Oscillation of a Cart and Springs

Equipment

1	PAScar Dynamics System	ME-6955
2	Compact Cart Mass	ME-6755
1	High Res Force Sensor	PS-2189
1	Rotary Motion Sensor	PS-2120A
1	Photogate	ME-9498A
1	Photogate Bracket	(in ME-8998)
1	Smart Timer Picket Fence	ME-8933
1	Spring Set	ME-8999
1	Braided String	SE-8050
1	Table Clamp	ME-9472
1	45 cm Rod	ME-8736
	Required but not included:	
1	Balance	SE-8723

Introduction

The period of oscillation of the cart and spring system is measured using the Picket Fence and Photogate. The spring constant is determined using the Force Sensor and Rotary Motion to measure the displacement.

The effect on the period is investigated when changing the spring constant, amplitude of the oscillation, and the mass of the cart.

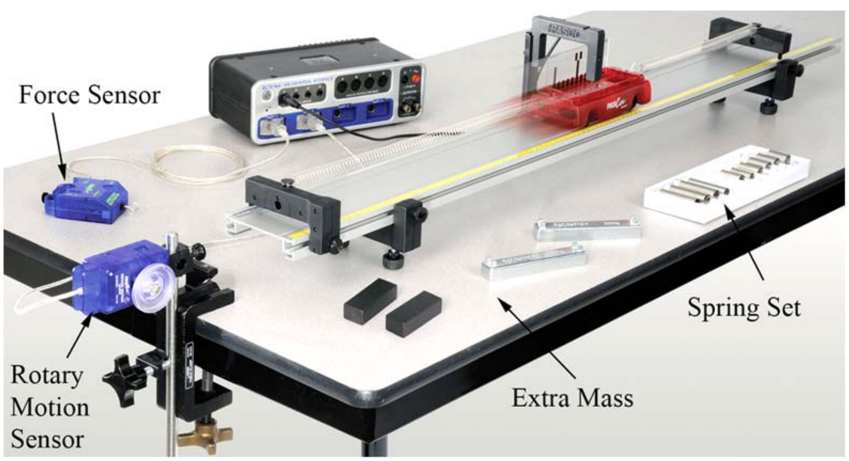

Figure 1: Cart and Spring Oscillation

The system is shown (Fig. 1) measuring the period of the oscillating cart using the Photogate and the Picket Fence. The Force Sensor and the Rotary Motion Sensor are used in a separate part of the experiment to directly measure the spring constant. Note that there are two springs: One connected to each end of the cart.

Written by Jon Hanks

Setup

1. Set up the track as shown in Figure 2, below. Attach the Photogate before adding the endstops.

2. Plug the Photogate into Digital Input #1.

3. The Spring Set contains three each of four different springs. Start with two of the stiffer, longer springs. When new, this spring has a small dab of red paint on one end.

4. It is easier to attach the springs to the cart using a short loop of string as shown in Figure 3. The other end of the spring loops directly over the post on the endstop (see Fig. 4).

5. Place the Picket Fence in the cart as shown. Adjust the height of the Photogate so that the "Double Flag" on the top of the Picket Fence breaks the beam as the cart moves through.

