ACTIVITY SEVEN
CONSERVATION OF MOMENTUM
INELASTIC COLLISIONS

PURPOSE

For this experiment, the Motion Visualizer (MV) is used to capture the motion of two frictionless carts moving along a flat, horizontal frictionless track. The overall goal of this activity is for students to gain an understanding of how momentum is conserved during *inelastic* collisions. This will be accomplished by examining the changes in velocity that occur when the two carts collide and stick together.

After this activity, students should be able to do the following:

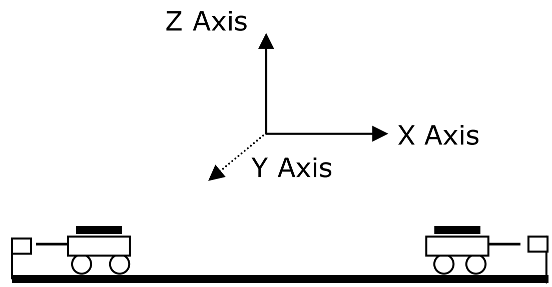
- √ Use words to describe momentum.
- √ Explain the vector nature of momentum
- √ Explain how an object's momentum can change.
- √ Write out the equation for momentum.
- √ Calculate the momentum of an object given mass and velocity data.
- √ Use words to describe an inelastic collision.
- √ Apply momentum conservation to various situations.

SOFTWARE SET-UP

This is a 2D, two-object experiment with horizontal motion. The distance from camera lens to plane of motion was set to 2.4 meters and the camera angle was set to -10°. With this set-up, the software displays the horizontal motion on the X-axis and the vertical motion on the Z-axis.

MATERIALS

- Low friction cart.
- 1 – 2 meter low friction track.
- Computer with MV software and hardware.
- Video camera with tripod.
- Angle measuring device.
- Tape measure or meter stick.
- Various bar masses.

