DEADLINE: Wednesday, March 6th

EXPERIMENT 2 LINEAR MOMENTUM AND CONSERVATION LAWS

OBJECTIVE

Linear momentum and conservation laws are investigated. Elastic and in elastic types of collisions are investigated. Theoretically calculated final velocities after collision are compared with experimentally calculated values.

THEORY AND PHYSICAL PRINCIPLES

The linear momentum $\vec{P}$ of an object is represented by its mass (m) and velocity $\vec{v}$.

$$\vec{p} = m\vec{v} \qquad (1)$$

Newton's second law of motion says that the force ($\vec{F}$) acting on an object is represented by its mass (m) and acceleration ($\vec{a}$).

$$\vec{F} = m\vec{a} \qquad (2)$$

The force $\vec{F}$ can also be written as rate of change in momentum:

$$\vec{F} = \frac{d\vec{p}}{dt} \qquad (3)$$

During the collision of a system of objects (net force acts on the system is zero), the change in momentum due to collision is zero for the system which means that the momentum is conserved.

$$\Delta\vec{p} = 0 \qquad (4)$$

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i = 0 \qquad (5)$$

$$\vec{p}_f = \vec{p}_i \qquad (6)$$

Consider the collision of two objects, object 1 of mass m_1 and velocity v_1 and object 2 of mass m_2 and velocity v_2,

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f} \qquad (7)$$

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f} \qquad (8)$$

Collisions can be divided into two types as elastic collision in which energy is conserved and inelastic collision in which energy is not conserved.

An object in motion has kinetic energy (K), which is determined by its mass (m) and velocity (v).

$$KE = \frac{1}{2}mv^2 \qquad (9)$$

Considering elastic cession and applying conservation of energy,

$$\Delta E(total) = 0 \qquad (10)$$

$$\frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2v_{2f}^2 - \left(\frac{1}{2}m_1v_{1i}^2 + \frac{1}{2}m_2v_{2i}^2\right) = 0 \qquad (11)$$

Consider elastic collision with object-1 initially moving and object-2 initially at rest, equation number 8 and 11 can be solved linearly to find the final velocities of objects after collision.

$$v_{1f} = \frac{(m_1 - m_2)}{(m_1 + m_2)} v_{1i} \quad (12), \qquad v_{2f} = \frac{2m_1}{(m_1 + m_2)} v_{1i} \quad (13)$$

In an inelastic collision where two objects stick to each other after collision, the conservation of momentum is rearranged to incorporate the one final velocity (v_f) for the combined masses.

$$m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i} = (m_1 + m_2)\vec{v}_f \quad (14)$$

The final velocity (v_f) after collision,

$$\vec{v}_f = \frac{m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i}}{(m_1 + m_2)} \quad (15)$$

In the laboratory experiment, velocities of the objects before and after collisions can be calculated by measuring time with a photogate. Then, conservation laws of momentum and energy can be investigated.

Velocity ($\vec{v}$) is calculated by the displacement ($\Delta\vec{x}$) and time (Δt).

$$\vec{v} = \frac{\Delta\vec{x}}{\Delta t} \quad (16)$$

APPARATUS AND PROCEDURE

- This experiment is done with the following simulation. https://www.gigaphysics.com/momentum_lab.html
- A very detail video tutorial with data collection from simulator and data analysis with excel can be found here: https://youtu.be/Xdlx-XgEWZU

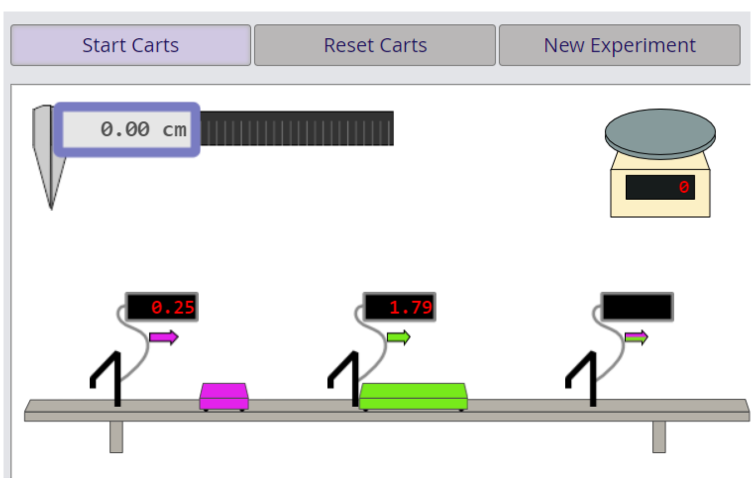

Figure 1 Simulator to study the momentum and conservation laws (Picture credit, https://www.gigaphysics.com)

Part A: Elastic collision

- Click and drag each cart and measure the mass of carts by placing them on the electronic balance on the top right corner.
- Click and drag each cart and measure the length of the carts by placing them on the vernier caliper on the top left corner.
- Set the type of collision to “elastic” by using the “cart behavior” menu.

