

Spring Cart Launcher

ME-6843

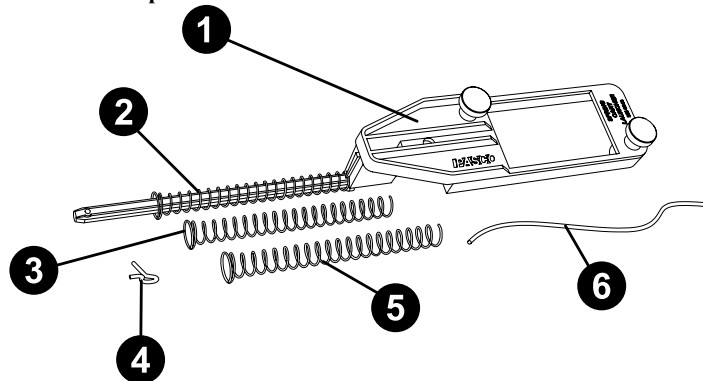
Introduction

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 the device 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 set up multiple launches with the exact same amount of spring compression.

This manual includes instructions for a sensor-based experiment using motion and force sensors, as well as a traditional experiment using hanging masses and an inclined track.

Components

Included components:



- ❶ Spring Cart Launcher
- ❷ Firm spring (black)
- ❸ Medium spring (blue)
- ❹ 2× release pins
- ❺ Soft spring (red)
- ❻ String (1 m)

Required equipment:

- PASCO cart, such as the Plunger Cart (ME-9430) or the Collision Cart (ME-9454)

 **NOTE:** The Smart Cart (ME-1240 or ME-1241) *cannot* be used with the Spring Cart Launcher, as the bed of the Smart Cart is too high and will cause misalignment with the track end stop.

- PASCO cart track, such as the 1.2 m Aluminum Dynamics Track (ME-9493) or the 2.2 m Aluminum Dynamics Track (ME-9779)
- Dynamics Track End Stops (ME-8971)

Recommended equipment:

- Compact Cart Mass (ME-6755)
- For sensor-based method:
 - Wireless Motion Sensor (PS-3219), *or* PASPORT Motion Sensor (PS-2103A) with PASPORT interface
 - Wireless Force Acceleration Sensor (PS-3202), *or* PASPORT Force Sensor (PS-2104) with PASPORT interface
- For traditional method:
 - Super Pulley with Clamp (ME-9448B)
 - Hooked Mass Set (SE-8759) or similar

Setup and launch

General setup of the Spring Cart Launcher requires the launcher itself (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 shown in Figure 1. Tighten the thumbscrews to secure the launcher in place.

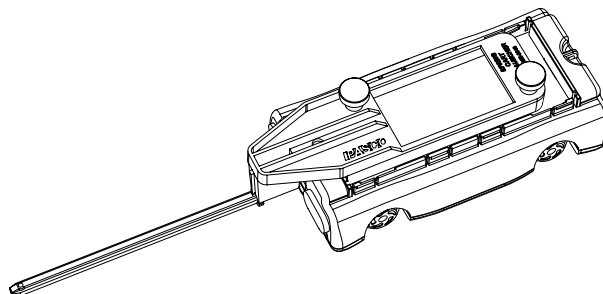


Figure 1

2. Select one of the included springs. Slide the spring onto the launcher shaft with the flared end out, then rotate the spring to secure the other end in the spring retention hole, as shown in Figure 2.

