

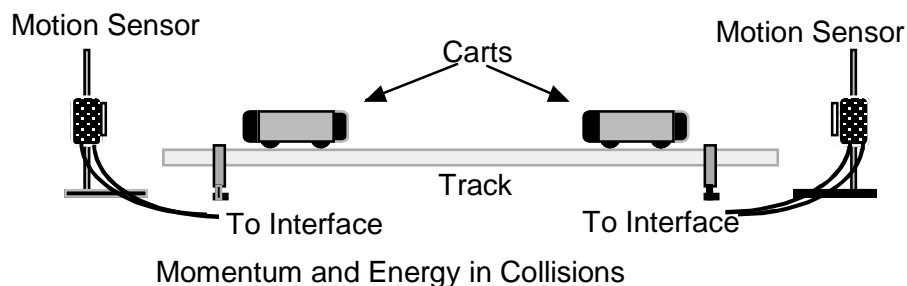
Momentum, Energy, and Collisions

Microcomputer-Based Lab

In this experiment you will analyze various collisions involving two carts on a track. You will determine whether momentum is conserved in each case, and whether kinetic energy is conserved.

The Experiment

Note that in our setup the motion sensors are mounted at the ends of the track.



Theory

The momentum of an object is its mass multiplied by its velocity. Momentum is a vector, so the direction is important.

QUESTION 1: In this experiment the motion is one-dimensional. How can you account for the direction of momentum in this case?

The kinetic energy of an object is given by $KE = \frac{1}{2} mv^2$. Kinetic energy is not a vector, so you don't need to worry about direction.

QUESTION 2: In this experiment you will be determining whether momentum and kinetic energy are conserved. What does it mean for a quantity to be conserved in a collision?

There are several types of collisions to investigate in this experiment. These are:

- *Super-elastic*, in which kinetic energy is larger after a collision.
- *Elastic*, in which kinetic energy is conserved.
- *Inelastic*, in which kinetic energy is lost.
- *Completely inelastic*, in which the objects stick together after the collision.

PROCEDURE

Similar to how a bat navigates, the motion sensors used in the experiment measure the position of the carts by bouncing ultrasonic waves off them. If your position graphs are not smooth, check to see whether the motion sensors are picking up stray reflections from you or from other objects placed close to the track.

Part I – Preliminary measurements

1. Check that the motion sensor at the left end of the track is connected to the Dig/Sonic 1 port on the Vernier interface. The motion sensor at the right end should be plugged in to Dig/Sonic 2. It is very important that the track is horizontal – levels are available for you to check this.
2. You should have two different carts, one with a plunger and one without, as well as one black mass. Each of these items has a mass of about 500 g, but you should weigh them.
3. The motion sensors have a limited range, so all collisions should take place at the center of the track. In collisions where one cart is initially stationary, this is easily accomplished by placing that cart at the center of the track.
4. Place the two carts at rest at the center of the track, stuck together by their Velcro bumpers. Keep your hands clear of the carts and click . Click on All Sensors to zero both motion sensors. This will establish the same coordinate system for both sensors. Check that the zeroing was successful by clicking and rolling the still-linked carts back and forth on the track. The graphs for each motion detector should overlap for a 30-40 cm range near the center of the track. If not, repeat the zeroing process.

QUESTION 3. Is the positive direction to the left or to the right in this experiment?

5. To determine the effect of friction in the experiment, record one cart as it rolls along the track from left to right. To do this, click and then give the cart a push toward the center of the track. You should see a graph of the cart's position as a function of time, and another showing its velocity as a function of time. The position graph will generally be smoother than the velocity graph, so we'll use the position graph to take measurements. To measure velocity from the position graph, click and drag with the mouse to select a small region. Click the Regression button, . A box will pop up with several checkboxes – the only box checked should be the one corresponding to the graph you're interested in. Hit OK. The velocity of the cart is the slope of the position graph, which is the m value.

QUESTION 4. Measure the cart's velocity at two or three times separated by about 0.5 seconds. What do you observe? Is momentum conserved in this situation? Does the Law of Conservation of Momentum apply here? Explain.


