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Determining Stretch of an Elastic Cord

Abstract:

This experiment seeks to find a way to determine how far an elastic cord will stretch when a weight is attached and dropped from a certain height. To determine the stretch of an elastic cord, we explored the relationship between the equilibrium cord length and the displacement of the cord length. A weight was attached to an elastic cord and hung from a structure. The equilibrium length of the cord was measured. Then, the weight was dropped from a height and the length of the fully stretched cord at the bottom of the drop was measured. The difference between these two lengths was calculated and determined to be the displacement of the length of the elastic cord. We measured the displacement for 10 different equilibrium lengths. The results gave us a relationship between the displacement of the cord and the equilibrium length of the cord which can be used to predict the final length of the cord when fully stretched. It is found that the cord will stretch to 1.46 times its equilibrium length. This is helpful for the bungee experiment as we want our bungee to stretch as close as possible to the ground without the egg hitting the ground. However, our results are only true for the specific height and weight that we used. Therefore, we can only use our results to predict the length of a fully stretched cord at the specific height and weight used in this experiment. Further experimentation is required to determine a relationship to predict the stretch of a cord with any equilibrium length, drop height, and weight.

INTRODUCTION:

This experiment seeks to find a way to determine the stretch of an elastic cord based on the equilibrium length of that cord. We want to know this because it will enable us to predict how far a cord is going to stretch when dropped with a weight attached to the end of the cord. This can be applied to a bungee jump situation in which the final stretch can be predicted so that the object in the bungee does not hit the ground. The following equations are used in this experiment:

Equation 1	$$\frac{\Delta X}{X_L} = a$$
Equation 2	$$X_L + aX_L = X_T$$

$$X_L = \text{equilibrium length of cord}$$
$$\Delta X = \text{displacement of cord}$$
$$X_T = \text{total length of stretched cord}$$
$$a = \text{slope of graph of equilibrium length versus displacement}$$

Equation 1: This equation shows that the displacement of the cord divided by the equilibrium length of the cord is equal to a value “a”.

Equation 2: This equation shows that the equilibrium length plus “a” times the equilibrium length will equal the total stretch length of the cord. Equation 2 can also be written as:

$$(1 + a)X_L = X_T$$

So, if “a” were equal to 5, then the total stretch length would be 6 times the original equilibrium length.

We found the value of the ratio between displacement of the cord versus the equilibrium length. This value is “a” (see equation 1). Using the determined value for “a”, we can utilize equation 2 to determine the total length of stretched cord based on the equilibrium length of the cord. However, we can only do this for the specific weight and drop height used in this experiment (weight of 0.05kg and drop height of 1.74m)

Hypothesis: There will be a value “a” that can be used to predict final stretch length of an elastic cord based on equilibrium length.

METHODS:

To find “a”, the relationship between equilibrium length and displacement, we first measured the equilibrium length of the elastic cord with a weight hanging on the end of the cord. Then, we dropped the weight from a specific height and measured the length of the elastic cord at its lowest point. The difference between these two length measurements equals the displacement of the cord length. Then, comparing displacement to equilibrium length for ten different starting equilibrium lengths we found a value for “a”. This value is used in equation 2 to predict final stretch length based on equilibrium length of the elastic cord.

Setup: A weight is hanging from a structure on an elastic cord at equilibrium. This is when the equilibrium length of the cord is measured. Then, the weight is dropped from a certain height, and the length of the stretched cord at its lowest point is measured. This difference between these two lengths is the displacement of the cord length.

