Conservation of Momentum   Name:

PES 1150 Report

Objective

The purpose of this experiment was to observe collisions between two carts, testing for the validity of the conservation of momentum. Also, we were attempting to ensure conservation of momentum continues to hold true for different types of collisions (elastic and inelastic).

Data and Calculations

Part A: Setup

1. Measure the masses of your carts and record them in your data table. The carts are labeled as "1" and "2".

Mass of cart 1	0.510 kg

Mass of cart 2	0.498 kg

Part B: Elastic Collision

From the position graphs you can determine the velocity before and after the collision for each cart. Measure the velocity for each cart, before and after collision, and enter the four values in the data table.

Repeat Step 9 two more times with the magnetic bumpers, recording the velocities in the data table.

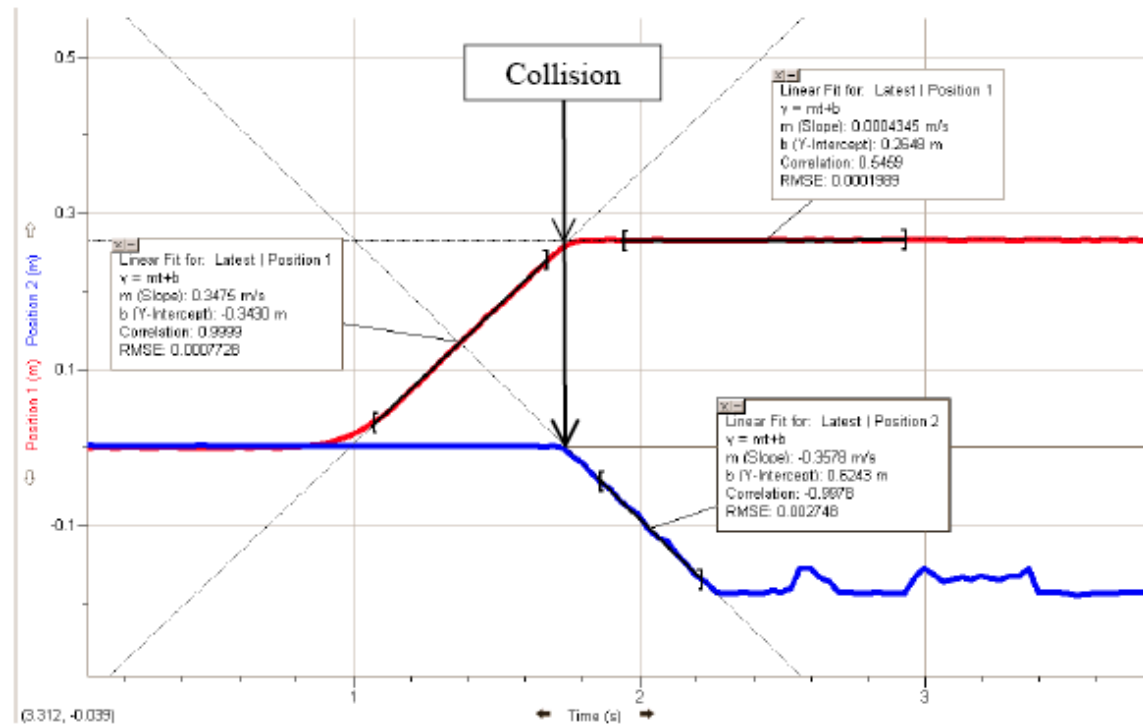Attach **one** graph printout to demonstrate how you measured the velocities.

Figure 1: Experimental Data Obtained from Logger Pro for an Elastic Collision

Run number	Velocity of cart 1 before collision	Velocity of cart 2 before collision	Velocity of cart 1 after collision	Velocity of cart 2 after collision
	(m/s)	(m/s)	(m/s)	(m/s)
1	0.3475	0	0.0004345	0.3578
2	0.3475	0	0.0004345	0.3578
3	0.3475	0	0.0004345	0.3578

Run number	Momentum of cart 1 before collision (kg·m/s)	Momentum of cart 2 before collision (kg·m/s)	Momentum of cart 1 after collision (kg·m/s)	Momentum of cart 2 after collision (kg·m/s)	Total momentum before collision (kg·m/s)	Total momentum after collision (kg·m/s)	Ratio of total momentum after/before
1	0.177225	0	0.0002215	0.1781844	0.177225	0.1784059	1.0067
2	0.177225	0	0.0002215	0.1781844	0.177225	0.1784059	1.0067
3	0.177225	0	0.0002215	0.1781844	0.177225	0.1784059	1.0067

Show examples of your work

Determining the velocity of Cart 1 before the collision:

