Section: 113-4

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Anna Kreynin, Thomas Harmon, Andrew Taylor

Modeling the Behavior of a Bungee Cord

Abstract:

In order to create a bungee jump that provides the greatest thrill with the safest outcome, we must first become familiar with the characteristics of our bungee cord. To do this, we tested the relationship between the mass of the object hung from the bungee cord and the resulting stretch of the cord, and found that, as expected, the greater the mass on the bungee cord, the further the stretch of the cord. We then graphed the relationship between the force of the bungee cord and the resulting stretch of the cord, and found that it could be modeled by the equation $F = 1.8219x^{0.6982}$, or by the equation $y = 1.6749x - 0.1405$, two modifications of Hooke's Law, F=kx. Because the power function provided the most accurate trend line, we chose $F = 1.8219x^{0.6982}$, although it is a slightly more complicated model. This model relays the force on the bungee that will occur with a given x, the displacement of the bungee from its un-stretched length. This model also demonstrates how much force our bungee cord can provide, which will aid us in deciding our bungee's design variables. Fully understanding the bungee cord's behavior, which our model will allow us to do, is crucial in creating a desirable bungee experience.

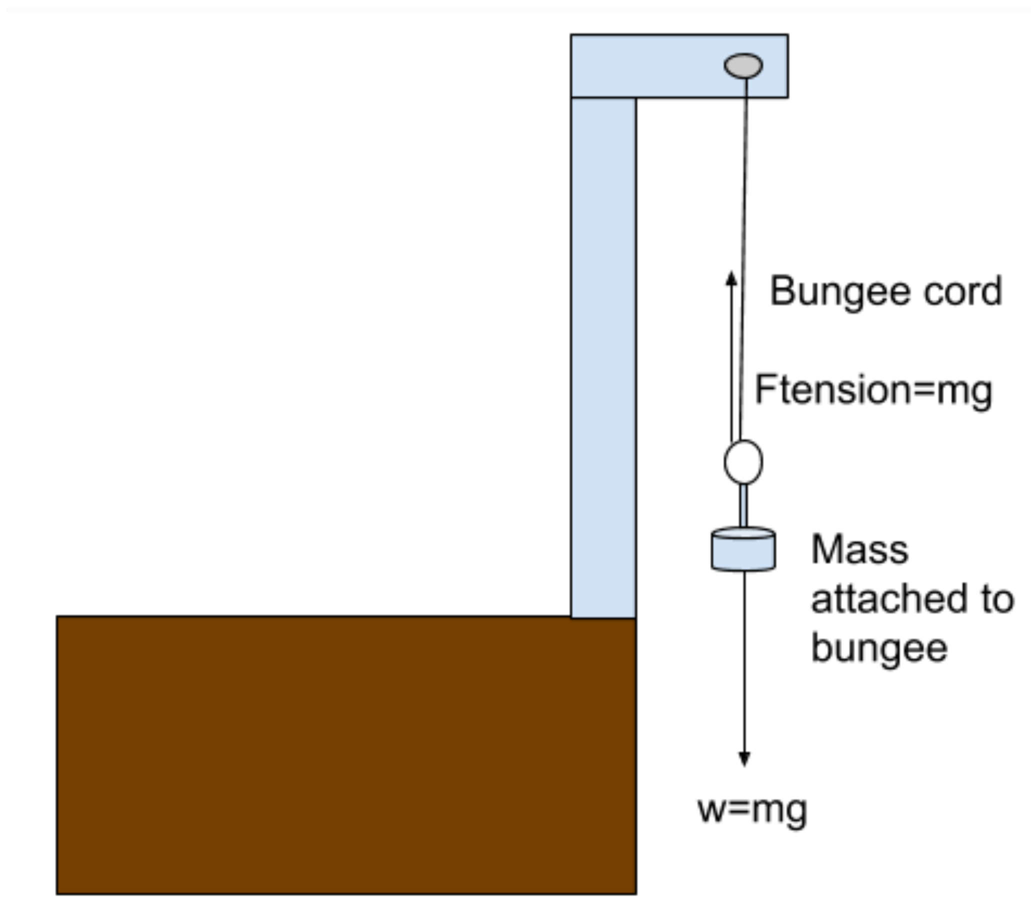
INTRODUCTION:

