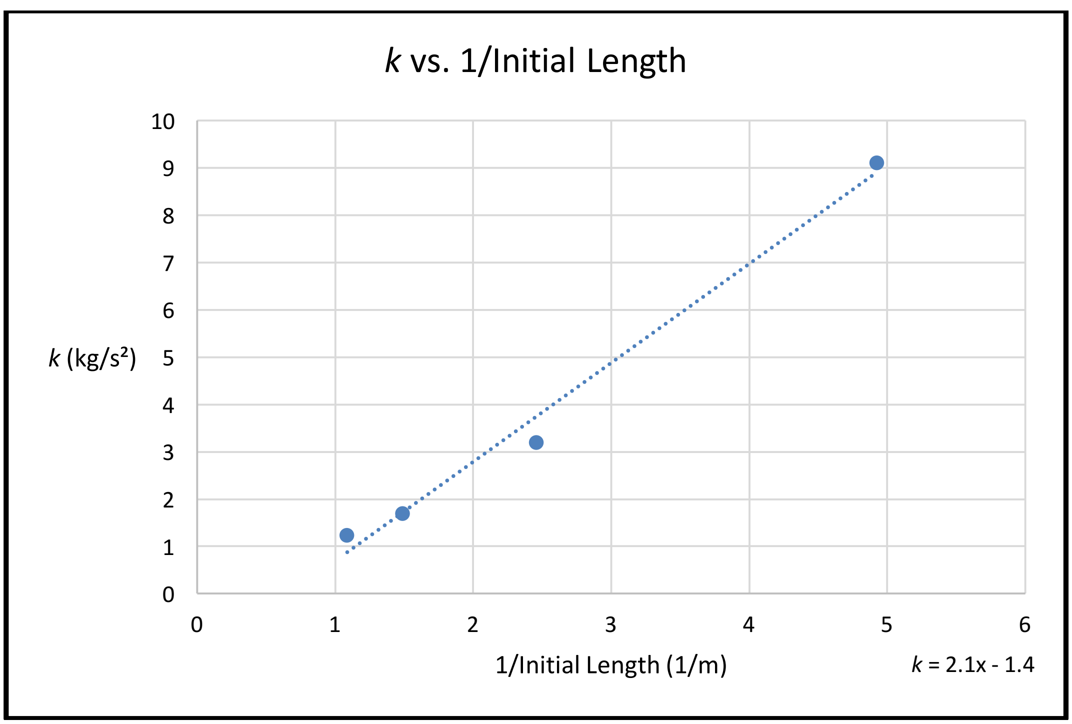
Initial Length (m)	*k* (kg/s^2)
0.203	9.1
0.407	3.2
0.672	1.7
0.922	1.24

Figure 6. ***k* vs. Initial Length.** A power trendline was fitted to the data.



$$k = 1.0431L^{-1.328}$$

Figure 7. ***k* vs. 1/Initial Length.** This is a linearization of the preceding graph. The equation provided by this graph will enable calculation of the value of *k* for a given length of cord.



$$k = 2.1x - 1.4$$

Figure 8. Uncertainties for Figure 7. These uncertainties were obtained using Excel's data analysis tool.

Uncertainty of Slope	Percent Uncertainty of Slope	Uncertainty of y-intercept	Percent Uncertainty of y-intercept
0.2	8	0.5	-30

Figure 9. Comparison of *k* for Single and Double Strands of Cord

# of Strands	Initial Length (m) ± 0.002 m	Force (N)	Displacement (m) ± 0.003 m
1	0.203	0.540	0.023
		1.030	0.064
		1.275	0.091
		1.521	0.122
		1.766	0.151
		2.011	0.182
2	0.203	0.540	0.010
		1.030	0.020
		1.275	0.026
		1.521	0.038
		1.766	0.048
		2.011	0.059

Figure 10. Force vs. Displacement for Single and Double Strands of Cord. The slope is the value of *k*.

