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Bungee Cord Static Data Collection

Abstract:

The purpose of this experiment was to determine if the un-stretched length of an elastic cord, L correlated to the elasticity constant of that particular length of cord, k. This correlation would allow us to accurately predict k based upon a given L. This lab was conducted by dangling a mass from a loop in the elastic cord. A tape measure was used to find the length of un-stretched cord and the distance of stretching under stress, Δx. This apparatus resembles that used to test simple harmonic motion, due to this resemblance, we are assuming that some elasticity constant, k describes the elastic tension acting upon the cord as it is stretched by some mass, m. Upon data collection and subsequent analysis in excel, Δx was plotted against force of weight, F. A linear regression yielded plots of F vs Δx for each L. The slope of these regressions were k values for each L. In an effort to attain a linear regression equation, 1/L was then plotted against each L's respective k. The trend line of this plot yielded the linear equation k=1.24(1/L)-0.68. Thereby demonstrating a correlation between L and k, thereby permitting us to predict k based upon the length of un-stretched cord, L.

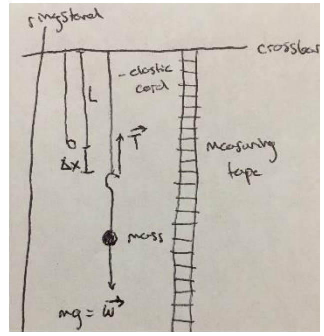
Introduction:

The motion of a mass bobbing up and down on an elastic cord appears to resemble that of a spring in harmonic motion. As the mass travels up and down, some force opposes the downward motion of the mass applying tension to the cord. While we are not entirely certain as to the nature of this force, this lab was performed under the impression that the elastic cord behaves like a spring. Thus, it was assumed that there was some constant k that describes the forces acting upon an elastic cord of a given length. The goal of this experiment was to determine the relationship between the constant of the elastic cord, k, and the un-stretched length of the cord, L. This correlation would theoretically allow us to determine k given some length of elastic cord. This relationship was found by graphing the difference between the length of the unburdened cord, and its length when mass was applied, versus the force of weight exerted on the cord. Force of weight was found by multiplying mass applied by gravity, $9.81 m/s^2$. A linear regression was performed on these scatterplots of every distinct L tested, the slopes of these resulting linear regressions being k. Finally, k found for each value of L, was graphed against one over its respective unburdened length, 1/L. 1/L was used to linearize the data and thereby get a linear regression equation. The resulting regression of this scatterplot was found to be the relationship between length of unstressed cord and k.

Methods:

In order to obtain the relationship between length of unburdened cord and the constant for that particular length, an elastic cord of variable length was hung from a horizontal metal crossbar (Diagram 1). A knot was tied into the cord such that a loop large enough to put a hook through was created. This hook had a plate attached denoting a total mass of 50 g for the hook alone. The knot was tied at variable locations along the cord allowing for variable lengths of cord to be tested. For each length of cord, mass was hung from the loop in the cord in increments of 25g, starting with the 50g hook up to 200g total. Each time the mass was gently lowered to its equilibrium point such that oscillation did not occur. Length of the cord was measured using a measuring tape hung from same crossbar as the cord, measurements being taken from the crossbar to the loop in the elastic cord. This process of adding mass and measuring the distance the cord stretched was repeated for 6 different lengths of cord. Data was then recorded in excel, mass was recorded in kg, while length of the unstressed cord was subtracted from the length of the stretched cord at each mass. This difference denoted the length of the stretch or Δx which was recorded in meters (Diagram 1). In order to generate a plot of force of weight versus the distance of stretch, mass was multiplied by acceleration due to gravity, $9.81 m/s^2$ in order to calculate the force exerted on the cord. A scatterplot of F versus Δx was generated for each L and a linear regression returned various linear trend line equations. The y intercept was not of particular significance for this lab so it was not used. However, the slope of each plot, k, was taken and placed into another data table against its L. 1 was then divided by L in order to achieve a linear plot so that we would get a linear regression equation. This plot of K vs 1/L produced a linear regression equation which was then taken to be the relationship between L and K. Finally, data analysis was performed in excel to check for error within this experiment.