To create a safe and enjoyable bungee experience, one must be familiar with the characteristics of the cord. Thus, we tested the behavior of the cord as it varied with mass, and then modeled the force of the bungee as it varied with its stretched length. Hooke's law, a principle that says that the necessary force to extend or a compress a spring-like object by a certain distance is directly proportional to that distance, is modeled by the equation F=kx, where F is the force applied, k is the spring constant, and x is the distance the object is stretched or compressed. We hypothesized that the bungee, when released from rest, would exhibit spring-like behavior, allowing us to use a modified version of Hooke's Law in our model.

Methods:

The un-stretched length of the bungee was measured, followed by the length of the bungee with 10 different masses attached. We then plotted the resulting displacements from the un-stretched length against the force of the weight of the mass to produce our model.

Figure 1. Experiment setup.



The bungee was hung from a metal crane that was attached to a desk. From the end of the bungee, 10 different masses were hung.

Procedure:

- The bungee cord was hung from a metal crane attached to the table. The length of the cord without a mass attached was measured.
- Ten masses were hung from the end of the cord and the resulting length of the cord with each mass was measured. The displacement of the cord from its un-stretched length was found by subtracting the length of the cord with no mass from the length of the cord with an attached mass.

- The force of the weight of each mass was calculated using the equation F=mg, where m is the mass and g is the acceleration due to gravity. This force was then graphed against its respective value of the cord's stretch. A trend line and an equation for the graph were chosen.

Results:

After graphing the force of the bungee against its resulting stretch, we found our bungee to be modeled by the equation $F = 1.8219x^{0.6982}$, a modification of Hooke's Law.

Figure 1. Stretch of the cord vs. mass of the hanging object. Ten masses were hung from the bungee cord and the stretch of the bungee was measured.

Displacement from length of un stretched cord (m +/- 0.02 m)	Mass of hanging object
0.07	0.025
0.14	0.05
0.24	0.075
0.38	0.1
0.56	0.125
0.75	0.15
0.96	0.175
1.17	0.2
1.37	0.225

Figure 2. Force of the mass vs. stretch of the bungee. The weight of the mass was found by multiplying the mass by g, the acceleration due to gravity. The graph was fitted with a power trend line and the equation was found.

