Lab 5 – Hooke's Law and Conservation of Energy

Objectives:

The objective of this lab is to determine the spring constant of a spring by applying Hooke's Law and experimentally supporting the Law of Conservation of Energy.

Theory:

Hooke's Law is a principle which describes how an elastic object responds to an outside distortion force (distortion = displacement from equilibrium). Specifically, Hooke's Law states that a restoring force produced in the object is directly proportional to the distortion, but in the opposite direction. The elasticity of a spring can be tested by measuring the elongation produced by different weights added to the spring. The force which tends to bring the spring back to its position of equilibrium is the restoring force, and when the spring is at rest, the restoring force (F_{spring}) is equal to the suspended weight,

$$F_{spring} = k|s| = mg \qquad \text{(Eq. 1)}$$

The absolute value sign in Eq. 1 ensures that the spring force is an upward (positive) force regardless of the choice of coordinate system. The elastic force produced is a conservative force, with a potential energy function (PE_{el}) that is proportional to the square of the distortion,

$$PE_{el} = \frac{1}{2}ks^2 \qquad \text{(Eq. 2)}$$

In both equations, k is called the spring constant (or force constant), and s is the distortion. Gravity is also a conservative force with its own potential energy function (PE_{grav}),

$$PE_{grav} = mgy \qquad \text{(Eq. 3)}$$

where y represents the vertical displacement of the object the gravitational force is acting on. If the only forces doing work on a system are conservative (i.e. gravitational and elastic), then the sum of kinetic and potential energies at any position must be the same as at any other position. This is the Law of Conservation of Energy in the absence of non-conservative forces,

$$PE_{grav\ i} + PE_{el\ i} + KE_i = PE_{grav\ f} + PE_{el\ f} + KE_f \qquad \text{(Eq. 4)}$$

In the case of a weight that is connected to a spring and dropped from its relaxed position, Eq. 4 simplifies to

$$PE_{grav\ i} + \cancel{PE_{el\ i}} + \cancel{KE_i} = PE_{grav\ f} + PE_{el\ f} + \cancel{KE_f} \qquad \text{(Eq. 5)}$$

The initial elastic potential energy in the spring must be zero because it is initially in a relaxed position, the initial kinetic energy of the weight is zero because it is initially at rest, and the final kinetic energy of the weight must be zero because it comes to rest. Therefore,

$$mg(y_i - y_f) = \frac{1}{2}ks^2 \qquad \text{(Eq. 6)}$$

<u>Procedure:</u>

1. Suspend the spring from the support. Using a vertical meter stick, observe the position of the lower end of the spring and record the reading.

2. Suspend a total of 150 g from the spring (including the mass of the hanger) and measure the amount of stretch of the spring.

3. Repeat the measurement of Procedure 3 for total masses of 250, 550, 650, and 750 grams.

4. With a total mass of 250 g on the hanger, lift the hanger to the position so the spring is totally relaxed, but not higher. Drop the mass (with spring attached) and measure the position of maximum distortion (where it stops at the bottom before going back up). You will probably need to try this several times to get a good measurement.

5. Repeat Procedure 4 two more times for a total of 3 independent measurements. Determine the average value of the distortion.

6. Repeat Procedure 4 and 5, but with 550 g total mass.

<u>Calculations:</u>

1. From the data of Procedure Steps 1–3, determine the distortion (elongation) produced by each load.

2. Using the results of the previous calculation, plot a graph using the values of distortion (in meters) on the abscissa (x axis) and the weight suspended (in Newtons) as the ordinate (y axis). Plot the best fit line for the data and determine the slope of the line. This is your spring constant k.

3. From the spring constant calculated above, calculate how far the 250 g and 550 g masses <u>should</u> distort the spring when dropped on a totally relaxed spring.

4. Compare the values calculated in the previous step to the data collected from Steps 4–6 by calculating percent errors.