

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, support stand with clamps, motion detector, LabPro interface, wire basket.

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:

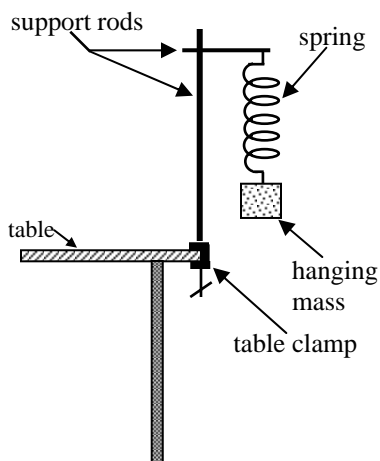
$$1) \quad F = -kx$$

where k is the spring constant and 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

$$2) \quad T = \sqrt{\frac{4\pi^2}{k} m}$$

where m is the mass supported by the spring.



Procedure:

1. Hang the spring on the support rod, as shown in the diagram, and measure the position of the lower end of the spring. Place 350 gm mass on the spring and observe its position. Now attach, in turn, masses of 450, 550, 650, 750, 850, 950, 1050 gm and measure how far the spring is stretched for each of these 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 Logger Pro software by clicking on its icon in the Physics Apps folder. From the program click on **Open/Mechanics/Hooke's Law** to open the file for this experiment. A graph of linear position vs time should appear. Place the motion detector on the floor beneath the hanging mass. Place the wire basket over the motion detector to protect it from any accidentally dropped masses. Once again place the 350 gm mass on the spring and pull the mass downward until the spring has been stretched 10 cm. Release the mass and observe the subsequent motion. Start collecting data by clicking on the **Collect** button. The time scale on your graph should allow for at least five cycles of the motion to be seen. Press the "**x=**" button and 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 (with $m = 1050$ g), fit the data to a sinusoidal function using the **Analyze/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.