Experiment 5: Conservation of Momentum

EQUIPMENT	
Two PASCO collision carts	*'BeeSpi' Photogate & holder*
PASCO Cart track	Calculator
Cart launcher	Cart mass

Momentum

The purpose of this lab is to observe the conservation of momentum for **inelastic** and **elastic** collisions. Momentum is inertia in motion and can be calculated by multiplying an object's mass by its velocity **(i.e., momentum = mass × velocity = mv).**

You have also studied something called impulse (impulse = force × time). Impulse is the change in momentum (i.e., force x time = change in momentum). In order to change momentum, an impulse (i.e., a force acting over some time period) must be applied from outside of the system.

A central law of mechanics is the **conservation of momentum**. This law states, "In the absence of an external force, the momentum a system remains unchanged." In any system wherein all forces are internal-as for example, cars colliding, atomic nuclei undergoing radioactive decay, or stars exploding- the net momentum of the system before and after the event is the same."

In the first part of the lab you will explore the conservation of momentum through an **inelastic collision of two carts**. *Inelastic collisions occur when two objects collide and stick together.* The initial momentum of one cart plus the initial momentum of the other cart must equal the final momentum of the two cart system once they have collided and stuck together.

$$m_{cart\ a}v_{cart\ a} + m_{cart\ b}v_{cart\ b} = (m_{cart\ a} + m_{cart\ b})v_{cart\ a+cart\ b}$$

$$\boxed{m_{cart\ a}v_{cart\ a} = (m_{cart\ a} + m_{cart\ b})v_{cart\ a+cart\ b}}$$

If cart B is initially at rest (i.e., $v_{cart\ b} = 0$), then the relationship above becomes

$$\boxed{m_{cart\ a}v_{cart\ a} = (m_{cart\ a} + m_{cart\ b})v_{cart\ a+cart\ b}}$$

In the second part of the lab you will explore the conservation of momentum through an **elastic collision** of two carts. *In this case the carts will collide, but they will not stick together.* For momentum to be conserved the initial momentum (i.e., before collision) of cart *a* plus the initial momentum of cart *b* is equal to the final momentum (i.e., after collision) of cart *a* plus the final momentum of cart *b.* In equation form this relationship looks like:

$$m_{cart\ a}v_{cart\ a\text{-before}} + m_{cart\ b}v_{cart\ b\text{-before}} = m_{cart\ a}v_{cart\ a\text{-after}} + m_{cart\ b}v_{cart\ b-\text{after}}$$

If cart B is initially at rest, then the relationship above becomes

$$\boxed{m_{cart\ a}v_{cart\ a\text{-before}} = m_{cart\ a}v_{cart\ a\text{-after}} + m_{cart\ b}v_{cart\ b-\text{after}}}$$

Procedure

Table 1 directions-

Cart masses are written on the carts. Be sure and convert to kilograms.

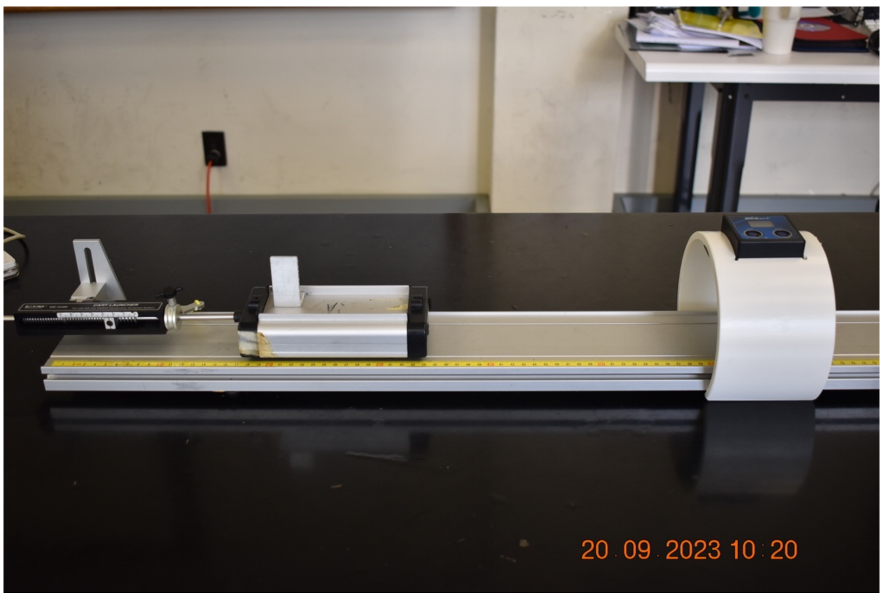
Inelastic Collision Data

Table 2 – Before collision data.

-See Figure below for how to configure cart. Place photogate about 40 (or so) cm from the cart.

-Cock firing apparatus by pushing plunger in until it clicks.