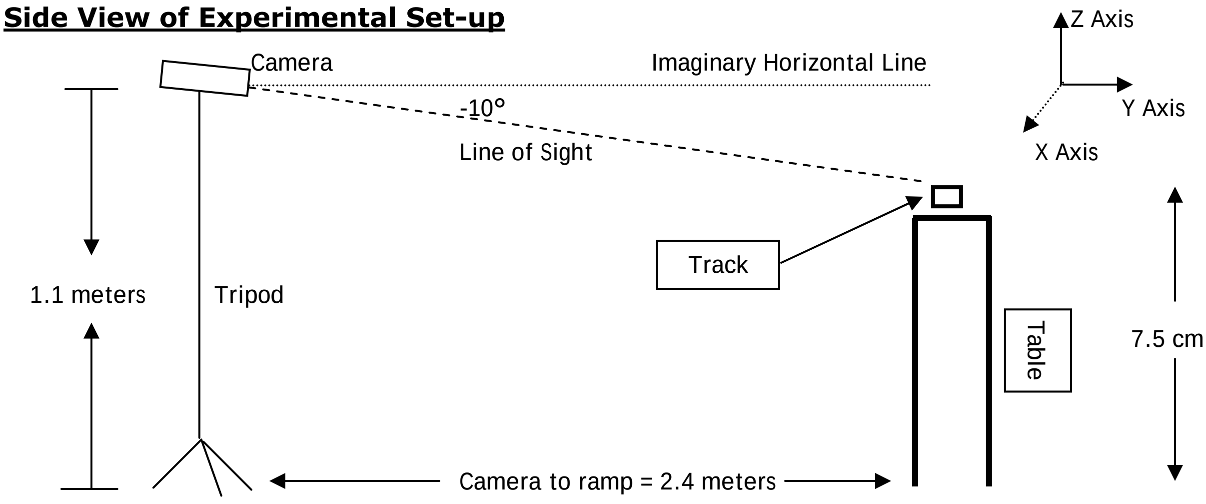


PROCEDURE

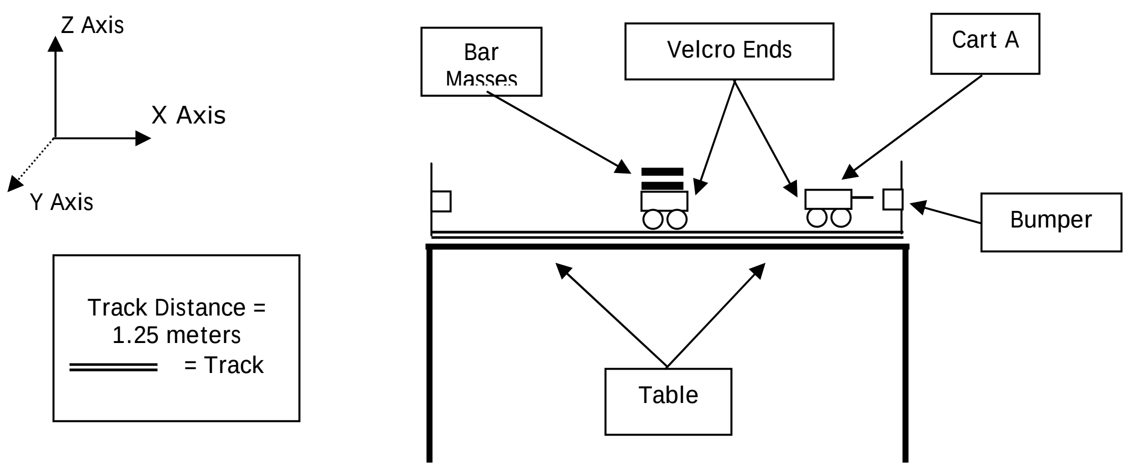
1. Place carts, with Velcro ends facing each other, on the track.
2. Label the carts A and B.
3. Add bar masses to carts depending on the situation.
4. Adjust the view finder of video camera to capture entire range of motion.
5. Use angle finder to determine camera angle. Enter this value in computer.
6. Measure distance from camera lens to plane of motion. Enter this value in computer.
7. Place Cart A at the end of the track. Place Cart B in the middle of the track.
8. Run experiment.

Written by Michael Quinlan. Michael is a Physics teacher at Newton North High School, Newton, Massachusetts

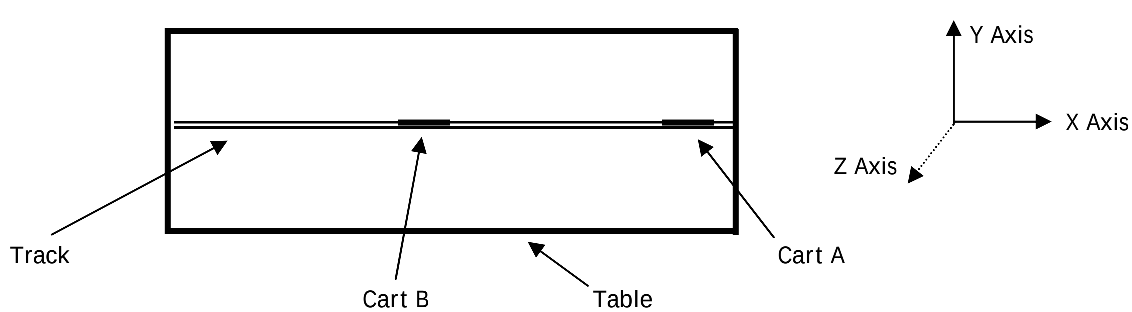
Side View of Experimental Set-up



Front (Camera) View of Experimental Set-up



Top View of Experimental Set-up



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DATA COLLECTION, PRESENTATION AND ANALYSIS GUIDELINES

In this activity, two frictionless carts are placed on a frictionless track. Bar masses are placed on the carts to vary the carts' masses. The carts' velocities are controlled by the spring loaded plunger connected to the back of each cart. The carts have magnets on one end so that they do not stick and will thus demonstrate *inelastic collisions*.

Inelastic Collisions – One in which the total kinetic energy is the **not** same before and after the collision. In these collisions, the objects may couple, deform or generate heat. Momentum, however, is conserved.

Data for the following types of elastic collisions are included in this activity:

PART A. Equal Masses

- Mass of Cart A (250 g) = Mass of Cart B (250 g)

PART B. Unequal Masses

- Mass of Cart B (500 g) is two times the Mass of Cart A (250 g)

Momentum – Inertia in motion. The product of an object's mass times its velocity. It is a vector that points in the same direction as the object's velocity. The total momentum of a system is the vector sum of the individual pieces that make up the system.

