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LAB #8: SIMPLE HARMONIC MOTION

OBJECTIVES:

To study the motion of two systems that closely resembles simple harmonic motion.

EQUIPMENT:

Equipment Needed	Qty	Equipment Needed	Qty
Balance	1	Table Clamp w/Rod	1
Pendulum Clamp	1	S. H. M. Container	1
Two-Meter Stick	1	Measuring Equipment Tray	1
Graph Paper			

SAFETY REMINDER	
• Follow all safety instructions. • Keep the area clear where you will be working and walking.	THINK SAFETY ACT SAFELY BE SAFE!

INTRODUCTION:

In this lab you will analyze the motion of a mass oscillating on a spring. You will then compare this to the motion of a mass swinging on a pendulum.

PROCEDURES:

Answer all of the questions on this handout.

PART 1: Determining the Spring Constant

For later calculations you will need the mass of the spring, so measure it now.

1. What is the mass of the spring in kilograms?

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Set up your table clamp, rod, pendulum clamp, two-meter stick, and spring as shown in Figure #1. Be sure to attach the wider end of the spring to the pendulum clamp. Have the rod as low as possible, even touching the floor, to give the arrangement more stability. Align the two-meter stick with the numbers increasing vertically downward.

Figure #1

When a spring is extended, the spring pulls back. We call this force the "restoring force" because it tends to restore the spring to its original length. For a "perfect" spring the restoring force is related to the spring's extension by Hooke's Law. That is

$$F_{spring} = -k\,x\ ,$$

where the extension "x" is the amount the spring has been stretched from its unstretched length, "F" is the spring's restoring force, and "k" is the spring's "spring constant". The minus sign indicates that the restoring force from by the spring is in the opposite direction to the extension. The spring constant describes how hard it is to stretch the spring, that is, how much the spring will stretch for a given force.

To determine this value for your spring, you must hang different masses on the spring, and measure the amount it stretches. Without any added weight, measure the position of the bottom end of the spring on the two-meter stick to the nearest 0.1cm. Enter this value in Column #3 in Data Table #1 in meters. This will be your spring's equilibrium position.

Hang the 50-gram mass hanger on the end of the spring and measure the new value for the end of the spring. Enter this value in Data Table #1. Increase the hanging mass by 50-grams each time and measure the spring position until you have a total of 400-grams hanging on the spring (remember to include the mass of the hanger in your total mass). Fill in the rest of Columns #1 and #3 of Data Table #1.

Hanging Mass (g)	**Force (N)**	**Spring Position (m)**	**Displacement (m)**
0			
50			

Data Table #1

In this case, the hanging masses are providing the applied forces to stretch the spring. The applied force is opposite in direction to the restoring spring force, and so

$$F_{applied} = k\,x\ .$$

Therefore, we won't need to worry about the minus sign. Determine the force each mass exerts and enter the force, in newtons, in Column #2 in Data Table #1. The spring's displacement is how far from its equilibrium position the spring stretches. Subtract the spring's equilibrium position from each spring position measurement and enter the values in Column #4 of Data Table #1. Your displacement for a force of "zero newtons" should then be "zero meters".
To determine the relationship between the force and the displacement, graph Column #2 (vertical axis) vs. Column #4 (horizontal axis). Be sure to choose the appropriate orientation for the graph on the paper, and reasonable axis scales. Include a graph title, axis labels, and slope calculation.

2. What is the slope of your graph?

This is your spring constant, k.

PART 2: Determining the Period of the Spring's Motion

When a mass on a spring is displaced, the restoring force causes it to oscillate up and down (or back and forth for a horizontal spring). One oscillation corresponds to the motion of the mass from one point in space with a particular velocity, back to that point again with the same velocity, for example, in Figure #2 from Point A to Point E. Notice that in Points A and E, the mass has the same location and velocity. However, in Points A and C, the mass has the same location, but not the same velocity. The motion from Point A to Point C is only one-half an oscillation, as is the motion from Point C to Point D. The time for one complete oscillation is called the period, which depends on the spring's spring constant and the oscillating mass. We will now measure the period of oscillation for a number of different masses.

