Oh Snap! A Reverse Bungee on a Ramp

Varnika Sinha
Section B
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Lab Partners: Sam Pendergast, Patrick Wilcox

Introduction

Purpose

To design and perform an experiment which analyzes the conservation of energy in a spring-based system.

Researchable Question

How does increasing the mass of a frictionless cart affect the maximum displacement of the cart down the ramp after it contacts a rubber band perpendicular to the ramp and stretches the rubber band?

Hypothesis

By increasing the mass of a frictionless cart, the maximum displacement of the cart down the ramp after it contacts a rubber band perpendicular to the ramp and stretches the rubber band also increases, where $\Delta x \propto m + \sqrt{m^2 + m}$.

Methodology

Diagram

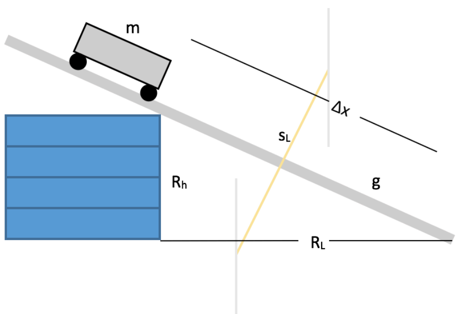


Figure 1: Side view of the Reverse Bungee on a Ramp

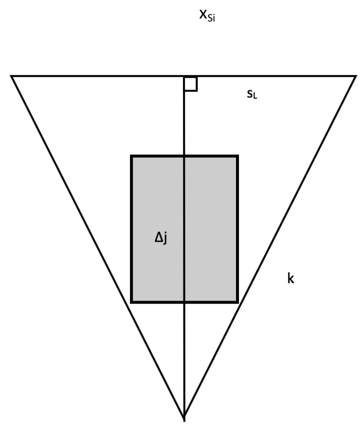


Figure 2: Top view of the Reverse Bungee on Ramp

Constants

R_h = 0.198 m
R_L = 2.284 m
s_L = 1.190 m
x_{Si} = 0.745 m
k = 5.0448 N/m (See Appendix A)
g = 9.8 m/s^2

Equations

$PE_g = mg\Delta h$
$W = \int F\, dx$
$PE_s = \int F_s\ dx = \frac{1}{2}k(\Delta x)^2$
$x[m] = 0.043317\left(\sqrt{m^2 + 70.9868m} + m\right) + 0.745$ (See Appendix B)

Procedure

The group used a ramp that was 2 meters long. They angled the ramp on 4 textbooks where the height of the ramp was 0.198 m and the length of the ramp, from the end of the textbooks to where the ramp is touching the ground, was 2.284 m. At 0.745 m, the spring, made of rubber bands stretched to 1.19 m, was placed perpendicular to the ramp. They placed the cart, originally weighing 1000 g with 4 blocks each weighing 500 g each, with the front end of it directly above where the textbooks and ramp contacted. The group released the cart and let it roll down the ramp. The group recorded where the cart stopped by using the meter stick on the ramp. The group repeated this by removing a block of 500 g each time for five trials.

