# Advanced Lab for the Conservation of Linear Momentum

Name_____ TA_____

Partners_____

Section #_____ Date_____

**Basic Instructions**

In this lab we are going to use the air track/glider system to investigate the conservation of momentum and kinetic energy during the collision of two objects.

To determine the velocity of the glider, we use a piece of tape as a "flag". If the flag width is L and flag blocks the photo gate for a time period of T (called "time in gate" in the Science Workshop or Datastudio), we know the velocity V = L / T.

Momentum of a mass moving at velocity v is **P** = m**v**. For a system of multiple objects, the total momentum is the vector sum of the momenta of individual objects.

Kinetic energy of a mass moving at velocity v is $E_k = \frac{1}{2}mv^2$. For a system of multiple objects, the total energy is the sum of the individual objects' energy.

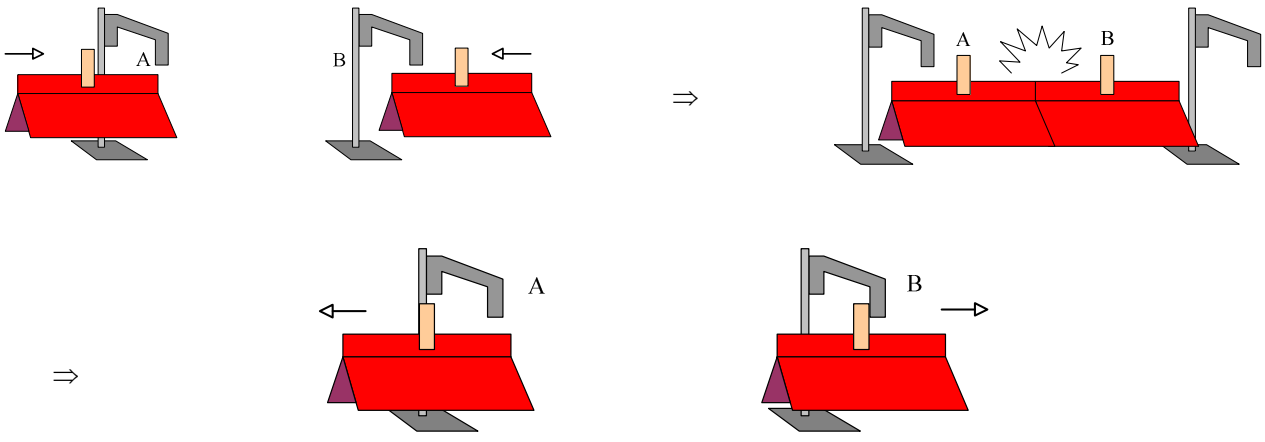
During any collision, the system's total momentum is always conserved. Kinetic energy is conserved only if the collision is elastic. For inelastic collisions, part of kinetic energy is lost (converted to other forms of energy).

**Notice: This experiment is very sensitive, so you will try several times to get better results. To save your time, an Excel sheet is provided. Use the format to calculate momenta. Remember how you collide with gliders for the later discussion.**

## 1. Collision of two objects of equal mass

Use the two large gliders. Place two gliders outside the two photogates. Push both gliders A and B against each other. Let them collide by the leaf springs with no Velcro.

Our system (the two gliders) should have momentum conserved. However, due to various reasons $P_A$ and $P_B$ you obtain from the experiment may not be exactly the same.



Flag width $L_A$ _____ Flag width $L_B$ _____

$m_A$ _____ $m_B$ _____

**Before collision**

| Trial # | $T_{A\,ini}$ | $T_{B\,ini}$ | $V_{A\,ini}$ | $V_{B\,ini}$ | $P_{A\,ini}$ | $P_{B\,ini}$ | Total initial $P_{ini}$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

**After collision**

| Trial # | $T_{A\,fin}$ | $T_{B\,fin}$ | $V_{A\,fin}$ | $V_{B\,fin}$ | $P_{A\,fin}$ | $P_{B\,fin}$ | Total final $P_{fin}$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

| Trial # | Percentage Error |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

For the percentage error, $\dfrac{\left|P_{ini} - P_{fin}\right| \times 100}{P_{ini}}$ (%) for each value.

