PHYS 1405 – Conceptual Physics 1
Laboratory #5
Momentum and Collisions

Investigation: Is the total momentum of two objects conserved during collisions?

What to measure: Velocities of two carts colliding on an air track, masses of those carts

Measuring devices: Air track with carts, photogates, various attachments for collisions

Calculations: total momentum, percentage difference

INTRODUCTION

In this experiment we shall investigate the nature of momentum. The momentum of an object depends on its mass and velocity, and is given by the formula

$$p = mv$$

Notice that momentum will have the very strange units of (kg m/s). When two objects interact, say in a collision, we can talk about the total momentum of the system. This is the momentum of both objects added together:

$$p_{tot} = m_1v_1 + m_2v_2$$

The purpose of this lab is to compare the total momentum of a system before the collision to the total momentum of a system after the collision. We shall set up four different situations, and see what happens to the colliding objects in each situation. We shall use the "air track" to study the collisions, because the air track is almost frictionless, thus eliminating one unknown factor. The photogates hooked up to the computer will help us measure the velocities of the "cars" as they move along the air track.

Situation 1: A "Perfect" Elastic Collision

A perfect elastic collision is one where the two objects "bounce off of" one another. We shall simulate this using a rubber band on one cart (Car #1), which will contact a "knife edge" on the other cart (Car #2). Use the bottom set of holes in all cases. Determine the masses of the cars.

Question 1: What do you expect will happen if Car #2 is stationary on the track and Car #1 collides with it? Arrive at an agreement with your group *before you actually try it* and write this prediction out. Give the prediction to Jim before you try.

Begin with Car #2 stationary between the photogates and Car #1 outside of gate #1. Make sure the air is turned on and that the cars can slide freely. Hit the "Collect" button on the computer, and push the car through Gate #1. The computer will display the velocity of Car #1 as it passes through Gate #1. Call this v_{1b} (Velocity of 1 before the collision). After the collision, measure the velocity of Car #2 as it passes through Gate #2. This will be v_{2a}. Car #1 may also pass through a gate; if so, record its velocity as v_{1a}. Remember that if one of the cars has a velocity opposite to the direction that you initially sent Car #1, that velocity is considered negative. Every time you take data, you will have 4 velocity values to record, and 4 momentum values to calculate. Some of those values may be zero, but there will always be 4 values.

Before Collision		After Collision	
Mass of Cart #1 m_1 (kg)	Mass of Cart #2 m_2 (kg)	Mass of Cart #1 m_1 (kg)	Mass of Cart #2 m_2 (kg)
Velocity of Cart #1 Before v_{1B} (m/s)	Velocity of Cart #2 Before v_{2B} (m/s)	Velocity of Cart #1 After v_{1A} (m/s)	Velocity of Cart #2 After v_{2A} (m/s)
Momentum of Cart #1 Before $m_1 v_{1B}$ (kg m/s)	Momentum of Cart #2 Before $m_2 v_{2B}$ (kg m/s)	Momentum of Cart #1 After $m_1 v_{1A}$ (kg m/s)	Momentum of Cart #2 After $m_2 v_{2A}$ (kg m/s)
Total Momentum Before $m_1 v_{1B} + m_2 v_{2B}$ (kg m/s)		Total Momentum After $m_1 v_{1A} + m_2 v_{2A}$ (kg m/s)	

Question 2: Describe in a few sentences what happens to both cars after the collision. How accurate was your prediction?

Do this five times, gathering 5 sets of data. Try a different speed for Car #1 every time. Calculate the total momentum of the system before the collision and the total momentum after. Then calculate the percentage difference between the "before" and "after" momentums, using the formula:

$$Percentage\ Difference = 100\% \times \frac{(p_{before} - p_{after})}{p_{before}}$$

Create a data table with one row for each trial, and the following columns: v_{1b}, v_{2b}, v_{1a}, v_{2a}, p_{tot} before, p_{tot} after, % difference.