MOMENTUM = MASS x VELOCITY
[Units = kg • m/sec]

Momentum is a vector quantity and follows the standard sign convention. When the velocity is positive, the momentum is positive. When the velocity is negative, the momentum is negative.

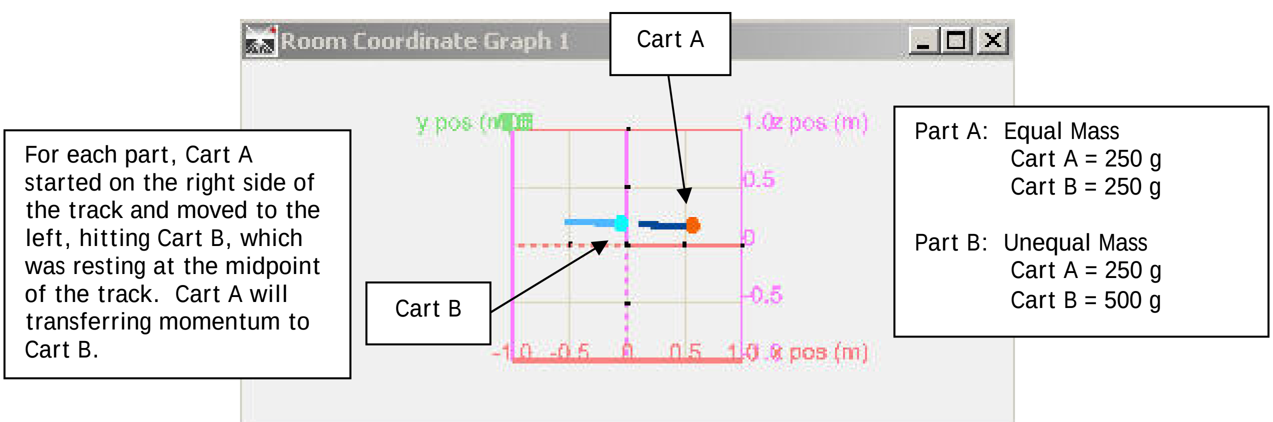
Conservation of Momentum – The total momentum of an isolated system remains constant before and after a collision.

INITIAL MOMENTUM = FINAL MOMENTUM

$$\sum M_1V_1 + M_2V_2 + \ldots + M_nV_n = \sum M_1V_1 + M_1V_1 + \ldots + M_nV_n +$$

Show the animation in the *Room Coordinate Graph* from different perspectives. This will give the students an opportunity to review the collisions.

<u>Room Coordinate Graph</u> - Front (Camera) view – This view shows the motion of the cart from the camera's perspective. The orientation of the carts on the track was the same for Part A and Part B.



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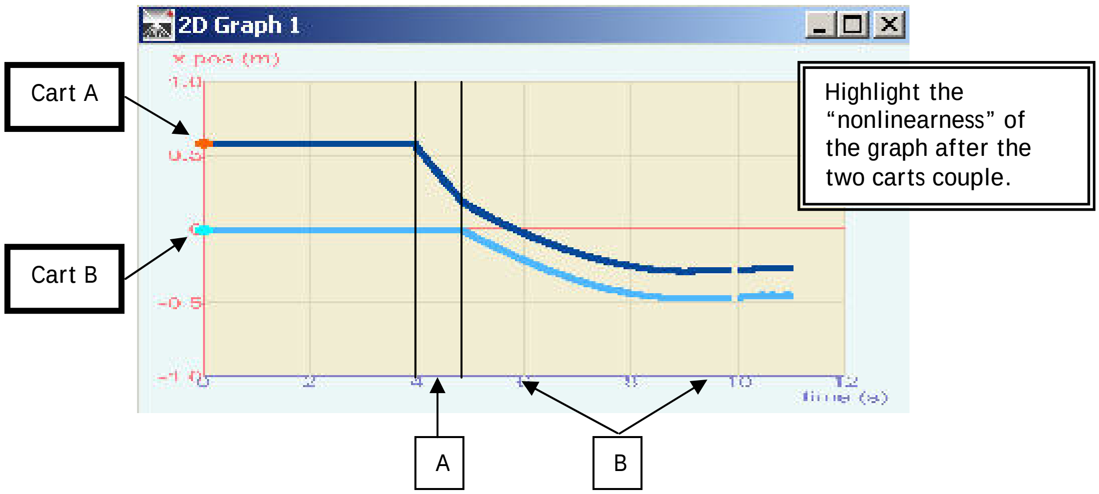
PART A: EQUAL MASSES

