Lauren Engelbrecht (Partner: Hayden Johnson)

Section: 113_06

Date: 11/14/16

TITLE: How the Length of the Bungee Cord and Mass Affect Maximum Stretch

ABSTRACT: The purpose of this experiment was to determine how various masses affected the maximum stretch of different bungee cord lengths. We used five different lengths and tested four masses at each length. Each individual mass was attached to the bungee cord, and using a video app on an iPad, we recorded the mass being dropped. Using this recording, we were able to find the length of the maximum stretch of the bungee cord. The unstretched/relaxed length of the bungee was subtracted from the maximum length to find the displacement. Using the data collected, we created a Weight vs. Amount of Elongation^2 graph for each bungee cord length. The slope of each of these graphs were then used to create a Slope Vs. 1/Length^2 graph. The equation of this graph provided us with a model that can be used to determine the length of the bungee needed based on the height of the jump. This model will ultimately help us determine the length of our bungee cord when given a specified mass and height of the jump.

INTRODUCTION: The purpose of this experiment was to determine how various masses ($\boldsymbol{m}$) affected the maximum stretch ($\boldsymbol{x_{max}}$) of different bungee cord lengths. In order to do this, we explored how to adjust the CWE Ideal Spring Model, $\boldsymbol{mgh} = \frac{1}{2}\boldsymbol{kx^2}$, to create an experimental model for our bungee cord. For this experiment, $\boldsymbol{h}$ is the height of our jump, $\boldsymbol{k}$ is the spring constant of the bungee, and $\boldsymbol{x}$ is the amount of elongation the bungee undergoes. To find $\boldsymbol{x}$, we found $\boldsymbol{x_{max}}$ and then subtracted the unstretched/relax length of the bungee ($\boldsymbol{x_L}$), so, $\boldsymbol{x} = \boldsymbol{x_{max}} - \boldsymbol{x_L}$. Another important model is the model we created in the Week 1 Bungee Experiment: $\boldsymbol{k = 1.11x_L - 0.198}$. This model allows us to find the value of $\boldsymbol{k}$ for any length of a bungee. We expect that larger masses will cause a greater $\boldsymbol{x_{max}}$ than smaller masses, and bungee cords of shorter length will have a smaller change in $\boldsymbol{x_{max}}$ as masses increase.

METHODS: In order to determine how various masses affect the maximum stretch of different bungee cord lengths, we tested four masses (ranging from 0.075kg—0.15 kg) on five different bungee cord lengths (ranging from 0.1m—0.55m). For each length we found the value of $\boldsymbol{x_{max}}$ by using a slow-motion video app on an iPad.

