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Physics: Spring Energy Lab Poster Template Section L

Introduction

- **Purpose**: Design and perform an experiment which analyzes the conservation of energy in a spring-based system.

- **Researchable Question:** How does the distance a reverse bungee is stretched downward affect the maximum height a mass reaches?

- **Hypothesis:** If the initial vertical stretch distance is increased, the square root of the maximum height the mass will reach will increase proportionally to the initial stretch distance.

Procedure

1. Bao Han linked together eleven rubber bands to make a stretchy string of rubber bands
2. Bao Han an Hazelyn selected a small rock that Maxi wrapped in duct tape and attached to a paper clip.
3. Maxi massed the rock, tape, and paper clip on a balance and Bao Han recorded the mass as 33.4 grams.
4. Maxi hung and taped one end of the string of rubber bands to a rod extending horizontally from a pole and connected the rock to the other end using the paper clip and some masking tape.
5. Hazelyn used duct tape to tape a meter stick next to the hanging mass so the 60 cm mark is aligned with the resting mass of the height.
6. Bao Han stretched the mass downward a specific distance in cm and waited until Maxi was ready to film with a phone camera in slow motion mode.
7. When Maxi said he was ready to start filming, he said so, and Bao Han released the mass.
8. Maxi stopped the video after the mass reached its maximum height.
9. The team agreed on the maximum height of the mass from the video and Bao Han recorded it in an excel sheet.