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Using the best fit lines from Logger Pro, we are given the following equation for Cart 1 (red line) before the collision:

$$position\ 1 = \left(0.3475\frac{m}{s}\right)t + \left(-0.3430\,m\right)$$

If we compare the equation for kinematic 2D motion for the x-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$x = v_{o,x}t + x_o$$

$$x = \left(0.3475\frac{m}{s}\right)t + \left(-0.3430\,m\right)$$

Thus:

$v_{o,x}$ [m/s]	x_o [m]
0.3475	-0.3430

Determining the velocity of Cart 1 after the collision:

Using the best fit lines from Logger Pro, we are given the following equation for Cart 1 (red line) after the collision:

$$position\ 1 = \left(0.0004345\frac{m}{s}\right)t + \left(0.2648\,m\right)$$

If we compare the equation for kinematic 2D motion for the x-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$x = v_{o,x}t + x_o$$

$$x = \left(0.0004345\frac{m}{s}\right)t + \left(0.2648\,m\right)$$

Thus:

$v_{o,x}$ [m/s]	x_o [m]
0.0004345	0.2648

Determining the velocity of Cart 2 after the collision:

Using the best fit lines from Logger Pro, we are given the following equation for Cart 2 (blue line) after the collision:

$$position\ 2 = \left(-0.3578\,\frac{m}{s}\right)t + (0.6243\,m)$$

If we compare the equation for kinematic 2D motion for the x-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$x = v_{o,x}t + x_o$$

$$x = \left(-0.3578\,\frac{m}{s}\right)t + (0.6243\,m)$$

Thus:

$v_{o,x}$ [m/s]	x_o [m]
0.3578	0.6243

** [NOTE: By examining the setup of the system (see comments above), we can see that the second sensor will record a negative velocity toward the sensor for cart 2. We then must change its sign to compensate for the direction the cart is actually moving. Recall that a velocity is *both* a magnitude and direction – so both must be carefully considered when analyzing momentum problems.] **

Determining the momentum of Cart 1 before the collision:

We know that momentum is given by:

$$p = mv$$

Using the velocity we found from above, we can plug everything right into the equation for momentum.

$$p_{1,before} = (0.510\ kg)\left(0.3475\,\frac{m}{s}\right) = 0.177225\ N\,s$$

$$p_{1,before} = 0.177225\ \frac{kg\ m}{s}$$

Determining the momentum of Cart 1 after the collision:

$$p_{1,after} = (0.510\ kg)\left(0.0004345\,\frac{m}{s}\right) = 0.000221595\ N\,s$$

$$p_{1,after} = 0.000221595\ \frac{kg\ m}{s}$$

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Determining the momentum of Cart 2 after the collision:

$$p_{2,after} = (0.498 \ kg)\left(0.3578 \frac{m}{s}\right) = 0.1781844 \ N \ s$$

$$\boxed{p_{2,after} = 0.1781844 \ \frac{kg \ m}{s}}$$

Determining the total momentum before the collision:

$$p_{Total,before} = \sum_{i=1}^{n} p_{i,before} = p_{1,before} + p_{2,before}$$

$$p_{Total,before} = \left(0.177225 \frac{kg \ m}{s}\right) + \left(0 \frac{kg \ m}{s}\right)$$

$$\boxed{p_{Total,before} = 0.177225 \ \frac{kg \ m}{s}}$$

Determining the total momentum after the collision:

$$p_{Total,after} = \sum_{i=1}^{n} p_{i,after} = p_{1,after} + p_{2,after}$$

$$p_{Total,after} = \left(0.000221595 \frac{kg \ m}{s}\right) + \left(0.1781844 \frac{kg \ m}{s}\right)$$

$$\boxed{p_{Total,after} = 0.178405995 \ \frac{kg \ m}{s}}$$

Determining the ratio of total momentums (After/Before):

$$Ratio \ of \ total \ momentums = \frac{p_{Total,after}}{p_{Total,before}}$$

$$\boxed{Ratio \ of \ total \ momentums = \frac{0.178405995 \frac{kg \ m}{s}}{0.177225 \frac{kg \ m}{s}} = 1.0067}$$

Since the ratio of the total momentum is nearly exactly 1, this means momentum is conserved, and the theory holds true.

Part C: Inelastic Collision

Change the collision by turning the carts so the Velcro bumpers face one another. The carts should stick together after collision. Practice making the new collision, again starting with cart 2 at rest.

