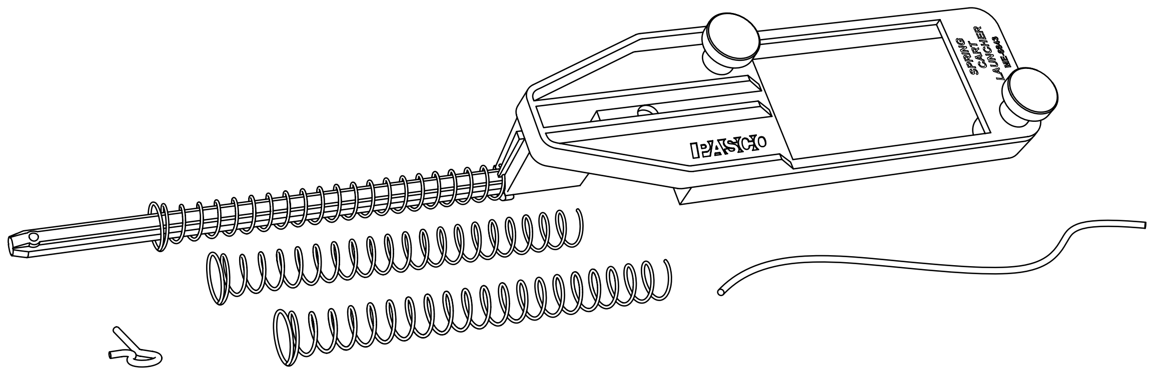
Spring Cart Launcher

ME-6843



Included Equipment	Quantity	Replacement Part Number
Spring Cart Launcher	1	ME-6843
Firm Spring (black)	1	
Medium Spring (blue)	1	
Soft Spring (red)	1	ME-6847[1] (Firm Spring through String)
Release Pin	2	
String	1 m	
Required Equipment		**Part Number**
Cart[2]	1	ME-6951, ME-6950, ME-9430, or ME-9454
Track[2]	1	ME-6953 or similar
End Stops[3]	2	ME-9469 (2-pack)
Recommended Equipment		
250 g Compact Cart Mass	2	ME-6755
For sensor-based method:		
Motion Sensor[4]	1	PS-2103
Force Sensor[4]	1	PS-2104
For traditional method:		
Super Pulley with Clamp	1	ME-9448A
Hooked Mass Set	1	SE-8759 or similar

[1] *ME-6847 replacement kit includes (2) of each spring and (4) release pins*
[2] *This part is included in many of the PASCO dynamics systems. See PASCO catalog or www.pasco.com for details.*
[3] *New-style plastic end stops required. These are included with PASCO dynamics systems starting in 2007.*
[4] *PASPORT sensors require a PASPORT interface. See PASCO catalog or www.pasco.com for details.*

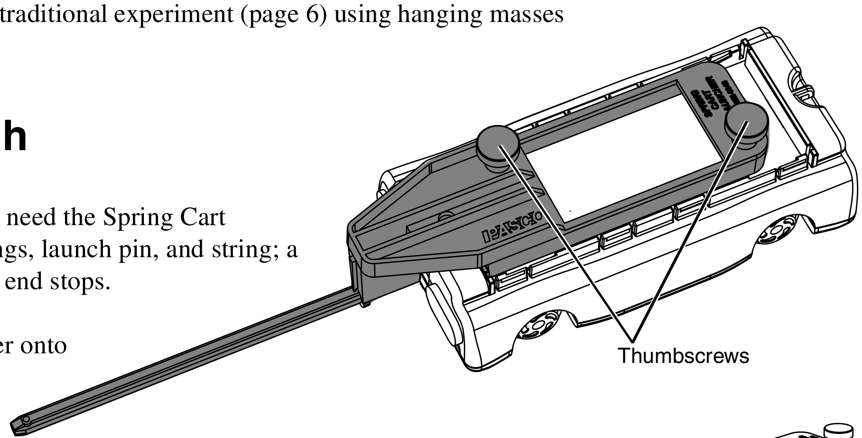
Introduction

The Spring Cart Launcher is designed for the study of force and motion, potential energy, conservation of energy, the work-energy theorem, Hooke's Law, and spring constants. Use it to launch any PASCO dynamics cart by compressing and releasing one of three interchangeable springs. The included release pin, in combination with two end stops, allows you to use precisely the same spring compression for multiple launches.

