Lab Report Outline—the Bones of the Story

In this course, you are asked to write only the outline of a lab report. A good lab report provides a complete record of your experiment, and even in outline form should convey a coherent and comprehensible story. This is an outline, not a summary. Give the relevant details *throughout—the details that answer the questions a scientifically educated reader might ask while following your story line. The emphasis is on clarity, thoroughness, and relevance, and of course conciseness (being an outline).* ***Report Outlines are individual assignments. Cite any work not your own, acknowledge any aid, and pledge the report.***

Fill in this form for reporting on experiments when required. (Did we say to give the relevant details throughout?) When finished, feel free to delete instructional verbiage or unused parts, for proofreading ease, and reading "flow."

Your name and your lab partner(s): Laura Bruce **Section:** W **Date: 11/15/2016**

TITLE:

What is the relationship between the unstretched bungee cord length and its spring constant?

ABSTRACT:

The overall purpose of this experiment was to investigate how the spring constant k varies with the elastic bungee cord length. To determine this relationship, we first confirmed that the bungee cord can be roughly modeled after Hooke's Law ($F_{spring} = -kx$) by keeping the bungee cord length constant, hanging various masses from the cord, and measuring the different displacements from the original cord length. The graph weight versus x-displacement resulted in a linear function with the slope representing the spring constant k, so we assumed that the bungee cord can be modeled after Hooke's Law. We repeated this same process four more times each with a different bungee cord length. Then, each individual k value was plotted against its corresponding bungee cord length, and the graph yielded a power function. When linearized, k was found to be inversely proportional to l, and our equation was k = 1.14(1/l) - 0.46. The uncertainty was 4%. Assuming our equation is accurate, we will be able to predict the spring constant k for any bungee cord length for the Bungee Challenge. Knowing the spring constant k and utilizing the CWE theorem, we can determine the maximum elongation the cord can undergo so that its maximum force does not exceed three times its weight.

INTRODUCTION*:*

For the bungee challenge, we will need to know whether the bungee cord can truly be modeled after Hooke's Law, and if it can, we must also determine the relationship between the spring constant k and the bungee cord length. If we find this relationship, we can accurately predict how the egg will behave with different bungee cord lengths.

Relevant equations that pertain to this set-up:

Hooke's Law: $F_{spring} = -kx$
Weight: $F_{weight} = mg$

In this specific setup,

$F_{weight} – F_{spring} = 0$
$F_{weight} = F_{spring}$
$m_{hanging}g = kx$

$m_{hanging}$ is the mass of the hanging mass measured in kg
g is the local gravity of the Earth measured in meters per second squared
k is the spring constant of the bungee cord measured in N/m
x is the displacement of the cord from its initial, non-stretched length to its final, stretched position from the mass hanging, measured in meters

Theoretical background:

Since we are determining the spring constant k in a static equilibrium system, we can set the force of the weight equal to the force of the bungee cord modeled after Hooke's Law. Therefore,