1. X Position v. Time Graph

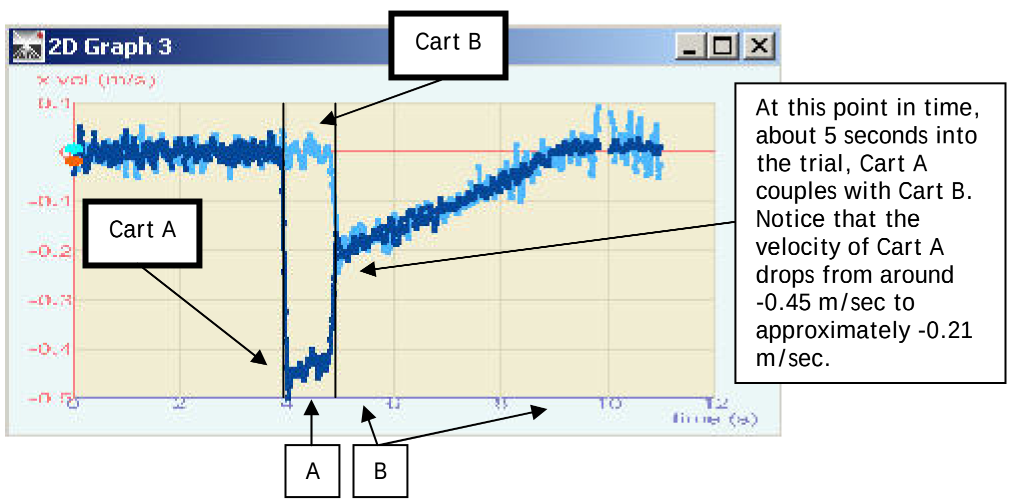


For this trial, there was one (1) collision that took place between Cart A and Cart B. The collision is described below.

COLLISION 1: CART A HITS CART B

Section A: Cart A moves to the left with a constant velocity and then slams into Cart B.
Section B: Cart A and Cart B move together, gradually coming to a stop.

2. X Velocity v. Time Graph



MOMENTUM = MASS x VELOCITY
[Units = kg • m/sec]

Velocity (m/sec)

	Section A		Section B
Cart A	-0.45		-0.21
Cart B	0.0		-0.21

Momentum (kg • m/sec)

	Section A		Section B
Cart A	-0.1125		-0.0525
Cart B	0.0		-0.0525

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INITIAL MOMENTUM = FINAL MOMENTUM

$$\sum M_1V_1 + M_2V_2 + \ldots + M_nV_n = \sum M_1V_1 + M_1V_1 + \ldots + M_nV_n$$

CONSERVATION OF MOMENTUM

COLLISION 1 √ Momentum is Conserved

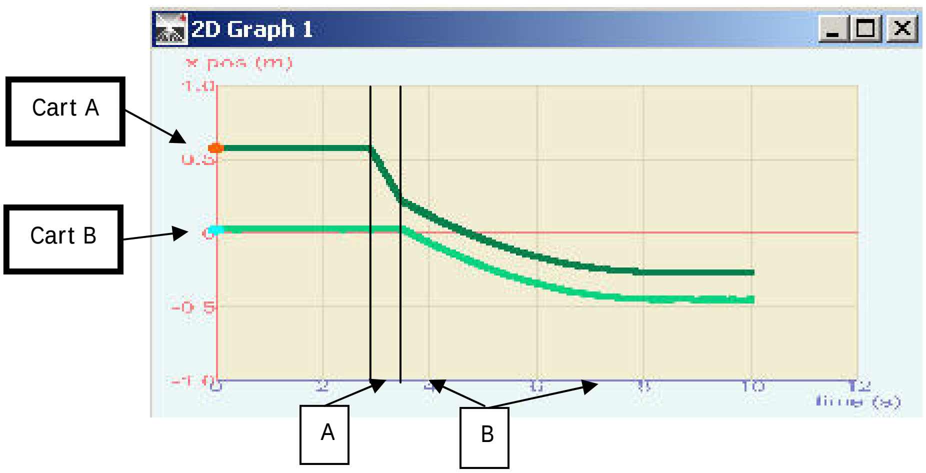
Before Collision = (-0.1125 + 0.0) kg • m/sec

