12. COLLISIONS IN ONE DIMENSION

Objectives: To verify that linear momentum and kinetic energy are conserved in elastic collisions.

To verify that linear momentum is conserved, but not kinetic energy, in totally inelastic collisions.

Materials: Collision carts (2), mass bar, linear track, tripod mounted video camera reference scale, and Pasco Capstone Software for video capture and analysis

Theory:

A collision is a short interaction in which relatively large interaction forces are involved between objects. In a collision the individual momentum of each particle changes in such a way that the total momentum of the particles involved is the same before and after the collision. The total linear momentum of a system of particles is given by the vector sum of the momentum of each of the particles. Mathematically, for two particles, of which only one is initially moving:

$$m_1\vec{v}_{1i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

where $\vec{v}_{1i}$ and $\vec{v}_{1f}$ correspond to the velocities of m_1 immediately before and after the collision, respectively; $\vec{v}_{2f}$ corresponds to the final velocity of m_2.

Another important physical quantity in collisions is the kinetic energy of the system. It may or may not be conserved in collisions. Collisions are categorized as elastic if the total kinetic energy of the system before and after the collision is the same. If the kinetic energy of the system is not conserved then the collision is called inelastic. A totally inelastic collision is a special case of an inelastic collision in which the colliding objects stick together after the collision. For two particles, of which only one is initially moving:

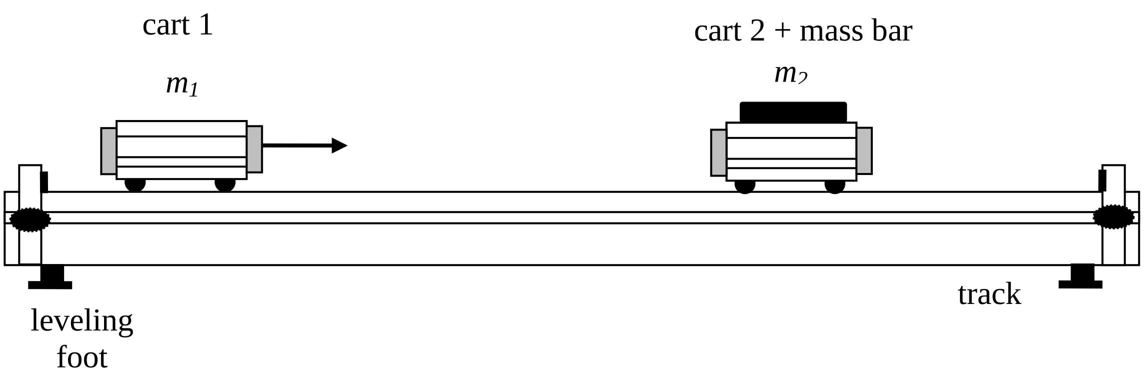
$$K_i = \frac{1}{2}m_1v_{1i}^2 \qquad\qquad K_f = \frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2v_{2f}^2$$

In the following experiments you will obtain the initial and final velocities of moving carts by video tracking the carts. Momentum and kinetic energies can be then calculated.

Procedure:

1. Carefully level the linear track by adjusting the appropriate feet. Place cart 1 near one end of the track (m_1 = mass of cart 1). Put one mass bar on cart 2 (m_2 = mass of cart 2 + mass of bar) and place it around the midpoint of the track. Start Capstone (in Physics Applications folder on Desktop) and add a **Movie Display** by double clicking on the **Movie** icon (lowest button on right hand toolbar). Click on **Record Movie with Synced Data.**

2. Play with colliding the carts. Observe qualitatively how the carts behave. Observe what happens when different masses are placed on the carts. Change the orientation of a cart by rotating the cart 180° and observe what happens.



A. Elastic Collisions

Set the carts (non-velcro sides face each other) so that the carts repel each other, which is due to small magnets hidden behind the bumpers. For the collision to be considered elastic, **the carts should not come in contact with each other**.

1. Recording Data: With the track centered and horizontal on the screen, click **Record** in the Controls Palette. Push m_1 towards m_2. After the collision click **Stop** in the Controls Palette. Click on **Playback Mode.** Click **Enter video analysis mode** in the Display toolbar.

