ACTIVITY SIX
CONSERVATION OF MOMENTUM
ELASTIC 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 *elastic* collisions. This will be accomplished by examining the changes in velocity that occur when the two carts collide.

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

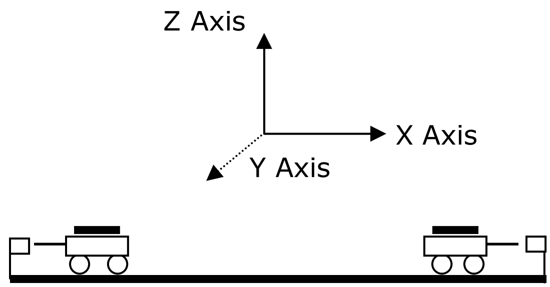
- √ Use words to describe momentum.
- √ Explain the vector nature of momentum
- √ Explain how an object's momentum can change.
- √ Write out the equation for momentum.
- √ Calculate the momentum of an object given mass and velocity data.
- √ Use words to describe an elastic collision.
- √ Apply momentum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

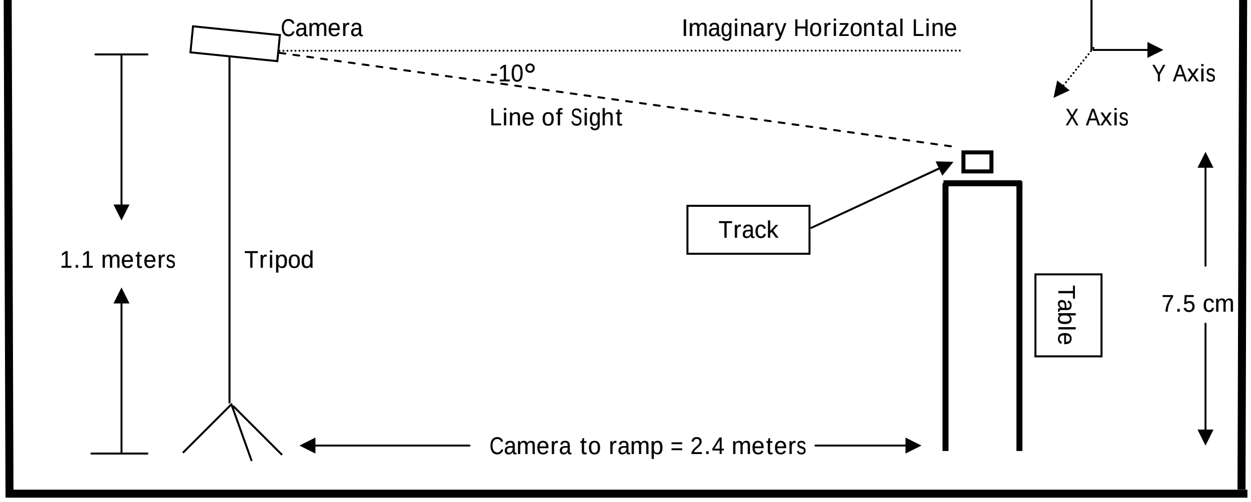


PROCEDURE

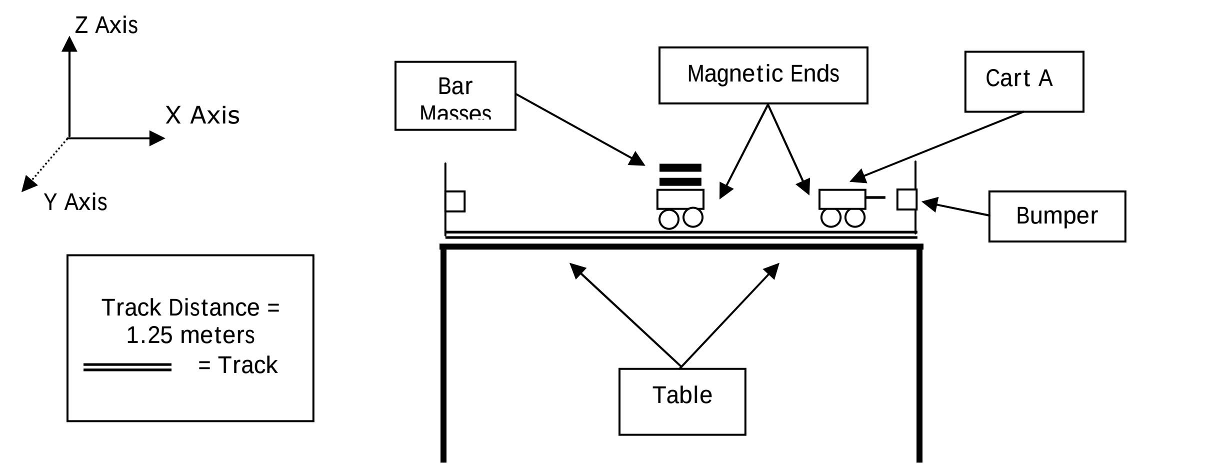
