Lab Report Outline—the Bones of the Story

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TITLE: What is the effect of the length of a rubber band on the displacement of a connected weight, when it is released from equilibrium?

ABSTRACT:

This experiment aims to find the relationship between the length of an elastic band and the resulting displacement of a weight dropped from equilibrium. Once this relationship is determined the band length for a later bungee experiment, in which an egg is dropped from a predetermined height, can be found. This experiment entails the use of a hanging apparatus with an aligned ruler that will allow the displacement of the dropped weight from the top of the ruler to be found after analyzing slow-motion footage of the drop. The displacement of the band is expected to increase when the length of the band is increased. The results found the relationship between the band length and weight displacement to be linear with an equation: Displacement (m) = 3.155 * Band Length (m), meaning if length increases the displacement increases proportionally. The raw uncertainties of the data collection as well as the percent uncertainty of the slope (.9%) were very small, proving this relationship to be linear. This resulting equation will be used in the future egg bungee experiment, to determine the length of the string.

INTRODUCTION:

The overall purpose is to determine the effect that the band length has on the displacement of a dropped weight, and to relate the findings back to the actual bungee experiment. In the bungee experiment an egg connected to a rubber band will be dropped from a predetermined height and must get as close to the ground as possible without breaking. This experiment aims to determine the relationship between the length of the band and how much it will stretch when released. By experimentally determining this relationship it can be applied to find the length of the band for a safe egg bungee drop.

Relevant equation(s) specific to this experimental purpose or setup, identifying variables:

- This experiment will find the displacement of the top of the weight when dropped, which is equal to the elongation of the band. An ideal Hooke's Law system uses the equation $(PE + KE)_{top} = (PE + KE)_{bottom}$ which is based on the CWE Theorem that states that energy is conserved throughout the experiment. Meaning the mechanical energy at the top of the bungee is equal to the mechanical energy at the bottom of the bungee.
- This equation can be altered to fit this experiment so that: $mgh = \frac{1}{2} kx^2$. Where m is the mass, g is the force of gravity, h is the drop height, k is the spring constant, and x is the elongation of the band.
- Since we know what the elongation will be for the egg bungee drop, this experiment will aid in determining the length the band must be to reach this elongation value.

Hypothesis: When band length is increased, displacement of the weight will also increase.

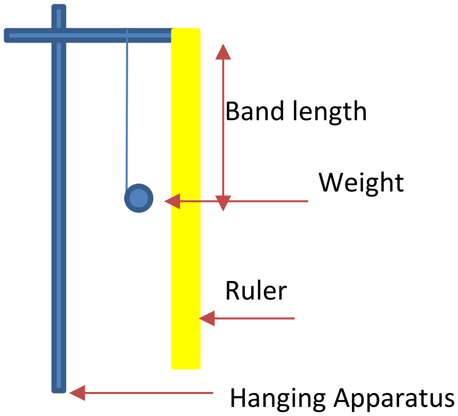
METHODS:

In order to determine the relationship between the length of the band and the displacement of the weight the weight must be kept constant and the length of the band must vary. This allows the data to analyzed later on to determine if the relationship is linear. The displacement of the weight is found by dropping the weight from equilibrium, which is at the top of the hanging apparatus with the top of the ruler even with the end of the band. Then a slow motion camera is used to determine the distance that the band stretches, by looking at the ruler in the video for the value when the band reaches its lowest point.

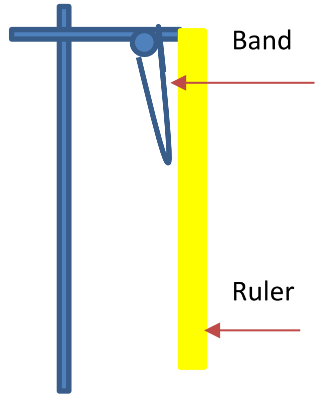
Figure #1, Experiment Set-up

How the experiment was set-up and what instruments were used

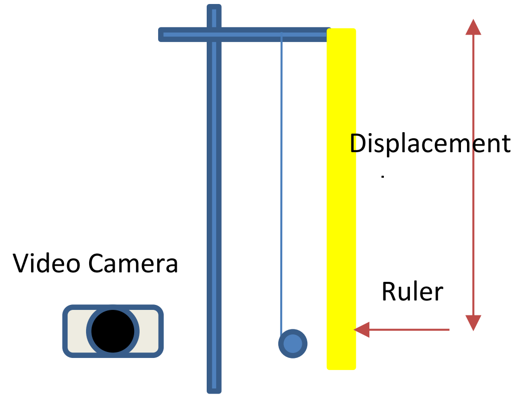
Length of band when hanging:



