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Effects of Bungee Cord Length

Abstract: In order to determine the effects of changing the length of bungee cord on the distance it will stretch and the forces it produces, a constant mass was hung and dropped while attached to different lengths of bungee cord. Bungee cord approximates a spring and performs oscillations based on Hooke's Law, or $\mathbf{F_S=kx}$, where $\mathbf{F_S}$ is the Spring Force, **k** is the Spring Constant, and **x** is the Displacement. The displacement at equilibrium, maximum displacement, maximum force, and force at equilibrium were recorded for each length twice. From these recorded values a graph of the original length versus the max displacement was made. Since this graph very closely matches a linear approximation, a linear equation was made and a regression analysis performed. Based on the trendline of the linear graph, the max stretch of any length of bungee cord can be predicted based on the equation $\mathbf{X_{MAX}=4.73X_L}$, where $\mathbf{X_{MAX}}$ is the maximum displacement and $\mathbf{X_L}$ is the original unstretched length. The uncertainty in these predictions based on the uncertainty of the slope in the graph, which is 2%. Using this we can make sure that any object being dropped from a height suspended by a length of bungee cord will not stretch too far and hit the ground.

(The force at equilibrium was subtracted from the maximum force in order to determine maximum spring force, but because this value stayed mostly constant, at about 2 Newtons, it is only showed in the results and not discussed in detail.)

Introduction: What is the effect of changing the length of bungee cord that suspends a weight?

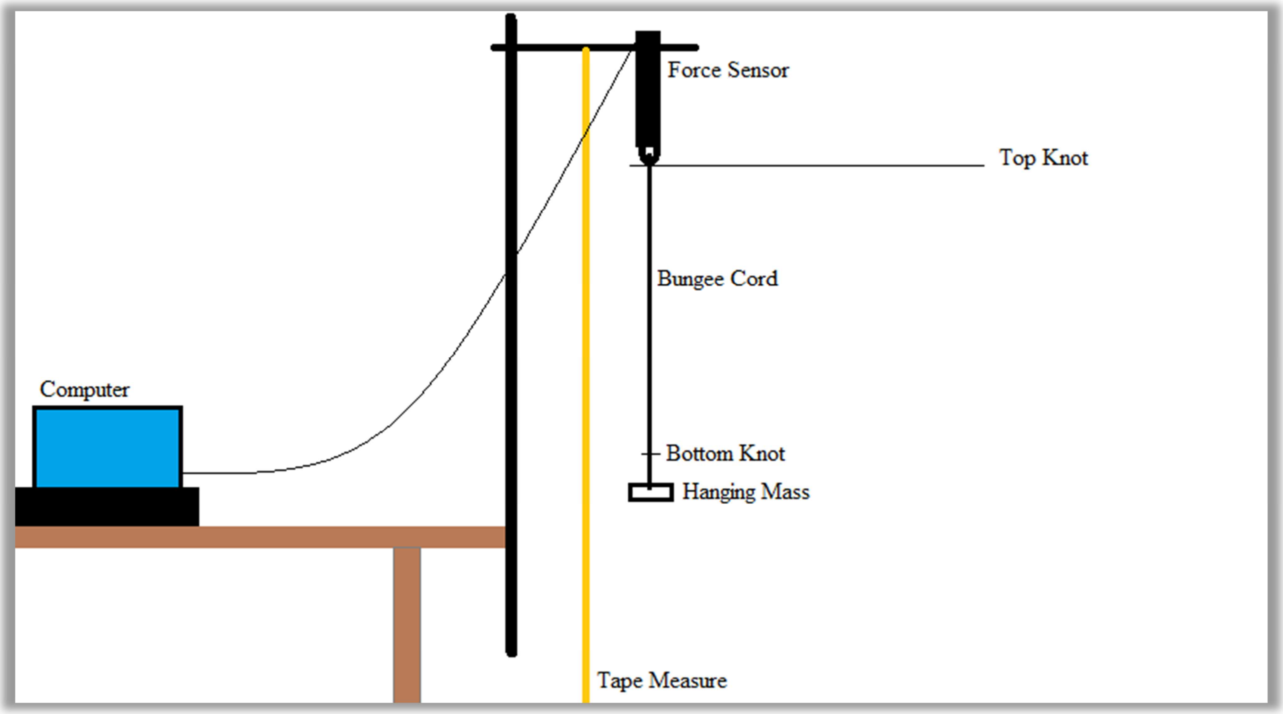
The purpose of this experiment was to see how the maximum stretch and spring force would change as we changed the original length of bungee cord, while keeping the mass attached to it constant.