1. Place carts, with magnetic ends facing each other, on the track.
2. Label the carts A and B.
3. Add bar masses to carts depending on the situation.
4. Adjust the view finder of video camera to capture entire range of motion.
5. Use angle finder to determine camera angle. Enter this value in computer.
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

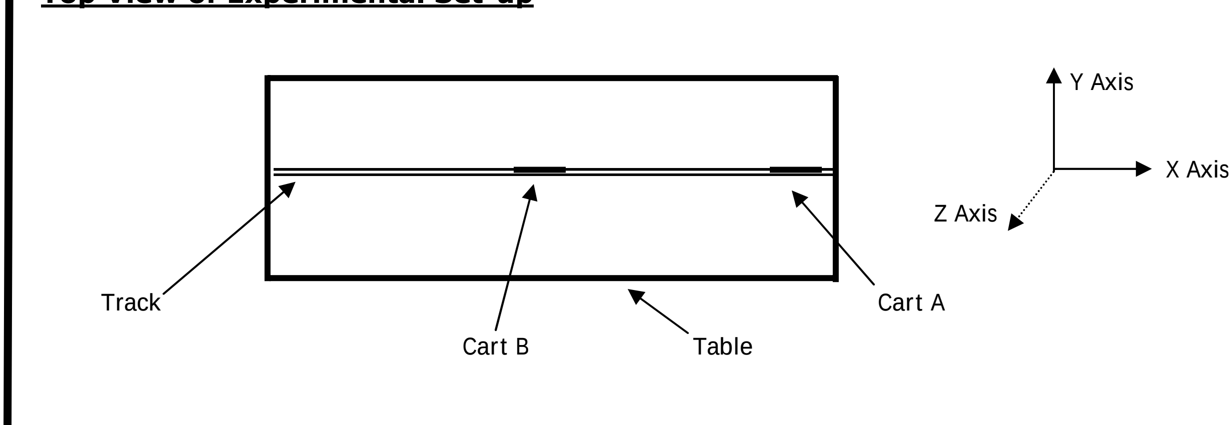
Side View of Experimental Set-up



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 *elastic collisions*.

Elastic Collisions – One in which the total kinetic energy is the same before and after the collision. In these collisions, the objects may bound or rebound without lasting deformation or generation of heat. Momentum 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.

