Laboratory 5
Simple Harmonic Motion

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WARNING: This Lab involves the use of rather strong magnets. If you have a mechanical watch (as opposed to a digital watch) you should not wear it to this Lab. Magnetized watches don't work well and having them demagnetized can be expensive. Keep any magnetic disks or tapes away from the magnets or you may destroy some of the recorded information.

1 Purposes:

1. determine if the periods of undamped and damped harmonic oscillators are independent of amplitude
2. determine the natural oscillating frequency of an oscillator
3. quantitatively analyze the effect of a damping force on a harmonic oscillator

2 Equipment

- air track
- car with an aluminum sail
- two springs
- stopwatch
- damping magnets
- in an assigned problem you derived the equation of motion for a car on an air track attached between two springs

3 Introduction

In this lab you will make use of a sort of system you analyzed in an assigned problem. In the apparatus you will use the damping due to air friction and friction between the car and air track should be very small, but we may artificially introduce extra damping with an aluminum "sail" attached to the car; this sail can be made to move between the poles of a magnet. When the sail passes between the poles of a magnet, electric currents called "eddy currents" are induced in it (you will learn why this happens in Physics 14). These currents heat the sail slightly and so dissipate energy. Because the magnetic forces causing the eddy currents are proportional to the speed of the sail and hence the speed of the car, the frictional force term in Newton's second law (also called the "damping term") can be expressed as $-Rv$, where R is a constant usually called the "damping constant" and v is the speed of the car. Before beginning your experimental work, write down the differential equation describing the motion of a damped harmonic oscillator with a damping term of the sort just described.

4 Procedure

1. Level the track. The springs should be disconnected from the car during this process. Do not let go of the car with one stretched spring attached as this will cause the car to be pulled violently to one side. This could cause damage to the car and/or the track, especially if the air supply is not on.

   Connect each end of the car with a sail to one end of one of the small diameter springs; the other end of each spring is attached to an end of the air track as shown in figure 1. Do this with the car removed from the track. Once the springs are connected to both the car and the track and the air supply is turned on, put the car onto the track. Do not use the

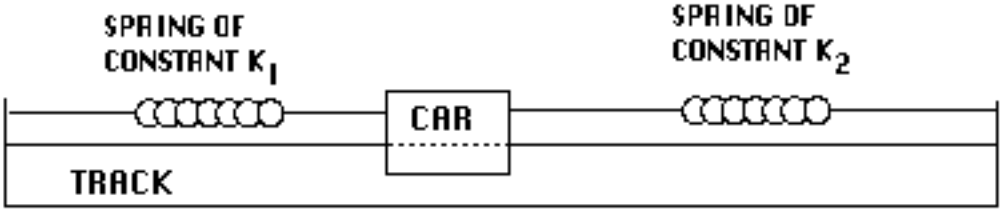

Figure 1

magnet yet

2. Measure the period of the simple harmonic motion of the car for various initial amplitudes. To increase the accuracy of your results, measure the time for 10 periods and then divide by 10 to get one period. Similar techniques for improving measurement accuracy should be used throughout the lab.

3. Measure the mass of the car with its sail and measure the spring constants k. (CAUTION: the springs that you are using are made of light-weight wire and can be easily stretched beyond their elastic limits. Do NOT hang excessive weight on the springs. Generally, a 100-gram mass will stretch the spring to the approximate length in which you are interested. Note also that with magnetic damping the amplitude cannot be much more than 10 cm because of the length of the sail). Check that the spring obeys Hooke's law to at least the amplitude of its motion in this experiment.

4. Now place the large, dark-colored magnet (as opposed to the smaller red magnets) so that the aluminum sail will pass between the poles of the magnet. Use a magnet gap setting of about 1 cm. Measure the period of oscillation when the amplitude is such that the sail remains between the poles. It will be convenient to slide the scale so that the equilibrium position ($x = 0$) coincides with a decimeter mark.

5. Measure the period, and check to see whether it is amplitude-independent. How do the periods of damped and undamped harmonic motion compare?

6. With the magnet still in place, measure the maximum displacement at the end of each of at least five consecutive cycles. [During the lab, remember to make estimates of the uncertainty of your measurements and to use the average of several (3-5) measurements as the accepted value of the quantities you are measuring.]

7. Your written report handed in at the end of the Lab should include the following items:
   a) A discussion of whether or not the periods of undamped and damped harmonic oscillators are amplitude-dependent;

   b) A calculation of the natural oscillating frequency:
   i. from the measured period with no magnetic damping;
   ii. from the measured mass and measured spring constants;
   iii. from the measured period with magnetic damping.
   Briefly discuss any differences in these three values. Are they significant given the measurement uncertainties?

   c) A calculation of the damping constant for the damped harmonic oscillator.

You may have your own way of doing the calculation in part (c) in which case spell out the procedure you wish to use. If you are not sure about how do proceed, plot $\log(X_{max})$ versus the number of periods where X_{max} is the maximum displacement at the end of a period. If you use semi-log graph paper you will have to calculate only the log of the points you use to determine the slope of the graph rather than the log of each individual X_{max}. The damping constant can be obtained from the slope of your graph whether you use linear or semi-log graph paper.