$mg = kx$, or
$W = kx$

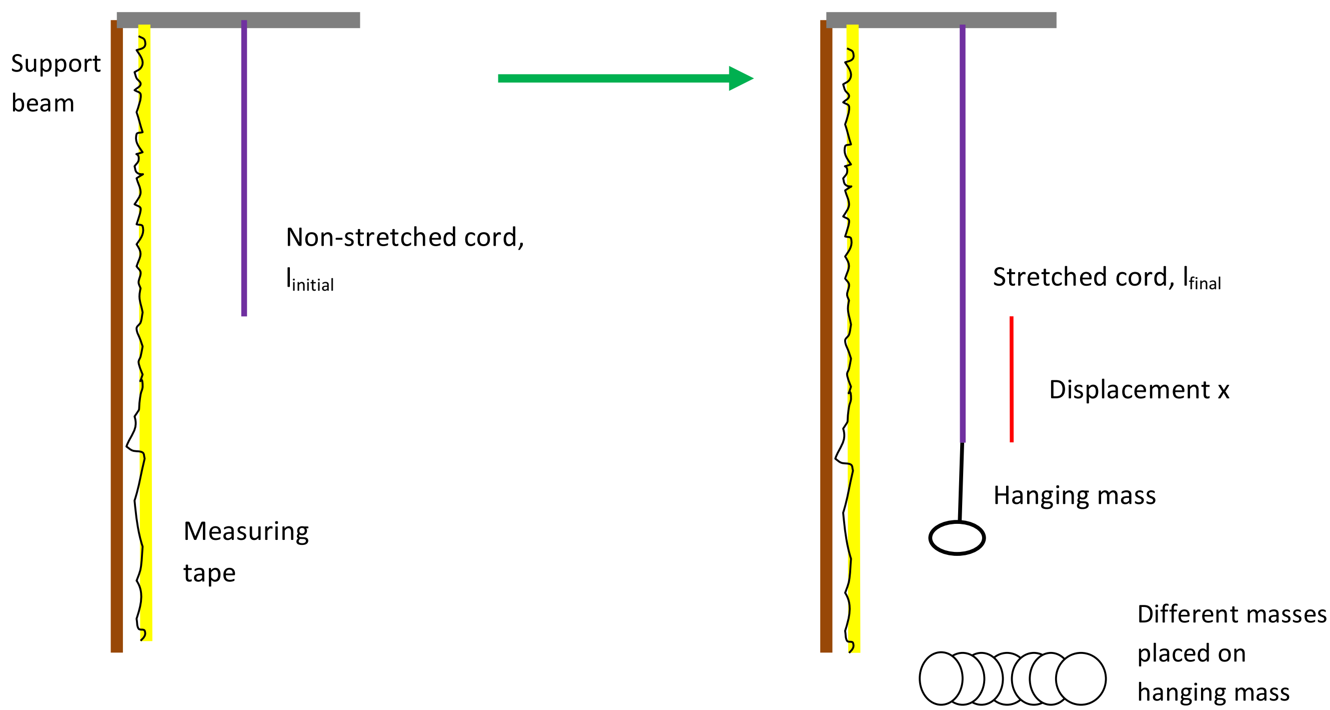
Expectations:

If we rearrange Hooke's Law $F= kx$, then $k = F/x$, where k is inversely proportional to the x displacement of the stretched and non-stretched bungee cord. We expected that k should also be inversely proportional to the initial, non-stretched bungee cord length.

METHODS:

We determined the relationship between the spring constant k and cord length by varying the mass, keeping the cord length constant, and measuring the different displacements from the non-stretched cord length. We created an equation relating the weight with the x displacement for non-stretched cord length, where the slope represents k. We repeated this process four more times, and then, we plotted the graph spring constant k versus non-stretched cord length.

Figure 1: *Non-stretched and stretched bungee cord*. *The displacement between the length of the non-stretched bungee cord and the stretched bungee cord is what will be used to determine the spring constant k.*



Setup:

A horizontal metal rod is attached to a vertical support beam. The measuring tape and bungee cord are closely fastened to the metal rod. A non-stretched cord length is determined. A hanging mass is closely tied to the cord, and various masses are added to the hanging mass, which result in different x displacements between the non-stretched cord and stretched cord.

Procedure:

- We fastened the measuring tape to the vertical metal beam.
- We tightly knotted the bungee cord to the vertical beam and made a small knot at a specific point on the cord.
    - The measured distance between the two knots was the non-stretched bungee cord length.
- We connected the hanging mass to the lower knot.
- We measured and recorded the displacement x between the non-stretched bungee cord and stretched bungee cord for each different mass.
- We repeated this process four more times each with a different non-stretched bungee cord length.
- We created the graph the spring constant k versus the non-stretched bungee cord length to find a relationship.
- The data was linearized by plotting the spring constant k with one over the length of the non-stretched bungee cord.