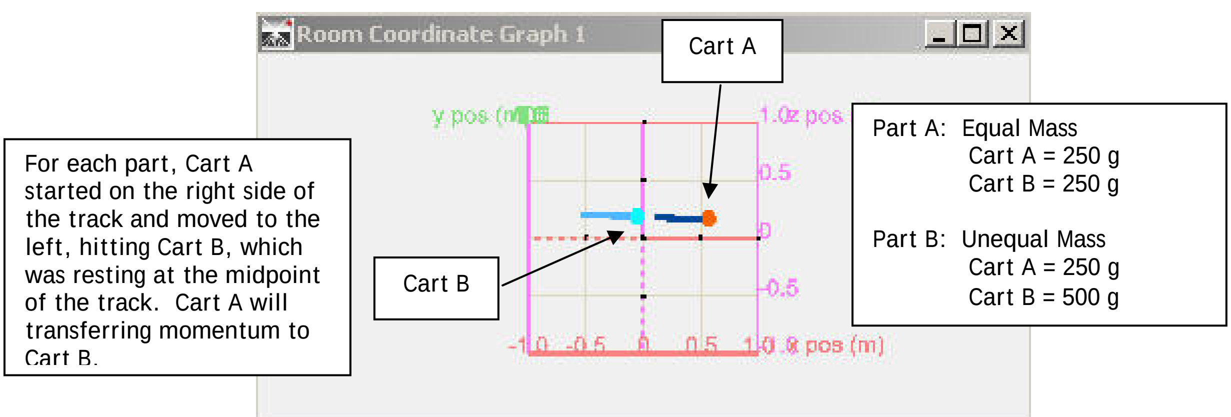
Conservation of Momentum – The total momentum of an isolated system remains constant before and after a collision.

INITIAL MOMENTUM = FINAL MOMENTUM

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

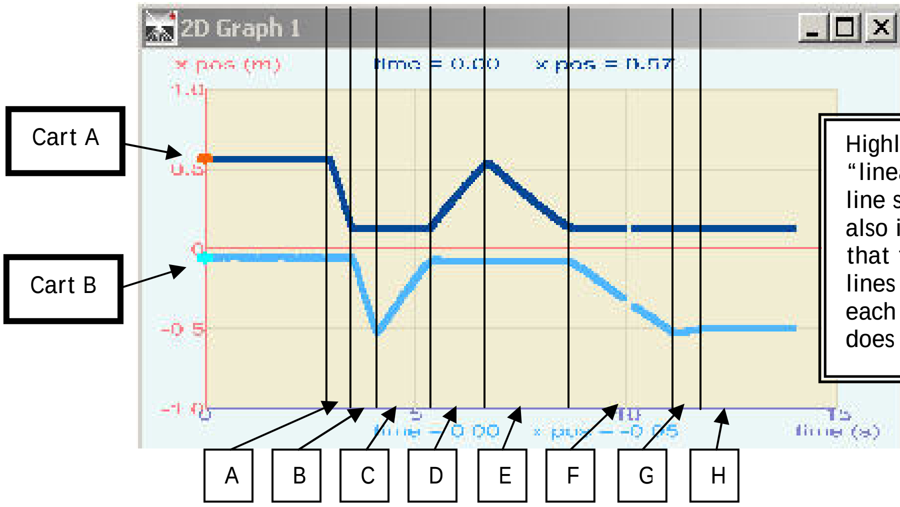
Show the animation in the *Room Coordinate Graph* from different perspectives. This will give the students an opportunity to review the collisions.

<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.



PART A: EQUAL MASSES

1. X Position v. Time Graph



Highlight the "linearness" of each line segment. It is also important to note that the slope of the lines decrease after each collision. Where does the energy go?

For this trial, there were four (4) collisions that took place between Cart A and Cart B. Each 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 stops and Cart B starts moving with the same velocity that Cart A started with.

COLLISION 2: CART B HITS CART A

Section C: Cart B hits the bumper at the end of the track and reverses its direction. *Since this interaction is external to the system [Cart A and Cart B], there is a decrease in the momentum from Collision 1.*
Section D: Cart B hits Cart A causing it to move in the same direction with the same speed.

COLLISION 3: CART A HITS CART B

Section E: Cart A hits the bumper at the end of the track and reverses its direction. *Since this interaction is external to the system [Cart A and Cart B], there is a decrease in the momentum from Collision 1.*
Section F: Cart A hits Cart B causing it to move with the same velocity.

COLLISION 4: CART B HITS CART A

Section G: Cart B hits the bumper on the left side of the track and changes its. *Since this interaction is external to the system [Cart A and Cart B], there is a decrease in the momentum from Collision 1.*
Section H: Both Carts are at rest.

