

Simple Harmonic Motion

Goals: To construct understanding of simple harmonic motion using a spring-mass system.

Equipment: Springs, ULI/computer, force and motion sensors, mass set with holder, stopwatch, and rulers.

Tasks:

1. Observations:

- (1) Hang a mass = 50 gram on a very light spring. Wait until the spring-mass system is at rest (the position of the mass at this initial state is called the equilibrium position), gently pull down the mass off the equilibrium position and let it go. (Please don't pull the mass off too much; it would destroy the spring.) Observe the motion of the mass and devise a way to measure the time that it takes the mass to oscillate through one full cycle. (Hint: avoid measuring the time for one cycle directly, use more than one cycle to minimize errors.)
- (2) Based on the observation above, try to sketch how the displacement of the mass changes as a function of time. On your sketch, please clearly indicate the equilibrium position of the system, the maximum position that the mass reached, and the time for the mass to vibrate through one full cycle.
- (3) Now click on **Logger Pro (2.1)** on the computer screen. Select **File -> Open** to open **Simple Harmonic Motion**. Then open the file **Anatomy of SHM**. Use the same setup, now again set the spring-mass system into a vertical oscillation (avoid side-to-side motion). After a few cycles, hit **Collect**. Use (**View->Autoscale Once**) to optimize your view of the distance vs. time graph. Copy down the position vs. time graph to your paper. On the graph, please indicate the maximum position that the mass reached, the equilibrium position, and the time for the mass to vibrate through one full cycle.
- (4) Now set the spring-mass system into a vertical oscillation again, but this time let the maximum distance for the mass to go be greater than that in (3). [You can use **Data ->Store Latest Run** to keep the data from (3).] After a few cycles, hit **Collect**. Use **View->Autoscale Once** to optimize your view of the distance vs. time graph. What is the time for the mass to vibrate through one full cycle in (4)? What did you observe about the times for the mass to go through one full cycle in (3) and (4)? Did it take the mass a longer time to go through one full cycle in which it went a greater maximum distance?
- (5) List all variables or factors that you think could be possibly change the time for the mass to vibrate through one full cycle.
- (6) Change one variable each time, use the computer program to observe and measure *how* the time changes for the mass to vibrate through one full cycle. Clearly write down your observations. You may use a table to represent your data.

2. Qualitative explanations and testing

- (7) On the basis of your observations above, develop your explanations of observed phenomena in part 1 (6).
- (8) Design some experiment(s) to test your qualitative explanations. Before you conduct the experiment, predict experiment results using your explanations in (7).
- (9) Conduct the experiment and record actual data. Describe whether or not your predictions are consistent with the actual experimental results and discuss any discrepancies.

3. Quantitative relationships

- (10) Based on the observations and the conceptual explanations, decide what are physical quantities that the time for the mass to vibrate through one full cycle depends on.
- (11) Use your knowledge of mechanics and kinematics to derive a relationship that will show how the time for the mass to vibrate through one full cycle depends on these physical quantities. (Hint: Analyze the forces acting on the mass and then apply Newton's 2nd law to the mass. You should get a second-order differential equation.)
- (12) Based on your observations about the displacement as a function of time, write down a solution $y(t)$ that satisfies the second-order differential equation in (11).
- (13) The time it takes for the mass to go through one full cycle is defined as period T . Use this definition and the solution derived in (12) to derive a quantitative expression of period T .
- (14) Design experiments to test this relationship that you just derived for the period T by making predictions on them. State your predictions and any assumptions or simplifications that you made.
- (15) Analyze your data, discuss whether or not your actual results support your predictions, and finally make your conclusion.

4. Overview Questions:

1. What did you observe in this lab?
2. What assumptions or **simplifications** did you make in this lab? How did they make sense to you?
3. What **physical quantities** did you explore in this lab? What **instruments** did you use to measure them?
4. What are the **relationships** among these physical quantities? How did you come up to know these relationships?
5. Give an example to show how you reconciled any differences between your **predictions** and results of the **experiments**?
6. Illustrate at least two **applications** from real life about the phenomena you studied in this lab.