Spring Energy Lab

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December 8, 2017
I Section

Introduction

- Purpose
  - The purpose of this lab was to design and perform an experiment which analyzes the conservation of energy in a spring-based system.
- RQ
  - In a system where a spring pushes an object forward, how will the distance that the spring is compressed affect the distance traveled by the object across a horizontal surface?
- Hypothesis
  - If the spring of the system is compressed at a greater distance, then the projected object will travel a greater distance across the horizontal surface, where $\Delta x_{BC} \propto \frac{k(\Delta x_{AB})^2}{2\mu mg}$.

Methodology: Procedure and Materials

- The projectile was created using six 2X4 Lego bricks. There were three layers of bricks with two bricks in each layer.
- The five different spring compression lengths were measured with a ruler and marked on a small piece of paper. The piece of paper was taped down to the table.
- Derek placed the toy spring on top of the piece of paper. The spring was oriented so that both of the ends were touching the piece of paper with one end of the spring placed at the "0" mark, and he tightly held the back of the spring with the fingertips of both his thumbs and index fingers.
- Rumani oriented the Lego block so that its bottom (the side with the holes) was touching the end of the spring at the "0" mark. Using the fingertips of her right thumb and index finger, she held the flat sides of the projectile that were perpendicular to the table. She pushed the back of the projectile to a setting and released the block (see Figure 3).
- Before the experiment, a meter stick was placed on the table perpendicular to the top (now front) end of the Lego block (the side with the eight circles). Abby measured the distance traveled based on the point of the projectile closest to the starting point.

Methodology: Diagram

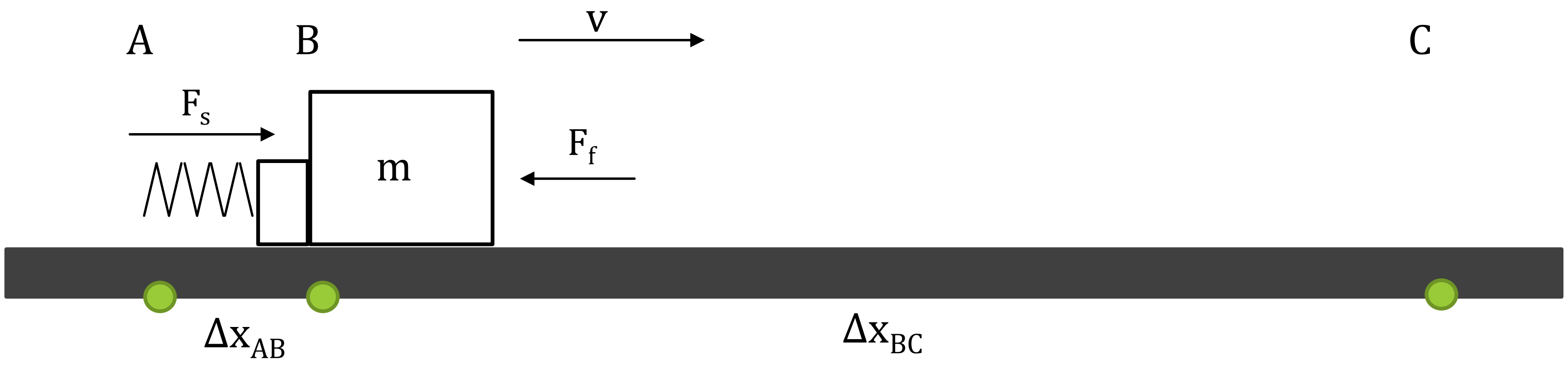

Figure 1: The setup of the experiment. A mass *m* was pushed from points B to A, which compressed the spring. When released, the spring would push the mass back to point B, from where it will slow to a stop at point C.

Methodology: Constants and Equations

Constants

- $m = 0.01457\ kg$
- $\mu = 0.1684$ (Appendix C)
- $k = 182\ N/m$ (Appendix D)
- $g = 9.8\ m/s^2$

Equations

- $\Delta x_{BC} = \frac{k(\Delta x_{AB})^2}{2\mu mg}$ (Appendix B)
- $F_f = \mu F_N$ (Appendix C)

Results: Data Summary

Table 1: The table shows a summary and data analysis of the experiment.

