

Purpose

In this lab, you will investigate one of the most fundamental principles in physics: conservation of energy.

Materials

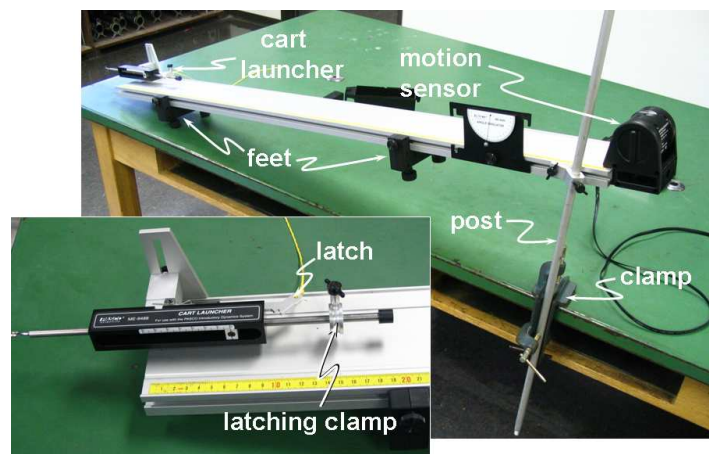
Collision cart, track and attachment, ME-9495 angle indicator, ME-9488 cart launcher, post, plastic-bottomed friction tray, force sensor, motion sensor, black 500 g mass, table clamp, string



Preliminaries

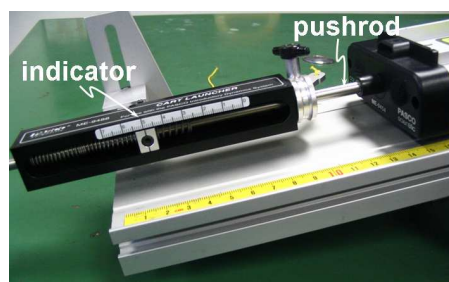
- Place the 500 g mass in the bottom of the friction tray near the center. Measure the mass of the tray (with the 500 g mass installed). Measure the mass of the collision cart. Record the values in the table at right.

cart mass (g)	
tray mass (g)	



- Set up the track with a 10° incline, as shown in the figure at left. Set the lower track feet at the 20 cm mark and ensure that the levelling screws in the feet are completely tightened. (If the screws are extended the track will sway when the cart is launched.) Affix the launcher at the 0 end of the track and the motion sensor at the other.

- Set the cart launcher latching clamp so that when the launcher is cocked the indicator is at the 5 mark. Adjust the height of the cart launcher so that the pushrod pushes the cart at the cart's center of mass. Launch the cart by pulling the string attached to the latch and verify that the cart does not travel past the 100 cm mark. If it does, readjust the launcher to a smaller indicator value when cocked.



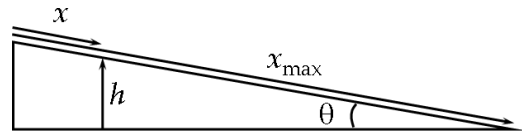
Conservation of energy

- Set up Data Studio to measure Position and Velocity from the motion sensor. Set the Sampling Rate to 20 Hz. Plot the Position and Velocity on a single graph. Check if the motion sensor is working properly and then delete all trial runs.

- Click Start to begin data acquisition, then launch the cart. Allow the cart to travel up the ramp, return and bounce off the end stop a few times before stopping data acquisition.

The total mechanical energy of a system is conserved. That is, the sum of an object's kinetic and potential energies should be a constant. When released, the cart obtains a kinetic energy $KE = \frac{1}{2}mv^2$.

As it rolls up the incline, its potential energy increases, where $PE = mgh$. Note that the height h at the position x is given by $h = (x_{\max} - x) \sin \theta$.



Kinetic energy of the cart

- In Data Studio, create a new calculation. Replace $y=x$ with the following:

$$KE = 0.5 * M_{\text{cart}} * v \wedge 2.$$

Set M_{cart} to be an Experiment constant equal to the mass of the cart in kg and v to be a Data measurement: the velocity of the cart. On the Properties panel, set the X Variable Name to be time, with Units of s and a Type of Time, and the Y Variable name to be KE, with Units of J and a Type of Other.

Potential energy of the cart

- Create a second calculation, where

$$PE = M_{\text{cart}} * g * \sin(\text{theta}) * (\max(x) - x).$$

Set x to be the a Data measurement: the position of the cart. Set g to be the gravitational acceleration, theta to be 10 and select the DEG button for the calculation. The function $\sin()$ is the Data Studio function that calculates the sine function but the default is to assume the argument is in radians (RAD button is set). $\max()$ is a Data Studio function that finds the maximum value of the data. On the Properties panel, set the X Variable Name to be time, with Units of s and a Type of Time, and the Y Variable Name to be PE, with Units of J and a Type of Other.

