Elastic and Inelastic Collisions: Air Track

Objective

In this experiment you will investigate collisions that are (nearly) *elastic* and others that are *completely inelastic*. In each case you will experimentally determine whether momentum is conserved and the extent to which kinetic energy is conserved.

Materials

1. Air track
2. Compressor
3. Gliders with plastic flags
4. Magnetic bumpers
5. Pasco 550 Interface
6. Photogate and stand
7. Pin and wax bumper set
8. Plastic pipe
9. Round glider weights
10. Rubber band bumpers
11. Triple-beam balance

Introduction

When momentum is conserved in a two-object collision

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f} \quad (1)$$

Rearranging, we have

$$\vec{p}_{1f} - \vec{p}_{1i} = -(\vec{p}_{2f} - \vec{p}_{2i}) \quad (2)$$

or equivalently

$$\Delta\vec{p}_1 = -\Delta\vec{p}_2 \quad (3)$$

That is, when momentum is conserved the change in the momentum of one object is equal and opposite the change in momentum of the other; the total momentum change is zero. In a one-dimensional collision we often use signs to indicate direction. In such a case total momentum tends to be the difference of two numbers and momentum change tends to be the sum of two numbers. For this reason, as pointed out above, equations (2) and (3) rather than equation (1) may provide your best test of whether or not momentum is conserved in a particular collision.

The apparatus used will consist of an air track, two gliders, two photogates, and a computer equipped with a Pasco 550 Interface. The computer will monitor the times that the photogates are blocked by the air track gliders. The air track should nearly eliminate friction on the gliders, making their collisions nearly isolated.

Procedure

Calibrating Photogates

- Connect photogates to Pasco Interface (Digital 1&2 ports).
- Open Pasco Software.
- Click Hardware Setup.
- Choose “Photogate” for both Digital 1&2 ports.
- If both photogates are connected successfully, close Hardware Setup and click Timer Setup.
- In Step 1, click the words “Pre-Configured Timer” and choose “Create a pre-configured timer” from the dropdown menu, then click “next”.
- In Step 2, make sure the boxes are ticked for both “Photogate, Ch1” and “Photogate, Ch2”, then click “next”.
- In Step 3, click the words “Select a Timer”, and choose “Collision (Single Flag)” from the dropdown menu, then click “next”.
- In Step 4, make sure the boxes are ticked for “Time in Gate 1”, “Time in Gate 2”, “Speed in Gate 1”, and “Speed in Gate 2”, then click “next”.
- In Step 5, measure the length of the flags for each of the gliders, and input the value in meters into the text box provided next to the words “Flag Length”. Both flags should be the same length. Once the length value is confirmed to be the same for both flags and input into the software, click “next”.
- In Step 6, Confirm the timer’s name is “Collision (Single Flag)”, then click “Finish”.
- Double check that all of the configurations are as they should be, then close Timer Setup.
- Double click the “Table” icon on the right side of the software, then choose “Speed in Gate 1, Ch 1” for the lefthand side and “Time in Gate 1, Ch 1” for the righthand side.
- Double click the “Table” icon again to open a second table, then choose “Speed in Gate 2, Ch 2” for the lefthand side of your second table and “Time in Gate 2, Ch 2” for the righthand side of your second table.
- The software is now ready to properly record the data.

Executing effective collisions

Place a glider on the air track and turn on the air supply. Carefully level the track so that the glider does not preferentially drift toward one end. Plug the photogates into digital Channels 1 and 2 of the 550-Interface. Place the two photogates so that they divide the air track approximately into thirds. Position them so that the plastic flag on top of the passing glider will block the photogate beams. For the speeds in the tables to be correct, each of the plastic flags should pass through the photogates perfectly perpendicularly to the beams (you should confirm this).

In the following experiments you should start the timer (click the “Record” button), then push the gliders from opposite ends of the air track toward the center. They should collide in the region between the photogates. As soon as they have passed back out of this region you should stop the timer (click “Stop”). You will need to assign directions to your speed values recorded in your tables to make them velocities (which way you will call positive and which negative). After each experiment you will place the appropriate sign to the “velocities”.

