Name _____   Class _____   Date _____

Activity P20: Conservation of Mechanical Energy
(Force Sensor, Photogate)

Equipment Needed	Qty	Equipment Needed	Qty
Economy Force Sensor (CI-6746)	1	**Photogate Mounting Bracket**	1
Photogate/Pulley System (ME-6838)	1	**Picket fence for cart (648-04704)**	1
Balance (SE-8723)	1	Ruler, metric	1
Base and Support Rod (ME-9355)	1	**String (SE-8050)**	0.5 m
'C'-Clamp	1	**1.2 m Track System (ME-9429A)**	1
Dynamics Cart (inc. w/ Track)	1		

What Do You Think?

What happens to the elastic potential energy of a spring stored in a compressed spring when it is released? What other form of energy does it become? Is energy conserved in this process?

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

Background

The elastic potential energy of a spring compressed a distance **x** from its equilibrium position is given by

$$PE_{elastic} = \tfrac{1}{2}kx^2$$

where **k** is the spring constant. As described by Hooke's Law, the force exerted by the spring is proportional to the distance the spring is compressed or stretched from equilibrium, **F = -kx**, where **k** is the proportionality or spring constant. The spring constant can be experimentally determined by applying different forces to compress the spring different measured distances. If force is plotted versus distance, the slope of the resulting straight line is equal to **k**.
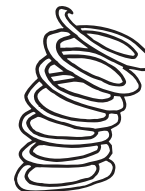
If energy is conserved, the elastic potential energy in the compressed spring will be completely converted into kinetic energy when the spring pushes an object of mass **m**.

SAFETY REMINDER
- Follow the directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

Pre-Lab For You To Do

Use the Force Sensor to measure the force that compresses the plunger spring in the Dynamics Cart. Measure the distance that the spring compresses and enter the distance into the computer. Use *DataStudio* or *Science Workshop* to plot force vs. distance. The slope of the best fit line of a graph of force versus distance is the spring constant k.

Pre-Lab PART I: Sensor Calibration and Equipment Setup

1. Put the five-pattern picket fence in the slots of the accessory tray on top of the Dynamics Cart. Place the picket fence so the pattern of 1 centimeter opaque bands is at the top.

2. Measure the mass of the cart and picket fence. Record the total mass in the Data Table in the Lab Report section.

3. Place the 1.2 meter Dynamics Track on a horizontal surface. Put the cart near the middle of the Dynamics Track and level the Dynamics Track by raising or lowering one end of the track so the cart will not roll one way or the other.

4. Mount the end stop at the left end of the Dynamics Track. Place the cart so the end of its plunger bar is against the end stop. Tie one end of a string to the small hole in end cap of the cart.

5. Mount the Force Sensor horizontally on a support rod and base. Position the Force Sensor at the left end of the Dynamics Track so the hook is at the same height as the top of the end cap of the cart. Use a "C"-clamp to firmly hold the base in position.

6. Tie the other end of the string to the sensor's hook.

7. Slide the Dynamics Track itself to the right (away from the Force Sensor) so the string is taut, and the end of the plunger is against the end stop, but the plunger spring is NOT compressed.
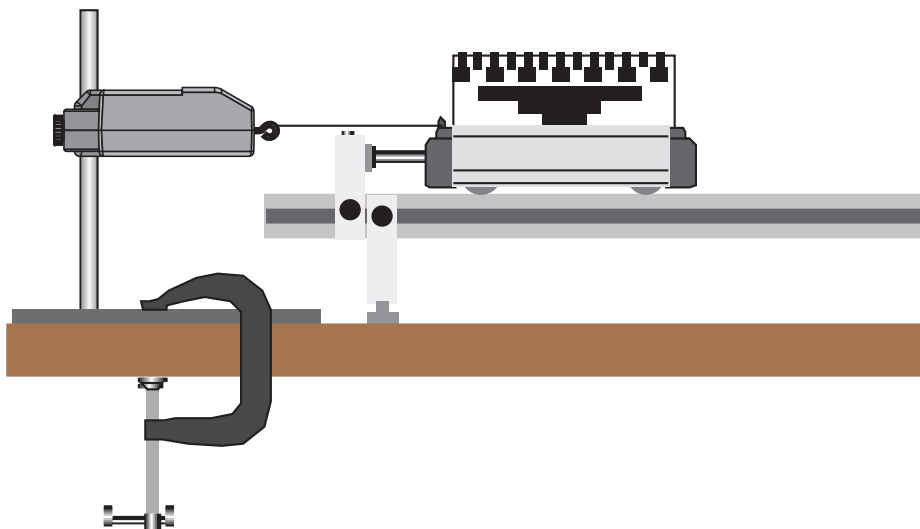
8.   Put a mark on the edge of the Dynamics Track to indicate the initial setup position of the left end of the cart.