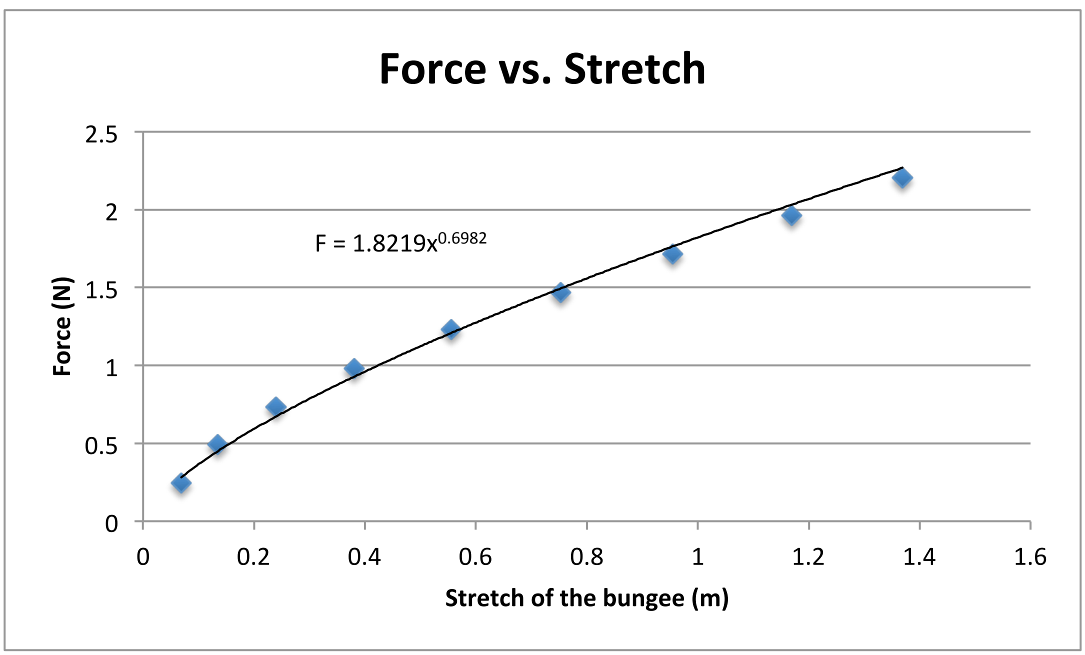


Figure 3. Force of the mass vs. stretch of the bungee. The weight of the mass was found by multiplying the mass by g, the acceleration due to gravity. The graph was fitted with a linear trend line and the equation was found.

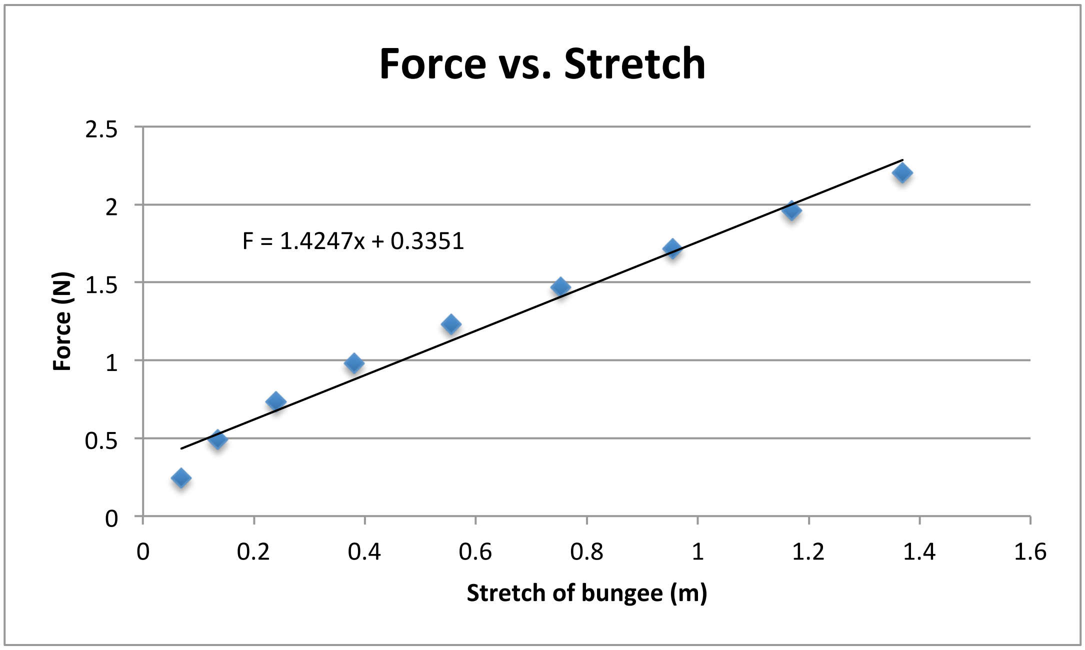
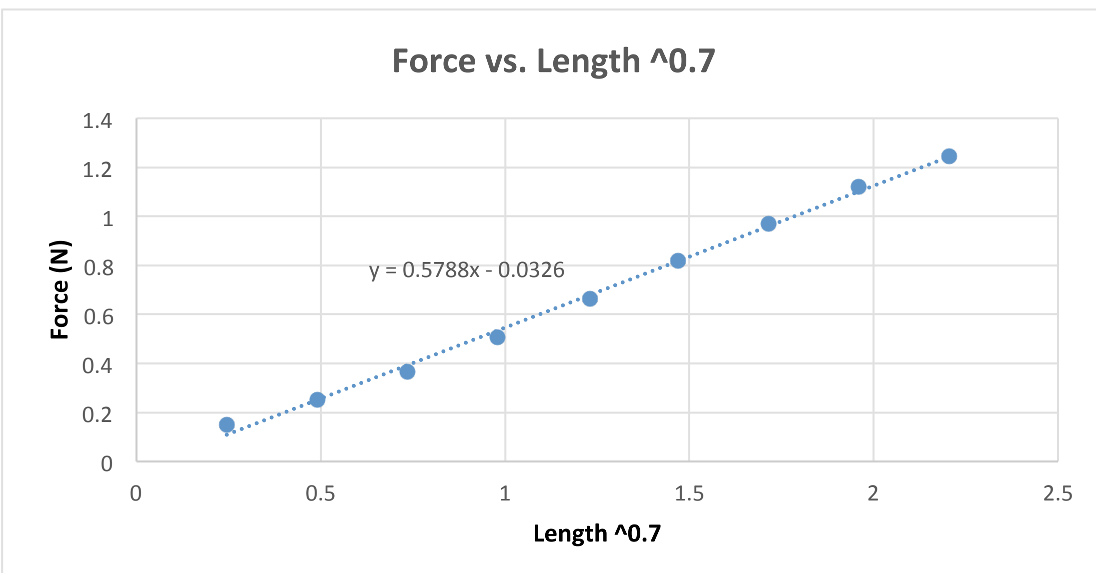


