ACTIVITY EIGHT
CONSERVATION OF MOMENTUM
EXPLOSIONS

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 an *explosion*. This will be accomplished by examining the changes in velocity that occur when the two carts suddenly separate from each other.

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

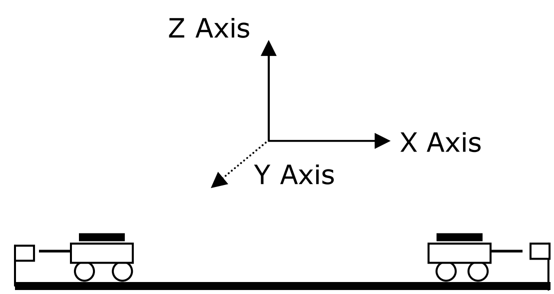
- √ Use words to describe momentum.
- √ Explain the vector nature of momentum
- √ Explain how an object's momentum can change.
- √ Write out the equation for momentum.
- √ Calculate the momentum of an object given mass and velocity data.
- √ Apply momentum conservation to various situations.

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

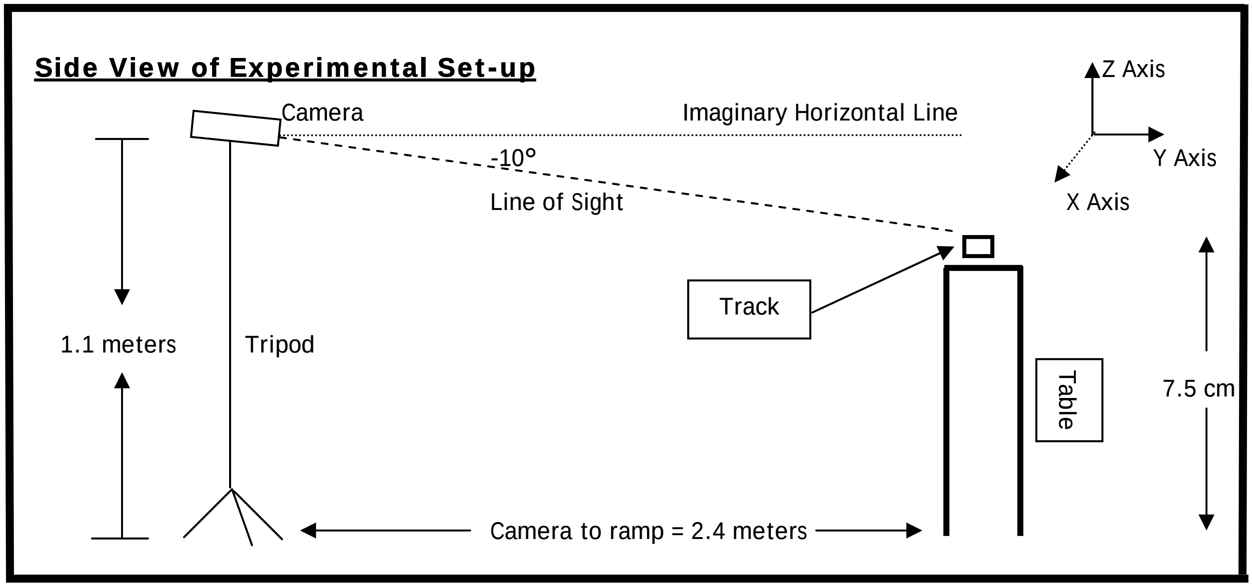
- Low friction cart.
- 1 – 2 meter low friction track.
- Computer with MV software and hardware.
- Video camera with tripod.
- Angle measuring device.
- Tape measure or meter stick.
- Various bar masses.