•   You can use the mark as a reference line during the data recording process.

Pre-Lab PART III: Data Recording

1.   Press the tare button on Force Sensor to zero the Force Sensor.

2.   Start data recording.

In *DataStudio*, move the Table display so you can see it clearly.

•   Click on the 'Start' button to start recording data. The 'Start' button changes to a 'Keep' and a 'Stop' button (✔ Keep ■). The Force will appear in the first cell in the Table display. Click the 'Keep' button to record the force value.

3.   Slide the Dynamics Track to the right (away from the Force Sensor) so the plunger spring is compressed 5 millimeters (0.005 m) against the end stop. Use the mark on the edge of the Dynamics Track as a reference line. Make sure the string between the sensor and the cart is taut. Hold the Dynamics Track in its new position.

•   Note: You may need to hold the sides of the cart so its wheels don't slip sideways out of the grooves in the Dynamics Track.

4.   Enter the value 0.005 m in the software. Record a Force value for your second compressed position by clicking 'Keep' in *DataStudio.*

5.   Slide the Dynamics Track to the right so the plunger spring is compressed 10 millimeters (0.010 m). Hold the Dynamics Track at the new position. Enter the compressed value and record a force value at this position.

6.   Continue to slide the Dynamics Track to the right in 5 mm increments until the plunger spring has been compressed 20 millimeters. Record a Force value at each new position.

7.   End data recording.

- In *DataStudio*, stop data recording by clicking on the 'Stop' button.

- The data will appear as Run #1.

8. When you are finished, do not let go of the track. Move the track <u>gently</u> toward the Force Sensor until the plunger is not compressed.

Pre-Lab Analyzing the Data

1. Determine the slope of the Force vs. Compression Graph.

- In *DataStudio*, click the 'Scale to fit' button (⊡) to rescale the Graph axes to fit the data. Next, click the 'Fit' menu button (✓ Fit ▼). Select 'Linear'.

2. Record the slope of the linear fit as the Spring Constant (k) in the Data Table in the Lab Report section.

3. Disconnect the string from the Force Sensor's hook. Remove the C-clamp from the base and set the Force Sensor aside.

For You To Do

Use a Photogate to measure the motion of a cart as its plunger spring de-compresses. Next, use *DataStudio* or *ScienceWorkshop* to calculate and display the velocity and maximum kinetic energy of the cart. Compare the measured kinetic energy to the calculated elastic potential energy.

PART I: Computer Setup

1. Unplug the Force Sensor's DIN plug from the interface.

2. Connect the Photogate digital plug to Digital Channel 1 on the interface.

3. Open the document titled as shown:
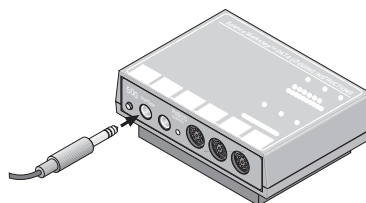
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
P20 Mechanical Energy.DS	P23 Cons. Mechanical Energy	P23_MECH.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.

- Data recording is set at 10 kHz.

PART II: Sensor Calibration and Equipment Setup

• You do not need to calibrate the Photogate.

1. Attach the Photogate to the Photogate Mounting Bracket. Mount the bracket on the side of the Dynamics Track.

2. Adjust the height of the Photogate so the beam will be blocked by the pattern of 1 centimeter opaque bands at the top edge of the picket fence.

3. Put the cart on the Dynamics Track so the end of the plunger bar is pressed against the end stop, but the plunger spring is not compressed. Position the Photogate bracket so the Photogate is as close as possible to the right edge of the picket fence.

4. Measure the length of the plunger relative to the end cap of the Dynamics Cart. Record the plunger length **x** in the Data Table in the Lab Report section.

• Note: When the cart is placed so the end of the plunger bar is pressed against the end stop, you can measure the length of the plunger by measuring the distance from the end stop to the cart.

5. Completely compress the plunger spring on the cart, and lock the spring in position by pushing the plunger in and then pushing the end of the plunger upward slightly so one of its notches will 'catch' on the metal rail inside the cart's end cap.
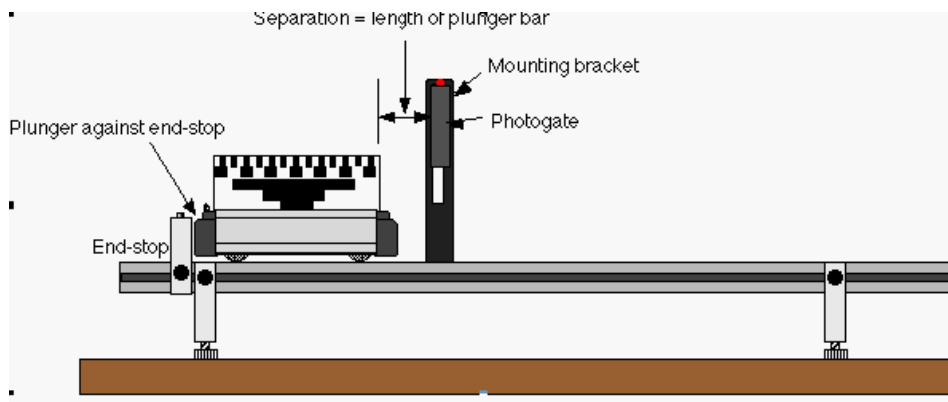
6. Put the plunger end of the cart against the end stop.

