Experiment: Momentum & Impulse in Collisions (Video)

Objectives:

- To utilize momentum carts to investigate the nature of different types of collisions
- To perform video motion analysis on elastic and inelastic collisions to explore the principle of momentum conservation graphically and numerically
- To observe how momentum, impulse and kinetic energy are transferred during elastic and inelastic collisions

Materials:

- a digital USB webcam camera & LoggerPro Software
- 2 motion carts
- Pasco collision track
- a meter stick

Introduction

The impulse-momentum theorem relates impulse, the average force applied to an object times the length of time the force is applied, and the change in momentum of the object:

$$\Sigma F\Delta t = mv_f - mv_i$$

Here we will only consider motion and forces along a single line. The average force, ΣF , is the net force on the object, but in the case where one force dominates all others it is sufficient to use only the large force in calculations and analysis.

For this experiment, a dynamics cart will roll along a level track and collide with a second cart. Using video technology, you will analyze the collision (before, during and after). Using Logger Pro to develop velocity-time graphs, you will test the Law of Conservation of Linear Momentum.

Part A: Initial Measurements & Camera Set-up

1. Obtain 2 matched collision carts. A matched cart pair will allow you to perform both elastic and inelastic collision experiments.
2. Measure the mass of both carts using a digital scale.
3. Record the mass of each cart in the table below.
4. Plug webcam into the USB slot on the computer
5. Open LoggerPro
6. Using the mouse, select "Insert"→"Video Capture"→"Camera Settings"
7. Use the Exposure controls to:

   (i) decrease the shutter speed to 1/300 sec

   (ii) increase the gain to roughly 60% to 80% (i.e. adjust the slide control to the right) to improve contract.

   (iii) set the "White Balance" to "Fluorescent"

9. Close the Camera Settings window.

Part B: An Inelastic Collision Visualized

Introduction:

In this section, you will set-up and perform video motion analysis on an inelastic collision to analyze the momentum and energy transfer that occurs between the two collision carts.

Procedure (Inelastic Collision):

1. Initial Set-Up and Video Capture:
    a. Level the collision track
    b. Orient two collision carts so that when they will "stick" together during impact.
    c. Set Cart 1 at one end of the track and Cart 2 near the center
    d. In LoggerPro, select "Insert" → "Video Capture". Before recording video, go over the following "Hints for cameraman" section
    e. Hints for cameraman:
        1. The camera must remain completely still during the digital recording process
        2. Be sure the track and both carts are clearly in the camera field of view
        3. Place a meter stick in the field of view (to be used as a reference length in LoggerPro, later on)
        4. Keep the track parallel to the horizontal direction in the field of view and focus the camera straight–on, to minimize "parallax" (or visual artifacts).
        5. The video file should capture the entire experiment, from just before the initial push through the post collision motion. *Note, the movie will be saved as an AVI format movie (*.avi).*
    f. To record video, click on "Start Capture".
    g. When the cameraman and the experimenter(s) are ready, start filming the movie then give Cart 1 a good push toward Cart 2
    h. To end recording, click on "Stop Capture". A Video window will open up in LoggerPro. View your movie in the camera to verify that it captured what you want.
2. Video Motion Analysis:
    a. Resize and move the movie field (if necessary) for viewability and convenience
    b. Use the QuickTime buttons to review the movie
    c. Click on the movie window and select the "Video Analysis" button (right-hand corner).
    d. Scale the movie using a meter stick as your reference.
    e. Select the positions for cart 1 in each frame. If possible, to try and get 10-20 points before and 10-20 points after the collision.

f. Using the QuickTime buttons, go back to the first frame where you started selecting points for cart 1. Click on the "Set Active Point" button then select the positions for cart 2 for the same frames as cart 1.

h. Right mouse click on movie frame and select "sent to back" to better view graphs.

i. Observe the graph window on the right side of the display. Select "X-Velocity" and "X-Velocity 2" for the y-axis.