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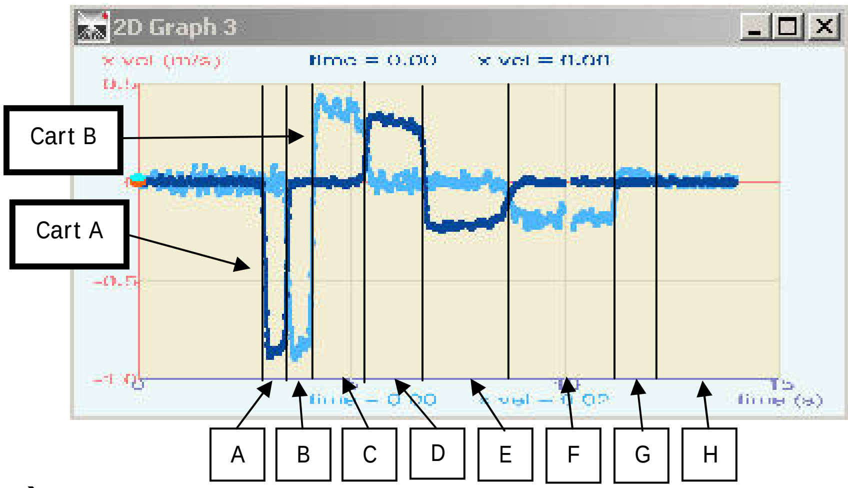
2. X Velocity v. Time Graph



Velocity (m/sec)

	Section A	Section B	Section C	Section D	Section E	Section F	Section G	Section H
	Collision 1		Collision 2		Collision 3		Collision 4	
Cart A	-0.8	0.0	0.0	+0.4	-0.2	0.0	0.0	0.0
Cart B	0.0	-0.8	+0.4	0.0	0.0	-0.2	+0.1	0.0

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

Momentum (kg • m/sec)

	Section A	Section B	Section C	Section D	Section E	Section F	Section G	Section H
	Collision 1		Collision 2		Collision 3		Collision 4	
Cart A	-0.2	0.0	0.0	+0.1	-0.05	0.0	0.0	0.0
Cart B	0.0	-0.2	+0.1	0.0	0.0	-0.05	+0.025	0.0

INITIAL MOMENTUM = FINAL MOMENTUM

$$\Sigma M_1V_1 + M_2V_2 + \ldots + M_nV_n = \Sigma\, M_1V_1 + M_1V_1 + \ldots + M_nV_n$$

CONSERVATION OF MOMENTUM

COLLISION 1 Before Collision = (-0.2 + 0.0) kg • m/sec After Collision = (0.0 + (-0.2)) kg • m/sec √ Momentum is Conserved.	**COLLISION 3** Before Collision = (-0.05 + 0.0) kg • m/sec After Collision = (0.0 + (-0.05)) kg • m/sec √ Momentum is Conserved.
COLLISION 2 Before Collision = (0.0 + 0.1) kg • m/sec After Collision = (0.1 + 0.0) kg • m/sec √ Momentum is Conserved.	**COLLISION 4** Before Collision = (0.025 + 0.0) kg • m/sec After Collision = (0.0 + 0.0) kg • m/sec √ Momentum is **Not** Conserved. Energy is lost to friction.

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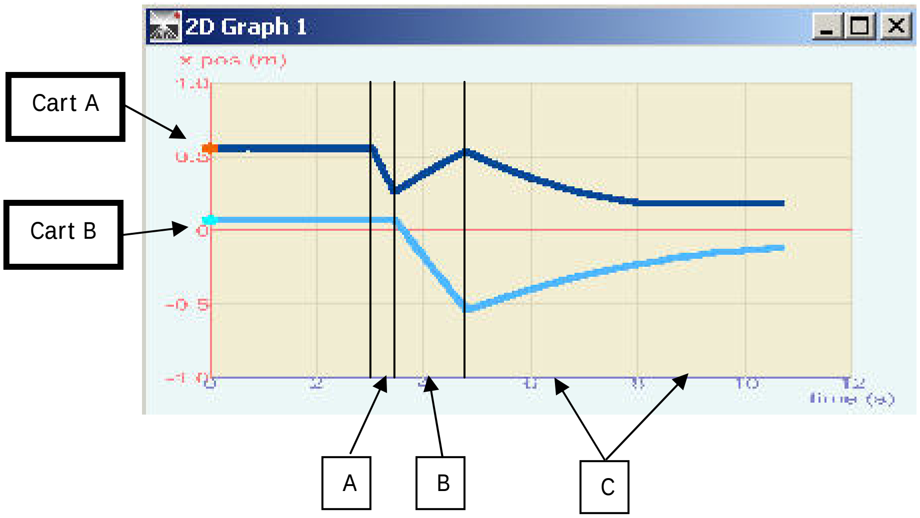
PART B: UNEQUAL MASSES (Cart A = 500 g; Cart B = 250 g)