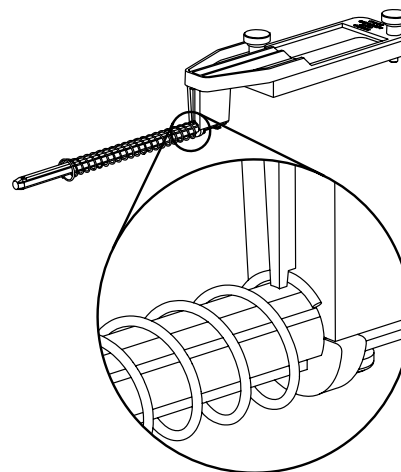


Figure 2

3. Tie the string to the release pin, as shown in Figure 3.

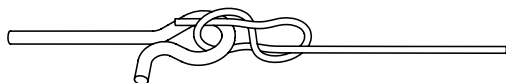


Figure 3

4. Install two end stops near one end of a dynamics track, between 3 cm and 10 cm apart (measured center-to-center), as shown in Figure 4.
5. Place the cart on the track, then move the cart so that the launcher shaft extends through the holes in both end stops, as shown in Figure 4. The spring will be compressed by this action.
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, pull sharply up on the string, as shown in Figure 4, to quickly pull the launch pin free.

 **NOTE:** As a simpler but less repeatable alternative, use only a single end stop and do not use the launch pin. Instead, pull the shaft through the end stop and release it from your hand.

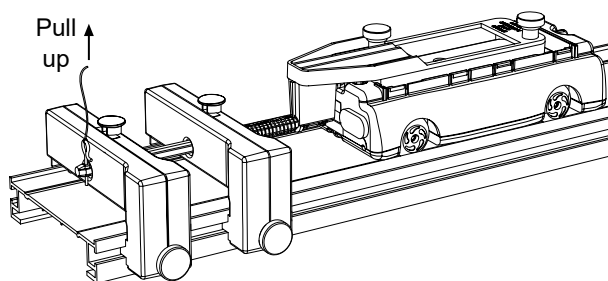


Figure 4

Cart Masses

The Spring Cart Launcher is designed to hold one or two Compact Cart Masses (ME-6755), which can be used to vary the mass of the cart. The launcher's design prevents these masses from shifting or sliding. Place the masses as shown in Figure 5.

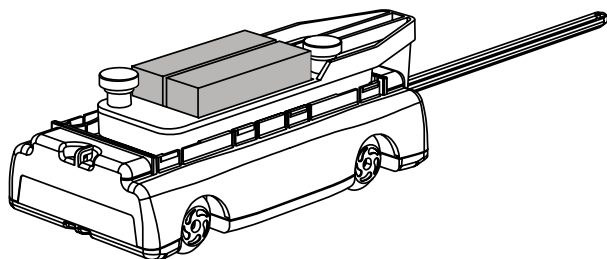


Figure 5

Theory

The spring constant of a spring is given by the equation:

$$k = \frac{F_x}{x} \quad (\text{Eq. 1})$$

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 an object, such as the end of a spring, from position x_1 to position x_2 , the work that you do is equal to the area under the graph of F_x versus x , or:

$$\int_{x_1}^{x_2} F_x dx \quad (\text{Eq. 2})$$

The potential energy of a spring is given by:

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

The kinetic energy of a cart moving on a track is given by:

$$K = \frac{1}{2} mv^2 \quad (\text{Eq. 4})$$

where m is the mass of the cart and v is the cart's velocity.

The change in a cart's gravitational potential energy as it moves up an inclined track is given by:

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

where g is the acceleration due to gravity ($g = 9.8 \text{ m/s}^2$), Δs is the distance traveled along the track in the uphill direction, and θ is the track's angle of inclination.

Sensor-based experiment

In this experiment, you will use PASCO sensors and data collection software to measure various quantities during the launch. A force sensor measures the force you apply to the spring. A motion sensor measures the displacement of the end of the spring as it is compressed, as well as the cart's position and velocity. Compatible sensors and software can be found under **Required equipment** in the **Components** section.

