# Exp. 4 – Conservation of momentum

## Introduction

You may have learned that a moving object possesses kinetic energy given by , where is the mass of the object and is its speed. Momentum is another property of a moving object, also related to its mass and velocity, which is useful to describe its behaviour. The momentum, , is the product of the mass and velocity of an object, .

In the previous experiment you have examined the motion of a single object as it underwent a variety of motions on an air track. You learned that an object subject to no external forces moves at constant velocity. Suppose now that the system consists of two objects that undergo a collision. Clearly, the velocity of each object will change as a result of the collision. However, if you were to consider two gliders on the same air track as a single system, how would the centre of mass of this system change, if at all, after a collision? In one dimension, the position of the centre of mass of two objects, , is given by

where the indices 1 and 2 refers to the first and second objects. In the first part of this experiment, you will analyse the motion of two gliders during a collision to examine the behaviour of their centre of mass.

You may also have learned that an external force produces a change in the momentum of an object. If we consider our system to be two gliders that undergo a collision, any force that each exerts on another are internal to the system. In the second and third part of this experiment, you will examine the momentum as well as the kinetic energy of both gliders before and after collisions to see what effect, if any, these forces have on the properties of a system. When two objects collide with each other (and there is no net force on the system), the total momentum () is conserved regardless of the type of collision. This translates as

where the primed notation refers to quantities after the collision.

We will be considering two types of collisions: elastic and inelastic. An elastic collision is one in which the two objects bounce off each other with no loss of kinetic energy. We will use elastic bumpers on the ends of the gliders to study elastic collisions and to minimize the energy losses due to friction during the collision. In reality, this *elastic* collision is slightly inelastic. A completely inelastic collision is one in which the two gliders hit and stick to each other. This type of collision will be studied in the final part of this experiment. This is accomplished using a pair of bumpers that are sticking together after a collision (a needle and a wax receptacle).

### Suggested reading

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| **Students taking** | **Suggested reading** |
| PHY 1121 | Chapter 8 | Young, H. D., Freedman, R. A., *University Physics with Modern Physics, 13th edition*. Addison-Wesley (2012). |
| PHY 1321-1331 | Chapter 9  | Serway, R. A., Jewett, J. W., *Physics for Scientists and Engineers with Modern Physics, 8th edition*. Brooks/Cole (2010). |
| PHY 1124 | Chapter 9  | Halliday, D., Resnick, R., Walker, J., *Fundamentals of Physics, 9th edition*. Wiley (2011). |

## Objectives

* Analyse the position-time graphs for the individual gliders and compare these to the position-time graph for the centre of mass of the system.
* Collect velocity-time data for two gliders experiencing different types of collisions.
* Compare the momentum of the system before and after collisions.
* Compare the kinetic energy of the system before and after collisions.

## Materials

* Computer equipped with *Logger Pro* and a Vernier computer interface
* Motion detectors
* Air track and accessories (air supply, hose, gliders, …)
* Electronic balance (one per classroom)

## Safety warnings

The air track is a fragile and expensive piece of equipment. Its surface must be free of defects in order to reduce the friction between the glider and the track to a minimum. Be careful to not hit the surfaces of the track with a hard object.

## References for this manual

* Gastineau, J., Appel, K., Bakken, C., Sorensen, R., Vernier, D., *Physics with Vernier*. Vernier software and Technology (2007).
* Dukerich, L., *Advanced Physics with Vernier – Mechanics*. Vernier software and Technology (2011).
* *ScienceWorkshop 750 Mechanics System*. PASCO scientific (2010).

## Procedure

### Part 1 – Centre of mass

1. Turn on your computer and launch the Logger Pro program.
2. Turn on the air supply machine and adjust the power button so that your single glider moves without friction. You are sharing your air supply with another team, make sure both teams are satisfied with the setting of the supply before moving forward with your experiment.
3. Level your track using the adjustable legs. Place one glider at the centre of the track. If the glider moves one way or the other, adjust the track to raise or lower one end. When the air track is properly leveled, the glider should be almost stationary (there is always a little bit of turbulence).
4. Make sure that the glider stoppers (the velcros) are wrapped around the air track about 10 cm in front of the motion detectors.
5. Make sure your motion detectors are set to *track*: .
6. Make the necessary adjustments so that a position vs. time graph for each detector is shown in the same graph window. Align the motion detectors and make sure each of them is detecting the position of the closest glider wherever it is along the track. Ensure the round discs attached to the gliders are facing the motion detectors. These discs are used to increase the surface area that the detectors see.
7. Go to Experiment 🡪 Set Up Sensors 🡪 LabQuest Mini. **Hold** both gliders close to the middle of the track and zero both motion detectors (click on the picture of the motion detector in the right column, see below, and select Zero). Also select Reverse Direction for one of the two detectors.