Diagram 1: Experiment apparatus



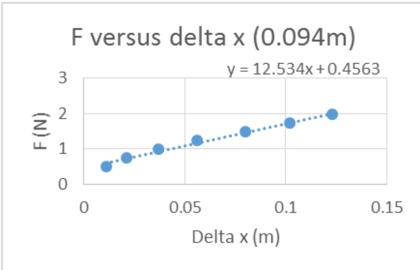
Results:

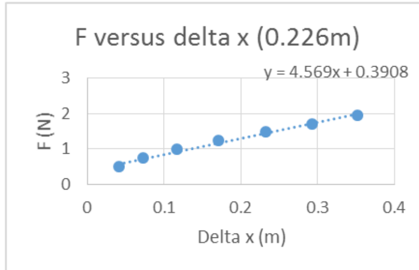
This experiment was conducted in order to find a relationship between length of un-stretched cord, L and the constant of elasticity, k. Once the apparatus was set up, measurements of the length of the cord were taken at 6 different lengths with measurements being taken at 7 different masses per length (table 1). This data was then used to create scatterplots with linear regressions for each length of unstressed cord (figure 1).

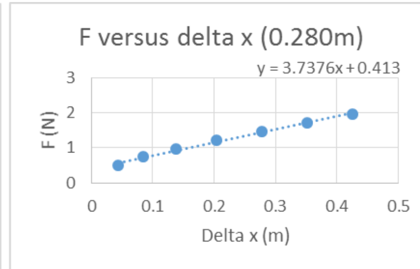
Table 1: Raw data and measurements, each box denoting a different L, L ranging from 0.09 on far left to 0.42 on far right

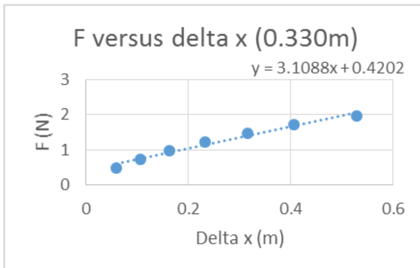
mass (kg)	F	L (m)	x(m)	delta x (m)	mass (kg)	F	L (m)	x(m)	delta x (m)	mass (kg)	F	L (m)	x(m)	delta x (m)	mass (kg)	F	L (m)	x(m)	delta x (m)	mass (kg)	F	L (m)	x(m)	delta x (m)
0.05	0.49	0.09	0.11	0.01	0.05	0.49	0.23	0.27	0.04	0.05	0.49	0.28	0.32	0.04	0.05	0.49	0.33	0.39	0.06	0.05	0.49	0.42	0.50	0.08
0.08	0.74	0.09	0.12	0.02	0.08	0.74	0.23	0.30	0.07	0.08	0.74	0.28	0.36	0.08	0.08	0.74	0.33	0.44	0.11	0.08	0.74	0.42	0.57	0.14
0.10	0.98	0.09	0.13	0.04	0.10	0.98	0.23	0.34	0.12	0.10	0.98	0.28	0.42	0.14	0.10	0.98	0.33	0.49	0.16	0.10	0.98	0.42	0.66	0.23
0.13	1.23	0.09	0.15	0.06	0.13	1.23	0.23	0.40	0.17	0.13	1.23	0.28	0.48	0.20	0.13	1.23	0.33	0.56	0.23	0.13	1.23	0.42	0.76	0.34
0.15	1.47	0.09	0.17	0.08	0.15	1.47	0.23	0.46	0.23	0.15	1.47	0.28	0.56	0.28	0.15	1.47	0.33	0.65	0.32	0.15	1.47	0.42	0.88	0.45
0.18	1.72	0.09	0.20	0.10	0.18	1.72	0.23	0.52	0.29	0.18	1.72	0.28	0.63	0.35	0.18	1.72	0.33	0.74	0.41	0.18	1.72	0.42	0.99	0.57
0.20	1.96	0.09	0.22	0.12	0.20	1.96	0.23	0.58	0.35	0.20	1.96	0.28	0.71	0.43	0.20	1.96	0.33	0.86	0.53	0.20	1.96	0.42	1.10	0.68

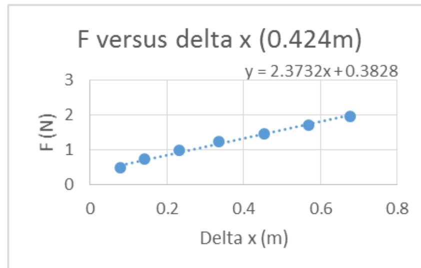
Figure 1: Graphs of F vs. Δx for each length of un-stretched cord, the number in parentheses denoting the L for that graph