If a constant mass is dropped from a consistent height while attached to different lengths of bungee cord, and the mass stretches to different distances from the initial drop point, then it can be assumed that the change in the maximum stretch of the bungee cord is related to the changing original lengths of bungee cord. Using the graph of max stretch versus initial length we can also predict the original length of bungee cord we will need to keep the max stretch from exceeding some defined value.

By assuming that the maximum stretch and the original length are linearly related, we can look for some equation that relates them as $\mathbf{X_{MAX}=kX_o}$, where **k** is some constant. Based on the experimental values for $\mathbf{X_{MAX}}$ and $\mathbf{X_o}$ we can find **k** and use that equation to predict other values for $\mathbf{X_{MAX}}$.

Hypothesis: If the original length of bungee cord is increased, then the max stretch length of the bungee cord will increase proportionately.

Methods: We steadily increased the original length of bungee cord ,while keeping the mass suspended from it constant, in order to determine the change in max stretch. From each original length, we measured displacement at equilibrium, force reading at equilibrium, maximum displacement, and maximum force reading.



Using an arrangement of metal poles and vices, we suspended a force sensor and a tape measure from a horizontal pole approximately three meters off the ground. We attached lengths of bungee cords to a force sensor at one end and to a .150kg weight at the other. The original length of the bungee cord was determined by the distance between the top knot attaching it to the force sensor and the bottom knot attaching the weight to the bungee.

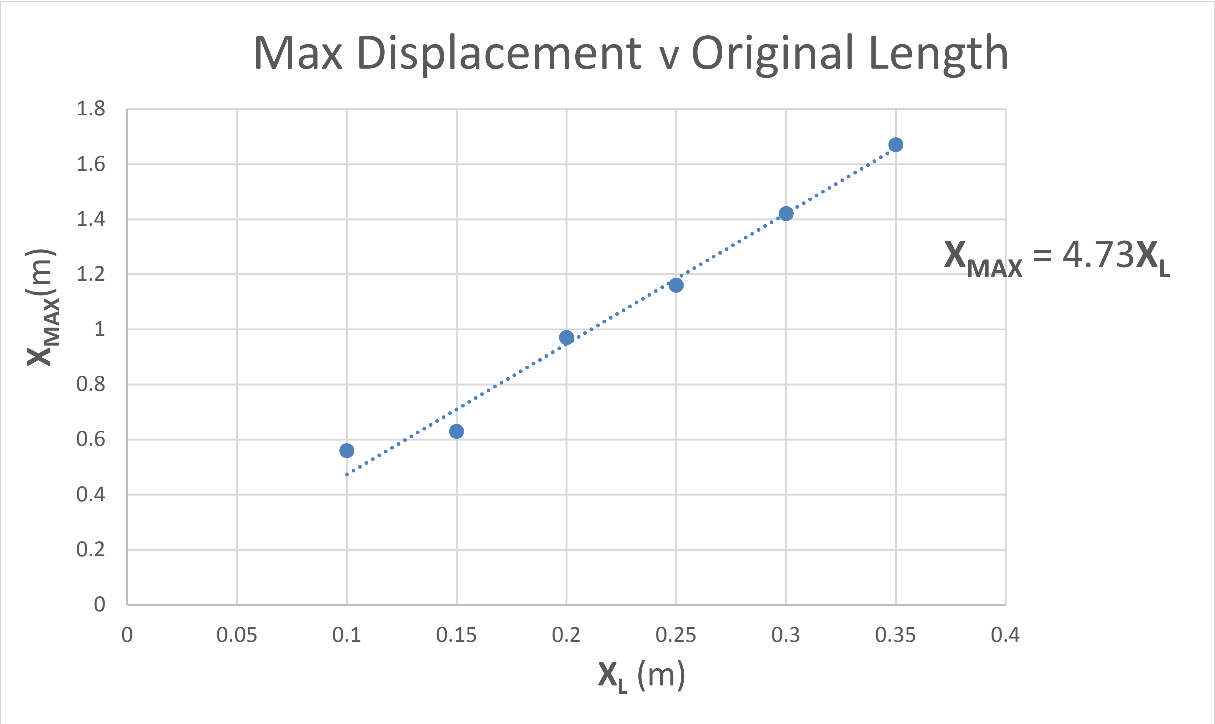
Starting with original length at .1 meters and increasing by .05 meters each time we measured and recorded the equilibrium stretch (by eye on the tape measure based on the position of the bottom knot), the force reading at equilibrium (by turning on the force sensor while the system was at equilibrium and recording the reading). Then we raised the mass so that the top and bottom knots lined up and dropped it. After the drop we measured the maximum displacement (by having one member of the group watch the weight as it fell and look at the lowest point on the tape measure that it reached, and then subtracting the length of the weight and hanger to get the lowest position of the bottom knot), and the max force (by having the force sensor recording over the duration of the drop and writing down the greatest magnitude of the force). We recorded these values for the lengths between .1 meters and .35 meters in .05 meter increments.

