Hooke's Law and the Simple Harmonic Motion of a Spring

Purpose: To determine the force constant of a spring and to study the motion of a spring and mass when vibrating under influence of gravity.

Equipment: Spring, masses, weight hanger, meter stick, stopwatch, support and stand with clamps, motion detector, Science Workshop.

Introduction: When a spring is stretched a distance x from its equilibrium position, it will exert a restoring force directly proportional to this distance. We write this restoring force, F, as:

1) $F = -kx$

where k is a constant called the spring constant which depends on the stiffness of the spring. The minus sign remind us that the direction of the force is opposite to the displacement. Equation 1 is valid for most springs and is called Hooke's Law. If a mass is attached to a spring that is hung vertically, and the mass is pulled down and released, the spring and the mass will oscillate about the original point of equilibrium. Using Newton's second law and some calculus we can show that the motion is periodic (repeats itself over and over) and has period, T (in sec), given by

2) $T = 2\pi\sqrt{\frac{m}{k}}$

where m is the mass supported by the spring and k is the spring constant.

Procedure:

1. Hang the spring on the support rod and measure the position of the lower end of the spring. Place a mass on the spring and observe its position. Repeat for 7 additional masses.

2. Make a plot of the downward force applied to the spring (y-axis) versus the displacement of the spring (x-axis). Remembering Equation 1, determine the force constant, k.

3. Start up the Science Workshop software and place the motion detector on the floor beneath the hanging mass. Tape an index card to the bottom of the hanging mass to give the motion sensor a larger surface to "see". Place the smallest mass on the spring and pull the mass downward. Release the mass and observe the subsequent motion. Start collecting data. The time scale on your graph should allow for at least five cycles of the motion to be seen. Determine the time for five cycles. From this number calculate the period of motion. Record your data. Repeat this for the other masses used in part 1. Create a data table which gives average T and m values.

4. Using the data for the last trial (the largest mass), fit the data to a sinusoidal function using the Analyze/Automatic Curve Fit option. Determine the period and the amplitude from your function. Compare the period with the value obtained in part 3.

5. Make a plot of T^2 (y-axis) vs m (x-axis). What conclusions can you reach about the validity of equation 2? From this equation, what should the slope of the line be? Find the slope from your graph and use it to calculate a value for k. Compare with the value of k obtained in part 1.

6. Repeat for an additional spring.