William Archie and Michael Sullivan **Section:** 1 **Date:** 10/9/2016

TITLE: Assessing The Nature of Our Bungee Against Hooke's Law

ABSTRACT: *We assessed whether or not our bungee cord was ideal. An ideal bungee would have a linear relationship between the weight attached to it and the equilibrium measurement. To determine if this was the case, we measured x_0 or the equilibrium length for the bungee at varying weights, but kept the unstretched length of the bungee, x_L, constant at 0.591 m. We collected, graphed, and analyzed our data. Our data was exponential, so we linearized it and got a model for our bungee at this length: W =* 2.14x – 0.24. *Our data was not linear and proved that our bungee did not fit Hooke's law, F=kx. This in turn proved that our bungee was not ideal. This showed that we would need to do further modeling of different aspects of our bungee to adequately prepare for the bungee drop in the final week of lab.*

INTRODUCTION*: Gives the purpose and conceptual or theoretical context.*

The goal of the experiment was to create a model for the spring constant (k) for our bungee cord. Hooke's law describes the distance from equilibrium with the weight of an object as linear. This relationship would allow us to easily determine k by graphing our data and simply finding the slope of the best-fit line. Knowing k for our bungee is vital. It will let us determine the maximum force applied to the object, our egg, during the jump. This is crucial because the total force on the egg cannot exceed three times the force of gravity or else the egg will likely crack.

Relevant equation(s) specific to this experimental purpose or setup, identifying variables:

F=kx W=mg

F: force exerted by the bungee

k: the spring constant

x: the distance of the object on the end of the bungee from equilibrium

W: weight

m: mass

g: gravity

The force exerted by a spring (in this case a bungee) is related to the distance traveled from equilibrium by the spring constant k. The spring constant is essentially a measure of the strength of the spring. Equilibrium is the point where the force exerted by the spring is equal to the force exerted by g, or where F is equal to W. The weight is given by the force of gravity on the mass of the object.

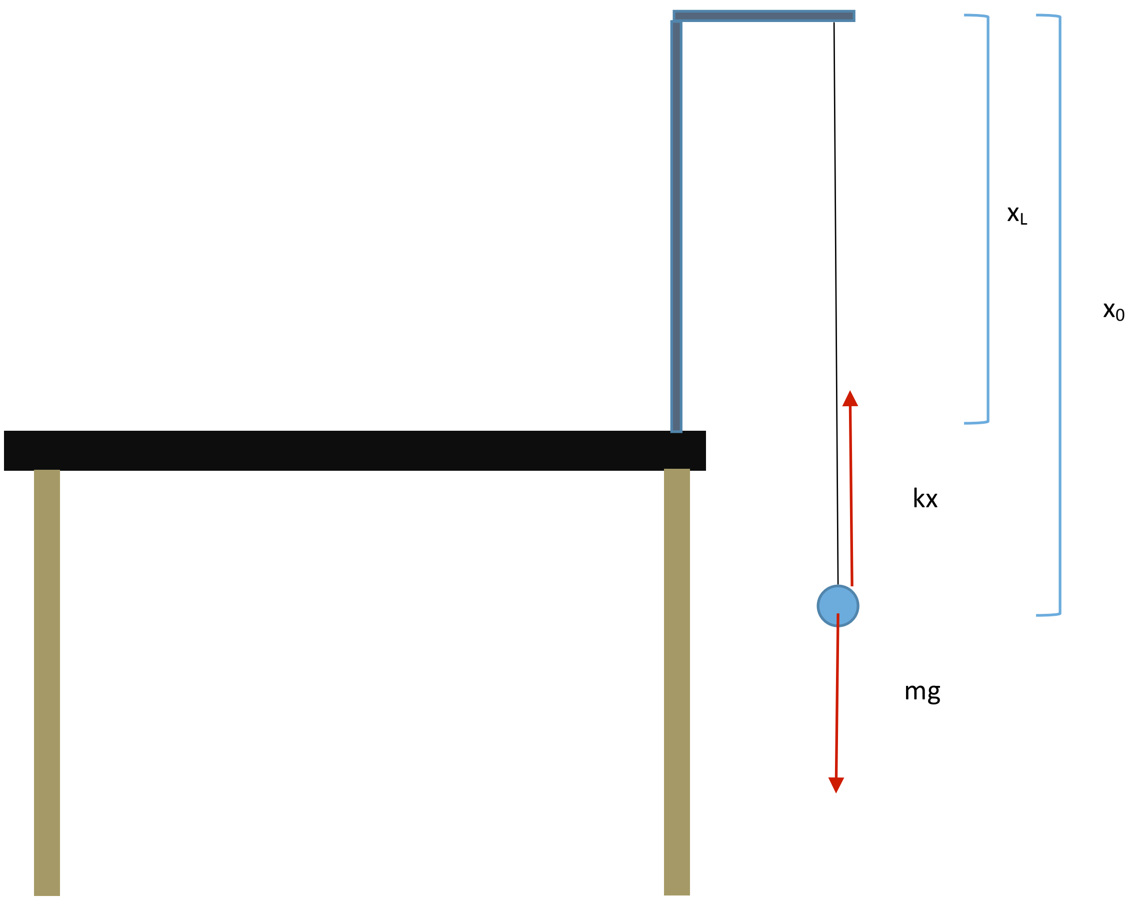
Hypothesis (or expectations): The bungee given to us by the physics department is ideal.

