In this lab you will investigate the conservation of momentum in one-dimensional collisions of objects. You will do this for both elastic and inelastic collisions.

Important! You need to print out the 2 page worksheet you find by clicking on this link and take it with you to your lab session.

If you need the .pdf version of these instructions you can get them here.

**Video**

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**Equipment**

- air track (that keeps glider motions one-dimensional and reduces the effect of friction)
- small glider that moves on the air track
- big glider that moves on the air track
- beam balance to weigh gliders (with 200 gram mass for weighing big glider)
- computer (using program Exp5_t1_t2 on the desktop)
- interface box
- 2 photogates
Introduction

Conservation laws are powerful and useful tools for understanding physical phenomena. In this experiment you will investigate the conservation of linear momentum in one-dimensional collisions of objects moving with the effects of friction kept small. A clever device called the air track allows both of these conditions – one-dimensionality and reduced friction – to be realized in a simple way. An aluminum bar (the “track”) shaped like a \( \wedge \) (i.e., an inverted V) has a hollow core, and many periodically spaced, small holes have been drilled between this hollow core and the outside. Since the \( \wedge \) -shaped sheetmetal protrusions on the bottom of each glider closely match the \( \wedge \) -shape of the track, air made to flow through the holes from the core to the outside can provide enough force to levitate the gliders and allow them to move with friction nearly eliminated. Because the gliders must move along the straight bar, their motion must be one-dimensional along a “horizontal” direction. When the air track is carefully leveled (made perpendicular to the gravitational acceleration \( g \)), the collisions between the gliders are particularly simple because no (net) external force acts on them: “no” friction and, effectively, “no” gravity. To a good approximation the only forces acting on the two-glider system are “internal”, viz., forces between them alone. The principle of the conservation of linear momentum says that for a system of particles interacting with no external forces on them (an isolated system), the linear momentum (vector!) of that isolated system is constant. The different particles making up the isolated system may exchange momentum with each other when they collide, but the vector sum of all their linear momenta does not change.

You should review Section 9.4 of Knight, Jones and Field, 2nd edition (KJF2), the optional textbook for our course, for a more detailed discussion of this principle. (If you do not have a copy, you’ll find one bolted to a table in the Help Room, A-131, in the physics building. Additional copies should be on closed reserve in the Math/Physics Library on the C-level of the physics building.) The figures there are helpful, e.g., Fig. 9.15 for a one-dimensional collision between two balls in an isolated system and Fig. 9.16 for three particles in an isolated system. Figure 9.17 shows a system of three particles that is not isolated because external forces are acting on them, too. In the first two cases, linear momentum is conserved; in the last case, it is not.
You will measure the velocity of each glider before the collision and again after the collision by measuring the amount of time that a metal tab on top of the glider blocks a photogate.

Starting with the small glider, use a meter stick to measure the width, \( w_s \), of the gray piece of aluminum sheet metal on its top that will block the photogate beam and use the beam balance at the front of the room to measure its mass, \( m_s \). Record your values on your worksheet. Repeat these two measurements for the big glider. Since the mass of the big glider exceeds the 200 gram capacity of the balance, you must put a 200 gram mass on the opposite pan. \textbf{Don't forget to add 200 grams to the reading for the big glider.}

Assume that each measured width has an absolute uncertainty of 2 mm and that each each measured mass has an absolute uncertainty of 1 gram.

\textbf{I. Elastic Collision: sliding the small glider into the big glider}

In this first part of the lab, you will arrange an elastic collision between a moving small glider and a big glider that is at rest before the collision. Examine the gliders carefully. Note that each one has a metal piece (it functions as a spring) projecting out from one end and a piece of velcro attached to the other end. Make sure each spring is rigidly attached to the glider. If they are not, get help from your instructor. Put the gliders on the air track with their “spring ends” facing each other.

Make sure the air flow to the air track is on and make sure that the track is level. To test for level-ness, use your hand to keep a glider at rest in the area between the two photogates and then carefully release it. If the glider does not move after the release, the air track is adequately level. (Why is this a good test for level-ness?) Place the big glider between the photogates, but not far from the second (downstream) photogate, and gently launch the small glider toward the resting big glider. (“Gently” means you want to avoid an up-down wobble of the glider that would cause friction.) You may want to practice this placement-and-launching procedure a few times and qualitatively observe what happens after the collision. When you're confident you have a reproducible procedure, observe the collision a “final” time, note the directions the two gliders take after the collision, and enter your observations into your worksheet.

Next get ready to take quantitative data. Turn on the computer and double click the icon “Exp5_t1_t2". A window with a spreadsheet on the left (having “Time, State 1, State 2 columns) comes up. On top is a window “Sensor Confirmation", where you may have to click “Connect” twice because there are two photogate sensors.