	Δx_{AB} (m)	Δx_{AVG} (m)	STDEV (m)	%RSD of Δx_{AVG}	Δx_{BCT} (m)	|%err| of Δx_{BC}	TE_i (J)	TE_f (J)	%E change of TE
IV1	0.010	0.231	0.020	8.7	0.378	38.7	0.009	0.006	-38.7
IV2	0.020	0.628	0.070	11.1	1.510	58.4	0.036	0.015	-58.4
IV3	0.025	0.695	0.087	12.5	2.359	70.5	0.057	0.017	-70.5
IV4	0.030	1.113	0.157	14.1	3.398	67.2	0.082	0.027	-67.2
IV5	0.035	1.343	0.166	12.3	4.625	71.0	0.111	0.032	-71.0
			Avg	**11.8**	Avg	**61.2**		Avg	**-61.2**

Results: Graph

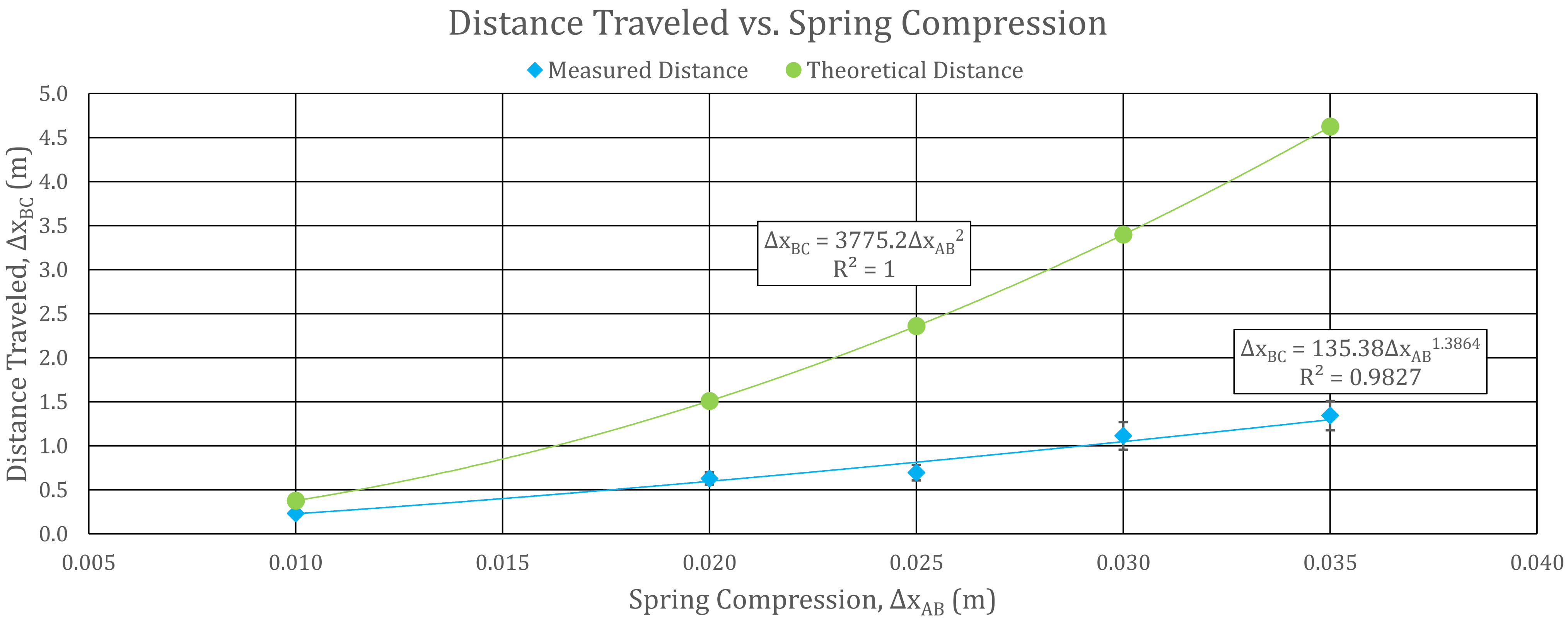

Figure 2: The blue points show the average distance traveled by the projectile for a particular spring compression distance, while the green points show the theoretical distance that the projectile could have traveled.

