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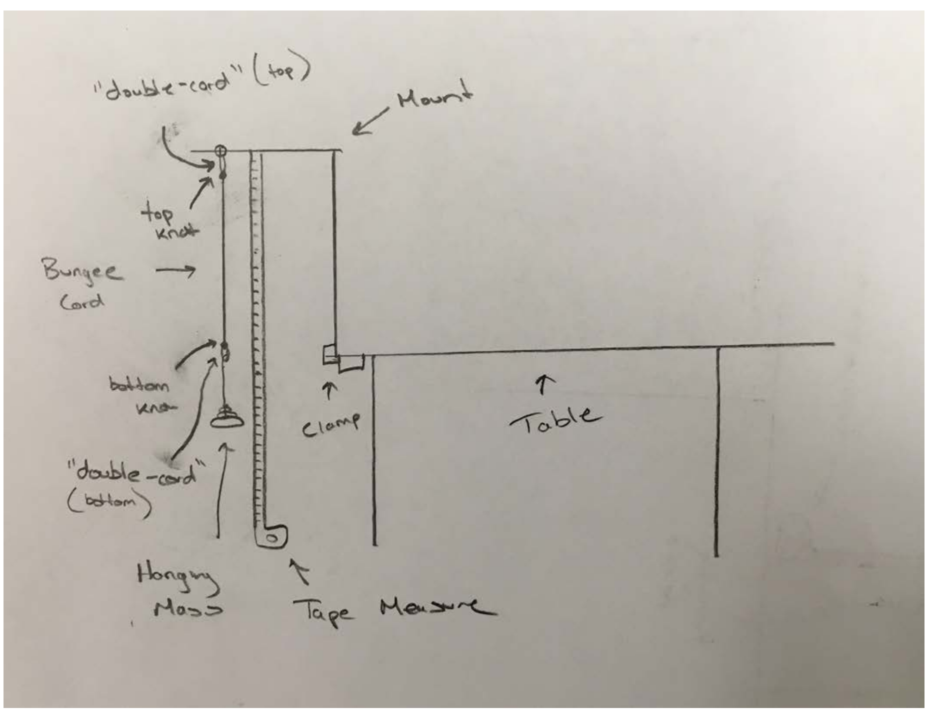
Investigating Bungee Behavior: Bungee Challenge Part 1

How can we accurately predict how our bungee cord will behave when our egg is falling in the Great Hall? How much will the cord stretch under a certain force? While we hypothesized that Hooke's Law ($F = -k*\Delta x$) would serve as an accurate model for the relationship between force and displacement for our bungee cord, we conducted an experiment to either verify this or find an alternative model based on empirical data.

We conducted a series of experiments in which we hung different masses from our bungee cord and measured the cord's displacement from equilibrium. We chose three different equilibrium lengths to test from, and we hung five different masses from the cord, measuring the difference between the equilibrium length of the cord and the length of the cord with the hanging mass. The displacement was plotted against the force exerted on the cord (which is simply the weight of the mass), and the graph was fit with a linear equation, confirming the relationship suggested by Hooke's Law.

In addition, we also observed the relationship between the constant of proportionality, k, and the equilibrium length. We found that k and the equilibrium length to be inversely proportional, as we plotted equilibrium length against 1/k. Thus, we found a model which we can use to estimate the k-value of the length of the cord we will use in our final drop.

Figure 2: *Diagram of Experiment Set-up*



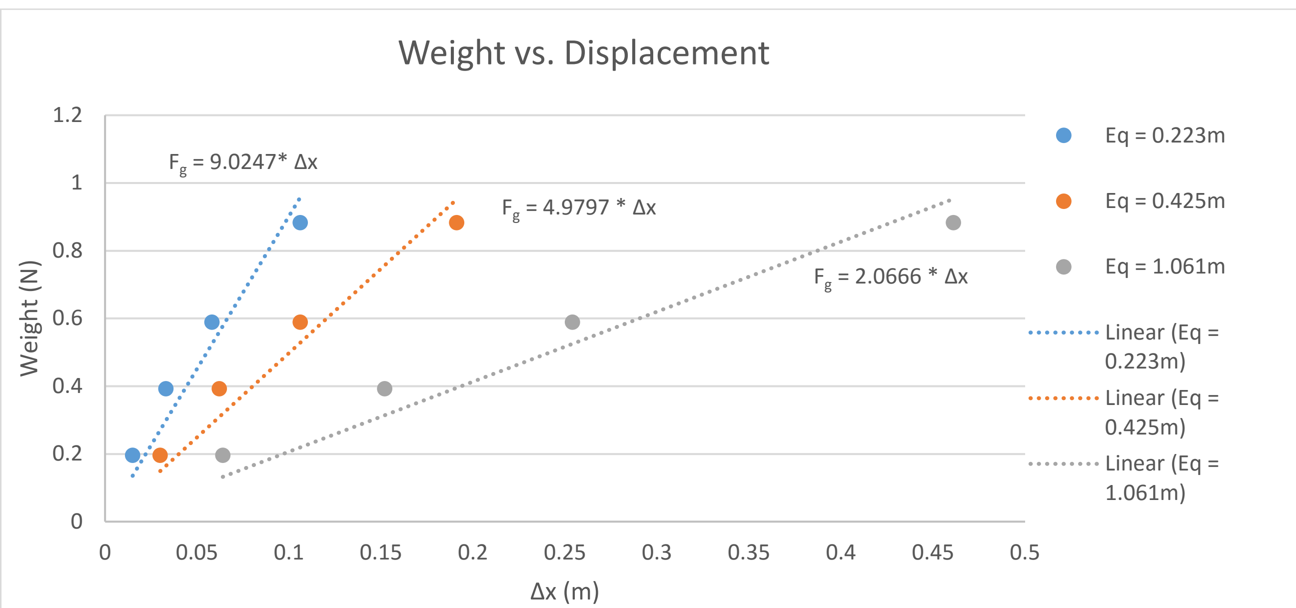
With a mount clamped to the table, we tied our bungee cord to a screw on the mount using a slipknot. We then hung a hanging mass from the bungee cord using another slipknot. Notice that these two slipknots create sections of “double-cord” where there were two layers of cord––one connecting the main, “single,” cord to the mount, and one connecting the main cord to the mass. We also hung a tape measure directly beside our hanging bungee cord in order to accurately measure the displacement of the cord.

