Relating Maximum Stretch of a Bungee to Initial Bungee Cord Length

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ABSTRACT: In order to accurately predict the fall of an egg in a bungee, it is important to determine the various parameters that will be used to create an effective bungee experience. In our experiment, we devised an equation that would relate the initial length of the bungee to its maximum stretch when an object is dropped. To do this, we attached a constant hanging mass (similar to an egg's mass) to varying lengths of a bungee cord and dropped the mass on each trial, using ten different bungee lengths. After measuring the stretch distance of the dropped bungee (X-max), we graphed X-max versus initial bungee length (X-L) to give us an equation relating X-L and X-max; X-max= 3.23(X-L) + 0.014 with .02% uncertainty. We may then use this equation to predict the X-max of a dropped object, for a specific bungee cord length. This will allow us to predict an appropriate bungee length to provide an egg with a safe bungee experience, without it hitting the ground.

INTRODUCTION:

To create a safe bungee experience for an egg dropped from a height, we must determine the length of the bungee cord we will use in the experiment. Previous experiments have used Hooke's law which relates Force and bungee maximum stretch: Force= kx, with spring constant *k* and bungee stretch length, *x.* However, we aimed to devise our own formula relating un-stretched bungee length (*x* in Hooke's formula) to maximum bungee stretch. To do this, we sought to model the relationship between different initial bungee cord lengths and the maximum stretch of that bungee when an object is dropped. With a constant mass similar to the egg's mass we will later use, we expect that our experimental formula will show a linear proportional relationship between initial bungee length (X-L) and maximum bungee stretch (X-max), such that X-max= (SLOPE) X-L.

METHODS:

To develop an experimental model for the relationship between initial length of a bungee cord and its maximum stretch when an attached mass is dropped, mass was kept constant and bungee cord length was varied on ten different trials. The mass was then dropped from the same height each time and the maximum stretch of the bungee was measured using slow-motion video recording.

Describe Set-up/Procedure:

A bungee cord of initial length, X-L, with unattached mass, was tied onto the top of a standing apparatus and hung. Length of the cord was varied and measured on ten different trials. A mass of 100 g was then attached to a loop at the bottom of the bungee cord. The mass was raised up so that the loop holding the mass at the bottom was even with the loop at the top of the apparatus. The mass was dropped from rest at this height each time and an iPad captured the drop in slow motion video. The maximum distance the cord stretched (X-max) was measured by pausing the slow-motion video at the lowest position of the bottom loop and determining the distance on a meter stick placed beside it.

Bungee Experiment Set-Up

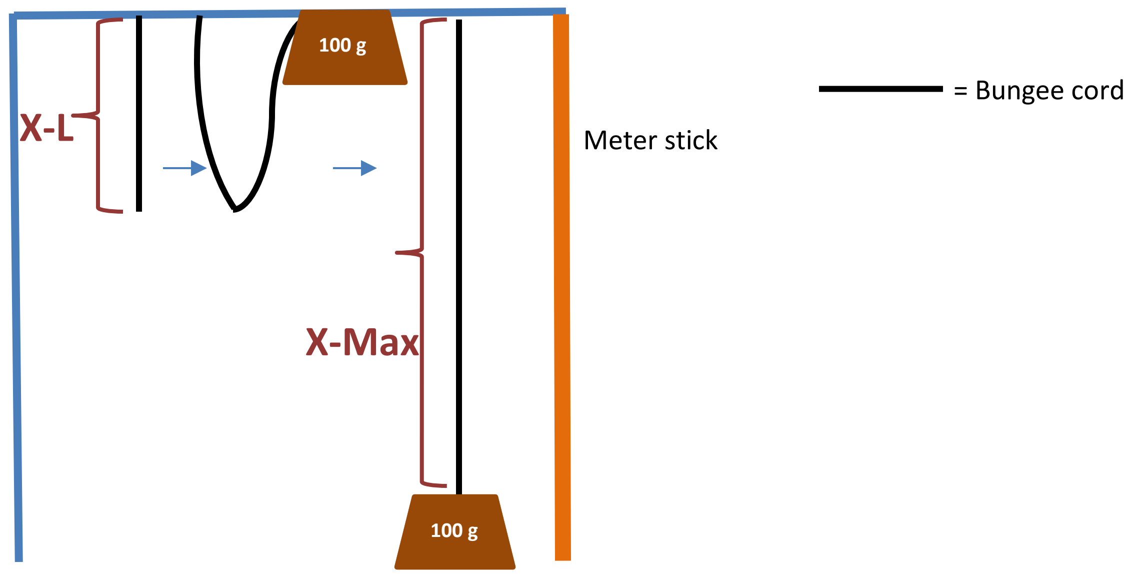

Figure 1. Diagram of experimental set-up with relevant variables.

RESULTS:

X-Max (maximum stretch distance of the bungee after the mass drop) was measured for ten different starting bungee lengths (X-L) and X-max versus X-L was graphed to obtain an experimental formula relating the two variables.

X-L (± 0.01 m)	X-Max (±0.01 m)
0.52	1.74
0.46	1.50
0.24	0.82
0.27	0.86
0.12	0.44

0.36	0.16
0.40	1.28
0.17	0.56
0.31	0.99
0.20	0.65

Table 1. "Raw" data of X-max (stretch of bungee) for ten different starting un-stretched bungee lengths (X-L) with estimated uncertainties based on smallest measurement.

