Relationship between Mass of Jumper, Height of Jump, and Length of String for a Bungee Jump

Introduction

After conducting an experiment (in Bungee Lab 1) that showed the relationship between the length of the bungee (L) and the height of the bungee (H), we concluded our results do not answer an important question: How do different masses affect L and H. Therefore, the focus of this lab report is to determine how changes in mass for different lengths affect the relationship between the length and the height of the bungee. A similar experiment is recorded in the Mass vs L/H for a Bungee Cord lab report from the first week of this assignment. This lab report will test the validity of the conclusions of Mass vs L/H. A different cord, with different elastic properties, will be used which invariably means our results will vary, but the general conclusion should be similar. The end result is an equation that will help us determine the L of a string most appropriate for a bungee jump of height H and bungee jumper mass m.

Methods

The stretch of the string (height of the jump) when the hanger is dropped from a horizontal supporting bar will be recorded for a set of six masses and three lengths (18 mass-length combinations total, refer to Table 1 in the Results section). The equipment used for the experiment included the following: an elastic string, a hanger, a set of additional masses (25g, 50g, 75g, 100g, 125g), an iPad with slow motion camera, a measuring tape, and a supporting structure made of two metal bars. The setup is pictured below:
The experiment requires two team members: the first will drop the hanger with additional mass attached to it and the second will capture the height of the jump using the iPad slow motion camera. Two trials were conducted for each mass-length combination.

The first team member holds the top of the hanger at the level of the horizontal supporting bar. A trial drop is conducted so that the second team member can position the camera approximately horizontally to the lowest point reached by the base of the hanger (refer to Graph 1). When the camera is set at the right position the two trials for any specific mass-length combination are conducted. After recording the heights of the drop from the two trials for a given mass, the experiment is repeated for the other five masses. Rinse and repeat for the other two lengths.
**Results**

The results of the experiment are twofold and included two graphs. The first graph represented the relationship between length and height: for any given mass, the longer the length of the string, the bigger the height of the jump. The second graph represented the relationship between mass and the slope of the first graph (H/L): as the mass increases, the slope of the first graph increases too. Therefore, with larger masses, the height of the jump is more sensitive to the length of the string. The gathered data is summarized in Table 1 below:

**Table 1. Data Gathered During Experiment.**

<table>
<thead>
<tr>
<th>Mass (kg) ±0.001</th>
<th>Length (m) ±0.001</th>
<th>Raw h1 (m) ±0.01</th>
<th>Adj. h1 (m) ±0.01</th>
<th>Raw h2 (m) ±0.01</th>
<th>Adj h2 (m) ±0.01</th>
<th>Avg h (m) ±0.014</th>
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<tr>
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<td>0.122</td>
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The raw height is the height measured using the iPad camera. The uncertainty of the raw height reflects the difficulty of putting the camera exactly horizontal to the base of the hanger when it reaches the lowest point of the jump. The height was then adjusted for two things. First, since the height was measured to
the base of the hanger, we subtracted the length of the hanger (0.196m±0.001) to get a more accurate measure for the height of the string alone. Second, since the measuring tape was attached to the top of the horizontal supporting bar and the string was tied around a metal screw in the middle of the bar, 0.004m±0.001 was subtracted to account for that difference. The average height is the simple average of the adjusted heights from the two trials. The uncertainty of the average height was calculated using a quadratic sum of the uncertainties of both adjusted heights. Using the data, two graphs were produced. Graph 2 below details the relationship between length and height for a set of masses.

Graph 2. Relationship between Length and Height for Six Masses.

Each relationship can be expressed as a linear equation. Noticeably, the slope of the graph increases as the mass increases. This relationship is graphed below:
The following equation is extracted from graph 3:

$H/L = 16.909m + 0.8856$

This equation has a similar purpose to Equation 1 from the Mass vs L/H for a Bungee Cord lab report – it helps tie together the three variables of the bungee jump. More detailed interpretation follows in the Discussion section.

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**Discussion**

The results of this experiment verify the conclusions made in the Mass vs L/H for a Bungee Cord lab report: for the same length of string, bigger mass results in a longer jump. Equation (1) can also be extremely useful for finding one of the three variables related to the bungee jump by knowing the other two. Thus, in theory, Equation (1) should be sufficient to model a realistic bungee jump with acceptable accuracy. Namely, we can use this equation to find the length of string we need to use when dropping an egg. The quantitative results of this lab report and Mass vs L/H for a Bungee Cord are not directly comparable (and
have slight discrepancies) because the strings used in each experiment are different and thus have different elastic properties. However, the overall conclusions are the same.

The biggest source of uncertainty during the experiment was measuring the height of the jump using the slow motion camera. As previously described, this was because the camera had to be horizontal to the base of the hanger when it reached the lowest point of the jump. If it was at an angle, then the measurement would not be accurate. The percent uncertainty of the height ranges from 7.2% for the shortest jump to 0.7% for the longest jump. Furthermore, the $R^2$ of Graph 3 is 0.9657 which means the equation should be highly accurate.

Conclusion

The purpose if this experiment was to find a valid relationship between $L$, $H$, and $m$ for a bungee jump. Equation (1) satisfies this purpose. The lab experiment also reached the same conclusions as Mass vs $L/H$ for a Bungee Cord lab report, though the string used in that experiment was different from the one used in this experiment. Readers can feel even more confident in the combined accuracy of the conclusions reached by both experiments.

This experiment provides the basis for determining the length of the string when we drop an egg from the second floor of the Great Hall. In order to make sure the egg survives the drop, further experiments determining the acceleration of the egg can be performed. The acceleration should not go above 3g. Therefore, even if the egg does not hit the ground, it could still break if acceleration is too high.