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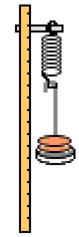
Mr. Croom's Physics Springs 05-07

Hooke's Law, The Period of a Spring, and Elastic Potential Energy *(Shorter)*



Objective:

- The student will be able to determine the **spring constant k** of a light spring via two different methods.
- The students will analyze the motion of a spring
- The students will analyze the conservation of energy in terms of elastic potential energy

Apparatus: Hooke's Law device, set of masses, masking tape, stopwatch timer.

Background Information:

Robert Hooke. His name is somewhat obscure today, due in part to the enmity of his famous, influential, and extremely vindictive colleague, Sir Isaac Newton. Yet Hooke was perhaps the single greatest experimental scientist of the seventeenth century. His interests knew no bounds, ranging from physics and astronomy, to chemistry, biology, and geology, to architecture and naval technology; he collaborated or corresponded with scientists as diverse as Christian Huygens, Antony van Leeuwenhoek, Christopher Wren, Robert Boyle, and Isaac Newton. Among other accomplishments, he invented the universal joint, the iris diaphragm, and an early prototype of the respirator; invented the anchor escapement and the balance spring, which made more accurate clocks possible; served as Chief Surveyor and helped rebuild London after the Great Fire of 1666; worked out the correct theory of combustion; devised an equation describing elasticity that is still used today (Hooke's Law); assisted Robert Boyle in studying the physics of gases; invented or improved meteorological instruments such as the barometer, anemometer, and hygrometer; and so on. He was the type of scientist that was then called a *virtuoso* -- able to contribute findings of major importance in any field of science. It is not surprising that he made important contributions to biology and to paleontology.

(See http://www.ucmp.berkeley.edu/history/hooke.html for a more thorough historical perspective.)

Hooke's Law. When a force is applied to an object, the object may be stretched, compressed, bent, or twisted. The electrical forces between atoms in the object resist these changes. These forces become greater as the atoms in the object are moved farther from their original positions. When the outside force is removed, theses forces return the object to its original shape. Too large an outside force may overcome these resisting forces and cause the object to deform permanently (a broken arm or leg). The minimum amount of stretch, compression, or torsion needed to do this is called the elastic limit. This force that restores the spring to its original shape is, therefore, called a **restoring force**.

Hooke's Law applies to changes **below** this elastic limit. Therefore, it is considered an **empirical law** (meaning derived from experiment), rather than a true physical law. It states that the amount of stretch or compression (the strain) is directly proportional to the applied force (the stress). The constant of proportionality is called the *spring constant, k*. A rigid spring has a high constant and a weak, flimsy spring has a low constant. Hooke's Law is written as **F = kx**.

Part 1. Hooke's Law Method:

NOTE: Do not over stretch the springs

1. Using the hooks law apparatus carefully add masses to the mass hanger and measure the amount of stretch in the spring. Completing the data table as shown.

Data Table 1: Simple Hooke's Law Data Spring 1.

n	mass (kg)	weight (N)	Initial Position (m)	Final Position (m)	stretch (m)
1					
2					
3					
4					

2. Use Microsoft Excel™ to construct a graph of **force F (y)** vs. **stretch x (x)** (**weight** vs. **stretch**).

3. Using the *Add Trendline* feature, determine the **slope of the line**, which is the **spring constant k** of your spring. This value will be considered your accepted value.

Equation of Line 1: ____

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Slope of the Line 1: ____

REPEATE PROCEDURE 1 for spring 2.

Data Table 2: Simple Hooke's Law Data Spring 2.

n	mass (kg)	weight (N)	Initial Position (m)	Final Position (m)	stretch (m)
1					
2					
3					
4					

Equation of Line 2: ____

Slope of the Line 2: ____

Part 2. Oscillatory Method:

4. Place mass on the mass hanger and attach it to spring 1. Displace it from the equilibrium a specific distance. Record this under Amplitude.

5. Release the mass hanger at the Amplitude.

6. Time 10 total vertical oscillations of the mass on the mass hanger. Again this can be done with a stop watch or photo gate.

7. Record these times in your data table.

8. Repeat steps 5-7 with the same masses you used in procedure 1.

9. Calculate the **period T** of the spring (i.e. one complete oscillation) and record.

10. The symbol ω is used to indicate the **angular frequency**, which is the number of oscillations the spring makes per second. Use the equation $\omega = \frac{2\pi}{T}$ to calculate k .

    NOTE: – so — — which equals— — which equals — which is in the form y=mx+b which y=mass, slope=k, and x= —

11. Fill in the rest of the data table as shown.

Data Table 3: Oscillation Data for the Hooke's Law Device Spring 1.

n	Amplitude x_{max}=A (m)	mass (kg)	Time for 10 oscillations (sec)	period T of oscillation (sec)	angular frequency ω (rad/sec)	angular freq squared ω^2 $(rad/sec)^2$	inverse of angular squared ω^2 $((rad/sec)^{2\ -1})$
1							
2							
3							
4							

12. Construct a second graph of the **mass m (y)** vs **inverse of angular frequency squared ω^2 (x).** The slope of this graph is the **spring constant k** of your spring. This is your experimental value for the spring constant.

Equation of Line 3: ____

Slope of the Line 3: ______________________________________

REPEATE PROCEDURE 2 steps 4-12 for the other 2 springs in your bag.

Data Table 4: Oscillation Data for the Hooke's Law Device Spring 2.

n	Amplitude x_{max}=A (m)	mass (kg)	Time for 10 oscillations (sec)	period T of oscillation (sec)	angular frequency ω (rad/sec)	angular freq squared ω^2 $(rad/sec)^2$	inverse of angular squared ω^2 $((rad/sec)^{2\ -1})$
1							
2							
3							
4							

Equation of Line 4: ______________________________________

Slope of the Line 4: ______________________________________

Calculate a **percent of error** between your two spring constant values assuming the first is your theoretical value. Record in the space provided.