This manual includes instructions for a sensor-based experiment (page 4) using motion and force sensors, and a traditional experiment (page 6) using hanging masses and an inclined track.

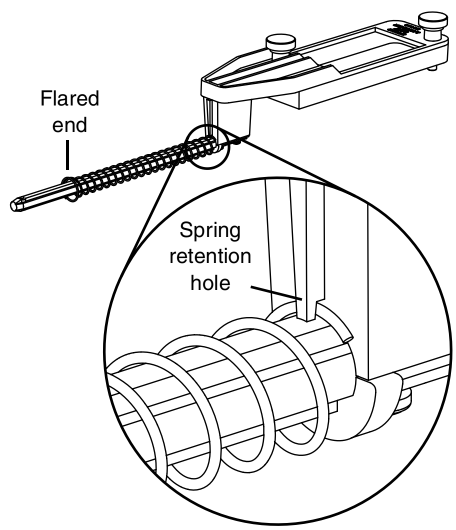
Set-up and Launch

For this general set-up, you will need the Spring Cart Launcher with its included springs, launch pin, and string; a cart; a track, and two adjustable end stops.

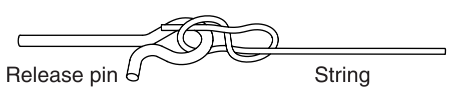


1. Fit the Spring Cart Launcher onto the top of the cart (as illustrated). Tighten the thumbscrews to secure it.

2. Select one of the included springs. Slide it onto the launcher shaft with the flared end out. Turn the spring to secure the end in the spring retention hole as illustrated.



3. Tie the string to the release pin.

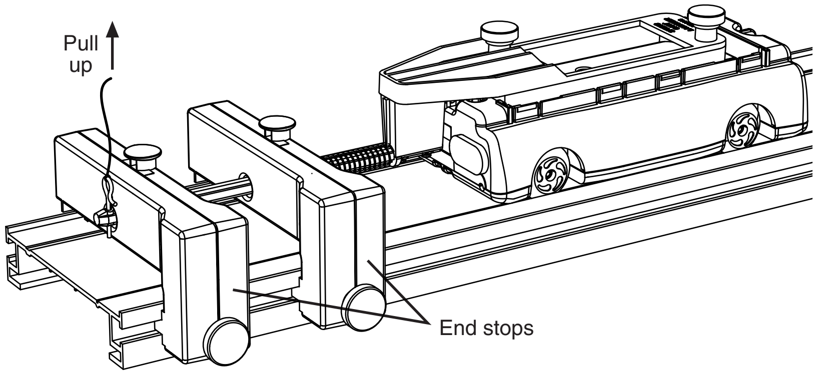


4. Install two end stops near one end of a dynamics track between 3 cm and 10 cm apart, measured center-to-center.

5. Place the cart on the track. Push the launcher shaft through the holes in both end stops.

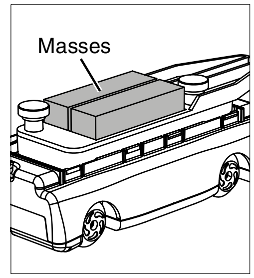
6. Insert the release pin through the hole in the end of the launcher shaft. Allow the launch pin to rest against the end stop.

7. To launch the cart, jerk the launch pin out by pulling sharply up on the string.



As a simpler, but less repeatable, alternative to the above set-up, use only one end stop and do not use the launch pin. Pull the shaft through the end stop and release it from your hand.

Cart Mass



For varying the mass of the cart, the Spring Cart Launcher is designed to hold one or two Compact Cart Masses (PASCO part ME-6755). The launcher prevents these masses from shifting or sliding. Place the masses as illustrated.

