**Momentum: Video Analysis**

**Background**

When we talk about *momentum*, it can be first helpful to define another quantity: *impulse*. Impulse is a vector (direction matters) represented by  There are two different ways to define impulse: The first is that impulse equals the change in momentum, or . The second is using the net force on the object and time, or . Combining these, we get



and if you divide both sides by time,



This means that if there is no net force on the body or system of bodies (), then . Time cannot be zero, so there must be no change of momentum within the system with time. This is known as ***conservation of momentum***.

Let’s take conservation of momentum one step farther. Since the change in momentum has to be zero,

 or 

Since we are talking about the whole system, remember that the final momentum is the sum of the final momentum of the parts, and the initial momentum is the sum of the initial momentum of the parts.

In today’s lab, you’ll be examining collisions. There are two types of collisions that will be examined. *Perfectly inelastic collisions* are collisions that hit, stick together, and move with a constant velocity after the collision. *Elastic collisions* are those where the objects do not stick together, but rather move separately from each other after the collision. (Elastic collisions also conserve kinetic energy.)

**Goal:** The purpose of this experiment is to use LoggerPro to measure the momentum in various collisions and determine whether conservation of momentum applies.

**Case I - Perfectly Inelastic Collision with Equal Masses**

* Open LoggerPro→Insert Movie→Logger Files (on Desktop) →Collision Videos→Colliding\_Carts\_37-mmi.mov. Go to Page→Auto Arrange to put your movie in the top left-hand corner. Set your scale and note the masses of the two carts from the first slide.
* Plot the location of the left cart by using the *Add Point* button. Click on a certain part of the cart (front, middle, back…) and the movie will advance to the next frame. Be consistent, plot the same part of the cart for every frame, and continue plotting the points until the end of the movie.
* Rewind the movie to the beginning. Press the *Set Active Point* button and select *Add Point Series* and plot the location of the cart on the right. You will notice that the dot is a different color. Start at the first slide and continue plotting the location, even if the cart is not moving.
* Use *LoggerPro* to determine the velocity of each cart by taking the slope of the position v. time graph before and after the collision. Record these values in the table below.
* Determine the momentum of each cart by going to Data→New Calculated Column. Name your new quantity “cart 1 p” or something similar. You will create an equation with constants and known variables. Note: to use a variable from your data, choose it from the *Variables* column. (For example, “*X Velocity*”) can be used to calculate the momentum in the x-direction.
  + Plot a “cart 1 p” v. time graph. Shade the part of the data that is a flat line before the collision and find the mean value by going to Analyze→Statistics. Do the same for after the collision. Record these values in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft |  |  |  |  |
| Cartright |  |  |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Two carts together |  |  |  |  |  |

**Case II - Perfectly Inelastic Collisions with Unequal Masses**

* Repeat the experiment above, this time using the Colliding\_Carts\_32-mMi.mov file.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft |  |  |  |  |
| Cartright |  |  |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Two carts together |  |  |  |  |  |

* Repeat the experiment above, this time using the Colliding\_Carts\_34-Mmi.mov file.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft |  |  |  |  |
| Cartright |  |  |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Two carts together |  |  |  |  |  |

**Case III - Perfectly Elastic Collisions with Equal Masses**

* Repeat the experiment above, this time using the Colliding\_Carts\_41-mme.mov file.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft |  |  |  |  |
| Cartright |  |  |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Cartleft |  |  |  |  |  |
| Cartright |  |  |  |

**Case IV - Perfectly Elastic Collisions with Unequal Masses**

* Repeat the experiment above, this time using the Colliding\_Carts\_45-mMe.mov file.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft |  |  |  |  |
| Cartright |  |  |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Cartleft |  |  |  |  |  |
| Cartright |  |  |  |

* Repeat the experiment above, this time using the Colliding\_Carts\_31-Mme.mov file.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft |  |  |  |  |
| Cartright |  |  |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Cartleft |  |  |  |  |  |
| Cartright |  |  |  |

**Examining Momentum Conservation**

If a system had no net outside force on it, one would expect conservation of momentum and Δp=0, always. Since we are measuring momentums of bodies, before and after collisions, there can be errors in measurement. Likewise, if there are net outside forces, then Δp≠0.

A measurement of error would be to compare Δp with . Since the cart on the right was always initially at rest, we can compare Δp with pleft cart, initial.