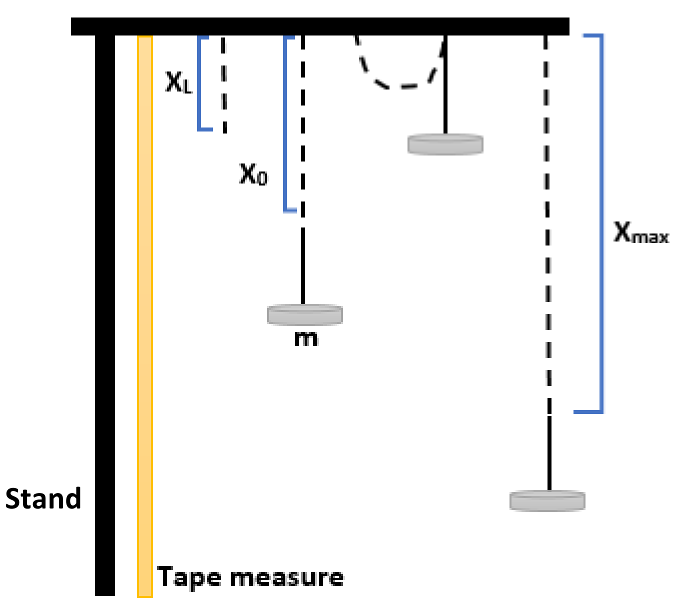

Fig. 1 Diagram of Experimental Setup

Procedure

1. We adjusted the stand at our lab table to easily be able to drop masses attached to the bungee and measure the maximum stretch. Once in a convenient location, we made sure the stand clamps were tight and secure.
2. To hang the bungee on the stand, we tied a slip knot at the top of the cord and hung it on one of the hooks on the top of the stand.
3. Using a measuring tape, we hung it on the stand as well. Close enough to the bungee cord so that when the mass is dropped we can easily take measurements.
4. We then chose the five lengths of our bungee cord we wanted to test. We wanted to have bungee lengths of around 0.1m, 0.2m, 0.3m, 0.4m, and 0.5m.
5. Starting with the 0.1m bungee cord length, we tied another slip knot on the bungee so the distance from the first knot to the second know was about 0.1m.
    a. For the other lengths, the distance between the two slips knots will be equal to the desired length of the bungee cord.
6. We measured then measured the exact length of the upstretched/relax bungee cord.
7. To attach the masses to the bungee cord (masses ranged from 0.075kg—0.15 kg), we put the hanging masses on the bottom slip knot of the bungee.
8. Once the mass was attached to the bungee, it was dropped from the top of the stand where the bungee was tied to.
9. We use an app called Coach My Video, to record the fall of the mass.
    a. We slowed down the recording to find the length of the maximum stretch of the bungee for that mass.
10. To find the amount of elongation (x) of the bungee cord for the specific mass, the unstretched length of the bungee cord was subtracted from maximum length.
11. Steps 5 through 10 were completed for all four masses on each of the five lengths of bungee cords.
12. Once the procedure for all the lengths were completed, a Weight Vs. (Amount of Elongation)^2 graph was created for each length.
13. We then took the slopes of these five graphs and plotted them against 1/Length^2 on a separate graph.

RESULTS: Using the CWE Theorem for an Ideal Spring, $\boldsymbol{mgh = \frac{1}{2}kx^2}$, we decided to plot Weight ($\boldsymbol{mg}$) Vs. (Amount of Elongation)^2 ($\boldsymbol{x^2}$) for each of the five lengths. Knowing this Theorem, we knew the slope of these graphs were $\boldsymbol{\frac{k}{2h}}$. To understand how $\boldsymbol{\frac{k}{2h}}$ varied with length, we plotted $\boldsymbol{\frac{k}{2h}}$ Vs. 1/Length^2.

Amount of Elongation^2 ***(x^2)*** m^2 (±0.001m)	Weight ***(mg)*** N (0.001N)
0.030	0.736
0.044	0.981
0.074	1.226
0.110	1.472

Fig. 2 Amount of Elongation^2 at various masses when x_L= 0.118 m

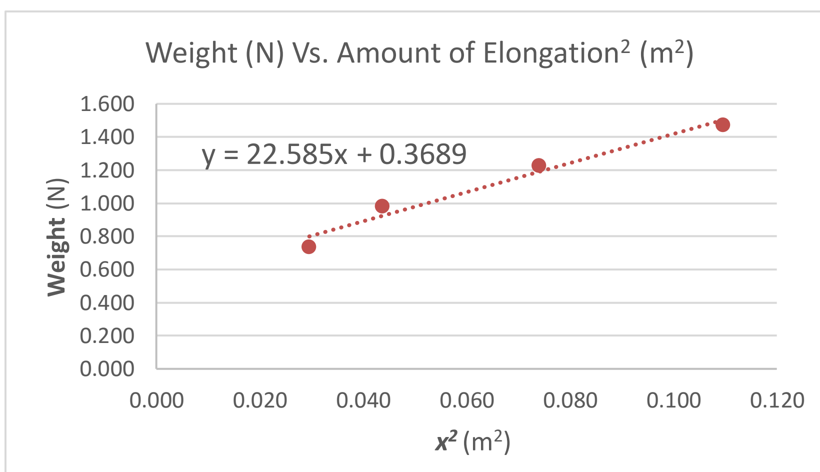

Fig. 3 Graph of Weight Vs. Amount of Elongation^2 when x_L= 0.118 m

Amount of Elongation² ***(x^2)*** m² (±0.001m)	Weight ***(mg)*** N (0.001N)
0.104	0.736
0.192	0.981
0.289	1.226
0.402	1.472