RESULTS:

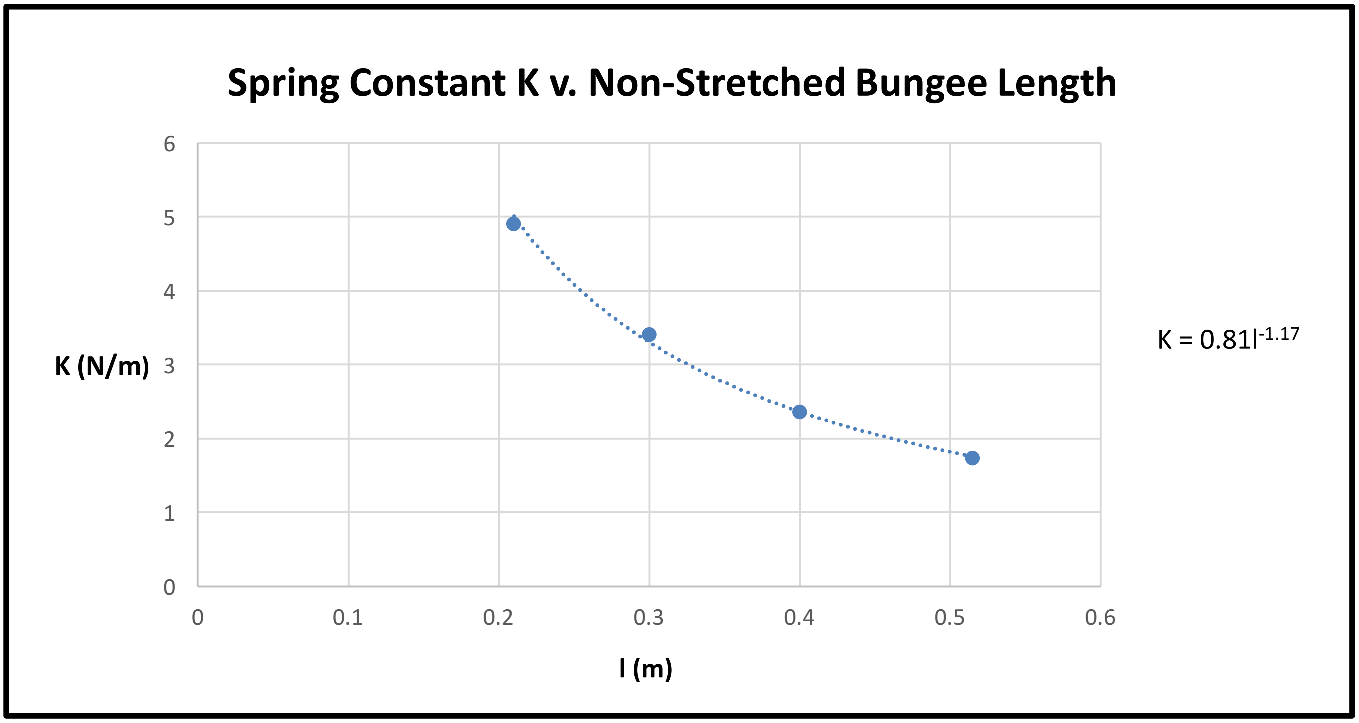
We chose five different non-stretched bungee cord lengths, and for each length, we created an equation with weight directly proportional to the x displacement. See Figure 5. Then, we identified the slopes of each of the five equations as their respective spring constants k, and we plotted the spring constant values with their corresponding non-stretched bungee cord lengths. We found that there k is indirectly proportional to the non-stretched bungee cord length.

Table:

Figure 2: ***Spring constants (k) for five different non-stretched bungee cord length values (l_1-l_5)***. *Five different values of k were determined by varying the mass of the hanging mass and finding a direct relationship between the weight and x displacement.*

Experimental spring constants, ***k*** (N/m) (±0.05 N/m)	Non-stretched bungee cord length, ***l*** (m) (±0.05 m)		1/Non-stretched bungee cord length,**1/*l*** (m) (±0.05 m)	
3.41	l_1	0.30	$1/l_1$	3.33
4.91	l_2	0.21	$1/l_2$	4.76
2.36	l_3	0.40	$1/l_3$	2.50
1.73	l_4	0.52	$1/l_4$	1.96
2.39	l_5	0.44	$1/l_5$	2.27

Figure 3: ***Spring Constant K versus Cord Length***. *For each cord length, a spring constant k was determined by varying the weight of the hanging mass. The relationship between the spring constant and its corresponding non-stretched bungee length is a power function.*