Theory

The spring constant of a spring is

Spring constant

(eq. 1) $$k = \frac{F_x}{x}$$

where F_x is the force applied to the spring and x is the displacement of the end of the spring from its equilibrium position.

As you push the end of a spring (or anything else) from position x_1 to x_2, the work that you do is equal to the area under the F_x versus x graph, or

Work done on a spring

(eq. 2) $$W = \int_{x_1}^{x_2} F_x dx$$

The potential energy stored in a spring is

Potential energy stored in a spring

(eq. 3) $$U_{\text{spring}} = \frac{1}{2}kx^2$$

The kinetic energy of a cart moving on a track is

Kinetic energy

(eq. 4) $$K = \frac{1}{2}mV^2$$

where m is the mass of the cart, and V is the magnitude of velocity.

The change in gravitational potential energy of a cart moving up an inclined track is

Potential energy of a cart on an inclined track

(eq. 5) $$\Delta U_{\text{gravity}} = mg\Delta s \sin\theta$$

where $g = 9.8$ m/s^2, Δs is the distance traveled along the track (in the uphill direction), and θ is the track's angle of incline.

Sensor-based Experiment

Note About Sensors and Interfaces

In this experiment, a force sensor measures the force that you apply to the spring; a motion sensor measures the displacement of the end of the spring as it is compressed, the position of the cart, and the velocity of the cart.

You can use the PASPORT sensors recommended on page 1 with a multiple-port interface (such as an Xplorer GLX or Power Link) or two single-port interfaces (such as USB Links). Most of the measurements described below can also be done with just one single-port interface using one sensor at a time. *ScienceWorkshop* sensors and interfaces would also work.

The instructions below refer to operations in DataStudio software such as connecting sensors, setting sampling rates, and setting up graphs. For information about these tasks, press F1 to open DataStudio Help. This experiment can also be done on the Xplorer GLX in standalone mode (without a computer).

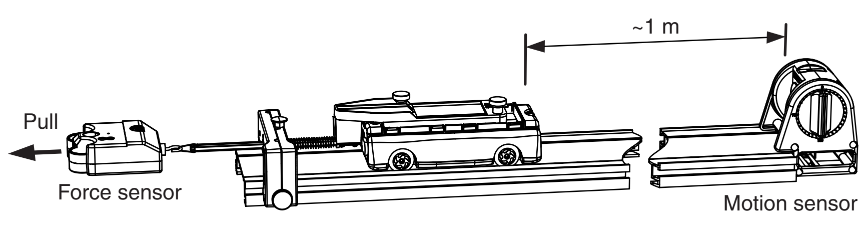
Additional Set-up

1. Follow set-up steps 1 through 3 on page 2.
2. Install one end stop on the track. If you are using a 1.2 m track, place the end stop near one end. If you are using a 2.2 m track, place the end stop in the middle.
3. Level the track so that the cart does not roll when release from a standstill.
4. Clip the motion sensor to the end of the track opposite from the end stop. Aim the sensor along the track. Set the range switch to the **NEAR** or cart setting.
5. Connect the motion sensor and a force sensor to your PAPORT interface (or interfaces). If you are using a computer, connect the interfaces to it and start DataStudio.
6. Set the sampling rate of both sensors to 20 Hz.
7. Prepare the following graphs: Position versus Time, Velocity versus Time, Position versus Force (Pull Positive).

Spring Constant, Work, and Spring Potential Energy

In this part you will use Equation 1 to determine k for your spring. The force sensor measures F_x, and the motion measures x. The slope of the F_x versus x graph equals k.

1. Place the cart on the track with the launcher shaft through the hole in the end stop.
2. Use a piece of string to tie the hook of the force sensor to the launcher shaft.



3. Pull back with the force sensor so that the end of the spring just touches the end stop, but do not compress the spring yet.

4. Press the **ZERO** or **TARE** button on the force sensor.

5. Start data recording.

6. Slowly pull back with the force sensor until the spring is *almost* completely compressed.

   Note: Have your partner hold the track to prevent it from slipping, but be careful not to block the motion sensor.