		Before Collision			**After Collision**		
Object	**Mass (kg)**	**$v_{average}$ (m/s)**	**$p_{average}$**	**$KE_{average}$**	**$v_{average}$ (m/s)**	**$p_{average}$**	**$KE_{average}$**
Cart 1							
Cart 2							

Summary of Momentum and Energy Change			
Object	**Mass (kg)**	**Δp**	**ΔKE**
Cart 1			
Cart 2			

Analysis:

1. Observe the velocity graphs for each cart. Describe them:

2. Use the "statistics" feature of LoggerPro to determine the average velocity of each cart just before and just after collision. Record values in the above table.
3. Calculate the average momentum of Cart 1 and Cart 2 before and after collision. Record in the above table.
4. Calculate the change in momentum (Δp) for both cart 1 and 2. Record the data table.
5. How does $\Delta p_{cart\ 1}$ compare with $\Delta p_{cart\ 2}$? What does this imply about the total system momentum before, during and after this particular collision?

6. Create a new calculated column in LoggerPro called "Total Momentum". Define its formula as the total momentum of Cart 1 and Cart 2 combined. Display and observe the Total Momentum vs. time graph.
7. Does the total momentum graph have a discernible slope? Select the points in the graph using your mouse the click on the "Linear Fit" button to determine this slope.

   Slope of Total Momentum vs. time: __________

   Slope Units? _______

8. What do you think the significance of this slope might be?

9. Calculate the KE and ΔKE for each cart. Record in the above table.
10. How does $\Delta KE_{cart\ 1}$ compare with $\Delta KE_{cart\ 2}$?

11. Create a new calculated column in LoggerPro called "Total Energy". Define its formula as the total KE of Cart 1 and Cart 2.
12. Click on the graph window and select "Total Energy" for the y-axis. Observe the Total Energy vs time graph.
13. Describe the TE vs time graph. Does its appearance surprise you?

Part C: An Elastic Collision Visualized

Introduction:

In this section, you will set-up and perform video motion analysis on an elastic collision to analyze the momentum and energy transfer that occurs between the two collision carts.

Procedure (Elastic Collision):

1. Orient two collision carts so that when they will not "stick" together following impact.
2. Set Cart 1 at one end of the track and Cart 2 near the center
3. Clear LoggerPro by selecting "New" experiment. There is no need to save the old experiment.
4. Perform video capture for an elastic collision using the same procedure as described above for the inelastic collision.
5. Perform video motion analysis the elastic collision using the same procedure as described above for the inelastic collision.

		Before Collision			After Collision		
Object	**Mass (kg)**	$v_{average}$ **(m/s)**	$p_{average}$	$KE_{average}$	$v_{average}$ **(m/s)**	$p_{average}$	$KE_{average}$
Cart 1							
Cart 2							

Summary of Momentum and Energy Change			
Object	**Mass (kg)**	**Δp**	**ΔKE**
Cart 1			
Cart 2			

Analysis:

1. Observe the velocity graphs for each cart. Describe them:

2. Use the "statistics" feature of LoggerPro to determine the average velocity of each cart just before and just after collision. Record values in the above table.
3. Calculate the average momentum of Cart 1 and Cart 2 before and after collision. Record in the above table.
4. Calculate the change in momentum (Δp) for both cart 1 and 2. Record the data table.
5. How does $\Delta p_{cart\ 1}$ compare with $\Delta p_{cart\ 2}$? What this imply about the total system momentum before, during and after this particular collision?

6. Create a new calculated column in LoggerPro called "Total Momentum". Define its formula as the total momentum of Cart 1 and Cart 2.
7. Insert "New Graph". Select "Total Momentum" for the y-axis. Observe the Total Momentum vs time graph.
8. Does the total momentum graph have a discernible slope? Select the points in the graph using your mouse the click on the "Linear Fit" button to determine this slope.

   Slope of Total Momentum vs. time graph: __________

   Slope Units? ________

9. What do you think the significance of this slope might be?

10. Calculate the KE and ΔKE for each cart. Record in the above table.
11. How does $\Delta KE_{cart\ 1}$ compare with $\Delta KE_{cart\ 2}$?

12. Create a new calculated column in LoggerPro called "Total Energy". Define its formula as the total KE of Cart 1 and Cart 2. Observe the Total Energy vs time graph.
13. Describe the TE vs time graph. Does its appearance surprise you?