PHYS 101 - Conservation of Momentum Worksheet

<u>Group Members</u>:

Utsav Chaudhary | Michael Savage

Casey McNelly | Olivia Do

Lia O'Donnell

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 $+\hat{x}$ while P2 travels in $-\hat{x}$). Also, we only want to analyze the first collision that occurs between the carts.

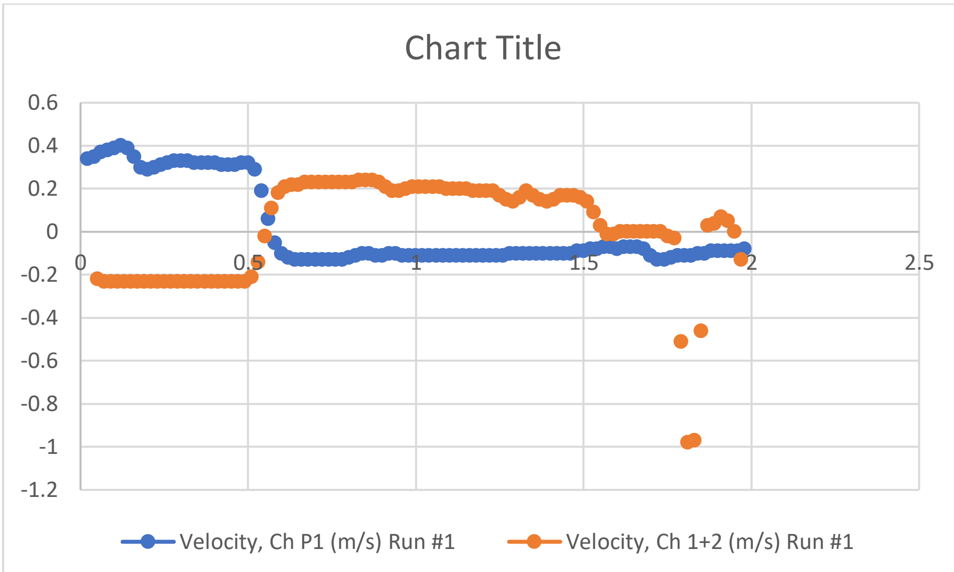
2.1 Elastic Collisions:

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:

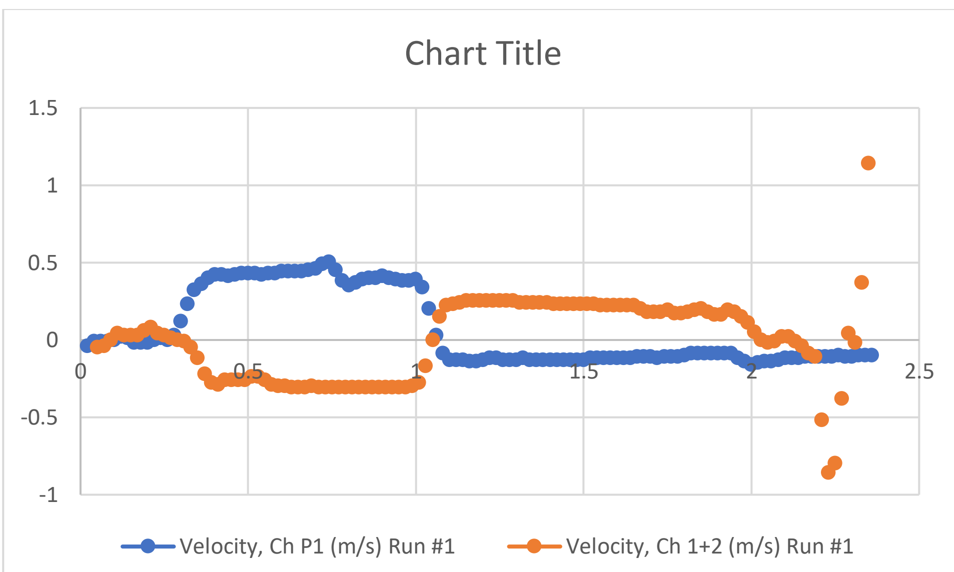
- Cart 2 at rest, both carts have the same mass or different masses (place 250 g on one cart)
- Carts move in opposite directions (i.e., towards each other) with same/different mass
- Carts move in the same direction with one faster than the other (may be more challenging)

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.
   The collision of carts P1 and P2 occurs at the specific instance where the velocities change sign, indicating a momentary halt or reversal in direction. This is evident in the v(t) graphs where the velocities transition from positive to negative or vice versa.