- **Questions**

**As for the conservation of momentum, discuss this with the following factors:**

1. Speed of gliders
2. State of collisions
3. Position of photo gates

Please discuss any other causes of error from your experiment.

**Pick out the best case of the above. Then, calculate the total energies of before and after collisions to see if the energy is conserved.**

| The Formula of Kinetic Energy: $E_k = \frac{1}{2}MV^2$ | |
|---|---|
| Total kinetic energy before collision | Total kinetic energy after collision |
| | |

**2. Collision of two objects of unequal mass**

Use the one large and one small glider. Place the gliders outside two photo gates. Push both gliders against each other. Let them collide by the leaf springs with no Velcro.

Flag width $L_A$ _____ Flag width $L_B$ _____

$m_A$ _____ $m_B$ _____

**Before collision**

| Trial # | $T_{A\,ini}$ | $T_{B\,ini}$ | $V_{A\,ini}$ | $V_{B\,ini}$ | $P_{A\,ini}$ | $P_{B\,ini}$ | Total initial $P_{ini}$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

**After collision**

| Trial # | $T_{A\,fin}$ | $T_{B\,fin}$ | $V_{A\,fin}$ | $V_{B\,fin}$ | $P_{A\,fin}$ | $P_{B\,fin}$ | Total final $P_{fin}$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

| Trial # | Percentage Error |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

For the percentage error, $\dfrac{\left|P_{ini} - P_{fin}\right| \times 100}{P_{ini}}$ (%) for each value.

- **Questions**

  **As for the conservation of momentum, discuss this with the following factors:**
  1. Speed of gliders
  2. State of collisions
  3. Position of photo gates

  Please discuss any other causes of error from your experiment.

  **Pick out the best case of the above. Then, calculate the total energies of before and after collisions to see if the energy is conserved.**

| The Formula of Kinetic Energy: $E_k = \frac{1}{2}MV^2$ | |
|---|---|
| Total kinetic energy before collision | Total kinetic energy after collision |
| | |

### 3. Completely inelastic collision

Use the large and small gliders. Place one of gliders between the two photo gates. Push one glider against the other. Let them collide by the leaf springs with Velcro so after collision they stick together.

- **Large hits small**

$L_A$ _____ $L_B$ _____ $m_A$ _____ $m_B$ _____

| Trial # | $T_A$ | $T_{A+B}$ | $V_A$ | $V_{A+B}$ | $P_A$ | $P_{A+B}$ | Errors $\frac{\lvert P_A - P_{A+B}\rvert}{P_A}\times 100\ (\%)$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

**As for the conservation of momentum, discuss this with the following factors:**

1. Speed of gliders
2. State of collisions
3. Position of photo gates

Please discuss any other causes of error from your experiment.

| Trial # | $KE_1 = \frac{1}{2} m_A V_A^2$ | $KE_2 = \frac{1}{2} (m_A + m_B) V_{A+B}^2$ | $\frac{\lvert KE_1 - KE_2\rvert}{KE_1}\times 100\ (\%)$ |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

**How much is the energy absorbed or dissipated?** (It is supposed to be 1/3 of the original energy.)

- **<u>Small hits large</u>**

$L_A$ _____ $L_B$ _____ $m_A$ _____ $m_B$ _____

| Trial # | $T_A$ | $T_{A+B}$ | $V_A$ | $V_{A+B}$ | $P_A$ | $P_{A+B}$ | Errors $\frac{\lvert P_A - P_{A+B}\rvert}{P_A}\times 100\ (\%)$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

**As for the conservation of momentum, discuss this with the following factors:**

4. Speed of gliders
5. State of collisions
6. Position of photo gates

Please discuss any other causes of error from your experiment.

| Trial # | $KE_1 = \frac{1}{2} m_A V_A^2$ | $KE_2 = \frac{1}{2} (m_A + m_B) V_{A+B}^2$ | $\frac{\lvert KE_1 - KE_2\rvert}{KE_1}\times 100\ (\%)$ |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

**How much is the energy absorbed or dissipated?** (It is supposed to be 2/3 of the original energy.)