Lendon Hall and Chris Osier **Physics Lab** 113-01 **Date:** 10/24/2016

Hooke's Law and Bungee Cord Characteristics

ABSTRACT:

The purpose of this experiment is to find the spring constant of a bungee cord. In order to do this, we measured how far the cord stretched with different masses tied to the end. We did this for two different lengths of the same bungee cord. It turns out that the larger the mass, the farther the bungee cord stretches. We graphed the results for the two different lengths of cord in order to find the relationship between cord length and the change in stretch over change in mass. We found that the slope of the mass vs. stretch graph was linear but different for each bungee cord length. The longer the bungee cord, the more it stretches with each increasing weight. This means the deceleration is smaller as the bungee cord length increases.

INTRODUCTION:

The purpose of this experiment is to find the relationship between the length of a bungee cord and the amount of deceleration the mass on the end experiences. In order to find this, we used two different lengths of the same bungee cord and dropped masses of different weights from a set height.

Relevant equation(s), identifying variables:

$$mgh = \frac{1}{2}kx^2$$

(where m is the mass, g is gravity, h is the height of the mass before it drops, k is the spring constant and x is the distance the bungee cord stretches from its initial not-stretched position)

Basis or brief theoretical background:

When constructing a bungee jump for humans, it is very important that the bungee cord is neither too long nor too short so that the person falling neither hits the ground nor comes to a stop with too much force. Too much deceleration during the fall could cause brain issues and even death. The equation above represents the equilibrium position of an ideal Hooke's Law system, and if used correctly, it can provide the information necessary to construct a bungee experience that is both safe and predictable.

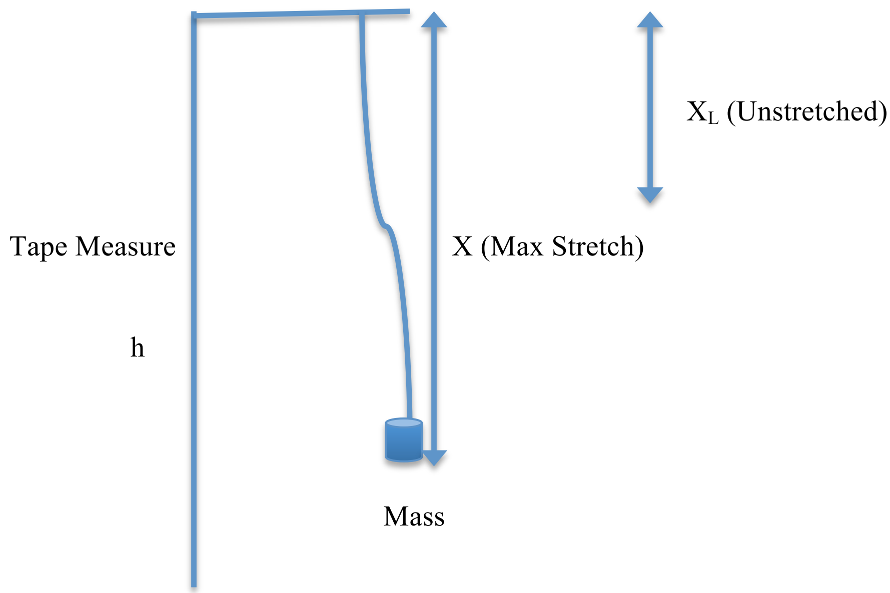
Hypothesis (or expectations):

The expectation for this experiment is that the mass will experience a greater deceleration as the bungee cord length decreases.

METHODS:

We attached the cord to a metal fixture that clamped on to our lab table and stuck up two meters above the floor, then tied on a mass carrier that we attached various masses to. We secured a tape measure to the spot at which the cord was attached and dropped the mass each time from this spot. We used a slow-motion camera to determine the exact distance each mass fell along the vertical path. We had to change the height for the first length of bungee cord because the mass was reaching the floor. However, it did not vary the results much.

Diagram: Lab Setup



Setup and procedure:

- We tested two different lengths of the bungee cord: 0.585 m and 0.363 m.
- The height (h) was set at 2.00 meters to start, but after using a mass of 0.080 Kg with the 0.585 m cord we raised the height to 2.345 meters because the mass would have hitr the floor.
- We measured the length of the unstretched bungee cord each time before adding the weight to it, and we dropped the mass from where the cord connected to the apparatus.
- As the mass fell, either my partner or I recorded a slow-motion video of the mass slowing to a stop before rising back upward. We used this footage to determine X (maximum stretch) for each trial.
- For the most accurate results, we would drop the mass one time to see roughly where it would stretch to, then situated the camera accordingly so as to get an optimal angle with respect to the tape measure.