Trial 1



Trial 2

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	0.75	0.32	-0.13	0.24	-0.0975	0.0384	0.0063
2	0.75	0.39	-0.13	0.2925	-0.0975	0.057	0.0063

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	0.75	-0.21	0.22	-0.1575	0.165	0.0165	0.01815
2	0.75	-0.3	0.22	-0.225	0.165	0.03375	0.01815

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	0.24	-0.0975	-0.3375	0.0384	0.0063	-0.0321
2	0.2925	-0.0975	-0.39	0.057	0.0063	-0.0507

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	-0.1575	0.165	0.3225	0.0165	0.01815	0.00165
2	-0.225	0.165	0.39	0.03375	0.01815	-0.0156

2. 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?

   For Trial 1:
   - The change in momentum for cart 1 is -0.3375 kg·m/s and for cart 2 is 0.3225 kg·m/s.
   - The sum of the change in momenta should be zero. The small discrepancy can be attributed to experimental error.

   For Trial 2:
   - The change in momentum for cart 1 is -0.39 kg·m/s and for cart 2 is 0.39 kg·m/s.

- The sum of the change in momenta is zero, indicating that momentum is conserved.

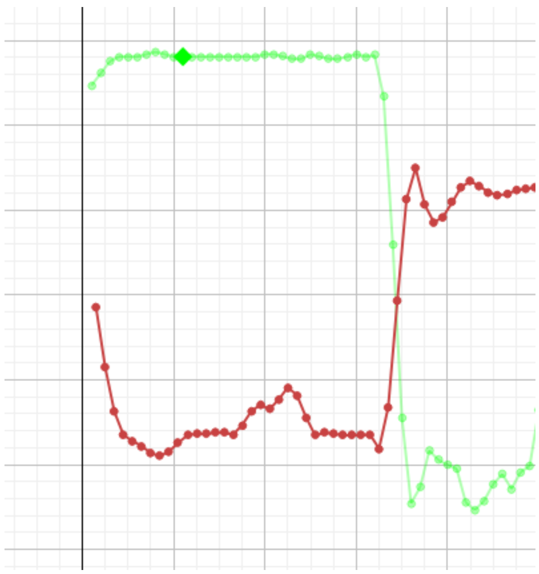
3. For trial 1 and trial 2, comment on the change in kinetic energy before and after the collision (make sure to investigate the TOTAL energy before/after). Is this what you would expect for an ELASTIC collision?
   For Trial 1:
   - The change in kinetic energy for cart 1 is -0.0321 J and for cart 2 is 0.00165 J.
   - The total change in kinetic energy is slightly negative, suggesting a minor loss, which may be due to experimental errors or non-ideal conditions. In an ideal elastic collision, kinetic energy should be conserved.

   For Trial 2:
   - The change in kinetic energy for cart 1 is -0.0507 J and for cart 2 is -0.0156 J.
   - The total change in kinetic energy is negative, which is unexpected for an ideal elastic collision. This discrepancy might be due to experimental limitations.

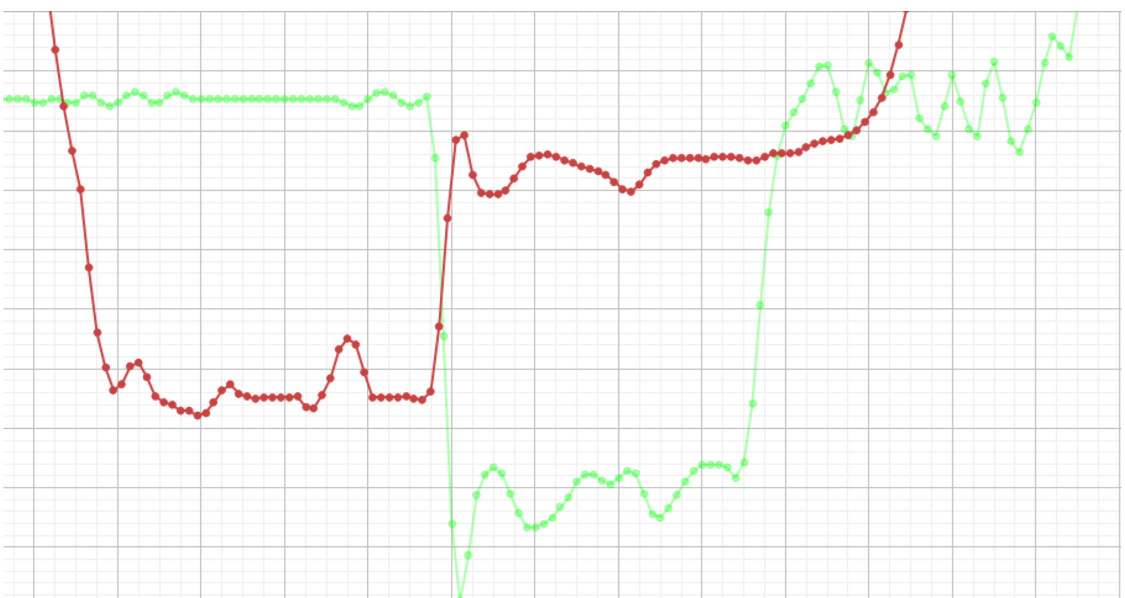
2.2 Inelastic Collisions:

