General Physics I Lab

M5 Conservation of Linear Momentum

Purpose

In this experiment you will investigate the conservation law of linear momentum in a collision between two gliders. Two different cases will be examined: elastic collision and inelastic collision.

Equipment and components

PASCO 550 Universal Interface, PASPORT motion sensor (x2), 2-meter air track system with bumper, variable output air supply, glider with flag (x2), electronic balance, wax receptacle & needle (1 each), rubber band bumper (x3), bumper blade, stand and clamp (x2).

Background

When different objects collide, whether locomotives, shopping carts, or your foot and the sidewalk, the final results can be complicated. Yet even in the most chaotic of collisions, as long as there is no external force acting on the colliding objects, one principle always holds and provides a useful tool for the understanding of the dynamics of the collision. This principle is called *the conservation of linear momentum*. For a two-object collision, the momentum conservation is stated mathematically by the equation:

$$m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = m_1\mathbf{v'}_1 + m_2\mathbf{v'}_2$$

where m_1 and m_2 are, respectively, the masses of the two objects, $\mathbf{v}_1$ and $\mathbf{v}_2$ are the initial velocities of the objects (before the collision), $\mathbf{v'}_1$ and $\mathbf{v'}_2$ are the final velocities of the objects (after the collision). If external forces such as friction are negligible, the sum of the linear momentum of the two gliders after a collision remains the same as that prior to the collision.

Procedure

In this experiment, the motion sensors will be used to measure the position and velocity of two gliders before and after a collision. The computer interface program records the velocities of the gliders.

Computer setup

1. Connect the *PASCO 550 Universal Interface* to the computer. Turn on the interface and the computer.
2. Connect the two PASPORT motion sensors into the "PASPORT 1" and "PASPORT 2" inputs on the interface respectively.
3. Open the "M5" program in the course folder. The program will open with a graph display of Velocity (m/sec) versus Time (sec) of the two gliders.

Equipment setup

1. Turn on the air supply for the air track and set to an appropriate flow rate, and then place a glider (without flag) on the track. Level the track by adjusting the two leveling feet of the track until the glider stops sliding.
2. Affix a rubber band bumper to each end of the air track.
3. Affix the needle, wax receptacle and flags on the two gliders as shown in Figure 1. ***CAUTION:*** The needle is protected with a cork, please handle it **carefully** once the cork is removed.

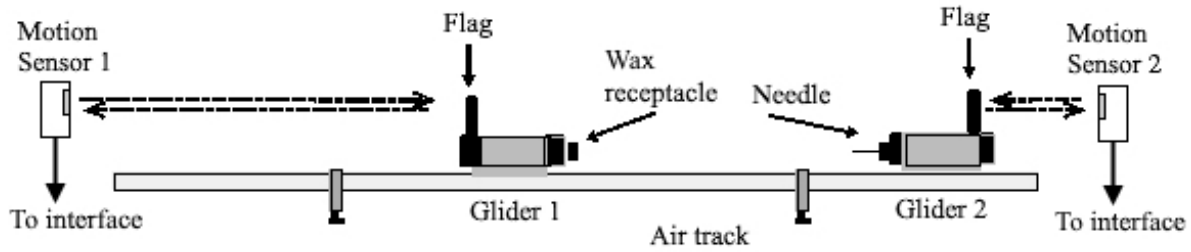

Figure 1 Setup of the collision experiment

4. Use an electronic balance to measure the mass of each glider with the attached accessories (e.g. flag, wax receptacle) and record the values in Data Sheet 1 in the lab report.
5. Use the stand and clamp to fix the position of the two motion sensors right above each end of the air track as shown in Figure 1. Each motion sensor surface should be at the same level as the upper portion of the flag. The motion sensors should be aligned in such a way that the sensor surfaces can reflect each other when there is no glider on the air track.
6. Put Glider 1 in the middle of the air track and Glider 2 near one end.

Data recording and analysis

Safety NOTE: Keep your body away from the path of the moving gliders during the collisions.

1. Push Glider 2 towards Glider 1 gently. What do you observe? What kind of collision is it?
2. Click the "Record" button to begin data recording and start the collision by pushing Glider 2 towards Glider 1.

   NOTE: - Make sure that collisions occur at the working range of the motion sensors (The minimum range of the motion sensor is about 0.15 meter).

   - A positive (+) velocity value means the glider is moving away from the motion sensor. Conversely, a negative (-) velocity value means the glider is approaching the motion sensor.
3. Click the "Stop" button to end data recording after the gliders go beyond the measurement limit. "Run #1" will appear in the Data Summary.
4. Rescale the velocity-time graphs of Glider 1 and 2 to display all the data points and then zoom in the portion of the curve you want to study in details.
5. Print the velocity-time graphs and paste them in Data Sheet 1.
   NOTE: Resize the graphs to suitable size before printing them.
6. Analyze the data:

   (a) On the velocity-time graph, use the **Data Highlighter** tool to enclose TEN data points that show the movement of Glider 2 right before collision. (Hint: How do you know when a collision starts?)

   (b) Use the **Statistics** tool to determine the mean and the standard deviation of the velocity of Glider 2 before collision. From the standard deviation, calculate the standard error of the velocity. Record the velocity and its error in Data Sheet 1.

   (c) Repeat steps (a) and (b) to find the average velocity of Glider 2 right after collision.

   (d) Repeat steps (a) to (c) to find the velocities of Glider 1 right before and right after collision.

   (e) Calculate the change of total momentum of the two gliders.
   NOTE: The velocity, and hence the momentum, is a vector.

7. Repeat steps 2, 3, 4 and 6 for at least one more trial with a different initial velocity of Glider 2.
8. Replace the needle and wax receptacle with the rubber band bumper and bumper blade to the gliders. **Safety NOTE:** Please cover the needle with the cork immediately after use.
9. Repeat the collision, observation, measurement, data recording and analysis. Record your data on Data Sheet 2.