Your name and your lab partner(s): Jack Richman and Chris Curfman **Section:** Wednesday Afternoon **Date:** 11/2/16

TITLE: Bungee 1: Using Hooke's Law to Determine a Spring Constant for a Bungee Cord

ABSTRACT: Our experiment in this lab was to collect data for our future egg bungee jump. We decided that the best way to obtain this data was to compare a bungee cord to a spring and hypothesized that both undergo similar oscillatory motion in certain cases. We decided to use Hooke's Law, which states that the force needed to compress a spring a certain distances is a function of that distance times a constant "k," in order to find a "k" value for our system. Our purpose in doing this lab was to find this "k" value, which we discovered varies with different masses as in Figure 4 below. We were able to find this "k" value by varying 11 different hanging masses on the system and measuring the static max stretch distance, then graphing the weight of the hanging mass versus the stretch distance. The setup we used to conduct our lab is shown in Figure 1 below. Our experiment yielded a method to find the "k" value with approximately a 3% uncertainty, which is highly accurate. This "k" value can be used with force equations and conservation of energy equations in order to determine relevant values that can be used for our future egg drop.

INTRODUCTION:

Purpose or question: Our purpose in this lab was to take measurements of a bungee cord system that we believed would help us determine values necessary for our final egg drop experiment. Our only value of interest was "k," the spring equation from Hooke's Law.

Relevant equation(s), identifying variables:

$W_{hanging} = mg$
$mgx_{max} = (1/2)k(\Delta x)^2$
$k=mg/x$
$F_{spring} = kx$

$W_{hanging}$ = Weight of the hanging mass in N, m = hanging mass in kg, g = Acceleration due to gravity in m/s^2, x_{max} and Δx see description of Figure 2 below, k = bungee constant in N/m, F_{spring} = Hooke's Law equation, force of the spring in Newtons. Our mgx_{max} equation was given to us in lab by Professor Cumming as one of the important equations in this lab, which we used to determine our x_{max} length for each mass.

Basis or brief theoretical background: The basis for our experiment was to experimentally calculate values for our bungee cord system that could be used to allow an egg to experience a bungee jump without breaking at all without using the egg to directly find our values. We believed that, since a spring and a bungee cord experience similar oscillatory motion, we could apply Hooke's Law to a bungee cord and determine a "k" value for our bungee cord.

Hypothesis (or expectations): Our Hypothesis is that a bungee cord system acts similar to a spring in motion, so therefore by measuring the distance the bungee cord is stretched by the addition of a hanging mass and comparing that to the weight of the mass, we may determine a "k" value similar to the values used in springs. This value can be used with force and conservation of energy equations in order to determine several important values for the actual egg drop.

METHODS:

Describe the overall method and its rationale in a sentence or two:

Our method in this lab was to treat the bungee cord as a physically similar object to a spring because they observe similar oscillation patterns and to use this similarity to determine a "k" value for our bungee cord. We will use this "k" value with force and conservation of energy equations in order to determine necessary values for our final egg drop experiment.

Diagram, identifying *all* items, variables and/or measurements--use *Word* (Insert-shapes-drawing canvas), a drawing program, or *at least* use a ruler and blank paper and scan it in:

Figure 1: Diagram of our Lab Setup

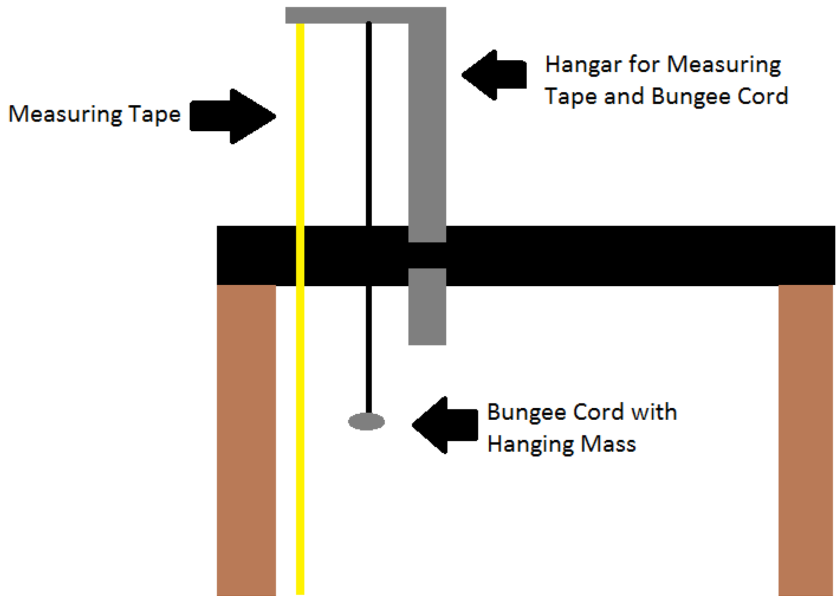
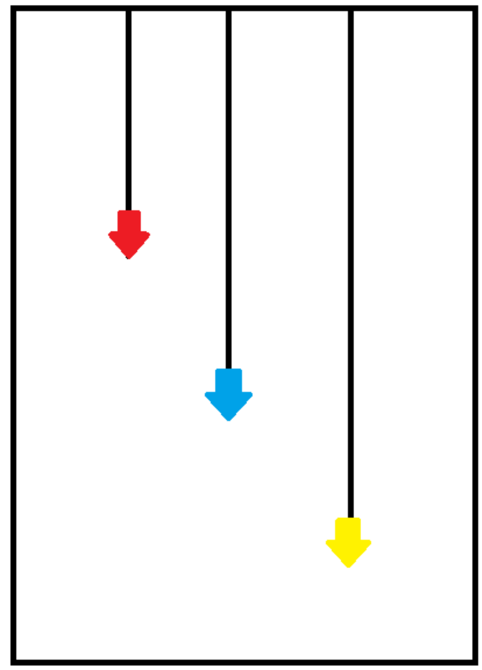


