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Title: Finding the K value of our Bungee Cord

Abstract:
The purpose of this experiment was to find the value *k* of our bungee from the equation $mgh=1/2kx^2$. We went about finding this by attaching a hanging mass to our bungee at a decided length of .32m and using an iPad to video the drop and get a measurement for the maximum distance the mass dropped. We varied the mass and found that, as our mass increased, so did our *k* value. While this does not agree with our original assumptions that our bungee cord would follow Hooke's Law, we found that the mass and *k* are proportional from our graph which produced a linear graph when we graphed 2mgh vs. Δx^2. We use this method to find the k value of our bungee cord to duplicate the egg drop, and while we know how heavy the egg will be we can calculate using the equation how great k will be and how far we should allow it to stretch.

Introduction:
The purpose of this experiment is to find the k value of our bungee cord from the equation $mgh=1/2k\Delta x^2$ by plotting $2mgh/\Delta x^2$. In doing so we can find how far the bungee will stretch at a certain mass.

Relevant Equations:
$Mgh=1/2kx^2$
$\Delta x=x_{max}-x_L$

$h=x_{max}$
x_{max}=max distance traveled by the mass
x_L=the length of the unstretched bungee
k=spring constant

We have learned that when discussing the CWE, $mgh=(1/2)kx^2$ so we used that as a basis for finding our k value.

Hypothesis: The value k will increase linearly as the mass increases.

Methods:
We dropped different masses from the same height and same length of bungee. Then we measured the x_L and x_{max} using the IPad. We then calculated the potential energy of each mass and plotted that against Δx^2 to see how k varied with Δx.

Diagram:

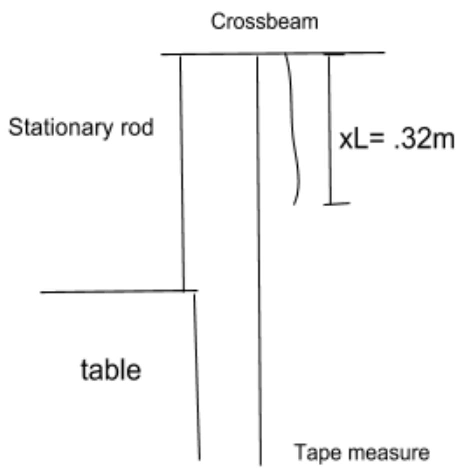


Figure 1: The diagram shows the crossbeam with the tape measure stretched from the crossbeam to the floor and the unstretched bungee.

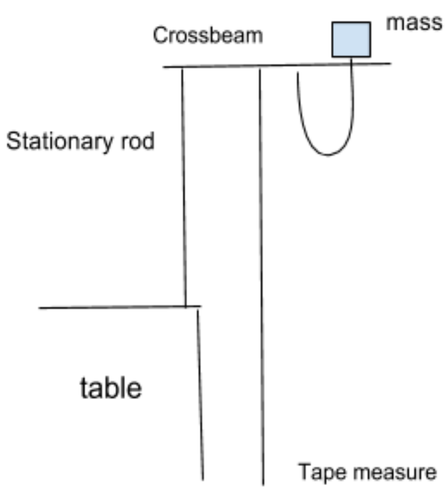


Figure 2: This diagram shows the set-up of the experiment right before we drop the mass. We hung the mass so that the bottom of the mass was right above the crossbeam.

Set-up:
We tied the bungee cord to a crossbeam that was attached to the top of a stationary rod attached to a table. We tied the mass to the end of a determined length x_L and then stretched a tape measure from the cross beam to the floor.

