Lab Report Outline—the Bones of the Story

In this course, you are asked to write only the outline of a lab report. A good lab report provides a complete record of your experiment, and even in outline form should convey a coherent and comprehensible story. This is an outline, not a summary. Give the relevant details *throughout—the details that answer the questions a scientifically educated reader might ask while following your story line. The emphasis is on clarity, thoroughness, and relevance, and of course conciseness (being an outline).* ***Report Outlines are individual assignments. Cite any work not your own, acknowledge any aid, and pledge the report.***

Fill in this form for reporting on experiments when required. (Did we say to give the relevant details throughout?) When finished, feel free to delete instructional verbiage or unused parts, for proofreading ease, and reading "flow."

Your name and your lab partner(s): Ron Perets and Sequoya Bua-Iam **Section:** 01 **Date: 10-22-16**

TITLE: Behavior of Elastic Cord Under Different Mass Loads

ABSTRACT: *Bungee cords have a wide range of uses, but the most popular use involves tall bridges and adventurous people. We sought to better understand the elastic capabilities of bungee cords using a similar concept to bungee jumping but on a smaller scale. To do this, masses of varying weights were attached to a singular thin cord (length of 0.50 m) and dropped repeatedly from the same height. We measured the maximum distance the cord stretched using slow motion footage and divided it by the un-stretched length of cord to find a percentage of stretch. The percentage stretch was modeled against the mass used for the drop. We found that the percent stretch was linearly correlated to the mass of the drop, modeled by the formula %stretch = 1050m + 12.2, where m is the mass used in the drop. Using the formula, and knowing the length of un-stretched cord, we can predict its* X_{max} *for a specific mass. In predicting the* X_{max} *we can make sure a jumper gets as close to the ground as possible without actually hitting the ground.*

INTRODUCTION:

Long free-falls and close encounters with the ground make for the most exhilarating bungee jumping experiences, but inaccurate predictions on the stretch of the cord can leave your jumper with a boring experience or a fatal encounter with the ground. Understanding how a bungee cord stretches can allow us to model how the cord will behave under varying conditions such as bridges of different heights or jumpers of various masses. Our aim in this experiment was to see the percent stretch of the bungee cord when a mass is attached to it and dropped from a specific height. By determining the percentage of stretch for a specific mass and varying the length of cord, we can determine what distance the mass will fall before the bungee pulls it back up.

Relevant equations:
$\%stretch = X_{max}/X_0 \times 100$
%stretch is the percentage of stretch of the bungee
X_{max} is the maximum length of the bungee during a drop
X_0 is the unstretched length of the bungee with a mass attached
$F = -k(X_0 + X_{max})$
F is the force of a spring
k is a spring constant
$w = mg$
w is a vector force
m is the mass of an object
g is the gravitational force constant near the earth

The bungee cord acts like a spring and the force exerted on the spring can be modeled by $F = -k(X_0 + X_{max})$. The force the mass exerts on the spring is its weight, which is equivalent to its mass times the constant g, so the formula can be rewritten as $mg = -k(X_0 + X_{max})$ when the mass is at position X_{max} because this is when the total force on the mass equals zero. The equation can then be rewritten as $X_{max} = mg/-k – X_0$ where g/-k is a constant for the bungee and X_0 and X_{max} can be measured. By comparing the change of X_0 to the change in X_{max} as a function of mass, we find the relationship between them as a percent change (%stretch). %stretch is the ratio of the maximum length of the bungee cord during a drop versus its unstretched length, calculated as a percentage. By comparing the unstretched length of the cord to the maximum length of the cord during a jump we are finding the percent change in the length of the cord. The %stretch can then be plotted against the mass of each fall to determine how it is influenced by the mass. By knowing the change in length the cord will undergo during a fall and the original length of the cord, we can determine the maximum length of the cord during a fall with a specific mass attached to it.

Hypothesis:
The percent stretch will increase linearly with an increase in the mass dropped.

METHODS:

We dropped different masses from the same height (and with the same length of bungee) and measured the X_0 and X_{max} of the bungee. We then plotted the %stretch against the mass of the drop to determine how the %stretch varied with each mass.