Hang a total of 100-grams from your spring. Displace it a few centimeters and notice that it oscillates up and down. With a stopwatch measure the time it takes for the mass to oscillate 20 complete cycles. Count the oscillations carefully. Enter your measurement in Data Table #2. Do this two more times letting different group members take measurements. If you get an anomalous measurement, do that one over. Find the average time for the 20 oscillations. Increase the hanging mass in increments of 50-grams, measuring the time for 20 cycles each time, until you have reached 300 grams. Enter your data in Data Table #2.

Divide your times by 20 to determine the period. The theoretical value for the period of a mass, m, oscillating on an ideal spring with spring constant, k, is given by

$$T = 2\pi\sqrt{\frac{m}{k}}\ .$$

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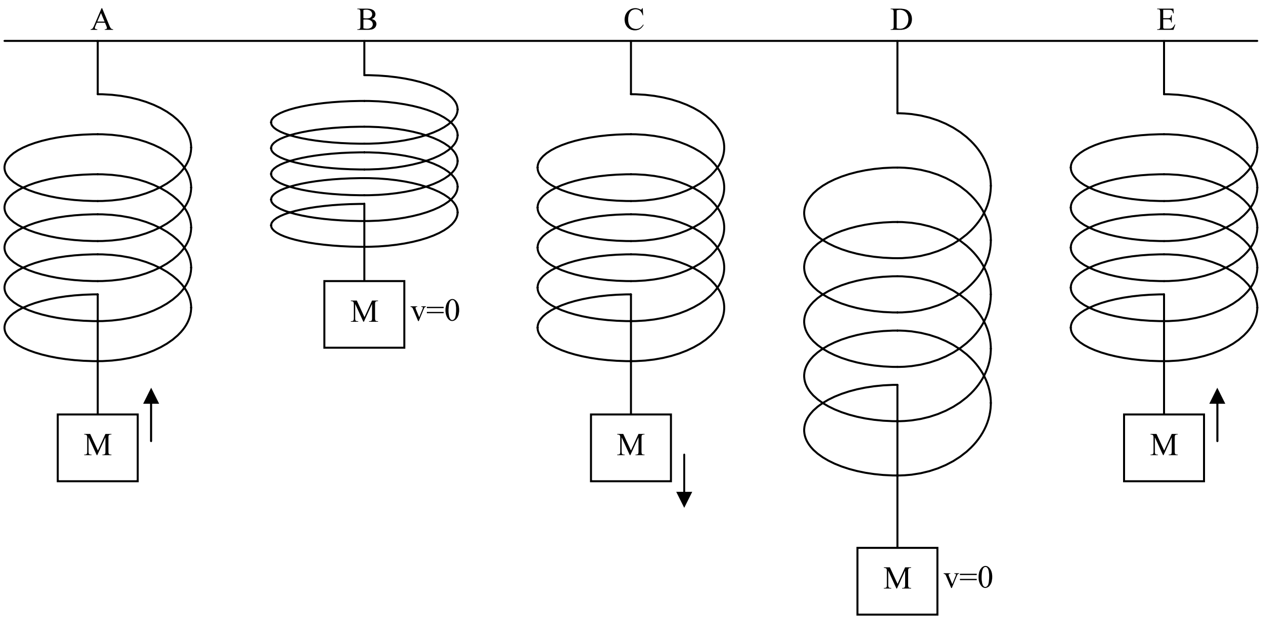

Figure #2

Mass (g)	**Time 20 Cycles (s)**	**Time 20 Cycles (s)**	**Time 20 Cycles (s)**	**Aver. 20 Cycles (s)**	**Meas. Period (s)**	**Theor. Period (s)**	**Percent Error**
100							

Data Table #2

Determine the theoretical values for the periods and enter them into Data Table #2. Watch your units! Determine your percent errors for the measured periods assuming that the theoretical values are the "correct" values. Your lab instructor may wish for you to turn in your calculations on a separate page.

An ideal spring is massless. Obviously our springs are not ideal in that sense. You may notice that as the mass oscillates up and down, some of the spring moves up and down, too. This moving part of the spring increases the effective mass that is in the equation for the period above. For a spring with mass, the "m" in the above equation should be replace with $M = m + ½ m_{spring}$. Using the mass you measured for the spring, recalculate the theoretical periods and complete Data Table #3.