7. Stop data recording.

8. Determine k from the slope of the F_x versus x graph.

9. Measure the area under graph. This area equals the work, W, that you did on the spring.

10. From the graph, determine the displacement (or *change* in position) of the end of the spring.

11. Use Equation 3 to calculate U_{spring}, the potential energy stored in the spring after you compressed it.

12. Compare W to U_{spring}. Do both values have the same (or equivalent) units? What is the percent difference?

13. Repeat steps 1 through 8 to determine the spring constants of all three springs.

Untie the string from the launcher shaft for the next part.

Spring Potential Energy and Kinetic Energy

In this part, you will study the relationship between the potential energy initially stored in the spring and the kinetic energy of the cart just after launch.

1. Place a second end stop on the track about 8 cm behind the first end stop.

2. Place the cart on the track with the launcher shaft through the hole in the first end stop. Position the cart so that the spring is touching the end stop but not compressed.

3. Start data recording.

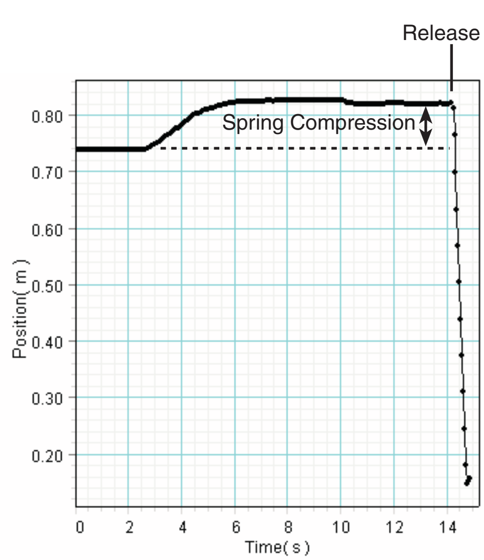
4. Wait a few seconds (to let the sensor measure the uncompressed position). Push the shaft through both and stops and put the release pin into the shaft. Let the pin rest against the second end stop and wait a few more seconds (to let the sensor measure the compressed position).

   Important: In the next step, have your partner catch the cart before it hits the motion sensor.

5. Pull out the release pin with a quick jerk to launch the cart

6. Stop data recording.

7. Determine the spring compression from the graph of position versus time.



8. Use the value of k that you found in the previous part and Equation 3 to calculate U_{spring}.

9. Look at the graph of velocity versus time to find the velocity of the cart just after the launch.

10. Measure the mass of the cart with the launcher and spring attached.

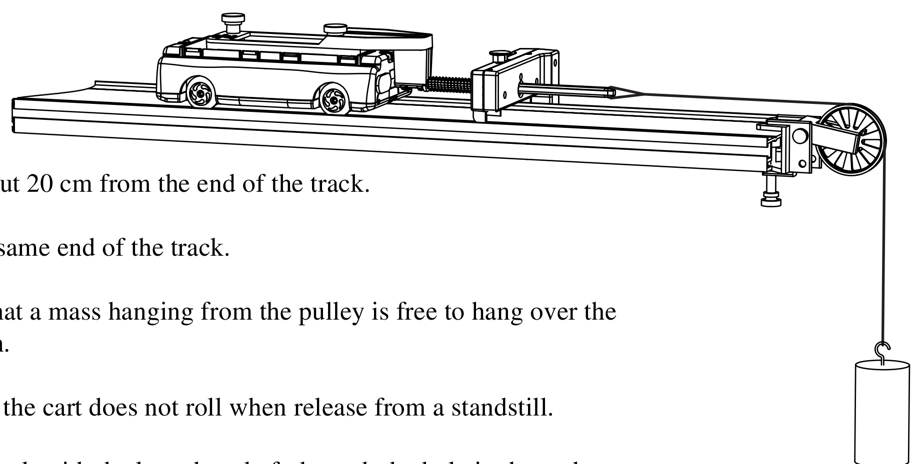
11. Use Equation 4 to calculate the kinetic energy of the cart.

