EXPERIMENT 6b
Elastic One-dimensional Collisions

Objectives
- to measure the momentum and kinetic energy of two objects before and after a one-dimensional collision
- to try to account for any change in KE in the nearly elastic collision
- compare and contrast the results obtained from the inelastic collision experiment with the results obtained from this experiment

Apparatus
The same apparatus used in the inelastic experiment will be used in this experiment. However, one of the carts will use an elastic bumper (see Figure 1 below). The second cart will be fitted with a bumper blade which will make contact with the elastic bumper on the first cart during the collision. A bumper blade is on the left hand side of the cart shown in Figure 1 and the elastic bumper is on the right hand side of the cart.

Figure 1
Procedure

In this experiment we will try to obtain an almost elastic collision of two carts on the air track. The main difference from the previous lab is that the carts will now move separately after the collision. The elastic bumper allows the carts to bounce off of each other with almost no conversion of kinetic energy into other forms of energy.

As before, Cart 2 is initially at rest. Before the collision we have to measure only the velocity of Cart 1, $v_{1i}$ (Figure 1). However, after the collision we have to measure the velocities of both carts, $v_{1f}$ and $v_{2f}$ (Figure 2). Thus, in all we have to measure three times ($t_{1i}$, $t_{1f}$, and $t_{2f}$), while the photogate system allows us to simultaneously measure only two of them.

We can get out of this situation if after the measurement of the initial time $t_{1i}$, but before the collision of the two carts, we reset the timer. You will probably have to make several practice trials to learn to quickly remember and reset the contents of the timer before the carts collide. Then, we can again use the contents of the timer display and the memory to find $t_{1f}$ and $t_{2f}$.

![Diagram of the experiment](image1.png)

**Figure 2:** The Initial State of the Carts Before the Collision
Figure 3: The Final State of the Carts After the Collision
The fins on two carts have the same length. Verify this by measuring these lengths $L_1$ and $L_2$. Again the masses of the carts can be varied by adding the metal disks, or weights, to them.

Remember, the experiment will be done with Cart 2 initially at rest. So in the initial state we have

**Initial state:**
- Cart 1: has a mass $m_1$ and initial velocity $v_1$
- Cart 2: has mass $m_2$ and is at rest, so $v = 0 \text{ cm/s}$

**After the collision (final state):**
- the two carts will be moving independently
- the speeds of the carts will be $v_{1f}$ for $m_1$ and $v_{2f}$ for $m_2$

You will do 6 trials with the following $m_1$ and $m_2$ choices:

- Trials 1 & 2: no mass disks on Cart 1, 2 mass disks on Cart 2; measure $v_{1i}$, $v_{1f}$ and $v_{2f}$
- Trials 3 & 4: 2 mass disks on Cart 1, 2 mass disk on Cart 2; measure $v_{1i}$, $v_{1f}$ and $v_{2f}$
- Trials 5 & 6: 2 mass disks on Cart 1, no mass disks on Cart 2; measure $v_{1i}$, $v_{1f}$ and $v_{2f}$

To measure these speeds you measure the times $t_1$, $t_{1f}$, and $t_{2f}$. Enter the data into the spreadsheet and have Excel calculate the momenta and kinetic energies before and after the collisions, as well as the percent change in the total momentum and in the kinetic energy. Due to the large number of equations involved in this experiment, all of the Excel formulae have been programmed in for you for this lab except for the formula for the final velocity of cart 1. Velocity is a vector quantity and in one dimension, its direction is indicated by its sign. For this experiment, the positive direction is defined as the direction of the INITIAL velocity of cart 1. In each of your trials you will need to in a formula for $v_{1f}$ – make sure you include the observed direction of this vector in your formulae!

Although almost all of the formulae are programmed into Excel for you, you need to include manual calculations for all of the cells highlighted in blue. The only formulae you will need to enter are the formula for the velocities. Remember, velocity (like momentum) is a vector and in one dimension its direction is indicated by its sign. Assign the initial direction of Cart 1 as the positive direction.

Start with Trial 1, enter your measurements into your spreadsheet and check the spreadsheet to see if the change in momentum and the change in kinetic energy is less than 5%. If either is not, you should repeat Trial 1 before proceeding to the other trials.