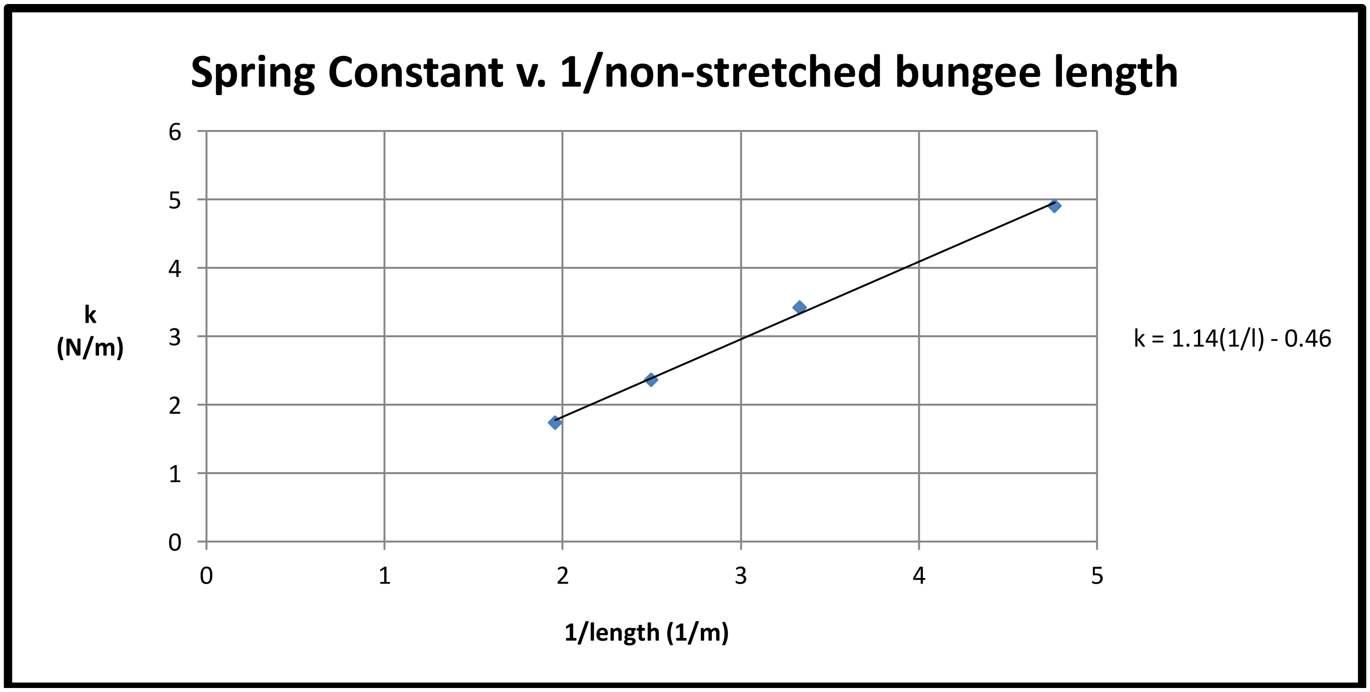


Equation of the curve-fit from the graph:

$K = 0.81l^{-1.17}$

***Linearized* graph:**

Figure 4: ***Spring Constant K versus 1/Cord Length***. *The coefficient in the equation is our experimental value of interest. The linearized function proves that the spring constant k is indirectly proportional to the bungee length.*



Linear equation from linearized graph:

k = 1.14(1/l) - 0.46

Use *Excel* regression analysis on any graph that has a **linear** fit only (see EG), to obtain:

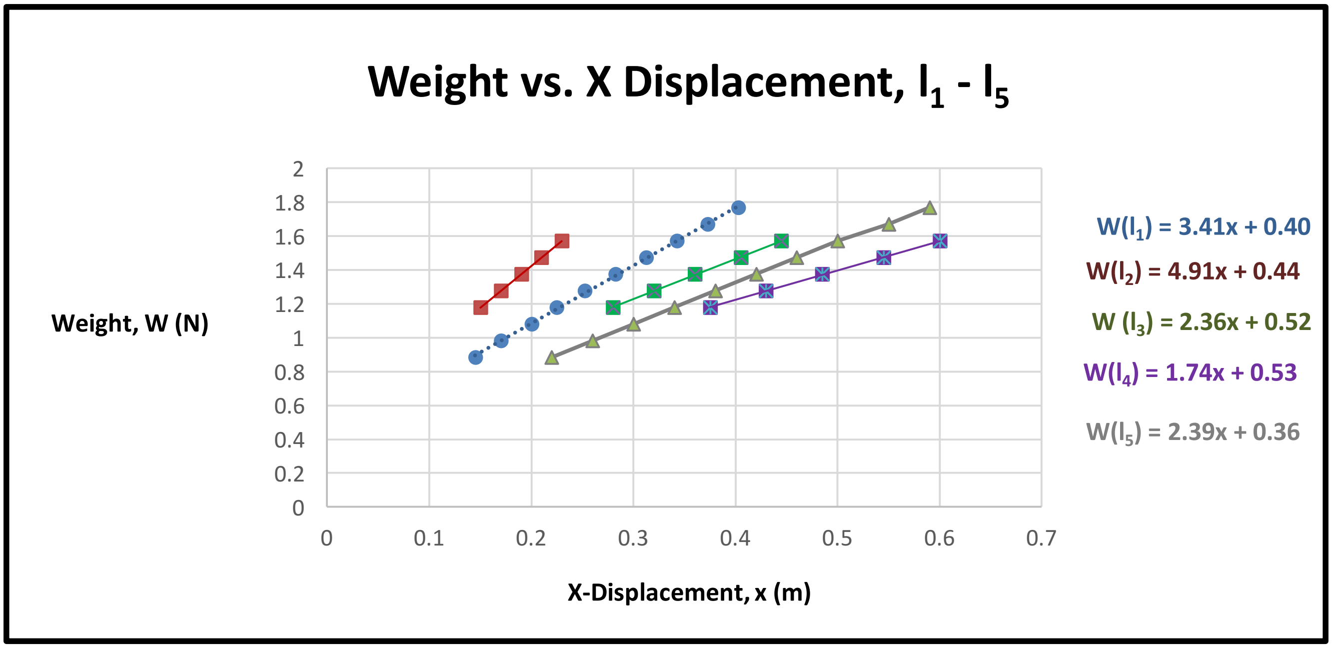
uncertainty for slope= ±0.04 N   % uncert= 4%

uncertainty for y-intercept= ±0.12 N/m   % uncert= 26%

*significant y-intercept

<u>Further graph for completeness:</u>

Figure 5: ***Weight vs. X Displacement, $l_1 – l_5$***. *Varying the masses, we plotted weight against x-displacement, so that it models the equation mg = kx. The coefficient in each of the five equations is the experimental k value for each non-stretched bungee cord length.*



Identify experimental value of interest

The experimental value of interest is the slope of the equation of k versus 1/bungee cord length because the value directly relates the spring constant to one over the bungee cord length. The units of the slope are those of the spring constant over those of the non-stretched bungee cord length, or (N/m)/(1/m) = N. For the bungee challenge, this equation, if accurate, allows someone to find the value of k for a predetermined length of bungee cord.

value obtained = 1.14 ± 0.04 N

uncertainty of experimental value(s) = ±0.04 N   % uncert= 4%

name the technique used for propagation of uncertainty (see *UG*), or where/how uncert was obtained: **Excel regression analysis**

Other ***pertinent info*** for the reader (who may not have done this experiment) to follow along:

We took out the 0.44 m non-stretched bungee cord length and 2.39 N/m spring constant from the graph Spring Constant K vs. Bungee Length l because it did not fit any of the trendlines, whereas all the other points neatly fitted a power function. We suspect that 0.44 m is an inaccurate measurement of the cord length.

Summarize Results:

By plotting the weight against x displacement for a fixed bungee cord length, the slope of the function was determined as the spring constant k. Each k value was plotted against its correspondent bungee cord length l. The linearized relationship between k and l was found to be k = 1.14(1/l) - 0.46. The uncertainty of the coefficient was 4%.