2. Calibrating the Measurements: Adjust the scale or calibration tool to match (by clicking on and dragging the circles at the end of the tool) the scale of a meter stick placed near the track, for example resting on the legs. To make more precise placement of the calibration tool, press the **Windows Key** + "**+**" to magnify the screen. Press **Windows Key** + "**Esc**" to exit. ***Calibration of real world units is a critical step in video analysis of moving objects.*** To do this, right click on the calibration tool. Select **Properties** – **Calibration Tool.** Scroll down until **Real World Length** is visible. Type the real world distance between the ends of the calibration tool. If using the full length of the meter stick full, no change is necessary since the default length for calibration tools is 1 meter. Exit the **Properties** window.

Most likely, the track will not be perfectly parallel to the horizontal screen axis. To adjust this, move the two dots displayed on the "x-axis" until it is parallel with the track.

3. Tracking the Carts: You will track both carts: m_1 before and after the collision and m_2 just after the collision. Choose some clearly visible reference point on the cart, e.g. the corner of the cart. Start tracking the cart approximately half a cart length before the collision and stop approximately half a cart length after.

Capstone places a "**+**" at the point of click and the video will advance to the next frame. After the

m_1 has been tracked, return the movie to its beginning and press **Create Tracked Object** in order to track m_2.

Create a new **Page** and then open **Graph** by double clicking on its icon. Click **<Select Measurement>** (on the vertical axis) in the display and select the x-position. Using linear fit, find the average velocity for m_1 before the collision. Note: fit only points where the data are linear, i.e. the velocity is constant without the acceleration that is occurring during the collision). Create a new page, make a graph, and fit the data for m_2.

Record the velocities on Table 1. For elastic collisions, speeds for m_1 in the range of 0.36 – 0.60 m/s work best. Speeds less than about 0.36 m/s is not desired because friction with the track becomes an external force that cannot be neglected.

Repeat two time more times.

B. Totally Inelastic Collisions

Set the carts so that the velcro sides face each other. Use the same setup and video analysis as part A. Push m_1 towards m_2. The two carts should stick together. Record the velocities of the carts in Table 4. Repeat two more times.

Data:

Mass of cart 1: m_1 = ______________________kg

Mass of cart 2 + mass of bar: m_2 = ______________________kg

Table 1. – Elastic Collision

	m_1	m_2	m_1	m_2
Trial	v_{1i} (m/s)	v_{2i} (m/s)	v_{1f} (m/s)	v_{2f} (m/s)
1		0		
2		0		
3		0		

Table 2. – Totally Inelastic Collision

	m_1	m_2	$m_1 + m_2$
Trial	v_{1i} (m/s)	v_{2i} (m/s)	v_{2f} (m/s)
1		0	
2		0	
3		0	

Analysis:

1. For each trial of all experiments, calculate the total initial and final momentum and the % change between these two values, and the total initial and final kinetic energy and the % change between these two values. Write your results in Table 3. Use of Excel to perform the calculations is strongly recommended. A sample of how to use it effectively is shown on the last page.

2. For the experiments in each section, calculate the average % change of momentum and kinetic energy (Table 4).

Table 3

	Total p_i (kg m/s)	**Total p_f** (kg m/s)	% change	Total K_i (J)	Total K_f (J)	% change
Trial	Elastic Collision					
1						
2						
3						
Trial	Totally Inelastic Collision					
1						
2						
3						

Results:

Table 4

Type of collision	linear momentum: average % change	kinetic energy: average % change
Elastic Collision		
Totally Inelastic Collision		

Conclusions or Summary:

Sample Excel Table

	A	B	C	D
1	m_1 =	0.504		
2	m_2 =	0.505		
	m_B =	0.501		
3	v_{1i}	v_2		
4	0.419	0.406		
5	0.520	0.500		
6	p_i	KE_i	p_f	KE_f
7	0.211	0.044	0.205	0.042
8	0.262	0.068	0.253	0.063

The above simulated Excel table represents a fraction of your data. It is showing the calculations for some of the elastic collisions trials. To make the best use of Excel, set up data from tables 1 and 2 in a similar form as above. Excel typically uses relative position notation, while we need to use absolute positions. Using the $ signs tells Excel to use the data from that column and/or row regardless of where you're performing the calculation. On the other hand, for B4 cell A4 is the cell one column to its left, same row. The KE_i in cell B7 is calculated using the expression =B2*A4^2/2 As you copy the expression in D7 the absolute cells keep their id but relative cells vary.