15105 Hooke's Law, Helical Spring

Purpose:

These materials permit a student investigation of Hooke's Law, and the determination of the spring constant of a helical spring using two different methods. They can also be used to conduct potential energy or simple harmonic motion experiments and demonstrations.

Warning: contains lead

The following components of this kit are fabricated with or of lead:

220 gram (approx.) Weight (with double hook)

While the risk of exposure to airborne or ingestible lead is minimal in association with these parts, proper handling and storage of these components should be observed.

Do:	Do Not:
wear gloves whenever possible	heat, cut, shape, or otherwise modify lead parts
- wash hands immediately after handling	- dispose of lead components as part of normal trash removal
store lead components in a clean, dry, secure location in a dedicated, tightly closed container	

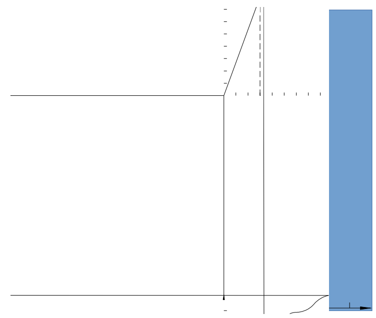
Required Accessories:

Laboratory stands, paper or straw or toothpick pointer, meter stick, timer or stopwatch

Assembly:

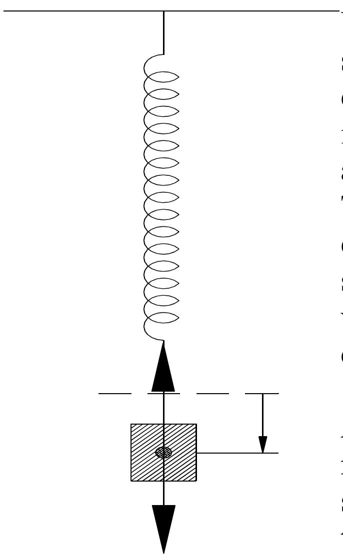
Suspend the spring from a height of nearly one meter. At the end of the spring to which weights will be attached, fashion a pointer from a soda straw or piece of paper or toothpick. Securely mount a meter stick behind the pointer. Hang the 220 g weight on the spring to straighten it. Record this initial pointer position by reading the scale on the meter stick.

Background:



The exact restoring force produced by the deformation of an elastic body depends in a complicated way on the shape of the body and the detailed properties of the material of the body. Hooke's Law is often a good approximation of the relationship provided that the deformation is small. In the special case of the coiled spring, the approximation is good enough to allow the employment of spring balances as a way to measure forces, if the spring is constrained so it cannot be over-extended.

The graph of **force versus spring extension** yields a straight line until the elastic limit is reached and the spring destroyed. The slope of this straight line is the constant used to define and classify any particular spring, for it pictures the restorative force from the action-reaction pair of forces when the spring is extended a certain amount by a force applied to it. Hooke's Law states that the magnitude of the restorative force is directly proportional to the deformation produced by the force applied, and is in the opposite direction:



Where **k** is the spring constant, the slope of the graph of force versus spring extension, **x** is the displacement the force produces from the equilibrium position, and the minus **(-)** means the restorative force acts in the opposite direction of the applied force. The spring constant is always a positive number, and a stiffer spring will have a higher value. The units for **k** are Newtons per meter (N/m). If a spring is over-extended but not broken, it will be found to have a new value of **k**, since its graph will then permanently have a different slope in the force versus spring extension graph. All other things being equal, the spring constant is inversely proportional to the number of coils.

A simple harmonic oscillator consists of a mass coupled to an ideal massless spring which obeys Hooke's Law, and therefore provides a second way of experimentally determining the spring constant. To state that the equation above applies to an oscillating mass, presumes that the coils remain spread apart and is equivalent to assuming a massless spring since all of the restorative force remains available to accelerate the mass attached to the spring. The period for the motion of a simple harmonic oscillator depends only on the spring constant and the mass, and will always be the same regardless of amplitude, a property called **isochronism**. Further, gravity does not effect the period of oscillation of this motion. It only affects the location of the equilibrium point as various masses are attached to the spring. From the general equation for the oscillator, **k** can be isolated as follows:

Where **T** is the period of oscillation, and **m** is the mass attached to the spring.

Procedure:

Hook additional masses on the spring individually and in combination and record the extension they cause using the pointer on the meter stick. Take data with zero, 500, 1000, and 1500 grams. Take care not to overload to avoid permanent damage to the spring, and to read the pointer while viewing perpendicular to the scale. Graph the results as previously described and calculate the spring constant.

Alternatively, the results from a single mass may be used. If mass **m** is placed on the spring and it stretches a distance **d**, then the restorative force must balance the load **mg** when at rest to yield the following:
Finally, with a given mass on the spring, the period of oscillation is determined by vertically displacing the mass and measuring the time for ten or so oscillations. It is instructive to do this for a small displacement, and then again for a larger one. Using data sets for mass and period, the spring constant can again be calculated and compared with the results of the other method.

Extensions:

In engineering terms this experiment demonstrates that there is a direct relationship between force applied to a spring, known as stress, and elongation of the spring, known as strain. Discussion might follow of ways to measure the mass of an astronaut while deployed on a space station in Earth orbit. As a further extension, perhaps the Inertial Balance, #14600, can now be re-examined in the context of Hooke's Law.

Explorations of simple harmonic motion might include an analysis of the acceleration of the mass as a function of position:

The energy stored in a stretched or compressed spring is called elastic potential energy, and is given by:

Time Allocation:

To prepare this product for an experimental trial should take less than ten minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.