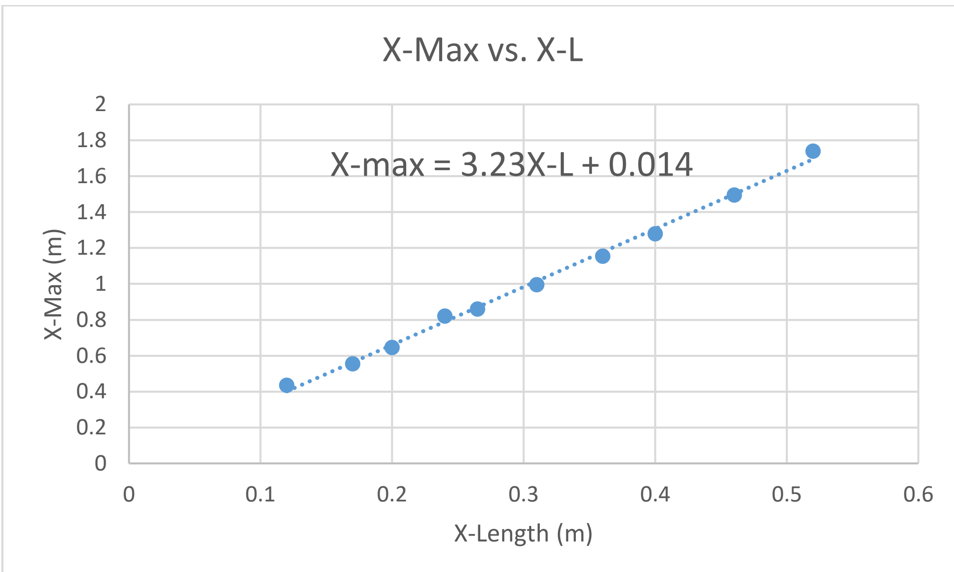

Figure 2. Graph of X-max (maximum bungee stretch after a mass was dropped) versus X-L (initial un-stretched bungee length).

Linear equation obtained from the graph:
X-max= 3.23(X-L) + 0.014

uncertainty for slope= **0.07** % uncert= **0.02%**

uncertainty for y-intercept= **0.02** % uncert= **2% (obtained through linear regression analysis)**

Using X-L, the initial un-stretched bungee length without mass attached, and X-max, the measured maximum stretch of the bungee cord when the mass was dropped, we graphed X-max versus X-L for ten different trials. A linear equation relating the two variables was extracted from the graph: X-max = 3.23(X-L) + 0.014. The experimental value of interest, the slope of the graph, linearly relates the two measurements with 0.02% uncertainty obtained through linear regression analysis. The slope, 3.23, implies that as X-L increases by one unit, X-max increases proportionally by 3.23 units.

DISCUSSION:

As we predicted initially, our formula, X-max = 3.23 (X-L) + 0.014, related X-max stretch and initial X-L of the bungee in a linear fashion. Therefore, as X-L increases by one unit, X-max increases by 3.23 units.
Because we sought to devise an experimental equation, there was no previous formula we could use to compare to this result. Therefore, an analysis of error could not be performed between any expected values. However, to determine the accuracy of our linear formula, we could perform an experimental test in which we would predict the X-max of a measured X-L using our formula, and compare this expected value to a later measured experimental value (actual measured X-max). In this case, we could then extract an error percentage and be able to determine the accuracy of our experimental formula for this mass.

Sources of uncertainty
Despite the small uncertainty in our results, some of the data may have been skewed as a result of several factors. For example, each time the mass was dropped, it may not have fallen in the same straight line which may have affected the maximum distance of its fall as well as the recorder's ability to read the measurement of a shaking mass. Furthermore, each time the mass was dropped, the bungee may have stretched further as a result of continual use and stretch from previous trials. This may have led to an incremental greater amount of stretch on each subsequent trial as the bungee became more springy and stretchable. However, the small amount of uncertainty in our results suggests that these sources of uncertainty are not critically influential.

Limitations and Future Directions
Since we only used one mass in our current experiment, it is difficult to know whether a linear relationship between X-L and X-max exists for all masses. Therefore, if our egg is not exactly 100 g, we may not be able to use the formula we devised in that scenario. Instead, we could perform the same experiment as before, but with different masses than the one we chose here. We could then devise equations based on data from each mass to predict X-max for each length. Depending on the mass of our egg, we can then use the appropriate formula to predict what distance the bungee will fall.

CONCLUSION:

Our results show that as the initial length of the bungee (X-L) increases by a unit, X-max increases linearly by 3.23 units. This confirmed our hypothesis of a linear relationship between X-L and X-max and provided us with an experimental equation that can potentially later be used to predict the fall of an egg in a bungee. We can use the equation obtained from this experiment to plug in various bungee cord lengths and to determine the maximum stretch of the bungee for each length. However, this specific formula and slope only applies to the 100 g mass we chose to use in this experiment. If our egg is not 100 g in the Bungee Challenge, we will be unable to use this exact formula to predict the bungee fall. We will later use different masses to gather an array of experimental formulas. In this way, using the appropriate formula for a later specified mass, we will be able to predict what length of bungee cord should be used to ensure a thrilling, but safe experience for the egg to reach as close as possible to the ground without impact.

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

Pledged: Katrina M. Volk