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Mass and Un-Stretched Length as they relate to maximum stretch of a bungee cord.

ABSTRACT:
Our experiment was designed around the goal of determining a quantitative relationship between two variables of a bungee cord drop with a third variable. The two variables we examined were the mass attached to the end of the bungee cord (M), and the un-stretched length of the bungee cord (L). Our experiment determined two equations, one for each variable, that showed the relationship of each respective variable to the maximum length to which the bungee cord will stretch during the drop (H). Each separate equation was found with a unique experiment. The experiment to determine how changes in mass affected the maximum stretch of the cord kept the un-stretched length of the cord constant and varied the masses attached to the end of the cord. The equation to determine how changes in the un-stretched length of the cord affected the maximum stretch of the cord kept the attached mass constant and varied the un-stretched length of the cord. These two experiments both followed the same general procedure. One end of the bungee cord was attached to a hanging apparatus and the end with the mass attached was dropped from the same apparatus, and the maximum stretch of the bungee cord during the drop was measured with a slow-motion camera. The results of our experiment yielded equations with extremely low percent errors, proving the accuracy of our methodology. Together, these two equations allow us to determine what one of the three variables (maximum stretch of the cord, mass attached to the cord, and un-stretched length of the cord) should be when the other two variables are given.

INTRODUCTION:

Purpose or question:

The Purpose of our experiment was to determine a quantitative relationship M and H, and a quantitative relationship between L and H.

Relevant equation(s), identifying variables:

- H=X+L
    - H=Height of the drop
    - X=max stretch length of the cord (after mass is dropped)
    - L=Un-stretched length of the cord
- mgh=1/2kx^2
    - m=Mass
    - h=length of the drop
    - x= max stretch length of the cord
    - k=spring constant
- F=-kx
    - F= Force of the bungee on the mass
    - K=spring constant
    - X=max stretch length of the cord

Basis or brief theoretical background:

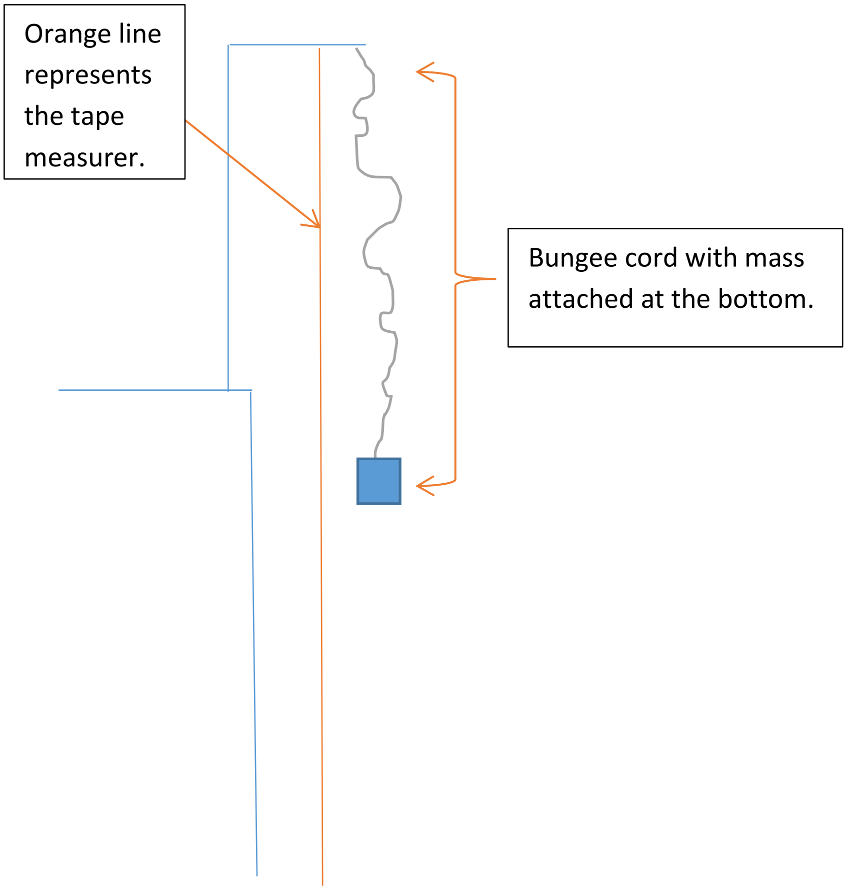
The equation F=-kx can be rewritten as mg=-kx, which is true at the bungee's max stretch length. This equation has two constants (g and k) and two variables (m and x). By keeping one variable constant and varying the other the varying variable's effect on the k value can be evaluated.

Hypothesis (or expectations):

We hypothesize that careful experimentation can yield precise equations relating two variables of a bungee cord drop (the mass attached to the cord and the un-stretched length of the cord) to the maximum distance the cord will stretch.

METHODS:

The rationale of our experiment was changing either the variable m (mass) or the variable L(length of the cord) while keeping the other constant. This allowed us to evaluate the way the changing variable effected the calculated K value.