Fig. 4 Amount of Elongation² at various masses when x_L = 0.206 m

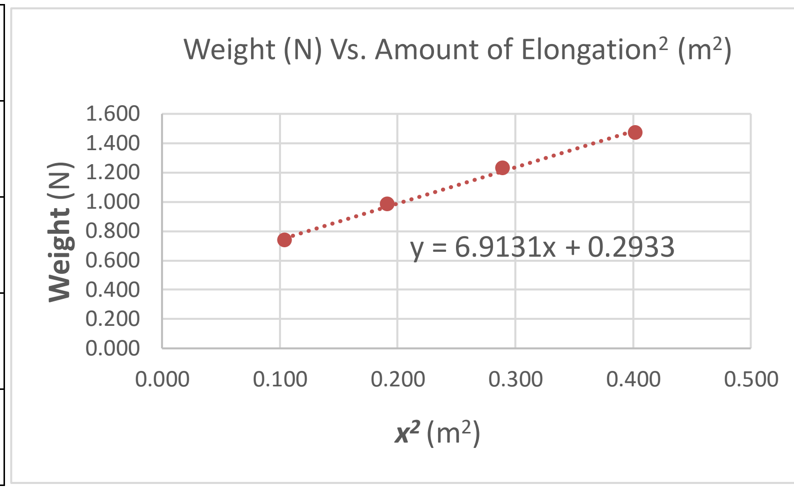

Fig. 5 Graph of Weight Vs. Amount of Elongation² when x_L = 0.206 m

Amount of Elongation² ***(x^2)*** m² (±0.001m)	Weight ***(mg)*** N (0.001N)
0.204	0.736
0.334	0.981
0.521	1.226
0.750	1.472

Fig. 6 Amount of Elongation² at various masses when x_L = 0.282 m

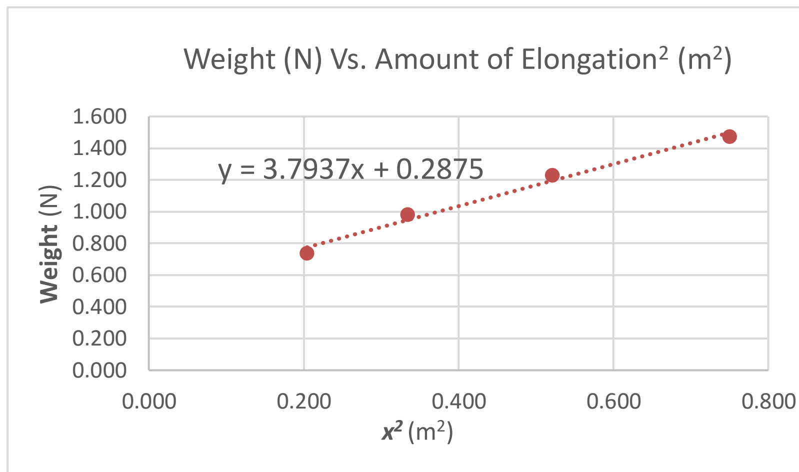

Fig. 7 Graph of Weight Vs. Amount of Elongation² when x_L = 0.282 m

Amount of Elongation² ***(x^2)*** m (±0.001m)	Weight ***(mg)*** N (0.001N)
0.398	0.736
0.714	0.981
1.117	1.226
1.631	1.472