Results

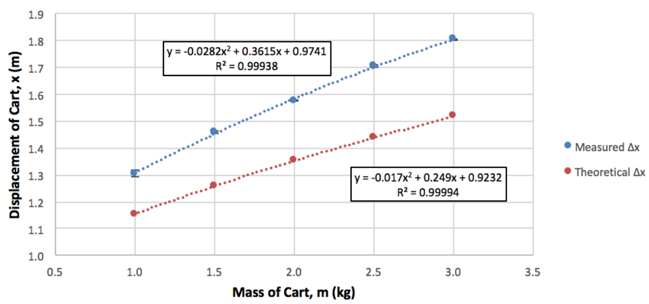
Data

Table 1: Data Summary

	m	Δx_{avg}	STDEV	%RSD	Δx_T	|%err|	$\sum E_i$	$\sum E_f$	ΔE %
	(kg)	(m)	(m)	of Δx_{avg}	(m)	of Δx	(J)	(J)	(J)
IV1	1.000	1.31	0.012	0.90	1.15	13.1	1.10	0.79	28.3
IV2	1.500	1.46	0.006	0.39	1.26	15.8	1.85	1.29	30.5
IV3	2.000	1.58	0.003	0.21	1.35	16.6	2.67	1.75	34.5
IV4	2.500	1.70	0.005	0.29	1.44	18.5	3.60	2.32	35.6
IV5	3.000	1.80	0.002	0.13	1.52	18.9	4.58	2.83	38.2
			Avg	**0.38**	Avg	**16.6**		Avg	**33.4**

Graph 1

Mass of Cart vs. Displacement of Cart



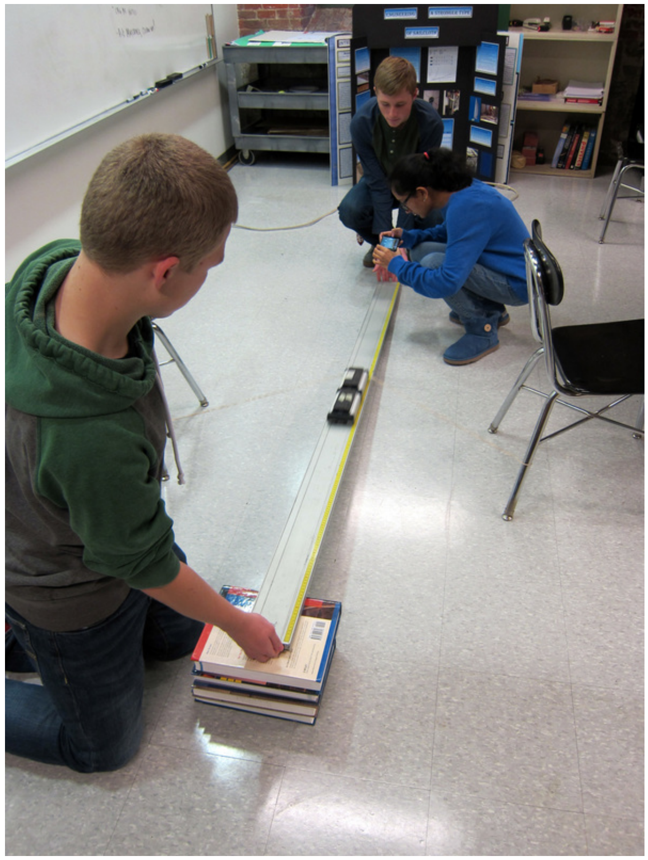


Figure 3: My lab partners and I working on our lab.

Analysis

The data shown on the table and graph is from ten trials. The relative standard deviation is 0.38%, indicating the data is highly precise and that the measurements taken during the experiment have a low discrepancy. The absolute error is 16.6%, denoting that the data is moderately accurate. The value of R^2 in the graph is 0.9999 for both equations, which is close to 1, shows that the best fit equation of the data collected is a strong mathematical fit.

Although the theoretical value of Δx is lower than the measured Δx of the collected data, there is only a slight difference between the measured Δx and theoretical value. The percent energy difference was 33.4%, which is relatively low. This difference furthers the idea that data was precise and accurate.

Possible sources of error could be that the rubber band heated up causing differences in energy to occur. As the rubber band was used more often, the k value of the rubber band increased. Because of this increase, the group’s data could be skewed. The group also assumed that friction would be neglected, so friction could play a role in the 33.4% energy reduction.

Conclusion

Summary of Outcomes

From the data collected and the analysis, it can be concluded that the hypothesis, by increasing the mass of a frictionless cart, the maximum displacement of the cart down the ramp after it contacts a rubber band perpendicular to the ramp and stretches the rubber band also increases, is proven correct. The proportionality $\Delta x \propto m + \sqrt{m^2 + m}$ proves to work accurately and precisely for the experiment performed.

