PHY 221 LAB 06-1: Energy of a Spring

Objective: Plot potential energy and kinetic energy for a harmonic oscillator. Investigate how the total energy depends on amplitude.

Introduction

The potential energy of a harmonic oscillator is

$$U_{spring} = \frac{1}{2}ks^2 \tag{1}$$

Since the only types of energy that change for a harmonic oscillator as the system oscillates are spring potential energy and kinetic energy, we can write the total energy

$$E_{sys} = U_{spring} + K = constant \tag{2}$$

where we have neglected the rest energy of the system since it doesn't change. When the object attached to the spring is at a turning point, $x = \pm A$, its speed is zero, and therefore the system's energy is all potential energy.

$$E_{sys} = U_{spring_{max}} = \frac{1}{2}kA^2 \tag{3}$$

When the object is at the equilibrium position, its speed is a maximum $v_{max} = \omega A$, the potential energy of the system is zero, and therefore the system's energy is all kinetic energy.

$$E_{sys} = K_{max} = \frac{1}{2}mv_{max}^2 \tag{4}$$

Don't lose sight of the fact that the total energy is constant! Though these are different expressions for the total energy, they will give the same result.

If you graph E and U, you will see something like the graph shown in Figure 1.

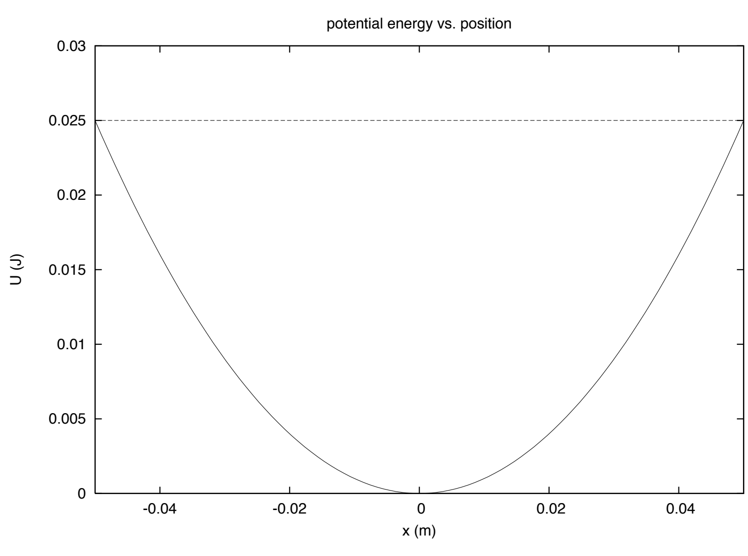

Figure 1: Potential energy and total energy for a harmonic oscillator

The horizontal line is the total energy. Thus, the kinetic energy at any value of x is the difference between the horizontal line (E) and the parabola (U).

On the graph in Figure 1, sketch the kinetic energy as a function of x, the distance the spring is stretched.

Experiment

1. Set up a vertically oriented spring and mass just as you've done in previous experiments.
2. Set up a LabPro data acquisition device and motion detector to measure the position of the hanging mass and verify that it works.
3. With the hanging mass in equilibrium, zero the motion detector.
4. Pull the mass down about 1 cm and release it from rest. Click the Collect button and collect data for about two cycles.
5. By fitting a curve to the graph of x(t), determine the amplitude of the oscillation.
6. By fitting a curve to the graph of v(t), determine the maximum speed during the oscillation.
7. Create a new calculated column for kinetic energy. For the formula, use $K = 1/2m * v^2$.
8. Plot K as a function of x. Sketch the graph. Does it look like what you expect?
9. Calculate the total energy using $E = 1/2m * v_{max}^2$. Create a new column for potential energy. For the formula, use $U = E - K$.
10. Plot the potential energy as a function of x. Sketch the graph. Does it appear a you expect?
11. Fit a curve to $U(x)$. Write the equation for the curve fit. Use this equation to determine the stiffness of the spring.
12. Repeat this experiment five more times. Record data for E and the amplitude A. Graph E vs. A and fit a curve to the graph. How does the total energy depend on the amplitude?