Weight Brought to Equilibrium before Drop:



Displacement of Weight When Dropped:



Describe setup:

- The ruler is connected to the hanging apparatus so that it is in line with the drop location of the band
- The rubber band with pre-measured length is connected to the hanging apparatus
- One end of the band is aligned with the top of the ruler
- The weight is attached to the free end of the band
- The Video Camera is set up so that it can capture the displacement of the weight when it is released from equilibrium

Describe procedure:

- The band length was measured and then connected to the hanging apparatus so that the bottom of the knot was in line with the top of the ruler.
- A .150kg mass was used for all trials, as its weight is close to that of the egg that will be used in the actual bungee experiment. The weight was then connected to the free end of the band.
- The weight was then drawn up so that the knot that connected the weight to the band was in line with the top of the ruler, this was the equilibrium location.
- The weight is then released so that the only forces acting upon it are the force of gravity and the restorative force of the band
- The first weight drop for each new band length is a test drop. This way the camera person can setup the lens according to the general displacement of the weight.
- The weight is then reset to equilibrium after the test drop, and when the camera person begins recording video and counts "3,2,1" the weight is released by the dropper.
- The film is then analyzed by the camera person in slow-motion to determine the displacement of the weight, which is the location on the ruler that the bottom end of the band reaches at its lowest location before the restorative force pulls it back towards equilibrium.
- This process was repeated three times for each band length. Six band lengths were used ranging from .141m to .544m.

RESULTS:

Six known band lengths were used when dropping a constant weight of .150g and the resulting displacements of the band were found for three trials and averaged for each band. This data was then graphed and was found to immediately hold a linear relationship. The equation of the graph represents the linear relationship between the band length and the displacement of the weight.

Figure #2, Data Table: Effect of Length on Displacement of Band

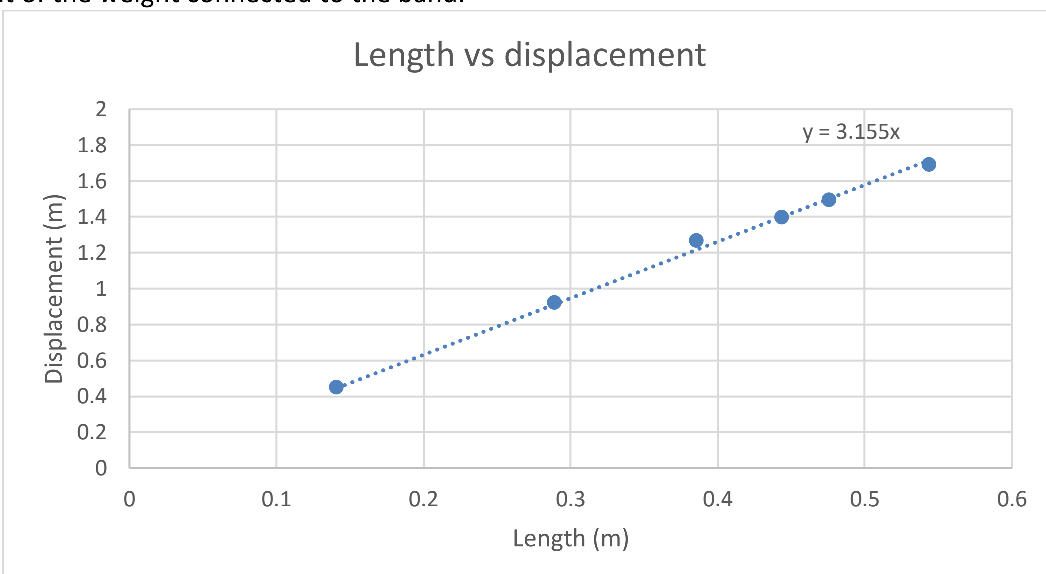
This Data Table contains the length of the elastic band and the experimentally determined average displacement values

Effect of Length on Displacement of Band	
Length of elastic (m) +/- .001m	Average Displacement (m) +/- .01m
0.141	0.447
0.289	0.919
0.386	1.265
0.444	1.396
0.476	1.493
0.544	1.689

The data shows that the average displacement of the weight increases as the length of the elastic band increases.

Figure #3, Graph: Length of Elastic Band (m) vs. Displacement of the Weight (m)

This graph shows the experimentally determined relationship between varying band lengths and the resulting displacement of the weight connected to the band.



This graph shows that as the length of the band increases on the x-axis, the displacement of the weight on y-axis likewise increases.

Equation: With the y-intercept of the graph set to 0 the equation is determined to be:

Y=3.155x

When the data is plotted the relationship was found to linear, as the equation y=3.155x depicts, no linearization was needed. In the context of this experiment the equation is:

Displacement (m) = 3.155 * Band Length (m)

The linear relationship of the graph means that displacement can be determined by multiplying the length of the band by the constant 3.155.