* Using the data you’ve collected, complete the table below to consider whether momentum was conserved in the collisions above.

|  |  |  |  |
| --- | --- | --- | --- |
|  | pleft cart, initial (Ns) | Δp (Ns) |  |
| Case 1 (mmi) |  |  |  |
| Case 2 (mMi) |  |  |  |
| Case 3 (Mmi) |  |  |  |
| Case 4 (mme) |  |  |  |
| Case 5 (mMe) |  |  |  |
| Case 6 (Mme) |  |  |  |

**Summary Questions**

1. Look at your position v. time graphs for the two carts in Case 6. If there was an outside force, like friction, how would that change the data? Draw an approximate graph (off to the side) showing what the velocities of the carts would be, before and after the collision.
2. Can we say there is conservation of momentum in this case with friction? Use the graph you drew above for evidence.
3. Two bodies on a frictionless surface come together, collide, and stick together. Fill out the rest of the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft | 0.600 | +5.50 |  |  |
| Cartright | 0.400 | -7.50 |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Two carts together |  |  |  |  | 0.00 |

1. Two bodies on a frictionless surface come together, collide, and separate. Fill out the rest of the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mass (kg) | vi (m/s) | pi (Ns) | Σpi (Ns) |
| Cartleft | 0.600 | +5.50 |  |  |
| Cartright | 0.400 | -7.50 |  |
|  | Mass (kg) | vf (m/s) | pf (Ns) | Σpf (Ns) | Δp (Ns) |
| Cartleft | 0.600 | -1.50 |  |  | 0.00 |
| Cartright | 0.400 |  |  |

**Momentum: Collision Carts**

**Background**

When we talk about *momentum*, it can be first helpful to define another quantity: *impulse*. Impulse is a vector (direction matters) represented by  There are two different ways to define impulse: The first is that impulse equals that change in momentum, or . The second is using the net force on the object and time, or . Combining these, we get



and if you divide both sides by time,



This means that if there is no net force of the body or system of bodies (), then . Time cannot be zero, so there must be no change of momentum within the system with time. This is known as ***conservation of momentum***.

Let’s take conservation of momentum one step farther. Since the change in momentum has to be zero,

 or 

Since we are talking about the whole system, remember that the final momentum is the sum of the final momentum of the parts, and the initial momentum is the sum of the initial momentum of the parts.

In today’s lab, you’ll be creating collisions. There are two types of collisions that will be examined. *Perfectly inelastic collisions* are collisions that hit, stick together, and move with a constant velocity after the collision. *Elastic collisions* are those where the objects do not stick together, but rather move separately from each other after the collision. In perfectly elastic collisions, the total kinetic energy of the objects is also conserved.

**Goal:** The purpose of this experiment is to measure the momentum in various collisions and determine whether conservation of momentum applies.

**Part I - Inelastic Collisions**

The plastic collisions carts are two sided. Since you are going to create an inelastic collision, you want the carts to stick together after they collide. So, put the two Velcro sides of the cart together for these trials. For ease, the carts will be referred to by their colors, either blue or red.

* Set up two *Photogates* - one at each end of the silver dynamics track. Attach a picket fence to the top of each car, and adjust the height of the photogates so that the sensor is passing over the white and black bands of the picket fence.
* This time, the Capstone program, set up is a bit longer. Connect the 850 Interface, and then add two *Photogate* sensors. When you do that, a new icon will appear in the left column - it says *Timer Setup*. There are a set of numbered items to check. Make them match the following list:

1. Preconfigured Timer
2. Photogate Ch. 1 and Photogate Ch. 2
3. Picket Fence>Collision Single Flag
4. Speed in Gate 1 and Speed in Gate 2
5. Enter Flag Spacing (the distance between black and white bands)
6. Enter a name for your display

* Create an output that displays a graph of the velocity measured in each photogate.
  + Use the data point immediately before the collision as the initial velocity of each cart. Use the data point immediately after the collision as the final velocity of each cart. You may want to use the graphing tools such as the *Smart Tool* or the *Delta Tool* to determine these values.
  + Velocity is a vector, however, so it will be your responsibility to keep track of which velocities are positive and which are negative. If you are unsure of how to do this, it may be helpful to remember that the right or east horizontal direction is usually considered to be positive.
* Carry out a series of inelastic collisions. Try for a range of conditions: one car initially stationary, both cars initially moving, different initial speeds, and by varying the mass of the cars. Use the table at the end of this report to record your raw data and to carry out the calculations.

**Part II - Elastic Collisions**

Now flip the carts around so that the magnetic sides will be near each other during the collision. Ensure that the collision is truly elastic by pushing the carts lightly enough that they do not actually hit (the magnetic repulsion is sufficient for redirecting the carts).

* Repeat the above experiments with a range of conditions. Use the table at the end of this report to record your raw data and to carry out the calculations.

**Summary Question**

Describe what you learned about conservation of moment.

**Part I Data - Inelastic Collisions**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
| Trial #1 |  |  |  |  |  |  |  |  |  |
| Trial #2 |  |  |  |  |  |  |  |  |  |
| Trial #3 |  |  |  |  |  |  |  |  |  |
| Trial #4 |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
| Trial #1 |  |  |  |  |  |  |  |  |  |
| Trial #2 |  |  |  |  |  |  |  |  |  |
| Trial #3 |  |  |  |  |  |  |  |  |  |
| Trial #4 |  |  |  |  |  |  |  |  |  |

**Part II Data - Elastic Collisions**