

Collisions and conservation laws

Goal: To test the conservation of linear momentum in collisions on an air track and to investigate kinetic energy changes in collisions.

Lab Preparation

Review the following before this lab:

Momentum. The momentum of an object is $p = mv$, where p represents the momentum, m represents the mass, and v represents the velocity. Note that momentum and velocity are vector quantities but since the entire lab is in one dimension the vector symbols will be dropped throughout the lab.

Conservation of momentum. The conservation of momentum states that the total momentum of a system is constant if the net external force acting on the system is zero (in equation form $p_i = p_f$). When collisions occur the forces between objects are internal forces and do not effect the total momentum of the system (it does effect the individual momentums of the objects however). Thus the conservation of momentum can also be stated this way:

The total momentum before a collision is equal to the total momentum after a collision (or $p_i = p_f$ where p_i is the momentum before the collision and p_f is the momentum after the collision).

For two objects:

$$p_i = p_{i1} + p_{i2} \quad \text{and} \quad p_f = p_{f1} + p_{f2}$$

thus $p_i = p_f$ turns into:

$$p_{i1} + p_{i2} = p_{f1} + p_{f2}$$

and since $p = mv$ this turns into:

$$m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$$

Inelastic collisions. A perfectly inelastic collision is one in which the objects stick together and move as a single unit after the collision. In this type of collision momentum is conserved, but kinetic energy is not conserved.

Elastic collisions. In perfectly elastic collisions objects bounce of one another when they collide. In this type of collision both momentum and kinetic energy are conserved (or $p_i = p_f$ and $K_i = K_f$).

Equipment

This lab uses the **air track** again. Remember to leave your air supply on until measurements are completed.

Also used is a timing system (Smart-timers) with photogates. The Smart-timers can record the speeds of the gliders before and after a collision by using a 'picket fence' attachment on the glider with two black bars spaced 1.00 cm apart. The timers can measure and remember the speed from two successive passages through each of two photogates.

For use in this experiment the Smart-timers **Measurement** (1) button should be set to speed (press 1 twice) and the **Mode** (2) button should be set to collisions (press 2 twice). To measure speeds press the **Start/Stop** (3) button until a * is displayed. The * indicates the timer is ready to measure speeds.

After two speeds have been recorded for each photogate, or after you have pressed the **Start/Stop** (3) button again if your collision does not involve determining four separate velocities, the timer will report two speeds for each photogate. Pressing the **Mode** (2) button alternates the displayed results between speeds for photogate 1 and photogate 2. Speeds are reported in cm/s.

Procedure

Please handle the air-track gliders with care and do not slide them without the air supply on. Keep glider speeds < 25 cm/s for best results in this experiment.

I. Single glider – no collision

- A. While your air-track is warming up measure the masses of the gliders along with the extra weights and record.
- B. Test the air track for levelness by making sure the gliders remain nearly stationary when placed near the middle of the air-track.
- C. Place the photogates about 40 cm apart. Measure the speed of one glider passing through the two photogates as it travels freely along the air-track. Take two trials and record the velocities.
- D. Measure the speed of one glider passing through the two photogates in the opposite direction. Take two trials and record the velocities. Be careful – make sure you know which reading gives the initial velocity now that you have switched directions. Also, the Smart-timers do not record the directions so it is up to you to add the appropriate sign to each speed when recording the velocity.

II. Inelastic collisions

We will now explore inelastic collisions between the sticky ends (needle going into wax) of two gliders.

- A. Equal glider masses. For this collision you will be sending glider 1 down the track and have it collide with glider 2 which will be initially at rest. You want to set up your photogates so they read the velocity right before and right after the collision.

Carry out two trials for this combination and record your data. Make sure you understand the correct way to read your smart timer (you may want to check with your TA just to be sure you are reading it correctly). Note that for sticking collisions, v_{2f} must equal v_{1f} since they move together as a unit. Do not record separately measured values of v_f for the two gliders as each passes through the photogate. Use the speed recorded by the first of the gliders to pass through the gate.

- B. Light glider into heavy glider. Add the additional masses to glider 2 and repeat part A (thus take 2 trials with glider 2 at rest).

III. Elastic collisions

Repeat the same combinations as part II above using the bumper ends of the gliders and gather the same kinds of information. Remember that it is up to you to put in the correct direction for the velocities.

Analysis

I. Open the collisions-analysis program and read any pop up menus that may appear. Enter your data for all trials (total of 12) in the appropriate columns being careful with units and signs.

II. Momentum. The program is set up such that it calculates the momentums of the individual gliders before and after the collision. To test and see if momentum is indeed conserved to you will need to create additional new calculated columns. Construct the following four columns:

*total initial momentum ($p_{i,total}$) before the collision

*total final momentum ($p_{f,total}$) after the collision

*the total change in momentum ($\Delta p = p_f - p_i$)

*the percentage change in momentum, $\% \Delta p = \frac{p_f - p_i}{|p_i|} \times 100\%$

Once finished examine the numbers to see if they seem reasonable.

III. Kinetic energy. Use page 2 of the collision-analysis program to examine kinetic energy conservation. Construct columns for K_{1i} , K_{2i} , K_{1f} , K_{2f} and then construct the following columns:

*total initial kinetic energy before the collision

*total final kinetic energy after the collision

*the total change in kinetic energy ($\Delta K = K_f - K_i$)

*the percentage change in kinetic energy, $\% \Delta K = \frac{K_f - K_i}{|K_i|} \times 100\%$

Once again, when finished examine the numbers to see if they seem reasonable.

IV. Print tables. If both tables seem reasonable, it is time to set up the tables to print. For table 1 on page 1 you want to print the following columns:

$$p_{i1}, p_{i2}, p_{f1}, p_{f2}, p_{i,\text{total}}, p_{f,\text{total}}, \Delta p, \% \Delta p.$$

To only print these columns choose "Options" and select "Table Options." There you should be able to select the columns you want printed. For table 2 on page 2 you want to print the same columns with kinetic energy. When finished selecting your columns go to "File" and select "Page setup" and make sure it is set to "Landscape" for printing. If all looks good print your tables.

***When finished with your lab clean up your lab station.**

Homework

1. Examine the results for part I in the procedure (first 4 trials of single glider). Did the direction of travel seem to make a difference? Explain using your results from table 1.

Ideally, if the track is level and friction is negligible, the glider's velocity should be unchanged as it travels along the track and the momentum should be exactly the same passing through both gates. In practice the readings from the two photogates may not be identical on a single pass due to slight differences in the photogates, some residual tilt or unevenness in the air track, and small drag forces on the glider. These measurements are intended to provide you with a rough sense of how significant these imperfections are in your measurements.

2. Examine the momentum results for part II and III of the procedure. How do these percentage changes compare to those of part I of the procedure? Is it reasonable to attribute some of the percentage change in momentum to slight differences in the photogates, some residual tilt or unevenness in the air track, and small drag forces on the glider? Explain.

3. For inelastic collisions, why is it better to use the first final velocity through the second photogate instead of using separate values of the two gliders successively passing through the photogate (part II A in the procedure)?

4. Was kinetic energy more nearly conserved in inelastic collisions or elastic collisions? Explain using your results from table 2. If there were any significant losses where did the energy go?