Linear Momentum

PHYS 211L – H02

Tuesday 10:05am – 12:05pm

Abstract

In this lab, we investigated the conservation of linear momentum by measuring the momentum before and after a collision. We started with two gliders of equal mass, then we experimented with the incident glider having more mass than the target glider, and vice versa. By calculating and comparing the total momentum before the collision to the total momentum after the collision, we found that, within uncertainties, momentum was conserved.

Introduction

The idea of the conservation of momentum is one that has its roots deep in history, conceptually originating as early as 530 A.D. with the philosopher Aristotle. His ideas, however, were fundamentally incorrect. He believed that an “impetus” force kept a moving object in motion through the air. As this concept developed over time, it began to resemble today’s form more and more. The English mathematician John Wallis1 was the first person to create and use the conservation of momentum as it is known in physics today.

In this lab, we seek to prove the law of conservation of linear momentum by creating a situation as close to ideal as possible. With the velocity of two carts being recorded before and after a collision, we can test the law of conservation of linear momentum. The equation we used to compare the total momentum before the collision with the total momentum after the collision is , where and are the masses of the incident and target gliders respectively, and are the velocities of the incident and target gliders respectively before the collision, and and are the velocities of the incident and target gliders respectively after the collision.

Procedure

In this lab, we used the following materials: balance, air track with blower, 2 gliders with bumpers, 4 glider masses, additional small masses, 2 photogates, 2 small plastic fences, computer with DataStudio, photogate port, and a USB link.

First, we recorded the mass of each glider, the mass of our large cylinders, the mass of our small cylinders, and the distance between bands on the picket fences. We made sure the track was level by placing one glider on it and turning the air on. If the glider barely moves, then the track is level. We then set up our photogates and DataStudio so that each gate would record the velocity of the glider traveling through it. We performed five trials for three scenarios. First, collisions between the two gliders when they have equal mass. Second, collisions between the two gliders such that the incident glider has more mass than the target glider. Lastly, collisions between the two gliders such that the target glider has more mass than the incident glider. For each collision, we recorded the velocity of the incident glider before it collided with the target glider, and we recorded the velocity of the target glider after it collided with the incident glider. After collecting our data, we did one final trial with just one glider passing through both gates. This was to help us calculate the percent uncertainty in our speed measurements. This uncertainty then spreads to the uncertainty in our momentum calculations.

**Setup One**

Bumpers

Photogates

Computer with DataStudio

Glider 2 with picket fence

Glider 1 with picket fence

Air track with blower

**Setup Two**

Glider mass

Computer with DataStudio

**Setup Three**

Glider mass

Computer with DataStudio

Results/Analysis/Physics

With our measurements, we can compare the total momentum before the collision with the total momentum after the collision while taking uncertainties into account. This will allow us to verify whether or not momentum was conserved. To calculate the percent uncertainty of our speed measurements, we used the formula , where and are the velocities of a single glider as it moves through both photogates. To calculate the percent uncertainty our momentum calculations, we used the formula , where is the momentum of the glider and is its velocity.

Measurements taken prior to Experiment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mass of Incident Glider (kg) | Mass of Target Glider (kg) | Mass of Large Cylinder (kg) | Mass of Small Cylinder (kg) | Distance between bands on Picket Fence (m) |
| 0.223 | 0.223 | 0.218 | 0.05 | 0.01 |

Carts have Equal Mass

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | Incident Velocity before Collision (m/s) | Incident Velocity after Collision (m/s) | Target Velocity (m/s) |
| 1 | 0.16 | 0.02 | 0.14 |
| 2 | 0.37 | 0.02 | 0.35 |
| 3 | 0.42 | 0.02 | 0.40 |
| 4 | 0.44 | 0.02 | 0.42 |
| 5 | 0.14 | 0.02 | 0.12 |

Incident Mass Greater than Target Mass

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | Incident Velocity (m/s) | Incident Velocity after Collision (m/s) | Target Velocity (m/s) |
| 1 | 0.44 | 0.155 | 0.54 |
| 2 | 0.46 | 0.170 | 0.55 |
| 3 | 0.44 | 0.155 | 0.54 |
| 4 | 0.62 | 0.225 | 0.75 |
| 5 | 0.75 | 0.286 | 0.88 |

Target Mass Greater than Incident Mass

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | Incident Velocity (m/s) | Incident Velocity after Collision (m/s) | Target Velocity (m/s) |
| 1 | 0.64 | -0.119 | 0.40 |
| 2 | 0.56 | -0.104 | 0.35 |
| 3 | 0.58 | -0.122 | 0.37 |
| 4 | 0.44 | -0.0532 | 0.26 |
| 5 | 0.49 | -0.0601 | 0.29 |

Finding Percent Uncertainty in Speed Measurements

|  |  |  |
| --- | --- | --- |
| v1 (m/s) | v2 (m/s) | Percent Uncertainty |
| 0.48 | 0.44 | 8.696% |

