Lab 12 - Conservation of Momentum And Energy in Collisions

Name ____

Partner's Name ____

I. Introduction/Theory

Momentum is conserved during collisions. The momentum of an object is the product of its mass and its velocity. By the law of Conservation of Momentum, the sum of the momenta in a system prior to a collision (or other interaction) equals the sum of the momenta in the system after the collision.

The purpose of this laboratory activity is to investigate the momentum of two carts before and after an elastic collision. The theorem of conservation of linear momentum states that, if the vector sum of the external forces on a system of particles is zero, then the total linear momentum of the system remains constant, no matter what parts of the system may do. For a system of just two objects moving in one dimension, on which no net external force acts, this gives

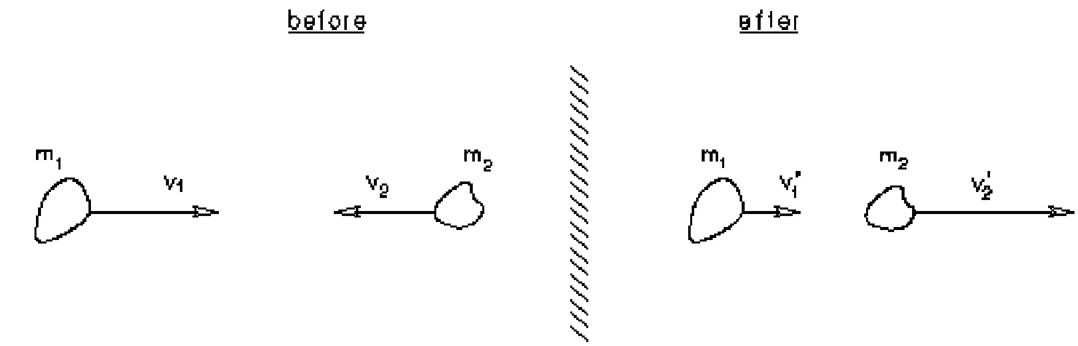


Figure 1 Collision in One Dimension

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1' + m_2\vec{v}_2' \qquad (1)$$

where m_1 and m_2 are the masses of the two particles, v_1 and v_2 their respective velocities at some instant, and v_1' and v_2' the velocities at some other instant. (In Eq.(1), all v's are positive to the right -- in Figure 1, v_2 would have a negative value.) In the case of a collision, v_1 and v_1' might be the velocities of object #1 just before and just after the collision, etc. Momentum conservation is particularly useful in collision-type situations, in which, typically, by far the most important forces are the internal forces that the two colliding objects exert on one another during the collision. Collision forces can frequently be assumed to be so strong that, just during the collision, other forces, even if not zero, can be ignored just during the collision.

In this experiment, we will assume external forces such as friction can ignored, the sum of the momenta of two carts prior to a collision is the same as the sum of the momenta of the carts after the collision. If the collision is *perfectly elastic* (i.e. conserves total kinetic energy during the interaction) the sum of the kinetic energy of two carts prior to a collision is the same as the sum of the kinetic energy of the carts after the collision.

II. Equipment

Computer with Interface
Motion sensor (two) with stands
Air track with blower
Air track carts (two) configured for collisions
Scale (for measuring mass)

III. Procedure/Data

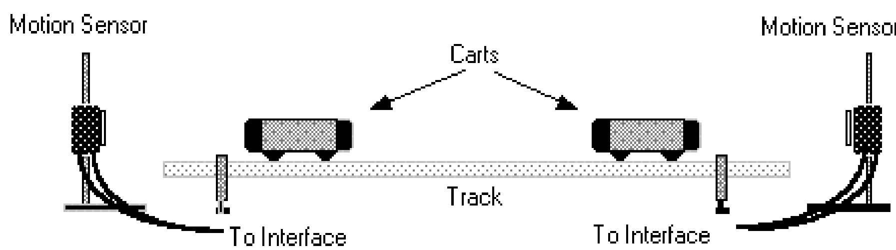
Part I: Computer Setup

1. Verify/Connect one motion sensor's phone plugs to Digital Channels 1 and 2 on the interface. Plug the yellow-banded (pulse) plug into Digital Channel 1 and the second plug (echo) into Digital Channel 2.
2. Verify/Connect the second motion sensor's phone plugs to Digital Channels 3 and 4 on the interface. Plug the yellow-banded (pulse) plug into Digital Channel 3 and the second plug (echo) into Digital Channel 4.
3. Verify/Connect the *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.
4. Open the *Science Workshop* file titled as shown:
   Macintosh: P16 Cons. of Momentum 1
   Windows: P16_CON1.SWS

