Purpose

The purpose of this lab is to design and perform an experiment which analyzes the conservation of energy in a spring-based system.

Research Question

How does increasing the stretch distance from equilibrium that a vertical rock-elastic system is released from affect the maximum height it reaches after release?

Hypothesis

If the weight is stretched further from the point of equilibrium, the maximum height it reaches will also be larger.

Procedure

1. The pole is taped down to the top of the cabinet.
2. The weight is attached to multiple rubber bands that have been looped together.
3. The rubber-band apparatus is taped to the end of the pole.
4. A meterstick and a ruler are lined up and taped down so that they measure the height of the apparatus from the ground.

5. The height at which the apparatus is at equilibrium is measured and recorded.
6. Neena pulls the bottom of the rock on the apparatus down to a specific height.
7. On the count of three, Akhi starts recording a video of the apparatus and Neena lets go of the rock.
8. Akhi reads the maximum height the rock reaches in the video, and Julia records the maximum height in an excel sheet.
9. 6-8 is repeated for all trials per height. When a new initial height is chosen, 5 is done again.

Materials

- Meterstick
- Ruler
- Rubber Bands
- Rock
- Duct Tape
- Pole
- Cabinet
- Computer
- Phone

Diagram

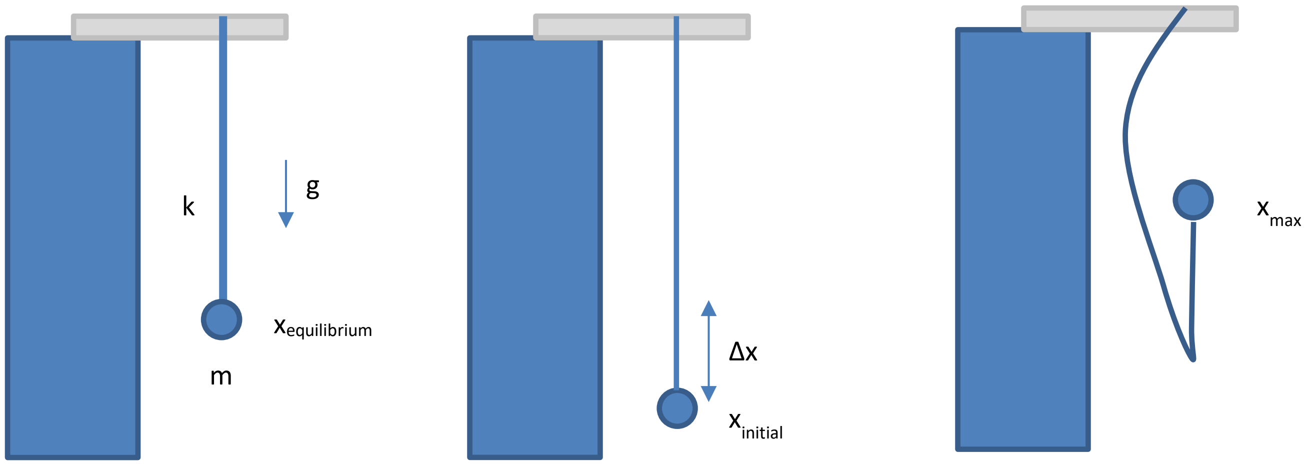

Figure 1. This diagram shows the three different positions the contraption is in at various points in time. The left-most diagram shows the apparatus as equilibrium. The diagram in the middle shows the apparatus being pulled down to $x_{initial}$, and the right-most diagram shows the apparatus after it is released, at x_{max}.

Constants + Equations

g=9.8m/s
m=0.077 kg
k=3.396 N/m (see appendix)

$$\sum E_i \pm W = \sum E_f$$

$$PE_{spring} = \frac{1}{2}k(\Delta x)^2$$

$$PE_{gravity} = mgh$$

$$h_f = h_i + \frac{k(\Delta x)^2}{2mg}$$ (see appendix)

Data Summary

$x_{initial}$ (m)	$x_{equilibrium}$ (m)	$x_{average}$ (m)	SD (m)	%RSD of avg	$x_{theoretical}$ (m)	% Error of avg	$TE_{initial}$ (J)	TE_{final} (J)	%ΔE (J)
0.10	0.72	1.138	0.038	3.35	0.965	18.0	0.73	0.86	18.0
0.15	0.72	1.027	0.013	1.31	0.881	16.5	0.66	0.77	16.5
0.20	0.72	0.966	0.012	1.29	0.808	19.5	0.61	0.73	19.5
0.25	0.72	0.882	0.027	3.10	0.747	18.1	0.56	0.67	18.1
0.30	0.72	0.832	0.020	2.40	0.697	19.4	0.53	0.63	19.4
`0.40	0.72	0.756	0.009	1.20	0.630	19.9	0.48	0.57	19.9
0.55	0.73	0.635	0.007	1.13	0.623	2.0	0.47	0.48	2.0
		Average	0.018	1.970	Average	16.2		Average	16.2

Figure 2. This data table is a summary of the data collected throughout this experiment. It shows the most important columns needed to understand the data well, while leaving out the actual data.