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Mass (g)	Meas. Period (s)	Theor. Period (s)	Percent Error

Data Table #3

PART 2: Determining the Period of a Pendulum

Remove the spring from the pendulum clamp and attach the pendulum string to the clamp. Adjust the length of the pendulum so that the center of the ball is about 10cm below the pendulum clamp. Measure the distance from the top of the string to the center of the ball to the nearest 0.1cm. This is the pendulum length. Enter this in Data Table #4.

Pull the ball to one side a small amount and release it. Make sure the angular displacement is less than 10^o. The period of a pendulum corresponds to the time it takes for the pendulum to complete one swing, that is, to pass through its vertical position moving to one side, right, for example as in Figure #3-A, move to its maximum height on the right, Figure #3-B, move back down through its vertical position moving to the left, Figure #3-C, move to its maximum height on the left, Figure #3-D, and finally pass back through its vertical position moving in the same direction as when the swing started, Figure #3-E. With the stop watch measure the time it takes for the pendulum to complete 20 swings. Enter this in Data Table #4. Do this two more times letting different group members take measurements. If you get an anomalous measurement, do that one over. Find the average time for the 20 swings.

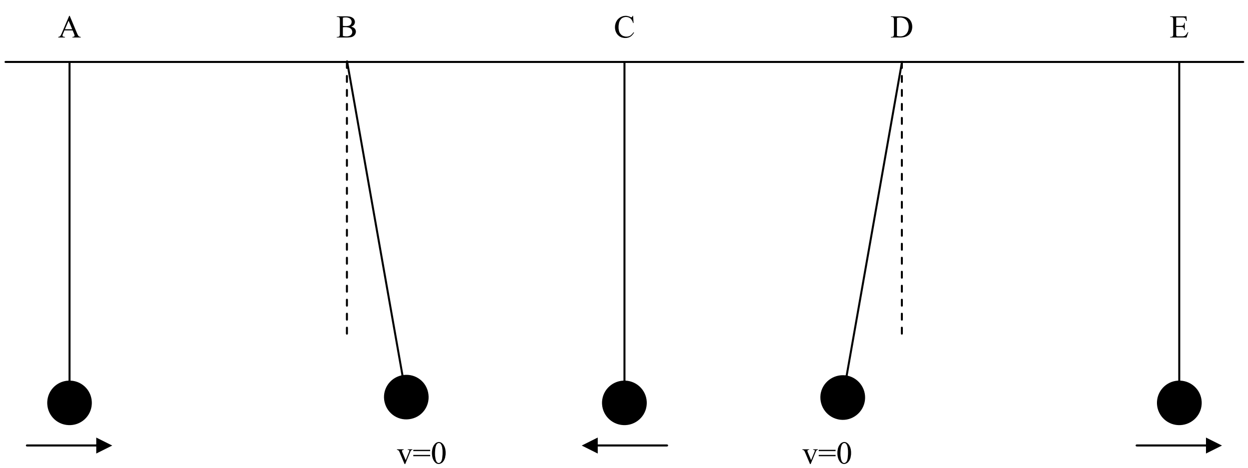

Figure #3

Adjust the length of the pendulum to about 20cm. Measure its length to 0.1cm and the time for 20 swings three times. Enter this data into Data Table #4. Continue to increase the length of the pendulum by about 10cm and to measure the time for 20 swings until you have completed with a pendulum with a length of about 1 meter.

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Length (m)	Time 20 Swings (s)	Time 20 Swings (s)	Time 20 Swings (s)	Aver. 20 Swings (s)	Meas. Period (s)	Theor. Period (s)	Percent Error
0.100							

Data Table #4

Divide your times by 20 to determine the period. The theoretical value for the period of a pendulum is given by

$$T = 2\pi\sqrt{\frac{L}{g}} \ ,$$

where "L" is the pendulum length and "g" is the acceleration due to gravity. For each length and period, calculate a corresponding value for "g" using the above equation. Determine the percent error for each value assume the accepted value for "g" is $9.80 m/s^2$.

3. Do your errors have a trend? That is, do shorter or longer lengths tend to be more accurate, or do the errors seem to be random?

4. What is your average value for "g" and its associated error?

5. The equation for the pendulum period seems to be independent of amplitude. What do you think would happen to the period if you let the pendulum swing more than 10^o?

Clean-Up

Replace all the equipment to the table top. Replace the masses on the mass holder.