

Simple Harmonic Oscillator – MCA Physical Science

Introduction

The simplest realization of a simple harmonic oscillator is a mass on a spring. The purpose of this lab is to measure the spring constant, k , and test the theoretical prediction that the period, T , of a simple harmonic oscillator is

$$T = 2\pi\sqrt{m/k} ,$$

where m is the mass, and k is the experimentally determined spring constant from static measurements.

Hypothesis: The period of oscillation of a mass on a spring is $T = 2\pi\sqrt{m/k}$.

Method

First, the spring constant, k , needs to be determined in order to predict the period for specific masses. This is done by measuring the stretch of the spring when given forces are applied. Carefully measure the stretch of the spring when hanging masses of 500g, 600g, 700g, and 1000g. Record the results in Table 1 in the Results section. Perform a least squares fit to a line for F (the force on the spring is the weight of the mass, mg) vs. x (stretch of spring). The spring constant, k , is the slope of this line. There may not be time to do the analysis during the lab. Be sure to collect all the data needed for later analysis by completing the stretch (x) column.

Second, measure the period of motion for masses of 250g, 500g, 600g, 700g, and 1000g by recording the time for 10 oscillations and dividing by 10. Make sure you complete the $10T$ (10 times the period) column of the table during the lab period. There may not be time to complete all the calculations for the table during the lab period. When time permits, complete the other columns in the table: measured T (period in seconds), predicted T (in seconds, given by formula in hypothesis), error (predicted T – measured T), and relative error (predicted T – measured T)/(measured T).

Results

| Mass (kg) | X (mm) | X (m) | F (N) |
|-----------|--------|-------|-------|
| 0.500 | 71 | 0.071 | 4.905 |
| 0.600 | 97 | 0.097 | 5.886 |
| 0.700 | 121 | 0.121 | 6.867 |
| 1.000 | 194 | 0.194 | 9.81 |

*Table 1: Hint – Divide x in mm by 1000 to get x in m. Multiply mass in kg by the acceleration of gravity to get the force in N. $f(x)=40.0349*x+2.0328$; $R^2=0.9999$*

Spring Constant k : 40.035 N/m (be sure to include units).

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| Mass (kg) | Measured 10T (s) | Measured T (s) | Predicted T (s) | Error (s) | Relative Error |
|-----------|------------------|----------------|-----------------|-----------|----------------|
| 0.250 | 4.897 | 0.4897 | 0.4965 | -0.0068 | -0.0138 |
| 0.500 | 6.903 | 0.6903 | 0.7022 | -0.0119 | -0.0172 |
| 0.600 | 7.567 | 0.7567 | 0.7692 | -0.0125 | -0.0165 |
| 0.700 | 8.150 | 0.8150 | 0.8308 | -0.0158 | -0.1938 |
| 1.000 | 9.73 | 0.973 | 0.993 | -0.020 | -0.0205 |

Table 2: Be sure to complete first two columns in lab period.

Your results section should also contain two graphs: 1) The graph of F vs. X from the data in Table 1 complete with the best fit line showing the slope and R squared. Make sure the axes are labeled properly (with units) and numbered. 2) The graph of Measured T vs. Mass from the data in Table 2. This graph should also include the theoretical prediction as a solid line. Again, make sure the axes are labeled properly (with units) and numbered. Graphs should also have descriptive captions.

These sheets can form the first two pages of your lab report with the figures described above, together with descriptive captions forming the rest of the results section. Your discussion section should contain answers to all the questions below. Your discussion should also state clearly whether the hypothesis was supported, as well as why you think it may or may not have been supported. If you were to perform this experiment again, how would you reduce the uncertainties and errors? How much larger is the period with the 1000 g mass than with the 250 g mass? Does this make sense? Why?

Your lab report will be graded as follows:

Results section: 80% broken down as 20% Table 1, 20% Table 2, 20% Figure 1, 20% Figure 2.

Discussion section: 20%

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The force vs. spring stretch for the spring used in this experiment is shown in Table 1 and graphed in Figure 1, along with the best fit line. The non-zero vertical intercept is attributable to a tightly wound coil spring that does not overcome its internal tension and begin to stretch at all until around 2N. The resulting spring constant is 40.035 N/m. The R squared value very close to 1 indicates an excellent fit to a line suggesting both highly linear behavior as well as reasonably careful measurements.

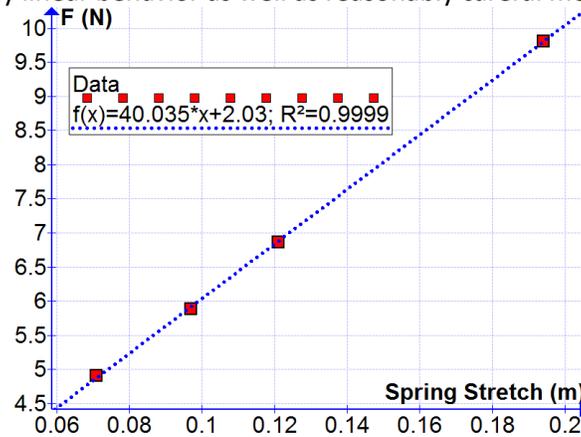


Figure 1: Force vs. spring stretch for simple harmonic oscillator, together with best fit line. The slope of the best fit line is $k = 40.035 \text{ N/m}$.

The period vs. mass data and predictions are shown in Table 2 and Figure 2. The predictions based on the measured spring constant are all within 2% or so, suggesting both reasonable support for the hypothesis as well as careful measurements.

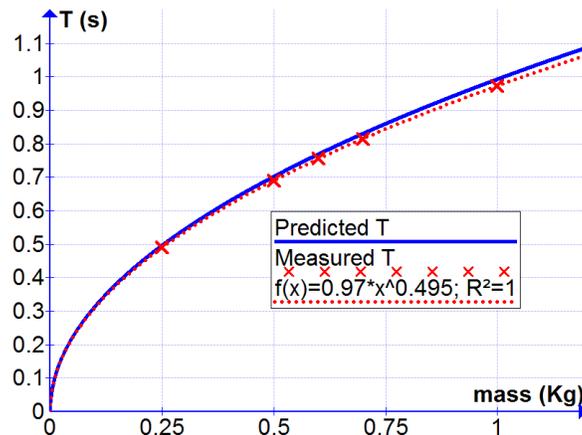


Figure 2: Period vs. mass for simple harmonic oscillator, together with prediction and best fit power law.

Discussion

The predicted periods were all within 2% or so, which supports the hypothesis to some degree. However, the errors seem to be growing in a systematic manner rather than being random or constant. Is this a systematic error in the experiment or a small error in the formula in the hypothesis? Some possibilities are: 1. The mass of the spring is not negligible 2. The masses used in the experiment are not exactly what is written on them 3. Friction and drag effects are lowering the periods 4. The spring does

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not have a perfectly linear response 5. The time base in the sampling digitizer is off.

If I were to perform this experiment again, greater attention might be given to the five potential sources of error listed above. Checking the masses with a laboratory balance is easy, as is checking the time base of the digitizer against an independent clock. The linear response of the spring could be checked by carefully measuring its stretch with smaller increments (say 50 g) over a larger range (say up to 1500 g). This would provide enough data points to try fitting to a quadratic (rather than a line) to see if there were a significant deviation from linearity for larger stretches.

The period of the 1000 g mass is close to twice the period of the 250 g mass, which makes perfect sense given the prediction that period scales as the square root of the mass. Increasing the mass by a factor of 4 should increase the period by a factor of 2.