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Simple Harmonic Motion Lab

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Objectives
- To measure the position and velocity as a function of time for an oscillating mass and spring
- To compare the observed motion to the mathematical model of simple harmonic motion
- To determine the effects of changing mass and amplitude on period and maximum velocity

Procedure
The experimental setup consists of a rod clamped perpendicular to the top of a ring stand and clamped to a spring, which hangs down from the rod. A mass hanger is attached (and taped) to the rod, and a paper plate is taped to the bottom of the mass hanger for better visibility for the LabQuest distance sensor. The LabQuest distance sensor is pointer straight up at the paper plate from the tabletop.

In part one, we determined the spring constant by measuring the mass of the mass hanger, finding the change in length of the spring with and without the mass hanger on it, and then using Hooke's Law.

In parts two through four, we used the known mass, amplitude, and spring constant to calculate the expected parameters for the sinusoidal equation that would model the SHM. Then, using a LabQuest distance sensor, we measured the vertical position of the graph as a function of time for ten seconds, used a sinusoidal curve fit, and compared the observed values to the expected (calculated) values. Between the different trials, we tested two different amplitudes (0.050m and 0.100m) and two different masses (0.1539kg and 0.2539kg) to test the effect of changing the mass and amplitude on the period and velocity of the SHM.

Data and Reflections

Part 1: *Determining the Spring Constant*

Distance the spring stretched:	$0.0640\,m$
Mass of mass hanger:	$0.050\,kg$
Spring constant (k):	$7.66\,\frac{N}{m}$

Part 2: *Control Trial*

Predictions

Total mass:	$0.1539\,kg$
Amplitude:	$0.050\,m$
Calculated maximum velocity:	$0.3526\,\frac{m}{s}$
Expected value for B:	7.053
Calculated expected period:	$0.8908\,s$
Calculated expected frequency:	$1.123\,Hz$

LoggerPro Data

Period (indicated by graph): $1.00\,s$
Sinusoidal wave parameters (from graph):
- A (amplitude): 0.0455
- B: 6.28
- D: 0.432

LoggerPro x-t curve fit equation: $x=0.0378\sin(6.372t+3.7226)+0.43191$
LoggerPro v-t curve fit equation: $v=0.2253\sin(6.349t+5.334)+0.001703$

Reflections

The predictions for A, B, period, and D were very close to the values given by the LoggerPro graph and equation. We observed that the velocity was zero when the displacement was at an extreme (maximum or minimum value), and that the velocity was at an extreme when the displacement was zero. The velocity vs. time also fits a sine curve (the equation is shown above). The B-value of the velocity-time curve is very similar to the B-value of the position-time curve, indicating that the periods of both functions are equal. However, our predicted maximum velocity of 0.3526m/s was much higher than the observed 0.2260m/s from the v-t curve fit equation, and this is probably due to a high air resistance (see Error Analysis section).

Part 3: *Trial with Increased Amplitude*

Predictions

Total mass: $0.1539\,kg$
Amplitude: $0.100\,m$
Calculated maximum velocity: $0.7053\,\frac{m}{s}$
Expected value for B: 7.053
Calculated expected period: $0.8908\,s$
Calculated expected frequency: $1.123\,Hz$

LoggerPro Data

Period (indicated by graph): $0.95\,s$
Sinusoidal wave parameters (from graph):
- A (amplitude): 0.0895
- B: 6.61
- D: 0.432

LoggerPro x-t curve fit equation: $x=0.07696(6.3185t+3.702)+0.4314$
LoggerPro v-t curve fit equation: $v=0.4539\sin(6.2861t+5.3741)+0.00632$

Reflections

Again, our predictions for the A, B, D, and period were very close to the observed values. The velocity-time graph again fit a sine-curve (the equation is shown above). Changing the amplitude did not affect the period (a change of 0.05s after the change in amplitude, likely due to human error), but it did affect the maximum velocity. The maximum velocity of the doubled amplitude was roughly double that of the first trial (0.4539m/s as opposed to 0.2253m/s for the first trial).

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Part 4: *Trial with Increased Mass*

Predictions

Total mass:	$0.2539\,kg$
Amplitude:	$0.050\,m$
Calculated maximum velocity:	$0.2746\,\frac{m}{s}$
Expected value for B:	5.49
Calculated expected period:	$1.144\,s$
Calculated expected frequency:	$0.8739\,Hz$

LoggerPro Data

Period (indicated by graph): $1.25\,s$

Sinusoidal wave parameters (from graph):

A (amplitude):	0.0445
B:	5.027
D:	0.285

LoggerPro x-t curve fit equation: $x=0.0427(5.0305\,t+3.888)+0.2791$

LoggerPro v-t curve fit equation: $v=0.2029\sin(5.006\,t+5.543)+0.003299$

Reflections

Again, our predictions for the A, B, D, and period were very close to the observed values. The velocity-time graph again fit a sine-curve (the equation is shown above). Changing the mass affected the period and the maximum velocity. The observed period for the 0.2539g mass was 1.25s and the observed maximum velocity was 0.2031m/s, compared to the 1.00s period and 0.2270m/s observed maximum velocity for the 0.1539g mass.

<u>Calculations</u>

Variables

A = amplitude, k = spring constant, m = mass of mass hanger and added masses

Hooke's Law

Spring constant: $k=\frac{F}{x}$

SHM Equations

Value for B: $B=\omega=\sqrt{\frac{k}{m}}=\frac{2\pi}{T}$

Maximum velocity: $v_{max}=AB$

Period: $T=\frac{2\pi}{B}$

Frequency: $f=\frac{1}{T}$

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Example Calculations from Parts 1 and 2

$$k=\frac{0.050\,kg\times 9.8\,ms^{-2}}{0.0640\,m}=7.66\,\frac{N}{m}$$

$$B=\sqrt{\frac{7.66\,Nm^{-1}}{0.1539\,kg}}=7.053\,s^{-1}$$

$$v_{max}=0.050\,m\times 7.053\,s^{-1}=0.3526\,\frac{m}{s}$$

$$T=\frac{2\pi}{7.053\,s^{-1}}=0.8908\,s$$

$$f=\frac{1}{0.8908\,s}=1.123\,Hz$$

Error Analysis

While most of our expected (calculated) values for A, B, and period were very close to the observed values from the LoggerPro curve fit, our expected values for the maximum velocity were all much higher than the observed values. This is probably due to a high air resistance from the paper plate that caused the motion to significantly slow down, when ideally there would be no friction and no slowing down. This corresponded with a graph whose amplitude visually quickly decreased. If we were to repeat this lab without the paper plate, but still managed to get an accurate distance reading from the LabQuest distance sensor, then we would probably get a maximum velocity that is much closer to the expected value.

Summary

We learned how to measure the position and velocity of an object in SHM using the LabQuest, and how to use the SHM equations to calculate expected values for the period, B, and maximum velocity with a known amplitude and mass. We learned how changing the amplitude and mass of the object in SHM affects its period and maximum velocity. The amplitude has no effect on period, but has a proportional relationship with maximum velocity. The mass has an direct correlation with the period (larger mass means a longer period), and an inverse relationship with maximum velocity (larger mass means a lower maximum velocity).

Conclusion

The amplitude of an object oscillating in SHM is proportional to its maximum velocity and has no effect on its period, while the mass affects both the period (directly correlating) and the maximum velocity (inversely correlating).