

**PHYS 1401**  
**General Physics I**

**EXPERIMENT 8**  
**CONSERVATION OF LINEAR MOMENTUM**

**I. INTRODUCTION**

The objective of this experiment is to test the validity of the law of conservation of linear momentum. Two air track gliders will be made to collide elastically and inelastically. The velocities of the gliders will be measured and their momenta will be calculated before and after the collision. The student will check if the **total** momentum is conserved during the collision. The law of conservation of momentum states

$$P_i = P_f \quad (1)$$

where *initial* and *final* represent the configurations of the system right before and right after the collision. For a system consisting of two objects, the above equation becomes

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}. \quad (2)$$

**II. APPARATUS**

Air track with accessory box, two photogates, assortment of masses, LabPro and a computer.

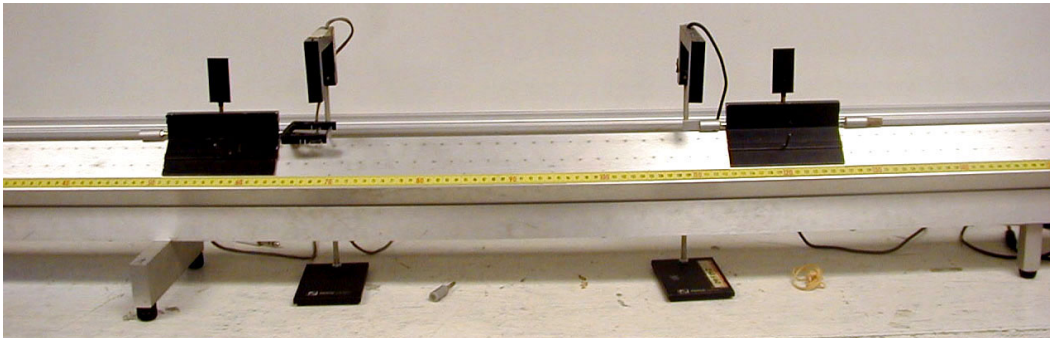


Figure 1: Air Track

**III. EXPERIMENTAL PROCEDURE**

1. Set up the apparatus as shown in figure (1). Connect the air hose to the air track, plug in the air compressor and level the air track.
2. Label one glider (1) and the other glider (2). Label one photogate (1) and label the other one (2). Plug photogate (1) into the LabPro Dig/Sonic (1) and photogate (2) into Dig/Sonic (2). The set up should be such that glider (1) goes through photogate (1) before the collision and glider (2) goes through photogate (2) before the collision.

3. Place the photogates in the middle part of the track leaving about 40 cm between them.
4. The computer should be on. If it is not, turn it on.
5. Open the **Logger Pro** folder by double clicking on it. Open the folder titled **Collisions**.
6. Affix a small flag on each glider and set up the photogate to the right height for the flag to pass under it and still block the beam when it goes through.
7. Measure the width of the flag using the following procedure:
  - (a) Record the position of the front of the glider when the beam is first blocked.
  - (b) Move the glider slowly until the beam is unblocked and record the position of the front of the glider again.
  - (c) The width of the flag is the difference between these two numbers.
8. Go to **Experiment** on the menu bar at the top and drag down to sampling. Change the number in the length box to the value you obtained for the width of the flag (in meters).

### Elastic Collisions

1. Affix a spring bumper (the one with the rubber band) to the front of glider (2) and a knife-edge bumper to the front of glider (1). These must be placed in the lower holes. Balance the gliders by placing a similar fixture on the other end.
2. Place the appropriate mass on the gliders as given in the data table. Measure the mass of each glider and record it in the appropriate place in the data table. Place glider (2) between the two photogates and bring it to rest. Click the Collect button and wait about two seconds and launch glider (1) towards glider (2) with the velocity suggested in the data table. In general, there will be two velocities before the collision and two velocities after the collision. The computer will record these velocities. If, either before the collision or after, one or both of the gliders is stationary, then the velocity of that glider is zero and its location on the computer screen will be blank. Record the velocities you obtained for this run in the data table.
3. Place 100 g (50 g on each side) on glider (1) and repeat step (2). Record the velocities in the data table.
4. For the third case of elastic collisions, use the same masses as case (2) and launch glider (1) and glider (2) at each other and record their velocities before and after the collision. The two velocities are in opposite directions, which means the momenta are also in opposite directions. One of them is (+) and the other is (-).

## Inelastic Collisions

1. Replace the elastic collision bumpers with the inelastic bumpers. These will allow the gliders to stick together when they collide.
2. Repeat steps 2, 3, and 4 to obtain three cases of inelastic collisions. Here, after the collision, the two gliders will stick together and should have the same final velocity. The computer will give two velocities which differ by a small amount. Record the first value given since it is the one that is most immediate after the collision. You are done with the experimental procedure. Turn the air track off. Proceed to the analysis part and calculate the initial and final momenta of the system to see if your data are in agreement with theory.

## IV. ANALYSIS

1. For each case, calculate the momentum of each glider and the total momentum before the collision and the total momentum after the collision. Momentum is a vector quantity and you should properly take the direction into account in your calculations.
2. Calculate the percent difference between the total momenta before and after the collision.

$$\% \text{ diff.} = \frac{|P_f - P_i|}{\left(\frac{P_f + P_i}{2}\right)} \times 100. \quad (3)$$

3. For each case, calculate the kinetic energy of each glider and the total kinetic energy before and after the collision.
4. For the elastic collision cases, calculate the percent difference between the total kinetic energy before and after the collision.

$$\% \text{ diff.} = \frac{|K_f - K_i|}{\left(\frac{K_f + K_i}{2}\right)} \times 100. \quad (4)$$

5. For inelastic collisions, kinetic energy is not conserved and a fraction of it is usually lost in the collision. Calculate the fraction of the initial kinetic energy lost in each of the inelastic collisions (in percent)

$$\% K_{\text{lost}} = \frac{K_f - K_i}{K_i} \times 100. \quad (5)$$

This will be a negative number (for loss).