-Place cart A against plunger (with Velcro side facing forward towards photogate). Make sure cart is touching the plunger. See figure below



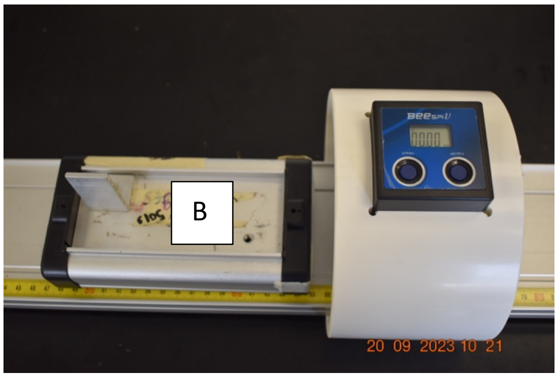
-Press start button on photogate. See Figure below

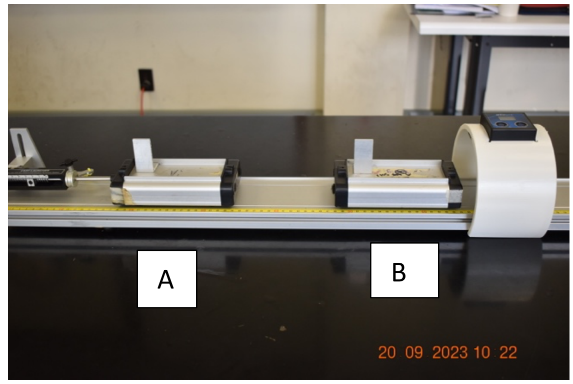
-Fire by pulling string. **Before firing make sure track is up against the clamp (or stop).** This will keep track from recoiling. Record velocity (for Cart A in **table 2 below**. Repeat 2 more times & record values.

Table 3 – After collision data.

- Re-cock and place cart A into firing position (as above)

- Place **cart B** (with Velcro side facing **cart A**) between cart A and photogate. See figures below.





- Fire by pulling string. Be sure and press "start button" before firing.

- Record velocity in table 3 **(this will be velocity of both carts since they 'stick' together)** in the table. Repeat 2 more times.

Elastic Collision Data

Table 4 – Before collision data

- **Reverse cart A** so that taped side is forward (toward photogate).

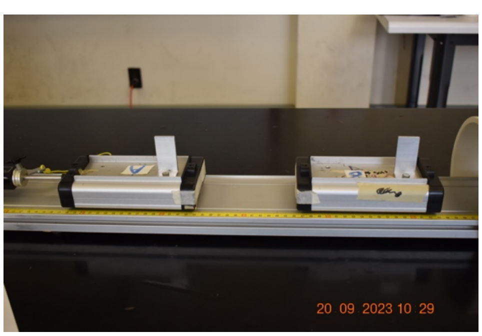
-Repeat what you did in table 2 above to **get initial velocity**. Values should be 'the same' or close to the values before.

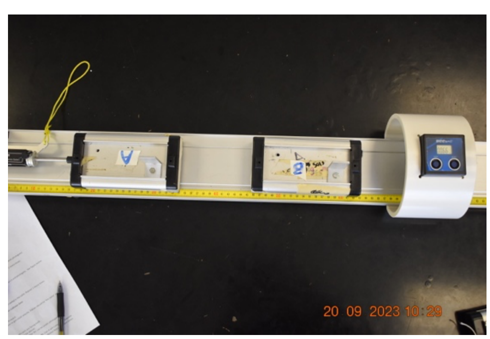
Table 5- After collision data.

- Reverse cart B so that taped sides on both carts are facing each. This will make the collision elastic.

- Re-cock and place cart A into firing position (as above)

- **Place cart B between cart A and photogate**. See figures below





- Fire by pulling string.

-Record velocity in table 5. **(This will be velocity of cart B).** Cart A will come to a complete stop (after rolling slightly). It thus has a **small amount** of momentum after collision. Repeat 2 more times and record velocities in table 5.

Elastic collision with mass added to cart A

Table 6 instructions

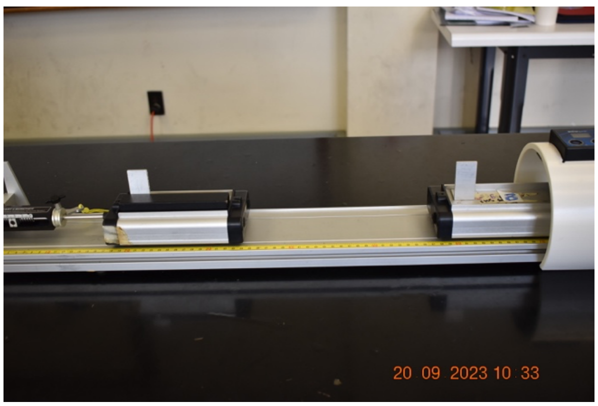
-Remove cart B from track

- Add a 500g mass to cart A and determine the velocity as you did above. Be sure tape side is forward.