Figure 1: Equilibrium Length
Weight hanging at equilibrium

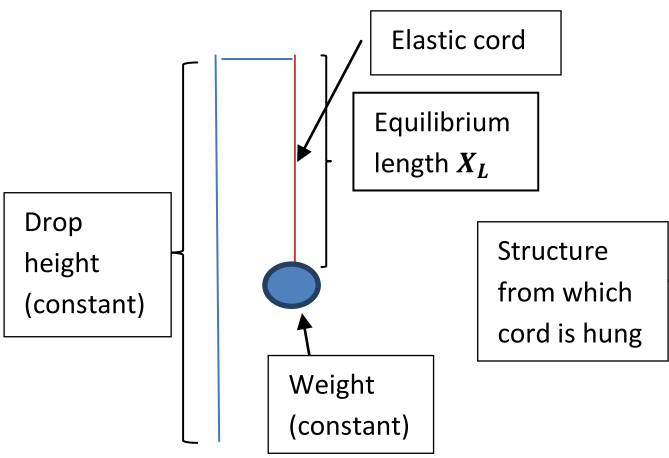
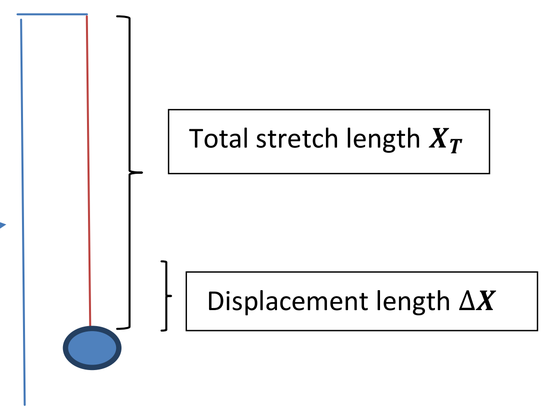


Figure 2: Stretch Length
Cord stretched to lowest point after drop



Constants:
Weight: 0.05 kg
Drop Height: 1.74 m

Procedure:

- attach elastic cord to structure so that it hangs down (see figure 1)
- attach weight to end of cord (see figure 1)
- measure length of cord with weight hanging at equilibrium
- drop the weight from the top of the structure
- using slow motion video, measure and record the final length of the cord at its greatest stretch (when the weight is at its lowest point)
- repeat steps for 10 different equilibrium lengths

RESULTS:

The measurements taken during this experiment leave us with 10 different equilibrium lengths and the displacement of the cord for each of those lengths. A graph of the equilibrium length versus displacement was created. In analyzing the graph, we found that the slope (“a”, see equation 1) gives us a constant that we can use to determine final stretch length from initial equilibrium length using Equation 2. Both equations are listed below for convenience.

$$\frac{\Delta X}{X_L} = a$$

$$X_L + aX_L = X_T$$

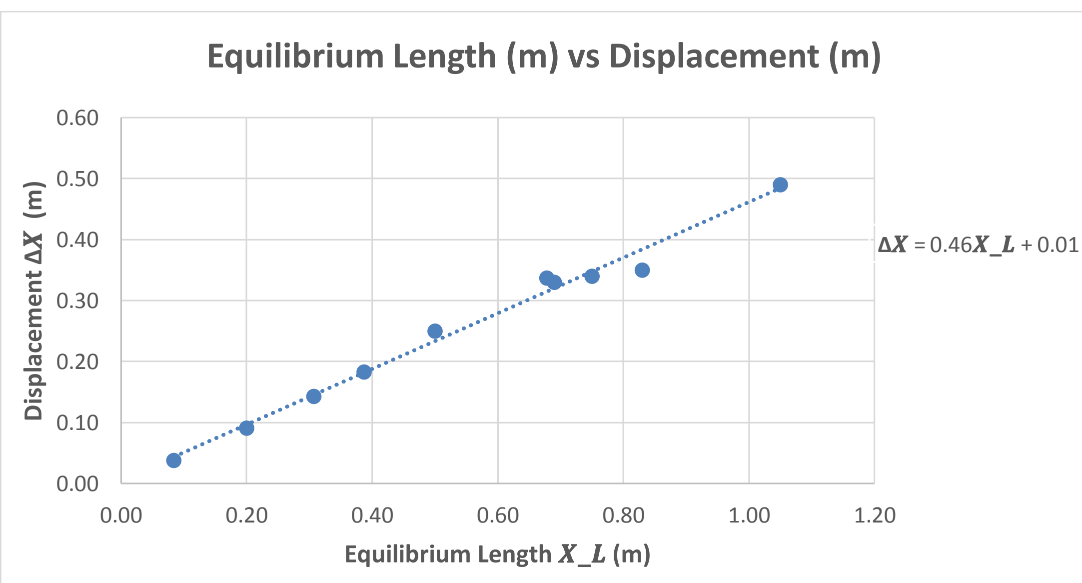
Table 1: Measurements of Length of Elastic Cord

This table shows the values measured for equilibrium length, final stretch length, and displacement of the cord. The equilibrium length was measured with the weight hanging on the cord. The final stretch length was measured when the weight was at its lowest point after being dropped from the top of the structure. The displacement was calculated as the difference between the equilibrium length and final stretch length.

