PHYS 1401 – General Physics 1
Laboratory # 10
Momentum and Collisions

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 five 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. Car #1 will have the rubber band accessory, and Car #2 will have a "knife edge" accessory. 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 and Car #1 on the other side 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.

Question 2: Describe in a few sentences what happens to both cars after the collision.

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. 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. Calculate the momentum of the system before the collision, the 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, Percent difference:

$$\text{Percent Difference} = \frac{p_{before} - p_{after}}{p_{before}} \times 100\%$$

Question 3: Is there a significant difference between the momentum of the system before and after the collision?

Situation 2: An Elastic Collision with Increased 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. Now repeat the process above five times with the more massive Car #1. 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, Percent difference.

Question 4: What does increasing the mass of Car #1 do to the overall momentum of the system? Present numbers from Situations 1 and 2 to back up your claim.

Question 5: 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.

Situation 3: Switching the Masses

Now take the weights off of Car #1 and place them on Car #2. Redetermine the masses of both cars. Now repeat the process five times with the more massive Car #2 as the stationary "target." 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. Create a data table as you have done before.

Question 6: What does increasing the mass of Car #2 do to the overall momentum of the system? Present numbers from Situations 1 and 2 to back up your claim.

Question 7: What effect does increasing the mass of Car #2 have on the final velocity of Car #2? Present evidence from Situations 1 and 2 to back up your claim.

Question 8: Is there a significant difference between the momentum of the system before and after these collisions?

Situation 4: An Inelastic Collision

An inelastic collision is one where the two objects stick together and move as one after the collision. Turn Car #1 around so that the pin holder is facing Car #2. Turn Car #2 so that the wax holder is facing Car #1. Take the little silver weights off, and determine the masses of both cars again.

Begin with Car #2 stationary and Car #1 on the other side 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 momentum of the system before the collision, and the momentum after. Then calculate the percentage difference between the "before" and "after" momentums, using the formula:

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, Percent difference.

Question 9: Is there a significant difference between the momentum of the system before and after the collision?

Situation 5: A Head-on Inelastic Collision

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. 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 10: 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.

BONUS: How would making one car more massive that the other affect your answer to Question 10? How would you set up an experiment to test your prediction?