METHODS:

We decided to calculate the spring constant for our bungee at a constant length by measuring the distance between x_L when the bungee was unstretched and x_0 when the bungee had reached equilibrium. At this point, weight was equal to the force of the bungee. We would be able to set weight equal to kx and derive k from the slope of the trendline of the data if the bungee was ideal.

Diagram, identifying *all* items, variables and/or measurements. Label it with a **Figure #, Title and caption**. Use *Word* (Insert-shapes-drawing canvas), a drawing program, or *at least* use a ruler and blank paper and scan it in:

Firgure #1: Bungee System *Our initial set up to measure x_0 for 0.591 m of bungee.*



Describe setup:
Raise arm to appropriate height and secure there. Secure bungee to the arm via knotted loop fixed to the arm by placing the loop around the bolt in the arm and attaching it via a bolt and washer. Secure measuring tape alongside bungee via another bolt and washer.

Describe procedure, *including relevant or significant details* (may be bullets):

- Pick length of cord (constant), tie two knots in bungee (loops) keeping them as small as possible

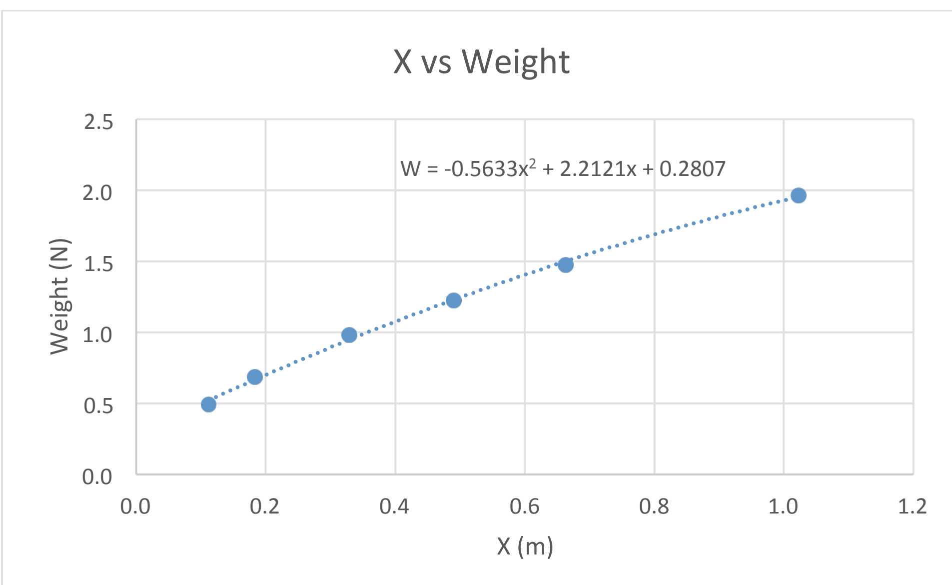
- Mount on arm via one loop. The other loop will be used to hang the weights
- Measure x_0 for six different weights to get $k(x_0)$
- allow them to reach equilibrium to measure x_0

RESULTS:

The results give the measured x_0 for varying weights at a constant x_L of 0.591 m. When our initial data was plotted we found that a non-linear model best described it. We linearized it and performed a regression analysis. This linear data and regression analysis gave us our model and its associated error.