6. Adjust the position of the Photogate on the track so that it is centered on the cart.

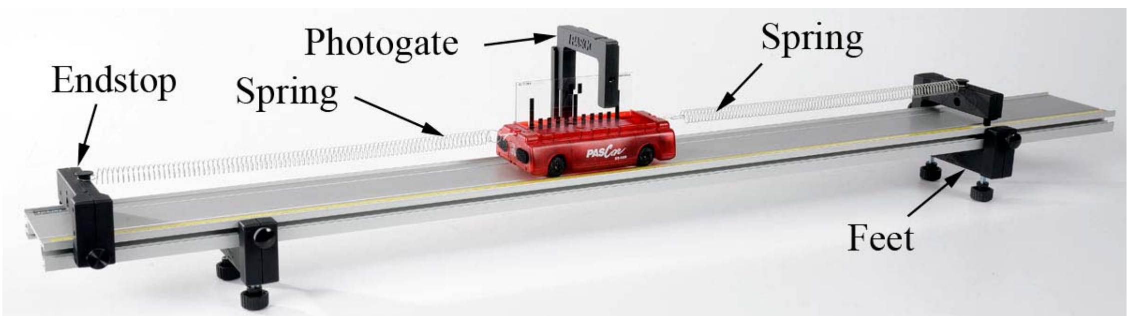

Figure 2: Cart and Track Setup

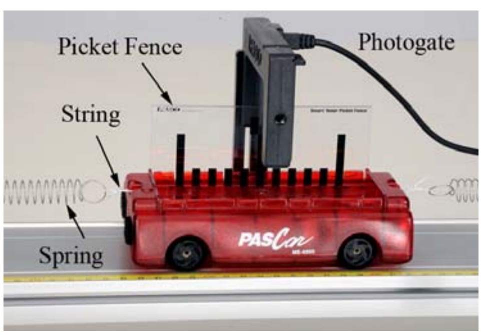

Figure 3. Attaching Springs

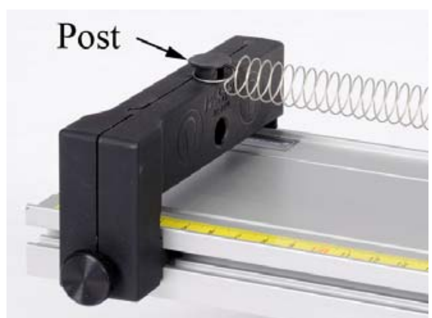

Figure 4. Endstop Post

7. In PASCO Capstone, create a custom timer for the photogate.
    a. Open the Timer Setup at the left of the page and select Custom Timer.
    b. Select Photogate, Ch.1.
    c. Set up a timing sequence that consists of Photogate, Ch.1 being blocked five times, since the double-flag will block the photogate five times when one period has passed.
    d. Specify the measurement name to be Period.

8. Create a table with one column with the Period and turn on the Mean on the statistics.

Measuring the Period of Oscillation:

1. Displace the cart from its equilibrium position by several centimeters and allow it to oscillate.

2. Click on Record to begin taking data. After each full oscillation, the measured period will be displayed in the table. After a few oscillations, click on Stop. Try another run. How much uncertainty is there in the value?

3. Displace the cart from its equilibrium position by 2 cm and record its period of oscillation. Repeat for an amplitude of 15 cm. Record your values below.

4. When you increased the amplitude of the oscillation, did the period increase, decrease, or stay about the same?

5. Incline the track by raising one end about 10 cm and adjust the Photogate so that is still centered on the cart. Measure the period of oscillation. Did the period increase, decrease, or stay about the same?

6. Put the cart back level. Move one of the endstops about 20 cm closer to the cart, so that the force exerted by the springs is now much less. Measure the period of oscillation. Did the period increase, decrease, or stay about the same?

7. Move the endstop back to its original position. Place one of the mass bars in the cart and measure the period of oscillation. Did the period increase, decrease, or stay about the same?

Procedure: Dependence of Period on Mass of Cart

1. Create a table as shown below. Both columns are User-Entered Data sets.

   Table II: Vary Mass

T (s)	mass (kg)

2. Measure the mass of the Cart + Picket Fence and record the value in row 1 of Table II. Measure the Period for a 5 cm amplitude oscillation and record the value in the Table.

3. Add one of the long silver mass bars to the cart. The mass is approximately 0.25 kg, but you can use the scale to be more exact. Record the new total mass of the Cart + Picket Fence + Mass Bar in row 2.

4. Measure the Period for a 5 cm amplitude oscillation and record the value in the Table.

5. Add the second mass bar (see Fig. 5) to the cart. Note that these masses stack. Record the new mass and period in row 3.

6. Add one of the black Compact Masses (see Fig 6) and record the new mass and period in row 4.

7. Add the second Compact Mass and record the new mass and period in row 5.

Figure 5: Adding Cart Masses

Figure 6: Using Compact Cart Masses

Analysis: Period vs. Mass

1. Create a graph of T vs. mass. Can you tell by the graph what the relationship is between Period and mass? Does it look linear?

2. Click on "mass" in the horizontal axis of the graph, pick "Quick Calc" and choose an m^2 or 1/m graph. Do either of these choices make it more linear?

3. Return the horizontal axis to graph "m". Use the "Quick Calc" on the vertical axis to graph T^2. Is this linear?

Setup: Measuring the Spring Constant

1. Remove all the extra masses from the cart.

2. Attach a string to the loop at the bottom of the cart as shown in Figure 7. This string runs under the endstop and over the large pulley of the Rotary Motion Sensor (see Fig. 8) and then hooks to the Force Sensor.