Fig. 8 Amount of Elongation² at various masses when x_L = 0.412 m

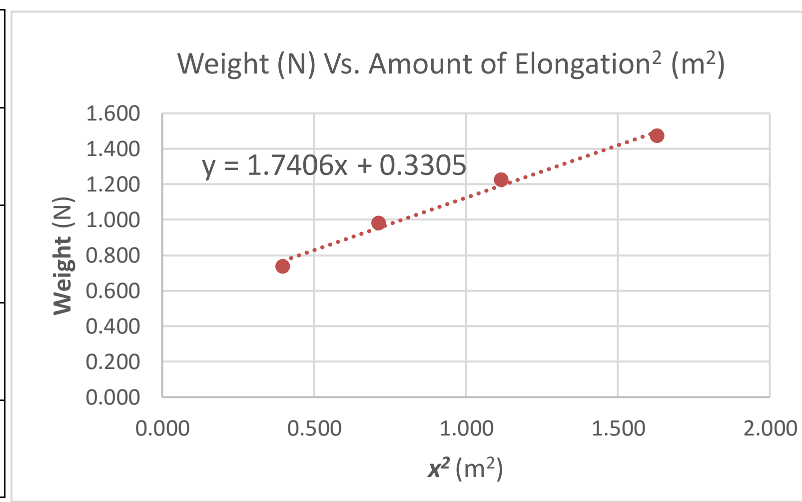

Fig. 9 Graph of Weight Vs. Amount of Elongation² when x_L = 0.412 m

Amount of Elongation² ***(x^2)*** m² (±0.001m)	Weight ***(mg)*** N (0.001N)
0.671	0.736
1.195	0.981
1.896	1.226
2.421	1.472

Fig. 10 Amount of Elongation² at various masses when x_L= 0.511 m

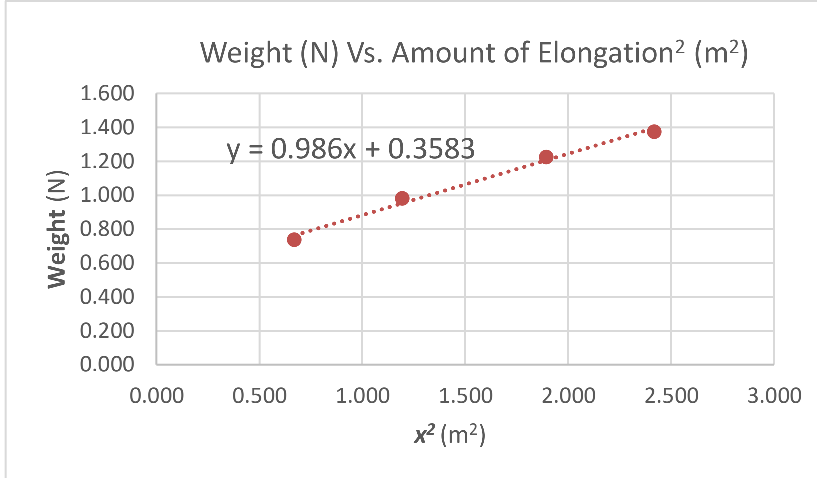

Fig. 11 Graph of Weight Vs. Amount of Elongation² when x_L= 0.511 m

1/Length² ***(x_L^2)*** m (±0.001m)	Slope ***($\frac{k}{2h}$)*** N (0.001N)
71.818	0.736
23.565	0.981
12.575	1.226
5.891	1.472

