

# Experiment VS Vibrating Systems

## Introduction

Many vibrating or oscillating systems around us are visible or audible, but most are hidden. The motion of a clock pendulum, or of a child on a swing, can be seen. The vibrations of a bell, or of any musical instrument, are not easily seen but are certainly audible. The oscillations of current in the tuned circuits of a radio, or in atoms emitting light, are not directly perceived but can be measured or inferred.

These systems and others have several things in common: some quantities (position, sound pressure, electric field, etc.) vary sinusoidally in time at one or more natural frequencies depending on the pattern of motion or mode of vibration. In each cycle of vibration there is an exchange of energy from kinetic to potential and back, or from electrical to magnetic and back. In the case of mechanical oscillators the potential energy is associated with the work done against a linear restoring force provided by the deformation of the spring in a mass/spring system. In the case of the pendulum the potential energy is associated with the work done against the component of the gravitational force along the direction of the circular arc of a pendulum's bob. The pendulum is only an approximate oscillator for small angles of arc. The kinetic energy is associated with the moving mass.

In this experiment you'll investigate the properties of four mechanical oscillating systems, simple pendulum with two strings, simple pendulum with one string, mass/spring oscillator, and cantilevered beam. All these systems have nearly linear restoring forces.

## Mass/Spring Oscillator

In its ideal form, the mass/spring oscillator has a massless spring of spring constant  $k$ , attached to a point-like with mass  $m$  and a rigid support. We'll use rubber bands and the cup of pennies as an approximation. Clamp the piece of wood to a desk or table, and suspend from it a chain of rubber bands (use all that you have of one kind) with a paper clip at each end. Join the rubber bands as shown in Figure 1.



Figure 1: Rubber Band linkage

Hang the cup from the lower clip and measure the distance between the nearest points of the two paper clips (i.e., the length of the chain of rubber bands) for total suspended penny masses of about 10, 20, 50, 100, 120, 150, 180, 200, and 250 g.

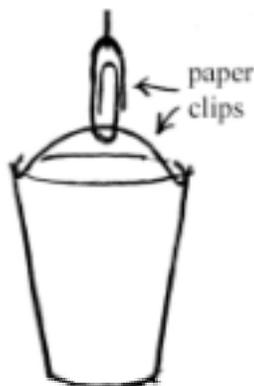
Note that the mass of a penny before and including 1981 is 3.1 g; from 1982 on it is 2.5 g. The paper cup has mass  $6.10 \pm 0.02$  g. Each paper clip has mass  $0.40 \pm 0.02$  g. Each rubber band has mass  $0.02 \pm 0.01$  g. Plot a graph of extension against suspended mass for this system. Is the graph linear?

Now measure the time for ten vertical oscillations and calculate the period of one vertical oscillation with a total suspended mass of about 150 g. Repeat for two different amplitudes of oscillation (one larger and one smaller).

Observe other possible oscillations -- pendulum and twisting motions -- of this oscillator. Look closely for any unusual features of the pendulum motion.

### **SIMPLE PENDULUM:**

We'll approximate the ideal "simple" pendulum -- a point mass on a massless inextensible string attached to a rigid support -- by a cup, containing pennies, attached by a long string (about 2 m) to a piece of wood clamped horizontally to a high support, for example a bookshelf, so that it projects well beyond the edge. Make a handle for the cup by first straightening out a paper clip. Pierce the ends of the paper clip through the top rim of the cup and then bend the ends of the clip with your needle nose pliers forming a jay shaped hook on each end. Attach the handle to the string using a paper clip (Figure 2).

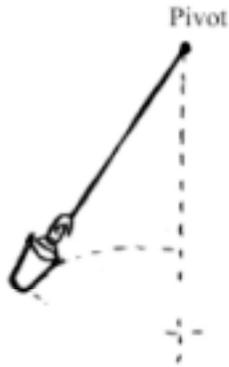


**Figure 2: Paper Cup Pendulum**

Suspend the cup, with 50 pennies, and time the period for swings of small amplitude -- say 10 degrees. Time a group of at least 10 swings. Don't forget to measure all lengths from the

attachment point to the center of gravity of the "bob" -- the pennies in the cup. Time how long it takes for the amplitude to decrease by 50%, and repeat with 5 pennies in the cup. Observe whether the period changes with the number of pennies in the cup. Repeat the period measurements with half the length of string.

Set the pendulum in circular motion forming a conical pendulum (Figure 3) and measure its period and other relevant parameters, for example the radius.



**Figure 3: Conical Pendulum**

### **EXPERIMENT VS -- PARTS LIST**

- 1 Length Twine
  - 1 Paper cup from Expt ET
  - 5 Rubber bands
  - 2 Paper clips
  - 1 Piece of wood  $1/2 \times 1/2 \times 10$
- Also C-clamp, and pennies from previous experiments.