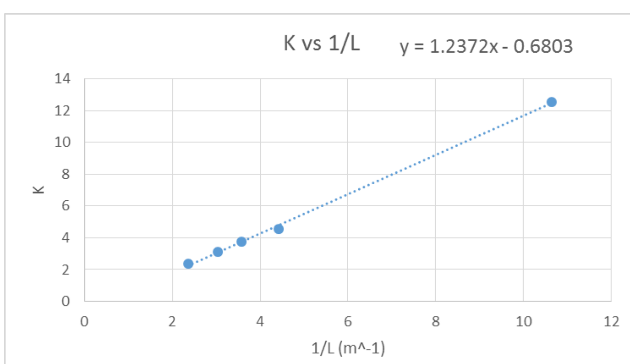


Each graph had a linear regression performed which resulted in a linear equation, the slope of which was the constant of elasticity in each length of cord, k (figure 1). All of the k values with standard error for each k are in table 2. This k was then plotted against 1/the length of unstressed cord, 1/L. 1/L was used in order to linearize the data so as to obtain a linear regression equation (table 2, figure 2). This plot of k vs 1/L also had a linear regression performed resulting in a linear regression equation of k=1.24(1/L)-0.68. Standard error was 0.023, or a percent error of 1.85% for the slope and a standard error of 0.038 and a percent error of 5.59% for the y intercept (figure 2).

Table 2: Data of length unstressed cord, L, and elastic constant, K, along with standard and percent errors

L	1/L	K	Std. Error K	% Error K
0.09	10.64	12.53	0.63	5.04
0.23	4.42	4.57	0.20	4.33
0.28	3.57	3.74	0.16	4.35
0.33	3.03	3.11	0.22	6.94
0.42	2.36	2.37	0.09	3.88

Figure 2: Graph of k vs 1/L and linear regression



Discussion:

This experiment was conducted in an attempt to relate the constant of elasticity for a given length of cord to the length of the unstressed cord. This was done so that one could accurately predict how far the elastic cord will stretch when a force of weight for a given mass acts upon the cord. The linear regression of Δx versus F of weight resulted in k values for each given length of cordage and data analysis related the standard and percent error for each k value found (Table 2). The standard and percent errors varied amongst k values, but the greatest percent error was 5.04%, indicating a relatively low level of error present in this experiment as it pertains to measurements. Furthermore, the standard error of the slope of the relationship between k and L was 0.023, or a percent error of 1.85% and a standard error of 0.038 and a percent error of 5.59% for the y intercept. Thus, the error present within the resulting relationships found from the data were all fairly low, suggesting that these results are in fact valid. However, there was error present within these results. One possible source of error might be the loop that was tied into the elastic cord. Each time a new length was used, the loop had to be raised or lowered on the elastic cord and the knot creating the loop had to be retied each time. Regardless of efforts to remain consistent in size of loop or technique used to tie the knot, there was inevitably some variation in the loop's size and tautness. Since this loop was constructed of the same elastic cord as aforementioned, it is likely that the loop would account for some variation in the stretch of the elastic cord, potentially skewing the data, and likely accounting for some of the error present in these results. Also, since this experiment involved measurement of a cord using a tape measure, it is likely that the measurements for length of cord and stretched cord were not entirely accurate. Once measurements of length of cord were taken, no further measurements or calculations were performed other than analysis in excel. Thus, this error likely originated from inconsistent loops in the elastic cord, and inaccurate measurements. Therefore, while error present does indicate that the relationship found between L and k is not entirely accurate, the small percentages of error on the slope and y intercept suggest that the relationship k=1.24(1/L)-0.68 is capable of accurately predicting the constant of elasticity, k for a given length of cord.

Conclusion:

This experiment was conducted in an effort to find the relationship between the length of an elastic cord, L and its constant of elasticity, k. This lab was performed under the assumption that an elastic chord with a dangling mass attached behaved similarly to a spring in harmonic motion. Thus, it was assumed that some constant k, describes the elasticity of the cord as it stretches, theoretically enabling us to relate k and L. For this experiment measurements were taken at various dangling masses and at various L. This data obtained allowed us to determine a linear relationship between L and k with relatively little error. This suggests that the relationship between k and L, k=1.24(1/L)-0.68 will accurately predict the k for a given length of cord, indicating that this lab was successful in finding an accurate relationship between k and L.