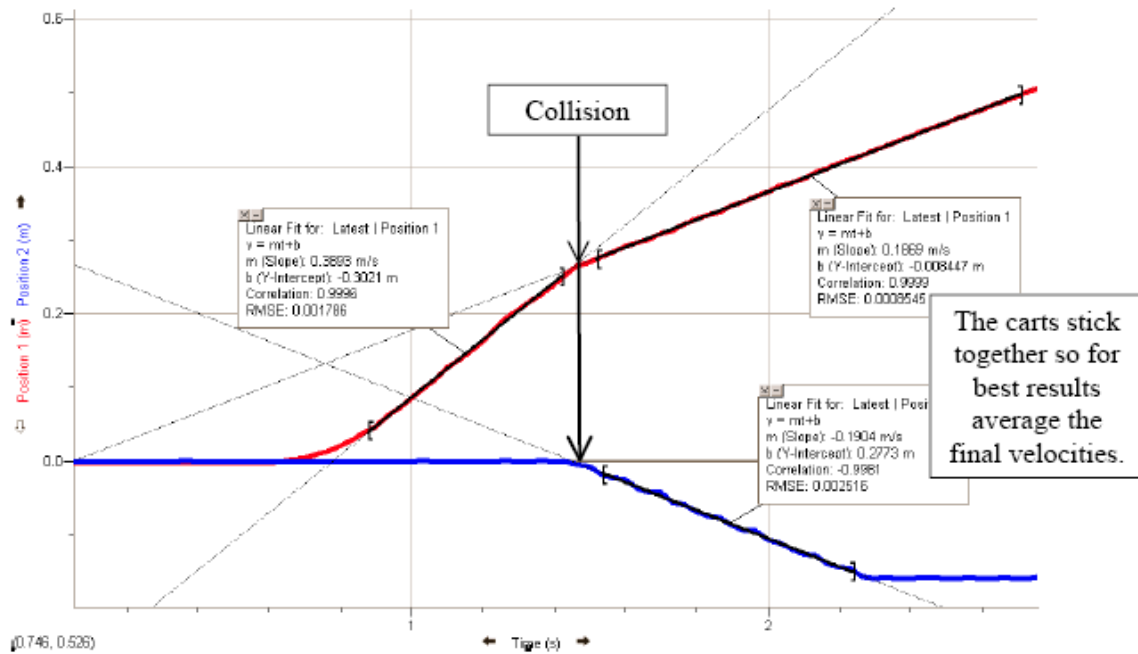Repeat the previous step two more times with the Velcro bumpers.

Figure 2: Experimental Data Obtained from Logger Pro for an Inelastic Collision

Run number	Velocity of cart 1 before collision	Velocity of cart 2 before collision	Velocity of cart 1 after collision	Velocity of cart 2 after collision
	(m/s)	(m/s)	(m/s)	(m/s)
1	0.3893	0	0.18865	0.18865
2	0.3893	0	0.18865	0.18865
3	0.3893	0	0.18865	0.18865

Run number	Momentum of cart 1 before collision (kg·m/s)	Momentum of cart 2 before collision (kg·m/s)	Momentum of cart 1 after collision (kg·m/s)	Momentum of cart 2 after collision (kg·m/s)	Total momentum before collision (kg·m/s)	Total momentum after collision (kg·m/s)	Ratio of total momentum after/before
1	0.198543	0	0.0962115	0.0939477	0.198543	0.1901592	0.95777
2	0.198543	0	0.0962115	0.0939477	0.198543	0.1901592	0.95777
3	0.198543	0	0.0962115	0.0939477	0.198543	0.1901592	0.95777

Show examples of your work

Determining the velocity of Cart 1 before the collision:

Using the best fit lines from Logger Pro, we are given the following equation for Cart 1 (red line) before the collision:

$$position\ 1 = \left(0.3893\frac{m}{s}\right)t + \left(-0.3021m\right)$$

If we compare the equation for kinematic 2D motion for the x-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$x = v_{o,x}t + x_o$$

$$x = \left(0.3893\frac{m}{s}\right)t + \left(-0.3021m\right)$$

Thus:

$v_{o,x}$ [m/s]	x_o [m]
0.3893	-0.3021

Determining the velocity of Cart 1 after the collision:

Using the best fit lines from Logger Pro, we are given the following equation for Cart 1 (red line) after the collision:

$$position\ 1 = \left(0.1869\frac{m}{s}\right)t + \left(-0.003447\,m\right)$$

If we compare the equation for kinematic 2D motion for the x-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$x = v_{o,x}t + x_o$$

$$x = \left(0.1869\,\frac{m}{s}\right)t + \left(-0.003447\,m\right)$$

Thus:

$v_{o,x}$ [m/s]	x_o [m]
0.1869	-0.003447

Determining the velocity of Cart 2 after the collision:

Using the best fit lines from Logger Pro, we are given the following equation for Cart 2 (blue line) after the collision:

$$position\ 2 = \left(-0.1904\,\frac{m}{s}\right)t + \left(0.2773\,m\right)$$

If we compare the equation for kinematic 2D motion for the x-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$x = v_{o,x}t + x_o$$

$$x = \left(-0.1904\,\frac{m}{s}\right)t + \left(0.2773\,m\right)$$

Thus:

$v_{o,x}$ [m/s]	x_o [m]
0.1904	0.2773

** [NOTE: By examining the setup of the system (see comments above), we can see that the second sensor will record a negative velocity toward the sensor for cart 2. We then must change its sign to compensate for the direction the cart is actually moving. Recall that a velocity is *both* a magnitude and direction – so both must be carefully considered when analyzing momentum problems.] **

Determining the average velocity of the two carts after the collision:

$$\langle v \rangle = \frac{v_1 + v_2}{2} = \frac{0.1869\,\frac{m}{s} + 0.1904\,\frac{m}{s}}{2} = 0.18865\,\frac{m}{s}$$

Determining the momentum of Cart 1 before the collision:

We know that momentum is given by:

$$p = mv$$

Using the velocity we found from above, we can plug everything right into the equation for momentum.

$$p_{1,before} = (0.510 \ kg)\left(0.3893\frac{m}{s}\right) = 0.198543 \ N \ s$$

$$\boxed{p_{1,before} = 0.198543 \ \frac{kg \ m}{s}}$$

Determining the momentum of Cart 1 after the collision:

$$p_{1,after} = (0.510 \ kg)\left(0.18865\frac{m}{s}\right) = 0.0962115 \ N \ s$$

$$\boxed{p_{1,after} = 0.0962115 \ \frac{kg \ m}{s}}$$

Determining the momentum of Cart 2 after the collision:

$$p_{2,after} = (0.498 \ kg)\left(0.18865\frac{m}{s}\right) = 0.0939477 \ N \ s$$

$$\boxed{p_{2,after} = 0.0939477 \ \frac{kg \ m}{s}}$$

Determining the total momentum before the collision:

$$p_{Total,before} = \sum_{i=1}^{n} p_{i,before} = p_{1,before} + p_{2,before}$$

$$p_{Total,before} = \left(0.198543\frac{kg \ m}{s}\right) + \left(0\frac{kg \ m}{s}\right)$$

$$\boxed{p_{Total,before} = 0.198543 \ \frac{kg \ m}{s}}$$

Determining the total momentum after the collision:

$$p_{Total,after} = \sum_{i=1}^{n} p_{i,after} = p_{1,after} + p_{2,after}$$

$$p_{Total,after} = \left(0.0962115 \frac{kg\,m}{s} \right) + \left(0.0939477 \frac{kg\,m}{s} \right)$$

$$\boxed{p_{Total,after} = 0.1901592 \frac{kg\ m}{s}}$$

Determining the ratio of total momentums (After/Before):

$$Ratio\ of\ total\ momentums = \frac{p_{Total,after}}{p_{Total,before}}$$

$$\boxed{Ratio\ of\ total\ momentums = \frac{0.1901592 \frac{kg\,m}{s}}{0.198543 \frac{kg\,m}{s}} = 0.95777}$$

Since the ratio of the total momentum is nearly exactly 1, this means momentum is conserved, and the theory holds true.

Additional Questions

1. If the total momentum for a system is the same before and after the collision, we say that momentum is *conserved*. If momentum were conserved, what would be the ratio of the total momentum after the collision to the total momentum before the collision?

If momentum is conserved, then the ratio of the total momentum after the collision to the total momentum before the collision would be exactly 1.

2. Is momentum conserved in the magnetic bumper collisions? Back up your answer.

The ratio of the total momentum after the collision to the total momentum before the collision for the magnetic bumper collision was 1.0067. Since this is *very* close to 1, this shows that momentum is conserved. (Evidence is provided in question 1 above.)

3. How about the Velcro collisions? Back up your answer.

The ratio of the total momentum after the collision to the total momentum before the collision for the Velcro collision was 0.95777. Since this is *very* close to 1, this shows that momentum is conserved. (Evidence is provided in question 1 above.)

4. Classify the collision types as elastic or inelastic.

The collision with the magnetic bumpers is elastic (since they do not stick together).

The collision with the Velcro is inelastic (since the two carts stick together and move off with the same velocity after the collision).

5. Name 5 *real world* examples of elastic collisions.

     a.   A tennis ball hitting a racquet.

     b.   Two cars hitting each other perpendicularly.

     c.   A rock falling out of the window onto a windshield.

     d.   A stunt man hitting the cement and bouncing.

     ~~a.~~e. A basketball player dribbling a ball.

6. Name 5 *real world* examples of inelastic collisions.

     a.   Throwing gum at the wall (and it sticking)

     b.   Two cars colliding head on.

     c.   A baseball player catching a line drive baseball in his mitt.

     d.   A bullet shot at a block of wood and getting stuck inside.

     ~~a.~~e. Chuck Norris' fist meeting his enemy's face.

Conclusion

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Calibration of Sensors
- Parallax in Measurement
- Snagging and catching
- Friction
- Sensor limitation parameters
- Computer processor speed and reading registration
- Sensor Alignment
- Other …

A few of the potential errors listed above may be applicable to YOUR experiment.