Results: Force readings are magnitudes; originals were negative due to their downward direction on the sensor. In review, we found that the initial and max force readings were basically constant for the duration of the experiment. We subtracted initial force readings from max force readings to find Bungee Force. We also graphed the max stretch versus original length based on the idea that they would vary proportionately.

Figure 1: A Table showing Original Length, Displacement at Equilibrium, Maximum Displacement, Force Reading at Equilibrium, Maximum Force Reading, and Force at Equilibrium subtracted from Maximum Force yielding Maximum Bungee Force.

Original Length X_L (m ±.01m)	Displacement at Equilibrium X_o (m ±.02m)	Maximum Displacement X_{MAX} (m ±.04m)	Force at Equilibrium F (N ±.01N)	Maximum Force F (N ±.01N)	Maximum Bungee Force F_B (N ±.01N)
0.10	0.21	0.56	1.70	3.69	1.99
0.15	0.32	0.63	1.85	3.87	2.02
0.20	0.46	0.97	1.83	3.87	2.04
0.25	0.63	1.16	1.82	3.89	2.07
0.30	0.72	1.42	1.79	3.91	2.12
0.35	0.82	1.67	1.78	3.85	2.07
		Averages:	1.80	3.85	2.05

Figure 2: Original Length versus Maximum Displacement graph with Linear Trendline and Equation.



From the graph we can see that the Maximum Displacement is increasing approximately linearly with the Original Length, so we performed a Linear Regression on the data.

Slope: $4.73\frac{m}{m}$ with uncertainty of $.09\frac{m}{m}$ or about 2%(based on Regression)

Based on this line equation we can predict the maximum stretch of any original length of bungee cord with some uncertainty. We can also find the range of original lengths of bungee cord that will keep us from exceeding some set maximum stretch value. This is useful to make sure that something dropped and suspended by a bungee cord will not hit the ground when it is dropped from a known height with a known original length of bungee cord.

Discussion: The graph of max stretch versus original length was not based on any previous known equation, it was a graph and equation that we found based on looking at our data and finding useful correlations. Because it was not based on a known equation, there was no known value to compare our results to, but based on the Linear Regression uncertainty of 2% we can be confident that our predictions will be close.

Our experiment did not account for every variance. Some of our measurements were done based on what the human eye can detect in the very short interval of time without the help of any video or recording technology. Measuring with the human eye can be inaccurate. Results can differ based on different lighting, angle from which an event is observed, or not remembering exactly where an object reached. Because of the possible mistakes that come with measuring anything by eye we chose our raw uncertainties accordingly, for example making the uncertainty on the max stretch greater than the uncertainty on the equilibrium stretch due to the fact that the mass was moving while we measured max stretch. The uncertainties for the force measurements were lower, due to the more consistent readings of the force sensor through the computer. The force uncertainties were based on the smallest decimal place in the original reading. The uncertainties in our final slope, the result of our experiment came from the linear regression analysis, and therefore were not based on our raw uncertainties.

Other uncertainties could have come from the small amount of bungee cord that was involved in the knots that secured the cord to the force sensor and the mass; however, we did make our measurements to be between the knots in order to minimize the effects of this problem.

We were aware during the experiment that there would be some change in the bungee cord over time as it was used simply due to the material, but we did not account for these in our procedure. We did try to minimize these overall stretches by fully stretching the cord out twoce before we began our experiment. Because we were expecting the overall length change to be small we assumed that it would not be necessary to address in detail through our procedures.

The equation we found will only be accurate for the one bungee cord we tested, and will probably not be applicable anywhere else because the properties of each different bungee cord vary from each other. Despite this, it is useful for finding a length of this bungee cord that will not stretch below a certain point.

Conclusion: Through this experiment we determined an equation that we can used to predict the max stretch of different lengths of original bungee cord. This will allow us to know that our egg will not hit the floor when we drop it from the Great Hall suspended by the bungee cord. This will not tell us the amount of bungee cord to use, since other factors like goal g-forces are in play, but it will at least be useful for trying to make sure that our egg does not hit the floor during its bungee experience.

On my honor I have neither given nor received any unacknowledged help on this lab report.

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