# Experiment 5: Conservation of Momentum

| EQUIPMENT | |
|---|---|
| *Triple beam balance* | *Photogate including:* |
| *Two PASCO collision carts* | *1. Power supply* |
| | *2. Microphone cord* |
| PASCO Cart track | Calculator |
| *Amadeus Program* | Cart masses |
| Cart launcher | Digital calipers |

**Momentum**

The purpose of this lab is to observe the conservation of momentum for inelastic collisions 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 x velocity).

You have also studied something called impulse (impulse = force x 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.

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

If cart B is initially at rest, 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**

**Inelastic Collision**

1. Set up the photogate on the middle of the PASCO track. Make sure that you adjust the height of the photogates so that the cars can pass under it but the bars still pass in between the sensor. Also, there must be enough room on the track for the carts to pass under the photogates and continue to move down the track.
2. To ensure that the track is level, place one cart in the middle of the track. If the cart starts to roll one way then you need to adjust the level of the track. This can be done by turning a screw on the leg at one end of the track.
3. Use a triple beam balance to measure the mass of both carts. Be sure and turn carts upside down so they do not roll off of the balance when measuring. Record mass in Table 1.
4. Now use a caliper to measure the width of the bars on top of the carts. Record these values in Table 1. Please note that Cart A has two bars. See Figure 1 below.

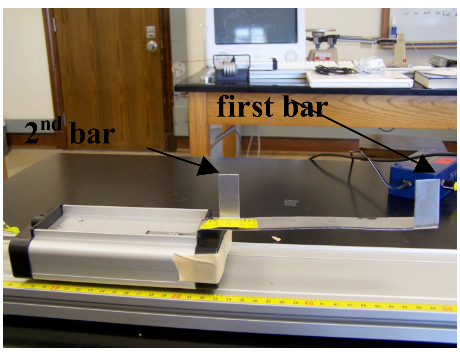

Figure 1

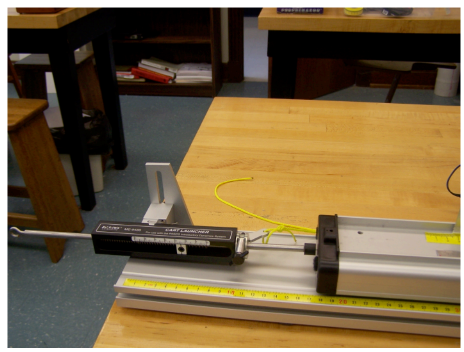
Figure 2

5. Make sure long bar is configured so that the internal magnets are attracted to each other for this part of the lab (i.e., **the carts should stick together when placed end to end.)**
6. Place cart A on the track.
7. Make sure the cart launcher is securely fastened to the track. Push the launcher arm back until it locks into place.
8. Set the cart against the launcher making sure that the wheels of the cart are in the grooves on the track. See Figure 2 above.
9. Now you will use the computer program called AMADEUS to measure the time it takes for the **bar 1** to pass through the photogate. There will be two waveforms displayed. We will ignore the 2nd one for the time being.
10. Begin collecting data on the computer (push "Record" button) and launch the cart by pulling back on the yellow string on the arm that holds it into place.
11. Record the time it takes for the first bar on cart A to pass through the photogate. You can use this number to calculate velocity of cart A. Show one calculation below.

$$velocity = \frac{width \text{ of bar}}{time} = \underline{\hspace{4cm}} = \qquad \text{m/s}$$

12. Repeat steps 6-11 once more to ensure that you are getting the same velocity (actually same time) or close a 2nd time.

13. Now you will create an inelastic collision by placing cart B on the track underneath the photogate. See Fig. 3. Note that no bar is necessary on cart B for this part of experiment.