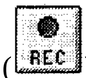
- The document will open with a Graph display of Position (m) versus Time (sec) for two objects.
- The Experiment Setup window has been resized. If you want to expand the Experiment Setup window to its original size, click on the "Zoom" box in the upper right hand corner of the window. (Note: To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu.)

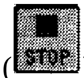
Part II: Equipment Setup and Sensor Calibration

1. Place the track on a horizontal surface.
2. Level the track by placing a collision cart on the track. If the cart rolls one way or the other, use the adjustable feet at one end of the track to raise or lower that end until the track is level and the cart will not roll one way or the other.
3. Use the balance to find the mass of each cart and record the values in the Table 1.
4. Verify/Mount each motion sensor on a support rod and base, and position one sensor at each end of the track. Place a cart at each end of the track. Adjust each motion sensor so that it can measure the motion of the cart nearest to it as that cart moves from the end of the track toward the middle of the track and back again. Remember that the minimum distance from the sensor to the cart it will measure is 0.40 m. Put marks on the track at spots that are 0.40 m from each motion sensor.
5. Calibrate the motion sensors for this experiment. Your instructor or lab technician/manager can assist you if needed.

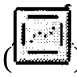


Part III: Data Recording

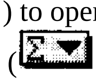
1. Prepare to measure the motion of each cart as it moves toward the other cart and then collides elastically by placing a cart at each end of the track. (Be sure that the carts are configured for elastic collisions with themselves and the ends of the tracks.)
2. Click the “REC” (

) to begin data recording.
3. Gently push the carts toward each other at the same time. Continue collecting data until the carts have collided and returned to the ends of the track.
4. Click the “STOP” (

) button to end data recording.

- The plots of the position versus time for each cart will appear in the Graph display. “Run #1” will appear in the Data list in the Experiment Setup window.
- If your data is not displayed after collection, click the “Autoscale” button () to resize the graph to fit the data. (If the data points still do not appear on the graph, check the alignment of the motion sensors and the carts and try again.)
- **Troubleshooting Note:** If your data is not smooth, check the alignment of the motion sensors. You may need to increase the reflecting area of each cart by attaching a rectangular cardboard “flag” (about 2 x 6“) to the front of the cart. To erase a trial run of data, select “Run #1” in the data sets list and press the “Delete” key.

Find the slope of the position versus time curve for each cart prior to collision and the slope of the curve for each cart after collision. The slope is the average speed of the cart. Compare the total momentum of the two carts before the collision with the total momentum of the two carts after the collision.

5. Click the “Statistics” button () to open the Statistics area on the right side of the Graph.
6. Click the “Statistics Menu” button () and select **“Curve Fit, Linear Fit"** from the Statistics menu.
7. In the plot area for the first sensor, use the mouse to click-and-draw a rectangle around the region of the position versus time plot for Cart #1 that shows its motion <u>before</u> the collision. (Record velocity in Table 1.)
8. Do the same for the plot of position versus time for Cart #2.
9. The slope of the selected region is coefficient **“a2”** in the Statistics area. This gives the average speed of each cart before collision. Record the average speed and use this value and the mass of each cart to calculate its momentum before the collision.

- Remember that momentum is a vector quantity, and that the momentum of one cart will be negative due to its direction of motion.

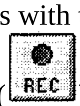
10. Use the mouse to click-and-draw a rectangle around the region of the position versus time plot for Cart #1 that shows its motion <u>AFTER</u> the collision. Do the same for the plot of position versus time for Cart #2.
11. The slope of the selected region gives the average speed of each cart AFTER collision. Record the average speed and use this value and the mass of each cart to calculate its momentum AFTER the collision. Remember that momentum is a vector quantity, and that the momentum of one cart will be negative due to its direction of motion.

