Matchbox Projectile

A SPRING-BASED LAUNCHER

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Introduction

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

2. **Researchable Question:** How does increasing the mass of a projectile launched across a level surface affect the distance the projectile travels until it comes to rest?

3. **Hypothesis:** The hypothesis states that as the mass of the projectile increases, the distance it travels along a level surface will decrease, or mass α distance traveled.

Methodology

- Chair
- Marking Tape
- 2 Large Rubber Bands
- Match Box
- 4 200g weights
- 1 50g weight
- Masking Tape
- Meter Stick

Methodology - Procedures

1. The first task in constructing the apparatus was to setup the launcher. This was done by tying two large rubber bands together in a knot and wrapping the two ends of the new larger rubber band around the front two legs of a standard classroom chair.
2. The projectile was prepared by adding the individual masses according to the mass needed for each IV setting, inside the matchbox, and using minimal amounts of masking tape to seal the projectile.
3. The rubber band, with the projectile being held along with it, is pulled back 20 cm from the initial resting place at the front two legs of the chair
   - The projectile was let go by releasing the fingers holding it, without obstructing the path of the projectile or rubber band
4. Once the projectile had come to a rest, the distance traveled by the projectile was measured from the initial resting position of the rubber band and projectile, using a meter stick
   - For further calculations, the .20 meters, as in the pull-back distance of the rubber band, was added to be accounted for

Diagram

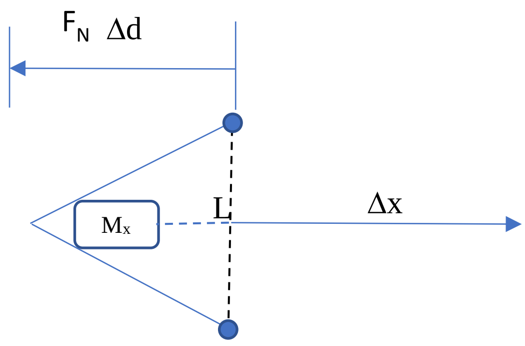


Figure 1: Bird's Eye View of the Apparatus

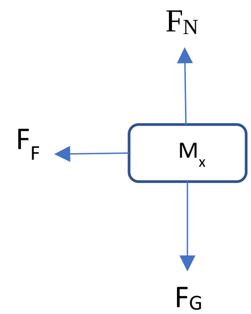


Figure 2: Free-Body Diagram

Constants And EQs

Equations:

$$\sum E_i = \sum E_f$$

$$F_f = \mu(F_N)$$

$$W_F = F(\Delta x)$$

$$PE_s = \frac{1}{2}K(\Delta d)^2$$

Constants:

$$K = 44.939\ N/m$$

$$\Delta d = 0.2\ m$$

$$\mu = 0.27818$$

First Derivation: $0.89878 = 2.7662M(.2 + \Delta x)$

Second Derivation: $\Delta x = \frac{0.89878 - 0.54524x}{2.7262x}$

Experimentation Photo

Figure 3: A Photograph of the Experimentation

Summarized Data

Table 1: Summarized Data from Experimentation

	Mass	D_{AVG}	STDEV	%RSD	d_T	|%ERR|	TE_i	TE_f	% EChange
	(kg)	(m)	(m)	of D_{AVG}	(m)	of d	(J)	(J)	%
IV1	0.0694	4.164	0.2407	5.781	4.550	0.085	0.89878	0.00	100.00
IV2	0.2699	0.808	0.0357	4.417	1.021	0.209	0.89878	0.00	100.00
IV3	0.4702	0.444	0.0527	11.862	0.501	0.114	0.89878	0.00	100.00
IV4	0.6705	0.198	0.0185	9.365	0.292	0.322	0.89878	0.00	100.00
IV5	0.8712	0.109	0.0091	8.341	0.178	0.388	0.89878	0.00	100.00
			Avg:	7.953	**Avg:**	0.224			

