Experiment 11
Simple Harmonic Motion

Advanced Reading

Halliday, Resnick and Walker
Chapter 15, Sections 15-1 through 15-6.

Equipment

- spring
- metal ball
- wooden ball
- pendulum clamp and rod
- string
- meter stick
- weight hanger
- masses (slotted)
- stopwatch
- Dial-o-gram balance

Objective

The objective of this experiment is to observe how the periods of two types of oscillators (a pendulum and a spring-mass system) vary with certain parameters.

Theory

The period of an oscillator is defined as the time needed for the oscillator to one complete cycle of motion. The period of a simple pendulum is

$$T = 2\pi\sqrt{L/g}\ , \qquad (1)$$

where T is the period, L is the length of the pendulum, and g is the acceleration due to gravity. For a spring that obeys Hooke's law (F=-kx) the period is

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

where m is the mass suspended from the spring and k is the spring constant of the spring.

Procedure

Part 1: Simple pendulum

The first part of this experiment is to test the *length* and *mass* dependence of the period of a simple pendulum.

1. Measure the mass the metal and the wooden balls with the Dial-o-gram balance. Construct a pendulum approximately 100 cm long using the metal ball. (Use the string clamp as pictured in Fig. 11-1). It is important that the pendulum pivot from only one point. Accurately measure the length L of the pendulum from *bottom* of the support (pivot point) to the *center* of the ball.

2. Measure the period T of the pendulum by timing the pendulum through thirty swings and dividing by the number of oscillations. This should be done for small amplitudes (approximately 5 degrees or less). Do three trials and calculate the average period.

3. Repeat step 2 for pendulums of approximate lengths of 80, 60, 40, and 20 cm. Plot T^2 vs. L, and measure the slope.

4. Make a 100 cm pendulum using the wooden ball instead of the metal ball. Measure the period as before, taking the average of three trials.

Part 2: Spring-mass oscillator

5. Hang the spring from the support rod. The wider end of the spring should point down. (See Fig. 11-2). Place a weight hanger on the spring and measure the height from the bottom of the weight hanger to the top of the table. Place 50 grams on the weight hanger and measure the height again. Continue this process in 50 gram increments until a total of 300g (i.e., 50g hanger + 250 of masses).

6. Graph F vs Δx, where F is the weight hanging from the spring and Δx is the displacement caused by the weight. Determine the spring constant k, which is the slope of the best-fit line of this graph.

7. Determine the mass of the spring. (You will use this mass in step 9.) Place 50 grams on the weight hanger (for a total of 100 grams) and start the spring oscillating by pulling the weight hanger down and releasing it. Measure the time for the apparatus to complete twenty oscillations and calculate the period. Calculate the average value for three trials.

8. Repeat step 7 with 150, 200, and 250 grams on the spring.

9. Plot T^2 vs. m (*this mass should consist of the hanging mass plus 1/3 of the mass of the*

spring) and determine the slope of the best-fit line through the data.

Questions/Conclusions

1. Does the period of a pendulum depend upon the mass? Explain.

2. How long would a simple pendulum need to be to have a period of 2.0 seconds? Show your work.

3. Do the graphs of T^2 vs. L and T^2 vs. m appear to pass through the origin? Should they pass through the origin? Explain.

4. According to Eq. (1), the slope of T^2 vs. L for a simple pendulum is $4\pi^2/g$. From the measured value of the slope, determine g and compare it to the accepted value of 9.80 m/s^2.

5. According to Eq. (2), the slope of T^2 vs. m for a spring-mass oscillator is $4\pi^2/k$. From the measured value of the slope, determine k and compare this value to the value determined statically (from Hooke's Law).