Additional setup

1. Once you have completed Steps 1 through 3 under **Setup and launch**, install a single 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.
2. Level the track so the cart does not roll when released from rest.
3. Clip the motion sensor to the end of the track farthest from the end stop. Aim the sensor along the track and adjust the range switch to the short range setting.
4. Connect the motion sensor and a force sensor to your chosen data collection software. (If you are using PASPORT sensors, you will need to connect the sensors to a PASPORT interface and then connect the interface to the sensor.) For more information on using the software, see the PASCO Capstone or SPARKvue online help.
5. Make sure both sensors are sampling at a rate of 20 Hz.
6. In the settings for the measurement of force, configure the force sensor to measure a pull on its hook as a positive force.
7. In the software, set up graphs of position versus time, velocity versus time, and force versus position.

Part 1: Work and spring potential energy

In the first part of the experiment, you will use Equation 1 to determine the spring constant k for your chosen spring. The force sensor measures F_x and the motion sensor measures x . A plot of F_x versus x can be used to determine the value of k .

1. Place the cart on the track with the launcher shaft through the hole in the end stop, as shown in Figure 6.

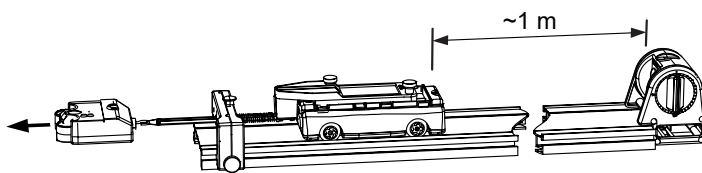


Figure 6

2. Use a piece of string to tie the hook of the force sensor to the launcher shaft, as shown in Figure 6.
3. Pull back with the force sensor so that the end of the spring just touches the end stop. Do *not* compress the spring yet.
4. Zero the force sensor using the software or the TARE button on the sensor.
5. Begin collecting data, then slowly pull back with the force sensor until the spring is *almost* completely compressed.

NOTE: Have a partner hold the track to prevent it from slipping. Make sure they do not block the motion sensor.

6. End data recording. Slowly move the cart away to prevent it from being launched by the spring.
7. Plot a best fit line for the force versus position graph data. The slope of this line is equal to k .
8. Using the program's data analysis tools, measure the area under the graph of force versus position. This area is equal to W , the work done on the spring.
9. From the graph, determine the maximum displacement, or change in position, of the end of the spring.
10. Use Equation 3 to calculate U_{spring} , the potential energy stored in the spring after you compressed it.
11. Compare W to U_{spring} . Do both values have the same (or equivalent) units? What is the percent difference between their values?
12. Repeat Steps 1 through 7 to determine the spring constants of all three springs.
13. Untie the string from the launcher shaft before proceeding to the next section.

Part 2: Spring potential energy and kinetic energy

In this section, 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 just touching the end stop but not compressed.
3. Begin recording data. Wait a few seconds to let the sensor measure the uncompressed position.
4. Without blocking the motion sensor, push the shaft through both end stops and place 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.

NOTE: Before performing the next step, have a partner ready to catch the cart before it reaches the motion sensor. Make sure the partner does not block the motion sensor.

5. Pull the release pin out with a quick jerk to launch the cart. Stop data recording as soon as your partner catches the cart.
6. Using the graph of position versus time, determine the distance x by which the spring was compressed.
7. Use the value of k that you found in Part 1, the distance x from the previous step, and Equation 3 to calculate U_{spring} .
8. Using the graph of velocity versus time, find the velocity of the cart just after the launch.
9. Measure the combined mass of the cart, launcher, and spring.
10. Using Equation 4, calculate the kinetic energy of the cart.
11. Compare the potential energy of the spring shortly before launch to the kinetic energy of the cart immediately after launch. Are these values equal? If not, what might account for the difference?

Traditional experiment

In this experiment, you will determine the spring constant without the use of sensors 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 moves up an inclined track.

Part 1: Spring constant

1. Once you have completed Steps 1 through 3 under **Setup and launch**, install a single end stop about 20 cm away from the end of the track.
2. Clamp a pulley to the end of the track nearest to the end stop, as shown in Figure 7.
3. Position the track so that a mass hanging from the pulley is free to hang over the edge of your lab bench.
4. Level the track so the cart does not roll when released from rest.
5. Place the cart onto the track so that the launcher shaft passes through the hole in the end stop.

