NOTE TO MR.ELLIS: I am pictures because we did not do the lab during class.

Energy Lab

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Section B
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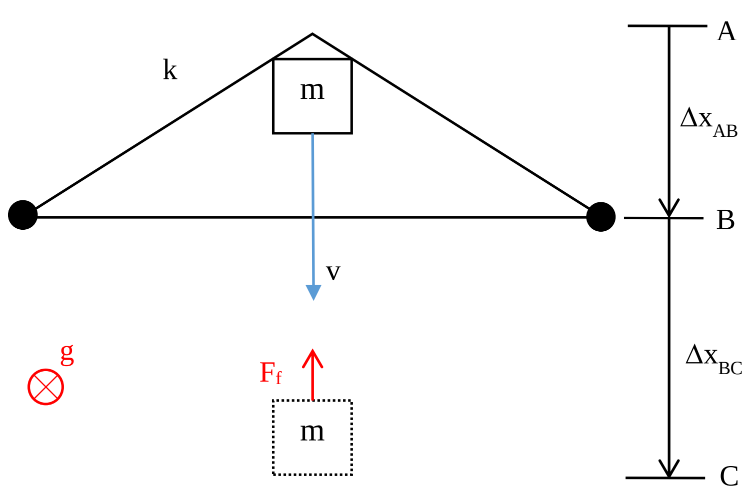
Introduction

The purpose of the lab was to design an experiment which analyzes the conversation of energy in a spring-based system. How does increasing the length a rubber band is pulled back affect the distance a wooden block slides, when the rubber band is wrapped around the legs of a chair, and the block is pushed against the band. If a rubber band is pulled across the legs of two chairs, and pulled back an increasing amount, then a block placed against the band will slide further because more potential energy is stored in the string, which will be converted to more kinetic energy, moving the block further, where $\Delta x_{traveled} \propto (\Delta x_{stretched})^2$.

Methodology

Mr. Ellis provided two rubber bands tied together, and wrapped them around the bottom legs of a chair. Da-Jin moved the chair against the wall, and placed a meter stick parallel to the wall, starting at the beginning of the rubber band. Malik placed tape under the chair starting at and perpendicular to the rubber band. Malik pushed the block back against the band and recorded how far he pulled by marking the tape with sharpie. He released the block, and Da-Jin recorded where the block stopped by marking the back of the block with a small dot of tape. After repeating for ten trials, Da-Jin measured the distance from the rubber band to the dots using the meter stick. Srinivas recorded the data on his laptop, and the trials were repeated for four other stretch distances. Da-Jin hooked the rubber band to a Vernier force sensor and pulled it to several distances on a meter stick. Malik used LoggerPro to measure the average force and Srinivas recorded the force and distance. Malik attached a force sensor to the block and pulled it at a slow constant speed on the rug.

Diagram



Constants

L_i = 22.8 cm = 0.228 m
m = 133.3 g = .1333 kg
k_{eff} = 36.74 N/m (See Appendix A)
F_f = 0.266 N (See Appendix B)
g = 9.8 m/s^2