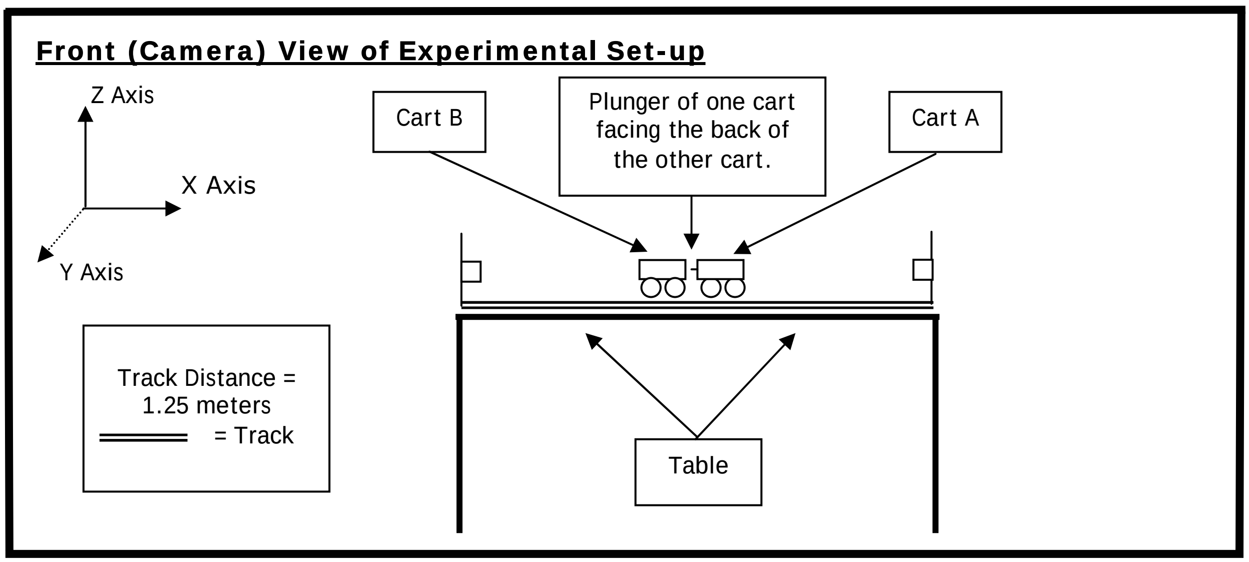


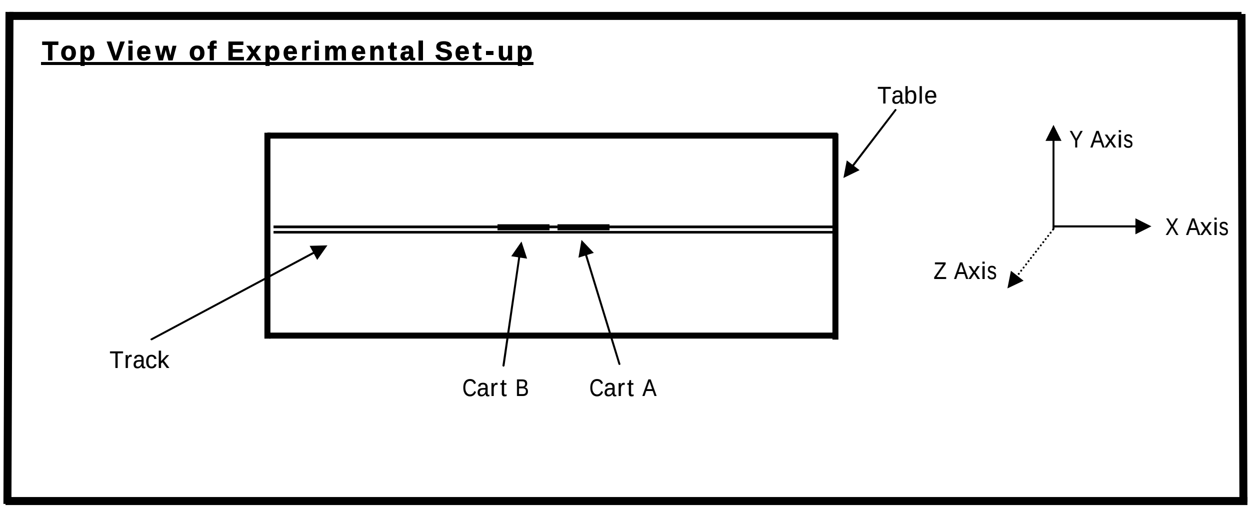
PROCEDURE

1. Place the two carts in the center of the track with the plunger pushed in.
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. Run experiment.

