M26a: Conservation of Linear Momentum

Introduction:

The data collected during this experiment will permit testing the law of conservation of momentum for one dimensional inelastic and elastic collisions. The data will also permit determining if kinetic energy is conserved during either collision. The event examined is a collision occurring between two carts utilizing an apparatus called an air track. The air track elevates the small carts on a cushion of air in order to minimize frictional forces. Several types of collisions will be examined between the two carts. The variations will be whether one cart is more massive than the other and if either cart has velocity prior to the collision. The data collected during the experiment will be used to determine the linear momentum before the collision and separately after the collision. Additionally the kinetic energy before the collision and separately after the collision will be determined. Comparison of the data and results, before verses after, will illustrate the conservation principles involved during these several types of collisions.

Apparatus:

- Complete Air Track System
- Computer Timing System using 2 Range-Finders
- Mass Kit
- Connecting Rods & Clamps
- Mass Scale

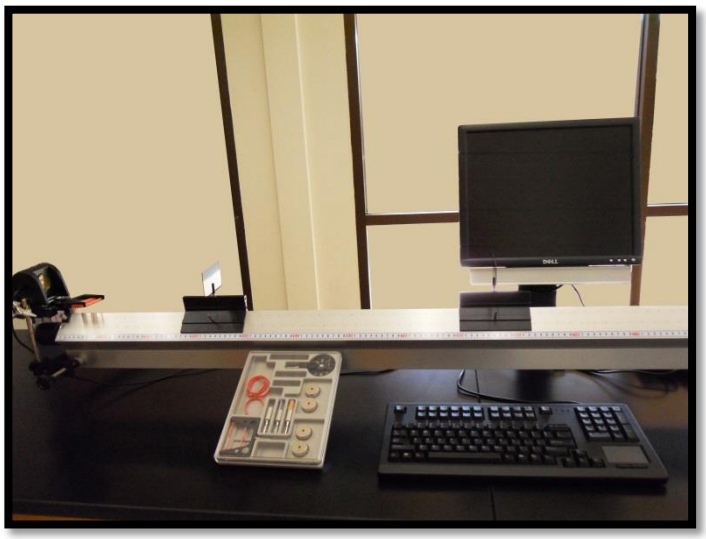


Figure 1

Figure 2

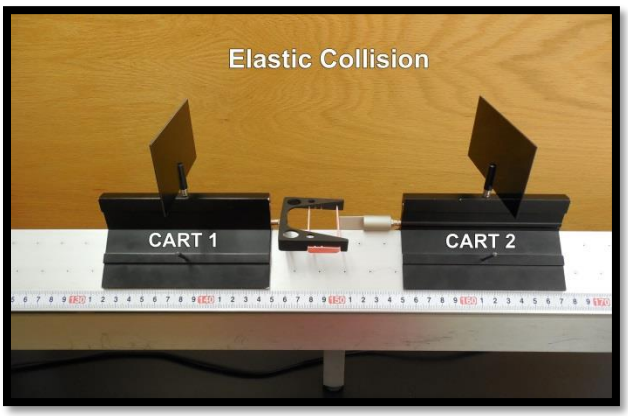


Figure 3

Discussion:

The law of conservation of linear momentum is one of the most fundamental laws of physics which has no exceptions in everyday life phenomena from the subatomic particles scale to the galactic clusters scale.

Linear momentum of an object is a vector quantity defined as the product of the mass of the object times its velocity:

$$\vec{p} = m * \vec{v} \quad (1).$$

Linear momentum of the system is a vector sum of individual linear momenta of the objects:

$$\vec{p} = \overrightarrow{p_1} + \overrightarrow{p_2} + \overrightarrow{p_3} + \ldots \quad (2).$$

In the case of one-dimensional collisions between two carts in this experiment, the law of conservation of the linear momentum yields:

$$m_1\overrightarrow{v_{1_i}} + m_2\overrightarrow{v_{2_i}} = m_1\overrightarrow{v_{1_f}} + m_2\overrightarrow{v_{2_f}} \quad (3),$$

where m_1 & m_2 are masses of the two carts, v_{1i} & v_{2i} are velocities of the two carts before the collision and v_{1f} & v_{2f} are velocities of the carts after the collision.

Collisions are called perfectly inelastic if the two objects stick together after a collision. Then equation (3) can be rewritten as:

$$m_1\overrightarrow{v_{1_i}} + m_2\overrightarrow{v_{2_i}} = (m_1 + m_2)\overrightarrow{v_{1,2_f}} \quad (4).$$

In some collisions, called elastic, kinetic energy of the system before collisions equals kinetic energy of the system after the collision. Applicable to collisions of two carts in this experiment this can be written as

$$\left(\tfrac{1}{2}m_1{v_{1_i}}^2\right) + \left(\tfrac{1}{2}m_2v_{2_i}^2\right) = \left(\tfrac{1}{2}m_1{v_{1_f}}^2\right) + \left(\tfrac{1}{2}m_2v_{2_f}^2\right) \quad (5).$$

Procedures:

Check with one of the lab instructors for complete information on the use of this apparatus before using the equipment.