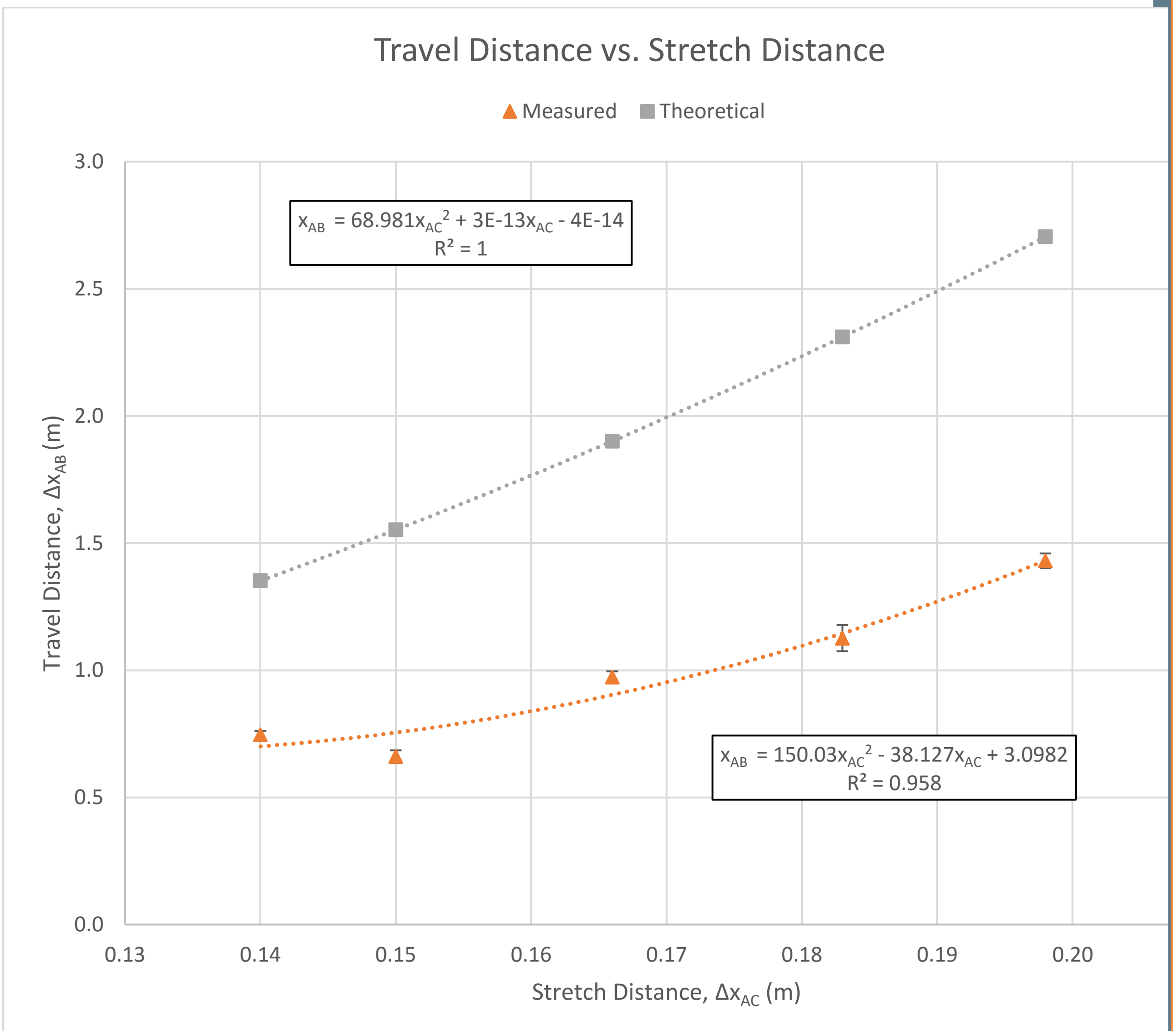
Equations

$$\Sigma E_i = W_f$$
$$PE_s = W_f$$
$$W = Fd$$
$$W_f = F_f(\Delta x_{AC})$$
$$PE_s = \frac{1}{2}k_{eff}(\Delta x_{AB})^2 \ See\ Appendix\ C$$
$$\frac{1}{2}k_{eff}(\Delta x_{AB})^2 = F_f(\Delta x_{AC})$$
$$\Delta x_{AC} = \frac{k_{eff}(\Delta x_{AB})^2}{2 * F_f}$$
$$\Delta x_{AC}[\Delta x_{AB}] = \frac{36.74 * x_{AB}^2}{2 * 0.266}$$
$$\Delta x_{AC}[\Delta x_{AB}] = 69.06 * x_{AB}^2$$