After Collision = (-0.0525 + (-0.0525)) kg • m/sec

After Collision = -0.1125 kg • m/sec

PART B: UNEQUAL MASSES (Cart A = 500 g; Cart B = 250 g)

1. X Position v. Time Graph



For this trial, there was one (1) collision that took place between Cart A and Cart B.

COLLISION 1: CART A HITS CART B

Section A: Cart A moves to the left with a constant velocity and then slams into Cart B.
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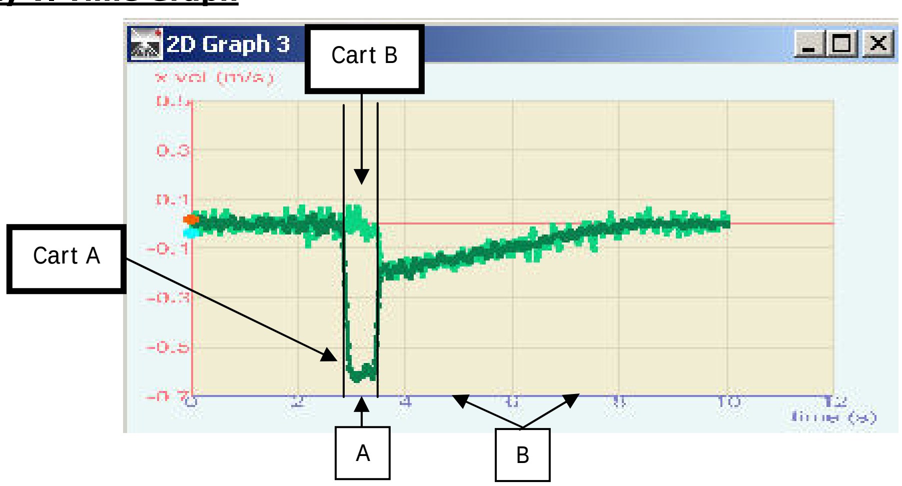
2. X Velocity v. Time Graph



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MOMENTUM = MASS x VELOCITY
[Units = kg • m/sec]

Velocity (m/sec) m/sec)

	Section A	Section B
Cart A	-0.60	-0.2
Cart B	0.0	-0.2

Momentum (kg •

	Section A	Section B
Cart A	-0.15	-0.05
Cart B	0.0	-0.10

INITIAL MOMENTUM = FINAL MOMENTUM

$$\sum M_1V_1 + M_2V_2 + \ldots + M_nV_n = \sum M_1V_1 + M_1V_1 + \ldots + M_nV_n$$

CONSERVATION OF MOMENTUM

COLLISION 1 √ Momentum is Conserved.

Before Collision = (-0.15 + 0.0) kg • m/sec After Collision = (-0.05 + (-0.10)) kg • m/sec = -0.15 kg • m/sec

EXTENSIONS

- Change the mass ratio of the carts. [3 to 1, 4 to 1, 3 to 2, 4 to 2, etc.]
- Launch two carts with the same mass toward each other.
- Launch two carts of different masses toward each other.

QUESTIONS

1. Two identical vehicles have the same speed, one traveling east and one traveling west. Do these cars have the same momentum? Explain.
2. On the Esplanade in Boston people watch the fireworks on the Fourth of July. What is the total momentum of one of the fireworks during its explosion? Explain.
3. Superman (mass = 92 kg) jumps off an overpass onto a criminal's speeding car (mass = 1100 kg) below. If the car is moving at 15 m/sec before he jumps on it, how fast is it moving once he is on it?
4. Site an example from your life of an inelastic collision. Explain your reasoning.
5. A receiver moving at 4.5 m/sec tackles a quarterback. The tackler holds onto the quarterback and the two move off together with a velocity of 2.5 m/sec. The mass of the receiver is 115 kg. Assuming that momentum is conserved, what is the mass of the quarterback?
6. On the Velocity v. Time axes below, sketch the above situation.