• The separation between the right edge of the picket fence and the Photogate should be the length of the plunger bar when the spring is not compressed.

PART IIIA: Data Recording

1. Begin data recording.

2. Use the end of a pencil or similar object to tap down on the plunger release knob.

• The cart will be pushed away from the end stop by the plunger spring.

3. End data recording after the entire cart has moved through the Photogate.

• The data will appear as Run #1.

4.   Repeat the data recording process two more times to produce Run #2 and Run #3.

PART IIIB: Data Recording

1.   Put the mass bar in the accessory tray of the cart and measure the mass of the cart plus bar. Record the total mass value in the Data Table in the Lab Report section.

2.   Repeat the data recording process as in Part IIIA.

•   The three data runs should appear as Run #4, #5 and #6.

Analyzing the Data

1.   Use the Calculator to make a calculation for Kinetic Energy.

In *DataStudio*, double click on the calculation for Kinetic Energy in the Summary Window. The Calculator window will open. The window shows the calculation for Kinetic Energy that was created as part of this activity

The cart mass is stored as an 'Experiment Constant'. If the total mass value for your cart is different than the value listed, in the Experiment Constants section, click on the

menu button ( ) and select 'Cart Mass' from the list. Highlight the mass value in the 'Value' window and type in your total mass value.

Click the 'Accept' button to save your change.

Close the Experiment Calculator window.
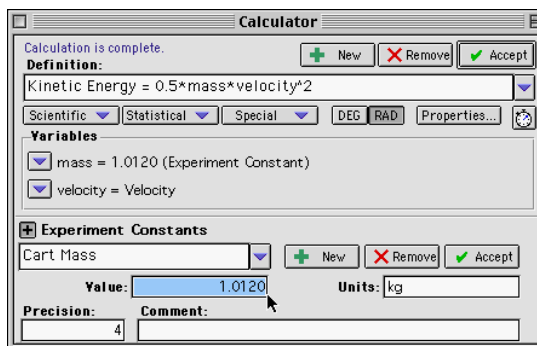
2.   Open a Graph and Table for your Kinetic Energy data from Run #1.

3.   Use the Statistics button to find the Mean value for the KE in Run #1, and record this value in the Data Table in the Lab Report section.

4.   Repeat the process for the next two runs of data. Record the Mean value of the KE for Run #2 and Run #3 in the Data section.

5.   Change the value of the mass in the formula for kinetic energy (KE) to take into account the extra mass for the three data runs Part IIIB.

In *DataStudio*, double click on the Kinetic Energy calculation in the Summary window. In the

'Experiment Constants' section, click the menu button (▼) and select 'Cart Mass' from the list. Highlight the mass value in the 'Value' window and type in your total mass value. Click the 'Accept' button to save your change. Close the Experiment Calculator window.

In *ScienceWorkshop*, click on the select 'Calculator Window' from the Experiment menu. Highlight the value of the mass of the cart in the formula area. Type in the value of the mass of the cart plus the bar. Click the 'equals' button in the Experiment Calculator to enter the change. Close the Experiment Calculator window.

6.   Find the Mean value for the KE of Run #4, and record this value in the Data section.

7.   Repeat the process for the last two runs of data.

8.   Calculate the elastic potential energy based on k and x. Record the values in the Data Table.

Record your results in the Lab Report section.

Lab Report - Activity P20: Conservation of Mechanical Energy

What Do You Think?

What happens to the elastic potential energy of a spring stored in a compressed spring when it is released? What other form of energy does it become? Is energy conserved in this process?

Data Table

Item	Value
Mass (cart & fence)	
Spring constant (k)	
Plunger length (x)	
Mass (cart & bar & fence)	

Run #	1	2	3	4	5	6	Average
KE (J)							

Elastic Potential Energy $= PE_{elastic} = \frac{1}{2}kx^2 =$ _____ **J**

Questions

1. What is the percent difference between the average kinetic energy and the elastic potential energy?

2. Which energy was larger in each case, the elastic potential energy or the kinetic energy of the cart?

3. What are possible reasons for the differences, if any?

4.   When the mass of the cart was increased, why did the elastic potential energy remain the same?