Figure 4. Linearized graph of the force of the bungee vs. its stretched length. The graph was linearized by raising the stretch of the bungee to a power of 0.7.



Uncertainty for slope= 0.012 % uncert= 2%

Uncertainty for y-intercept= 0.017 % uncert= 5%

The value 0.59 is of interest because it represents the "spring constant" of the bungee cord in the linearized graph. This value is the slope of the linearized graph with the equation 0.5788x-0.0326.

Value obtained = 0.59

Uncertainty of experimental value(s) = 0.012 % uncert=2%

The uncertainty was obtained using Excel regression analysis.

We can model the behavior of the bungee using a modified version of Hooke's law. Rather than the linear graph a perfect spring displays, the behavior of the bungee creates a power fit, yielding the equation $y = 1.8219x^{0.6982}$. This model provides us with a representation of how our bungee behaves, which is important in designing our final bungee.

DISCUSSION: *What do you make of your results? Evaluate them.*

The slope of our line, 0.59, garnered an uncertainty of 0.012 and a percent uncertainty of 2%. Because the uncertainty is less than the percent uncertainty, we can say that our data is acceptable. To further test our model, we could measure the maximum force releasing the bungee from rest creates using Capstone, a computer program. We could then plug this force into our equation, and determine the experimental value of the maximum stretch of the bungee. We would then compare this experimental value to the accepted value which we would find from actually measuring the stretch of the bungee. The main source of uncertainty came from physically measuring the length of the bungee with the attached mass because the bungee continuously swayed side to side, and we could not hold the bungee in place for fear of accidentally compressing or stretching it.

We can evaluate the model of our bungee using two different trend lines: a power function fit and a linear fit. The power function fits our data more precisely, as demonstrated by Figure 2. However, it provides the more complicated model of $F=1.8219x^{0.7}$. Another option for modeling our bungee cord would be attaching a linear fit to our data. The linear fit, however, does not match our data perfectly, as illustrated by Figure 3. Nevertheless, the linear equation $F = 1.6749x - 0.1405$ is simpler. Thus, a challenge arises in choosing the best model for our bungee cord. Since the power function trend line more closely fits our data, we believe the model $F=1.8219x^{0.7}$ should be chosen.

We expected our bungee cord model to display similarities to the Hooke's law equation $F=kx$, since the bungee does act as spring below the equilibrium point. Our model, $F=1.8219x^{0.7}$ is therefore a modified version of Hooke's Law because of the addition of the exponent. However, it still aligns with Hooke's Law, which we expected.

CONCLUSION:

The behavior of our bungee cord can be modeled with the equation $F=1.8219x^{0.7}$, a modified version of Hooke's Law, $F=kx$. This model displays the force on the bungee that will occur with a given x, the displacement of the bungee from its un-stretched length. Our model provides us with a clear idea of how much force our bungee cord can provide, which will aid us in deciding our bungee's design variables, including the un-stretched length of the bungee cord, the number of bungee cords we will need, and whether or not we will need to add a static cord to our design. Fully understanding our bungee cord will be essential in creating a safe, thrilling bungee experience for the egg.