Diagram

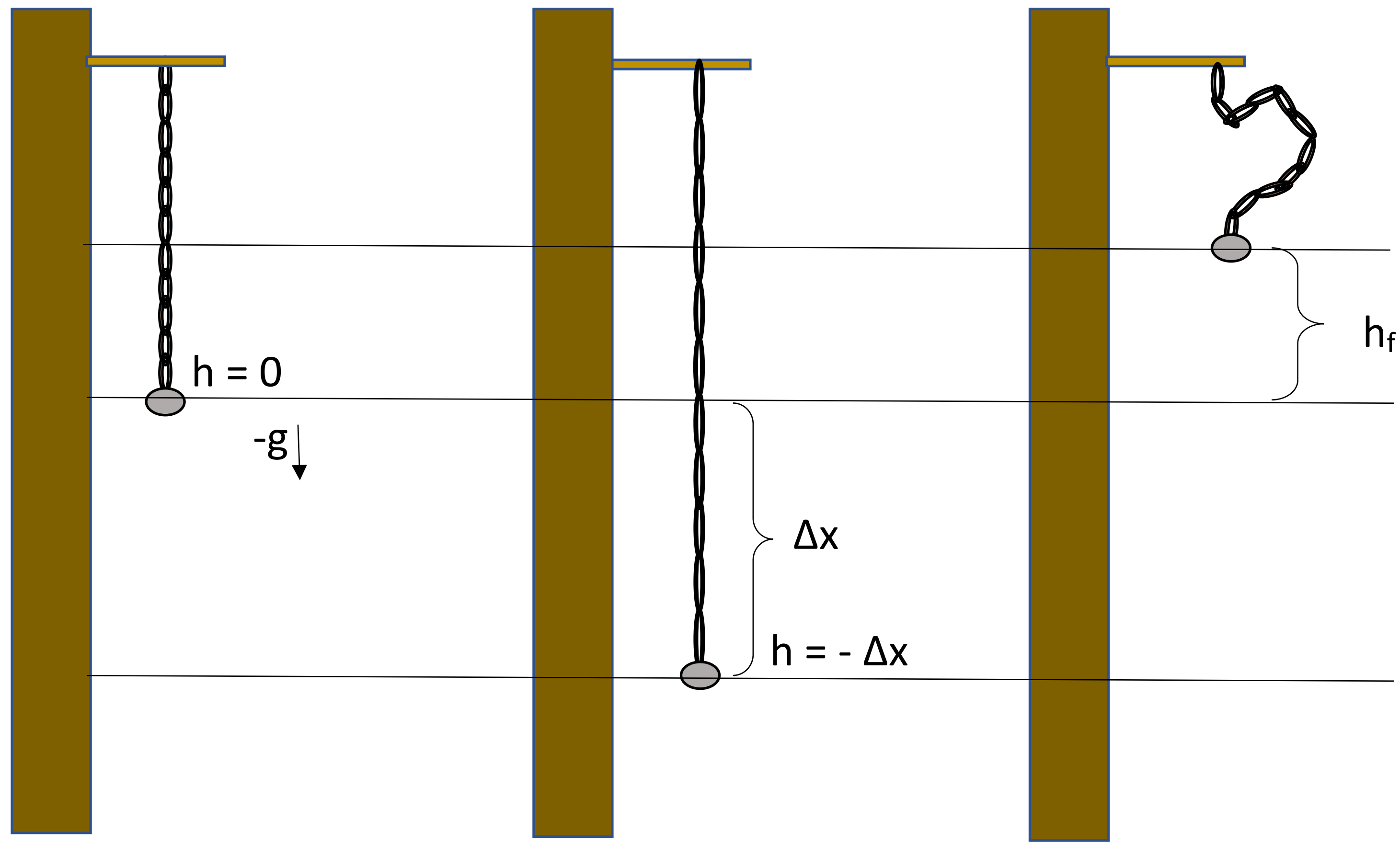

Figure 2: The experimental set up

Constants and Equations

m = 33.4 g = 0.0334 kg
k = 37.65 N/m
g = 9.8 m/s^2

$$F_s = -k\Delta x$$

$$h_f[\Delta x] = \frac{\frac{1}{2}k\Delta x^2 + mg\Delta x}{mg}$$

Photograph of Team Collecting Data

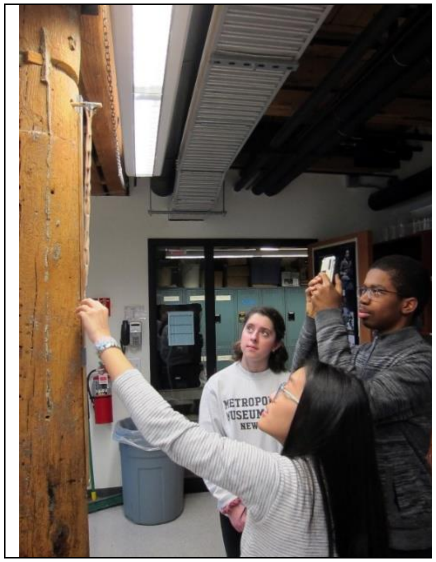

Figure 1: Bao Han stretched the rubber bands and holds onto the mass as Maxi prepares to film and Hazelyn is ready to verify a maximum height measurement.

Data Table

Table Information: Experimental data relating the average maximum height the mass reached (h_{fAvg}) for each distance (Δx) the rubber bands were stretched.

Δx	**h_{fAvg}**	**SD**	**%RSD**	**h_{fT}**	**|%err|**	**E_i**	**E_f**	**%ΔE**
(m)	**(m)**	**(m)**	**of h_{fAvg}**	**(m)**	**(m)**	**(J)**	**(J)**	**(m)**
0.0500	0.058	0.032	54.44	0.094	38.0	0.031	0.019	-38.0
0.0800	0.124	0.071	56.85	0.288	56.9	0.094	0.041	-56.9
0.0900	0.229	0.060	26.03	0.376	39.1	0.123	0.075	-39.1
0.1100	0.295	0.053	17.94	0.586	49.7	0.192	0.097	-49.7
0.1300	0.363	0.057	15.61	0.842	56.9	0.276	0.119	-56.9
		Average	34.17	**Average**	48.1		**Average**	-48.1