1. Go to Experiment and then Data collection. Set the length of the measurement to 10 sec.
2. Install a pair of elastic bumpers on your gliders (see Figure 1).
3. Bring glider 1 close to its motion detector and leave glider 2 at rest at the centre of the track. Begin collecting data and then gently push the glider 1 towards glider 2. Be sure to keep your hands out of the way of the motion detectors. Repeat until you get a satisfactory run.
4. Weigh both gliders with their bumpers and discs attached.
5. Create a new calculated column to calculate the position of the centre of mass during your collision. Click Data 🡪 New Calculated Column. Give the column a proper name and units. Enter the formula to calculate the position of the centre of mass () in the Expression box and click Done.
6. Add the position of the centre of mass vs. time to your position vs. time graph. To do so, simply click on the label of the y-axis and select More…. You should be able to select your calculated column from the list.
7. Perform the following six linear fits:
8. the position of glider 1 vs. time before the collision,
9. the position of glider 1 vs. time after the collision,
10. the position of glider 2 vs. time before the collision,
11. the position of glider 2 vs. time after the collision,
12. the position of the centre of mass vs. time before the collision,
13. the position of the centre of mass vs. time after the collision.
14. Adjust your page to be ready for printing. This should be your Graph 1. Make sure all fit results are clearly visible. Among other things, make sure to add a proper title to your graph and adjust your window to use as much space as possible.
15. Save your Graph 1 to a pdf file. Save your experiment file.



Figure 1 - Air-track setup to study collisions between two gliders

### Part 2 – Elastic collisions

You will now perform a series of elastic collisions in various conditions. You can use the Logger Pro file you had for the previous section or you can start over with a new file. If you do start with new file, remember to zero your detectors and to reverse the direction of one of them like you did in the previous section. For all the collisions below, you should always feel free to repeat your manipulations if you are not satisfied with the given collision results or data collection.

1. With the same setup used in the previous section, record an elastic collision between a moving glider 1 and a stationary glider 2.
2. Using your position vs. time curves, perform four linear regressions to obtain the velocities of both gliders before and after the collision. Record your results for this first run in Table 1.
3. Run 2: Add two weights on glider 2 (one on each side). Make sure glider 2 is still freely sliding on the track (increase the air pressure if needed). Record a new collision between a moving glider 1 and a stationary (and heavier) glider 2. Record your results in Table 1.
4. Run 3: Keeping the extra weights on glider 2, record a new collision between a moving glider 2 and a stationary (and lighter) glider 1. Record your results in Table 1.
5. Prepare a graph example for the elastic collision using run 3. This should be your Graph 2. Make sure all fit results are clearly visible. Save your Graph 2 to a pdf file.

### Part 3 – Inelastic collisions

To perform inelastic collisions, you will use bumpers that are sticking together after a collision (a needle and a wax receptacle).

1. Remove the extra weights on glider 2. Switch the elastic bumpers for the needle and wax receptacle bumpers.
2. Run 4: Record a collision between a moving glider 1 and a stationary glider 2. Record your results for this run in Table 2.
NB. Make sure the attached gliders are able to travel all the way to the other end of the track without stopping to ensure good results.
3. Run 5: Add two weights on glider 2. Record a new collision between a moving glider 1 and a stationary (and heavier) glider 2. Record your results in Table 2.
4. Prepare a graph example for the inelastic collision using run 5. This should be your Graph 3. Make sure all fit results are clearly visible. Save your Graph 3 to a pdf file.
5. Run 6: Keeping the extra weights on glider 2, record a new collision between a moving glider 2 and a stationary (and lighter) glider 1. Record your results in Table 2.

### Cleaning up your station

1. Turn off the air supply. Submit your graphs in Blackboard Learn. If you locally saved your files, send them to yourself by email. Pick up your USB key if you used one to save your files. Turn off the computer.
2. Put back the gliders, bumpers and weights on the table.
3. Recycle scrap paper and throw away any garbage. Leave your station as clean as you can.
4. Push back the monitor, keyboard and mouse. Also please push your chairs back under the table.