If the either change is greater than 5% you should verify that the air track is level before redoing the trial. When running your trials, it is very important that both carts are balanced. That is, a counter balance is attached to both Carts 1 and 2. In addition, all of these accessories must be placed in the lower holes on Carts 1 and 2. Furthermore, Cart 2 must be at rest prior to the collision, Cart 1 must have passed through the first photogate before the collision; you must have read the first time from the photogate timer and pressed the reset button before the fin on top of either cart enters one of the photogates.
After the collision, it is important that both carts are NOT passing through different photogates simultaneously. Since the spreadsheet is set up it is easy to see whether momentum and/or energy are better conserved with every trial you do.

For some of your trials, one of the carts may be stationary after the collision. What does this mean? Answer: Its velocity is zero. What time must you use in your spreadsheet in order to simulate/approximate this final velocity (you will need to enter a numerical value)?

QUESTIONS

1. For which of your trials was momentum conserved? Justify your response.

2. For which of your runs was kinetic energy conserved? Justify your response.

3. Qualitatively compare the results of the elastic and inelastic collision experiments (i.e. what was conserved and what was not).
4. Where did the kinetic energy go that was lost in the inelastic collisions you performed in the previous experiment?

Summary of formulae for momentum and kinetic energy

*Initial state:

Measure photogate time $t_1$, calculate $v_1$ and the error in $v_{1i}$ (called $\delta v_{1i}$ on the spreadsheet)*

Momentum: $P_i = m_1v_1$ and kinetic energy: $KE_i = \frac{m_1v_{1i}^2}{2}$

*Final state:

Measure the photogate times $t_{1f}$ and $t_{2f}$, calculate $v_{1f}$, $v_{2f}$ and the error in the final velocities (called $\delta v_{1f}$ and $\delta v_{2f}$ on the spreadsheet)*

Momentum: $P_f = m_1v_{1f} + m_2v_{2f}$ and kinetic energy: $KE_f = \frac{m_1v_{1f}^2 + m_2v_{2f}^2}{2}$

Note: Momentum is a vector quantity i.e. in one dimension it has a sign.

The difference between the final state and the initial state is:

Momentum: $P_{\text{diff}} = P_f - P_i$ which is called $P_{\text{diff}}$ in the spreadsheet

Kinetic energy: $KE_{\text{diff}} = KE_f - KE_i$ which is called $KE_{\text{diff}}$ in the spreadsheet
*Summary of uncertainties*

You have to determine (this means choose) the uncertainties in the length measurement (δL) and your time measurement (δt). There is a brief discussion on estimating uncertainties in part 2 of Course Supplement A.

Here we will neglect the uncertainty in the mass measurement. The uncertainty in the velocity is given by:

\[
\frac{\delta v}{v} = \frac{\delta L}{L} + \frac{\delta t}{t}
\]

resulting in

\[
\delta v = v \left( \frac{\delta L}{L} + \frac{\delta t}{t} \right)
\]

The uncertainty in momentum is:

\[
\delta P = P \frac{\delta v}{v}
\]

and the uncertainty in kinetic energy is:

\[
\delta KE = 2 \frac{\delta v}{v}
\]

The uncertainties in the differences for the momenta and kinetic energies are then:

\[
\delta P_{diff} = \delta P_f + \delta P_i \quad \text{and} \quad \delta KE_{diff} = \delta KE_f + \delta KE_i
\]
Tabulate the results of the measurements on this sheet.  
**Carts’ masses, grams**

<table>
<thead>
<tr>
<th></th>
<th>Cart 1</th>
<th>Cart 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mass disks</td>
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<td></td>
</tr>
<tr>
<td>2 mass disks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Length of the fin on cart 1 __________ cm

Length of the fin on cart 2 __________ cm

**Measured times, sec**

<table>
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<tr>
<th>Trial #</th>
<th>$t_{\text{initial}}$</th>
<th>$t_{\text{final}}$</th>
<th>Memory</th>
<th>$t_{\text{final}}$</th>
<th>Comments</th>
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</thead>
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<td></td>
<td></td>
<td></td>
<td>0 disks on Cart 1</td>
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<td>2 disks on Cart 1</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 disks on Cart 2</td>
</tr>
</tbody>
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