3. Use the table clamp and 45 cm rod to mount the Rotary Motion Sensor as shown in Figure 8. Note that the top knob on the table clamp has been removed. The large pulley on the 3-step pulley should be on the outside. The track must be positioned so that the string coming from the cart runs straight down the track. Adjust the height so that the string does not touch either the track or the endstop.

4. Plug the Force Sensor and Rotary Motion Sensor into the PASPORT ports as shown in Figure 1.

   Note that the top knob on the table clamp has been removed. This allows the Rotary Motion Sensor to be adjusted low enough. The string must run under the endstop without touching.

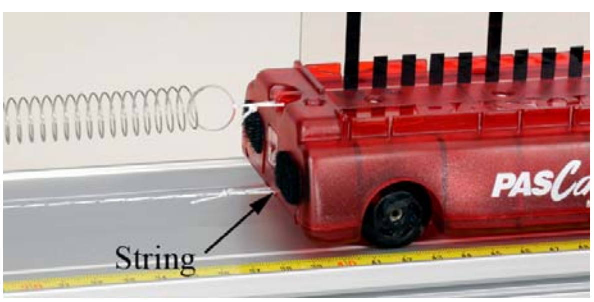

Figure 7: String Attachment for Force Sensor

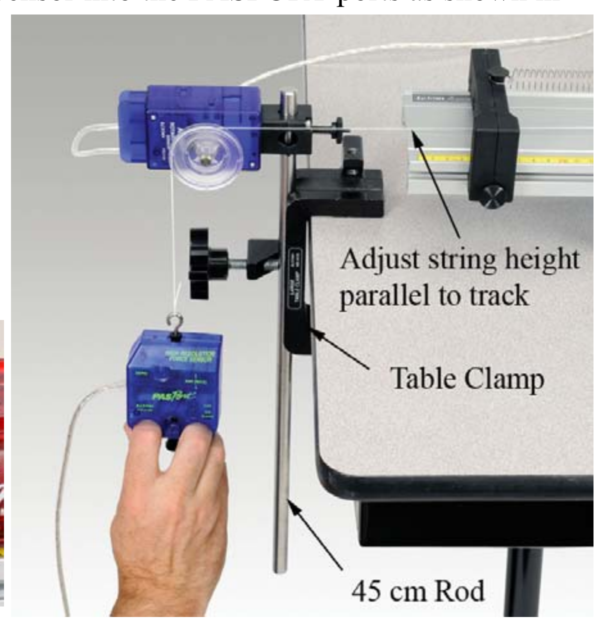

Figure 8: Measuring the Spring Constant

Procedure: Measuring the Spring Constant

When force is applied to a spring, the resulting extension or compression of the spring maintains a linear relationship with the applied force. This relationship manifests itself in Hooke's Law:

$$F = k\,\Delta x \qquad (1)$$

where F is the applied force, Δx is the extension or compression of the spring measured from its unstretched length and k is the spring constant.

1. Use the set-up shown in Figure 8. Remove the string from the hook, and then press the zero button on the Force Sensor. Reconnect the string. Make sure the string goes over the large diameter pulley.

2. Set the Common Sample Rate to 20 Hz.

3. In Capstone, create a graph of Force vs. Position (from the Rotary Motion Sensor).

4. Create another table as shown below. Select the period T in the first column. Then click on the Set and select "Create New User-Entered Data Set" to get Set 2. In the second column, create a new User-Entered Data set called "k" with units of N/m. Also select Set 2 for this column.

   Table III: Vary Spring

Set 2	Set 2
T (s)	k (N/m)

5. Click on Record to start recording data. Gently pull down on the Force Sensor. Do not extend the springs more than 20 cm. Click on Stop.

6. Since the force reading with the Force Sensor is negative for a "pull", apply a "QuickCalc" on the vertical axis to make the forces positive. If the displacement for your data is negative, you can choose a QuickCalc on the horizontal axis as well. Just click on Position in the graph and choose a "-x" QuickCalc.