In this first experiment, we collected data on the behavior of the main, single strand of bungee cord, choosing three different equilibrium lengths and measuring the difference between the length of the cord after hanging five different masses from the cord and the equilibrium length.

Table 1: *Summary of k-values based on equilibrium length. Uncertainty was calculated by taking the average standard error of each of our k-value.*

Equilibrium Length (m)	k (N/m) +/- .38794 N/m
0.223	9.024657534
0.425	4.979704924
1.061	2.066556336

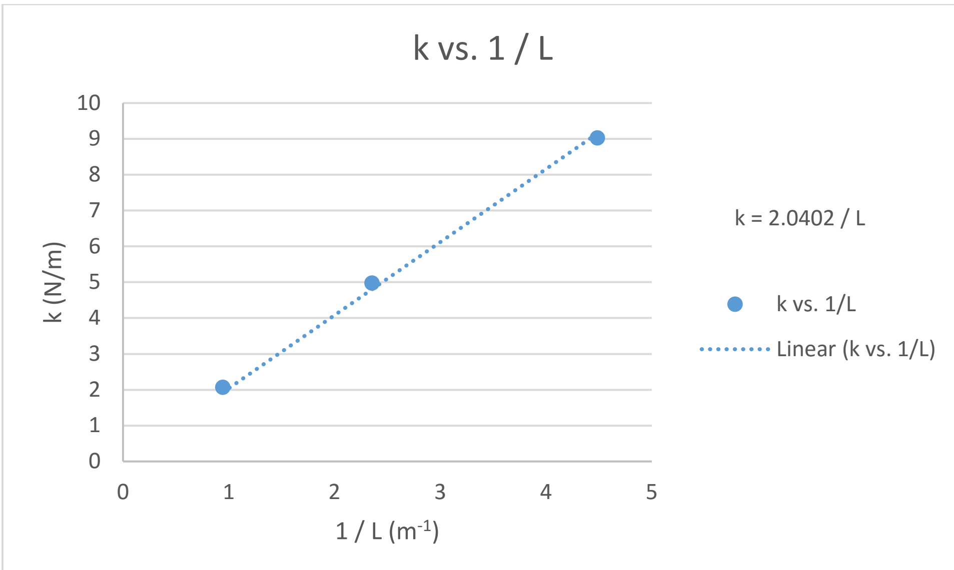
Chart 1: *The plots of weight (F_g) vs. displacement (Δx) for each of our three equilibrium lengths.*



For all three equilibrium displacements, we found that the relationship between force and displacement was mostly linear, within some degree of uncertainty.

Furthermore, we are not only interested in what the k-values are for these equilibrium lengths. Rather, we would like to be able to use this data to create a model to determine what k will be for any equilibrium length. Notice that at first glance, k seems to not only decrease as the equilibrium increases, but decrease proportionally to how much the equilibrium changes. As the equilibrium displacement roughly doubles, the value of k is roughly halved. Likewise, as the equilibrium increases by a factor of 4, k approximately decreases by a factor of 4. We have plotted the k-values against the equilibrium lengths below to more precisely describe the relationship.

Chart 2: *Plot of k against 1 / L, where L is the equilibrium length, for each of our average k-values.*



Thus, we found an equation for k with respect to equilibrium length to be k = 2.0402 / L, with a standard error of 0.03585 for our constant. Hence, the data we have collected will help us predict how our bungee cord will behave in the Great Hall bungee jump, as we can now calculate an estimated k-value for any equilibrium length, and further, use Newton's Second Law to calculate the displacement of the cord given a downward force.

In summary, we discovered that Hooke's Law accurately describes the relationship between force and the displacement of our bungee cord. Moreover, we found an equation relating k and equilibrium length to be k = 0.2.0402 (+/- .03585) / L. We will be able to use this, along with Hooke's Law, to predict how far our bungee cord will stretch given a certain equilibrium length and magnitude of downward force being applied. We also collected data on the behavior of the sections of "double-cord", but we omit the analysis from this report. Further experimenting and analysis can be done to quantify the effective k-values for our sections of double-bungee, as well as to investigate the force at which our bungee cord might stretch, in which case its equilibrium length would be altered.