Relationship between Mass and X_{max}/X_L

Chris Cotton & Laws Smith   Section: 04   Date: 11/12/16

ABSTRACT:
During the second week of the bungee lab we were able to find a model for the relationship between mass (M) and the ratio of X_{max} to X_L, where X_{max} is the maximum length when dropped and X_L is the unstretched length of the bungee cord with no mass. To find this information we varied both the mass on the bungee cord and the length of the bungee cord. During our test we dropped the mass from the very top of the system where the bungee cord was hung and measured for the X_{max} value. With the data that we collected we noticed a relationship between the mass and the ratio of the X_{max} value to the X_L value. The linear model of this relationship is M=0.0488X-0.046, where $X=X_{max}/X_L$. Although the model we found doesn't stem from any theoretical model, we believe it could help us determine the X_L value of our final bungee jump.

INTRODUCTION:

The initial purpose of our experiment was to find the k value of Hooke's law in a dynamic setting. However, after testing and looking at our data we found a very strange yet very clear relationship between M and X_{max}/X_L. We decided to explore this relationship after testing, when we analyzed our data.

Relevant equations-
$M=X_{max}/X_L$
$Mgh=1/2kx^2$

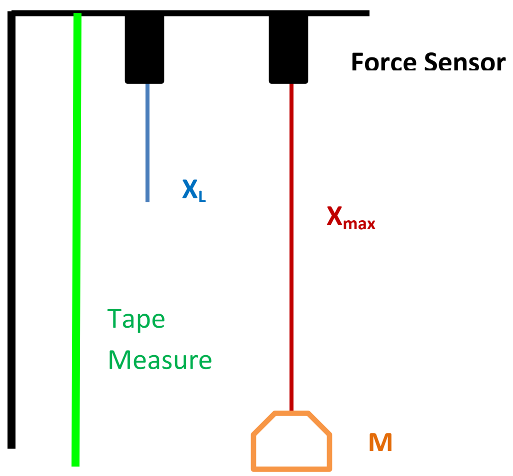
Basis or brief theoretical background-
The equation $M=X_{max}/X_L$ came from our own testing and data, the equation $Mgh=1/2kx^2$ is the potential energy equation associated with Hooke's law. The potential energy of a spring is modeled by $PE_{spring}=1/2kx^2$. And this equation is set equal to the normal potential energy equation which is PE=Mgh.

Hypothesis or expectations-
We expected to find a working k value from our data after testing the cord in a dynamic setting, by using the equation $Mgh=1/2kx^2$.

METHODS:

For our experiment we hung a mass to our bungee cord and dropped the mass from the top of the system where the bungee cord was being hung. We measured the initial length, X_L, of the cord with no mass hanging on the cord and we measured the X_{max} value, the length of the cord with the mass hanging on it at the lowest point of the drop, with the IPad after every drop.

Diagram-



Describe setup:

We first attached the force sensor to the top of the hanging apparatus and hung our bungee cord from the force sensor. Parallel to the cord, we hung a tape measure to measure the X_L and X_{max} values. We used a blank white board behind the bungee cord while recording the drop in order to be able to determine the X_{max} value more precisely.

Describe procedure-

- **Measure the X_L length, no mass.**
- **Attach a mass to the end of the bungee cord, measure equilibrium length.**
- **Raise the mass to the top of the bungee cord and drop.**
- **Using the IPad's slow motion video, capture and measure the X_{max} length.**
- **Replace the mass and repeat until you have a sufficient amount of data or the mass begins hitting the floor.**
- **Vary the length after enough trials of the first length have been conducted.**

RESULTS:

Introduce the Results section-

After running our tests we received a plethora of data, some of which is supplementary and not needed in our final understanding of the lab, however we kept the supplementary data to further understand other properties of the drop not explored in this journal. We focused in on the relationship between the mass (M) and the ratio of X_{max}/X_L, which to our surprise, was almost perfectly linear.

Tables

Trial 1

XL (m)	M (kg)	F (N)	Xmax (m)	Xmax-XL (m)	Xmax/XL
0.802	0.050	1.52	1.590	0.788	1.982544
0.802	0.055	1.62	1.635	0.833	2.038653
0.802	0.060	1.66	1.730	0.928	2.157107
0.802	0.065	1.75	1.793	0.991	2.235661
0.802	0.070	1.82	1.878	1.076	2.341646