Each time that you run a new experiment the old one will be saved (as Run 1, Run 2, ...). To erase your experiment runs simply click on "Delete Last Run" at the bottom of your screen.

Caution: These experiments should take place at fairly low speeds. You will know the gliders were going too fast if you hear a metallic clatter when they collide. This sound will probably mean that the collision has caused a glider to break through the cushion of air and bang against the air track. In such a case you no longer have a nearly isolated collision. Now you're ready to begin!

(Nearly) Elastic Collisions

Equip each of the gliders with a rubber band bumper. By means of the triple-beam balance, carefully determine the mass of each glider.

One stationary glider, one mobile glider, equal masses

Position one glider between the photogates and leave it stationary. Propel the other glider toward the stationary glider such that the rubber bands reflect one another and be careful to note which glider is detected by which photogate. Compute the momentum, $\dot{p}=m\dot{v}$, of each glider before and after the collision. *Again, keep in mind that momentum is a vector, so use appropriate signs to indicate direction; you will have to assign appropriate + or − signs to your velocities.* How do the momentum changes of the gliders compare? What is the total momentum before and after the collision? Was momentum conserved in the collision to within the accuracy of your measurements?

Note that a better answer to this last question may come from considering changes in momentum, as in equations (2) and (3), rather than considering total momentum before and after, as in equation (1). Because it is fairly easy to produce a collision in which the two gliders have nearly equal but opposite momenta, it is fairly common to have a total momentum that is very small compared to the momentum of either glider. In such a case a small error in the momentum of either glider can lead to an error in the total momentum on the same order of magnitude as the total momentum itself. Such an occurrence can give the false impression that momentum *was not even approximately conserved*. On the other hand, because of the reversal of direction, the momentum change of either glider will tend to be large and less affected by small uncertainties.

Compute the kinetic energy $KE = \frac{1}{2}mv^2$ of each glider before and after the collision. Since kinetic energy is a scalar, only positive numbers will be involved. Was kinetic energy conserved in the collision? If not, how much energy was lost? What became of this energy?

Two mobile gliders, equal masses

This time propel both gliders such that they collide between the photogates. Was momentum conserved in the collision to within the accuracy of your measurements? Was kinetic energy conserved in the collision?

Two mobile gliders, unequal masses

Add mass to one of the gliders, using the cylindrical masses in the kit, by positioning one mass on the post on each side of the glider. Determine the new mass of the glider. Again, propel both gliders such that they collide between the photogates. Was momentum conserved in the collision to within the accuracy of your measurements? Was kinetic energy conserved in the collision?

Completely Inelastic Collisions

Replace one of the rubber band bumpers with a pin bumper, and replace the other with a wax receptacle, into which the pin will stick when the gliders collide. At moderate speeds this bumper arrangement will cause the gliders to stick together on collision. After each collision you will need to use some small object to press the wax back into the hole made by the pin. As before, start the timer and cause the gliders to collide between the photogates. Stop the timer after they have exited together through one of the gates. In this case that photogate will have three-time intervals: one for the entering glider and two approximately equal times for the two gliders that pass together through it.

One stationary glider, one mobile glider, equal masses

Position one glider between the photogates and leave it stationary. Propel the other glider toward the stationary glider such that the pin sticks into the wax without the cases “clacking”. Is momentum conserved in this type of collision? Is kinetic energy conserved? If not, how much is lost? What becomes of the lost energy?

Two mobile gliders, equal masses

This time propel both gliders such that they collide between the photogates. If you happen to produce a collision in which they are nearly at rest after collision, analyze it for momentum and energy conservation by using zero for the final velocity; then repeat the experiment with different initial velocities which cause the gliders to come through a photogate soon after colliding. Is momentum conserved in this type of collision? Is kinetic energy conserved? If not, how much is lost? What becomes of the lost energy?