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Modeling Bungee Cord Resistance

Abstract:

In this lab, we used a uniform latex cord to act as a bungee for a fallen object and are asked to model the properties of it, specifically force from the cord in respect to the length it is stretched. Since no information regarding the cord is given, we will attempt to model the cords resistance using Hooke's law. Variations in force and stretch on the cord will help us to better model the cord. Once the properties of the cord are modeled, we can use that information specifically to predict force from displacement, and further the cord's behavior when a falling object, such as an egg, is attached and the distance the egg will fall before being pulled back up by the force of the cord.

Intro:

While the latex cord is not a spring, the behavior of the two are nearly identical. With that, we can begin to model the properties of the cord using Hooke's law, and establish a linear relationship between force provided from the cord and its displacement. Hooke's law states the force (of pull or resistance, F_s) of the cord is proportion to the distance it is stretched (displacement), s, and a constant factor, -k, commonly referred to as the spring constant. This coefficient is negative because the resistance provided by the cord acts opposite to the direction of stretch.

$$F_{spring}=-ks$$

By manipulating parts of the equation in lab setting, we can use the variations in data to establish a workable k constant. Since in the end goal of this series of labs is to use the cord to drop an egg attached as close to the ground as possible without breaking, the k value yielded through this experiment must be accurate and well representing of the true behavior of the cord, or else the egg will break. The purpose of this lab is render a k constant, and observe other none quantitative properties of the cord that may be important for later experiments.

Methods:

Our method to establishing a working k constant involved changing the force of pull the cord provides and measuring the amount of stretch that happens from the change in force. We can change the force simply by adding weight to the end of the cord as it is hung vertically, and wait until the force from the cord is equal the weight (mass*gravity) of the added mass. When the system is at equilibrium, as in not oscillating but suspended above the floor, we know that F_s (the spring force) is equal to the force provided by the weight. Displacement was measured by setting a single length of cord, which was kept constant through the entire experiment, and subtracting that from the length of the cord when it had weight on it at equilibrium. As follows:

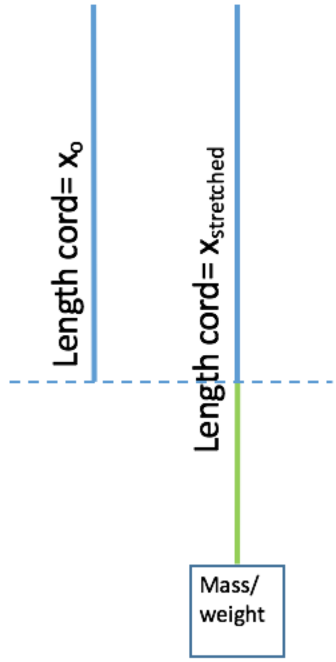

Figure 1: Explanation of displacement

- $X_{stretched} - x_0$ = displacement=

The cord should be hung from an elevated bar, using the smallest knot to attach it to that as well as to attach the weight. From there, the length of the cord at equilibrium should be measured. After you have your equilibrium, attach a mass, and allow the system to come to rest. At rest, measure the new length of the cord. The new length minus the first equilibrium length (no mass) is displacement. From the measurements taken in displacement, we can use them in the Hooke's law where F_s equals the weight (mass*gravity) and the values rendered using the technique above to find s (displacement). By having those two pieces we used basic algebra to find k in F_s=-ks.

Results:

After collecting data, we can graph displacement versus F_s where the slope of the line yielded is equal to k.

Mass (kg) σ=±.001kg	Weight (N)	Displacement (m) σ=±.015m
0.2	1.96	1.07
0.175	1.71	0.86
0.145	1.42	0.69
0.135	1.32	0.6
0.125	1.22	0.53
0.115	1.12	0.46
0.105	1.03	0.4
0.095	0.93	0.34
0.085	0.83	0.28

