

PHY 123 Lab 6 – Conservation of Linear Momentum

The purpose of this lab is to demonstrate conservation of linear momentum in collisions of objects and compare elastic and inelastic collisions.

Equipment

- LabQuest 2
- 2 Vernier Dynamics cart
- Vernier Dynamics track
- Vernier Photogate
- Cart picket fence
- 500 g standard mass



Introduction

Conservation laws are very powerful tools in understanding physical phenomena. What takes place in collisions is governed by momentum conservation. The experiment will use a dynamics track to study collisions in one dimension and demonstrate that momentum is conserved in these relatively simple processes. They are simple because no external forces (e.g., friction) act in the horizontal direction.

You will measure the velocity of each dynamic cart, before and after the collision, by measuring the amount of time that a single 5 cm wide bar (cart picket fence) on top of a cart blocks the photogate. Using the width of the single bar of the picket fence, $w = 5 \text{ cm}$, and the time that it blocks the photogate you can calculate the speed of the cart with the formula:

$$v = \frac{0.05\text{m}}{t}$$

Linear momentum of an object of mass m and velocity v is defined as:

$$p = mv$$

Linear momentum is a vector quantity. You will need to pay close attention to the direction of each cart before and after collisions in order to find the momentum vector. Since the collisions for this experiment are only in one dimension, the direction of this vector is given by the sign according to your reference. This is important to calculate the total linear momentum before and after collisions.

The mass of the carts is 500 g and it can vary according to the accessories that are incorporated, which are small comparing with the cart. Therefore, you can use the 500 g as the total mass of each cart and assume an absolute error of 1 g.

Procedure: Elastic collision light cart into heavy cart

In this part of the lab, there will be an elastic collision between a moving light cart and a stationary heavy cart. First, you will need to add the 500 g standard mass in the middle of one of the carts to make this car the “heavy cart”.

For the first collision, you will collide the light cart with the heavy cart, which is at rest (the target). Make sure the dynamics track is level. If you release a cart at rest in the area between the two photogates, it should not move. Set the carts with the non-velcro ends of each cart facing each other.

The photogates should be attached to the brackets about 30 cm apart in the middle of the track. Connect both interfaces to the digital channel ports of the LabQuest2. The photogate connected to Digital channel 1 is Gate #1 and the other Gate #2.

On the right of the meter screen tap “Mode” and then select “Gate” as the Photogate Mode, and the length of the object is the width of the single bar of the picket fence (0.05 m).

Place the heavy cart in between the photogates, closer to the second photogate, and the light cart before the first photogate. Gently launch the light cart toward the resting heavy cart. **Make sure to catch the carts before they run off the track.**

After you become familiar with the procedure you are ready to start the experiment. Position the light incident cart before Gate #1 and the heavy target cart between both photogates and close of Gate #2. Make sure your incident cart goes into Gate #1 first.

Select Table screen and click “Start” to collect data. After the collision, make sure you Stop data collection. You will see a table with several rows and columns, focus your attention at the next part of your table (the order of the last two rows may change)

TABLE 1

D1: Ga (s)	D1: (m/s)	D2: Ga (s)	D2: (m/s)
t_{light}	v_{light}		
		t'_{heavy}	v'_{heavy}
t'_{light}	v'_{light}		

The first and third columns are time and the second and fourth columns are velocity.

Record these values in your notebook, note that the unprimed variables are for values of time and velocity before the collision and the primed values are for the values after collision.

Procedure: Elastic collision heavy cart into light cart

This part is exactly the same as the previous part of your lab except that you will slide the heavy cart into the light cart that is at rest. Again, start the data collection and launch the heavy cart (you may need to apply more force to the heavy cart to increase the initial velocity). Make sure your incident cart goes into Gate #1.

