I wish to determine how the length of which a rubber band is stretched affects the distance which the rubber band will travel after being released.

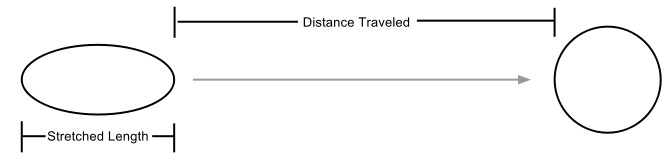
In this experiment I will stretch a rubber band at various lengths and then release the rubber band. After I have released the rubber band, I will measure the total distance that the rubber band has traveled since its initial location. In this experiment, my independent variable is the length of which the rubber band is stretched and my dependent variable is the total distance the rubber band travels.

There are four variables that I see that can affect the results of this experiment. Therefore, I must control these variables to limit their influence on the data I intend to collect. To effectively control these variables, I must do the following:

* Rubber Band Type Used
  + For each trial and iteration, I will use the same brand of rubber band.
* Elasticity of the Rubber Band
  + For each trial and iteration I will use a different rubber band of the brand to keep the elasticity constant throughout the course of the experiment.
* Environment
  + The environmental conditions will be maintained as constant as possible throughout the course of the experiment.
* Surface the Rubber Band Travels Against (Friction)
  + For each trial and iteration, I will use the same surface to keep the amount of friction acting of the rubber band while it is traveling as constant as possible.

The experiment will proceed as followed. I will stretch a rubber band at six different lengths. A three meter long stick will be aligned across a flat, wooden floor and will be stretched to its maximum length to ensure that the measurements are indeed horizontal and as accurate as possible. The rubber band will then be stretched to the desired length. I will than release the rubber band and allow it to move across the flat surface of the ground for the entirety of its movement. After being launched, I will than record the distance between where the beginning of the rubber band was aligned and where the end of the rubber band was after being launched. This recorded measurement is the distance traveled.

I will stretch the rubber band in the following manner. I will flatten the rubber band on a flat surface and will now consider the rubber band as two-dimensional. I will then allow the rubber band to be released and return to its natural, circular shape. Now I will choose two points on the rubber band that are opposite of each other so that it will be a diameter of the circle of the rubber band. With these two points, I will hold the first point of the rubber band at point zero and then pull the other end to the desired stretch length so that length is the distance between the two previously selected points.

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*\*Not drawn to scale\**

I will repeat this experiment for five iterations before beginning the next trial. The first trial’s initial stretch length will be 10 cm. Each successive trial will increase the initial stretch length by 2 cm and each trial will have five iterations. The experiment will be concluded when six trials are completed.

Stretch Length vs. Distance Traveled

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Trial** | **Stretch Length** S / cm ∆S = ± 1.0 cm | **Average Stretch Length** ∆S = ± 1.0 cm | **Distance Traveled** D / cm ∆D = ± 1.0 cm | **Average Distance Traveled** ∆D = ± 21.5 cm |
| 1 | 10.0 | 10.0 | 72.0 | 86.6 |
| 10.0 | 73.0 |
| 10.0 | 95.0 |
| 10.0 | 96.0 |
| 10.0 | 97.0 |
| 2 | 12.0 | 12.0 | 132.0 | 142.6 |
| 12.0 | 136.0 |
| 12.0 | 136.0 |
| 12.0 | 154.0 |
| 12.0 | 155.0 |
| 3 | 14.0 | 14.0 | 292.0 | 297.6 |
| 14.0 | 302.0 |
| 14.0 | 298.0 |
| 14.0 | 296.0 |
| 14.0 | 300.0 |
| 4 | 16.0 | 16.0 | 447.0 | 465.4 |
| 16.0 | 470.0 |
| 16.0 | 450.0 |
| 16.0 | 470.0 |
| 16.0 | 490.0 |
| 5 | 18.0 | 18.0 | 477.0 | 507.0 |
| 18.0 | 511.0 |
| 18.0 | 512.0 |
| 18.0 | 515.0 |
| 18.0 | 520.0 |
| 6 | 20.0 | 20.0 | 564.0 | 581.2 |
| 20.0 | 563.0 |
| 20.0 | 580.0 |
| 20.0 | 598.0 |
| 20.0 | 601.0 |