	Cart#1	Cart#2
mass (kg)		
V before (m/s)		
mV before (kg•m/s)		
½mV^2 before (kg•m^2/s^2)		
V after (m/s)		
mV after (kg•m/s)		
½mV^2 after (kg•m^2/s^2)		

Total mV_{before} = ____________ Total mV_{after} = ____________

Total ½mV^2_{before} = ____________ Total ½mV^2_{after} = ____________

Table 1

12. Configure the carts for inelastic collisions, your instructor or lab technician/manager will show how this is to be done.
13. Prepare to measure the motion of each cart as it moves toward the other cart and then collides inelastically by placing a cart at each end of the track. (Be sure that the carts are configured for inelastic collisions with themselves and the ends of the tracks are still set for elastic collisions.)
14. Click the "REC" (

) to begin data recording.
15. Gently push one cart toward the other which should be stationary near the middle of the track. Continue collecting data until the carts have collided and returned to the end of the track.
16. Click the "STOP" (

) button to end data recording.

- The plots of the position versus time for each cart will appear in the Graph display. "Run #n" (where n = 1, 2, 3,…) will appear in the Data list in the Experiment Setup window.
- If your data is not displayed after collection, click the "Autoscale" button () to resize the graph to fit the data. (If the data points still do not appear on the graph, check the alignment of the motion sensors and the carts and try again.)
- **Troubleshooting Note:** If your data is not smooth, check the alignment of the motion sensors. You may need to increase the reflecting area of each cart by attaching a rectangular cardboard "flag" (about 2 x 6") to the front of the cart. To erase a trial run of data, select "Run #1" in the data sets list and press the "Delete" key.

Find the slope of the position versus time curve for each cart prior to collision and the slope of the curve for each cart after collision. The slope is the average speed of the cart. Compare the total momentum of the two carts before the collision with the total momentum of the two carts after the collision.

17. Click the "Statistics" button () to open the Statistics area on the right side of the Graph.

18. Click the "Statistics Menu" button () and select **"Curve Fit, Linear Fit"** from the Statistics menu.
19. In the plot area for the first sensor, use the mouse to click-and-draw a rectangle around the region of the position versus time plot for Cart #1 that shows its motion <u>before</u> the collision. (Record velocity in Table 2.)
20. Do the same for the plot of position versus time for Cart #2.
21. The slope of the selected region is coefficient **"a2"** in the Statistics area. This gives the average speed of each cart before collision. Record the average speed and use this value and the mass of each cart to calculate its momentum before the collision.

- Remember that momentum is a vector quantity and that the momentum of one cart will be negative due to its direction of motion.

22. Use the mouse to click-and-draw a rectangle around the region of the position versus time plot for Cart #1 that shows its motion <u>AFTER</u> the collision. Do the same for the plot of position versus time for Cart #2.
23. The slope of the selected region gives the average speed of each cart AFTER collision. Record the average speed and use this value and the mass of each cart to calculate its momentum AFTER the collision. Remember that momentum is a vector quantity, and that the momentum of one cart will be negative due to its direction of motion.

	Cart#1	Cart#2
mass (kg)		
V before (m/s)		
mV before (kg•m/s)		
½mV^2 before (kg•m^2/s^2)		
V after (m/s)		
mV after (kg•m/s)		
½mV^2 after (kg•m^2/s^2)		

Total mV_{before} = _____________ Total mV_{after} = _____________

Total ½mV^2_{before} = _____________ Total ½mV^2_{after} = _____________

Table 2

IV. Analysis

1. In the elastic collision, how does the total momentum before the collision compare to the total momentum after the collision?

2. In the elastic collision, how does the total kinetic energy before the collision compare to the total kinetic energy after the collision?

3. In the elastic collision, what factors do think may cause there to be a difference between the before the collision and after the collision momentum and kinetic energy?

4. In the inelastic collision, how does the total momentum before the collision compare to the total momentum after the collision?

5. In the inelastic collision, how does the total kinetic energy before the collision compare to the total kinetic energy after the collision?

6. In the inelastic collision, what factors do think may cause there to be a difference between the before the collision and after the collision momentum and kinetic energy?

V. Conclusions (include physical concepts and principles investigated in this lab, independent of your experiments success, and summarize without going into the details of the procedure.)