RESULTS:

We found that as mass increased, so did X. We increased mass in increments of 0.01 Kg from 0.05 Kg up to .140 Kg. The uncertainty of each mass was ±0.0001 Kg, and the uncertainty of each X measured was ±0.001 m. We used the Hooke's Law equation ($mgh = .5kx^2$) to derive the spring constant, k from each trial, and we graphed mass vs. max stretch to see how the stretch increased with mass given the length of the bungee cord.

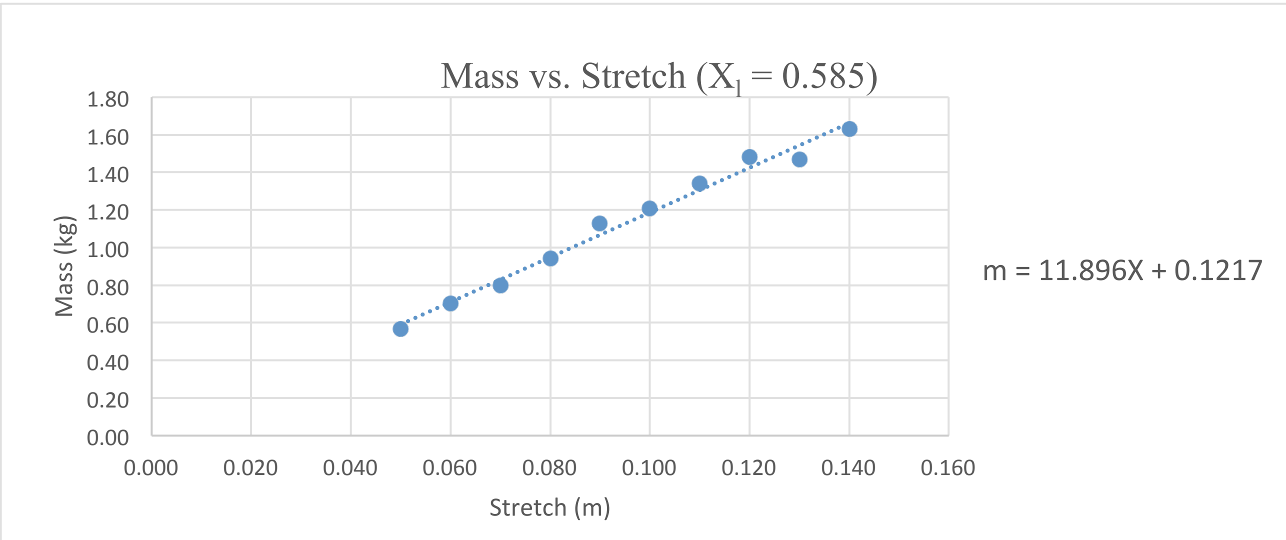
Tables and Graphs:

Table 1: Bungee cord length X_l = 0.585 m

Trial	m (Kg)	h (m)	X (m)	($X-X_l$)	k
1	0.050	2.000	1.151	0.57	6.12
2	0.060	2.000	1.287	0.70	4.78
3	0.070	2.000	1.385	0.80	4.29
4	0.080	2.000	1.528	0.94	3.53
5	0.090	2.345	1.715	1.13	3.24
6	0.100	2.345	1.791	1.21	3.16
7	0.110	2.345	1.925	1.34	2.82

8	0.120	2.345	2.067	1.48	2.51
9	0.130	2.345	2.055	1.47	2.77
10	0.140	2.345	2.215	1.63	2.42