12. Compare the initial potential energy of the spring to the kinetic energy of the cart. Are they equal? If not, what might account for the difference?

Traditional Experiment

In this experiment (which does not require sensors), you will determine the spring constant by using a hanging mass to apply a known force. To determine the energy transferred to the cart, you will observe the maximum height that the cart reaches as it runs up an inclined track.

Spring Constant



1. Follow set-up steps 1 through 3 on page 2.

2. Install an end stop about 20 cm from the end of the track.

3. Clamp a pulley to the same end of the track.

4. Position the track so that a mass hanging from the pulley is free to hang over the edge of your lab bench.

5. Level the track so that the cart does not roll when release from a standstill.

6. Place the cart on the track with the launcher shaft through the hole in the end stop.

7. Tie a piece of string (about 40 cm long) to the launcher shaft. Run the string over the pulley and hang a 100 g mass from the string.

8. Adjust the pulley so that the string is horizontal between the pulley and the launcher shaft.

9. In a table, record the position of the cart on the track and the total mass hanging from the string.

10. Add 100 g to the hanging mass.

11. Repeat steps 9 and 10 up to about 500 g.

12. Calculate the force applied to the spring at each step: $F_x = m_h g$, where m_h is the hanging mass and g = 9.8 m/s^2.

13. Make a graph of F_x versus cart position.

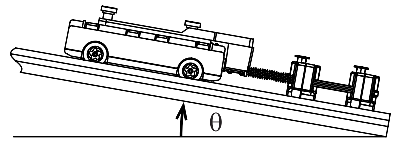
14. Draw a best-fit line on your graph. The slope of that line equals the spring constant, k.

Untie the string from the launcher shaft and remove the pulley for the next part.

Spring Potential Energy and Kinetic Energy

1. Place a second end stop on the track about 8 cm behind the first end stop.

2. Elevate one end of the track by about 20 cm.



3. Hold the cart on the track with the launcher shaft through the hole in the first end stop, and with the spring just touching the end stop, but not compressed. Record this position of the cart as x_1.

4. Push the shaft through both and stops and put the release pin into the shaft. Let the pin rest against the second end stop. Record this position of the cart as x_2.

5. Pull out the release pin with a quick jerk.

6. Watch the cart carefully as it ascends the track. Observe the highest position achieved. Try to read it to the nearest centimeter. Record this position as x_3.

7. Calculate the spring compression: $x = x_1 - x_2$

8. Use x, the value of k that you found in the previous part, and Equation 3 to calculate the initial potential energy of the spring.

9. Calculate the distance traveled by cart: $\Delta s = x_3 - x_2$

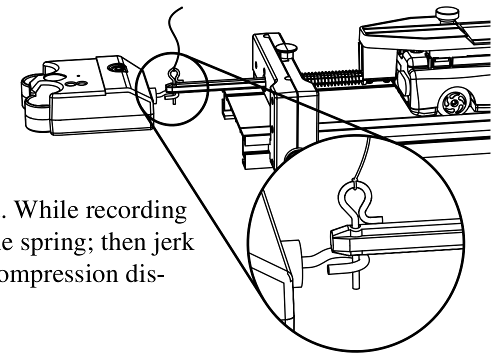
10. Measure the mass, m, of the cart with the cart launcher and spring attached.

11. Measure the angle, θ, of the track.

12. Use Equation 5 to calculate the change in gravitational potential energy of the cart.

13. Compare the initial potential energy of the spring to the maximum gravitational potential energy of the cart. Are they equal? If not, what might account for the difference?

