Lab Report Outline

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How force changes with various elastic cord lengths

ABSTRACT:

Although from our previous bungee cord experiment we can predict the force of our drop with a certain un-stretched cord length (X_L), it is still informative to understand the relationship between force and bungee cord length. While cord length is mainly important for dropping the egg as close to the floor as possible without smashing it, we wanted to analyze its effect (if any) on the force of the drop. A greater "thrill"—acceleration—of the drop would make our team more competitive, but we must also be careful to not have a drop force exceeding three times the weight of the egg system. In order to analyze how force changes while varying cord length and keeping mass constant per experiment drop, a force sensor was attached to our system. Based on our results, we concluded that change in cord length has no major effect on the force of the drop. This result is not surprising, given we observed little change in elasticity (% stretch) with varying X_L in our first bungee lab. This result also has comforting implications for if we tie together multiple bungee cords for the final, longer drop. Nevertheless, the accuracy of our data could have been skewed by a 0.01m visual estimation uncertainty and could have been improved by conducting more than one trial.

INTRODUCTION*:*

In our first bungee lab, we focused on the elastic properties of the cord, and how they changed with different cord lengths and masses; however, for this second bungee lab, we wanted to test an aspect that affects the force of the drop—in this case, un-stretched cord length (X_L). From the previous bungee cord experiment, we can predict the force of our drop with a certain un-stretched cord length, but we neglected to analyze the relationship between force and bungee cord length. We were initially concerned with cord length to better plan how to drop the egg as close to the floor as possible without smashing it. This time, we pursued analyzing the effect (if any) of cord length on the force of the drop. Drops with no change in mass but higher forces are indicative of an increase in acceleration (*see Equation 1*) and a greater "thrill" drop. One of our final goals is to have a drop with the greatest acceleration possible. If our drop exceeds three times the weight of the egg system, then our egg will most likely experience mid-air cracking. Results from this experiment could inform the use of multiple bungee cords (X_L to an even larger scale) for the final drop.

Relevant equations (with variables identified):

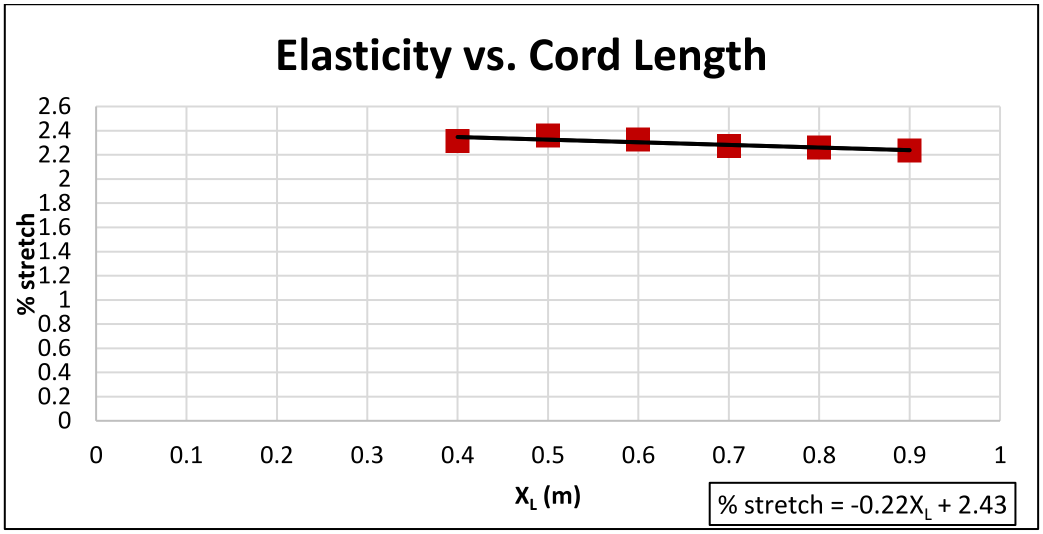
Equation 1 Newton's 2nd Law: $\vec{F} = m\vec{a}$

F = Force (in N)
m = Mass (in kg)
a = Acceleration (in m/s^2)

Hypothesis:

The elastic properties of a stretched cord give it a resistance factor potentially affecting the force of a mass dropping while attached to that cord. Since elasticity (% stretch) had little change with different X_L values (based on our first bungee lab, *see Figure 1*), we expected an insignificant change in force as we varied X_L.