Diagram:

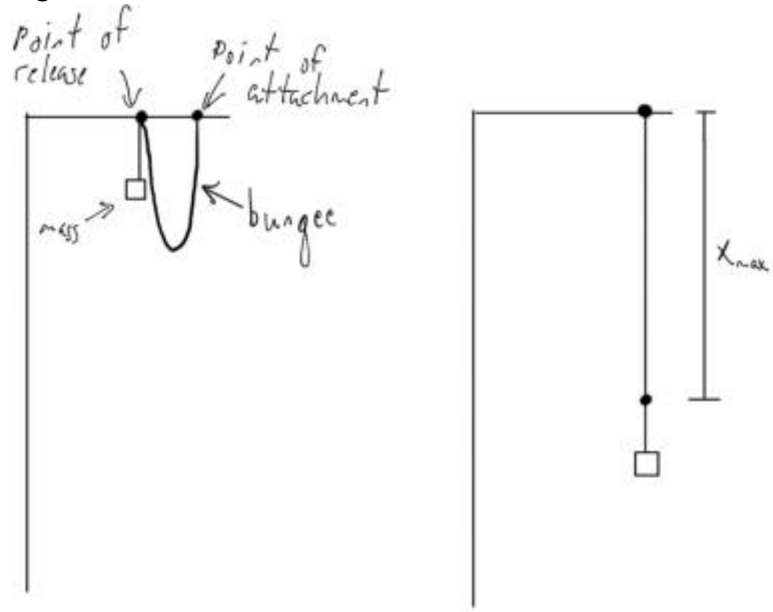

Figure 1. Method for dropping mass.

The image on the left shows how the mass was dropped, with the knot of the bungee cord tied directly to the crossbeam and the knot connecting the mass brought up to the height of the cross beam (note that the distance between the two knots along the crossbeam has been exaggerated to properly show the setup, in actuality the knots were placed as close as possible to each other). The diagram on the right demonstrates how we determined X_{max}, the height from the top of the crossbeam to the knot connecting the mass to the bungee cord.

Setup:

A stationary rod attached to a table with a crossbeam at the top was used as a representation of a bridge. A length of bungee cord was tied to the crossbeam so that the knot ended up resting right along the bottom edge of the beam. A slotted mass carrier was tied to the other end of the bungee and different slotted masses between .001kg and .100kg were used.

Procedure:

- Tied one end of bungee to crossbeam and used tape to hold the knot exactly at the lower edge of the crossbeam
- Attached tape measure to crossbeam

- Measured out 0.5m of bungee cord and tied hook of slotted mass carrier to bungee at the 0.5m mark (measured from bottom of the crossbeam to the knot itself), used tape to hold knot at exactly the top of the slotted mass carrier
- Set up slow motion camera (iPhone 7 at 240fps) approximately 1m away from tape measure
- Measured X_0 for each drop was measured by a tape measure affixed to the top of the crossbeam. X_0 is the distance from the knot at the bottom edge of the crossbeam to the knot at the top of the slotted mass carrier
- Measured X_{max} by bringing knot attaching slotted weight carrier to bungee up against the knot attaching the bungee cord to the crossbeam, starting the slow motion camera, and dropping the slotted mass carrier
- X_{max} was the farthest point the slotted mass carrier fell as measured from the knot at the crossbeam to the knot on the slotted mass carrier as could be seen from the slow motion video (played frame by frame)
- 2 technical replicates completed for each mass interval (between 0.050kg and 0.160kg)
- Slotted masses were added to the carrier and measurements repeated for that mass

RESULTS:

We plotted %stretch (X_{max}/X_0 x 100) of each fall against the mass of that fall and created a formula relating %stretch to mass based on the slope of the trendline of the graph.

Mass (kg) (±1%)	*X_0 avg (m) (±0.01m)*	*X_{max} avg (m) (±0.01m)*	*% stretch (%)*
0.050	*0.60*	*1.18*	*67.5*
0.065	*0.65*	*1.30*	*79.0*
0.080	*0.70*	*1.48*	*96.3*
0.095	*0.76*	*1.63*	*112*
0.110	*0.84*	*1.80*	*128*
0.125	*0.93*	*1.91*	*140*
0.140	*1.03*	*2.11*	*160*
0.155	*1.15*	*2.30*	*177*
0.160	*1.19*	*2.35*	*182*

Table 1. The mass of each drop along with the average X_0 for the two replicates and the average X_{max} for the replicates. %stretch was calculated using the formula %stretch = X_{max}/X_0 x 100. Uncertainties for X_0 and X_{max} were calculated by taking the quadratic sum of the individual replicates.