Graph

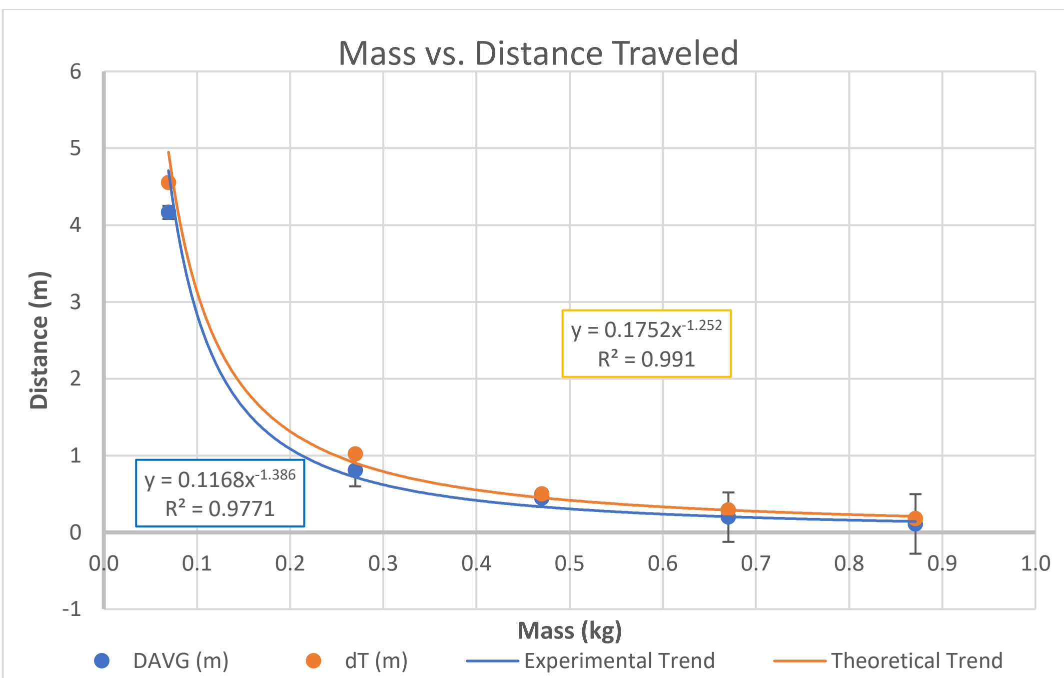


Figure 4: A Graph of the Mass vs Distance Traveled

Analysis

- Trends
  - The quantitative data from the graph, Mass vs Distance Traveled (IV vs DV), shows that as mass increase the Δ distance decreases.
- Limits and Insights
  - Due to the lost thermal energy, as the mass gets higher, the theoretical distance it travels will eventually become negative (at around 1.649 kg)
- Potential Sources of Error
  - Thermal energy that was transferring to both the ground and surrounding air was never formally accounted for
  - As each launch of the matchbox projectile was imperfect resulting in a lot of non-linear motion through the travel, rotational energy was never accounted for
  - Launch forces may not have been consistent throughout
- Precision
  - With a %RSD of 7.593 %, this precision would be categorized under “Moderate”
- Accuracy
  - With a %err of 22.4%, this level of accuracy would be categorized under “Low”
- Strength of Model
  - With a R^2 value of .9771, the strength of this model be categorized as “Strong”