Spring 1 Slope 1 and 3 Percent of Error = ____

Spring 2 Slope 2 and 4 Percent of Error = ____

Part 3: Period of a Spring

To investigate the period of a spring, you need to do a *controlled* experiment; that is, you need to make measurements, changing only one variable at a time. Conducting controlled experiments is a basic principle of scientific investigation.

Procedure:

1. First, you need to set up your spring. Hang the spring with the middle hook's law constant from crossbar in the table, and attach a mass hanger

   NOTE: You can use a stopwatch or a photogate to measure the following time.

2. You will do 9 total trials. In each trial, you will set the spring in motion and time how long it takes to make **ten** periods (remember, *one period is one **up and down** motion – it is the time it takes to get back to its original point).* You will then divide the time by 10 to get the time of one period. Record these numbers in the table on the back.
3. For the first three trials, you will use the same spring and mass, but measure **3 different starting amplitudes.**
4. For the next three trials you will keep the spring from trials 1-3 and use the middle amplitude from trials 1-3. This time use **3 different masses**.
5. For last three trials use the same mass as in trials 1-3 and use the same displacement as trial 2. What is different about this set is that you need to change the spring to test the period of 3 different springs.
6. Record all measurements in MKS units.
7. Compute the period of your spring based on your measurements and then compare your answer to the actual answer you got from the stopwatch. Do a percent error between the two periods.

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8. Answer the questions below when complete

Neatly show any work and have units for every number on an attached separate sheet of paper.

	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
Displacement (m) =						
Mass (kg)=						
Spring Constant (N/m)=						
t (10 periods)=						
t (1 period) =						
THEORETICAL $T = 2\pi\sqrt{\frac{m}{k}}$						
EXPERIMENTAL T (stopwatch)=						
% Error Between Periods						

<u>Questions:</u>

Q1. Comment on your percent error. What range did you have? Where did the error come from?

Q2. How does the initial displacement affect the period of a spring?

Q3. How does mass affect the period of a spring?

Q4. How does the spring constant of the string affect the period of a spring?

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Part 4. Determine the spring Energy

Open up http://webphysics.davidson.edu/physlet_resources/gustavus_physlets/VerticalSpring.html

A 2-kg mass hangs from a massless spring of spring constant k = 5 N/m. The spring has an equilibrium (unstretched) length of 13 m. The displacement of the spring from equilibrium is shown in meters, and the velocity of the mass is shown in m/s. Pull down or push up on the end of the spring to displace the mass from its initial position, and then push "Play" to watch it move up and down. Study the graphs of kinetic energy, gravitational potential energy, spring potential energy, and total energy as functions of time.

The graph produced here is Energy vs Time. What would an Energy vs Position Graph Look like? Produce a similar graph for your spring that had the middle spring constant by following the directions below to calculate all of the energies with an energy table.

1. Determine the stretch of the spring with a mass you determine based on Hooke's Law. Record this value as the equilibrium point. Note that without a mass on the spring the equilibrium point would be 0m.

2. Determine how far you would like to stretch the spring from the equilibrium point and record the total distance the spring has been now stretched from the no mass equilibrium. (This should be 5-15cm more than the value found in #1) (HINT: Keep this an integer value)

3. At this location calculate the Elastic Potential Energy. Remember that at the Amplitudes the velocity is zero therefore the kinetic energy is zero. Set the maximum stretch as the zero point for the Gravitational Potential Energy.

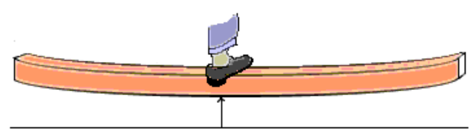
4. Add together the 3 energies found in procedure #4. This is your total energy for the entire problem.

5. Use an excel spread sheet to calculate the energies at a 1 cm mark from the bottom to the top. (This should be similar to the tables I have passed out)

6. Remember, Gravitational Potential Energy + Elastic Potential Energy + Kinetic Energy = Total Energy (a constant)

7. Graph the three energies simultaneously vs. position

Part 5. Hooke's Law with other substances (OPTIONAL):



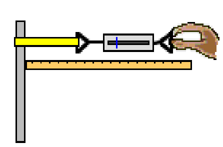
Wood Beam

In this portion of the laboratory you will determine the behavior of a standard 2 by 4 beam (2x4) under flexural stress resulting from a point load at the center of the beam. Each student will use their own weight as a point force applied to the center of a 2x4. The 2x4 is supported at each end.

1. Mark the center of the 2x4. Measure and record the vertical distance from the floor to the upper surface of the beam at the center. This will be the initial equilibrium position from which central deflection of the beam will be measured. *
2. Each student in the class will stand at the center of the beam on one foot. (Classmates should help the student to maintain balance while the distance from the floor to the beam is measured.) Record the distance from the floor to the top of the 2x4 and find the mass (in kg) of the student with the bathroom scales provided. Record both these numbers in the table provided at the chalkboard. Remember to copy the completed data set before leaving the lab.

(*Note: There are many suitable alternative methods of measuring the central beam deflection.)

Rubber Band



Finally, you will examine the stretch of a rubber band. True rubber is a natural product produced from the sap of the rubber tree. (The rubber band provided may be made from a similar manufactured substance.)

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1. Fix the rubber band to the support and attach the spring scale to the other end.
2. From the spring scale, determine 10 values of force that you will apply to the rubber band. Determine a consistent location from which to measure the stretch of the rubber band.
3. Make 10 measurements of the force and resulting stretch of the rubber band provided.