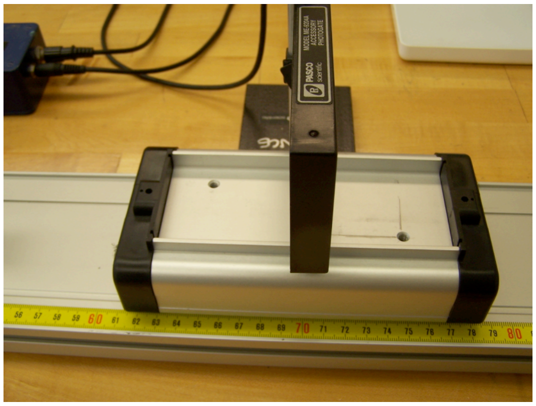

Figure 3. Cart B Inelastic Collision

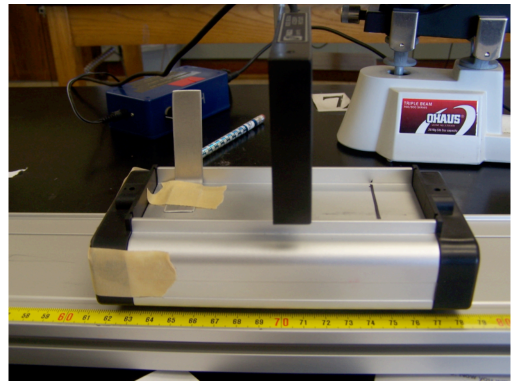

Figure 4. Cart B-Elastic Collision with bar added

14. Now you will use AMADEUS to measure the time it takes for the **both bars** on cart A to pass through the photogate. Please note that as arranged, the first bar on cart A goes through the photogate **before the collision** and the second bar (on cart A) does so **after the inelastic collision**.
15. Arm the launcher, and place the cart back against it. Make sure that cart is up against the plunger before launching. See Figure 2 above again.
16. Once everything is set up **hit record** on your computer. Simultaneously launch the cart. The carts should collide and stick together from the Velcro and magnets.
17. The wave pattern measured by Amadeus should have two signals on it. The first is from bar 1 (which gives the initial or before velocity) and the $2^{nd}$ is bar 2 (which yields the velocity on *both carts* after the inelastic collision).
18. In tables 2 & 3 record the times it takes for the bars to pass through the photogate (if your cars are of equal mass the 2nd time should be about twice as long as the time measured in step 11.
19. Repeat steps 13-18 to ensure that you are getting the same velocity (or close to it) every time. Record your calculations on your data sheet.

**Elastic Collision** (you may need to reduce the spring tension in this part)

**20.** Now you will observe an elastic collision. Reconfigure (reverse direction of) the bar on Cart A so **the magnets on the carts repel each other when placed end to end.**
21. Now set up the photogate such that it measures the timing of cart A before the collision and both carts after the collision. **Add bar to cart B**. See Figure 4 above. Keep in mind that when you make your calculations your initial velocity of cart B will be zero.
22. Begin collecting data, and launch your cart.
23. Measure the times it takes for cart A to pass through the photogate twice, and measure the time it takes for the cart B to pass through the other photogate once. (Your carts should collide elastically with cart B moving much faster than cart A in same direction.)
24. Calculate your velocities, and record them in data table 4.

**Table 1**

| Cart | Mass of Cart(s) (kg) | Width of Bar 1 on Cart ( convert from mm to m) | Width of Bar 2 on Cart ( convert from mm to m) |
|---|---|---|---|
| A | | | |
| B | | Width of Bar 3 here | xxxxxxxxxxxxxxxxxxx |
| A+B | | xxxxxxxxxxxxx | xxxxxxxxxxxx |

# Inelastic Collision Data

**Table 2**

**Before Collision**

**Cart A** **Cart B**

| Trial | measured time in **seconds** for bar 1 | Velocity Cart A (m/s) (divide bar 1 width by time) | Momentum kg-m/s | | Velocity Cart B (m/s) | Momentum |
|---|---|---|---|---|---|---|
| 1 | | | | | **0** | |
| 2 | | | | | **0** | |
| 3 | | | | | **0** | |

Average initial (before) momentum=___________________kg-m/s

**After Collision**

**Table 3**

**Cart A+B**

| Trial | measured time in seconds for bar 2 | Velocity (divide bar 2 width by time) | Momentum kg-m/s |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

Average initial (before) momentum=___________________kg-m/s

# Elastic Collision

**Table 4 Before Collision**

| Trial | Cart A: measured time in **seconds** for bar 1 | Cart A: velocity Cart A (m/s) (divide bar 1 width by time) | Cart A: momentum kg-m/s | | Cart B: velocity Cart B (m/s) | Cart B: momentum kg-m/s |
|---|---|---|---|---|---|---|
| 1 | | | | | **0** | |
| 2 | | | | | **0** | |
| 3 | | | | | **0** | |

Average initial (before) momentum=___________________kg-m/s

**Table 5 After Collision**

| Trial | Cart A: measured time in **seconds** for bar 2 | Cart A: velocity Cart A (m/s) (divide bar 2 width by time) | Cart A: momentum kg-m/s | | Cart B: measured time (s) for bar 3 | Cart B: Velocity Cart B (m/s) (divide bar 3 width by | Cart B: 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

## Elastic Collision with increase Mass of Cart A

25. If time permits, double the mass of cart A and repeat steps 20 through 24 but put data in Tables 6 & 7. Please note that the initial momentum will depend on new mass of cart A.

New mass of cart A (use in table 5 & 6 below) =________________kg

## Elastic Collision With Added Masses to Cart A

**Table 6 Before Collision**

**Cart A** **Cart B**

| Trial | measured time in **seconds** for bar 1 | velocity Cart A (m/s) (divide bar 1 width by time) | 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

**Table 6 After Collision**

**Cart A** **Cart B**

| Trial | measured time in **seconds** for bar 2 | velocity Cart A (m/s) (divide bar 2 width by time) | momentum kg-m/s | | measured time (s) for bar 3 | Velocity Cart B (m/s) (divide bar 3 width by | 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**

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 experience? Would it be more damaging to the people inside if the cars stuck together or bounced apart? Why?

5. Picture two astronauts holding on to one another in space. 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 other?