Figure 2: Diagram of the different distances that the hanging mass may be at



The figure on the left (Figure 1) is a diagram of the system in our lab which we used to determine our measurements. The figure on the right (Figure 2) is a rough depiction of the varying heights of the bungee cord. The top of the box is the hanger, and the bottom is the floor. The distance the bungee cord reaches at the red arrow is the maximum positive vertical displacement from equilibrium, the distance the bungee cord reaches at the blue arrow is the point of equilibrium, and the distance the bungee cord reaches at the yellow arrow is the max stretched distance (x_{max}). The difference in height between the equilibrium point and the max stretched distance is referred to as Δx.

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

- Create two loops in bungee cord .49 m apart from each other, one for weight and one to attach to hanger
- Attach bungee cord to hanger and weight to bungee cord
- Quickly measure stretch distance of bungee cord for that specific amount of hanging mass to not damage our cord
- Remove weight from bungee cord, and repeat for each different mass measurement listed in Figure 3

RESULTS:

In a sentence or so, give the reader context—data collected, and how it is analyzed to get the relevant result:

We began by taking several different objects with different known masses and hanging them from our bungee cord system. By measuring the difference between stretched and unstretched distances, we were able to determine the "k" value in this bungee cord for different hanging masses. With this data, we are able to apply this "k" value towards finding the total energy of the system and finding relevant information for our real egg drop such as distance or velocity.

Table(s), inserted from *Excel*, labeled with units and uncertainties, including "raw" data and averages/standard deviations where appropriate, and with columns identified further if needed:

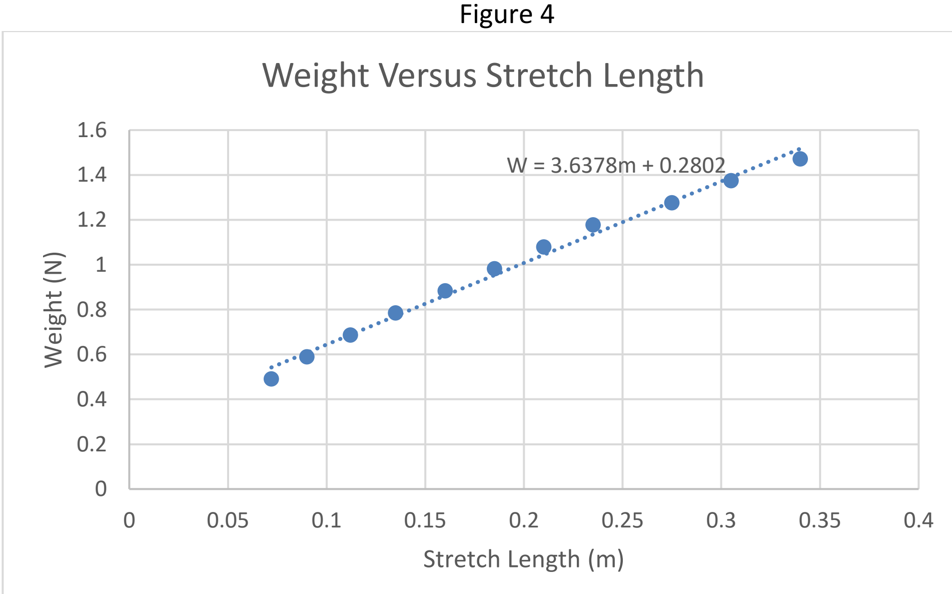
Figure 3: Raw Data Table from Lab

Hanging Mass (kg) ± 0.001 kg	**Weight (N) ± 0.001 N**	**Δx (m) ± 0.005 m**	**k=mg/x ± 0.003 N/m**
0.05	0.49	0.07	6.81
0.06	0.59	0.09	6.54
0.07	0.69	0.11	6.13
0.08	0.79	0.14	5.81
0.09	0.88	0.16	5.52
0.10	0.98	0.19	5.30
0.11	1.08	0.21	5.14
0.12	1.18	0.24	5.01
0.13	1.28	0.28	4.64
0.14	1.37	0.31	4.50
0.15	1.47	0.34	4.33

Table with all of the raw figures from our measurements in lab. Our cord length between the two loops during data collection was .47 m

Graph, if applicable, inserted from *Excel*, labeled with axes and units, and with ***curve-fit*** (also known as "trendline" in *Excel,* this could be a linear or non-linear fit):

Figure 4



This is the resultant graph from our lab data. The slope of the line is our "k" value, and this trend can be used to reliably determine what the "k" value will be for any given mass.