Procedure:

- Tie one end of the bungee to the crossbeam
- Attach the tape measure with tape to the cross beam with the measurement of 0cm at the top edge of the crossbeam and stretch it all the way down to the floor
- Measure x_L

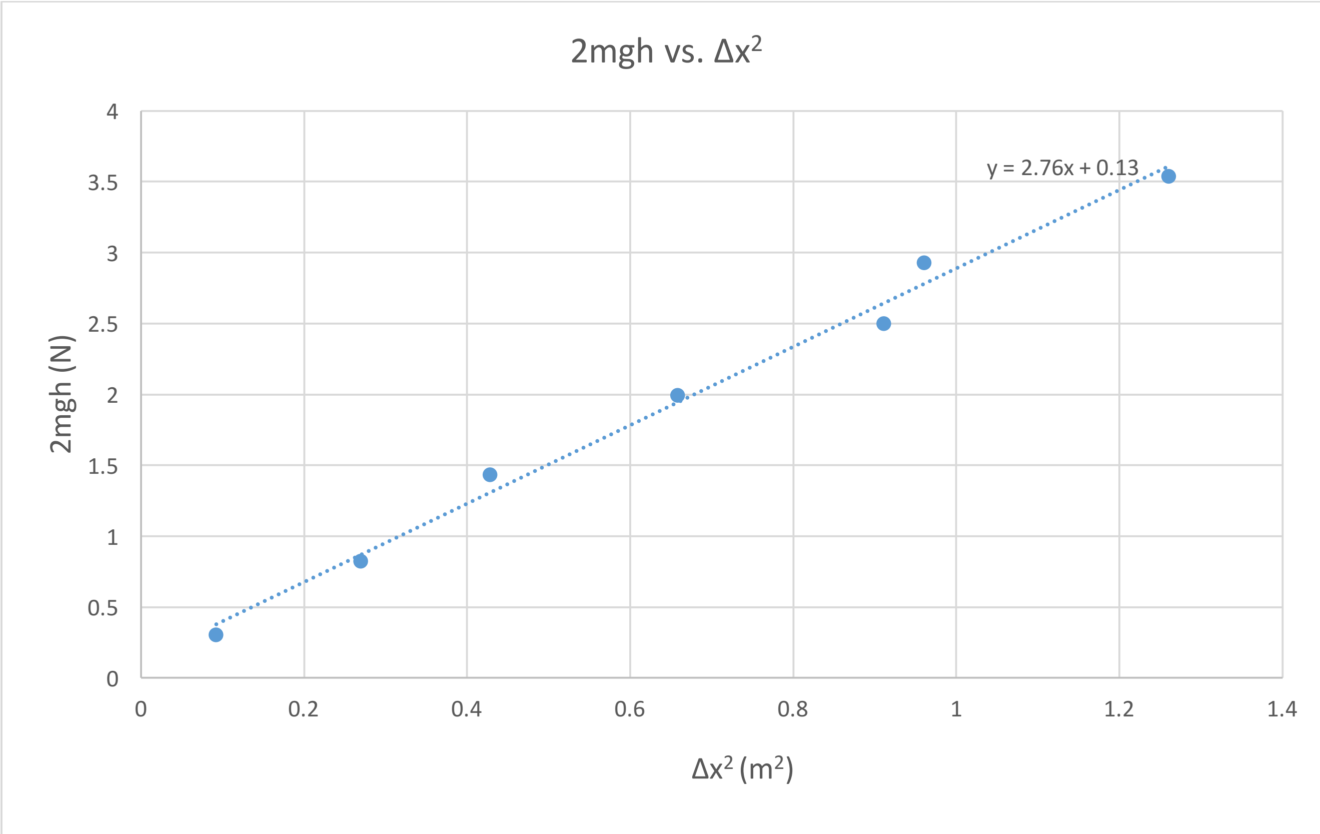
- Measure out .032m of the bungee and tie a knot, then slide the hook of the mass through the knot
- Set up IPad camera so that it is in line with the approximate $x_{max.}$ Make sure the cinematographer is eye level with the camera.
- Measure x_{max} by bringing the mass up to the crossbeam so that the bottom of the mass is in line with the top edge of the crossbeam, start the slow motion camera, then drop the mass
- The x_{max} will be the lowest point the mass reaches (or the farthest in reference to the tape measure) as seen by the slow motion camera (played frame by frame)
- Repeat the drop twice for each mass
- Entire procedure is repeated for the 7 masses chosen

Results:

For each mass, two trials were done and then the average was taken of the two trials. Then we calculated Δx from x_{max}-x_L and squared the value to get our x values of the graph. Then we multiplied the individual masses by *g* and the corresponding h(x_{max}) and made those values our y values of the graph. However, you will notice we have graphed 2mgh because, like the equation mgh=1/2kx^2, we have to account for the ½ in front of the k value so we multiply mgh by 2.