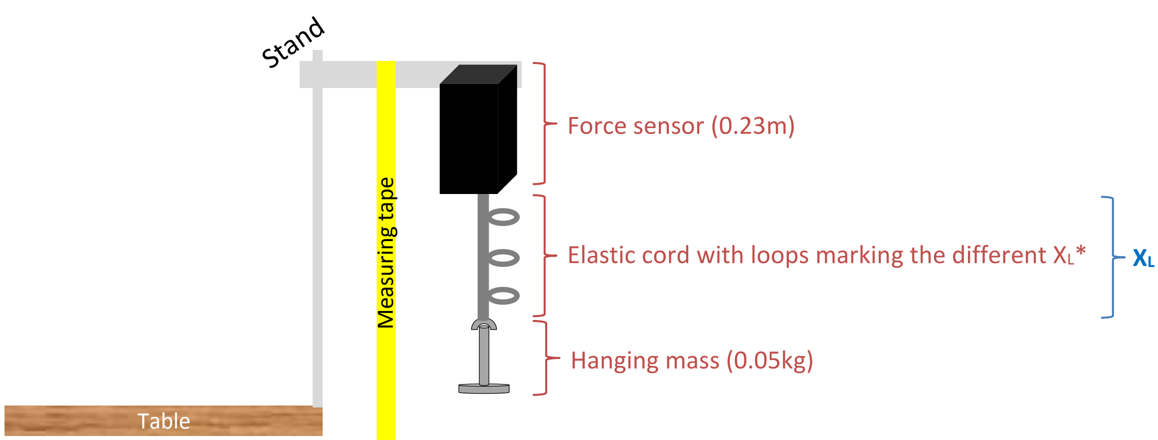
Figure 1: Results from the first bungee lab. The change in elasticity (% stretch) with cord length (X_L) is not only linear, but overall fairly horizontal as well, signifying barely any change.



METHODS:

We conducted ten drops with different cord lengths (X_L) but the same mass (0.05kg) to test how (if) cord length affects the force of the drop as measured by a force sensor and recorded by the Capstone computer program (*see Figure 2*).

Figure 2: Overall experiment setup. The bungee cord was attached to the bottom of the force sensor. We altered the un-stretched elastic cord length (X_L) by changing loop location for the hanging mass, which itself was not included in the X_L value. *Each loop was untied before moving on to the next length, so the ones shown here are at arbitrarily selected locations.



Setup/Procedure:

- We hung the force sensor at the top of the table stand.
- We had to calibrate the force sensor by taring it without anything attached.
- We stretched the new bungee cord before conducting any drops to prevent it from fatiguing.
- We taped the top of the bungee cord to the bottom hook of the force sensor.

- To achieve different un-stretched elastic cord lengths, we tied a loop at a different cord location for each trial, untying any previous ones.
- We hung measuring tape alongside our system in order to visually estimate where to tie our loops (keeping in mind the length of the sensor and stopping at the top of the hanging mass).
- We only used the hanging mass, never adding further mass, so it remained 0.05kg throughout the whole experiment.
- For the drop, we lifted the top of the hanging mass up to the bottom hook of the force sensor and let it go.
- The force value that we recorded for each drop was provided by the force sensor's compatible computer program, Capstone.
- We did 10 drops, one trial per length, with X_L = 0.1m, 0.2m, 0.3m, 0.4m, 0.5m, 0.6m, 0.7m, 0.74m, 0.8m, and 0.9m.

RESULTS:

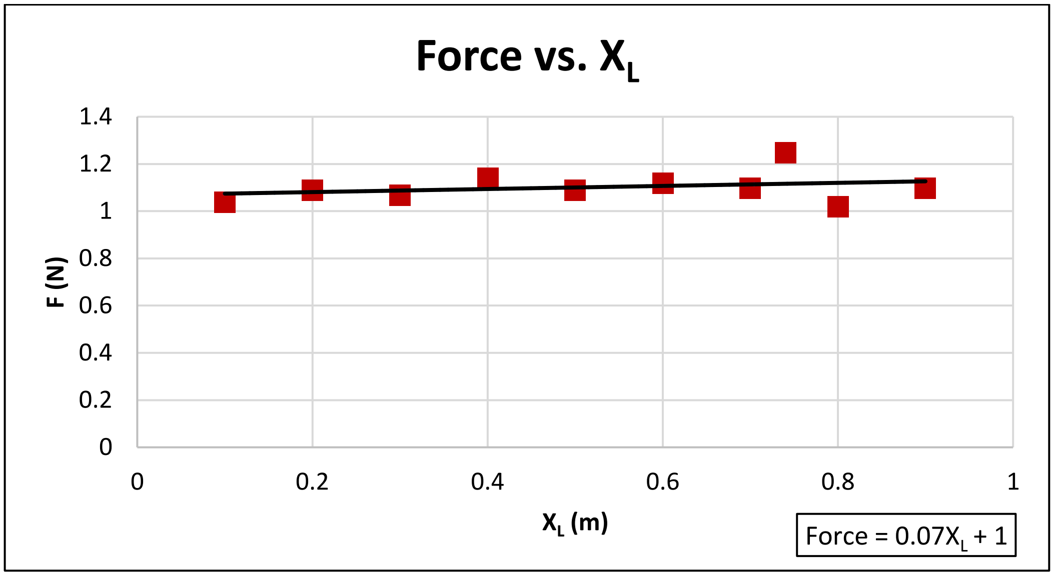
We recorded the force values of drops conducted with increasing un-stretched cord lengths but a constant mass of 0.05kg (*see Figure 3*) and then plotted the two factors against each other in order to determine if they have a considerable relationship (*see Figure 4*).