Summary Data

	Δx_{AB}	Δx_{ACavg}	STDEV	|%RSD|	Δx_{ACtheo}	|%err|	ΣE_i	ΣE_f	ΔE	|%ΔE|
	(m)	(m)	(m)	(%)	(J)	(%) of Δx_{AC}	(J)	(J)	(J)	(%)
IV1	0.140	0.746	0.015	2.052	1.352	44.846	0.360	0.000	0.360	100.000
IV2	0.150	0.661	0.025	3.747	1.552	57.431	0.413	0.000	0.413	100.000
IV3	0.166	0.973	0.024	2.449	1.901	48.839	0.506	0.000	0.506	100.000
IV4	0.183	1.126	0.051	4.551	2.310	51.249	0.615	0.000	0.615	100.000
IV5	0.198	1.430	0.029	2.036	2.704	47.111	0.720	0.000	0.720	100.000
			Avg.	**2.967**	Avg.	**49.895**				

Graph



Travel Distance vs. Stretch Distance
Measured
Theoretical
$x_{AB} = 68.981x_{AC}^2 + 3E-13x_{AC} - 4E-14$
$R^2 = 1$
$x_{AB} = 150.03x_{AC}^2 - 38.127x_{AC} + 3.0982$
$R^2 = 0.958$
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.20
Travel Distance, Δx_{AB} (m)
Stretch Distance, Δx_{AC} (m)

Analysis

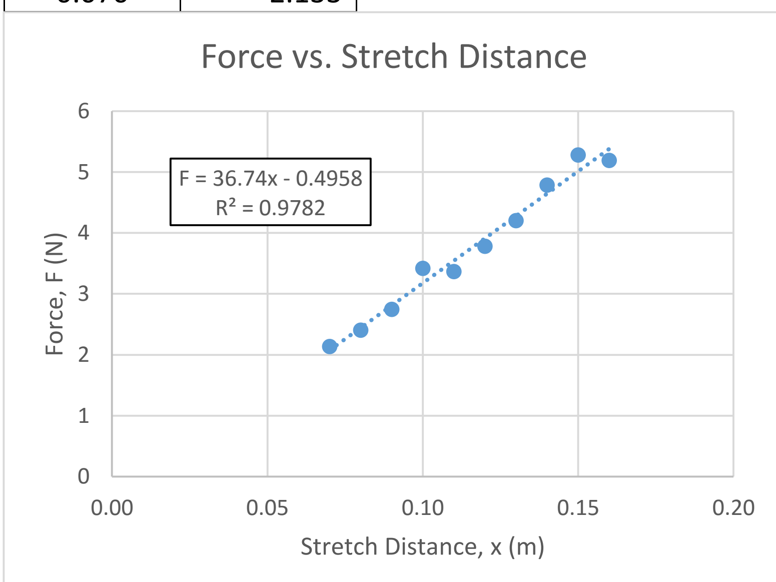
The data had high precision, with an average percent standard deviation (%RSD) of 2.967%. The data had an average percent error of 49.895% which indicates low accuracy. The models were strong. The theoretical model had an R^2 value of 1, and the measured was 0.958. The functions should start at the origin, because the block should move 0 meters forward if the band is stretched 0 meters. The theoretical model comes very close, but the measured model has a y-intercept of 3 meters. The model will only remain accurate within the range of the data, that is, from 0.14 meters to 0.20 meters of stretched distance. All energy was lost to friction. Sources of error include inaccuracies when measuring data, not measuring the coefficient of friction for the same carpet as the one used for the experiment, and improperly calibration when measuring force data. During the experiment the ruler used to measure the stretch distance was moved often and started at different locations, and the meter stick was placed far away from where the block stopped, requiring the experimenters to guess approximately where to mark the distance traveled. When the block did not travel exactly straight, some distance traveled would not be accounted for due to the meter stick only measuring in a fixed axis. When the force of friction was measured, the part of the carpet used was not exactly the same as the section used during the experiment. The force sensor was not properly zeroed, as the y-intercept of the force vs stretch data is -0.496. This should not impact the data, as the slope was used to get the effective sprint constant, but may be indicative of the inaccuracy of the data collected.