Results: Pictures

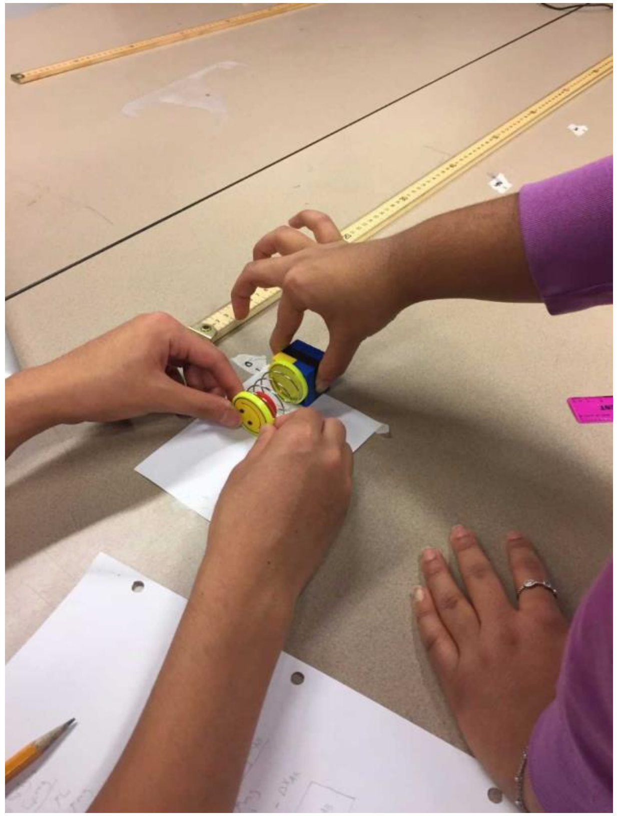

Figure 3: Preparing to launch the projectile

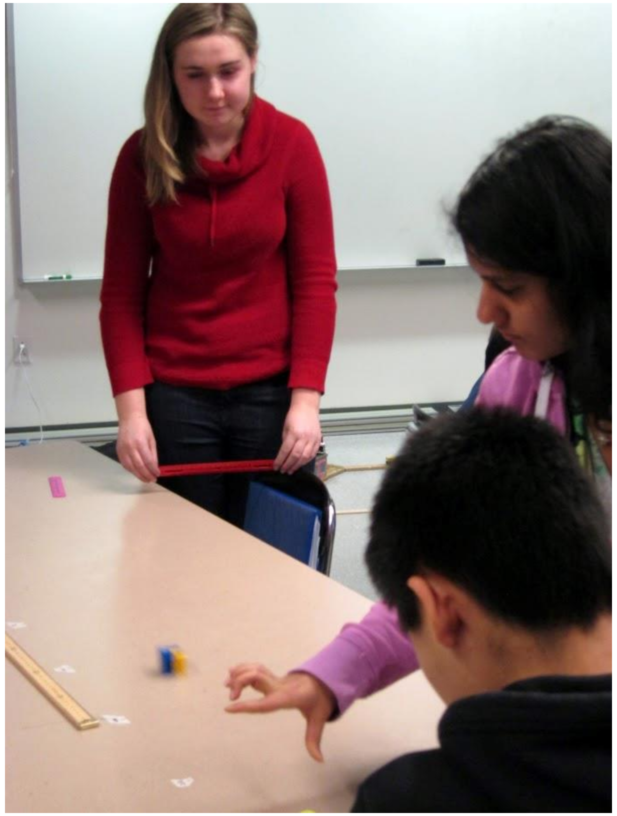

Figure 4: The projectile in motion

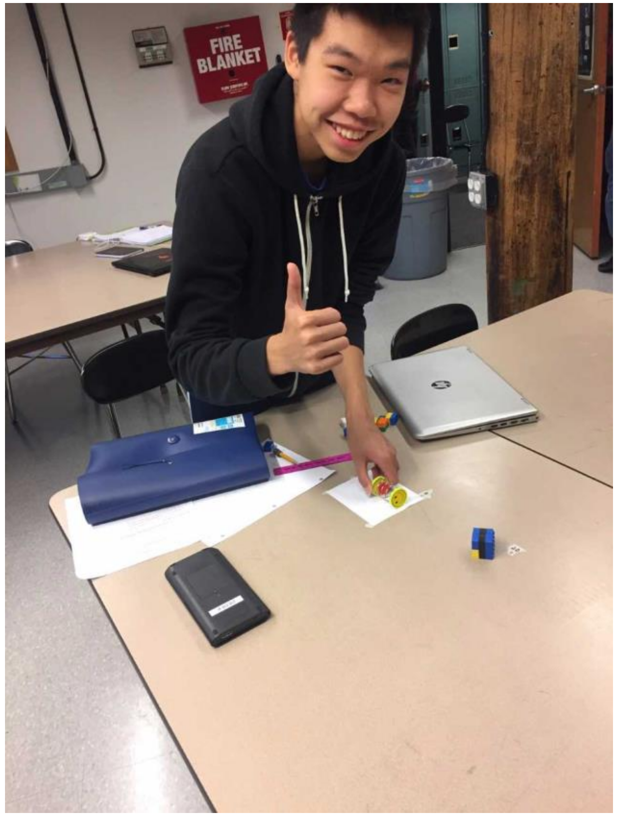

Figure 5: Physics!