Note: The carts will be moving from left to right. "Cart 1" is the one on your left and "Cart 2" is the one on your right.

Part 1: Inelastic Collisions

1. Open the appropriate data collection program on the computer.
2. Turn the air supply on for the air track.
3. Check the end bumpers on the air track for adequate elastic bands.
4. Attach the appropriate accessories to each cart needed for inelastic collisions, see Figure 2.

Equal Cart Masses:

Measure the mass of each cart including the accessory attached to each.
Conduct two trials with the carts of equal mass. See Table 1 for specifics.

Unequal Cart Masses:

Measure the mass of each cart including the accessory attached to each for each trial.
Conduct two trials with the carts of unequal masses. See Table 1 for specifics.

Part 2: Elastic Collisions

1. Open the appropriate data collection program on the computer.
2. Turn the air supply on for the air track.
3. Check the end bumpers on the air track for adequate elastic bands.
4. Attach the appropriate accessories to each cart needed for elastic collisions, see Figure 3.

Equal Cart Masses:

Measure the mass of each cart including the accessory attached to each.
Conduct two trials with the carts of equal mass. See Table 1 for specifics.

Unequal Cart Masses:

Measure the mass of each cart including the accessory attached to each for each trial.
Conduct two trials with the carts of unequal masses. See Table 1 for specifics.

Table 1

Inelastic Collisions		
Trial #	Cart Mass	Initial Velocities
1	$m_1 = m_2$	$v_1 > v_2 = 0$
2	$m_1 = m_2$	$v_1 > v_2 > 0$
3	$m_1 > m_2$	$v_1 > v_2 > 0$
4	$m_1 < m_2$	$v_1 > v_2 > 0$

Elastic Collisions		
1	$m_1 = m_2$	$v_1 > v_2 = 0$
2	$m_1 = m_2$	$v_1 > v_2 > 0$
3	$m_1 > m_2$	$v_1 > v_2 > 0$
4	$m_1 < m_2$	$v_1 > v_2 > 0$

Analyses:

1. For each trial, calculate the linear momentum of each car before and after the collision. Then calculate the linear momentum of the system before collision $\overrightarrow{\boldsymbol{p_i}}$, and after the collision $\overrightarrow{\boldsymbol{p_f}}$.

2. For each trial, calculate the percent difference between initial and final momentum of the system.

3. Conclude on whether the linear momentum was conserved in all collisions or not. Support your conclusions with your results.

4. For each trial, calculate the kinetic energy of each car before and after the collision. Then calculate the kinetic energy of the system before collision $\boldsymbol{K_i}$, and after the collision $\boldsymbol{K_f}$.

5. For each trial, calculate the percent difference between initial and final kinetic energy of the system.

6. Conclude on whether the kinetic energy was conserved in all collisions or not. Support your conclusions with your results.

7. Based on your results and calculations, identify which collisions were elastic and which were inelastic. Support your conclusions with your results.

Experiment M26a: Collisions & Conservation of Linear Momentum

Student Name_____

*Lab Partner Name*_____

*Lab Partner Name*_____

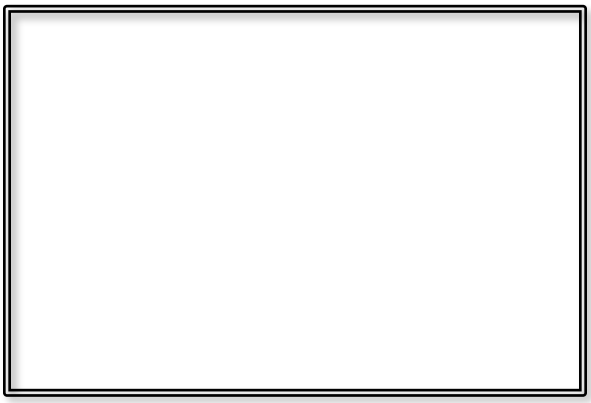
Physics Course_____

Physics Professor_____

Experiment Start Date_____

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed



Data Sheet 1: M26a: Collisions & Conservation of Linear Momentum:

Part 1: Inelastic Collision

Cart 1			Cart 2		
Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)

Part 2: Elastic Collision

Cart 1			Cart 2		
Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)

Data Sheet 2: M26a: Collisions & Conservation of Linear Momentum: Calculations

Part 1: Inelastic Collision

Linear Momentum			Kinetic Energy		
Initial (kg m/s)	Final (kg m/s)	Percent Difference	Initial (J)	Final (J)	Percent Difference

Part 2: Elastic Collision

Linear Momentum			Kinetic Energy		
Initial (kg m/s)	Final (kg m/s)	Percent Difference	Initial (J)	Final (J)	Percent Difference