Fig. 12 Slope ($\frac{k}{2h}$) for every length and 1/Length²

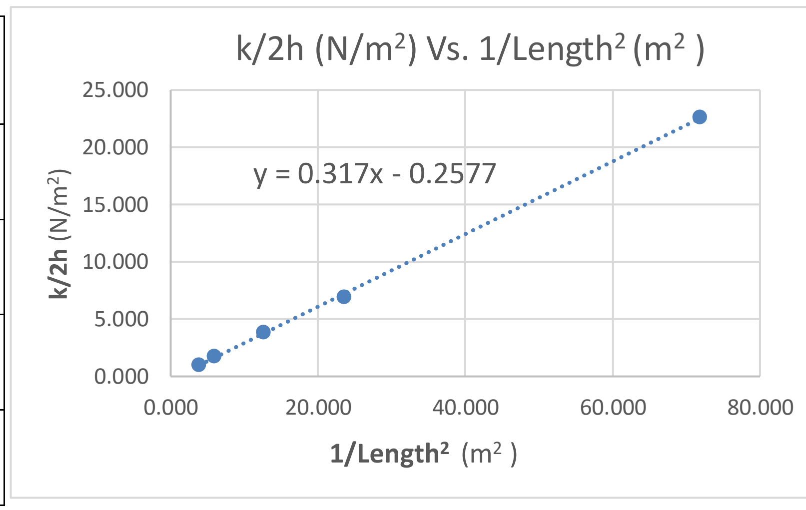

Fig. 13 Graph of k/2h Vs. 1/Length². K/2h was plotted against 1/Length² instead of length to create a linearized line

Experimental Value of Interest:
Our experimental value of interest comes from the Equation of the Slope Vs. 1/Length² Graph. This equation is of value as it tells us the length of the bungee cord we should us based upon the height of the jump.

Equation 1: *Equation of the Slope Vs. 1/Length² Graph*

$$\frac{k}{2h} = \frac{0.317}{x_L{}^2} - 0.258$$

uncertainty for slope= ±0.004 m % uncert= $(\frac{uncertainty}{slope}) * 100\% = 1.3\%$

uncertainty for y-intercept= ±0.1 N/m² % uncert= $(\frac{uncertainty}{y-intercept}) * 100\% = 39\%$

Technique Used for Propagation of Uncertainty: Regression Analysis on Excel.

DISCUSSION: There is no accepted value for $\frac{k}{2h}$ we were not able to carry out error analysis for our experimental value. Instead we will determine the acceptability of our $\frac{k}{2h}$ value in the equation $\frac{k}{2h} = \frac{0.317}{x_L{}^2} - \mathbf{0.258}$ by using our value from the Regression Analysis on Excel. Our percent uncertainty for our slope is 1.3%, which is a low uncertainty and therefore we can accept it. We also need to determine the significance of our y-intercept. This is done by comparing the uncertainty for the y-intercept, 0.1 N/M to the value of our y-intercept in our equation, 0.258 N/M. These two values are only .1 N/M away from each other, and therefore we say that the y-intercept is insignificant. As always, there is numerous possible ways error may have occurred in our experiment. Halfway through our measurements of $\boldsymbol{x_{max}}$, we realized that we had been measuring to the bottom of the mass instead of measuring to where the mass was attached to the bungee. We tried to fix this by just subtracting the height of the masses from the value we found for $\boldsymbol{x_{max}}$, however this could have brought slight error into our data. Also, for our first two lengths of bungee cord, we were using a mass that started to compromise our bungee. So the effects of that mass on our bungee, may have also altered the stretch characteristic of the bungee thus adding error to our experiment. Finally, we have a knot in our bungee that will not come out which weakens our bungee cord. As for our hypothesis we were correct. The heavier masses caused a significantly larger $\boldsymbol{x_{max}}$ than the lighter masses. Also, the shorter lengths of bungee had a smaller amount of elongation $\mathbf{(}\boldsymbol{x^2}\mathbf{)}$ for each mass than the bungee cords that were longer.

CONCLUSION: From this experiment we were able to conclude that our hypothesis was correct. We were also able to create a model that will help us determine the length on the bungee cord we should use based on the height of the jump and the k-value of the bungee cord. Using the model from our Week 1 Bungee experiment, $\boldsymbol{k = 1.11x_L - 0.198}$, and combining it with our model from this experiment, $\frac{k}{2h} = \frac{0.317}{x_L{}^2} - \mathbf{0.258}$, we obtain: $\frac{1.11x_L - 0.198}{2h} = \frac{0.317}{x_L{}^2} - \mathbf{0.258}$. Using this equation, we will be able to predict the length of bungee cord based on the height of the jump. However, the one concern we have about this final model is the fact that we are able to calculate the length on a bungee cord just based upon the height of the jump. Mass should also be a factor we consider when determining the length of a bungee.

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: Lauren Redell Engelbrecht