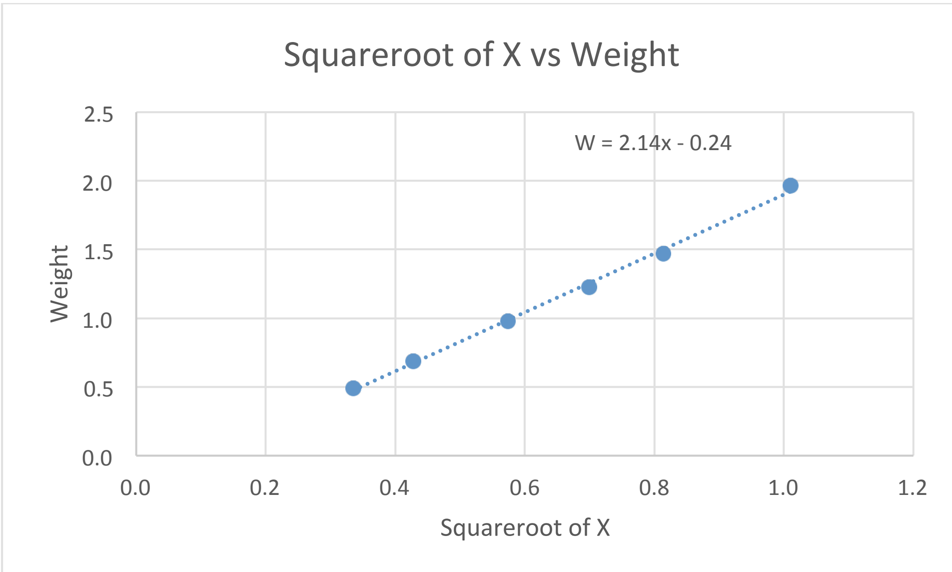
Table 1: This table gives our measurements for mass and equilibrium (x_0) along with their uncertainties. It also gives our calculated weights and stretch distance (x) calculated by subtracting x_L (0.0591 m) from x_0.

±0.001 Kg	±0.001 m		±0.001 N
mass	x_0	x	weight
0.050	0.703	0.112	0.491
0.070	0.774	0.183	0.687
0.100	0.920	0.329	0.981
0.125	1.081	0.490	1.226
0.150	1.254	0.663	1.472
0.200	1.613	1.022	1.962



Graph 1: This graph gives the relationship between our raw data for x and weight.

Best fit equation: $W = -0.5633x^2 + 2.2121x + 0.2807$



Graph 2: This graph gives our linearized data and shows the relationship between weight and the squareroot of x.

Linear Best fit Equation: W = 2.14x – 0.24

uncertainty for slope= ±0.06 % uncert= ±3%

uncertainty for y-intercept= ±0.04 % uncert= ±16%

The value of interest is the x coefficient of our linearized data. It gives the slope of the data, and represents the relationship between x and weight at equilibrium. Our initial data was linearized and the resulting trend line gave us the coefficient.

value obtained = 2.14

uncertainty of experimental value(s) = ±0.06 % uncert= ±3%

name the technique used for propagation of uncertainty (see *UG*), or where/how uncert was obtained:
Regression analysis via excel

Our results gave us a model for the equilibrium of the bungee at 0.591 m: W = 2.14x – 0.24. The x coefficient gives us the k for this length of our bungee.

DISCUSSION:

Our uncertainty was 3%, which is an acceptably small amount. In order to better test this, we would use our model to calculate x_0 for an untested weight. We'd then follow our procedure its actual x_0. Then we'd calculate our error within our experimentally determined value.

The two loops tied in the bungee will stretch differently than the un-knotted portion of the cord, throwing off our value for k. The bungee itself likely stretched out due to having significant weight hung from it for relatively prolonged periods.

The results do not support our main hypothesis. We measured the difference between the unstretched length of our bungee and the equilibrium, x_0, point for different weights. Had our bungee been ideal, we would have gotten clearly linear data, with the slope of the line k. In this context k would have described the relationship between weight and x. Instead we found a linear relationship between the square root of x and weight, and this does give us a relationship between weight and x_0. However, the data had to be linearized, and did not give a linear relationship between weight and x. This indicated that our bungee could not be described by Hooke's Law, and was not ideal.

CONCLUSION:

The experimental outcome that weight is related linearly to the square root of x and not to x itself disproves our hypothesis that our bungee is ideal.

This shows that we cannot rely on the theoretical model during preparations for our bungee jump. We must more completely model our bungee, specifically in how k changes with length. An understanding of this will be vital to extrapolating our predictions from the lab to the great hall.

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

Pledged: William Archie