Graph

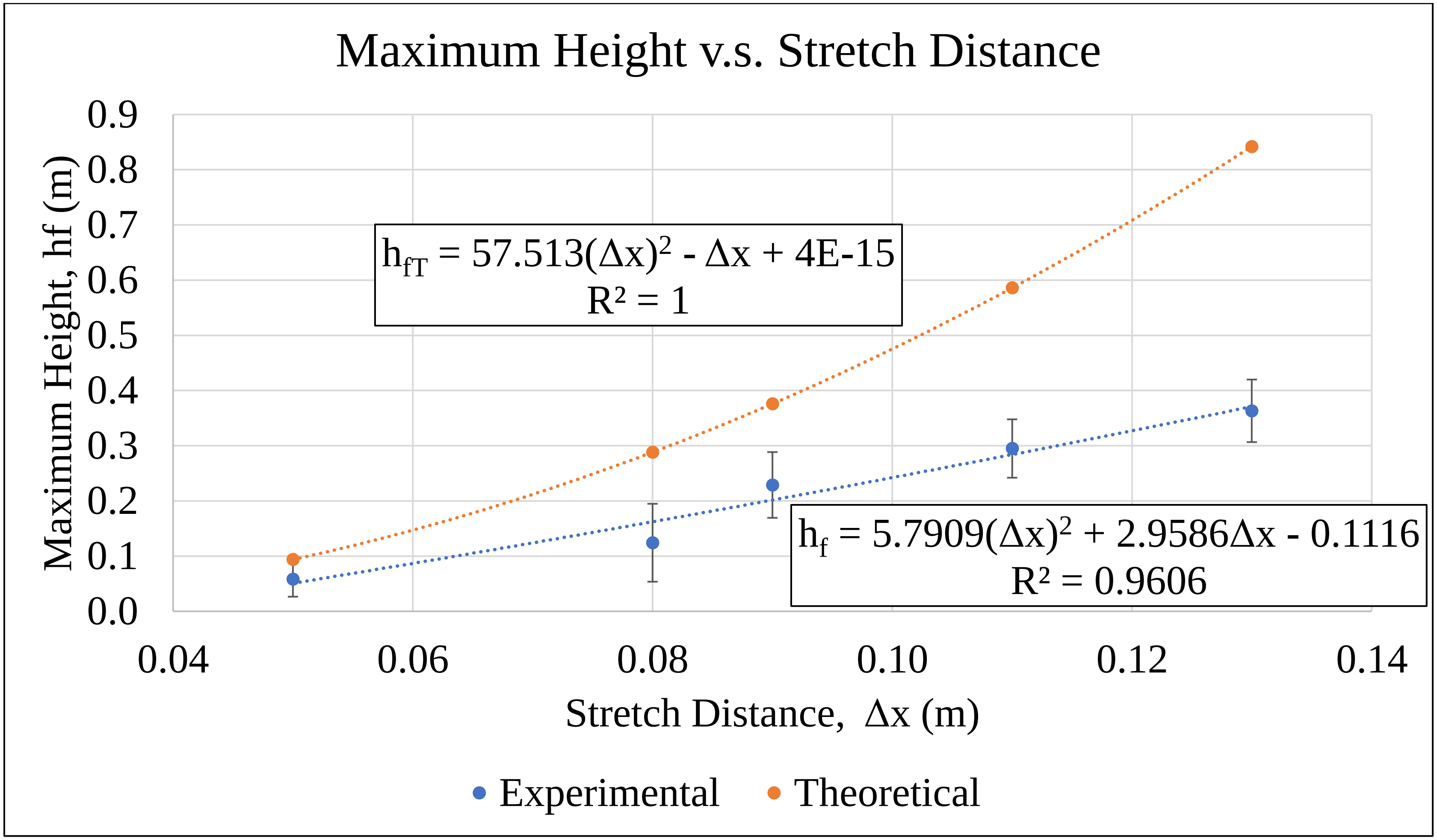

Figure 3: Experimental data relating the average maximum height the mass reached (h_{fAvg}) for each distance (Δx) the rubber bands were stretched along with a theoretical model based on conservation on energy for comparison.

Discussion

- The maximum height vs. stretch distance graph above shows the maximum height (h_f) the mass reaches increases as the corresponding stretch distance (Δx) increases for both the experimental data and the theoretical model.
- More specifically, the quadratic regression equation for h_f as a function of Δx suggests $h_f \propto (\Delta x)^2$ (see the Constants and Equations Section). Likewise, the quadratic regression equation for h_{fT} as a function of Δx suggests $h_{fT} \propto (\Delta x)^2$.
- The conservation of energy equation $PE_{si} + PE_{gi} = PE_{gf}$, where PE_{si} is the initial potential energy of the strand of rubber bands due to being stretched a distance Δx and PE_{gf} and PE_{gf} are, respectively, the initial and final gravitational potential energy of the mass due to the height of the mass.
- As shown in the appendix, the aforementioned conservation of energy equation yields an equation for the theoretical maximum height (h_{fT}) as a function of Δx.
- A trend shown in the data is h_f being consistently lower than h_{fT} and the disparity increases as Δx increases. This demonstrates that some of the energy stored in the mass and rubber band system as elastic potential energy from stretching the rubber bands is lost as the mass rises to its maximum height. Furthermore, the energy lost increases as Δx increases. More specifically, the average energy loss is 48.1%.