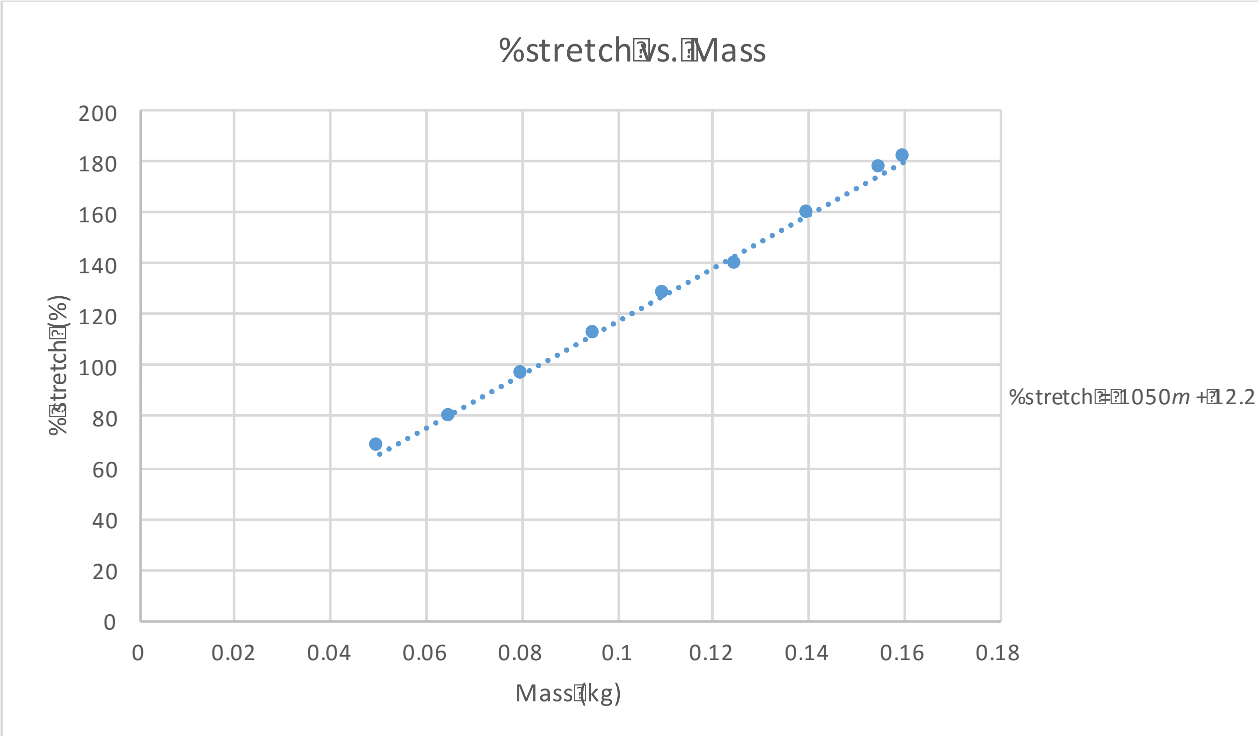

Figure 2. %stretch as a function of mass. The %stretch was plotted against the mass of that drop and the linear trendline for the data was found to be represented by the function %stretch = 1050*m* + 12.2 (where *m* is the mass of the drop).

Equation:

%stretch = 1050*m* + 12.2

uncertainty in coefficient(s)= 20 (1/kg)   % uncert= 2%

The sum-of-squares method was used to calculate the uncertainties of X_0 and X_{max}.

The coeffificent of *m* is of interest because it is the factor that relates the mass of the drop to the %stretch of the bungee. By knowing this factor, we can calculate %stretch of the bungee cord just by knowing what mass is attached to it.

value obtained = 1050 (1/kg)

uncertainty of experimental value(s) = 20 (1/kg)   % uncert= 2%

Uncertainty was calculated using the sum-of-squares method by taking the uncertainties of X_0 and X_{max}. Since the fractional uncertainties of X_0 and X_{max} varied based on the drop, the highest fractional uncertainty was found and used.