Graph 1: Mass vs. Stretch for cord length 0.585 m

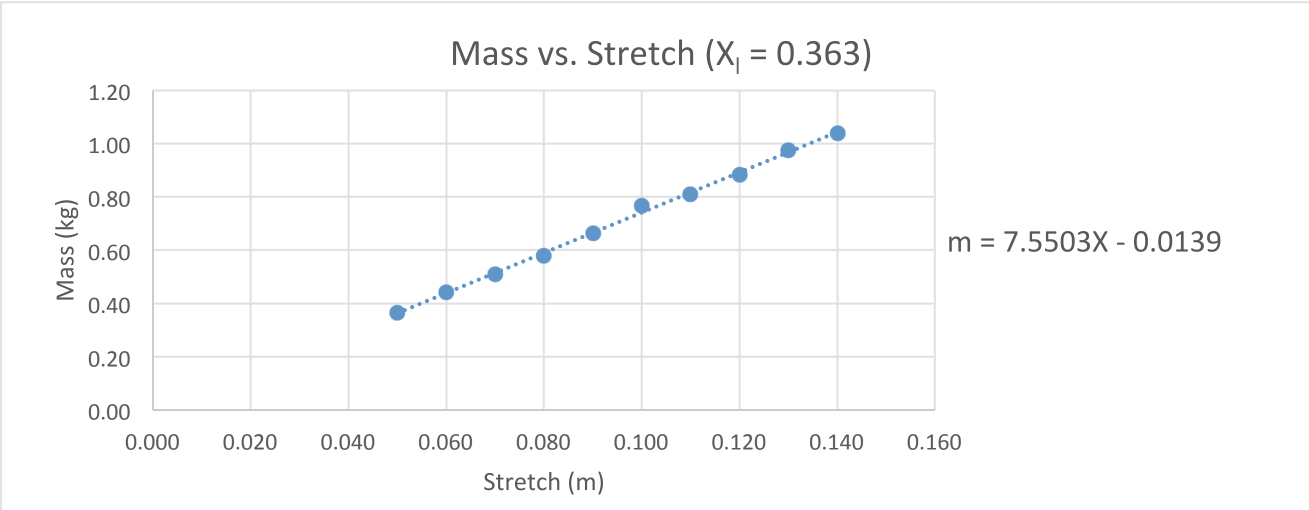


Uncertainty for slope = 0.004 % uncertainty = 0.03%

Table 2: Bungee cord length X_l = 0.363 m

Trial	m (Kg)	h (m)	X (m)	$X - X_l$ (m)	k
1	0.050	2.142	0.728	0.37	15.77
2	0.060	2.142	0.805	0.44	12.91
3	0.070	2.142	0.873	0.51	11.31
4	0.080	2.142	0.942	0.58	10.03
5	0.090	2.142	1.027	0.66	8.58
6	0.100	2.142	1.130	0.77	7.14
7	0.110	2.142	1.173	0.81	7.05
8	0.120	2.142	1.245	0.88	6.48
9	0.130	2.142	1.340	0.98	5.72
10	0.140	2.142	1.401	1.04	5.46

Graph 2: Mass vs. Stretch for bungee cord length 0.363 m



Uncertainty for slope = 0.002 % uncertainty = 0.03%

Experimental Values of Interest:

The most important part of the data and the resulting graphs is that the mass vs. stretch graphs were mostly linear. This means that for each length of bungee cord there is a linear relationship between mass and how far the bungee cord will stretch. Therefore as the length of the cord increases, the slope of the mass vs. stretch graph also increases. Not only does the bungee cord "constant" k vary with the mass on the cord, but also with the length of the bungee cord. The important thing is that it varies with a linear relationship, so it is therefore predictable. This also confirms that as the length of the bungee cord increases, the magnitude of deceleration decreases.

DISCUSSION:

Error analysis

There were no "accepted" values for the slope of these graphs or for the stretch constant for the bungee cord, so there is no way to compare the experimental values obtained to the expected values. However, the slopes of the two graphs have a very low % uncertainty, which indicates how likely it is that the relationship is actually linear.

The uncertainty for the calculations for k is 0.002. This was found with the propagation of uncertainty for division equations. The uncertainty for height was 0.0001 m and the uncertainty for X was 0.001 m. The uncertainty for the stretch was .001 m as well.

Sources of uncertainty:

The bungee cord gets stretched out over time, and the amount of stretch that remains in the cord could affect the data above. The slow-motion camera was helpful, but it was difficult to see exactly how low the mass got before it rebounded upward. The angle of the camera altered the measurement on the tape measure, but the frame speed was adequate enough to get a few frames of the mass hanging still.

The main results support the hypothesis that the relationship between mass and stretch increases linearly. They also show that as the length of the bungee cord increases, so does the slope of the relationship of mass vs. stretch. This means that a longer cord has a wider variability in weight capacities.

CONCLUSION

Bungee cords with longer lengths can sustain more weight and will stretch less than a shorter cord with the same mass hanging on it. The relationship between mass and stretch is linear, and it depends on the length of the bungee cord. Also, the deceleration experienced by the mass is less when the length of the bungee cord is greater.

Implications:

With regards to a human bungee jump experience, this experiment shows that it is safer for the bungee cord to be as long as possible, because it reduces the deceleration of the mass on the end. If the bungee cord is too short, a human could experience enough deceleration to kill him/her. Therefore the next step is to determine the relationship between deceleration and the length of the bungee cord.

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

Pledged: Lendon Hall