Question 3: For the instruments we are using, a 10% difference can be considered significant. Is there a significant difference between the momentum of the system before and after the collision?

Situation 2: An Elastic Collision with Increased "Incoming" Mass

Now we'll change things a bit by increasing the mass of Car #1. Place the two "side weights" on Car #1, and redetermine its mass.

Question 4: What do you expect will happen this time if Car #2 is stationary on the track and the more massive Car #1 collides with it? Arrive at an agreement with your group *before you actually try it* and write this prediction out. Give the prediction to Jim before you try.

Now repeat the process from Situation 1 above five times with the more massive car in motion. Create a data table with one row for each trial, and the following columns: v_{1b}, v_{2b}, v_{1a}, v_{2a}, p_{tot} before, p_{tot} after, % difference.

Question 5: What does increasing the mass of Car #1 do to the overall momentum of the system? Present evidence from Situations 1 and 2 to back up your claim.

Question 6: What effect does increasing the mass of Car #1 have on the final velocity of Car #2? Present evidence from Situations 1 and 2 to back up your claim.

Question 7: Describe in a few sentences what happens to both cars after the collision. How accurate was your prediction?

<u>Situation 3: An Elastic Collision with Increased "Stationary" Mass</u>

Now take the side weights off Car #1 and put them on the stationary Car #2.

Question 8: What do you expect will happen this time if the more massive Car #2 is stationary on the track and Car #1 collides with it? Arrive at an agreement with your group *before you actually try it* and write this prediction out. Give the prediction to Jim before you try.

Now repeat the process from Situation 1 five times with the more massive car stationary. Create a data table with one row for each trial, and the following columns: v_{1b}, v_{2b}, v_{1a}, v_{2a}, p_{tot} before, p_{tot} after, % difference.

Question 9: Describe in a few sentences what happens to both cars after the collision. How accurate was your prediction?

<u>Situation 4: A Perfectly Inelastic Collision</u>

A perfectly inelastic collision is one where the two objects stick together and move as one after the collision. Remove the side weights from the cars. Flip the cars so that Car #1 has the pin holder facing forward, and Car #2 has the wax holder facing Car #1. Determine the masses of both cars again.

Begin with Car #2 stationary between the photogates and Car #1 on the outside of gate #1. Make sure the air is turned on and that the cars can slide freely. Hit the "Collect" button on the computer, and push the car through Gate #1. The computer will display the velocity of Car #1 as it passes through Gate #1. Call this v_{1b} (Velocity of 1 before the collision). After the collision, measure the velocity of the two cars stuck together as they pass through Gate #2.

Do this five times, gathering 5 sets of data. Try a different speed for Car #1 every time. Hit the Stop button on the computer screen when you have finished 5 trials. Calculate the total momentum of the system before the collision, the total momentum after, and the percentage difference between the two.

Create a data table with one row for each trial, and the following columns: v_{1b}, v_{2b}, v_{1a}, v_{2a}, p_{tot} before, p_{tot} after, % difference.

Question 10: Is there a significant difference between the momentum of the system before and after the collision?

<u>Situation 5: A Head-on Inelastic Collision</u>

In the past few experiments, we have held one car stationary. Now both cars will be moving, and collide "head-on." The cars will still stick together.

Begin with both cars outside the photogates, one on each side of the track. Send Car #1 through Gate #1 and Car #2 through Gate #2. Make sure that the cars collide between the two gates; if they don't, try again. When recording the velocities before and after the collision, consider the initial velocity of Car #1 to be in the positive direction. Thus, the initial velocity of Car #2 will be negative. Do a total of five trials, varying the velocities of both cars each time. Sometimes try to have Car #1 be the faster car, sometimes Car #2. Remember to keep the velocities fairly low! Do calculations and create a data table as before.

Question 11: If the masses of the two cars are essentially equal, what determines the speed and direction of the combined cars after the collision? Present data to back up your claim.

Question 12: In which of the situations above was momentum conserved? Present data to back up your answers, bearing in mind that we can expect about a 10% difference from measurement error.