The best fit line of this graph has a gradient of 53.3435. This suggests that the distance traveled in centimeters increases by this this factor for every centimeter of additional stretch length. Using a linear fit line, I have an R2 value equal to 0.9646, which means that I have a correlation coefficient of 98.21%. This is statistically significant; however, I am troubled by the fact that the y-intercept is 453.41 centimeters below zero. With my data, that would mean that if I were to stretch the rubber band 0 centimeters, the rubber band would travel backwards   
453 centimeters. Either there is a major unanticipated systematic error present of the true relationship is not linear. To further ascertain the relationship, I created a logarithmic graph.

The gradient of this logarithmic graph’s best fine line is equal to the power to which the stretch length is raised to determine the distance traveled. The power is calculated to be 2.9117. This logarithmic graph indicates a R2 value of 0.9523 which means there is a 97.59% correlation between the logarithms. Although this is statically more insignificant, this graph has eliminated my fear that was presented from the last graph; the y-intercept being too high. On this graph, the y-intercept is 0.9523 below zero rather than 453.51.This is a much better y-intercept and is still within the bounds of experimental error. To further ascertain the relationship, I created the following graph with the stretched length value raised to the third power.

This graph shows the stretched length raised to the third power versus the original distance traveled. This power was calculated in the logarithmic graph and shows a linear relationship. Because of these factors, I propose that the distance the rubber band will travel is the length it was pulled back cubed. This graph indicates a R2 value of 0.8927 which means there is a 94.5% correlation between the variables.

Since the correlation coefficient is statically high, I hypothesize that there exist a relation between the length that you stretch a rubber band and the distance it travels when released.

The best fit gradient is calculated to be 0.0973.

Calculating maximum and minimum gradients:

Maximum gradient = (593 – 74.1) / (6170 - 990) = 5180.

Minimum gradient = (568 – 99.1) / (6150 - 1010) = 5140.

The gradient uncertainty would be 1/2(5180 - 5140) = 20:

Therefore the gradient is calculated to be **0.0973 ± 20.**

According to my data, there is a relation of a rubber band between the length at which you stretch it and the distance it will travel when you release it. All of the graphs both support this conclusion. The relationship calculated is that the distance traveled will be the cube of each additional stretch length. The graphs are accurate enough to determine this conclusion because of their R2 value and coefficient correlation. All the trials support this because when I increased the stretch length of the rubber band, the distance traveled by the rubber band also increased. To account for random error, I have taken repeated measurements for each trial performed. To account for systematical errors, I had to do several test runs to get a general idea as to where most of the rubber bands would land and to avoid outliers that would skew my overall data.

Throughout the data recording part of the experiment, I found that when I released the rubber band after being stretched, the rubber band would travel on different paths and would sometimes not travel across the wooden floor. These two uncontrolled variables presented random errors to my experiment and could have messed with my final results thus giving me false information. I tried to account for these variables by doing several test runs to get a general idea as to what should be expected, but still, it is a random error that must be accounted for.

Since random error represents the largest uncontrolled uncertainty, I must modify my procedure to reduce or eliminate its effect. To fix this problem of accurately launching the rubber band, I propose using a system that has a hook and a clamp on a movable track that can be locked into place all on the same board to eliminate the human error involved of releasing the rubber band. The idea here is that you would be able to load the rubber band by first moving the clamp to the appropriate length and that you would be able to lock it into place on the track. You then would be able to put the front of the rubber band through the hook and then stretch the rubber band to the clamp and then clamp the rubber band into the device. This would eliminate some uncertainty of the stretch length and you would be able to release the rubber band with more accuracy. As well, the surface traveled on created inconsistencies with the amount of friction acting on the rubber band. To fix this problem I propose using a surface with a very low friction and have a constant friction across the surface of the plane of which the rubber band would travel on. Combining these two fixes, you would be able to minimize the amount of random errors that would be able to affect the results of the experiment.