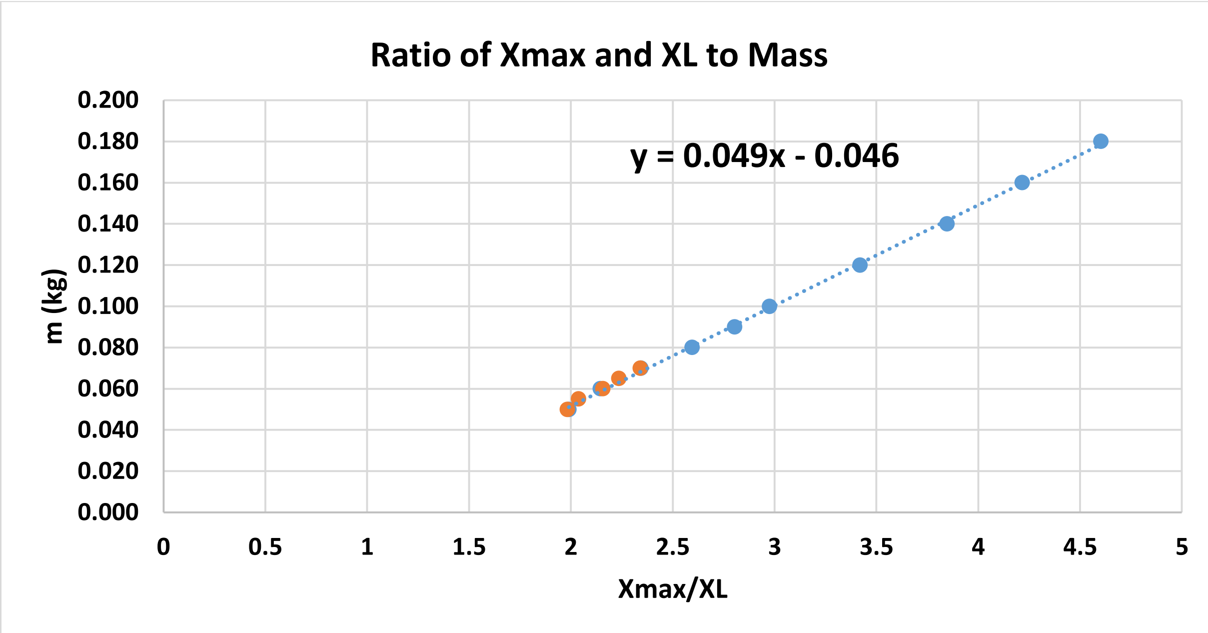
This is the data collected from our first trial with an X_L length of .802 m. You will notice a smaller amount of data than the second trial because we could only measure to 0.070 kg before the mass started hitting the ground during the drop.

Trial 2

XL (m)	M (kg)	F (N)	Xmax (m)	Xmax-XL (m)	Xmax/XL
0.421	0.050	1.53	0.838	0.417	1.990499
0.421	0.060	1.69	0.903	0.482	2.144893
0.421	0.070	1.85	0.987	0.566	2.344418
0.421	0.080	2.03	1.093	0.672	2.5962
0.421	0.090	2.21	1.181	0.760	2.805226
0.421	0.100	2.35	1.253	0.832	2.976247
0.421	0.120	2.82	1.440	1.019	3.420428
0.421	0.140	3.32	1.620	1.199	3.847981
0.421	0.160	3.86	1.775	1.354	4.216152
0.421	0.180	4.50	1.938	1.517	4.603325

This is the data collected from our second trial with an X_L length of .421 m.

Graph



This is the graph of X_{max}/X_L to mass, using both sets of data. The orange dots represent the first trial, the blue dots represent the second trial.

Equation-
M=0.049X-0.046, where $X=X_{max}/X_L$

Identify experimental value(s) of interest-
The experimental value we found is the coefficient in front of the ratio of X_{max} and X_L. We're not exactly sure what this coefficient means, it seems to be some sort of value related with the bungee cords elasticity.

value obtained = **0.049**
uncertainty of experimental value(s) = **0.00040** % uncert= **0.0082%**
name the technique used for propagation of uncertainty (see *UG*), or where/how uncert was obtained:
We used the regression analysis tool on excel to find the uncertainty of the experimental value.

Summarize Results-
The experiment we ran and the measurements we took gave us a very wide array of data points to work with. Although we didn't work with all the data, the most surprising find was the relationship between m and X_{max}/X_L. It is almost perfectly linear and should help us a lot in our design of our bungee jump.

DISCUSSION:

Error analysis-
We are unable to quantitatively compare our discovery to any theoretical values; however, we did devise a test to see how accurate our model, m=0.0488X-0.046, really is. We can plug in X_{max}/X_L for X in the equation and then solve for X_{max}. This yields the equation $X_{max}=(X_L(m+0.046))/0.0488$. And by using this equation we could enter a mass, and original length of the cord with no mass, to find the X_{max} value. And if we solved for X_L, which would be especially helpful for our bungee drop, we could predict the starting

length of our bungee cord because we will already know the mass of our egg and the maximum length of the drop.

Sources of uncertainty-
The IPad was a little difficult to gauge when making measurements because the video quality was choppy and not very clear. Also, the exact height from which we dropped the mass might vary slightly for each drop simply because we couldn't replicate the same starting point everytime.

Describe whether your main results support your hypothesis-
Our final results actually didn't come close to our original hypothesis because we were unable to achieve a consistent or accurate k value, which we were originally testing for. And although our discovery doesn't line up with any theories we have been working with, our model seems fairly accurate, an almost infinitesimal percent error, and when tested practically it seemed to be accurate when we eyeballed the results.

CONCLUSION:

Clearly and definitively state the experimental outcome-
From our experiment we were able to successfully model the relationship between m and X_{max}/X_L and from that model, we can now predict the M, X_{max}, or X_L values, as long as we know the other two factors. This will be very helpful with our final bungee jump because we already know the mass and X_{max} value, therefore we can use our equation to solve for our X_L value.

Implications of these conclusions and next step-
The biggest implication of this discovery is that we might be able to predict the exact X_L value of our bungee jump using our model. The next step in this process would be to test our model extensively to find out how accurate it really is and if it holds up to our original hopes. We also were unable to determine the effects of gravity on the mass as it decelerates rapidly at the bottom of its decent which could possibly prove fatal in our final jump.