Lab 07: Collisions

The Objectives

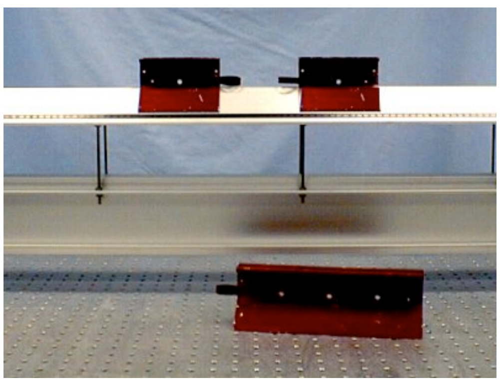
A perfectly elastic collision is one in which both momentum and energy are conserved. This type of collision is difficult to stage and observe in the lab, but we will create a collision that comes very close to perfect elasticity. However, the observation and the collected data may seem to contradict each other. Part of this exercise will be about reconciling observations that seem to be mutually exclusive. Partially elastic or perfectly inelastic collisions are far easier to stage, and we will be observing several of these types of collisions as well. Our specific objectives include:

- Observe the differences between elastic and inelastic collisions
- Analyze momentum and energy conservation quantitatively
- Examine experimental equipment and techniques for sources of error
- Perform error analysis to determine the accuracy of the results

The Procedure

Work in groups of four. There are two independent experiments to perform: air track collisions and ballistic pendulum. Because there is a single air track, only one group may use that apparatus at a time. The data are acquired quickly, so you will not have to wait very long for a turn. In the meantime, perform the ballistic pendulum experiment.

Air Track Collisions



Separate the photogates on the air track to create a collision interval. The first cart should be placed before the first gate, and the second cart should be placed in the collision interval between the gates. Make sure that the air blower is running before you slide the cart on the track. Sliding the cart when the blower is off will damage the track.

For the elastic collision, both carts must be flagged. The first cart will pass through the first gate before the collision, and the second cart will pass through the second gate after the collision. Arrange the carts so that the metal bumpers will collide, then stage the collision. Repeat twice more.

For the inelastic collision, remove the flag on the second cart. The first cart will pass through both of the gates, so only one flagged cart is necessary. Arrange the carts so that the velcro bumpers will stick together on collision, then stage the collision. Repeat twice more.

The Data and Reduction

Record the mass of each cart and each flag. Record the time before and the time after each collision.

Calculate the velocity, momentum, and kinetic energy for each trial of each collision, before and after. Pay careful attention to units here. Notice that, because each flag is 5 cm long, that the velocity will always be

$$v = \frac{0.05\text{m}}{t}$$

where t is the time it takes for the flag to pass through the photogate.

If you have not already, organize the information into a neat and easy to navigate table (one for each collision staged):

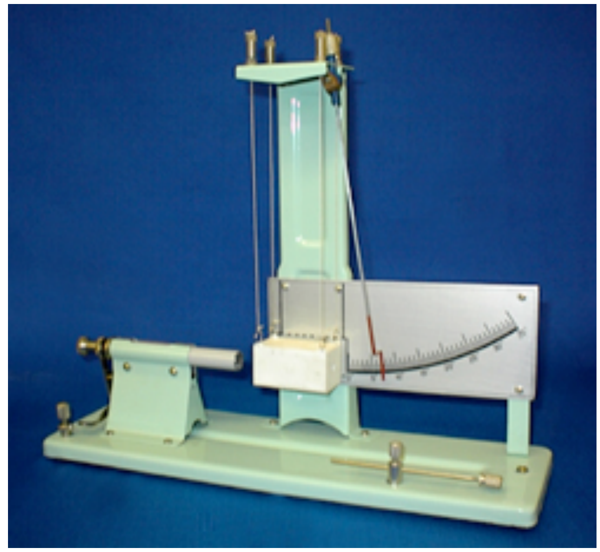
Cart	Mass (kg)	Time t_1 (s)	Time t_2 (s)	Velocity v_1 (m/s)	Momentum p_1 (kg·m/s)	Velocity v_2 (m/s)	Momentum p_2 (kg·m/s)	Kinetic Energy K_1 (J)	Kinetic Energy K_2 (J)
A									
Flag A									
B									
Flag B									

The Analysis

Based on our initial assumptions, what qualitative observation supports our assertion that the elastic collision is, in fact, perfectly elastic? For each elastic trial, calculate the change in momentum as a percent lost or gained. Calculate the change in the kinetic energy (as a percent lost or gained) for each elastic trial. Use a table to summarize your results.

For each inelastic trial, calculate the change in momentum as a percent lost or gained. Determine the energy lost as a percentage of the original kinetic energy. Predict and calculate the theoretical energy loss for a perfectly inelastic collision (this requires some symbolic algebra!). Again, summarize the calculations in a neat table.

Ballistic Pendulum



For the ballistic pendulum, a steel ball is launched by releasing a compressed spring. The projectile becomes embedded in the bob of a pendulum (a plastic block), which swings up as a result. The projectile gun has three settings for the spring compression. You should fire the steel ball three times at each spring compression setting.

The Data

You will need to measure and record the mass of the steel projectile ball (m), the mass of the block (M), and the length of the pendulum cord (L). At the lowest setting (spring compressed the least), fire the steel ball into the block and record the height angle θ. Reset the pendulum and repeat twice more, then repeat for the other spring compression settings. As always, present your data in a neat and organized table.

The Reduction and Analysis

Use momentum conservation at the instant of collision:

$$p_1 = p_2$$

$$mv_1 = (m + M)v_2,$$

and energy conservation after the collision:

$$K_2 = \tfrac{1}{2}(m + M)v_2^2$$

$$U_3 = (m + M)gh_3$$

$$K_2 = U_3,$$

to derive an expression for the launch velocity of the projectile in terms of the variables you have measured (m, M, L, θ).

For each setting, calculate the average angle to which the block rose. Use this value to find the launch velocity for each of the projectile gun settings.

Compare the calculated launch velocities to the known values by calculating the percent error. Connect this to the perceived loss of momentum during the collision.

Error Analysis

Random Error

Is the air track experiment really about identifying random errors and reducing their effects? Are the large losses of momentum and energy seen with the air track the result of random errors whose effects could be reduced by collecting more data? What about the ballistic pendulum experiment? Is the much smaller discrepancy between the measured launch velocity and the known launch velocity the result of random measuring errors? Could collecting more data substantially reduce the difference between the measured and predicted launch velocities?

Systematic Error

Obviously nothing here was conserved that should have been, and the actual energy loss during the inelastic air track collision far exceeds the prediction. Discuss whether this is the result of the experimental technique, or whether there is some missing physics that need to be included in the analysis (or possibly both).

The Conclusions

Comment on the overall success of these experiments. If you have not already, suggest some ways in which the experiments could be improved to better demonstrate the principles of conservation.