**PHYS 101 - Conservation of Momentum**

**Worksheet**

**Group Members**:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Before starting the lab be sure to watch the videos on blackboard. As always, be sure to show all work/plots in order to receive full credit.*

**1. Data Analysis:**

In this section, we will go over the various datasets and the parameters associated with each dataset. For both inelastic and elastic collisions, we focus on the time around the collision between the carts!

Note: When looking the velocity of P1 and P2 in the files below, multiply the velocity of P2 by -1. This accounts for the fact that P1 and P2 travel in opposite directions when they collide but only one direction can be positive, and the other direction must be negative (i.e. P1 travels in while P2 travels in ). Also, we only want to analyze the first collision that occurs between the carts.

**2.1 Elastic Collisions:**

Begin by investigating how momentum and kinetic energy behave in an elastic collision. **Ensure that the carts are aligned such that the magnetic side facing each other**. You may look at different initial conditions for the collision. Some examples for you to choose from are, but not limited to:

* Cart 2 at rest, both carts have the same mass or different masses (place 250 g on one cart)
* Carts move in opposite directions (i.e., towards each other) with same/different mass
* Carts move in the same direction with one faster than the other (may be more challenging)

**2.1.1 Plotting the Data:** To get started, we wish to see the *v*(*t*) graphs for P1 and P2. Using the motion sensors and the computer output, record the *v*(*t*) graphs for the motion you chose in 2.1. The *v*(*t*) data for P1 and P2 should be overlaid in one plot. Overlaying the plots allows us to compare the positions and velocity of each cart. From the *v*(*t*) plots calculate the average velocity for before and after the collision. We can calculate the average velocity by summing up the velocities over a certain interval of time and dividing by the number of velocities we added together. Using these calculations, we can determine if momentum and energy are conserved.

1. In a few sentences, comment on the collision of carts P1 and P2 and the time that this occurs.

Table 2: P1 Data from *v*(*t*)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Trial:** | **Mass (kg)** | **Initial Velocity** | **Final Velocity** | **Initial Momentum** | **Final Momentum** | **Initial Kinetic Energy** | **Final Kinetic Energy** |
| 1 | 500g | 0m/s | -0.20m/s | 0 Ns | -0.1 Ns | 0 J | 0.01 J |
| 2 | 500g | 0m/s | -0.20m/s | 0 Ns | -0.1 Ns | 0 J | 0.01 J |

Table 3: P2 Data from *v*(*t*)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Trial:** | **Mass (kg)** | **Initial Velocity** | **Final Velocity** | **Initial Momentum** | **Final Momentum** | **Initial Kinetic Energy** | **Final Kinetic Energy** |
| 1 | 500g | -0.31m/s | 0.02m/s | -0.155 Ns | 0.01 Ns | 0.024025 J | 0.0001 J |
| 2 | 1000g | -0.2m/s | -0.04m/s | -0.2 Ns | -0.04 Ns | 0.02 J | 0.0008 J |

Now, we will calculate the change in momentum and energy of the carts. Comment on how these values compare.

Table 4: P1 Change in momentum and energy

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Trial** | **Initial Momentum** | **Final Momentum** | **Change in momentum** | **Initial Kinetic Energy** | **Final Kinetic energy** | **Change in Kinetic Energy** |
| 1 | 0 Ns | -0.1 Ns | -0.1 Ns | 0 J | 0.01 J | 0.01 J |
| 2 | 0 Ns | -0.1 Ns | -0.1 Ns | 0 J | 0.01 J | 0.01 J |

Table 5: P2 Change in momentum and energy

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Trial** | **Initial Momentum** | **Final Momentum** | **Change in momentum** | **Initial Kinetic Energy** | **Final Kinetic energy** | **Change in Kinetic Energy** |
| 1 | -0.155 Ns | 0.01 Ns | 0.165 Ns | 0.024025 J | 0.0001 J | -0.023925 J |
| 2 | -0.2 Ns | -0.04 Ns | 0.16 Ns | 0.02 J | 0.0008 J | -0.0192 J |

1. For trial 1: compare the change in momentum that cart 1 and cart 2 experienced, what do you notice about the change in momenta? What do you notice about the sum of the change in momenta? What would you expect the change in momentum to be for the system? Repeat for trial 2. Is this what you would expect from an ELASTIC collision?

Trial 1: ∆p1 + ∆p2 = -0.1Ns + 0.165Ns = 0.065 Ns

Trial 2: ∆p1 + ∆p2 = -0.1Ns + 0.16Ns = 0.06 Ns

Change in momentum when one cart is heavier is smaller. Should theoretically be 0 in both cases if no external forces act on the carts.

1. For trial 1 and trial 2, comment on the change in kinetic energy before and after the collision (make sure to investigate the TOTAL energy before/after). Is this what you would expect for an ELASTIC collision?