7. Select a linear curve fit. You can also use the select tool to choose only a selected portion of the data.

8. What is the physical meaning of the slope? Does it have units? Enter your value for k in row 1 of Table III.

Changing the Spring Constant

Note: The mass bars are not used during this part of the experiment

1. Measure the period of the cart for a 5cm amplitude oscillation. Leave the string attached to the cart bottom loop, as you will need it for the next part. If you simply unhook the Force Sensor, the light string sliding back and forth doesn't have much effect. Enter the value in row 1 of Table III.
2. Replace one of the springs with one of the weaker, long springs.
3. Use the procedure from the last section to measure the new Spring Constant. If you do not get a different value, check your springs!
4. Measure the new period of the cart oscillation.
5. Enter values for the period and spring constant in row 2 of Table III.
6. Replace the other original spring with one of the weaker, long springs.
7. Measure the new Spring Constant and Period, and enter the values in row 3 of the Table.
8. Replace one of the weak long springs with two of the weakest short springs as shown in Figure 9. The weak short springs are the ones without the blue paint.
9. Measure the new Spring Constant and Period, and enter the values in row 4 of the Table.
10. Add the remaining weak short spring to the end of the long weak spring on the track.
11. Measure the new Spring Constant and Period, and enter the values in row 5 of the Table.

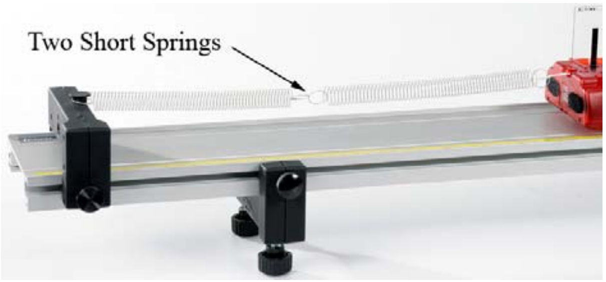

Figure 9: Using Short Springs

Analysis

1. Create a graph of T vs. k and choose Set 2. The graph shows the period data you took for five different Spring Constants. Can you tell by the graph what the relationship is between Period and mass? Does it look linear?

2. Use a "QuickCalc" on the horizontal axis to graph k^2. Does this make it more linear?

3. Use a "QuickCalc" on the horizontal axis to graph 1/k. Does this make it more linear?

4. Leave the horizontal axis as 1/k. Use the "Quick Calc" on the vertical axis to graph T^2. Is this linear?

Combined

In the first part of the lab you varied the mass of the oscillating cart, and discovered that the square of the period is directly proportional to the mass. In the second part of the lab you varied the spring constant, and discovered that the square of the period is inversely proportional to the mass. This means that the period is proportional to the square root of the mass to spring constant ratio.

$$T \propto \sqrt{\frac{m}{k}} \qquad (2)$$

1. You will now combine all the data you took into one graph. From Table II (Vary Mass), copy the Period Data into column 1 of a new table as shown below. Select a new data set (Set 3) for each column. The last column is a calculation made in the Capstone calculator:

   (m/k)^.5=([mass]/[k])^.5

   Table IV: Combined

Set 3	Set 3	Set 3	Set 3
T (s)	mass (kg)	k (N/m)	(m/k)^.5

2. From Table II (Vary Mass), copy the Mass Data into column 2 of Table IV.

3. What was the value of the Spring Constant for this part of the experiment? Hint: Look at the data in Table III (Vary K). Enter this value in column 3 for each of the rows.

4. Note that a (square root m/k) calculation is being automatically performed for each data set, and displayed in column 4. Check at least one of the values to confirm that it is correct.

5. Note that the units have been left off the calculation. What are they? Reduce your answer as far as possible!

6. From Table III (Vary k), copy the Period Data and paste it into the data in column 1 of Table IV below the data that is already there.

7. From Table III (Vary k), copy the Spring Constant Data and paste it into the data in column 3 of Table V.

8. What was the Cart Mass for this part of the experiment? Enter this value in column 2 for each of the new rows.

9. Create a graph of T vs. (m/k)^.5 and choose Set 3.

10. Select the linear curve fit from the graph tool palette. What is the physical meaning of the slope? Does it have units? What is the uncertainty in your value?

11. What is the accepted value for the proportionality constant for equation #2? *Hint: It is some multiple of* π*!*

12. Compare to the accepted value using the % error calculation.

13. Does the accepted value agree with your measured value within the uncertainty of the experiment?