Figure #4, Linear Regression:

This is an analysis of the linear graph, showing the uncertainty behind the system.

Coefficients	*Standard Error*
0	#N/A
3.154701128	0.028480578

***Excel* regression analysis**:

uncertainty for slope= 0.028m % uncert= 0.9%

The uncertainty for the slope is equivalent to the Standard Error of the x-intercept in the linear regression. The percent uncertainty is determined by dividing the standard error of the x-intercept by the coefficient of the x-inercept.

Since the y-intercept is set to 0 there is no uncertainty in the y-intercept.

Identify experimental value of interest:

The experimental value of interest is the coefficient of the linear equation, 3.155. This value is important because it shows the linear relationship between the length of the band and the displacement of the weight. This value can be used to determine unknowns in the equation, such as the length of the band when the displacement is known.

value obtained = 3.155m

uncertainty for coefficient= 0.028m % uncert= 0.9%

The uncertainty for the coefficient is equivalent to the Standard Error of the x-intercept in the linear regression. The percent uncertainty is determined by dividing the standard error of the x-intercept by the coefficient of the x-intercept in the regression.

The results of the experiment show that the relationship between the length of the elastic band the displacement of the weight is linear. They are related by the equation: Displacement (m)= 3.155 * Band Length (m). The uncertainty of the slope, which is the experimental value of interest equal to 3.155, was determined to be 0.9%.

DISCUSSION:

There are no accepted or expected values that these results can be compared to in order to find the error in the experiment. However, the equation $mgh = \frac{1}{2} kx^2$ can be used to find the elongation of the band (x). The elongation could be compared to the experimentally determined values for displacement of the weight, since both of these qualities of the band are equivalent. This equation could be used to find the error in the displacement, however it was previously determined in the first bungee experiment that the band did not portray a perfect Hooke's Law Relationship, therefore it does not have a k-value. Since we do not know the k-value of the band we cannot use this equation to find the elongation of the band because there are two unknowns. Once an altered k-value is determined the error in the experiment could be found.

There was uncertainty when measuring our raw data. For the static measurement of the band there was +/- .001m uncertainty as it was easier to get a more precise as well as accurate measurement. However, there was a larger uncertainty when measuring the displacement of the weight because this measurement was taken from a moving object. The use of a video camera that had slow motion features enabled us to remove a large percent of uncertainty when compared to the measurement of the naked eye, however the film quality was slightly blurred so there was still a +/- .01m uncertainty for the displacement measurement. Additional uncertainties from recording data include the uncertainty of how the weight was dropped. For instance, there is uncertainty in if the end of the band was aligned perfectly with the top of the ruler before it was dropped, as well as whether or not the weight was dropped without any downward force from the person dropping it. If there was an additional downward force by the hand this would cause the elongation of the band to not accurately reflect its true stretch length for the given band length.

The experimentally determined value of uncertainty for the linear slope of the system was .9%, determined with a linear regression. This is an extremely low value for a percent uncertainty and proves that the relationship between the length of the band and the displacement of the weight is indeed linear. This experiment shows that when the length of the elastic band is increased its displacement will likewise increase.

The results of a linear relationship between band length and displacement, in which when one variable increases the other increases proportionally by a factor 3.155, are in accordance with our hypothesis. Although the experimentally determined values for displacement cannot be compared to the expected values to check for their error currently, further analysis of our previous experiment involving the k-value for the band would enable us to find an altered k-value for the band and find the error of displacement using the equation $mgh = \frac{1}{2} kx^2$.

CONCLUSION:

This experiment provided us with the linear equation: Displacement (m) = 3.155 * Band Length (m), meaning that as band length increases the displacement also proportional increases. This relationship is important in finding what band length we should use for the future bungee experiment. We will be given the drop height and will be able to determine the elongation of the band using the equation $mgh = \frac{1}{2} kx^2$, after we find the k-value of the elastic band. Once we find the elongation of the band this experiment provides us with the data to find the length of the unstressed band because they are proportional. This equation, Displacement (m) = 3.155 * Band Length (m), was found with a constant mass that is slightly lower than that of the egg, so we will need to determine if this equation is only applicable for the .150g mass or if it can also be used for the bungee egg drop. To test this a .170g mass can replace the .150g mass in this experiment at one of the known band lengths, and if the displacement is within its uncertainty then the equation is applicable and can be used in the final bungee drop. The final step in determining the set up for the bungee egg drop is finding the k-value for the elastic band.

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

Pledged: Ashleigh Meade