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







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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. When released, the spring loaded plunger on Cart A will push Cart B, causing them to fly away from each other simulating an explosion.

Data for the following types of explosions 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 (750 g) is three times the Mass of Cart A (250 g)

For explosions, the total momentum of the system before and after the event must be zero. Since the two carts do not move prior to the release of the plunger, they have no momentum. They move after the explosion but in opposite directions. The ratio of the carts' velocities after the collision is inversely proportional to the ratio of the carts' masses, as shown below.

INITIAL MOMENTUM = FINAL MOMENTUM

$$M_1V_1 + (-M_2V_2) = 0$$

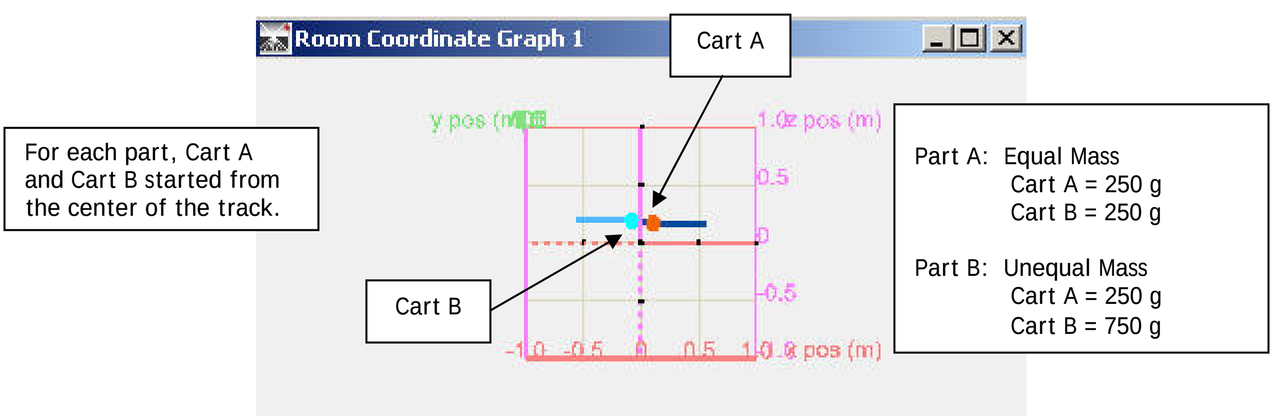
$$M_1V_1 = M_2V_2$$

$$\mathbf{V_1 / V_2 = M_2 / M_1}$$

Since the carts move in *opposite* directions, after the explosion, one of the velocities will be negative. Using standard convention, the rightward direction is positive and the leftward direction is negative.