Mass (kg) ±1kg	X_L (m)	$X_{max\ avg}$ (m) ±0.005m	Δx (m) ±0.005m	2mgh (N)	Δx^2 (m^2)
0.025	0.32	0.62	0.30	0.31	0.09
0.05	0.32	0.84	0.52	0.82	0.27
0.075	0.32	0.97	0.65	1.43	0.43
0.09	0.32	1.13	0.81	1.99	0.66
0.1	0.32	1.27	0.95	2.50	0.91
0.115	0.32	1.30	0.98	2.93	0.96
0.125	0.32	1.44	1.12	3.54	1.26

Table 1: The Δx of each varying height. For each mass, 2 trials were taken and the results were then averaged and then the Δx was calculated by subtracting x_L from x_{max}. Then, mgh and Δx^2 were calculated for each mass.



Graph 1: The Potential Energy, Doubled, vs. the Change in X, Squared, of the Mass. The slope, 2.76 ±0.12 N/m^2 is the value *k* of the bungee cord.

Equation of the curve-fit from the graph:

$2mgh=2.769x^2+0.13$

Uncertainty:
Uncertainty of slope= ±0.12 N/m^2 %uncert=±4.35%
Uncertainty of y-intercept=±0.09 N/m^2 %uncert=±6.92%

Experimental Values of Interest:
The experimental value of interest is the value *k* (the coefficient of x) because 2mgh/Δx^2 results in the value *k.* In knowing this, we can find how short or long we should make our bungee cord based on the mass of our egg.

Uncertainty of experimental value=±0.12 N/m^2 %uncert=±4.35%

Through finding the $x_{stretch}$ and x_{max} at varying masses we were able to find the spring constant *k* of our bungee cord. This will allow us to calculate how short or long the cord must be based on the egg's mass when dropping our egg.

Discussion:

The slope value (k) increased linearly and positively as the mass increased as we hypothesized. From this, we are able to assume that using potential energy and Hooke's Law to find an average spring constant is a valid method. Additionally, on Excel, when we would set the intercept at zero, the slope of the line changes by about .2 N/m^2 which tells us that there is a slight variance (uncertainty), so we can say that k is not constant. This causes our original statement that *k* is constant to be taken back. Although, while *k* is not completely constant there is still little variance in it.

The percent uncertainty of our x coefficient is about 4%. This means that, when calculating for how far the bungee cord will stretch, when the egg is attached to it, to ensure the egg doesn't break, we may need to calculate for a longer stretch than prepared for. Especially since the *k* value increased as mass increased. The uncertainty in x potentially comes from the wear of the bungee over time, as it slowly stretches itself out over time when a force is applied. Also when recording the x_{max} could have caused uncertainty based on the angle the cinematographer takes the video. If the frames are blurry or clear makes it difficult to get an exact measurement of the x_{max}.

The results of the experiment do support our hypothesis that the *k* value would increase as mass increases, although we also assumed that *k* would be constant (based on Hooke's Law) however it is not. I still believe our results are considered acceptable though because *k* is still showing the ratio of the potential energy over Δx^2 which gave us nearly a constant slope as seen on our graph.

Conclusion:

In conclusion, the experiment reveals that when you set potential energy and the energy of a spring equal to one another, the mass and the value of *k* are proportional to one another. This means that as the mass increases, so does the k value. And while our bungee's *k* does not follow Hooke's Law for an ideal spring we found an average change that will help us determine the correct length the bungee needs to be for our egg drop. We can calculate this because we will know how much our egg weighs and the x_{max} the egg needs to drop so we can calculate for *k* at that specific mass.