- 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, as shown in Figure 7.

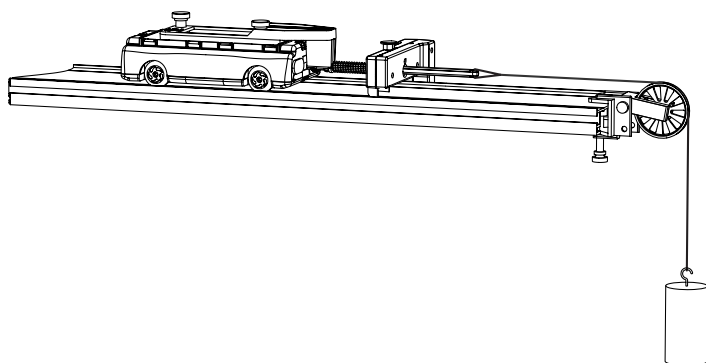


Figure 7

- Adjust the pulley so that the length of string between the pulley and the launcher shaft is horizontal.
- In a table, record the total mass hanging from the string and the position of the cart on the track.
- Add an additional 100 g to the hanging mass.
- Repeat Steps 8 and 9 until you have reached a total hanging mass of about 500 g.
- Calculate the force applied to the spring at each step in the process using the equation:

$$F_x = m_h g$$

where m_h is the hanging mass and $g = 9.8 \text{ m/s}^2$.

- Create a graph of F_x versus cart position.
- Draw a best-fit line of your graph. The slope of this line equals the spring constant k .
- Untie the string from the launcher shaft and remove the pulley before moving on to Part 2.

Part 2: Potential and kinetic energy

- Place a second end stop on the track about 8 cm behind the first end stop.
- Elevate one end of the track by about 20 cm, as shown in Figure 8.

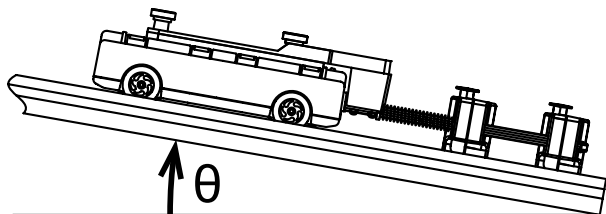


Figure 8

- Hold the cart on the track with the launcher shaft through the hole in the first end stop, with the spring just touching the end stop but not compressed, as shown in Figure 8. Record this position of the cart as x_1 .
- Push the shaft through both end stops, insert the release pin into the shaft, and allow the pin to rest against the second end stop. Record this position of the cart as x_2 .

- Quickly pull the release pin free of the launcher using the attached string, then watch the cart carefully as it ascends the track. Make note of the highest position it reaches, measuring this value to the nearest centimeter if possible. Record this position as x_3 .



NOTE: All positions should be measured relative to the same point on the cart.

- Calculate the spring compression x with the equation:

$$x = x_1 - x_2$$

- Use x , the value of k you determined in Part 1, and Equation 3 to calculate the initial potential energy of the spring.

- Calculate the distance the cart travels using the equation:

$$\Delta s = x_3 - x_2$$

- Measure the total mass m of the cart, launcher, and spring.
- Measure the angle θ that the elevated track forms with the table.
- Use Equation 5 to calculate the change in the cart's gravitational potential energy.
- Compare the initial potential energy of the spring to the maximum gravitational potential energy of the cart. Are the values 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 shown in Figure 9. While recording data from the motion sensor and force sensor, pull the force sensor to compress the spring, then quickly pull out the pin to launch the cart. This process allows you to record compression distance, spring force, and launch velocity in a single data run.