-**Record in table 6** before collision.

-Repeat 2 more times & record these velocities.

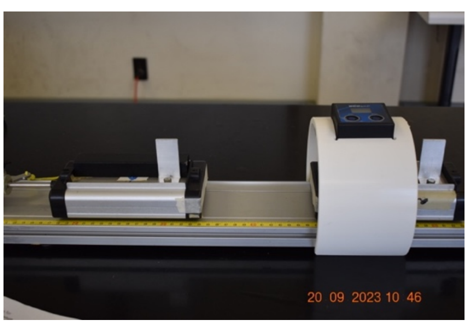
-**Place cart B** between cart A and photogate. Note the position of cart B. 'Tape side' should ace cart A. See figure below.



-Fire and observe what you see. **Cart A will not stop this time**

-Redo and measure the velocity of cart B first**.** Repeat 2 more times. **Record in cart B columns** of table 7.

-Redo and measure the velocity on cart A. This is done **by moving photogate** (not cart B) to where it is between the carts. See figure below. *Cart B should be where it was in the step above.* Record the velocity **in cart A part of table.** Repeat two more times.



Masses for collisions

Table 1

Cart	Mass of Cart(s) (kg)
A	
B	
A+B **(use only for inelastic collision)**	

Inelastic Collision Data

Table 2 Before Collision

	Cart A			Cart B	
Trial	Velocity Cart A (m/s)	Momentum (kg*m/s)		Velocity Cart B (m/s)	Momentum (kg*m/s)
1				**0**	
2				**0**	
3				**0**	

Average initial (before) momentum=____________________ kg*m/s

After inelastic collision

Table 3 Cart A+B

Trial	Velocity (m/s)	Momentum (kg*m/s)
1		
2		
3		

Average initial (before) momentum=____________________ kg*m/s

Elastic Collision

Table 4 Before Collision data

Trial	velocity Cart A (m/s)	momentum (kg*m/s)		velocity Cart B (m/s)	momentum (kg*m/s)
	Cart A				**Cart B**
1				**0**	
2				**0**	
3				**0**	

Average initial (before) momentum=____________________ kg*m/s

Table 5 After Collision

Trial	velocity Cart A (m/s)	Momentum (kg*m/s)		Velocity Cart B (m/s)	Momentum (kg*m/s)
	Cart A			**Cart B**	
1					
2					
3					

Average initial (after) momentum for Cart A=____________________ kg*m/s

Average initial (after) momentum for Cart B=____________________ kg*m/s

Total momentum after collision_______________________ kg*m/s

Elastic collision with added masses to cart A

Table 6 Data before Collision

Trial	velocity Cart A **with added mass** (m/s)	Momentum (kg*m/s)		velocity Cart B (m/s)	Momentum (kg*m/s)
		Cart A		**Cart B**	
1				**0**	
2				**0**	
3				**0**	

Average initial (before) momentum=____________________ kg*m/s

Table 7 Data after Collision

	Cart A			Cart B	
Trial	velocity Cart A (m/s)	Momentum (kg*m/s)		Velocity Cart B (m/s)	Momentum (kg*m/s)
1					
2					
3					

Average initial (after) momentum for Cart A=____________________ kg*m/s

Average initial (after) momentum for Cart B=____________________ kg*m/s

Total momentum after collision________________________ kg*m/s

Questions (are continued on next page)

1. Using the results from the experiment, determine whether or not momentum is conserved in each part of the experiment. Is momentum conserved in both (all) parts? If not, give some possible sources of error.

2. What is impulse, and where did you see impulse in this experiment?

3. What's the difference between inelastic and elastic collisions? Is momentum conserved in both? If momentum is not conserved in a collision, what can you conclude?

4. When to cars collide in an automobile accident, what type of collision do the cars (typically) experience? 'Mostly inelastic' or 'mostly elastic' should also be considered. Would it be more damaging to the people inside if the cars stuck together or bounced apart? Explain your answers.

5. Picture two astronauts holding on to one another in space (Their initial velocity with respect to each other is zero). If one astronaut pushes the other away, what is the total momentum of both astronauts? If one astronaut weighs (on earth) twice as much as the other, what can you say about the velocity of the less massive one compared to the more massive one? Explain your answer.

6. In the last part of the experiment you added mass to the first cart (effectively doubling its mass) and when it elastically collided with a stationary cart with ½ half the mass *it kept moving* after the collision.

   What do you think would happen to both carts if a smaller cart elastically collided with a stationary cart that has twice the mass (of the smaller cart)?

   Explain your answer in the context of what you observed this experiment, i.e.,
   1)What happens when an object elastically collides with an object of the same mass
   2) What happens when an object elastically collides with an object that has half its mass

   It is also helpful to think about what happens if a small object (like a small rubber ball) elastically collides with a very massive object like a concrete wall.