Conclusion

If a rubber band is stretched further, then the distance that the block travels increases at a rate proportional to the stretch distance squared. The data supports this proportionality, but conservation of energy was not demonstrated, even after accounting for friction. This experiment could be modified to conserve energy, simplifying calculations and reducing sources of error. The band could launch a ball up a ramp, and the max height could be recorded. This would remove the calibration step used to calculate the coefficient of friction that was needed in this experiment, and conservation of energy would be easily demonstrated through the potential energy of gravity.

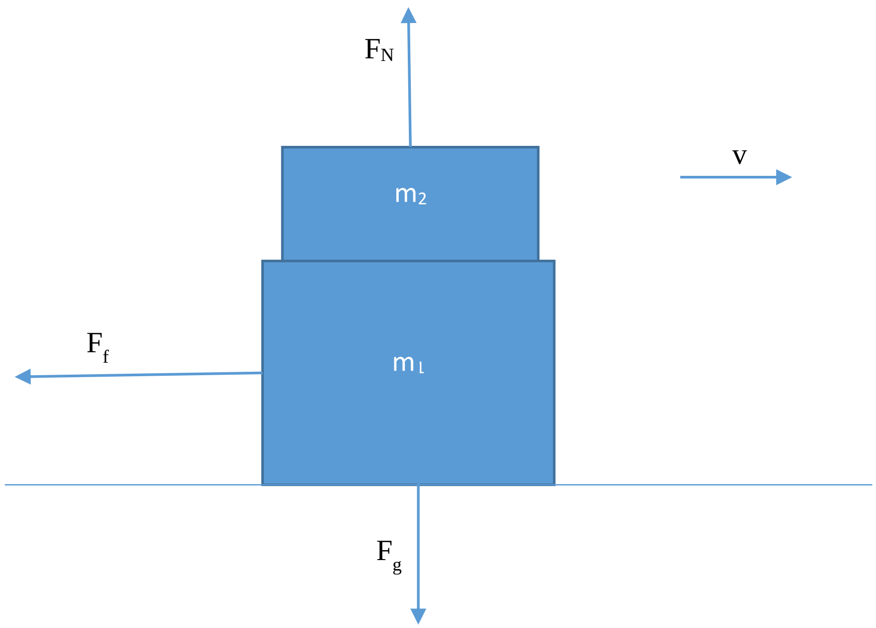
Appendix A

Stretch Distance	Force
(m)	(N)
0.100	3.418
0.150	5.277
0.120	3.778
0.160	5.191
0.110	3.367
0.090	2.743
0.130	4.2
0.080	2.401
0.140	4.785
0.070	2.133



Effective Spring Constant, k_{eff},
=36.74 N/m

Appendix B



Constants	Equations
$m_2 = 496.9\ g = \ 0.4969\ kg$ $m_1 = 133.3g = \ .1333\ kg$ $F_f = 1.259\ N$ $g = 9.8\ m/s^2$	ΣF_y: $F_N - F_g = ma_y$ $F_N - mg = 0$ $F_N = (.4969 + .1333)(9.8)$ $F_f = \mu F_N$ $\mu = \frac{F_f}{F_N}$ $\mu = \frac{(.4969 + .1333)(9.8)}{1.259}$ $\underline{\mu = 0.204}$ $For\ m_1 alone$: $F_N = (.1333)(9.8) = 1.306\ N$ $\boxed{F_f = (0.204)(1.306) = 0.266\ N}$

Appendix C

$$F_s[x] = kx$$

$$PE_S = \int F_s[x]$$

$$PE_s = \int_0^x kx\,dx$$

$$PE_s = \frac{1}{2}kx^2$$