Analysis

The data show that the precision is low because of the average percent RSD value of 11.8 percent. Accuracy was also low because of the average percent error of 61.2 percent. Despite the low precision and low accuracy, the R^2 value of 0.98 makes the mathematical model a strong fit to the data. The slope of best fit appears to have a positive trend; as the amount of spring compression increases, the distance traveled by the projectile also increases. However, this trend cannot continue increasing infinitely as the amount of spring compression cannot exceed the length of the spring. The slope of the curve of best fit becomes larger as the compression of the spring increases, which suggest that the amount of distance traveled by the projectile is greater between consecutive distances as the amount of spring compression increases. The measured distances seem to deviate farther from the theoretical distances as the spring compression distances become greater, which can also be seen in the increasing percent errors. The change in energy also exhibits this behavior. Interestingly, the percent errors and change in energy also match in each setting.

Conclusion

The data support the hypothesis which states that as a spring is compressed a greater distance, the distance traveled by the projectile will increase as well. However, there were many sources of error. The theoretical equation does not take into account heat or sound energy loss. When the projectile was released, it began to spin, which suggest that one finger released the projectile sooner than the other, causing one side of the projectile to begin moving while the other side was still stuck to a finger. Because of this error in launching the projectile, the path of the projectile was not parallel to the meter stick, so the actual distance traveled by the projectile was a little farther than the measured distance. Another source of error could be the fact that part of the projectile started on the piece of paper, which would have a different coefficient of friction. All these sources of error could explain the lower distance traveled compared to the theoretical values. Future extensions to this experiment would aim to eliminate as many sources of error as possible. A new apparatus could be created to release the projectile. The apparatus should launch the projectile straight and prevent it from spinning. It could also contain notches with set distances, so that the piece of paper does not have to be used to mark the distances. In addition, more trials could be done with different settings, and different springs and projectiles can be used.

Appendix A: Full Data

Table 2: This table shows the data summary in addition to all the distances traveled by the projectile for all the trials for each setting.

	Δx_{AB}	Δx_{BC1}	Δx_{BC2}	Δx_{BC3}	Δx_{BC4}	Δx_{BC5}	Δx_{BC6}	Δx_{BC7}	Δx_{BC8}	Δx_{BC9}	Δx_{BC10}	Δx_{AVG}	STDEV	%RSD	Δx_{BCT}	|%err|	TE_i	TE_f	%E change
	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	of Δx_{AVG}	(m)	of Δx_{BC}	(J)	(J)	of TE
IV1	0.010	0.229	0.260	0.232	0.233	0.252	0.227	0.210	0.227	0.251	0.192	0.231	0.020	8.7	0.378	38.7	0.009	0.006	-38.7
IV2	0.020	0.625	0.714	0.758	0.669	0.531	0.583	0.554	0.599	0.634	0.616	0.628	0.070	11.1	1.510	58.4	0.036	0.015	-58.4
IV3	0.025	0.785	0.831	0.620	0.602	0.604	0.664	0.678	0.789	0.623	0.755	0.695	0.087	12.5	2.359	70.5	0.057	0.017	-70.5
IV4	0.030	0.922	0.991	1.092	1.154	1.241	1.332	1.119	0.957	0.966	1.354	1.113	0.157	14.1	3.398	67.2	0.082	0.027	-67.2
IV5	0.035	1.472	1.605	1.307	1.417	1.408	1.446	1.342	1.235	1.029	1.170	1.343	0.166	12.3	4.625	71.0	0.111	0.032	-71.0
													Avg	**11.8**	Avg	**61.2**		Avg	**-61.2**

Appendix B: Deriving Theoretical Equation

- $\Sigma \mathrm{E}_i - W = \Sigma E_F$
- $PE_s - F_f \Delta x_{BC} = 0$
- $PE_s = F_f \Delta x_{BC}$
- $\frac{1}{2} k \Delta x_{AB}{}^2 = \mu F_N \Delta x_{BC}$
- $\frac{1}{2} k \Delta x_{AB}{}^2 = \mu m g \Delta x_{BC}$
- $\frac{\frac{1}{2} k \Delta x_{AB}{}^2}{\mu m g} = \Delta x_{BC}$
- $\Delta x_{BC} = \frac{k \Delta x_{AB}{}^2}{2 \mu m g}$