Error Analysis: Case 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Collision | Incident Glider’s Momentum before Collision  (kg \* m/s) | Incident Glider’s Momentum after Collision  (kg \* m/s) | Target Glider’s Momentum after Collision  (kg \* m/s) | Percent Uncertainty in Momentum for Incident Glider  (pre-collision) | Percent Uncertainty in Momentum for Incident Glider (post-collision) | Percent Uncertainty in Momentum for Target Glider  (post-collision) |
| 1 | 0.03568 | 0.00446 | 0.03122 | 1.939% | 1.939% | 1.939% |
| 2 | 0.08251 | 0.00446 | 0.07805 | 1.939% | 1.939% | 1.939% |
| 3 | 0.09366 | 0.00446 | 0.08920 | 1.939% | 1.939% | 1.939% |
| 4 | 0.09812 | 0.00446 | 0.09366 | 1.939% | 1.939% | 1.939% |
| 5 | 0.03122 | 0.00446 | 0.02676 | 1.939% | 1.939% | 1.939% |
| 6 | 0.18612 | 0.06570 | 0.12042 | 3.686% | 3.686% | 3.686% |
| 7 | 0.19458 | 0.07193 | 0.12265 | 4.034% | 4.034% | 4.034% |
| 8 | 0.18612 | 0.06570 | 0.12042 | 3.686% | 3.686% | 3.686% |
| 9 | 0.26226 | 0.09501 | 0.16725 | 3.672% | 3.672% | 3.672% |
| 10 | 0.31725 | 0.12101 | 0.19624 | 3.679% | 3.679% | 3.679% |
| 11 | 0.14272 | -0.02648 | 0.16920 | 1.939% | 1.939% | 1.939% |
| 12 | 0.12488 | -0.02317 | 0.14805 | 1.939% | 1.939% | 1.939% |
| 13 | 0.12934 | -0.02717 | 0.15651 | 1.939% | 1.939% | 1.939% |
| 14 | 0.09812 | -0.01186 | 0.10998 | 1.939% | 1.939% | 1.939% |
| 15 | 0.10927 | -0.01340 | 0.12267 | 1.939% | 1.939% | 1.939% |

Total Momentum before and after each Collision

|  |  |  |
| --- | --- | --- |
| Collision | Total Momentum before collision (kg \* m/s) | Total Momentum after collision (kg \* m/s) |
| 1 | 0.03568 | 0.03368 |
| 2 | 0.08251 | 0.08231 |
| 3 | 0.09366 | 0.09346 |
| 4 | 0.09812 | 0.09722 |
| 5 | 0.03122 | 0.03012 |
| 6 | 0.18612 | 0.18524 |
| 7 | 0.19458 | 0.19389 |
| 8 | 0.18612 | 0.18192 |
| 9 | 0.26226 | 0.25972 |
| 10 | 0.31725 | 0.30985 |
| 11 | 0.14272 | 0.13875 |
| 12 | 0.12488 | 0.11942 |
| 13 | 0.12934 | 0.12749 |
| 14 | 0.09812 | 0.09692 |
| 15 | 0.10927 | 0.10752 |

Conclusion

[*What was learned*] What this experiment determined and what we set out to prove was the concept of the conservation of linear momentum. We wanted to show that the total momentum in a system is the same before and after a collision occurs. With our recorded data, we can conclude that, within an uncertainty, the momentum of the system () was conserved during the collision. [*Uncertainties*] In the system, however, the existence of outside forces causes it to be less than ideal. While the blowing track reduced *most* of the friction between the track and the glider, some momentum was lost because of the non-negligible presence of the force of friction. Additionally, during the glider’s travel across the track, there was another friction force between the glider and the air. Due to wind resistance, some energy was transferred from the system to the environment, causing a discrepancy between recordings and calculations.

[*First Universal Question*] The data that was recorded was substantially close to what was expected from the experiment. It was calculated that the percent uncertainty for momentum ranged from approximately 1.939% to approximately 4%. This is an acceptable margin of error given the outside forces of friction present in the experiment. As expected, our data shows a small amount of momentum was lost to the system due to the imperfect nature of the setup.

[*Second Universal Question*] The concept of the conservation of momentum is present in almost any circumstance where two objects collide. In a car accident, for instance, assuming a moving car hits a parked car, the car that was moving slows down upon collision as a portion of its momentum is transferred to the NOW moving parked vehicle. The larger the car that causes the collision, the more momentum is transferred to the parked car. Another real-life example is found during a game of baseball. When a batter strikes the ball with a bat of much higher mass, the ball experiences a drastic change in momentum caused by the collision with the bat. The smaller mass of the ball experiences a much higher velocity than the bat with a larger mass.

Lab Questions

2. Momentum was conserved in this experiment.

3. Newton’s 3rd Law is most closely associated with momentum conservation.

4. Not every collision was the same for each configuration, so taking the average of all the initial momenta and final momenta would result in less accurate data.

Eat shit.

References

1. Scott, J.F. (1981). *The Mathematical Work of John Wallis, D.D., F.R.S.* Chelsea Publishing Company. p. 111. ISBN 0-8284-0314-7.