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

<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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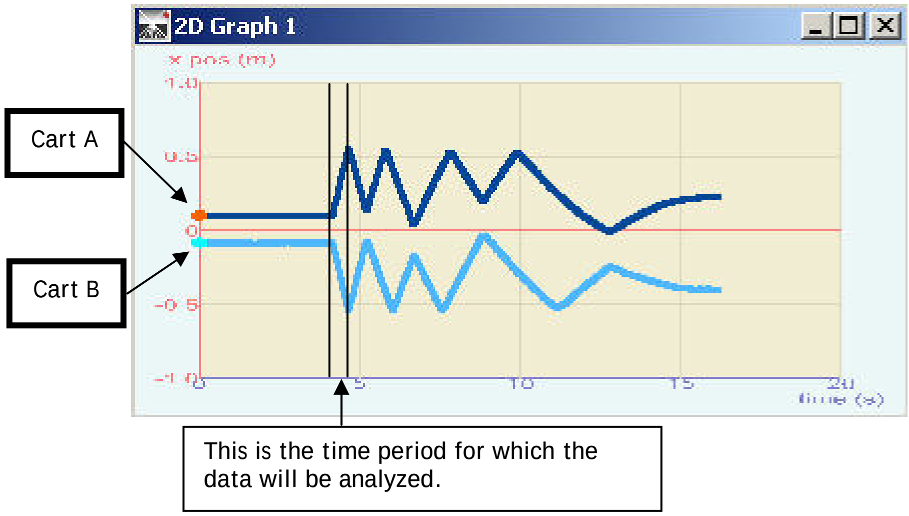
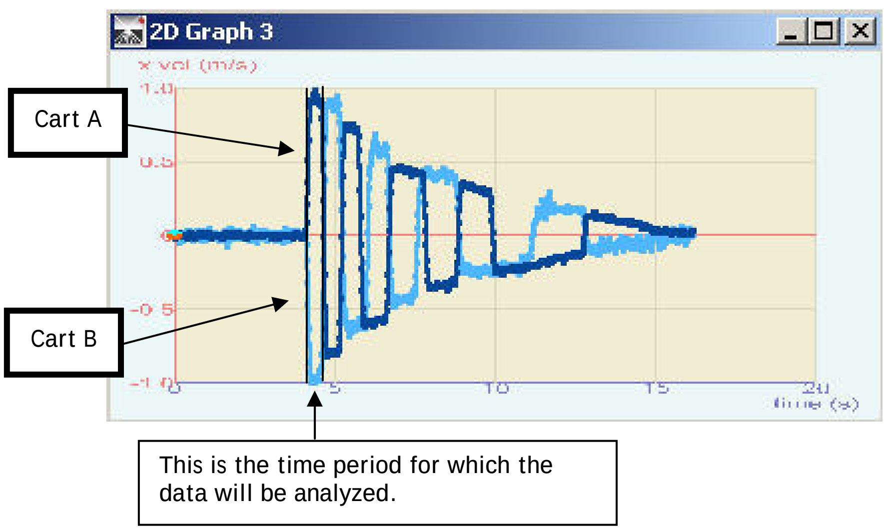
PART A: EQUAL MASSES

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



For this activity, only the data immediately after the explosion will be used in the analysis to verify that momentum is conserved.

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



By examining the graph, it becomes clear that the velocities of the two carts, immediately following the explosion, are equal in magnitude but opposite in direction. To verify this, the raw data for the activity can be imported into Excel. Here is the data from the above trial:

Cart A Velocity (m/sec)	**Cart B Velocity (m/sec)**
0.87	-0.87

$$M_1V_1 = M_2V_2$$

$$(0.75)*(0.26) = (0.25)*(0.75)$$

$$0.19 \text{ kg m/sec} = 0.19 \text{ kg m/sec}$$

Since the masses are equal and the velocities are equal in magnitude but opposite in direction, momentum is indeed conserved.

