# The Concept of Oscillation

## Background

Any motion that repeats itself in equal intervals of time is called *periodic motion*. As we shall see, the displacement of a particle in periodic motion can always be expressed in terms of sines and cosines. Because the term harmonic is applied to expressions containing these functions, periodic motion is often called *harmonic motion*.

If a particle in periodic motion moves back and forth over the same path, we call the motion oscillatory or vibratory. The world is full of oscillatory motions. Some examples are the oscillations of the balance wheel of a watch, a violin string, a mass attached to a spring, atoms in molecules or in a solid lattice, and air molecules as a sound wave passes by.

Many oscillating bodies do not move back and forth between precisely fixed limits because frictional forces dissipate the energy of motion. Thus a violin string eventually stops vibrating and a pendulum stops swinging. We call such motions damped harmonic motions. Although we cannot eliminate friction from the periodic motions of gross objects, we can often cancel out its damping effect by feeding energy into the oscillating system so as to compensate for the energy dissipated by friction. The main spring of a watch and the falling weight in a pendulum clock supply external energy in this way, so that the oscillating system, that is, the balance wheel or the pendulum, moves as if it were undamped.

## Spring-Mass System

A body of mass $m$ attached to an ideal spring of force constant $k$ and free to move over a frictionless horizontal surface is an example of a simple harmonic oscillator (see Fig.1(a) below). Note that there is a position (the equilibrium position: see Fig.1(b) below) in which the spring exerts no force on the body. If the body is displaced to the right (as in Fig.1(a)), the force exerted by the spring on the body points to the left and is given by

$$F = -kx.$$

If the body is displaced to the left (as in Fig.1(c)), the force points to the right and is also given by

$$F= -kx.$$

In each case the force is a *restoring* force. The motion of the oscillating mass is *simple harmonic motion.*

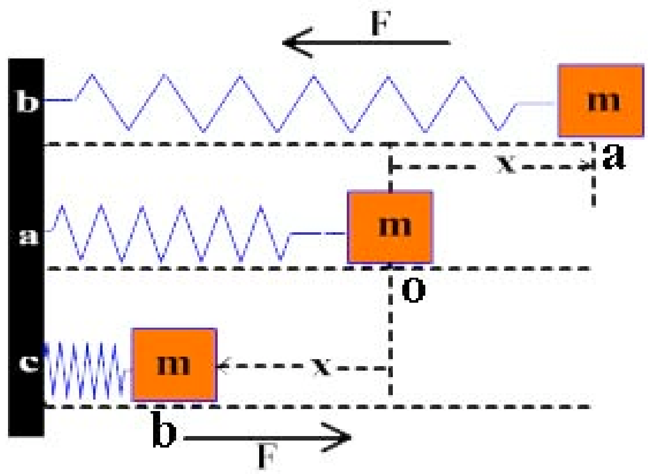

**Figure 1**

**Experiment 1: Spring-Mass System**

**Supplies**

1. Several soft springs having different stiffness.
2. Objects of mass (for example, wood, blocks or any object weighing more than the spring).
3. Something to which the spring can be attached securely. (Examples: a piece of plywood, ceiling, or metal frame, etc).

NOTE: This experiment can be performed either vertically or horizontally, but as shown in Figure 2 a vertical arrangement is easier to construct.


**Figure 2**

**Procedure (for vertical arrangements)**

1. Attach spring to the wood or metal frame and measure the total length of the spring.
2. Hang a weight on the end of the spring.
3. Measure the distance that the end of the spring moves (x) due to the weight (F).
4. Repeat step 3 for each weight (F).

5. Plot Force vs. x (displacement) on graph paper or Excel worksheet (more advanced student). The slope of the line (units lb/in) gives the spring stiffness k.
6. Pull the weight downward and release. Count the number of oscillations occurring over one minute. Divide the number of oscillations by 60 seconds to get the frequency (f).
7. Compare the measured frequency to the predicted frequency:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \ ,$$

where $m = \frac{weight}{386.1}$ , and k has units lb/in.

8. Repeat steps 1-7 for different springs. Plot frequency vs. spring stiffness and the mass.

**(Alternative Experiment)**

**Experiment 2: Spring Pendulum**

**Equipment**

- Spring
- Metal ball or wooden ball
- Pendulum clamp and rod
- Meter stick
- Weight hanger
- Masses (slotted)
- Stopwatch

**Procedure**

Hang the spring from the support rod. The wider end of the spring should point down. 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 10 gram increments until the weight hanger is as close to the top of the table as possible. Graph F vs. x, where F is the weight hanging from the spring and x is the displacement caused by the weight. Determine the spring constant k, which is the slope of the best-fit line of this graph. Determine the mass of the spring (optional).

**Part 2**

Place 150 grams on the weight hanger 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.