1. <u>X Position v. Time Graph</u>

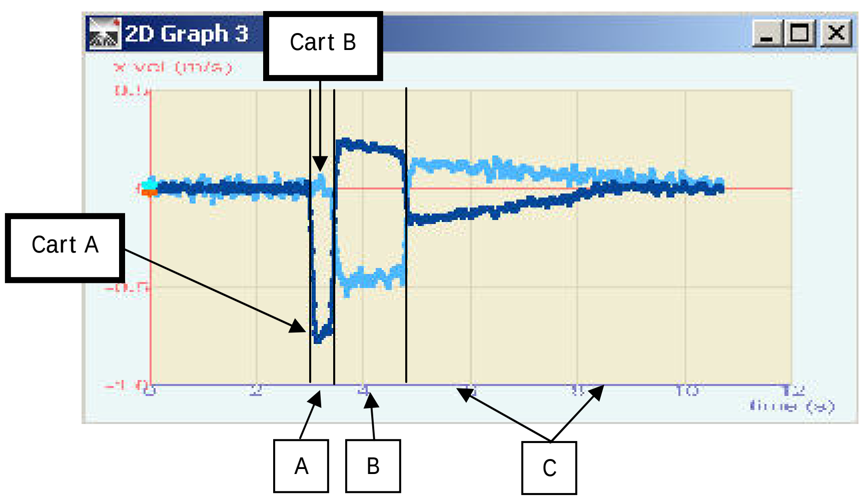


For this trial, there was one (1) collision that took place between Cart A and Cart B.

<u>COLLISION 1: CART A HITS CART B</u>

Section A: Cart A moves to the left with a constant velocity and then slams into Cart B.
Section B: Cart A rebounds but with a smaller velocity and Cart B starts moving to the left.
Section C: Both carts rebound off the bumper at the end of the track and gradually stop.

2. <u>X Velocity v. Time Graph</u>



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

<u>Velocity (m/sec)</u>
<u>m/sec)</u>

	Section A	Section B
Cart A	-0.75	0.25
Cart B	0.0	-0.5

<u>Momentum (kg •</u>

	Section A	Section B
Cart A	-0.1875	0.0625
Cart B	0.0	-0.25

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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

Before Collision = (-0.1875 + 0.0) kg • m/sec

After Collision = (0.0625 + (-0.25)) kg • m/sec = -0.1875 kg • m/sec

√ Momentum is Conserved.

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. Can a bullet and a truck have the same momentum? Explain.
2. When a bullet is fired, the gun "kicks back." Is momentum conserved? Explain.
3. Why is the direction of the velocity important when analyzing momentum?
4. Site an example from your life of an elastic collision. Explain your reasoning.
5. A *bumper* truck with a mass of 2000 kg slams into a stationary 1000 kg *bumper* Volkswagen bug. With what speed does the Volkswagen take-off at? [Assume the truck comes to an immediate stop.]
6. The following table gives mass and velocity data for two objects before a variety of collisions.

Before Collision Data

	Mass (kg)	**Velocity (m/sec)**
Cart A	2.0	8.0
Cart B	6.0	0.0

Assume the collisions are completely elastic; fill in Cart B's velocity.

After Collision Data

Velocity of Cart A (m/sec)	**Velocity of Cart B (m/sec)**
0.0	
-2.0	
-4.0	

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