Graph

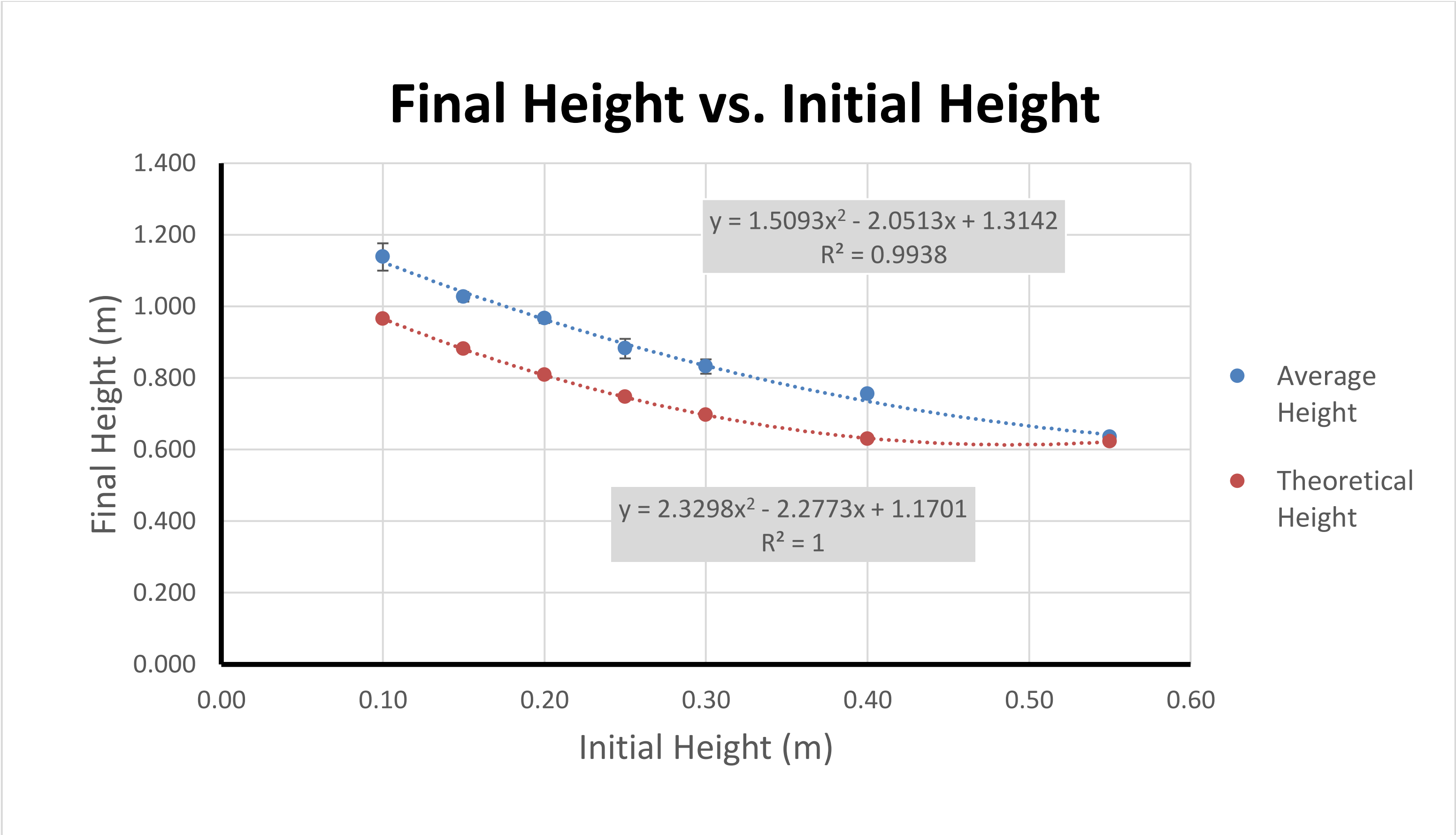

Figure 3. This graph shows how changes in the initial height of the object affected the maximum height that the object reached. This graph also shows a side-by-side comparison of the data collected and the theoretical values for the data, given the k value found in the appendices.

Photograph

Figure 4. An image illustrating how the data was collected. Julia (left) watches, while Neena (middle) releases the apparatus and Akhi (right) analyzes the video he took to find the maximum height the weight reached.

Statistical Analysis

The data is not the most accurate, with an average percent error of 16.2% (when comparing the calculated values with the theoretical values), but it makes up for this in its precision. Overall, the data is very precise, as seen with an average %RSD value of less than 2% (meaning that, on average, all data points stayed within 2% of the mean). The model for the data is pretty strong, given that the R^2 value is 0.9938, or rather, that 99.38% of the data is explicable by the line of best fit.

Conclusion

The initial hypothesis was supported; as the initial height decreases, the final height increases. This means that, whenever the weight was pulled down further, the potential energy of the bungee was greater, which then propelled the apparatus up to a higher height. The average height was actually larger than the theoretical height, which is probably mainly due to having released the weight at a slightly lower point, or giving the weight additional energy by not waiting for the weight to reach equilibrium at the initial height. Future extensions could include changing the mass of the weight in order to see whether it affects the maximum height reached, or changing the elastic of the bungee to see how a change in the k constant would affect the height.

Appendix

Derivation of Theoretical DV:

1. $\sum E_i = \sum E_f$
2. $PE_i + PE_{spring} = PE_f$
3. $mgh_i + \frac{1}{2}k(\Delta x)^2 = mgh_f$
4. $h_f = \frac{mgh_i + \frac{1}{2}k(\Delta x)^2}{mg}$
5. $h_f = h_i + \frac{k(\Delta x)^2}{2mg}$

Obtaining the k-value:

Akhi, Neena, and Julia had measured the force for the bungee apparatus for various changes in x, the results of which are shown on the graph below. The linear line of best fit for this is also shown below, the slope for which should be the approximate k value. This is the value used in subsequent calculations.