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.

4. In a few sentences, comment on the collision of carts P1 and P2 and the time that this occurs.
   The collision of carts P1 and P2 in inelastic collisions results in the carts sticking together or moving with some loss of kinetic energy, as shown in the changes in velocities.



Trial 1



Trial 2

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

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.75	0	-0.27	0	-0.2025	0	0.0273
2	0.75	0	-0.19	0	-0.1425	0	0.0137

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

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.75	-0.56	-0.25	-0.42	-0.1875	0.1176	0.0234
2	0.75	-0.38	-0.16	-0.285	-0.12	0.05415	0.009

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 (kg·m/s)	Final Momentum (kg·m/s)	Change in Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)	Change in Kinetic Energy (J)
1	0	-0.2025	-0.2025	0	0.0273	0.0273
2	0	-0.1425	-0.1425	0	0.0137	0.0137

Table 9: P2 Momentum and Energy

Trial	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Change in Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)	Change in Kinetic Energy (J)
1	-0.42	-0.1875	0.2325	0.1176	0.0234	-0.0942
2	-0.285	-0.12	0.165	0.05415	0.0096	-0.04455

5. 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?
   For Trial 1:
   - The change in momentum for cart 1 is -0.2025 kg·m/s and for cart 2 is 0.2325 kg·m/s.
   - The sum of the change in momenta should be zero. The small discrepancy can be attributed to experimental error.

   For Trial 2:
   - The change in momentum for cart 1 is -0.1425 kg·m/s and for cart 2 is 0.165 kg·m/s.
   - The sum of the change in momenta should be zero. The small discrepancy can be attributed to experimental error.

6. 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?
   For Trial 1:
   - The change in kinetic energy for cart 1 is 0.0273 J and for cart 2 is -0.0942 J.
   - The total change in kinetic energy is negative, which is expected for inelastic collisions where kinetic energy is not conserved, and energy is transformed into other forms such as heat or deformation.

   For Trial 2:
   - The change in kinetic energy for cart 1 is 0.0137 J and for cart 2 is -0.04455 J.
   - The total change in kinetic energy is negative, aligning with the expected outcome for inelastic collisions.

4. Analysis Questions:

1. What experimental evidence do you have showing that momentum is conserved in inelastic and elastic collisions?
   In both elastic and inelastic collisions, the changes in momenta for the carts is approximately equal and opposite, indicating conservation of momentum.

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

The data shows the changes in kinetic energies are almost equal and opposite for elastic collisions, supporting the conservation of kinetic energy.

3. How does your data support the non-conservation of kinetic energy in inelastic collisions?
   The data reveals a significant reduction in total kinetic energy post-collision, illustrating the non-conservation of kinetic energy in inelastic collisions.

4. Why is kinetic energy not conserved in inelastic collisions? Where is the energy lost?
   Kinetic energy is not conserved in inelastic collisions because it is converted into other forms of energy such as heat, sound, and deformation energy. In our case when the carts got stuck with each other due to that Velcro strap, some energy is lost there too.

5. In what situations is momentum not conserved? Briefly discuss one example.
   Momentum is not conserved in systems where external forces are acting on the colliding objects. For example, frictional forces in real-world scenarios can lead to loss of momentum.