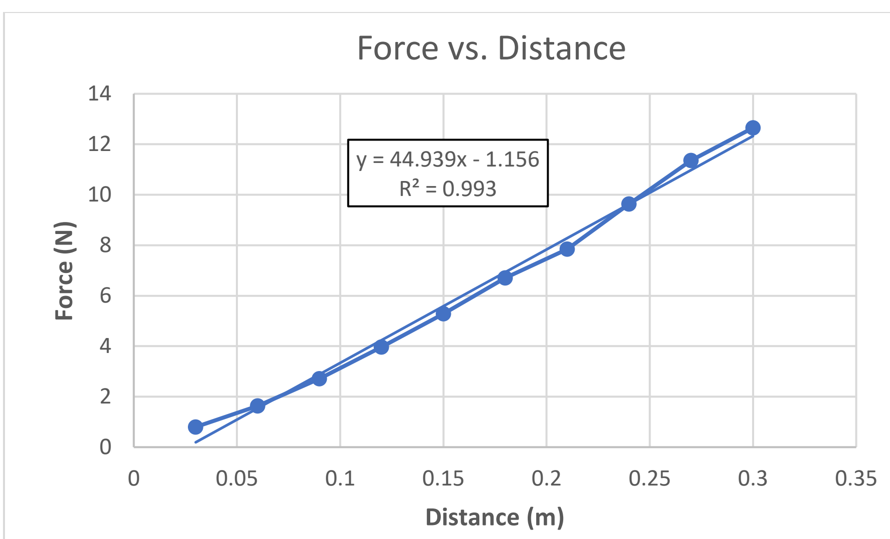
Conclusion

- The researchable question was initially; how does increasing the mass of a projectile launched across a level surface affect the distance the projectile travels until it comes to rest?
  - After conducting the experiment and comparing it to the theoretical, our hypothesis that mass α (1 / distance) traveled, or that mass is inversely proportional to distance traveled was confirmed
  - This means that if mass is increased, the distance that the projectile travels will decrease
  - The opposite is also true that if distance traveled is increased, then the mass must have decreased
- In further extensions, to improve this experimental design the following should occur:
  - Account for the loss of thermal energy in the apparatus
  - Account for rotational energy during the launch
    - Potentially using a track or course with measurable distances
    - Utilizing an alternative, more stable projectile
  - Test using other variables
    - i.e. time

Appendix

1. Derivation of the Spring Constant
    - To calculate the Spring Constant (K) of the connected rubber bands, a test was conducted to calculate the amount of force required to pull the band a specified distance (multiple different tests were run to create multiple data points)
    - Once this set of data was gathered, the data points were plotted
    - Once a graph was formed, the Spring Constant was established as being the slope of the line of best fit through the points, as a Spring Constant is the Force/Displacement. This came out to be **44.939 N/m**.

Force per Distance		
Trial	Dist (m)	Force (N)
1	0.03	0.8
2	0.06	1.63
3	0.09	2.71
4	0.12	3.96
5	0.15	5.29
6	0.18	6.71
7	0.21	7.85
8	0.24	9.63
9	0.27	11.36
10	0.3	12.65



2. Derivation of the DV_T

$$\sum E_i = \sum E_f$$

$$PE_s - W_f = 0$$

$$PE_s = W_f$$

$$\frac{1}{2}K(\Delta d)^2 = F(\Delta x + \Delta d)$$

$$\frac{1}{2}K(\Delta d)^2 = \mu F_N(\Delta x + \Delta d)$$

$$\frac{1}{2}K(\Delta d)^2 = \mu(M)(G)(\Delta x + \Delta d)$$

$$\frac{1}{2}(44.939)(0.2)^2 = (0.27818)(9.8)M(\Delta x + 0.2)$$

$$0.89878 = 2.7262M(\Delta x + 0.2)$$

$$0.89878 = 2.7262\Delta xM + 0.54524M$$

$$0.89878 - 0.54524M = 2.7262\Delta xM$$

$$\Delta x = \frac{0.89878 - 0.54524M}{2.7262M}$$

3. Raw Data

	Mass (kg)	DV1 (m)	DV2 (m)	DV3 (m)	DV4 (m)	DV5 (m)	DV6 (m)	DV7 (m)	DV8 (m)	DV9 (m)	DV10 (m)	D_{AVG} (m)
IV1	0.0694	4.018	3.975	4.085	4.203	4.017	4.216	4.261	4.826	4.008	4.029	4.164
IV2	0.2699	0.807	0.800	0.774	0.874	0.842	0.820	0.833	0.738	0.801	0.791	0.808
IV3	0.4702	0.389	0.464	0.403	0.465	0.464	0.578	0.433	0.419	0.389	0.436	0.444
IV4	0.6705	0.158	0.183	0.192	0.198	0.190	0.216	0.213	0.205	0.228	0.195	0.198
IV5	0.8712	0.118	0.114	0.113	0.123	0.110	0.116	0.107	0.098	0.100	0.093	0.109

STDEV (m)	%RSD of D_{AVG}	d_T (m)	|%ERR| of d	TE_i (J)	TE_f (J)	% EChange %
0.2407	5.781	4.550	0.085	0.89878	0.00	100.00
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