You are now ready for taking data. Position the small (incident) glider upstream of photogate #1 and the big (target) glider close to but upstream of photogate #2. You will want to make sure that your incident glider goes through photogate #1 (giving time interval \( t_i \) in the table below) after you launch it. Click the green “Collect” icon and launch the small glider. You must make sure to stop the computer before either of the two gliders hits the end of the air track and bounces back. After the collision, you should see something like this table on the computer screen.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
Time & State 1 & State 2 \\
\hline
1.6471 & 1 & \\
1.7873 & 0 & \\
2.0445 & 1 & \\
2.2690 & 0 & \\
2.4698 & 1 & \\
3.3753 & 0 & \\
\hline
\end{tabular}
\end{table}

Before the collision (unprimed variable), \( t_i \), the time the incident glider takes to pass through the photogate, is \( 1.7873 - 1.6471 = 0.1402 \text{ s} \). After the collision (primed variables) \( t_i' \), the time for the big glider to pass through the photogate, is \( 2.2690 - 2.0445 = 0.2245 \text{ s} \), and \( t_i' \), the time for the small glider to pass through the photogate, is \( 3.3753 - 2.4698 = 0.9055 \text{ s} \). Of course, the data from your own measurements will be different. Enter your time intervals into Table 1 of your worksheet.
II. Elastic Collision: sliding the big glider into the small glider

This part is the same as Part I of your lab except that now you will slide the big glider into the small glider that is initially at rest. Again, start the data collection and gently launch the big glider. Make sure your incident glider goes through photogate #1. Enter your measured time intervals into Table 2 on your worksheet.

Part III. Inelastic Collision: sliding the big glider into the small glider

In this part you will observe a perfectly inelastic collision between a moving big glider and a small glider initially at rest. Perfectly inelastic means that the objects stick together and become “as one” after the collision. This is accomplished by mating pieces of velcro on each glider. To enable this you must turn the gliders around so that their velcro ends are facing each other. Launch the big glider toward the stationary small glider and observe what happens. Make sure your incident glider goes through photogate #1. For this collision you only record two time intervals, viz., the interval for the big glider to go through photogate #1 alone before the collision and the time interval for the small glider to go through photogate #2 after the collision (the small glider because it is the first one of the now-joined pair to go through the photogate). Enter your measured times into Table 3 on your worksheet.

Analysis

You obtain the velocity $v$ of the gliders before and after the collision with use of the formula

$$v = \frac{w_s}{t}$$

(5.1)

The uncertainty in $t$ is so small that you may neglect it, and, therefore, you may assume that the relative uncertainty $\Delta w_s/w_s$ of $w_s$ is equal to the relative uncertainty $\Delta v/v$ of $v$. Calculate the absolute uncertainty of $v$ with use of Eq. (E.4) in the Lab 1 manual, *Uncertainty, Error and Graphs*.

The momentum of each object is given by

$$\vec{p} = m\vec{v}$$

(5.2)

Since the motion of both gliders is one-dimensional (along a line), the direction of the vectors can be specified by algebraic signs: positive, say, for motion to the right and negative for motion to the left. That is one of the things that makes the study of one-dimensional motion “easy”.

Your previous lab, Lab 4, dealt with the conservation of energy, and in this lab you again deal with this concept by seeing whether or not kinetic energy is conserved in collisions. The kinetic energy $KE$ of each object is one-half of its mass times the square of its speed:

$$KE = \frac{1}{2}mv^2.$$  

(5.3)
The tool below will calculate the velocities, momenta, and kinetic energies of the objects before and after the three collisions. You should then verify for each collision whether momentum is conserved and whether kinetic energy is conserved. Bear in mind that what you need to determine from your data is whether the total momentum and/or total kinetic energy is or is not the same before and after the collision within experimental error. As you are now used to, this means that the before-and-after values do not need to be identical, but to be consistent their “experimental error bars should overlap”. If their error bars do not overlap, they are not consistent. Discuss your results with your TA!

**Enter your measured glider widths and masses and their uncertainties in the appropriate boxes below:**

\[
\begin{align*}
\text{width of small glider} &= w_s = \pm \text{m} \\
\text{width of big glider} &= w_b = \pm \text{m} \\
\text{mass of small glider} &= m_s = \pm \text{kg} \\
\text{mass of big glider} &= m_b = \pm \text{kg}
\end{align*}
\]

Copy the measured results from your three experiments into the tables below:

**Table 1. Elastic Collision: sliding the small glider into the big glider:**

<table>
<thead>
<tr>
<th>Glider</th>
<th>(t_i)</th>
<th>(t'_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Elastic Collision: sliding the big glider into the small glider**

<table>
<thead>
<tr>
<th>Glider</th>
<th>(t_i)</th>
<th>(t'_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3. Inelastic Collision: sliding the big glider into the small glider (with velcro ends facing each other)**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>(t_i)</th>
<th>(t'_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-collision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-collision</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**submit**