Future Extensions

Because the group did a reverse bungee on a ramp, maybe the same can hold true for a bungee on a ramp. The same proportionality and hypothesis would be instilled to check if the system works backwards with the same conclusion. The conservation of energy states that energy is conserved from one state to another. So, if the group is to flip the initial energy and final energy, the same should hold true for that experiment as well. That would strengthened this experiment if the same conclusions are reached and ensure that the proportionality, $\Delta x \propto m + \sqrt{m^2 + m}$, always works.

Appendix A

Calculating k

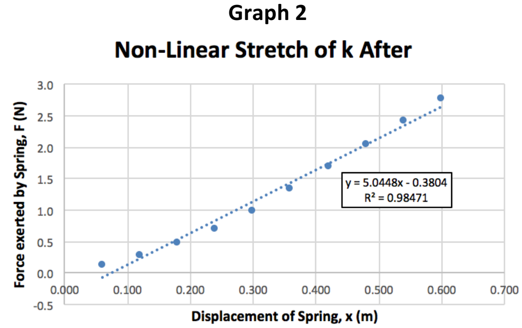
Procedure

The group stretched the spring made of rubber bands 1.19 m horizontally and then stretched the spring perpendicular to its initial stretch. The perpendicular stretch increase by 0.06 m for 10 trials. The force for each displacement was measured by a force meter and recorded. The data was then graphed, and the slope of the line was found to be the value k.

Table 2: Non-Linear Stretch of Spring After Experiment

Non-Linear Stretch After	
F (N)	x (m)
0.127	0.060
0.281	0.120
0.474	0.180
0.704	0.240
0.989	0.300
1.343	0.360
1.688	0.420
2.046	0.480
2.420	0.540
2.772	0.600

Graph 2



Appendix B

Deriving the theoretical function of x[m]

$$\sum E_i \pm W = \sum E_f$$
$$mgh_i - \int_0^j (4kj)dj = mgh_f$$
$$-2kj^2 = mg\Delta h$$
$$-2kj^2 = -mg\sin(R_h - R_L)(x_{Si} + j)$$
$$2(2.4335)j^2 = m(9.8)\sin(0.198/2.284)(0.745 + j)$$
$$j = 0.043317(\sqrt{m^2 + 70.9868m} + m)$$
$$x = j + 0.745$$
$$x[m] = 0.043317\left(\sqrt{m^2 + 70.9868m} + m\right) + 0.745$$

Appendix C

Table 3: Full Data Collected from Experiment

	m	Δx_1	Δx_2	Δx_3	Δx_4	Δx_5	Δx_6	Δx_7	Δx_8	Δx_9	Δx_{10}	Δx_{avg}	STDEV	%RSD	Δx_T	|%err|	$\sum E_i$	$\sum E_f$	ΔE %
	(kg)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	of Δx_{avg}	(m)	of Δx	(J)	(J)	(J)
IV1	1.000	1.3050	1.3050	1.3065	1.3020	1.3060	1.3085	1.3065	1.3075	1.3045	1.3010	1.31	0.012	0.90	1.15	13.1	1.10	0.79	28.3
IV2	1.500	1.4635	1.4600	1.4645	1.4575	1.4555	1.4650	1.4625	1.4590	1.4545	1.4500	1.46	0.006	0.39	1.26	15.8	1.85	1.29	30.5
IV3	2.000	1.5800	1.5800	1.5810	1.5795	1.5765	1.5765	1.5775	1.5750	1.5790	1.5700	1.58	0.003	0.21	1.35	16.6	2.67	1.75	34.5
IV4	2.500	1.6965	1.7045	1.7095	1.7075	1.7060	1.6985	1.7100	1.7110	1.6995	1.6965	1.70	0.005	0.29	1.44	18.5	3.60	2.32	35.6
IV5	3.000	1.7745	1.7975	1.8125	1.8055	1.8135	1.8145	1.8095	1.8100	1.8025	1.8045	1.80	0.002	0.13	1.52	18.9	4.58	2.83	38.2
													Avg	**0.38**	Avg	**16.6**		Avg	**33.4**