Describe setup and procedure, *including relevant or significant details* (may be bullets):
Our method centered around two different experiments, one in which Mass (M) was varied and one in which the un-stretched length of the cord (L) was varied. For both experiments one end of the bungee cord was attached to a hanging apparatus, and a mass was attached to the other end. A tape measurer was hung from the apparatus and extended to the ground. We then dropped the mass from the apparatus, at the same height as the end of cord that was attached to the apparatus. The maximum length of the bungee cord during its drop was measured using a slow-motion video (captured by an iPad) and the tape measurer. Each video would show the mass (in slow-motion) falling adjacent to the tape measurer, stopping, and then rising back up the tape measurer. The maximum length of the bungee cord was determined as the point at which the mass was stopped. For the first experiment, the un-stretched length of the cord was kept constant, and the mass attached to the end of the bungee was varied. For the second experiment, the mass on the cord was kept constant, and the un-stretched length of the cord was varied.

RESULTS:

to get the relevant result:

We collected two sets of data. One of which measured the maximum stretch length of the bungee cord with masses varying from 15g to 50g (while the length of the cord was held constant at .74m). The other data set measured the maximum stretch length with the un-stretched length of the cord varying from .21m to .66m (while mass was held constant at 100g).

Figure 1: Table of Mass (M) vs. Height of the drop (H)

M(kg)	H(m)
0.015	1.01
0.020	1.08
0.025	1.14
0.030	1.20
0.035	1.24
0.040	1.32
0.045	1.40
0.050	1.48

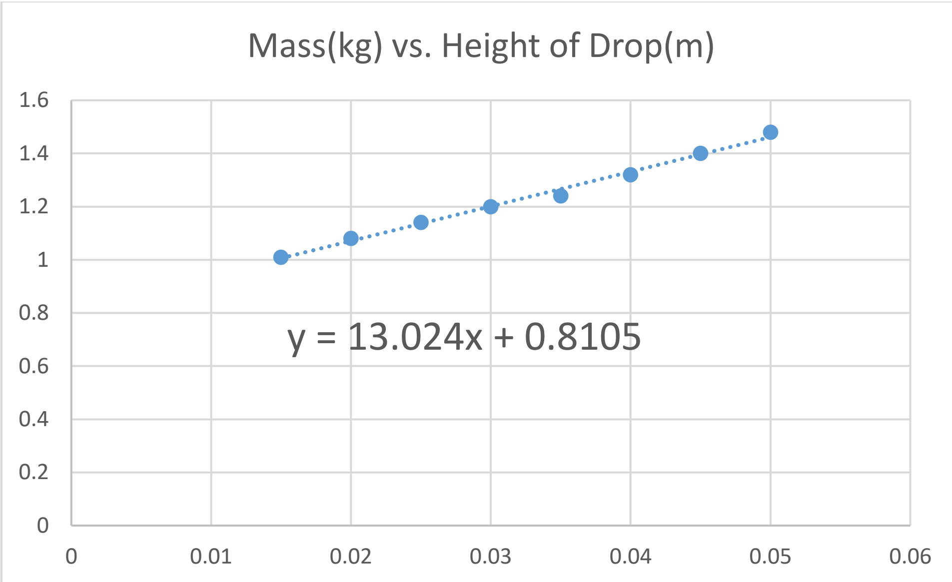
- Here Height refers to the length of the cord at its moment of maximum stretch.
- The un-stretched length of the cord was held constant at .74m
- The uncertainty for the Height measurements was .05m
- The uncertainty for the Mass measurements was negligible.

Figure 2: Table of Un-Stretched Length of cord (L) vs. Height of the drop

L(m)	H(m)
0.447	1.352
0.660	1.992
0.210	0.682
0.313	0.982

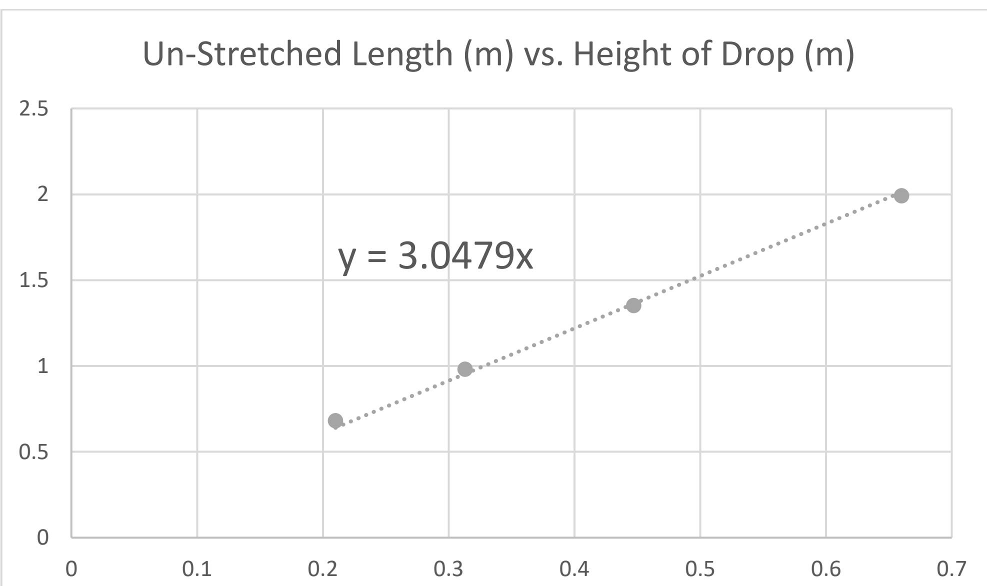
- In this table Height again refers to the length of the cord at its moment of maximum stretch
- The mass attached to the bungee cord was held constant at 100g
- The uncertainty for the Height measurements was .05m
- The uncertainty for the L measurements was .005m