Other Suggested Experiments



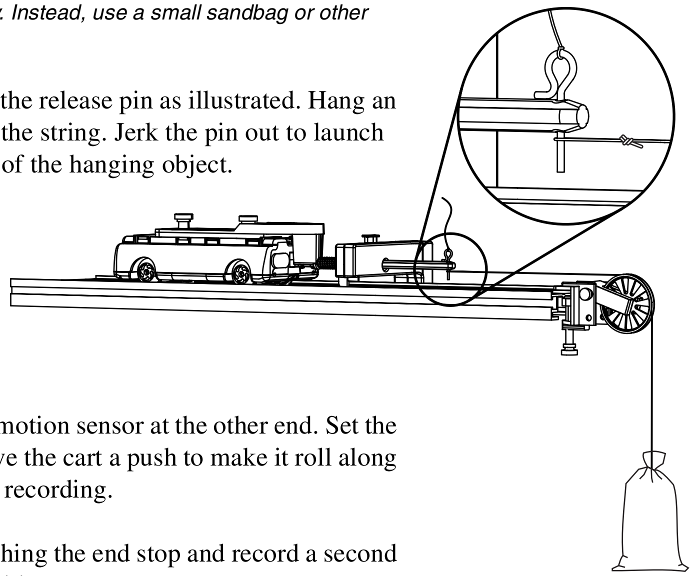
Launch from a Force Sensor

Set up an end stop, a force sensor, and the release pin as illustrated. While recording motion- and force-sensor data, pull the force sensor to compress the spring; then jerk out the release pin to launch the cart. In this way, you can record compression distance, spring force, and launch velocity in a single data run.

Launch from a Hanging Mass

Important: Do not use precision masses in this activity. Instead, use a small sandbag or other object that will not be damaged when dropped.

Set up an end stop, a Super Pulley, a string, and the release pin as illustrated. Hang an object of known mass (up to about 500 g) from the string. Jerk the pin out to launch the cart. The spring force is equal to the weight of the hanging object.



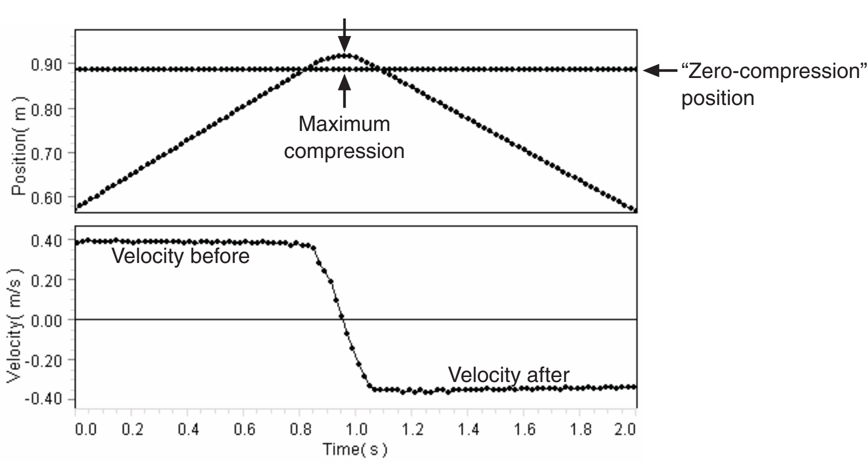
Collision with a Fixed Object

Set up a track with an end stop at one end and a motion sensor at the other end. Set the sampling rate to 50 Hz. Start data recording. Give the cart a push to make it roll along the track and bounce off the end stop. Stop data recording.

Hold the cart stationary with the spring just touching the end stop and record a second data run to measure the “zero-compression” position.

Use the velocity data to determine the kinetic energy of the cart before and after the collision. Use the position data to determine the maximum spring compression (that is, the maximum position measured during the collision minus the position measured when the spring was just touching the end stop). From the compression distance, calculate the maximum potential energy stored in the spring.

In this collision, energy is transferred from kinetic energy to potential energy and back to kinetic energy. At each step, how much energy is “lost?” Where does it go?



Specifications

Launcher dimensions	31 cm × 5 cm × 4 cm
Shaft length	14 cm
Spring length	10 cm
Spring diameter	1 cm
Spring constants	142 ± 14 N/m (black) 112 ± 11 N/m (blue) 84 ± 8 N/m (red)

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S.)

Fax: (916) 786-7565

Web: www.pasco.com

Email: support@pasco.com

Limited Warranty
For a description of the product warranty, see the PASCO catalog.