Appendix C: Calculating µ

- $F_f = \mu F_N$
- $F_f = \mu mg$
- $\mu = \frac{F_f}{mg}$
- $\mu = \frac{1.674}{1.01457 * 9.8}$
- $\mu = \frac{1.674}{9.94279}$
- $\mu = 0.1684$

Table 3: This table shows the values used to calculate the coefficient of friction μ between the projectile and the table.

F_f (N)	m (g)	g (m/s^2)	µ
1.674	1.01457	9.8	**0.1684**

Appendix D: Calculating k

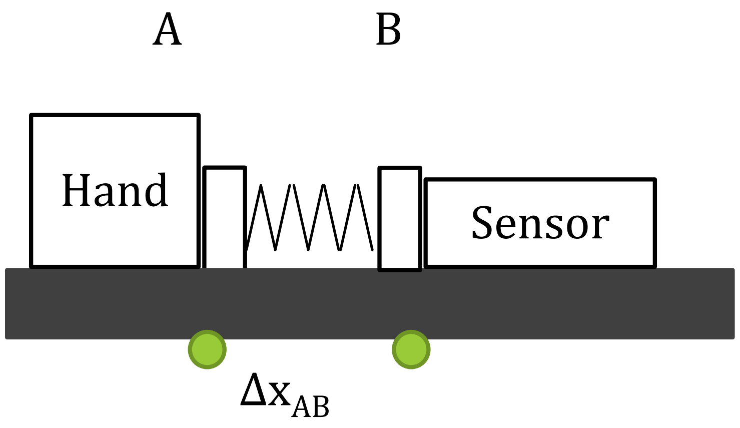

Figure 6: To find the k value, a hand compressed the spring to certain distances, and the sensor returned a force value.

To find the spring constant *k*, Logger Pro software from Vernier was used. One end of the spring was put against a force sensor. When a hand compressed the spring a certain distance, the software returned a force value. With four different distance and force values, a graph was produce, and the slope of the curve of best fit was the *k* value.

Appendix D: Calculating k

Table 4: This table shows the values used to calculate the spring constant *k*.

Force (N)	**Δx_{AB} (m)**	**k (N/m)**
1.995	0.0100	200
3.570	0.0200	179
5.281	0.0300	176
7.475	0.0400	187
	Slope	**182**

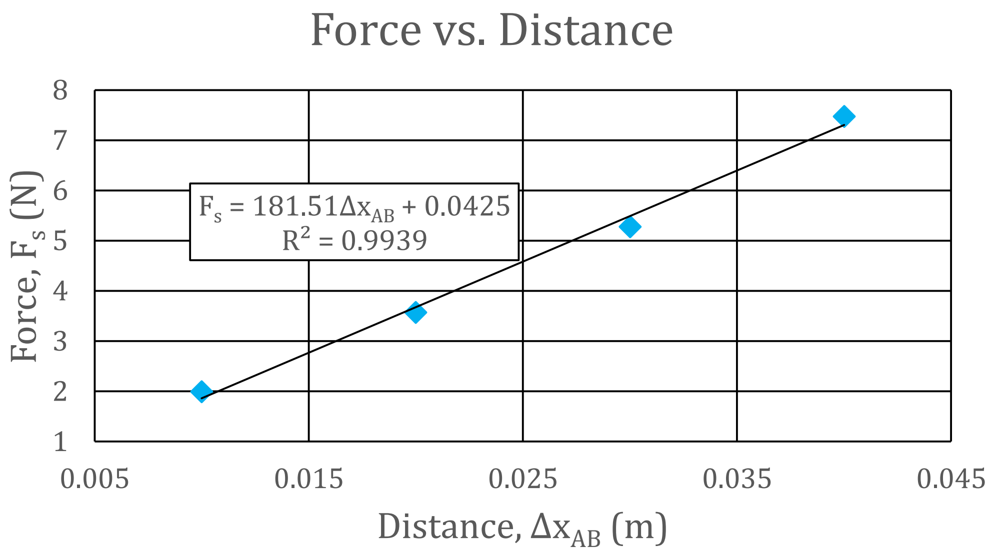

Figure 7: The values were graphed to find the slope, which was the spring constant.