The function relating mass to %stretch was found to be represented by the equation %stretch = 1050*m* + 12.2, which allows us to determine the percentage that a bungee cord is stretched when a specific mass is dropped. With this equation, we can determine the X_{max} of a drop by just knowing the unstretched length of the bungee, the mass used in the drop and both formulas for %stretch.

DISCUSSION:

The formula for determining %stretch was linear as expected. When the mass has reached its X_{max} the two main forces acting on it are the force of gravity pulling it towards the ground and the force of the bungee, which is of equal magnitude but in the opposite direction. Since the forces are of equal magnitude to each other at X_{max}, the force of the weight of the mass on the spring can be modeled solely by F = *ma* where *a* is the acceleration due to gravity. Since *a* is constant, F is directly proportional to the mass attached to the bungee. Since they are directly proportional, an increase in *m* will cause a linear increase in F and linearly change the position of X_{max}.

The percent uncertainty for our mass coefficient is approximately 2%, which equates to a 2% uncertainty in the %stretch. Since the ultimate goal of the project is to produce a bungee experience in which the mass is as close to the ground as possible without hitting the ground, a 2% uncertainty is acceptable for shorter falls, but at higher falls, compensation must be made so that the jumper does not hit the ground, even if that means not getting as close to the ground as possible. A potential method for testing the acceptability of this uncertainty for higher falls would be to have a bungee cord much longer than the one used and a jumper of a known mass. By using our formulas for %stretch we can predict what distance the jumper would fall (X_{max}) and place the bungee at the appropriate height so that the jumper doesn't hit the ground. The jumper could then be dropped repeatedly to see if they hit the ground, if not then our uncertainties are acceptable. If the jumper does hit the ground, then our uncertainties are unacceptable and must be compensated for.

Sources of uncertainty include frame rate and angle of the slow motion camera. The mass could potentially have reached X_{max} in between frames and the angle of the camera could have made it appear that the mass was either lower or higher than it actually was. Another source of uncertainty was the method used for measuring X_0, which involved using a tape measure placed up against the bungee cord. The effects of hysteresis on the bungee over many jumps could have increased uncertainty over time. The uncertainty of the mass of the slotted masses used could have further increased uncertainty.

The change in %stretch based on the mass of the drop was linear as predicted. Theoretically, %stretch should be linear and our findings show that this is in fact the case. Unfortunately, without expected values and a lack of time to determine the acceptability of our results, we cannot know for sure how well we will be able to predict the X_{max} of a drop.

CONCLUSION:

The equation for %stretch derived from the %stretch versus mass is exactly what is needed to predict the X_{max} of a jumper. By being able to determine X_{max} we can make sure that the jumper is high enough or the bungee is short enough so that the jumper does not hit the ground. The next step will be to analyze if this relationship between mass and %stretch is conserved over different lengths of bungee cord. If this relationship is conserved, then only the formulas %stretch = 1050*m* + 12.2 and %stretch = X_{max}/X_0 x 100 are necessary to predict the maximum distance a jumper will fall using the cord.

READ OVER your report outline—do not skip this step! *Look for the* ***logical progression*** *from one item to the next, from one section to the next, while thinking of that reader who hasn't done this experiment. Does the reader have the* ***information needed*** *to follow the report, and even repeat the experiment? You must put yourself into your reader's shoes, in order to do this.* ***Delete instructional verbiage*** *or unused parts, for proofreading ease, and reading "flow."* ***Finally, REVISIT ABSTRACT:*** *Revise your abstract, above, or even completely rewrite it. Your understanding of the experiment probably (hopefully!) evolved as you worked through the outline above.*

Does your revised abstract fairly represent the rest of this document, AND coherently tell the story of the experiment? If you struggle with writing it clearly, then you probably need to do more thinking on the outline —does each step logically and smoothly flow to the next? Is the story consistent? Will someone reading this report grasp the meaning and significance of your conclusions, and "believe" them? Identify weak or vague points in the document, revise the outline, and then try revising the abstract again.

When finished, REPLACE your original draft Abstract with your final draft. Do NOT leave it here for your reader to find after the fact.

Report Outlines are *individual assignments*. Cite any work not your own, acknowledge any aid, and pledge the report:

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

Pledged: Ron Perets