Trial 1: ∆K1 + ∆K2 = 0.01J + -0.023925J = -0.013925J

Trial 2: ∆K1 + ∆K2 = 0.01J + -0.0192J = -0.0092J

Same as before: change is non-zero, but still smaller when including the higher mass cart.

**2.2 Inelastic Collisions:**

Turn the carts around to make their non-magnetic sides face each other. Follow the same instructions as section 2.1 and 2.1.1 to fill in the plots below. Be sure to include all plots, fits and work.

1. In a few sentences, comment on the collision of carts P1 and P2 and the time that this occurs.

In both trials below, cart 1 started at rest and was struck by a moving cart 2, when the carts became stuck together.

Table 6: P1 Data from *v*(*t*)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Trial:** | **Mass (kg)** | **Initial Velocity** | **Final Velocity** | **Initial Momentum** | **Final Momentum** | **Initial Kinetic Energy** | **Final Kinetic Energy** |
| 1 | 500g | 0m/s | -0.08m/s | 0 Ns | -0.04 Ns | 0 J | 0.0016 J |
| 2 | 500g | 0m/s | -0.18m/s | 0 Ns | -0.09 Ns | 0 J | 0.0081 J |

Table 7: P2 Data from *v*(*t*)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Trial:** | **Mass (kg)** | **Initial Velocity** | **Final Velocity** | **Initial Momentum** | **Final Momentum** | **Initial Kinetic Energy** | **Final Kinetic Energy** |
| 1 | 500g | -0.25m/s | -0.08m/s | -0.125 Ns | -0.04 Ns | 0.015625 J | 0.0016 J |
| 2 | 1000g | -0.32m/s | -0.18m/s | -0.32 Ns | -0.18 Ns | 0.0512 J | 0.0162 J |

**3.1 Analysis and Conclusion**

Now, we will calculate the change in momentum and energy of the carts. Comment on how these values compare.

Table 8: P1 Momentum and Energy

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Trial** | **Initial Momentum** | **Final Momentum** | **Change in momentum** | **Initial Kinetic Energy** | **Final Kinetic energy** | **Change in Kinetic Energy** |
| 1 | 0 Ns | -0.04 Ns | -0.04 Ns | 0 J | 0.0016 J | 0.0016 J |
| 2 | 0 Ns | -0.09 Ns | -0.09 Ns | 0 J | 0.0081 J | 0.0081 J |

Table 9: P2 Momentum and Energy

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Trial** | **Initial Momentum** | **Final Momentum** | **Change in momentum** | **Initial Kinetic Energy** | **Final Kinetic energy** | **Change in Kinetic Energy** |
| 1 | -0.125 Ns | -0.04 Ns | 0.085 Ns | 0.015625 J | 0.0016 J | -0.014025 J |
| 2 | -0.32 Ns | -0.18 Ns | 0.14 Ns | 0.0512 J | 0.0162 J | -0.035 J |

1. For trial 1: compare the change in momentum that cart 1 and cart 2 experienced, what do you notice about the change in momenta? What do you notice about the sum of the change in momenta? What would you expect the change in momentum to be for the system? Repeat for trial 2. Is this what you would expect from an INELASTIC collision?

Trial 1: ∆p1 + ∆p2 = -0.04Ns + 0.085Ns = 0.045 Ns

Trial 2: ∆p1 + ∆p2 = -0.09Ns + 0.14Ns = 0.05 Ns

This time, the change in momentum is smaller when then smaller mass carts collide. Theoretically, it should still be 0 for both since no external forces act on the carts.

1. For trail 1 and trial 2, comment on the change in kinetic energy before and after the collision (make sure to investigate the TOTAL energy before/after). Is this what you would expect for an INELASTIC collision?

Trial 1: ∆K1 + ∆K2 = 0.0016J + -0.014025 = -0.012425J

Trial 2: ∆K1 + ∆K2 = 0.0081J + -0.035J = -0.0269J

Nonzero for both, as expected for an inelastic collision. The total KE loss is higher when the more massive cart collide, which makes sense as more energy is dissipated in a higher impulse collision.

**4. Analysis Questions:**

1. What experimental evidence do you have showing that momentum is conserved in inelastic and elastic collisions?

The changes in momentum gathered are small, and generally consistent with each other across experiments. This implies that a single bias force acts on all experiment causing a non-zero positive change in momentum, probably from the magnetic force when the carts collide and some friction from the track.

1. How does your data support the conservation of kinetic energy in elastic collisions?

∆K is nonzero for both experiments, but smaller for the elastic collisions. So, we can assume that KE is conserved within experimental error.

1. How does your data support the non-conservation of kinetic energy in inelastic collisions?

The data say that ∆K is fairly significantly nonzero, even higher as the total mass of the carts increases.

1. Why is kinetic energy not conserved in inelastic collisions? Where is the energy lost?

It gets dissipated into sound/heat at the time of collision.

5. In what situations is momentum not conserved? Briefly discuss one example.

Whenever there is an external force acting on the system. For example, if the force of friction from the track on the cart is significant, net momentum will be lost.