Total mechanical energy of the cart

- Create a third calculation, where the total energy TE is given by $TE=KE+PE$. On the Properties panel, set the X Variable Name to be time, with Units of s and Type of Time, and the Y Variable Name to be TE, with Units of J and a Type of Other.



Plot the results of the three calculations on a single graph and export it for submission with your lab.

- ? Do you find that the total mechanical energy is conserved? Justify your answer.

? What is the maximum kinetic energy of the system? When in time does the system have its maximum kinetic energy? (Identify this point on your plot. Either use the Annotate button or draw on the plot by hand.)

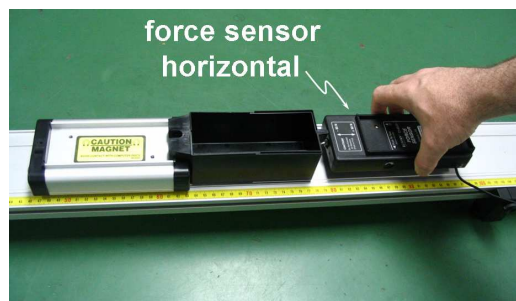
? After launch, what is the maximum potential energy of the system? When in time does the system reach its maximum potential energy? (Identify this point on your plot.)

Dissipative forces

1. Remove the track from the post and adjust the track so that it is level.
2. Hook the friction tray onto the cart as indicated in the figure at right. Delete all previous runs. As in the previous section, launch the cart and record Position and Velocity data.



3. Now connect the force sensor to the PASCO interface and set up the force sensor in Data Studio. (You can remove the motion sensor from the end of the track.) With no load on the force sensor, push the Tare button.



4. Taking care to (i) move at a constant speed and (ii) hold the force sensor horizontally above (not touching) the track, push the friction tray/cart assembly and measure the force required to do so.

? What is the value of the force you recorded? (Use the select tool when computing the mean and standard deviation.)

For dissipative systems, mechanical energy of the system is used to perform work on the external world. For the frictional system here, that work goes into heat and is lost. The work done is just $W = F \cdot x$, where F is the frictional force you measured.

Kinetic energy of the system

5. Create a new calculation where

$$KE2 = 0.5 * M_{sys} * v \wedge 2.$$

Use the Velocity data from the run in part 2 of this section for v and set the mass M_{sys} to be the total mass of the system (cart+friction tray+500 g mass). On the Data Properties panel, set the X Variable Name to be time, with Units of s and a Type of Time. Set the Y Variable Name to be KE2, with Units of J and a Type of Other.

Work done by the system


6. Create a new calculation in which you set

$$W = F * (\max(x) - x).$$

Set F to be an Experimental Constant, using the value of force you obtained in part 4. Set x to be the Data measurement of the Position from part 2 in this section. On the Data Properties panel, set the X Variable Name to be time, with Units of s and a Type of Time. Set the Y Variable Name to be W , with Units of J and a Type of Other.

Total mechanical energy of the system

7. Create another new calculation in which you set $TE2=KE2+W$. On the Data Properties panel, set the X Variable Name to be time, with Units of s and a Type of Time. Set the Y Variable Name to be $TE2$, with Units of J and a Type of Other.

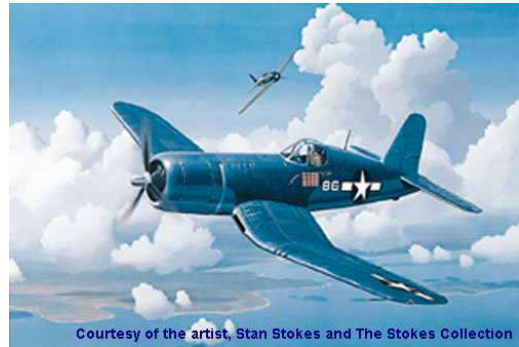
 Plot the results of the three calculations and export it for submission with the handout.

? Is the Total Energy conserved? Justify your answer.

? What is the maximum kinetic energy of the system? When in time does this occur? (Identify the point on your plot.)

Making connections

💡 Fighter pilots believe strongly in the maxim “Speed is life.” As a result, they are always aware of the “energy state” of their aircraft. Why should a pilot care about altitude?



💡 Why would physicists refer to gravity as a “conservative” force? Are there liberal forces?