Equation of the curve-fit from the graph, if applicable (*substitute* your variables for *Excel's* y and x):

W = 3.6378m + 0.2802

Use *Excel* regression analysis on any graph that has a linear fit *only (see EG)* to obtain

uncertainty for slope= 0.117 % uncert= 3.22%

uncertainty for y-intercept= 0.025 % uncert= 8.33%

Identify and calculate experimental value(s) of interest (usually relating to equation in introduction) from the data or graph equation. Report them…

Experimental values of interest, and how obtained, briefly:

"k" was calculated by dividing the weight of our hanging mass by the distance stretched by the hanging mass

uncertainty of experimental value(s) = 0.117 % uncert= 3.22%

name the technique used for propagation of uncertainty *(see UG)*: Data Regression in Excel

Include any other pertinent info for the reader (who may not have done this experiment) to follow along:

Summarize "what happened" (just the facts)—give the important, relevant results, and why/how they are relevant to the purpose, in a sentence or two:

We measured the static distance between the equilibrium point of the bungee cord and the strected distance of the cord with varying masses hanging from it. These values allowed us to calculate "k," which can be used with conservation of energy equations in order to calculate relevant values necessary for the final egg drop.

DISCUSSION:

Error analysis--Quantitatively compare, if possible, the value(s) obtained to "accepted" values from theory or some other source. Identify the values:

Uncertainty vs. error, or % uncertainty vs. % error, for each value of interest from Results section:

If no values are available for comparison, determine "acceptability" of uncertainty in your value(s) according to your needs. AND determine a test of your value(s) for "error" -- e.g. use your result to predict something, and then measure it (if time permits), or briefly describe how you would test it:

Since both of our percent uncertainties are under 10% error, I believe that both are within acceptable values for our experiment. In order to test for our error in this problem, we can calculate the maximum positive distance from equilibrium using our other two measured distances, and then measure the experimental distance in lab to determine accuracy. I believe our uncertainty is most important is our uncertainty for our y-intercept, since it is the largest value we had and is crucial to the calculation of our "k" value.

Any observations or extenuating circumstances that aid in interpretation or evaluation:

Sources of uncertainty and their relative significance (PLEEEASE don't say "human error." Identify *specific* sources of "error"—think of things that may add uncertainty or skew data, rather than "bad" things or "mistakes"):

Possible sources of error include the gradual stretching of the bungee cord over time due to force being applied to it, the degradation of the rubber on the bungee cord due to the oils on our hands, and the possibility of the masses which were hung from the bungee cord not having the exact proper mass due to slight degradation over time from use.

In a couple sentences, describe whether your main results support your hypothesis. How well were the results in agreement with theory, expectations, or otherwise deemed "acceptable"? Why/how so, or not?

Since the motion of a bungee cord is similar to the motion of a spring in certain cases and our measurements were able to determine an accurate trend for a "k" value in relation to weight and stretch distance, our hypothesis was supported by our results and calculations. While there are certain cases in which this would not be true, such as if the cord is stretched to a much longer length or if the cord transitioned horizontally in addition to vertically, those cases are not applicable to our current lab, so our results are in agreement with our hypothesis.

CONCLUSION:

Clearly and definitively state the experimental outcome(s) in terms of your question or purpose:

The experimental outcome of our equation was a relation between stretch distance and weight of a varying hanging mass which gives us a "k" value that can be used for future egg drop situations with the same bungee cord.

Implications of these conclusions (e.g. the significance to larger questions), next steps proposed:

These conclusions allow us to use Hooke's Law for springs with bungee cords in other similar cases and on a larger scale by keeping the length of the cord constant, as well as allow us to determine distance travelled by an egg and forces acting on an egg in future egg dropping scenarios. An example of a larger scale use for this data is an actual human bungee jump, and an example of a similar case to this experiment would be in an experiment that used similar conditions but varied the mass to a different value from what we varied it to. Our "k" value could also possibly lead to a connection with the length of the cord, which could also prove useful for the final egg drop if we decide to change the length of the cord.

REVISIT ABSTRACT: Our experiment in this lab was to collect data for our future egg bungee jump. We decided that the best way to obtain this data was to compare a bungee cord to a spring and hypothesized that, since both undergo similar oscillatory motion in certain cases, we could use Hooke's Law, which states a relationship between the force needed to compress a spring a certain distance and the distance times a constant "k," to find a "k" value for our system. We were able to find this "k" value by varying the hanging mass on the system and measuring the static max stretch distance, then graphing the weight of the hanging mass versus the stretch distance. Our experiment yielded a method to find the "k" value with approximately a 3% uncertainty, which is highly accurate. This "k" value can be used with force equations and conservation of energy equations in order to determine appropriate values that can be used for our future egg drop.

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

I had a friend of mine, John Harashinski, read over this.

Pledged: Jack Richman