TABLE 2

D1: Ga (s)	D1: (m/s)	D2: Ga (s)	D2: (m/s)
t_{heavy}	v_{heavy}		
		t'_{light}	v'_{light}
		t'_{heavy}	v'_{heavy}

Notice the order of the carts when they pass through Gate #2. Record these values in your notebook, note that the unprimed variables are for values of time and velocity before the collision and the primed values are for the values after collision.

Note that for both elastic collisions, one of the carts has to pass through one photogate twice, if that doesn't happen, you will need to increase the initial velocity.

Procedure: Inelastic collision heavy cart into light cart

In this part, you will observe a perfectly inelastic collision between a moving heavy cart and a stationary light cart. Perfectly inelastic means that the objects stick together after the collision, which is accomplished by a piece of velcro on each cart. For this collision, you will collide the heavy cart into the light cart. Now, make sure that the velcro ends of each cart are facing each other. Launch the heavy cart and observe. Make sure your incident cart goes into gate #1. For this experiment, you will only record two time intervals: the heavy cart in Gate #1 before the collision, and the light in Gate #2 after the collision.

TABLE 3

D1: Ga (s)	D1: (m/s)	D2: Ga (s)	D2: (m/s)
t_{heavy}	v_{heavy}		
		t'_{light}	v'_{light}
		t'_{heavy}	v'_{heavy}

Notice that you only need the time and velocity of the light cart in Gate #2. Record these values in your notebook, note that the unprimed variables are for values of time and velocity before the collision and the primed values are for the values after collision.

Analysis

Calculate momentum for each cart before and after collision using Eq. (2). Assume an absolute uncertainty of 0.1 m/s for the velocity (this considers the propagation of error due to any imperfection of the length of width of the single bar, the uncertainty in time can be neglected). Propagate the uncertainty in the mass and the velocity to find the absolute uncertainty in the momentum. This can be done with the following equation:

$$\frac{\Delta p}{p} = \sqrt{\left(\frac{.001\text{kg}}{m}\right)^2 + \left(\frac{0.1\text{m/s}}{v}\right)^2}$$

The kinetic energy of each cart is given by

$$KE = \frac{1}{2}mv^2$$

You should propagate the uncertainty taking in to account the uncertainty for both the velocity v and the mass m . This can be done with the following equation:

$$\frac{\Delta KE}{KE} = \sqrt{\left(\frac{\Delta m}{m}\right)^2 + \left(2\frac{\Delta v}{v}\right)^2}$$

Now it is time to test the Conservation of Linear Momentum and Conservation of Energy laws.

To do that, you will need to calculate the total momentum before and after each collision, and those momenta should be **consistent** within the estimates of uncertainty. Use the equation:

$$p_{before} = p_{after}$$

$$p_{light} + p_{heavy} = p'_{light} + p'_{heavy}$$

Note 1: Momentum is a vector and you will need to add the sign of each momentum according to the directions of the velocity of each cart before and after collision.

Note 2: The absolute uncertainty in each momentum value is not the same as the absolute uncertainty for the total momentum before or after, you will need to propagate the uncertainty again using the uncertainty for each individual momentum, according to the following equation:

$$\Delta p_{total} = \sqrt{(\Delta p_1)^2 + (\Delta p_2)^2}$$

Is the linear momentum conserved for each collision?

To find the total kinetic energy before and after collision, use the next equation with Eq. (3)

$$KE_{before} = KE_{after}$$

$$KE_{light} + KE_{heavy} = KE'_{light} + KE'_{heavy}$$

Is the kinetic energy conserved for each collision?

Answer the following questions:

1. Do you need to take into account the direction of the velocities of the carts before and after the collision when you calculate Kinetic Energy? Why or why not?
2. Assume that you will do the elastic collision heavy into light cart experiment one more time, and instead of launching the heavy cart you are pushing it all the time (before and even after the collision). What could you say about the conservation of momentum in this case, is it conserved?
3. Assume that you will do the experiment one more time but the dynamic track is not level, should the linear momentum be conserved in this situation? Why or why not?