Statistical Analysis

- The accuracy and strength of the experimental model is high because R^2 equals 0.9606.
- However, the data has low accuracy, since the average |%error| is 48.1% and low precision, since the average %RSD is 34.17%.

Sources of Error

- Significant sources of error (other than human error) include…
  - Imprecise maximum height measurements due to the speed of the ascent of the mass
  - Variations in the video recording quality
  - Variations in the way in which the rubber bands were stretched and released
- Various ways in which elastic potential energy from stretching the rubber bands is lost as the mass rises to its maximum height include…
  - heat
  - friction (such as air resistance)

Summary of Outcomes

- The data collected does support the hypothesis because it suggests $h_f \propto (\Delta x)^2$.
- However, it does not match the theoretical energy conservation model because elastic potential energy of the rubber bands is lost as the mass rises to its maximum height.

Future Extensions

Future extensions to this lab could include…

- Increasing/Decreasing mass
- Increasing/Decreasing length

…while keeping the stretch distance constant.

Appendix

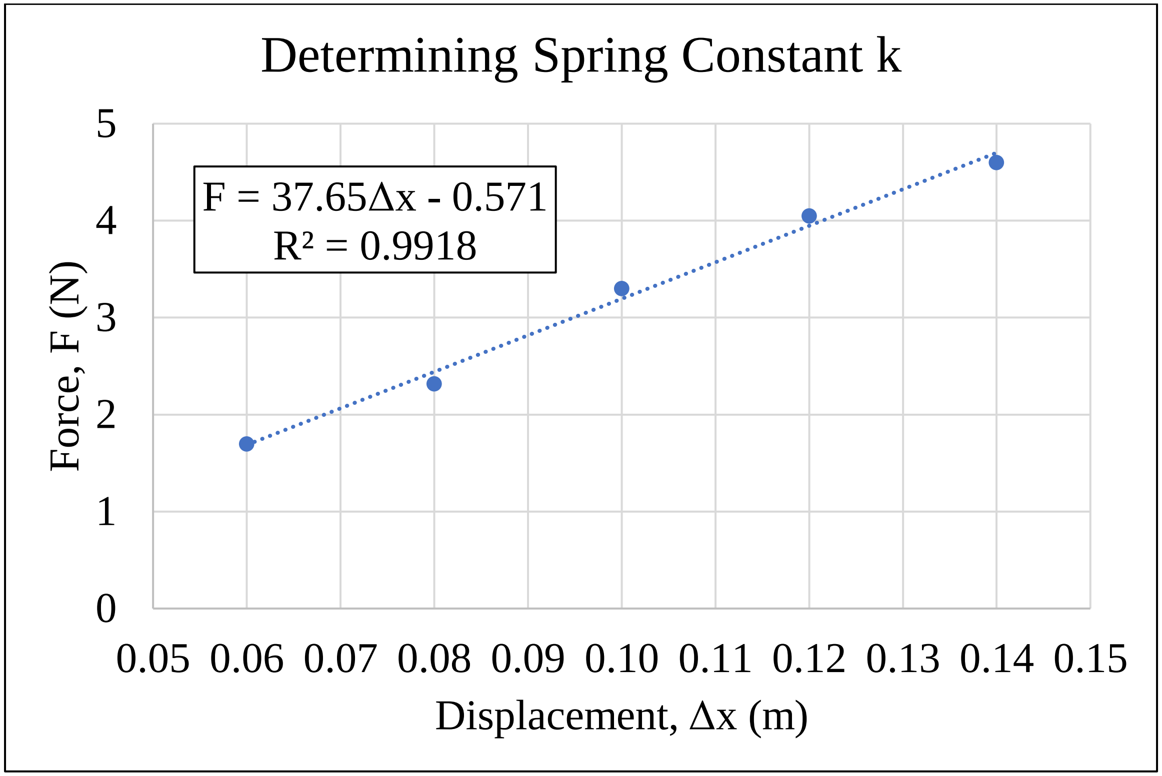

Figure 4: A force vs. displacement graph for the string of rubber bands, the slope of which is the spring constant k in N/m of the string of rubber bands.

DV Equation Derivation

$$PE_{si} + PE_{gi} = PE_{gf}$$

$$\frac{1}{2}k\Delta x^2 + mg\Delta x = mgh_f$$

$$h_f[\Delta x] = \frac{\frac{1}{2}k\Delta x^2 + mg\Delta x}{mg}$$