- Set the “same direction” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.
- Photogates have an arrow with color which indicates the cart number and the direction of motion.
- Set the “opposite direction” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.
- Set the “one cart stationary” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.

Part B: Inelastic collision

- Set the type of collision to “inelastic” by using the “cart behavior” menu.
- Set the “same direction” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.
- Photogates have an arrow with color which indicates the cart number and the direction of motion.
- Set the “opposite direction” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.
- Set the “one cart stationary” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.

Part C: Partially elastic collision

- Set the type of collision to “partially elastic” by using the “cart behavior” menu.
- Set the “same direction” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.
- Photogates have an arrow with color which indicates the cart number and the direction of motion.
- Set the “opposite direction” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.
- Set the “one cart stationary” on the “cart’s direction” menu.
- Click on “start carts” and record the times on photogates with direction of motion. Consider the left to right is +x direction.

PRE LAB QUESTIONS

1) What is meant by the system in the case of conservation of momentum?
2) If a system contains two objects, is there a possibility that total momentum of one object is not conserved? Explain your answer?
3) Explain how to find the impulse that acts on one object during the collision?
4) What are the types of collisions?
5) Describe the types of collisions by suing conservation laws?

DATA ANALYSIS AND CALCULATIONS

Data tables, calculations and graphs must be done in excel. All the excel functions should be added below each table in the lab report.

Table 1 Time measurements of carts before and after collision

Cart 1		Cart 2	
Mass, m1 [ ]	Length, L1 [ ]	Mass, m1 [ ]	Length, L1 [ ]

	Time before collision		Time after collision	
	Cart 1	Cart 2	Cart 1	Cart 2
	t_{1i} [ ]	t_{2i} [ ]	t_{1f} [ ]	t_{2f} [ ]
Elastic collision Carts moves to same direction				
Elastic collision Carts moves to Opposite direction				
Elastic collision One cart at rest				
Inelastic collision Cart moves to same direction				
Inelastic collision Cart moves to opposite direction				
Inelastic collision One cart at rest				
Partially elastic collision Cart moves to same direction				
Partially elastic collision Cart moves to opposite direction				
Partially elastic collision One cart at rest				

Table 2 Analysis of final velocities with theoretical and experimental

	Velocity before collision		Velocity after collision	
	Cart 1	Cart 2	Cart 1	Cart 2
	v_{1i} [ ]	v_{2i} [ ]	v_{1f} [ ]	v_{2f} [ ]
Elastic collision Carts moves to same direction				
Elastic collision Carts moves to Opposite direction				
Elastic collision One cart at rest				
Inelastic collision Cart moves to same direction				
Inelastic collision Cart moves to opposite direction				
Inelastic collision One cart at rest				
Partially elastic collision Cart moves to same direction				
Partially elastic collision Cart moves to opposite direction				
Partially elastic collision One cart at rest				

Table 3 Analysis of momentum conservation

	P_i *(total)* Initial Total [ ]	P_f *(total)* Final Total [ ]	Changing Momentum ΔP [ ]	Does the momentum conserved or not? Explain why or why not?
Elastic collision Carts moves to same direction				
Elastic collision Carts moves to Opposite direction				
Elastic collision One cart at rest				
Inelastic collision Cart moves to same direction				
Inelastic collision Cart moves to opposite direction				
Inelastic collision One cart at rest				
Partially elastic collision Cart moves to same direction				
Partially elastic collision Cart moves to opposite direction				
Partially elastic collision One cart at rest				

Table 4 Analysis of energy conservation

	E_i *(total)* Initial Total [ ]	E_f *(total)* Final Total [ ]	Changing Energy ΔE [ ]	Does the energy conserve or not? Explain why or why not?
Elastic collision Carts moves to same direction				
Elastic collision Carts moves to Opposite direction				
Elastic collision One cart at rest				
Inelastic collision Cart moves to same direction				
Inelastic collision Cart moves to opposite direction				
Inelastic collision One cart at rest				
Partially elastic collision Cart moves to same direction				
Partially elastic collision Cart moves to opposite direction				
Partially elastic collision One cart at rest				