6. Write a conclusion summarizing your results. Comment on the accuracy of this experiment. Let us arbitrarily choose 10% as an acceptable error and still be able to say that your results are in agreement with the law of conservation of momentum. Which case(s) is (are) not in agreement? What do you think are the two most important sources of error in this experiment?

| <b>Table (1): Suggested Masses and Initial Velocities for Elastic and Inelastic Collisions</b> |                           |                |                    |                |
|--|---------------------------|----------------|--------------------|----------------|
| Run  | $m_1$ (kg)                | $v_{1i}$ (m/s) | $m_2$ (kg)         | $v_{2i}$ (m/s) |
| 1&4  | cart + accessories        | $\sim 0.3$     | cart + accessories | 0.0            |
| 2&5  | cart + accessories +0.100 | $\sim 0.3$     | cart + accessories | 0.0            |
| 3&6  | cart + accessories +0.100 | $\sim 0.4$     | cart + accessories | $\sim 0.3$     |

**Table (2): Elastic Collisions**

| <b>Before the Collision</b> |            |                |          |            |                |          |               |
|-----------------------------|------------|----------------|----------|------------|----------------|----------|---------------|
| Run                         | $m_1$ (kg) | $v_{1i}$ (m/s) | $P_{1i}$ | $m_2$ (kg) | $v_{2i}$ (m/s) | $P_{2i}$ | $P_{total,i}$ |
| 1                           |            |                |          |            |                |          |               |
| 2                           |            |                |          |            |                |          |               |
| 3                           |            |                |          |            |                |          |               |
| Run                         | $m_1$ (kg) | $v_{1i}$ (m/s) | $K_{1i}$ | $m_2$ (kg) | $v_{2i}$ (m/s) | $K_{2i}$ | $K_{total,i}$ |
| 1                           |            |                |          |            |                |          |               |
| 2                           |            |                |          |            |                |          |               |
| 3                           |            |                |          |            |                |          |               |
| <b>After the Collision</b>  |            |                |          |            |                |          |               |
| Run                         | $m_1$ (kg) | $v_{1f}$ (m/s) | $P_{1f}$ | $m_2$ (kg) | $v_{2f}$ (m/s) | $P_{2f}$ | $P_{total,f}$ |
| 1                           |            |                |          |            |                |          |               |
| 2                           |            |                |          |            |                |          |               |
| 3                           |            |                |          |            |                |          |               |
| Run                         | $m_1$ (kg) | $v_{1f}$ (m/s) | $K_{1f}$ | $m_2$ (kg) | $v_{2f}$ (m/s) | $K_{2f}$ | $K_{total,f}$ |
| 1                           |            |                |          |            |                |          |               |
| 2                           |            |                |          |            |                |          |               |
| 3                           |            |                |          |            |                |          |               |

**Table (3): Inelastic Collisions**

| <b>Before the Collision</b> |                    |                |             |            |                |          |               |
|-----------------------------|--------------------|----------------|-------------|------------|----------------|----------|---------------|
| Run                         | $m_1$ (kg)         | $v_{1i}$ (m/s) | $P_{1i}$    | $m_2$ (kg) | $v_{2i}$ (m/s) | $P_{2i}$ | $P_{total,i}$ |
| 4                           |                    |                |             |            |                |          |               |
| 5                           |                    |                |             |            |                |          |               |
| 6                           |                    |                |             |            |                |          |               |
| Run                         | $m_1$ (kg)         | $v_{1i}$ (m/s) | $K_{1i}$    | $m_2$ (kg) | $v_{2i}$ (m/s) | $K_{2i}$ | $K_{total,i}$ |
| 4                           |                    |                |             |            |                |          |               |
| 5                           |                    |                |             |            |                |          |               |
| 6                           |                    |                |             |            |                |          |               |
| <b>After the Collision</b>  |                    |                |             |            |                |          |               |
| Run                         | $(m_1 + m_2)$ (kg) |                | $v_f$ (m/s) |            | $P_{total,f}$  |          |               |
| 4                           |                    |                |             |            |                |          |               |
| 5                           |                    |                |             |            |                |          |               |
| 6                           |                    |                |             |            |                |          |               |
| Run                         | $(m_1 + m_2)$ (kg) |                | $v_f$ (m/s) |            | $K_{total,f}$  |          |               |
| 4                           |                    |                |             |            |                |          |               |
| 5                           |                    |                |             |            |                |          |               |
| 6                           |                    |                |             |            |                |          |               |

| <b>Table (4): Elastic Collisions</b> |                     |                     |
|--------------------------------------|---------------------|---------------------|
| Run                                  | % Difference in $P$ | % Difference in $K$ |
| 1                                    |                     |                     |
| 2                                    |                     |                     |
| 3                                    |                     |                     |
| <b>Inelastic Collisions</b>          |                     |                     |
| Run                                  | % Difference in $P$ | % Loss in $K$       |
| 4                                    |                     |                     |
| 5                                    |                     |                     |
| 6                                    |                     |                     |