Equilibrium Length (m) (±0.02m)	Final Stretch Length (m) (±0.02m)	Displacement (m) (±0.02m)
0.39	0.57	0.18
0.75	1.09	0.34
0.83	1.18	0.35
1.05	1.54	0.49
0.68	1.02	0.34
0.69	1.02	0.33
0.50	0.75	0.25
0.31	0.45	0.14
0.20	0.29	0.09
0.08	0.12	0.04

Graph 1: Equilibrium Length versus Displacement

This graph shows the relationship between equilibrium length and displacement of an elastic cord. Ten different equilibrium lengths are plotted with their respective displacement values. This is only for the specific drop height and weight used in this experiment.



Equation: $\Delta X = 0.46X_L + 0.01$

Slope= 0.46 uncertainty for slope= 0.09 % uncert= 3.94%

Experimental Value of Interest:
value obtained = 0.46 = a
The slope of graph 1 is considered the value of "a". This value is the displacement of the cord over the equilibrium length. Using equation 2, this value can be used to determine the length a cord will stretch based on its equilibrium length (if the same height and weight from this experiment are used). For reference, here is equation 2:

$$\boldsymbol{X_L + aX_L = X_T}$$

Uncertainty of experimental value:
uncertainty of experimental value(s) = 0.09 % uncert= 3.94%
This uncertainty value was obtained using excel regression analysis of Graph 1.

Using equation 1 and equation 2 (listed below) we determined the value of "a" as well as a way to predict the total stretch of a cord based on the cord's equilibrium length. Based on our data, a cord will stretch to 1.46 times its equilibrium length when dropped from the specific height and weight used in our experiment (drop height of 1.74m and weight of 0.05kg).

$$\boldsymbol{\frac{\Delta X}{X_L} = a}$$

$$\boldsymbol{X_L + aX_L = X_T}$$

DISCUSSION:

Error analysis
The experimental value we obtained is the value of "a" that fits into equation 1 and equation 2. This value seems accurate because the cord seems to stretch to about 1.5 times its length during the dropping of the weight. However, to compare this value to an "accepted" value we would have to carry out further experiments. These experiments include testing the stretch of the elastic cord for various drop heights and various weights to get a better sense of all the factors that affect the total stretch length of the cord.

Testing Uncertainty of Value of "a"
The uncertainty for the value of interest, "a", is 3.94%. To test the acceptability of this value, we would use this value of "a" to predict stretch length of a cord using equation 2. We would drop a weight attached to elastic cord and measure the final stretch length of the cord. We would need to use the same mass (0.05 kg) and drop height (1.74 m). We would compare this final stretch length to our predicted stretch length, and determine if the model accurately predicts the final stretch length. If the predicted value is within 3.94% of the actual value, then the uncertainty of our obtained value ("a") is acceptable.

Sources of uncertainty
The uncertainty in our experiment comes strictly from the length measurements taken. All length measurements had an uncertainty of ±0.02m based on the accuracy of the tape measure used.

It is important to understand that while our model predicts the final stretch length based on equilibrium length for a specific drop height and weight, further experimentation is required to find a model to predict final stretch length of an elastic cord for ANY drop height and weight. These further experiments would include measuring displacement of an elastic cord while varying drop height as well as varying weight.

Our results support our hypothesis there is a value “a” that can be used to predict total stretch length from equilibrium length. However, the value for “a” obtained in this experiment only works for the specific drop height and weight that we used.

CONCLUSION:

This experiment reveals a way to predict the total stretch of an elastic cord based on its equilibrium length. Based on our calculations, the cord will stretch to 1.46 times its equilibrium length. However, the model created in this experiment only works for the specific drop height and weight used in this experiment. So, we can use the results of this experiment to predict the stretch length of a cord when the attached weight is 0.05 kilograms and the drop height is 1.74 meters. To predict the stretch of an elastic cord for any drop height and weight, we would need to run this experiment for various drop heights and weights and determine a function of the experimental value “a” that can make this prediction. In doing these further experiments we could come up with a model that would predict how far a bungee mechanism would fall, enabling us to give the bungee jumper a thrill without having them hit the ground.

Acknowledged Aid

Worked with Thomas Zusi (lab partner) on determining how to analyze our results before writing the report.

Lab Report Outline Guidelines provided by Professor Cumming

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

Pledged: Griffin P. Coffey