In trials 1-9 one cart is initially stationary. If you start the second cart to the left of the stationary cart, the graphs labeled 1 will apply to the stationary cart and the graphs labeled 2 will apply to the second cart.


Please try to stop the carts from rolling into the motion sensors after the collision.

The spring-loaded plunger on the plunger cart can be armed by pushing it in and pulling up. It can then be triggered by striking the pin above the plunger with one of the black masses.

Part II – Collisions using magnetic bumpers

Turn the plunger cart around so its magnetic bumpers face the second cart (we'll call that the collision cart). In the collisions involving the magnetic bumpers, be careful that the carts do not actually make contact. In other words, the initial speed should not be too large. For each trial, record the mass of each cart, and the velocity of each cart before and after the collision.

- Trial 1 – Equal masses. With no extra mass on either cart, place a cart at the center of the track. Click  and then roll the second cart toward the first. You should see a position graph and a velocity graph for each cart. Measure four velocity values – the velocity of each cart just before the collision, and the velocity of each immediately after the collision.

To measure each velocity, select a small region of one graph either just before or just after the collision. As you did in part I, use the Regression button, , to find the slope, which is the velocity. You'll need to do more than once to find all the velocities you need, selecting the appropriate graph or graphs each time. Note that you can use the velocity graph to help you select an appropriate region on the position graph.

- Trial 2 – Stationary cart has more mass. Place the black mass on the cart that is initially stationary, and repeat the experiment.
- Trial 3 – Stationary cart has less mass. Move the mass to the cart that is given the initial push, and repeat the experiment.

QUESTION 5. The equal mass collision with the magnetic bumpers is a special case. Do you notice anything special about it, compared to the collisions between unequal masses?

Part III – Collisions using Velcro bumpers

Turn the plunger cart around again so its Velcro bumpers face the collision cart. The plunger should be all the way in. In these collisions the two carts should stick together after the collision.

- Trial 4 – Equal masses. As with part II, place one cart at rest at the center of the track, and roll the second cart toward it.
- Trial 5 – Unequal masses. Place the mass on one of the carts, and repeat the experiment with one cart stationary. It's up to you which cart you put the mass on.

Part IV – A “collision” with everything initially stationary

Place the carts next to each other at the center of the track, with the plunger next to the collision cart. The plunger should be armed. It's probably better if the plunger is not all the way in, so the carts won't stick together with the Velcro.

- Trial 6 – Equal masses. Fire off the plunger by giving the pin on top of the cart a sharp tap with one of the black masses.
- Trial 7 – Unequal masses. Place the mass on the collision cart, and repeat the experiment. Note that you can arm the plunger cart again by pushing the plunger back in and pulling up.

Part V – The carts make contact but do not stick together

For these collisions make sure the plunger is all the way out, and facing the collision cart.

- Trial 8 – Equal masses. Place one cart at rest in the center of the track, and roll the other one towards it. The plunger should hit the collision cart (or vice versa), and the carts should move separately after the collision.
- Trial 9 – Unequal masses. Repeat with the black mass on one of the carts.

Extensions

If there is time, try other collisions. Note that there is extra space in the data table. For instance, you could have both carts moving toward each other before the collision, or have both carts traveling in the same direction before the collision. These are a little trickier, because you need to arrange it so the collision takes place close to the center of the track.

QUESTIONS AND ANALYSIS

After completing the momentum and energy calculations and filling in the tables, what can you conclude about the collisions you observed? Was momentum conserved in each collision? Was kinetic energy conserved?

QUESTION 6. What are some of the possible sources of error in this experiment?

QUESTION 7. Four types of collisions as described in the Theory section. What type were the collisions you carried out in Part II with the magnetic bumpers? What about the collisions in part III with the Velcro, the collisions where everything was initially at rest, and the collisions in part V where the carts did not stick together afterwards?

QUESTION 8. In part IV you carried out collisions in which neither cart was moving beforehand, and both were moving afterwards. Could you set up a collision in which the reverse happened? Explain how you could do this, and what type of collision it would be. Would momentum be conserved in this collision? You can even try it in the lab to see if you're correct.