

# Experiment 11

## Simple Harmonic Motion

### Advanced Reading

Matter & Interactions 4<sup>th</sup> Ed by Chabay  
Chapter 4, Section 4.11

### Equipment

Triple Beam Balance	Meter stick
Spring	Masses
Metal Ball	String
Wood Ball	Stop watch
Pendulum Clamp & Rod	Table clamp

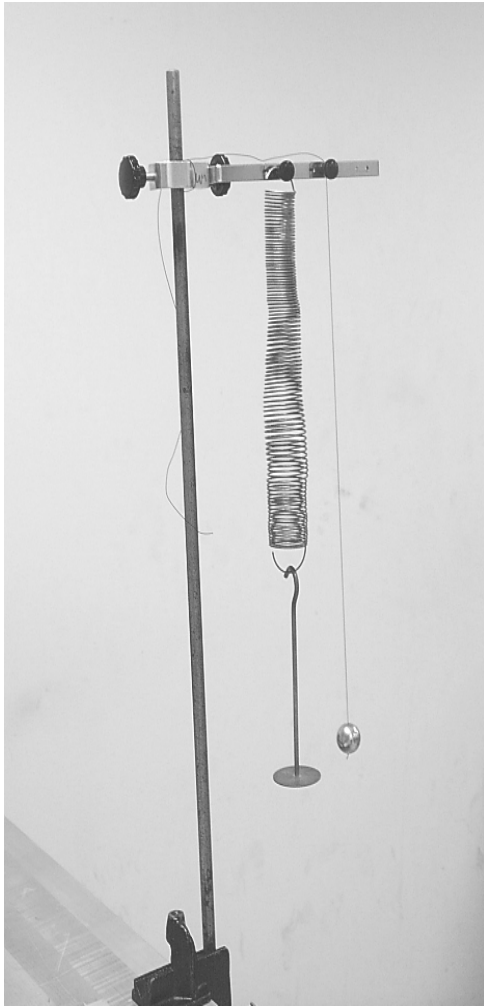


Figure 11-1

### Objective

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

### Theory

Periodic motion is defined as “motion of an object that regularly returns to a given position after a fixed time interval.”

A special kind of motion occurs in mechanical systems when the force acting on an object is proportional to the position of an object relative to some equilibrium position. If this force is always directed towards the equilibrium position, the motion is called simple harmonic motion. *An object moves with simple harmonic motion whenever its acceleration is proportional to its position and is oppositely directed to the displacement from equilibrium.*

The period of an oscillator is defined as the time needed for the oscillator to complete one cycle of motion. The period of a simple pendulum (using small angle approximation) is

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

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** ( $F = -k\Delta x$ ) its period is

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

where  $m$  is the mass acted on by the spring and  $k$  is the spring constant of the spring. It should be noted the relationship above assumes a “massless” 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 of the metal and the wooden balls with the triple beam 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. **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 twenty swings and dividing by the number of oscillations. This should be done for small amplitudes (approximately 10 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 determine 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. 11-1). Place a weight hanger on the spring and measure the height from the bottom of the weight hanger to the top of the table or some other reference (e.g., top of a stool). 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  $\Delta x$ , where  $F$  is the weight hanging from the spring and  $\Delta x$  is the displacement caused by the added masses. 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.

### Post Lab Questions/Conclusions

1. A stopwatch was used to time the period of the pendulum. Using the uncertainty of a stopwatch (either 0.1s or 0.01s depending on what stopwatch was used) ) **were your periods the same for the 100 cm wooden ball and the 100 cm metal ball.** Normally they are not in this experiment.

If your periods were not the same, what do you think might be the problem? Think about how these were timed and whether your timing error was large enough and a second thing to consider is what forces or factors were ignored.

2. Draw a free body diagram for the oscillating mass (on a spring) at the following locations:

- Mass at the equilibrium position.
- Mass at the top of an oscillation.
- Mass at the bottom of an oscillation.

3. Given a mass on a string with a length of two meters and starting angle of 20 degrees, what was the speed of the ball as it passes through the lowest point of its oscillation?

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  $9.80 \text{ m/s}^2$ .

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).