Figure 2: Data Table

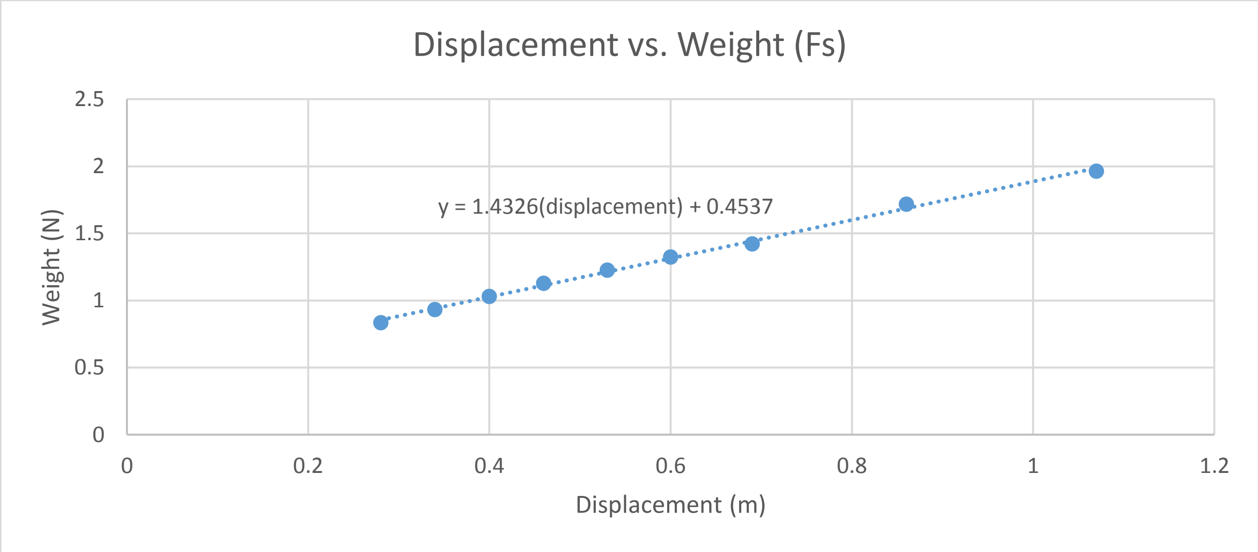

Figure 3: data graphed, displacement vs weight

- Weight here is equal to F_s since the system is at equilibrium
- Slope is equal to k

	Coefficients	*Standard Error*
y-intercept	0.453713016	0.018006745

Slope (k constant)	1.432577984	0.02860216

Figure 4: Regression Analysis of data

We ended up taking more data points with lower weights then those tabled, but those points compromised the linearity, and are also insignificant because in the long run we are focused on the behavior of the cord when the mass attached is that of an egg and harness, close to .15 kg. Through this experiment the k constant of our cord came out to be 1.433 n/m.

Through computer analysis of our data (figure 4), there comes an uncertainty of .02 in the slope of our line, the k constant. This value is close to the uncertainty in our displacement measurements, and is expected. However, we expected the y- intercept of this graph to be 0. This is unexpected because Hooke's law states displacement is proportional to force, but if at the y-intercept displacement is 0, there should be a force of zero as well.

Discussion:

From regression analysis and comparison to linear relationship in Hooke's law states, we know that the behavior of the cord is not exactly that of a spring. By isolating data points close to the forces we expect from a falling egg, we created a model for the cord's behavior at those points, not all points/weights. This should be taken into consideration and revisited later if we find the forces expected in the contingent lab are greater than the ones used in this lab.

There are other possibilities for discrepancy in our k value that are important to note. The knots used to fix the cord to an elevated bar and to the weight ruin uniformity. The k constant is compromised when there are double strands at each end. The k yielded is that of the piece of rubber with 2 knots in it, not just the cord of rubber. Next, the stress on the cord from mass to mass "stretches out" the cord, meaning the k constant after stretching the cord out a few times aggressively may be different from the original constant. Also, as mentioned in results, at lower weights the k constant did not present us with linear data, contrary what we expected. This could be an indication the cord may behavior differently at particularly high weights, such as .4kg.

Conclusion:

Through this lab, we were able to model the force that the cord provides in respect its displacement using Hooke's law. But because our model had a flaw in it (note y intercept in figure 4), we have to realize that there are some issues/inconsistencies. Our model represents the k constant when the weights used where in the range of about 1 to 2 newtons, not for all weight ranges. To model the behavior of cords accurately, there must be some prerequisite weight class you are trying to find, then go about modeling the cord by using surrounding points. The k constant is actually not as constant as we'd hope when it comes to bungee cords.