Physics   Name:

Lab: Conservation of Energy in a Spring-Mass System

Equipment Needed

Motion Sensor (CI-6742)	Hooked Collar
Mass Hanger and Mass Set	90º clamp
Spring	Metal lab poles

What Do You Think?

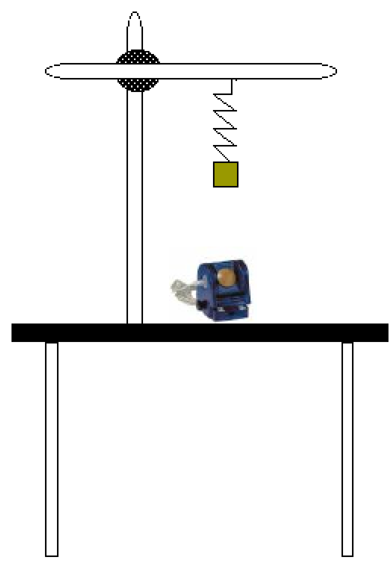
How well is energy conserved when a mass oscillates up and down on a spring?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Potential energy is sometimes called *stored energy*. Any body lifted above the ground has stored potential energy called *gravitational potential energy*. A compressed spring has stored potential energy called *elastic potential energy*. Kinetic energy is called the *energy of motion*. An object in motion has kinetic energy.

The amount of force that a spring can pull back with depends on how far it is stretched and how strong the spring is (called the **spring constant**). Likewise, the amount of elastic potential energy (stored energy) a spring has depends on how far it has been stretched and its spring constant.



A body raised up off the ground in a gravitational field has stored potential energy given by the equation: $GPE = mgh$ where ***m*** is the mass of the body and ***h*** is the height above ground. A spring that is compressed a distance **x** from its normal position has an amount of elastic potential energy given by: $EPE = \frac{1}{2}kx^2$ where ***k*** is the spring constant and ***x*** is the distance that the spring is compressed. The amount of kinetic energy that an object has depends on how much mass it has and how fast it is moving. The formula for kinetic energy is: $KE = \frac{1}{2}mv^2$ where ***m*** is the mass of the object, and ***v*** is the speed of the object.

In this lab you will hang a mass on a spring and stretch the spring (What kind of energy does the spring have at that point?) When you let go, the mass will oscillate up and down. If energy is conserved, the elastic potential energy in the compressed spring will be completely transformed into kinetic energy and gravitational potential energy when the spring contracts.

SAFETY REMINDER

- Do not let the mass hit the Motion Sensor.
- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

Procedure

A. Determining the Spring Constant (Hooke's Law)

1. Suspend a spring from a hooked collar as shown in the apparatus drawing.

HINT: The position of the unstretched spring will serve as a reference position for EPE.

2. Use the motion sensor to determine the position of the weight hanger on the *unstretched* spring. You may wish to carefully hold an index card at the base of the hanger to make it easier for the sensor to read its position. <u>Be sure to lift gently so the spring is not stretched.</u> Record this in table 2 as "position 1".

3. Hang a 150 g mass from the spring and measure the elongation. This elongation corresponds to the force exerted by the 150g mass. Calculate the amount of stretch (in meters) from the unstretched position.

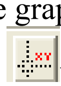
4. Repeat this with four to five different masses. Make sure you do not exceed the elastic limit of the spring (and don't hit the sensor)!

5. Enter the data into a MS Excel spreadsheet plot a graph with the elongation in **meters** on the x-axis and the force in **Newtons** on the y-axis (should you include the point (0,0) in your table?). Make a best fit line and determine the *slope* of the graph. The slope of the graph is the *spring constant, k*.

B. Conservation of Energy

1. Hang a 250g mass from the spring and use the motion detector to determine the equilibrium position (where the mass is at rest and the spring is stretched). This is position 3. Record the location of position 3 in table 2.

2. When the spring is pulled below position 3 and let go it will oscillate back and forth between its highest and lowest positions. Pull the spring down a few centimeters and gently let it go. It will oscillate. BE CAREFUL NOT TO LET THE MASS FALL ONTO THE MOTION SENSOR! Use the motion sensor to record 10 oscillations (What do you notice about the amplitude as the spring oscillates?).

3. Use the graph of *position verse time* to determine the top and bottom points of the moving mass (the smart tool  will make this easy). What kind(s) of energy does it have at the top? What kind(s) does it have at the bottom? Record the he top of the oscillation, position 2, and the bottom of oscillation, position 4 in table 2 below.