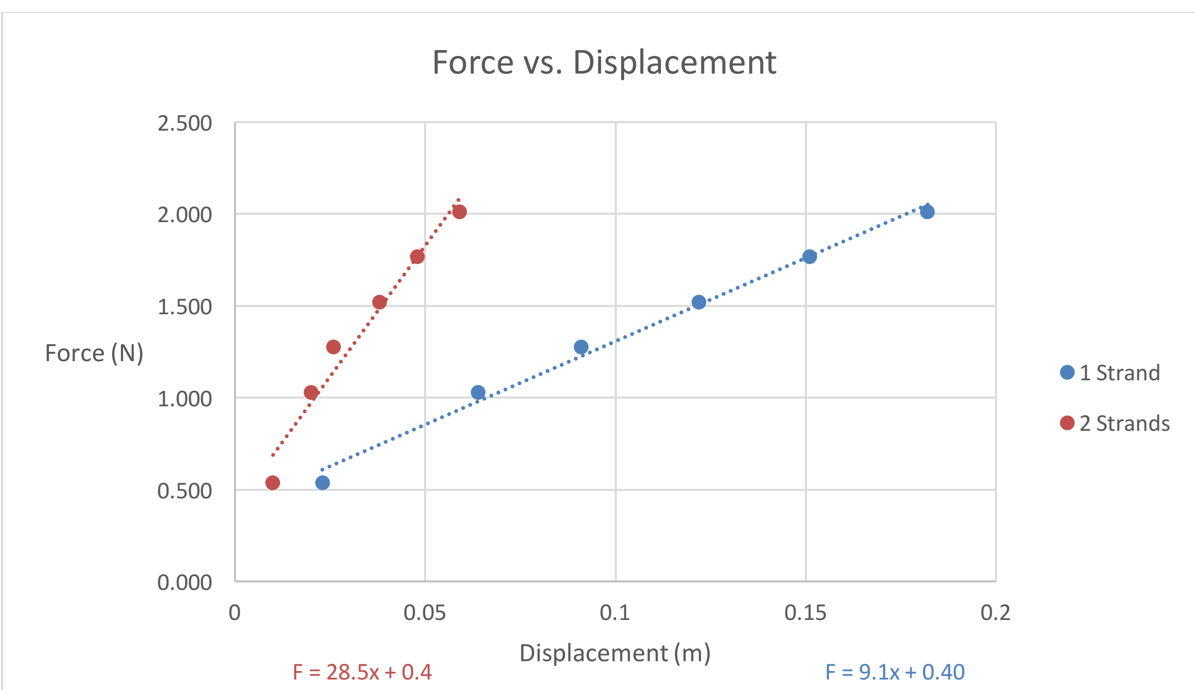


Figure 11. Uncertainties for Figure 10. These uncertainties were obtained using Excel's data analysis tool.

Number of Strands	Equation	Uncertainty for Slope	Percent Uncertainty for Slope	Uncertainty for y-intercept	Percent Uncertainty for y-intercept
1	F = 9.1x + 0.40	0.4	5	0.05	10
2	F = 28x + 0.4	3	10	0.1	30

The value of interest is the slope of the graph of *k* vs. 1/Initial Length.

value obtained = 2.1

uncertainty of experimental value(s) = 0.2 % uncert= 8%
The uncertainty was obtained by performing Excel regression on the graph of *k* vs. 1/Initial Length.

The equation *k* = 2.1x - 1.4 will allow us to calculate the value of *k* for a known length of bungee cord. We also found that doubling the bungee cord approximately triples the value of *k*.

DISCUSSION:

The main uncertainty in this lab came from the measurements of the initial and final lengths of the cord. The fact that each graph of force vs. displacement had a y-intercept shows that Hooke's law, which predicts no y-intercept, does not apply perfectly.

The value of *k* did indeed change as the length of cord changed. This is potentially due to the cord being composed of multiple polymers, each acting as an individual spring. Thus, any given length of cord would consist of multiple springs arranged both in parallel and in series. Changing the initial length of cord would change the number of polymers included and thus change the value of *k*.

CONCLUSION:

This experiment showed that the value of *k* increases approximately according to the equation *k* = 2.1x - 1.4, in which x is one over the length of bungee cord. Furthermore, the value of *k* approximately triples when the bungee cord is doubled.

Knowing how to determine the value of *k* for a given length of bungee cord will aid us in determining how long the bungee cord used in our egg bungee jump project should be.

Report Outlines are *individual assignments*. Cite any work not your own, acknowledge any aid, and pledge the report:
On my honor, I have neither given nor received any unacknowledged aid on this assignment. I acknowledge that I used my physics textbook and my lab manual and that I skimmed multiple articles on Pubmed in order to decide how to use first/third person. I also acknowledge the aid of my three peer reviewers.
Pledged: Lisa Roth