Figure 3: Table of our independent (X_L) and dependent (F) values.

Un-stretched elastic cord length $\mathbf{X_L}$ (m) ± 0.01m	Force **F** (N) ± 0.02N
0.1	1.04
0.2	1.09
0.3	1.07
0.4	1.14
0.5	1.09
0.6	1.12
0.7	1.1
0.74	1.25
0.8	1.02
0.9	1.1

The raw X_L uncertainty is based on our confidence in visually estimating the length location of the loop along the tape measure. The raw force uncertainty is based on the results of taring the sensor multiple times before beginning our experiment.

Figure 4: Plot of Force vs. Un-stretched elastic cord length (X_L). Notice the linearity and horizontalness of the trendline, indicating little change in force with varying cord length.



Equation of the linear-fit from the graph: Force = $0.07X_L + 1$

***Excel* regression analysis for the linear-fitted graph:**

uncertainty for slope = 0.08m % uncertainty* = 50%

uncertainty for y-intercept = 0.05N % uncertainty = 6%

* % uncertainty = 100 (standard deviation / average of that variable), rounded to have one significant figure

Experimental values of interest: We mainly focused on the overall relationship between un-stretched cord length and force rather than trying to determine a specific value. However, force values close to 1.47N may be of greater interest given this value is three times the weight of the hanging mass. We could attempt to scale our final drop X_L to achieve a force just below 3(mass)(gravity).

Closest value obtained = 1.25N at X_L = 0.74m
Observation: This value appears to be a potential outlier in our data, and it is still quite below 1.47N.

uncertainty of experimental value = ± 0.02N % uncertainty* = 2%

* % uncertainty = 100 (raw uncertainty / actual value), rounded to have one significant figure

Results summary:

- The force of a drop is not greatly influenced by the un-stretched elastic cord length (*see in Figure 4*), so this relationship should not be of major concern when combining multiple cords for the final drop.
- All of our force results were well below the 3(m)(g) limit (*see Figure 3*).

DISCUSSION:

Error analysis:

% error of the force value of interest* = 15% > % uncertainty = 2% , so results appear not accurate

* % error = 100 [(accepted value - actual value) / accepted value]

All values less than 1.47N (which is three times the egg system weight) were acceptable from a max force standpoint, so 1.47N was used as the accepted value.

Sources of uncertainty/Steps for improvement:
Visually, the trendline of Figure 4 appears almost horizontal, and according to our original hypothesis, the slope should be ~0.0m. However, its actual value is 0.07m, so sources of uncertainty may explain why we got this higher than expected result.

- We gave our visual estimations of where the loops should be located along the cord at ± 0.01m raw uncertainty value.
- Since we neglected to tare the force sensor before each trial, we did not practice achieving high precision.
- We also did not practice achieving high precision due to only having conducted one trial (due to time constraints).
- The accuracy of our results could have been further assessed by conducting some sort of test.

Our main results supported our hypothesis, but while conceptually acceptable, statistically they are not acceptable.

CONCLUSION:

Change in un-stretched elastic cord length had no major effect on the force of the drop; therefore, cord length is most important for general height calculations with the consideration of the cord's elasticity.

Implications:

- If we tie together multiple bungee cords for the final drop (which will most likely be the case), we should not have to worry about this dramatically altering our drop force.
- We can more accurately predict the force of our final drop knowing the final drop's X_L and given the graphical and mathematical relationship produced by this second bungee lab.

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

Pledged: *Sequoya Bua-Iam*