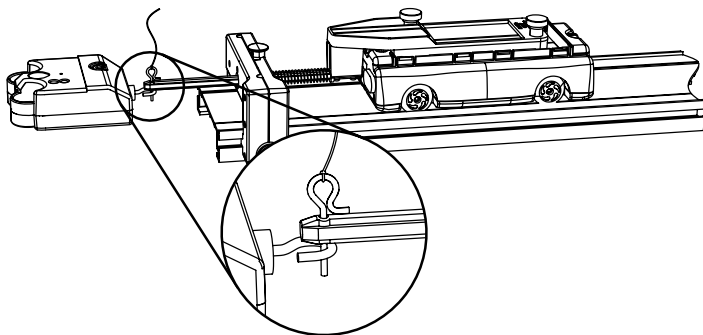


Figure 9

Launch from a hanging mass

Set up an end stop, a Super Pulley, a string, and the release pin as shown in Figure 10. Hang an object of known mass up to about 500 g from the string. Quickly pull the pin out to launch the cart. The spring force in this experiment is equal to the weight of the hanging object.



IMPORTANT: Do NOT use precision masses in this activity. Instead, use a small sandbag or other soft object that will not be damaged or cause damage to the floor when dropped.

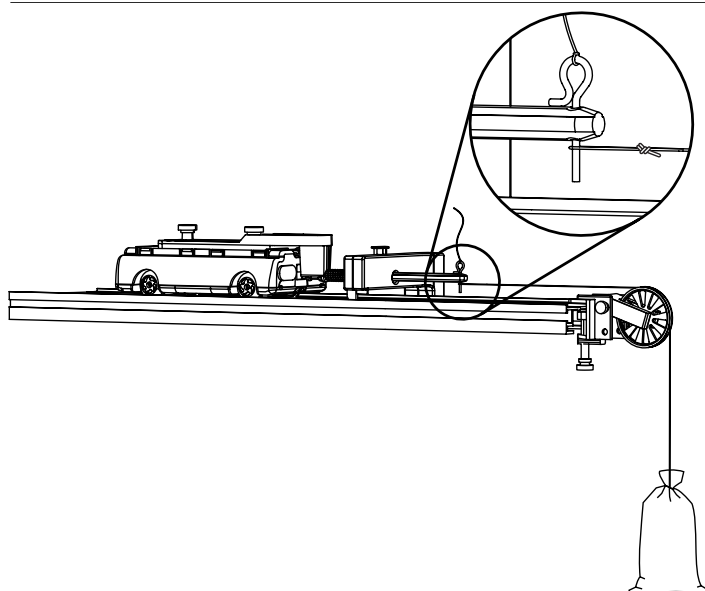


Figure 10

Collision with a fixed object

1. Set up a track with a solid end stop at one end and a motion sensor at the other end. Set the sampling rate for the sensor to 50 Hz.
2. Begin recording data, then give the cart a push to make it roll along the track, strike the end stop with the spring, and bounce off the end stop. Once the bounce occurs, stop recording data.
3. Hold the cart stationary with the spring just touching the end stop, then record a second data run to measure the "zero compression" position.
4. Use a plot of velocity versus time to determine the kinetic energy of the cart before and after the collision.
5. Use a plot of position versus time to determine the maximum amount by which the spring was compressed. Use this value to calculate the maximum potential energy stored in the spring.
6. In this collision, energy is converted from kinetic energy to potential energy and then back to kinetic energy. At each step, how much energy is "lost"? Where does it go?

Software help

The SPARKvue and PASCO Capstone Help provide information on how to use this product with the software. You can access the help from within the software or online.

SPARKvue

Software: Main Menu  > Help

Online: help.pasco.com/sparkvue

PASCO Capstone

Software: Help > PASCO Capstone Help

Online: help.pasco.com/capstone

Experiment files

Download one of several student-ready activities from the PASCO Experiment Library. Experiments include student handouts and teacher notes. Visit pasco.com/freelabs/ME-6843.

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-  Phone 1-800-772-8700 x1004 (USA)
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Limited warranty

For a description of the product warranty, see the Warranty and Returns page at www.pasco.com/legal.

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