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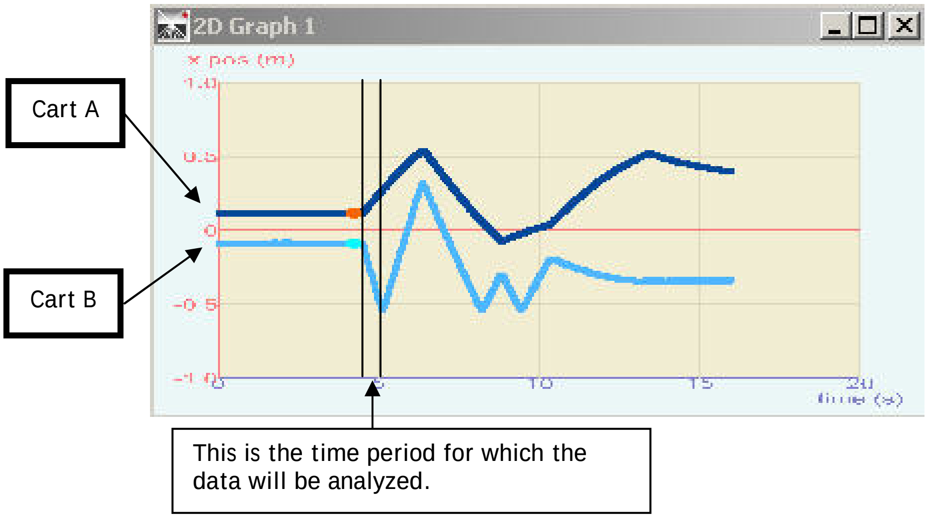
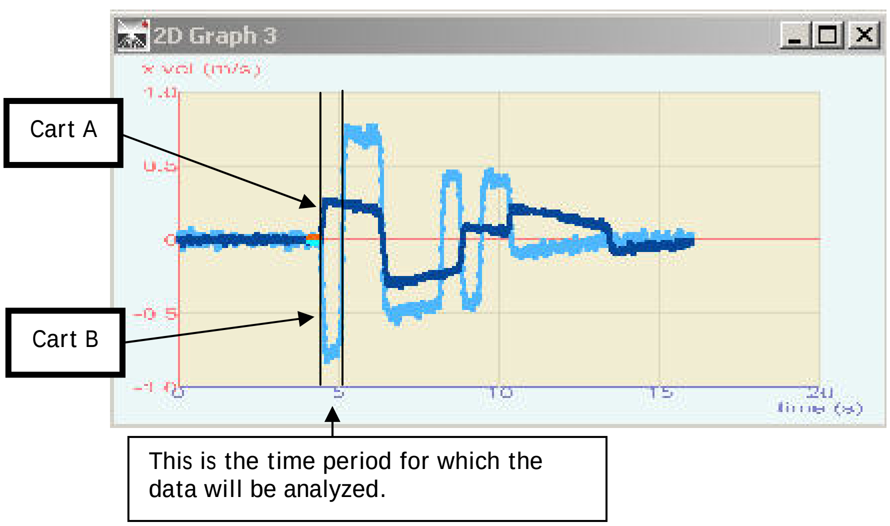
PART B: UNEQUAL MASSES (Cart A = 750 g; Cart B = 250 g)

1. **X Position v. Time Graph**



For this activity, only the data immediately after the explosion will be used in the analysis to verify that momentum is conserved.

2. **X Velocity v. Time Graph**



By examining the graph, it can be determined that the velocity of Cart A, right after the explosion, is approximately 0.25 m/sec and the velocity of Cart B is approximately -0.75 m/sec. Cart A, with three times the mass of Cart B, moved only 1/3 as fast as Cart B. To verify this observation, the raw data for this activity can be imported into Excel. Here is a sample data table from the above trial:

Velocity of Cart A (m/sec)	Velocity of Cart B (m/sec)
0.26	-0.75

$M_1V_1 = M_2V_2$

(0.75)*(0.26) = (0.25)*-0.75)

0.19 kg m/sec = 0.19 kg m/sec

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EXTENSIONS

- Change the mass ratio of the carts. [3 to 1, 4 to 1, 3 to 2, 4 to 2, etc.]
- Change the setting of the plunger.

QUESTIONS

1. Two vehicles have the same speed, one traveling east and one traveling west. If their combined momentum is zero, how doe their masses compare?
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 right after it explodes? Explain.
3. Superman (mass = 92 kg) and Spiderman (mass = 184 kg) are on ice skates and push off each other. How do their velocities compare? What is their combined momentum?

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