Data:

Unstretched spring position: ____________cm

Table 1: Spring Constant

Mass (g)	Weight (N)	Spring position (cm)	Amt. Stretch (m)

Table 2: Positions and Speeds During Oscillation

***For simplicity, call position one "zero" and record all distances relative to it.*

Ex: Pos 1 = 0.366cm & Pos 2 = 0.264

→ Pos 1 = 0 cm and Pos 2 = 0.102

	Position (m)	Speed (m/s)
Position 1		
Position 2		
Position 3		
Position 4		

Table 3: Energy at Each Position for a 250.0g Mass

	Position 2	Position 3	Position 4
Elastic PE			
Kinetic Energy			
Gravitational PE			
Total Energy			

Table 4: Efficiency of Energy Transfer

Change in EPE from 2 to 4	
Change in GPE from 2 to 4	
Efficiency of Energy Transfer from 2 to 4	
% Energy lost from 2 to 3	
% Energy lost from 3 to 4	
Area under graph from pos 1 to pos 4	
ΔEnergy from pos 1 to pos 4	
% Error in calculated work	

Analysis:

- (Total Energy at Position 2) Using data from table 2, calculate the *spring potential energy* by using the formula E.P.E. = ½ kx^2, where x is the distance between positions 1 and 2. Remember that the kinetic energy at this point will be zero (Why?).
- Now, calculate the *gravitational* P.E. at position two by using the formula G.P.E.= mgh, where h is the distance between positions two and four. Enter these values in Table 3.
- (Total Energy at position 4) Repeat the above for position four. This time, the distance that the spring is stretched is the distance from position 1 to position 4. Since position 4 is the lowest position of the spring it is considered the "zero point" for G.P.E. So, there is no G.P.E. at position four.
- Add the G.P.E. and the E.P.E. at position two. Enter this value in Table 3 as the "Total Mechanical Energy" at position 2. Repeat for position four.
- Follow the same steps as above to determine the E.P.E. and the G.P.E. at position 3 and record your results.
- In order to determine <u>speed at position 3</u>, record the time at which the mass is at position 3 on the position v. time graph. Then change the graph of *position v. time* to *velocity v. time*. Use the velocity v. time graph to determine the speed of the oscillating mass at position 3.

- Now add up the GPE, EPE, and KE at position 3. Record this in table 3 as the Total Energy at Position 3. How does the total energy at each position compare? Does this surprise you?

Efficiency of energy transfer

- As the mass falls from position 2 to 4 it loses G.P.E. but gains E.P.E. Calculate the gain in E.P.E. from positions 2 to 4. Enter this value into Table 4.
- As the mass rises from position 4 to position 2 it loses E.P.E. and gains G.P.E. Calculate the gain in G.P.E. from position 4 to position 2. Enter this value into Table 4.
- Since all the G.P.E. at position 2 was transferred to E.P.E. at position 4 we should expect the calculated gains in energy above to be equal. However, due to friction and air resistance there is some loss of energy. So the energy transfer was not 100% efficient. Calculate the efficiency of energy transfer from position 2 to position 4. Use the formula: Eff = (ΔE.P.E.) ÷ (ΔG.P.E.) x 100. Your answer will be a percentage. Enter this into table 4.
- Determine the % energy lost between each of the positions using: $\% lost = \frac{Energy3 - Energy2}{Energy2} \times 100$

Applying the Work-Energy Theorem

- Calculate the *total work done* by the mass on the spring by calculating the area under the graph of *force vs.* distance from position 1 to position 4. This value also represents the *total elastic energy* stored in the spring. Why is that the case? You may need to forecast your graph forward in order to include the distance the spring was stretched on your plot.
- Recall that the work done by the mass to stretch the spring is equal to *the change in Energy* (Work-Energy Theorem) of the spring. Use this fact to calculate the work done to stretch the spring from position 1 to position 4.

  Work done = ΔE = (E at pos. 4) - (E at pos. 1) = (E.P.E. at pos. 4) - (G.P.E. at pos. 1)
- Compare the values from your graphical measurement of work done by the spring and the calculated experimental change in Total P.E.. Account for differences.

Questions

1. How do the total energies at each point compare? What percentage of the total energy was lost from 2 to 3; from 3 to 4?

2. Why is the kinetic energy zero at positions 2 and 4? Explain.

3. Describe all the energy transfers taking place as the mass falls from position 2 to 4?

4. Why does the total work done by the mass stretching the spring (found by calculating the area under the curve) also represent the total elastic energy stored in the spring?

5. What reasons can you offer for why the energy transfer calculations in #1 and #4 are less than 100%?

6. Use concepts of conservation of energy to determine the amount that a 165 lb bungee jumper will stretch a bungee cord (k = 1240 N/m) when they fall from a height of 35.0m to a height of 15.5m. Does the weight of the bungee jumper matter?

Error Analysis

What was your % error? What sources of error exist in this lab, be specific?

Conclusion

What did you do? What did you find? What generalizations can you make?