DISCUSSION:

Acceptability of uncertainty and test for error:

The uncertainty of the slope of the linearized equation k = 1.14(1/l) - 0.46 was 4%. Our uncertainty is precise, as the four data points on the graph spring constant v. 1/non-stretched bungee cord length closely align with a linear function, but it is still unknown if the slope of the function is acceptable. There is not a model to compare the linearized function with. Also, there is a significant y-intercept, so the actual, unknown k value could be significantly different from our experimental value. Our function may not be acceptable since there are only four data points.

To determine a test of our value, we would first choose a new bungee cord length. Then, we would calculate the value of k as we did for the previous five bungee cord lengths. This would be our experimental k value. We would plug the new bungee cord length into the function k = 1.14(1/l) - 0.46. This would be our accepted k value. If the values of the experimental and accepted k values are similar, then we prove that our linearized function can successfully determine the value of k for a determined bungee cord length.

Sources of uncertainty:

The greatest source of uncertainty is from measuring the stretched and non-stretched bungee cord lengths. We only measured the non-stretched bungee cord length a single time, and it is highly possible that one of our cord length values was inaccurate.

Also, to connect the bungee with the metal beam and the hanging mass, we had to make two knots. We tried to make these knots as small as possible. However, as more mass was added to the hanging mass, the knots increased in length, and therefore, they added uncertainty to the x displacement measurements. For each non-stretched bungee cord length, we had to make a different knot to connect to the hanging mass, and it is highly possible that the size of the knots significantly varied as we transitioned to another cord length.

The measuring tape was also a significant, horizontal distance away from the bungee cord. We did not want the bungee coming in contact with the tape. This distance made it difficult to make a precise measurement of the non-stretched and stretched bungee cord lengths.

In addition, if we had a wider range of non-stretched bungee cord lengths, we would have a more accurate, linearized equation that determines the value of k for a specific non-stretched bungee cord length.

Any further observations or extenuating circumstances that aid in interpretation or evaluation:

We decided to leave the 0.44 m cord length and 2.39 N/m k value out of the k versus cord length graph because it did not align with any function and skewed the data, whereas all the other cord lengths and k values closely aligned with a power function. We would have gotten a more accurate experimental value of interest if we measured that cord length accurately.

In a couple sentences**, describe whether your main results support your hypothesis.** How well were the results in agreement with theory, expectations, or otherwise deemed "acceptable"? Why/how so, or not?

Yes, most of our main results support our hypothesis. We presumed that k varies indirectly with the non-stretched bungee cord length, and we were correct. Our linearized equation is k = 1.14(1/l) - 0.46 with an uncertainty of 4%. However, our y-intercept, -0.45 N/m is significant, and its uncertainty is 26%. The significant y-intercept proves that our bungee cord cannot be fully modeled with Hooke's Law.

CONCLUSION:

Experimental outcome in terms of purpose:

The relationship between the spring constant k and the non-stretched length of the bungee cord is an inverse proportion. The percent uncertainty of the coefficient in the linearized function k = 1.14(1/l) - 0.46 is 4%.

Implications of these conclusions and next steps proposed:

If our test for error is successful, our linearized equation that determines the value of k for any bungee cord length will be invaluable in the Bungee Challenge. If we can always calculate the spring constant k from any bungee cord length l, we will be able to analyze the behavior of the bungee as it falls using the conservation of work-energy theorem where

$(PE + KE)_{top} = (PE + KE)_{bottom}$
$mgh = (1/2)kx^2$.

If we know the accurate value of k, the mass of the egg, the height at which the egg is dropped, we can determine x, or the amount of elongation that the elastic bungee undergoes. Then, assuming that the bungee can be modeled after Hooke's law, we can equate kx with the force the bungee experiences when it begins to stretch. If the force is close to the value 3mg, we will have determined the maximum amount of elongation of the bungee. This maximum force may require a combination of elastic and inelastic bungee cord.

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.

Pledged:

Laura E Bruce