Figure 3: Graph of Mass (M) vs. Height of the drop (H)



- The Y-axis of this graph represents the H values, while the X-axis represents the M values.
- The un-stretched length of the cord was held constant at .74m
- The equation of the best fit line is H=13.024(M) + .8105
- uncertainty for slope= .452 (obtained through excel regression analysis)
    - % uncert= 3.47%
- uncertainty for y-intercept= .0156 (obtained through excel regression analysis)
    - % uncert= 1.92%

Figure 4: Graph of Un-Stretched Length of cord (L) vs. Height of the drop



- The Y-axis of this graph represents the H values, while the X-axis represents the L values.
- The mass attached to the bungee cord was kept constant at 100g
- The equation of the best fit line is H=3.0479(L)
    - The y-intercept of this graph was set to be (0,0), because if the cord had a hypothetical length of 0m the hypothetical maximum stretch of the cord would also be 0m.
- uncertainty for slope= .0361 (obtained through excel regression analysis)
    - % uncert= 1.18%

The important results of our experiment were not any specifically obtained values but obtained equations that relate the respective variables mass and un-stretched length of cord to the maximum stretch of said cord (H=13.024(M) + .8105 and H=3.0479(L). However, the coefficients of these equations regarding mass and un-stretched length (13.024 and 3.0479 respectively) give the rate at which changes in each variable affects changes in the total distance the bungee cord will stretch, a very important concept for the egg drop.

DISCUSSION:

Our two values of interest were the coefficients of the best fit lines of our graphs. Since there are no "accepted" or "expected" values for our coefficients, there is no possible way to compare the accuracy of our coefficients, although we can evaluate the precision by examining the uncertainty of our data.
For the Mass(kg) vs. Height (m) data:

- Coefficient = 13.024
- Uncertainty of the coefficient = .452
- %Uncertainty of the coefficient = 1.92%

For the Un-Stretched Length of the cord (m) vs. Height (m) data:

- Coefficient = 3.0479
- Uncertainty of the coefficient = .0361
- %Uncertainty of the coefficient = 1.18%.

Analyzing the %Uncertainties for our coefficients reveals that our data was very consistent. Both percents fall below 2%, meaning the experiment was consistent and the values of the coefficients can be trusted. Unfortunately, we did not have enough time to experimentally test the accuracy of the coefficients of our graphs, but doing so would hypothetically be a trivial task. For example, if the coefficient in question was the slope of the Mass vs. Height data (13.024) a test for the accuracy of that value would go as follows:

1. Add another mass M (different from those used in the data table) to the end of the bungee cord while keeping the un-stretched length of the cord a constant .74m
2. Plug the mass M into the equation H=13.024(M) + .8105, and solve for H.
3. Perform the experiment (drop the mass from the top of the apparatus), and record the maximum length of the cord by using the slow-motion video.
4. Compare the calculated H value with the experimentally tested H value.

Potential sources for our uncertainties:

- The frames per second captured of the iPad could have failed to capture accurate H values.
- It was difficult to always drop the mass from the exact same height relative to the apparatus.
- The cord itself could have permanently stretched some over the course of the experiment.
- Friction in the air.
- The mass could have touched the hanging tape measurer significant enough way to skew the experiment but insignificant enough for us to not visibly notice.

The extremely low percent errors of our coefficients reveal that our hypothesis was correct. We successfully related the two variables (mass and un-stretched length of the cord) to the maximum length that the cord will stretch.

CONCLUSION:

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

Our experiment yielded two important quantified relations: how changes in mass affect the length to which a bungee cord will stretch, and how changes in the un-stretched length of the bungee cord affect the length to which said bungee cord will stretch. Since both of these equations (H=13.024(M) + .8105 and H=3.0479(L)) solve for the same H, they can be equated to each other, i.e. 13.024(M) + .8105 = .30479(L). However, this derived equation was never experimentally verified. In order to conclusively determine a relation between the variables Mass, Un-Stretched Length, and K value, a quantitative relationship between Un-Stretched Length and Mass must be experimentally determined. Nonetheless, our equations, as determined by our experiment, allow us to determine the proper un-stretched length of a bungee cord when given the mass that will be attached to it, and a maximum height to which the cord can stretch.