Lab 9: Conservation of Linear Momentum

Objectives:

- To understand the concept of conservation of momentum
- To be able to work problems using the conservation of momentum
- To understand that kinetic energy is not always conserved in a collision
- To be able to use your knowledge of work, kinetic energy, and momentum to work problems

Equipment:

- Air track
- 3 gliders, one of a different mass
- 2 photogates
- 1 balance
- 1 meter stick

Exploration 1

Exploration 1.1 You have learned in class about the conservation of momentum. Consider two objects of masses m_1 and m_2 moving towards each other with velocities $\mathbf{v_1}$ and $\mathbf{v_2}$. Write an equation that demonstrates the conservation of momentum.

Exploration 1.2 Examine the setup in front of you. You have gliders that are free to move on air tracks. You have two photogates that can be used to measure the speed of a glider that passes through the photogate. The photogate measures the time that elapses while a glider passes through. How can you determine the speed of the glider from the photogate measurement? Explain, showing equations, if relevant.

Exploration 1.3 Try it out. With the air on, determine the speed of a glider that passes through the photogate. Is there any uncertainty in the speed measurement? How could you determine the uncertainty? Would you need to make more measurements? Record any relevant measurements in the table below. Label the columns with measurements made and quantities calculated. Below the table, record the speed of the glider +/- the uncertainty in its speed. Explain how you determined the uncertainty.

Speed _____ +/- uncertainty _____

Exploration 2.1 Consider two types of collisions, one where the objects stick together (inelastic) and one where they bounce off each other (elastic). First, consider the case where they stick together, an inelastic collision. Would the kinetic energy be conserved in the collision? (Predict.) Explain your reasoning, showing any relevant equations.

Exploration 2.2 Would the kinetic energy be conserved in an elastic collision? (Predict.) Explain your reasoning, showing any relevant equations.

Investigation 1 Inelastic collisions

Level the air track.

Measure the mass and length of each available glider, and record these data below.

Glider 1 Mass _____ Length _____

Glider 2 Mass _____ Length _____

Glider 3 Mass _____ Length _____

Investigation 1.1 Use two gliders of equal mass. Attach the needle point to one glider and the wax filled container to the other glider so that the two gliders stick together on impact. Does this change the mass of each glider? Record any changes below.

Glider 1 mass _____ Glider 2 mass _____

Set up an experiment to test the conservation of momentum with one glider starting at rest in the middle of the track. Where does the other glider have to start to record its initial velocity?

Start the second glider with a gentle push, recording the photogate times and the initial velocity of glider 1 and the final velocity of the two gliders moving together below.

Glider 1

photogate 1 time _____ initial velocity _____

Gliders 1 and 2

photogate 2 time _____ final velocity _____

Investigation 1.2 Calculate the momentum before and after the collision, including an uncertainty estimate and see if the momentum was conserved within your uncertainty. Show your work below.

Initial momentum _____ +/- _____

Final momentum _____ +/- _____

Investigation 1.3 Calculate the kinetic energy before and after the collision. Show your work below.

Initial kinetic energy _____

Final kinetic energy _____

Is the kinetic energy conserved within your uncertainty? Does it agree with your prediction?

What fraction of kinetic energy remains after the collision? Show your work.

Investigation 1.4 Repeat the experiment for two gliders of different masses.

Glider 1 mass _____ Glider 2 mass _____

Glider 1

photogate 1 time _____ initial velocity _____

Gliders 1 and 2

photogate 2 time _____ final velocity _____

Investigation 1.5 Calculate the momentum before and after the collision for Investigation 1.4, including an uncertainty estimate and see if the momentum was conserved within your uncertainty. Show your work below.

Initial momentum _____ +/- _____

Final momentum _____ +/- _____

Investigation 1.6 Calculate the kinetic energy before and after the collision. Show your work below.

Initial kinetic energy _____

Final kinetic energy _____

Is the kinetic energy conserved within your uncertainty? Does it agree with your prediction?

Investigation 2 Elastic Collisions

Investigation 2.1 Now set up the experiment for an elastic collision.

First use two gliders of equal mass with an elastic bumper sticker on one side of each glider. How do you have to set up the gliders and photogates to get the initial and final speeds for each glider?

Push the gliders so that they move slowly. You will have to record the initial time for each glider and then move the memory switch to pre- and post- collision times.

In order to obtain the post collision time, you will have to subtract the pre-collision time.

Show your work and record your data below.

Glider 1 mass _____ Glider 2 mass _____

Glider 1

initial photogate 1 time _____ initial velocity _____

final photogate 1 time _____ final velocity _____

Glider 2

initial photogate 2 time _____ initial velocity _____

final photogate 2 time _____ final velocity _____

Investigation 2.2 Calculate the momentum before and after the collision, including an uncertainty estimate and see if the momentum was conserved within your uncertainty. Pay attention to the sign of the velocity. Show your work below.

Glider 1 Initial momentum _____ +/- _____

Glider 2 Initial momentum _____ +/- _____

Glider 1 Final momentum _____ +/- _____

Glider 2 Final momentum _____ +/- _____

Total Initial momentum _____ +/- _____

Total Final momentum _____ +/- _____

Investigation 2.3 Calculate the kinetic energy before and after the collision. Show your work below.

Glider 1 Initial kinetic energy _____ +/- _____

Glider 2 Initial kinetic energy _____ +/- _____

Glider 1 Final kinetic energy _____ +/- _____

Glider 2 Final kinetic energy _____ +/- _____

Initial kinetic energy _____

Final kinetic energy _____

Is the kinetic energy conserved within your uncertainty? Does it agree with your prediction?

Investigation 2.4 Repeat the experiment for two gliders of different masses.

Glider 1 mass _____ Glider 2 mass _____

Glider 1

initial photogate 1 time _____ initial velocity _____

final photogate 1 time _____ final velocity _____

Glider 2

initial photogate 2 time _____ initial velocity _____

final photogate 2 time _____ final velocity _____

Investigation 2.5 Calculate the momentum before and after the collision for Investigation 2.4, including an uncertainty estimate and see if the momentum was conserved within your uncertainty. Show your work below.

Glider 1 Initial momentum _____ +/- _____

Glider 2 Initial momentum _____ +/- _____

Glider 1 Final momentum _____ +/- _____

Glider 2 Final momentum _____ +/- _____

Total Initial momentum _____ +/- _____

Total Final momentum _____ +/- _____

Investigation 2.6 Calculate the kinetic energy before and after the collision. Show your work below.

Glider 1 Initial kinetic energy _____ +/- _____

Glider 2 Initial kinetic energy _____ +/- _____

Glider 1 Final kinetic energy _____ +/- _____

Glider 2 Final kinetic energy _____ +/- _____

Initial kinetic energy _____

Final kinetic energy _____

Is the kinetic energy conserved within your uncertainty? Does it agree with your prediction?